System 3 Manual

Hardware Reference

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RZ2 BioAmp Processor

RZ2 Overview

The RZ2 BioAmp Processor has been designed for high channel count neurophysiology recording and signal processing. The RZ2 features two (RZ2-2), four (RZ2-4), or eight (RZ2-8) digital signal processors cards. Any card can be either a single standard processor card (RZDSP) or a quad-core processor card (QZDSP). Standard single processor cards use a single Sharc DSP; quad-core processor cards use four Sharc DSPs Cores with the potential to more than double the power of the RZ2.

All cards are networked on a multiprocessor architecture that features efficient onboard communication and memory access. The highly optimized multi-bus architecture uses four dedicated data buses to eliminate data flow bottlenecks - all transparent to the user. This architecture yields an extremely powerful system capable of sophisticated real-time processing and simultaneous acquisition on all channels.

The RZ2 is typically used with a Z-Series Amplifier (such as the PZ5). High bandwidth data is streamed from the amplifier to the RZ2 over a lossless, fast, fiber optic connection. Both single and quad-core processors cards may include an optical interface for connection to devices such as the RS4 Data Streamer, an IZ2 Stimulator or a secondary PZ Amplifier (see Specialized Interface Boards for more information).

Each onboard optical connection can support 256 channels at sampling rates up to ~25 kHz and 128 channels at sampling rates up to ~50 kHz. The RZ2 also features 16 channels of
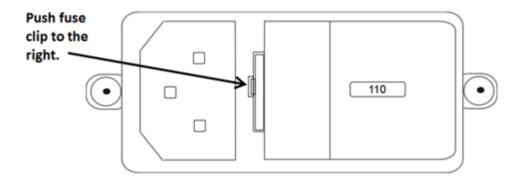
analog I/O, 24 bits of digital I/O, two Legacy optical inputs for Medusa PreAmps, and an onboard LCD for system status display.

Power and Communication

The RZ2's Optibit optical interface connects to a PO5, PO5e, PO5c, or UZ3 computer interface card for fast and reliable data transfer from the RZ2 to the PC. Connectors on the back panel are color coded for correct wiring.

The RZ2's integrated power supply is shipped from TDT configured for the end user's regional voltage setting (110 V or 220 V). If you need to change the voltage setting:

1. Turn off the RZ2

2. Use a small flathead screwdriver to gently push the clip along the left side of the fuse plate to the right to remove it.

3. Remove the white AC voltage selector and rotate it until the desired voltage is displayed, then reinsert it and put the fuse plate back on.
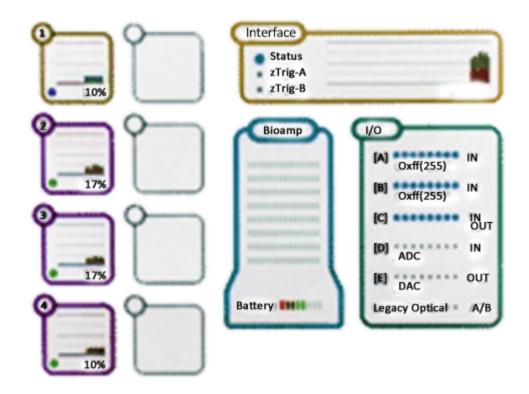
The RZ2 is UL compliant, see the RZ2 Operator's Manual for power and safety information.

Software Control

TDT's Synapse software controls the RZ2 and provides users a high level interface for device configuration.

RZ2 TouchScreen

The touchscreen shows information about each DSP, the optical PC interface, a connected PZ preamplifier, and system I/O.

Touch a section of the screen to display more detailed information.

DSPs

A stacked bar plot shows cycle usage for each DSP with the bottom section (blue) showing the cycle usage taken up by circuit operation and the top section (pink) showing the cycle usage required for data transfer.

If the cycle usage surpasses 100%, a bar is drawn above the 100% line in the cycle use bar plot and will persist until the RZ2 is rebooted. For quad-core DSPs, the core with the highest cycle usage is displayed.

```
                    DSP  #1  Details                              Core-A
  _____
                                                                 Core-B
    Firmware  Version:        84
    Model:                    RZ2  Bioamp  Processor             Core-C
    DSP  Type:                Quad  Core  DSP
    Sample  Rate:             12  kHz  ( 24414.0625  Hz )        Core-D
    Time  Slice:)             10
    Component  Usage:         0  of  768  Max
    Core  Cycle  Use:         0%
    Optical  Config:          None
    Memory  Usage:
                    XM  =>  0  of  65536  kBytes
                    DM  =>  0  of  32768  Bytes
                    PM  =>  0  of  28672  Bytes

    Data  Pipe  Source:
                    Pipe[A]  =>  Inactive
                    Pipe[B]  =>  Inactive
```

Optical Config is the peripheral device supported by the DSP, if any.

Data memory (DM) is the amount of DM used for filter delay line and short delays.

External Memory (XM) is the amount of XM used for long delays and buffers.

Program Memory (PM) is the amount of PM used to hold filter coefficients.

Tabs are enabled for quad-core DSPs, with one Core per tab.

Interface

Virtual Status lights display status of the interface (Status), zTrig-A, and zTrig-B. A stacked bar chart shows data transfer rate in MB/s.

Touch to Display:

```
            zBus  Interface  Detail
    ──────────────────────────────────────

        Firmware  Version:  1.2
        MBytes  Received:  8.628
            MBytes  Sent:  384.397
                Errors:  0
```

Firmware version, MB data received/sent and transfer errors.

Amp

Touch to Display: Amp model, number of channels and firmware version of connected PZ series amplifier to dedicated 'PZ Amplifier' fiber optic port on the back of the RZ2.

```
            Amplifier  Details
    ──────────────────────────────────────

        Amplifier  Model:  No  amplifier  connected
        Firmware  Version:  0
            Channels:  0
```

I/O

Virtual indicator lights.

[A], [B], and [C]: Digital I/O, LED will light for an input bit or it will show the logic level for an output bit.

[D] and [E]: Analog I/O, 16 lights indicate the signal level, green when a signal is present and red to warn that the signal is approaching the maximum voltage (at which point clipping would occur).
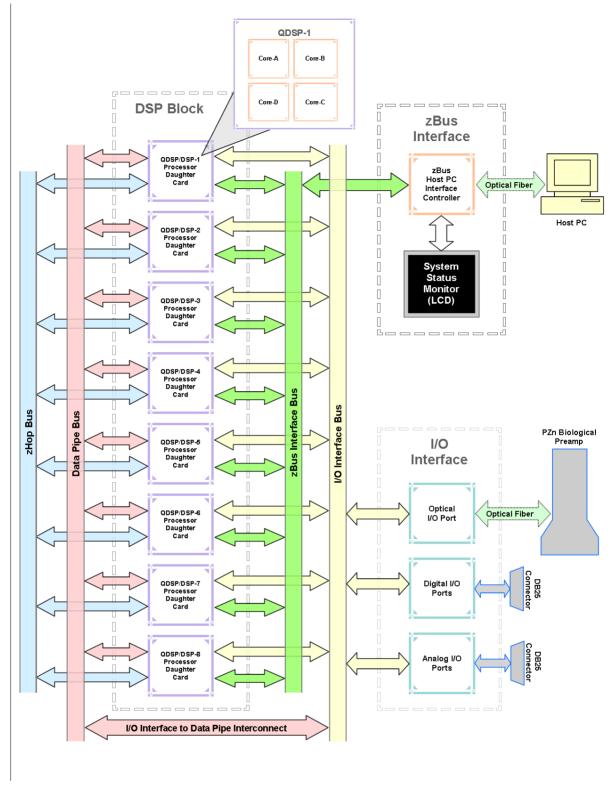
Legacy Optical: Amp Light For The Legacy Preamplifier Sync, Flashes yellow when no amp is connected and will be light green when the amplifier is correctly connected.

> ✎ **Note**
>
> Older versions of the RZ2 have a selection knob that allows the user to highlight a section of the screen. To display more detailed information, rotate the knob to select a system component and then push the knob to show the information view.

RZ2 Architecture

The RZ2 processor uses a highly optimized multi-bus architecture and offers four dedicated data buses for fast, efficient data handling. While the operation of the system architecture is largely transparent to the user, a general understanding is important when designing experiments.

RZ2 Multi-DSP Architecture Functional Diagram

As shown in the diagram above, the RZ2 architecture consists of three functional blocks:

The DSPs	Each DSP in the DSP Block is connected to a local interface to the four data buses: two buses that connect each DSP to the other functional blocks and two that handle data transfer between the DSPs. Each standard DSP is connected to 64 MB SDRAM and each core in a QZDSP is connected to 256 MB DDR2. This architecture facilitates fast DSP-to-off-chip data handling.
	Because each DSP has its own associated memory, access is very fast and efficient. However, large and complex circuits should be designed to balance memory needs (such as data buffers and filter coefficients) across processors. Memory use can be monitored on the RZ2 front panel display.
	The maximum number of circuit components for each RZ2 standard RZDSP is 768 and 1000 for each QZDSP core.
The zBus Interface	The zBus interface provides a connection to the PC. Data and host PC control commands are transferred to and from the DSP Block through the zBus Interface Bus, allowing for large high-speed data reads and writes without interfering with other system processing.
The I/O Interface	The I/O interface serves as a connection to outside signal sources or output devices. It is used primarily to input data from a PZ amplifier via the high speed optical port, but also serves the Legacy amplifier inputs and digital and analog channels. The I/O Interface Bus provides a direct connection to each DSP and the Data Pipe Bus.

For the best performance, processing tasks must be efficiently distributed across the available DSPs. Synapse software automatically handles this. For custom circuit programming, see the RPvdsEx manual.

Bus Related Delays

A standard two sample delay is associated with the zHop, and Data Pipe. However, these delays are managed for the user in Synapse software.

50 kHz Sampling Rate Acquisition with the PZ Amplifier

The RZ2 and PZ amplifier support sample rates from ~6 kHz to ~50 kHz. When sampling at a rate of ~50 kHz, only the first 128 PZ amplifier channels will be available.

Data Transfer Rate

As with other devices, your expected sustained RZ-to-Host PC data rate should not exceed ½ to ⅔ of the rated data transfer speed. For the RZ2 device this is 160 Mbits/second (Mbps) so your designs should have a sustained data rate of no more than ~100 Mbps. When the RZ2 is processing, the current data transfer rate (Mbps) is displayed in the top right corner of the LCD Screen. This maximum rate may be further limited by your PC's ability to store the data to disk.

RZ2 Features

Amplifier and Onboard Analog I/O

The RZ2 is equipped with both optical port amplifier input and onboard analog I/O capabilities. The high speed fiber optic port (located on the RZ2 back panel) allows a direct connection to a PZ5 amplifier. The Legacy fiber optic ports on the front panel allow a direct connection to Medusa preamplifiers. Physiological signals are digitized on the preamplifier and transferred across noiseless fiber optics.

The RZ2 also includes onboard D/A for stimulus generation and experiment control, and A/D for input of signals from a variety of other analog sources.

The table below provides a quick overview of these I/O features and how they must be accessed during experiment design.

Analog I/O	Description	Synapse Access	Notes
Port D	Analog Inputs	ADC Tab	Port D front panel BNCs or Analog I/O labeled DB25
Port E	Analog Outputs	DAC Tab	Port E front panel BNCs or Analog I/O labeled DB25
PZ Amplifier Port	PZ5 Amplifier Input	PZn Hal	Port located on RZ back panel next to zBus Interface
Legacy Amp-A	Medusa PreAmp Input	RAn Hal	
Legacy Amp-B	Medusa PreAmp Input	RAn Hal	

Onboard Analog I/O

The RZ2 is equipped with eight channels of 16-bit PCM D/A and eight channels of 16-bit PCM A/D. All 16 channels can be accessed via front panel BNCs marked Port D and Port E or via a 25-pin analog I/O connector. See DB25 Analog I/O Pinout and BNC Channel Mapping.

PZ Amplifier Fiber Optic Port

This is the RZ2's primary amplifier input and is located on the back panel. The connectors on the fiber optic pair used for PZ amplifier communication are color coded for correct wiring. This port can read up to 256 channels at a maximum sampling rate of ~25 kHz or 128 channels at a maximum sampling rate of ~50 kHz.

Legacy Fiber Optic Ports

The RZ2 station has two Legacy fiber optic ports labeled -A- and -B- to acquire digitized signals from the Medusa4Z, RA16PA, RA8GA, or HTI3 interface. Each port can read up to 16 channels at a maximum sampling rate of ~25 kHz.

Digital I/O

The digital I/O ports include 24 bits of programmable I/O. The digital I/O is divided into three ports (A, B, and C) as described in the chart below. All digital I/O lines are accessible via the 25-pin connector on the front of the RZ2 and ports A and C are available through BNC connectors on the front panel. See DB25 Digital I/O Pinout and BNC Channel Mapping. If using a PP24 Patch Panel, see PP24 to RZ2 Digital I/O.

The digital I/O is configured in the Synapse RZn Hal.

Digital I/O	Description	DB25	BNCs	Notes
Port A	bits 0 - 7	Yes	Yes	byte addressable
Port B	bits 0 - 7	Yes	No	byte addressable
Port C	bits 0 - 7	Yes	Yes	bit addressable

The data direction for the Digital I/O is also configured in the Synapse RZn Hal.

The RZ digital I/O ports have different voltage outputs and logic thresholds depending on the type. The table below depicts the different voltage outputs and thresholds for both types.

Digital I/O Type	Output High	Output Low	Input High	Input Low
Port A & Port B	5 V	0 V	>=2.5 V	0-2.45 V
Port C	3.3 V	0 V	>=1.5 V	0-1.4 V

UDP Ethernet Interface

The RZ UDP Ethernet interface can transfer low bandwidth data directly to or from a PC. RZ devices equipped with a UDP interface have an additional Ethernet port and RS232 serial port located on the back panel. See RZ-UDP Communications Interface for more information.

> ✎ **Note**
>
> If the RZ2 has 4 optical DSP cards (see below) installed, the RS232 serial port is not available.

Specialized DSP/Optical Interface Boards

The RZ standard DSP boards can be replaced with specialized DSP boards which include an optical interface for communication and control of RZ compatible devices, such as the Subject Interface and RS4 Data Streamer. RZ devices equipped with one or more specialized DSP boards include an optical port for each card. The ports are located on the back panel and labeled for easy identification.

DSP	Supported Peripheral
RZDSP-I	IZ2 Stimulators
RZDSP-M	Subject Interface, PZ5 amplifier, iCon Behavioral Controller
RZDSP-P	PZ amplifier. It can be used to expand the number of channels that can be acquired on any RZ processor.
RZDSP-S	RS4 Data Streamer, allowing the RZ device to stream data directly to the RS4's storage arrays.
RZDSP-U	PO8e interface card, allowing the RZ device to stream data directly to client software.
RZDSP-V	RV2 Video Tracking System
QZDSP_OPT	Supports all of the above devices.

RZ2 Technical Specifications
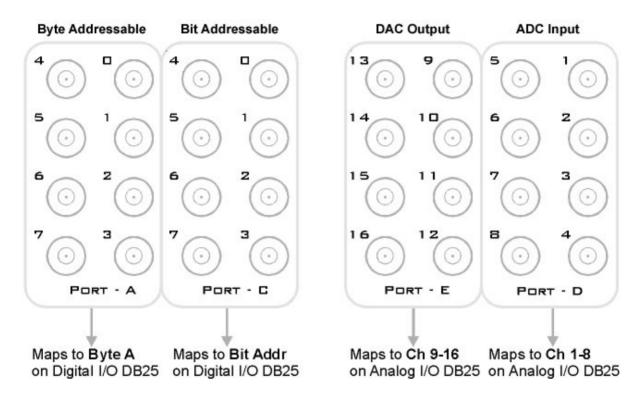
DSP	Up to eight standard DSPs and/or quad-core (QZDSP) DSP: 400 MHz DSPs, 2.4 GFLOPS peak per DSP QZDSP: Four 400 MHz DSPs, 2.4 GFLOPS per core
Memory	64 MB SDRAM per standard DSP 256 MB DDR2 RAM per core, four cores per QZDSP
Digital I/O	8 programmable bits: 3.3 V (5.0 V max input), 25 mA max load 2 programmable bytes (16 bits): 5.0 V (6.0 V max input), 35 mA max load
D/A	**8 channels, 16-bit PCM**
Sample Rate	Up to 48828.125 Hz
Frequency Response	DC - 0.44 * Fs (Fs = sample rate)
Voltage Out	±10.0 V, 175 mA max load
S/N (typical)	82 dB (20 Hz - 20 kHz at 9.9 V)
Output Impedance	10 Ohms
A/D	**8 channels, 16-bit PCM**
Sample Rate	Up to 48828.125 Hz
Frequency Response	DC - 7.5 kHz (3 dB corner, 2nd order, 12 dB per octave)
Voltage In	±10.0 V
S/N (typical)	82 dB (20 Hz - 20 kHz at 9.9 V)
Input Impedance	10 kOhms
Fiber Optic Ports	
PZ Amplifier	One 256-channel input The maximum sample rate is 48828.125 Hz when recording up to 128 channels or 24414.0625 Hz when recording 129 - 256 channels).
Legacy (Medusa)	Two 16-channel inputs
Add-on (Optional)	Up to four, one per QZDSP_Opt or Optical DSP card upgrade.
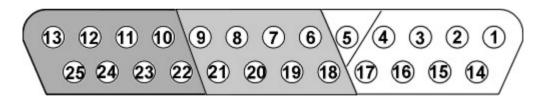
> ✏️ **Note**
>
> Technical specifications for preamplifier A/D converters are found in the specific preamplifier document.

BNC Channel Mapping

Please note channel numbering begins at the top right block of BNCs for each port and is printed on the face of the device.
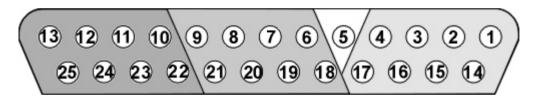
Byte Addressable

4	□
5	1
6	2
7	3

PORT - A

Maps to **Byte A** on Digital I/O DB25

Bit Addressable

4	□
5	1
6	2
7	3

PORT - C

Maps to **Bit Addr** on Digital I/O DB25

DAC Output

13	9
14	10
15	11
16	12

PORT - E

Maps to **Ch 9-16** on Analog I/O DB25

ADC Input

5	1
6	2
7	3
8	4

PORT - D

Maps to **Ch 1-8** on Analog I/O DB25

DB25 Analog I/O Pinout

Pin	Name	Description	Pin	Name	Description
1	NA	Not Used	14	NA	Not Used
2	NA		15	NA	
3	NA		16	NA	
4	NA		17	NA	
5	AGND	Analog Ground	18	A1	Analog Input
6	A2	Analog Input	19	A3	
7	A4		20	A5	
8	A6		21	A7	
9	A8		22	A9	Analog Output
10	A10	Analog Output	23	A11	
11	A12		24	A13	
12	A14		25	A15	
13	A16				

DB25 Digital I/O Pinout

Pin	Name	Description	Pin	Name	Description
1	C0	Port C Bit Addressable	14	C1	Port C Bit Addressable
2	C2		15	C3	
3	C4		16	C5	
4	C6		17	C7	
5	GND	Digital I/O Ground	18	A0	Port A Word Addressable
6	A1	Port A Word Addressable	19	A2	
7	A3		20	A4	
8	A5		21	A6	
9	A7		22	B0	Port B Word Addressable
10	B1	Port B Word Addressable	23	B2	
11	B3		24	B4	
12	B5		25	B6	
13	B7				

If using a PP24 Patch Panel, see PP24 to RZ2 Digital I/O.

RZ5D BioAmp Processor

RZ5D Overview

The RZ5D BioAmp Processor features up to four digital signal processors cards. Any card can be either a single standard processor card (RZDSP) or a quad core processor card (QZDSP). Standard single processor cards use a single Sharc DSP; quad-core processor cards use four Sharc DSPs cores with the potential to more than double the power of the RZ5D. All cards are networked on a multiprocessor architecture that features efficient onboard communication and memory access. The RZ5D is a versatile solution for real-time processing and simultaneous acquisition and stimulation.

The RZ5D acquires and processes up to 32 channels of neurophysiological signals in real-time. Data can be input from a PZ5 amplifier or digital headstage manifold at a sampling rate of up to ~50 kHz. The RZ5D also supports microstimulation applications. The RZ5D can be used with TDT's IZV Subject Interface (SI) for up to 128 channels of stimulation and switching headstages (ZC_SW) to comprise a complete microstimulation system.

Both single and quad-core processors cards may include an optical interface for connection to devices such as the RS4 Data Streamer or a second PZ Amplifier.
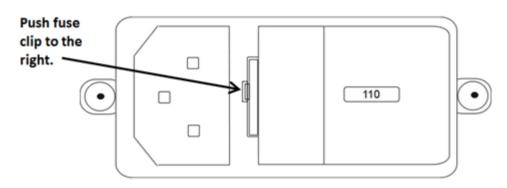
The RZ5D also features eight channels of analog I/O, 24 bits of digital I/O and an onboard monitor speaker with volume control.

Power and Communication

The RZ5D's Optibit optical interface connects to a PO5, PO5e, PO5c, or UZ3 computer interface card for fast and reliable data transfer from the RZ2 to the PC. Connectors on the back panel are color coded for correct wiring.

The RZ5D's integrated power supply is shipped from TDT configured for the end user's regional voltage setting (110 V or 220 V). If you need to change the voltage setting:

1. Turn off the RZ5D

2. Use a small flathead screwdriver to gently push the clip along the left side of the fuse plate to the right to remove it.

3. Remove the white AC voltage selector and rotate it until the desired voltage is displayed, then reinsert it and put the fuse plate back on.
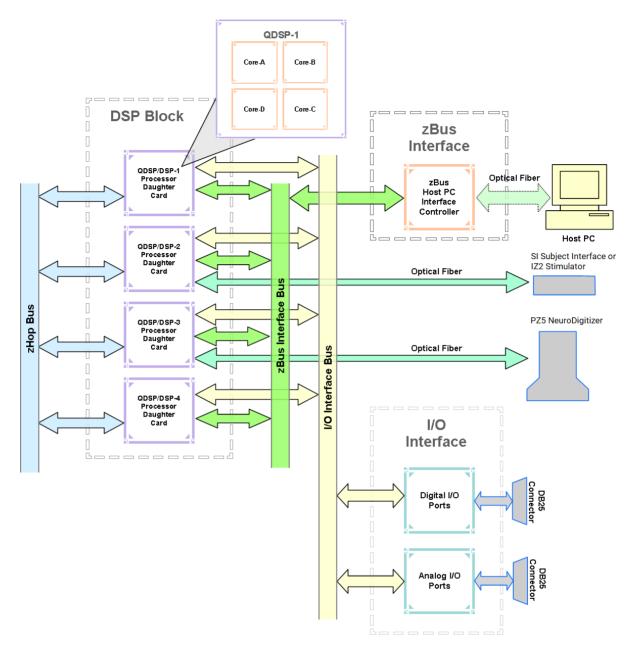
The RZ5D is UL compliant, see the RZ5 Operator's Manual for power and safety information.

Software Control

TDT's Synapse software controls the RZ5D and provides users a high level interface for device configuration.

RZ5D Architecture

The RZ5D processor uses a multi-bus architecture and offers three dedicated, data buses for fast, efficient data handling. While the operation of the system architecture is largely transparent to the user, a general understanding is important when designing experiments.

RZ5D Multi-DSP Architecture Functional Diagram

As shown in the diagram above, the RZ5D architecture consists of three functional blocks:

The DSPs	Each DSP in the DSP Block is connected to a local interface to the three data buses: two buses that connect each DSP to the other functional blocks and one that handles data transfer between the DSPs. Each standard DSP is connected to 64 MB SDRAM and each core in a QZDSP is connected to 256 MB DDR2. This architecture facilitates fast DSP-to-off-chip data handling.
	Because each DSP has its own associated memory, access is very fast and efficient. However, large and complex circuits should be designed to balance memory needs (such as data buffers and filter coefficients) across processors.
	The maximum number of circuit components for each RZ5D standard RZDSP is 768 and 1000 for each QZDSP core.
	DSP-2 and DSP-3 are special optical DSPs to connect directly to peripheral devices such as the SI, PZ, or iCon.
The zBus Interface	The zBus interface provides a connection to the PC. Data and host PC control commands are transferred to and from the DSP Block through the zBus interface bus, allowing for large high-speed data reads and writes without interfering with other system processing.
The I/O Interface	The I/O interface serves as a connection to outside signal sources or output devices. It is used to input data from the preamplifier inputs and digital and analog channels. The I/O interface bus provides a direct connection to each DSP.

Bus Related Delays

A standard two sample delay is associated with the zHop. However, these delays are managed for the user in Synapse software.

RZ5D Features

DSP Status Lights

These LEDs report the status of the multiprocessor's individual DSPs and will be lit solid green when the corresponding DSP is installed and running. The corresponding LED will be lit dim green if the cycle usage on a DSP is 0%. If the demands on a DSP exceed 99% of its capacity on any given cycle, the corresponding LED will flash red (~1 time per second). For QZDSPs, the LED indicates levels for the core with the highest cycle usage.

Front Panel Display Screen

```
Idle    u1   u2              All
Cyc.    0    0               0%
```

                                MODE
                                 ☐

The front panel display screen reports detailed information about the status of the system. The top line reports the system mode, Run!, Idle, or Reset. The second line reports the user's choice of status indicators for each DSP followed by an aggregate value.

The user can cycle through the various status indicators using the Mode button to the bottom right of the display. Push and release the button to change the display or push and hold the button for one second then release to automatically cycle through each of the display options. The display screen may also report system status such as booting status (Reset).

> ✏️ **Note**
>
> When burning new microcode or if the firmware on the RZ is blank, the display screen will report a cycle usage of 99% and the processor status lights will flash red.

Indicator	Description
Cyc	Cycle usage. For QZDSPs, the highest core cycle usage is shown
Bus%	Percentage of internal device's bus capacity used
I/O%	Percentage of data transfer capacity used

PZ Preamplifier Port

The RZ5D acquires digitized signals from a PZ5 preamplifier via a fiber optic cable through the port labeled 'PZ' on the front panel. This port can input up to 32 channels at a maximum sampling rate of ~50 kHz. The PZ port can be used with any of the PZ preamplifier and is configured in Synapse software.

SI Subject Interface Port

The output port labeled SI can be used with a Subject Interface, PZ5 amplifier, or iCon Behavioral Controller for up to 128 channels of electrical stimulation, neurophysiological recording, or behavior control.

> ✏️ **Note**
>
> RZ5D with serial number <1215 had an IZ port for IZ2 Stimulator support.

Onboard Analog I/O

The RZ5D is equipped with four channels of 16-bit PCM D/A and four channels of 16-bit PCM A/D. All 8 channels can be accessed via front panel BNCs marked ADC and DAC or via a 25-pin analog I/O connector. See RZ5D Technical Specifications for the DB25 pinout.

The following table provides a quick overview of the analog I/O features and how they must be accessed during experiment design.

Analog I/O	Synapse Access	Notes
ADC Analog Inputs	ADC Tab	Accessed through ADC Input BNCs or Analog I/O labeled DB25
DAC Analog Outputs	DAC Tab	Accessed through DAC Output BNCs or Analog I/O labeled DB25

Monitor Speaker

The RZ5D is equipped with an onboard speaker. To use the speaker, feed the desired signal to the first DAC output channel. The speaker is provided primarily for audio monitoring of a single channel of electrophysiological potentials during recording.

Digital I/O

The digital I/O ports include 24 bits of programmable I/O. The digital I/O is divided into three bytes (A, B, and C) as described in the chart below. All digital I/O lines are accessed via the 25-pin connector on the front of the RZ5D and bits 0 - 3 of byte C are available through BNC connectors on the front panel labeled Digital. See RZ5D Technical Specifications for the DB25 pinout.

The digital I/O is configured in the Synapse RZn Hal.

Digital I/O	Description	DB25	BNCs	Notes
Byte A	bits 0 - 7	Yes	No	byte addressable
Byte B	bits 0 - 7	Yes	No	byte addressable
Byte C	bits 0 - 7	Yes	Yes*	bit addressable

*Note: Byte C Bits 0 - 3 are available via front panel BNCs

The data direction for the Digital I/O is also configured in the Synapse RZn Hal.

The RZ digital I/O ports have different voltage outputs and logic thresholds depending on the type. Below is a table listing the different voltage outputs and thresholds for both types.

Digital I/O Type	Output High	Output Low	Input High	Input Low
Port A & Port B	5 V	0 V	>=2.5 V	0-2.45 V
Port C	3.3 V	0 V	>=1.5 V	0-1.4 V

LED Indicators

The RZ5D has 16 LED indicators for the analog and digital I/O located directly below the display screen and DSP status LEDs.

Digital I/O

These LEDs indicate the state of the 8 bit-addressable I/O of byte C.

Light Pattern	Description
Dim Green	Bit is configured for output and is currently a logical low (0)
Solid Green	Bit is configured for output and is currently a logical high (1)
Dim Red	Bit is configured for input and is currently a logical low (0)
Solid Red	Bit is configured for input and is currently a logical high (1)

Analog I/O

These LEDs indicate the state of the four ADC and four DAC channels.

Light Pattern	Description
Off	Analog I/O channel signal voltage is less than ±100 mV
Dim Green	Analog I/O channel signal voltage is less than ±5 V
Solid Green	Analog I/O channel signal voltage is between ±5 V to ±9 V
Solid Red	Analog I/O channel clip warning (voltage greater than ±9 V)

UDP Ethernet Interface

The RZ UDP Ethernet interface can transfer low bandwidth data directly to or from a PC. RZ devices equipped with a UDP interface have an additional Ethernet port and RS232 serial port located on the back panel. See RZ-UDP Communications Interface for more information.

Specialized DSP/Optical Interface Boards

The RZ standard DSP boards can be replaced with specialized DSP boards which include an optical interface for communication and control of RZ compatible devices, such as the Subject Interface and RS4 Data Streamer. RZ devices equipped with one or more specialized DSP boards include an optical port for each card. The ports are located on the front panel and labeled for easy identification.

| DSP	Supported Peripheral
RZDSP-I	IZ2 Stimulators
RZDSP-M	Subject Interface, PZ5 amplifier, iCon Behavioral Controller
RZDSP-P	PZ amplifier. It can be used to expand the number of channels that can be acquired on any RZ processor.
RZDSP-S	RS4 Data Streamer, allowing the RZ device to stream data directly to the RS4's storage arrays.
RZDSP-U	PO8e interface card, allowing the RZ device to stream data directly to client software.
RZDSP-V	RV2 Video Tracking System
QZDSP_OPT	Supports all of the above devices.

RZ5D Technical Specifications
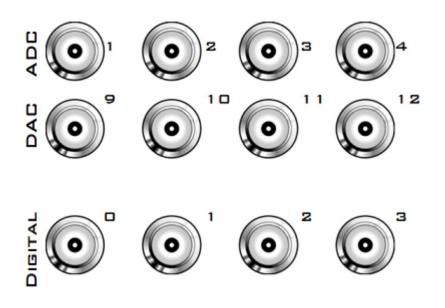
> ✏️ **Note**
>
> Specifications for amplifier A/D converters are found under the preamplifier's technical specifications.

|	
DSP	Up to four standard DSPs and/or quad-core (QZDSP) DSP: 400 MHz DSPs, 2.4 GFLOPS peak per DSP QZDSP: Four 400 MHz DSPs, 2.4 GFLOPS per core
Memory	64 MB SDRAM per standard DSP 256 MB DDR2 RAM per core, four cores per QZDSP
Digital I/O	8 programmable bits: 3.3 V (5.0 V max input), 25 mA max load 2 programmable bytes (16 bits): 5.0 V (6.0 V max input), 35 mA max load
D/A	**4 channels, 16-bit PCM**
Sample Rate	Up to 48828.125 Hz
Frequency Response	DC - 0.44 * Fs (Fs = sample rate)
Voltage Out	±10.0 V, 175 mA max load
S/N (typical)	82 dB (20 Hz - 20 kHz at 9.9 V)
Output Impedance	10 Ohms
A/D	**4 channels, 16-bit PCM**
Sample Rate	Up to 48828.125 Hz
Frequency Response	DC - 7.5 kHz (3 dB corner, 2nd order, 12 dB per octave)
Voltage In	±10.0 V
S/N (typical)	82 dB (20 Hz - 20 kHz at 9.9 V)
Input Impedance	10 kOhms
Fiber Optic Ports	
M	Two connections for Subject Interface, PZ5, or iCon (serial >=1233)
SI	One connection for Subject Interface, PZ5, or iCon (serial 1215-1232)
IZ	One connection for IZ2 Stimulator (serial <1215)
PZ	One connection for PZ5 NeuroDigitizer (serial <1233)
Add-on (Optional)	Up to two, one per QZDSP_Opt or Optical DSP card upgrade.
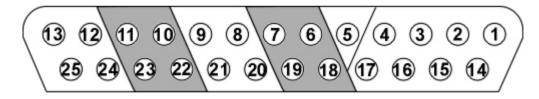
> ✏️ **Note**
>
> Technical specifications for preamplifier A/D converters and stimulator outputs are found in the specific preamplifier / stimulator document.

BNC Channel Mapping

Please note channel numbering begins at the top left block of BNCs for both analog and digital I/O and is printed on the face of the device to minimize miswiring.
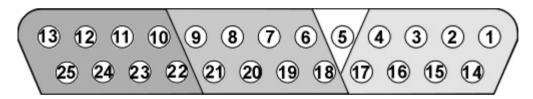

DB25 Analog I/O Pinout

Pin	Name	Description		Pin	Name	Description	
1	NA	Not Used		14	NA	Not Used	
2	NA			15	NA		
3	NA			16	NA		
4	NA			17	NA		
5	AGND	Analog Ground		18	A1	Analog Input	
6	A2	Analog Input		19	A3		
7	A4			20	NA	Not Used	
8	NA	Not Used		21	NA		
9	NA			22	A9	Analog Output	
10	A10	Analog Output		23	A11		
11	A12			24	NA	Not Used	
12	NA	Not Used		25	NA		
13	NA						

DB25 Digital I/O Pinout

Pin	Name	Description		Pin	Name	Description
1	C0	Port C Bit Addressable		14	C1	Port C Bit Addressable
2	C2			15	C3	
3	C4			16	C5	
4	C6			17	C7	
5	GND	Digital I/O Ground		18	A0	Port A Word Addressable
6	A1	Port A Word Addressable		19	A2	
7	A3			20	A4	
8	A5			21	A6	
9	A7			22	B0	Port B Word Addressable
10	B1	Port B Word Addressable		23	B2	
11	B3			24	B4	
12	B5			25	B6	
13	B7					

If using a PP24 Patch Panel, see PP24 to RZ5D Digital I/O.

RZ10x Lux Integrated Processor

RZ10x Overview

The RZ10x platform includes light driving/sensing capabilities for lock-in amplification fiber photometry setups. The RZ10x model has two banks of light driving/sensing ports for running multiple subjects or to add optogenetic stimulation, and includes fiber optic connections for integrated multi-channel neurophysiology.

The RZ10x Lux Integrated Processor has three 400 MHz Sharc digital signal processors (DSPs). It includes two banks of integrated Lux light drivers and photosensors. It is expandable to up to four DSPs.

Each Lux bank has 3 output drivers and 2 inputs. Each output port can have either a Lux LED, an M8 connector to drive an external LED, or a BNC connector to control a voltage signal. Each input port can have either a Lux PS1 or PS2 photosensor, a Lux PM1 power meter, or a BNC connector to measure a voltage input. The components are interchangeable by the user.

The RZ10x includes two additional analog input channels. The RZ10x fiber optic input port can acquire up to 32 channels of neurophysiological signals from a PZ5 or Subject Interface amplifier at up to ~50 kHz for real-time processing synchronized to your fiber photometry data and/or optogenetic stimulation.

The RZ10x features 24-bits of digital I/O (four bits are accessible on the front panel BNC connectors) and a legacy fiber optic port to acquire neurophysiological signals from a Medusa4Z, RA8GA, or RA16PA preamplifier.
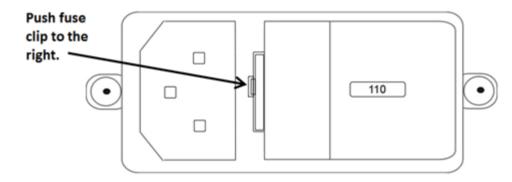
This manual provides hardware information for the RZ10x. For a full application guide specific to fiber photometry using the RZ10x, see the Fiber Photometry User Guide.

Power and Communication

The RZ10x's Optibit optical interface connects to a PO5e, PO5c, or UZ3 computer interface for fast and reliable data transfer from the RZ10x to the PC. Connectors on the back panel are color coded for correct wiring.

The RZ10x's integrated power supply is shipped from TDT configured for the end user's regional voltage setting (110 V or 220 V). If you need to change the voltage setting:

1. Turn off the RZ10x

2. Use a small flathead screwdriver to gently push the clip along the left side of the fuse plate to the right to remove it.

3. Remove the white AC voltage selector and rotate it until the desired voltage is displayed, then reinsert it and put the fuse plate back on.

The RZ10x is UL compliant, see the RZ10x Operator's Manual for power and safety information.
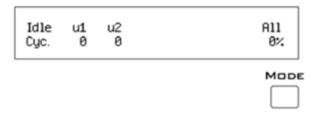
Software Control

TDT's Synapse software controls the RZ10x and provides users a high level interface for device configuration.

RZ10x Features

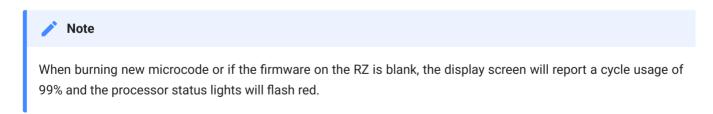**DSP Status Lights**

PROCESSORS

These LEDs report the status of the multiprocessor's individual DSPs and will be lit solid green when the corresponding DSP is installed and running. The corresponding LED will be lit dim green if the cycle usage on a DSP is 0%. If the demands on a DSP exceed 99% of its capacity on any given cycle, the corresponding LED will flash red (~1 time per second). For QZDSPs, the LED indicates levels for the core with the highest cycle usage.

Front Panel Display Screen

```
Idle   u1    u2                 All
Cyc.    0     0                  0%
```

MODE

The front panel display screen reports detailed information about the status of the system. The top line reports the system mode, Run!, Idle, or Reset. The second line reports the user's choice of status indicators for each DSP followed by an aggregate value.

The user can cycle through the various status indicators using the Mode button to the bottom right of the display. Push and release the button to change the display or push and hold the button for one second then release to automatically cycle through each of the display options. The display screen may also report system status such as booting status (Reset).

> ✎ **Note**
>
> When burning new microcode or if the firmware on the RZ is blank, the display screen will report a cycle usage of 99% and the processor status lights will flash red.

Indicator	Description
Cyc	Cycle usage. For QZDSPs, the highest core cycle usage is shown
Bus%	Percentage of internal device's bus capacity used
I/O%	Percentage of data transfer capacity used
Opt	Connection (sync) status of legacy amplifier

Fiber Optic Port

The fiber optical port next to the Digital I/O connector can be used with a Subject Interface, PZ5 amplifier, or iCon Behavioral Controller for up to 128 channels of electrical stimulation, 32 channels or neurophysiological recording, or behavior control. It is labeled 'M' or 'SI'.

> ✏️ **Note**
>
> RZ10x with serial number <2000 had a port labeled 'PZ' for PZ5 NeuroDigitizer support only.

Legacy Fiber Optic Port

The RZ10x has one Legacy fiber optic ports labeled Legacy Amp to acquire digitized signals from the Medusa4Z, RA16PA, or RA8GA. This port can read up to 16 channels at a maximum sampling rate of ~25 kHz.

Onboard Analog Inputs

The Onboard Lux I/O is the primary analog I/O on the RZ10x. However, the RZ10x has two extra channels of 16-bit PCM A/D input accessible through the BNCs marked 'ADC4' and 'ADC8'. See the Synapse Manual for information on using these inputs.

Digital I/O

The digital I/O ports include 24 bits of programmable I/O. The digital I/O is divided into three bytes (A, B, and C) as described in the chart below. All digital I/O lines are accessed via the 25-pin connector on the front of the RZ10x and bits 0 - 3 of byte C are available through BNC connectors on the front panel labeled Digital. See RZ10x Technical Specifications for the DB25 pinout.

The digital I/O is configured in the Synapse RZn Hal.

Digital I/O	Description	DB25	BNCs	Notes
Byte A	bits 0 - 7	Yes	No	byte addressable
Byte B	bits 0 - 7	Yes	No	byte addressable
Byte C	bits 0 - 7	Yes	Yes*	bit addressable

*Note: Byte C Bits 0 - 3 are available via front panel BNCs

The data direction for the Digital I/O is also configured in the Synapse RZn Hal.

The RZ digital I/O ports have different voltage outputs and logic thresholds depending on the type. Below is a table listing the different voltage outputs and thresholds for both types.

Digital I/O Type	Output High	Output Low	Input High	Input Low
Port A & Port B	5 V	0 V	>=2.5 V	0-2.45 V
Port C	3.3 V	0 V	>=1.5 V	0-1.4 V

LED Indicators

The RZ10x has 16 LED indicators for the analog and digital I/O located directly below the display screen and DSP status LEDs.

Digital I/O

These LEDs indicate the state of the 8 bit-addressable I/O of byte C.

Light Pattern	Description
Dim Green	Bit is configured for output and is currently a logical low (0)
Solid Green	Bit is configured for output and is currently a logical high (1)
Dim Red	Bit is configured for input and is currently a logical low (0)
Solid Red	Bit is configured for input and is currently a logical high (1)

Analog I/O

These LEDs indicate the state of the four ADC and four DAC channels.

Light Pattern	Description
Off	Analog I/O channel signal voltage is less than ±100 mV
Dim Green	Analog I/O channel signal voltage is less than ±5 V
Solid Green	Analog I/O channel signal voltage is between ±5 V to ±9 V
Solid Red	Analog I/O channel clip warning (voltage greater than ±9 V)

> ✏️ **Note**
>
> ADC channel 3 and DAC channel 4 are used internally while the RZ10x is actively running, so the ADC3 and DAC4 LEDs will flash ~1 Hz during normal operation.

UDP Ethernet Interface

The RZ UDP Ethernet interface can transfer low bandwidth data directly to or from a PC. RZ devices equipped with a UDP interface have an additional Ethernet port and RS232 serial port located on the back panel. See RZ-UDP Communications Interface for more information.

Specialized DSP/Optical Interface Boards

The RZ standard DSP boards can be replaced with specialized DSP boards which include an optical interface for communication and control of RZ compatible devices, such as the Subject Interface and RS4 Data Streamer. RZ devices equipped with one or more specialized DSP boards include an optical port for each card. The ports are located on the back panel and labeled for easy identification.

| DSP	Supported Peripheral
RZDSP-I	IZ2 Stimulators
RZDSP-M	Subject Interface, PZ5 amplifier, iCon Behavioral Controller
RZDSP-P	PZ amplifier. It can be used to expand the number of channels that can be acquired on any RZ processor
RZDSP-S	RS4 Data Streamer, allowing the RZ device to stream data directly to the RS4's storage arrays
RZDSP-U	PO8e interface card, allowing the RZ device to stream data directly to client software
RZDSP-V	RV2 Video Tracking System
QZDSP_OPT	Supports all of the above devices

Onboard Lux I/O
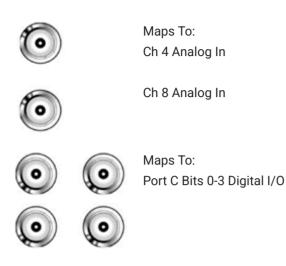
The RZ10x has two banks of integrated Lux components. Each Lux bank has three built-in current driver outputs for driving integrated LEDs directly, or external LEDs connected to an M8 cable. Each Lux bank also has two input slots for photosensors and/or power meters.
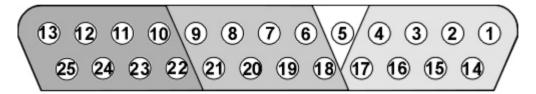
RZ10x Technical Specifications

> ✏️ **Note**
>
> Specifications for amplifier A/D converters are found under the preamplifier's technical specifications. See the Lux hardware manual for more information and technical specifications of the Lux pods.

DSP	Up to four standard DSPs and/or quad-core (QZDSP)
	DSP: 400 MHz DSPs, 2.4 GFLOPS peak per DSP
	QZDSP: Four 400 MHz DSPs, 2.4 GFLOPS per core
Memory	64 MB SDRAM per standard DSP
	256 MB DDR2 RAM per core, four cores per QZDSP
Digital I/O	8 programmable bits: 3.3 V (5.0 V max input), 25 mA max load
	2 programmable bytes (16 bits): 5.0 V (6.0 V max input), 35 mA max load
A/D	**1 channel, 16-bit PCM**
Sample Rate	Up to 48828.125 Hz
Frequency Response	DC - 7.5 kHz (3 dB corner, 2nd order, 12 dB per octave)
Voltage In	±10.0 V
S/N (typical)	82 dB (20 Hz - 20 kHz at 9.9 V)
Input Impedance	10 kOhms
Fiber Optic Ports	
SI	RZ10x (serial >=2000): One connection for Subject Interface, PZ5, or iCon
PZ	RZ10x (serial <2000): One connection for PZ5 NeuroDigitizer
Legacy Amp (Medusa)	16-channel input, up to 24414.0625 Hz

BNC Channel Mapping

Please note channel numbering is printed on the face of the device to minimize mis-wiring.

Maps To:
Ch 4 Analog In

Ch 8 Analog In

Maps To:
Port C Bits 0-3 Digital I/O

DB25 Digital I/O Pinout

Pin	Name	Description		Pin	Name	Description
1	C0	Port C Bit Addressable		14	C1	Port C Bit Addressable
2	C2			15	C3	
3	C4			16	C5	
4	C6			17	C7	
5	GND	Digital I/O Ground		18	A0	Port A Word Addressable
6	A1	Port A Word Addressable		19	A2	
7	A3			20	A4	
8	A5			21	A6	
9	A7			22	B0	Port B Word Addressable
10	B1	Port B Word Addressable		23	B2	
11	B3			24	B4	
12	B5			25	B6	
13	B7					

If using a PP24 Patch Panel, see PP24 to RZ10x Digital I/O.

RZ6 Multi I/O Processor

RZ6 Overview

The RZ6 Multi I/O Processor is a high sample rate processor with flexible input/output capabilities. The RZ6 features up to four digital signal processors cards. Any card can be either a single standard processor card (RZDSP) or a quad core processor card (QZDSP). Standard single processor cards use a single Sharc DSP; quad-core processor cards use four Sharc DSPs cores with the potential to more than double the power of the RZ6. All cards are networked on a multiprocessor architecture that features efficient onboard communication and memory access. Two channels each of sigma-delta analog input and output provide a dynamic range of up to 115 dB and sampling rates up to ~200 kHz.

The single device form factor incorporates two channels of onboard programmable and manual attenuation and can drive headphones and standard, magnetic, or electrostatic speakers. It includes an onboard monitor speaker, two channels of amplification for analog inputs, and 24 bits of digital I/O. XLR, audio jack, and BNC connections are supported. Optionally, the RZ6 can be equipped with a fiber optic input, allowing it to support a four channel Medusa preamplifier.

The RZ6-A base version starts with a single DSP and makes an excellent all-in-one psychoacoustics system or can be added to any system to add audio stimulus generation to experiments.

The RZ6-A-P1 comes equipped with four DSPs for more processing power and includes the optional fiber optic input port, allowing it to serve as a BioAmp base station for ABR and OAE studies using TDT's BioSigRZ software.

Both configurations can be upgraded with additional single or quad-core DSP cards (up to a maximum of four DSP cards) for complex filtering and high frequency applications.
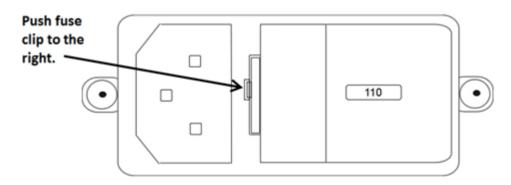
> ✏️ **Note**
>
> RZ6-A-P1 serial number <3000 came with three DSPs in the standard configuration.

Power and Communication

The RZ6's Optibit optical interface connects to a PO5, PO5e, PO5c, or UZ3 computer interface card for fast and reliable data transfer from the RZ2 to the PC. Connectors on the back panel are color coded for correct wiring.

The RZ6's integrated power supply is shipped from TDT configured for the end user's regional voltage setting (110 V or 220 V). If you need to change the voltage setting:

1. Turn off the RZ6

2. Use a small flathead screwdriver to gently push the clip along the left side of the fuse plate to the right to remove it.

3. Remove the white AC voltage selector and rotate it until the desired voltage is displayed, then reinsert it and put the fuse plate back on.
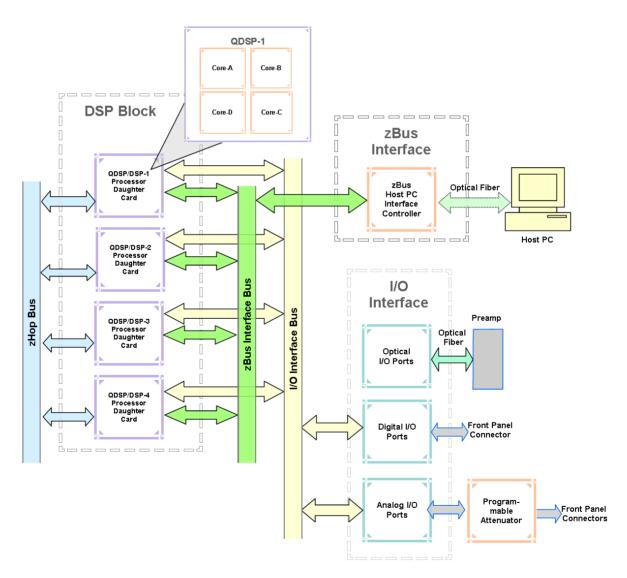
The RZ6 is UL compliant, see the RZ6 Operator's Manual for power and safety information.

Software Control

TDT's Synapse or BioSigRZ software controls the RZ6 and provides users a high level interface for device configuration. If using RPvdsEx to design circuits for the RZ6, see the Legacy System 3 Manual for information on what macros to use.

RZ6 Architecture

The RZ6 processor uses a multi-bus architecture and offers three dedicated, data buses for fast, efficient data handling. While the operation of the system architecture is largely transparent to the user, a general understanding is important when designing experiments.

RZ6 Architecture Diagram

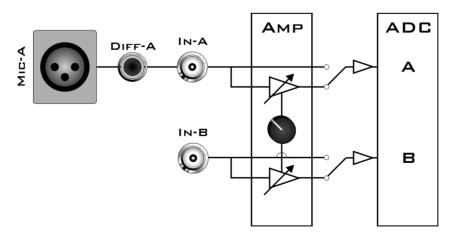As shown in the diagram above, the RZ6 architecture consists of three functional blocks:

The DSPs	Each DSP in the DSP Block is connected to a local interface to the three data buses: two buses that connect each DSP to the other functional blocks and one that handles data transfer between the DSPs. Each standard DSP is connected to 64 MB SDRAM and each core in a QZDSP is connected to 256 MB DDR2. This architecture facilitates fast DSP-to-off-chip data handling.
	Because each DSP has its own associated memory, access is very fast and efficient. However, large and complex circuits should be designed to balance memory needs (such as data buffers and filter coefficients) across processors.
	The maximum number of circuit components for each RZ5D standard RZDSP is 768 and 1000 for each QZDSP core.
The zBus Interface	The zBus interface provides a connection to the PC. Data and host PC control commands are transferred to and from the DSP Block through the zBus interface bus, allowing for large high-speed data reads and writes without interfering with other system processing.
The I/O Interface	The I/O interface serves as a connection to outside signal sources or output devices. It is used to input data from the preamplifier inputs and digital and analog channels. The I/O interface bus provides a direct connection to each DSP.

Bus Related Delays

A standard two sample delay is associated with the zHop. However, these delays are managed for the user in Synapse software.
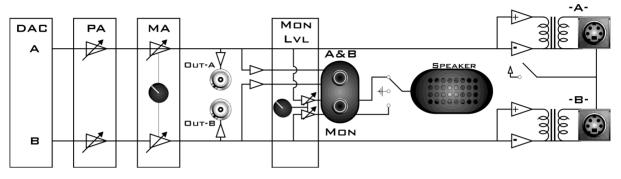
Functional Signal Flow Diagrams

The following diagrams illustrate how analog signals for channels A and B flow through the RZ6 and its modules. For more information on analog input and output see Onboard Analog I/O and Optional Amplifier Input.

RZ6 Analog Input Flow Diagram

Input signals for channel A are input either through the XLR input (Mic-A), the audio jack input (Diff-A), or BNC (In-A). Input signals for channel B are input through the BNC (In-B).

A switch located to the left of the gain control knob allows a single gain setting for both channels to be applied or bypassed completely.

RZ6 Analog Output Flow Diagram

Signals A and B flow out of the DAC and pass through the programmable and manual attenuation modules prior to being output on the front panel BNC connectors (Out-A and Out-B).

The signals for channels A and B are also passed to two stereo headphone output ports labeled A&B and Mon. Individual stereo power amplifiers are used for the BNC and stereo headphone outputs.

A single channel monitor speaker is connected either to signal A, signal B, or disabled based on the monitor control switch setting. The monitor level knob controls the sound level of both the stereo headphone jack labeled Mon and the monitor speaker.
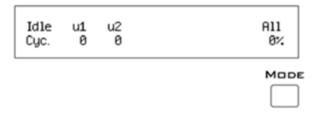
Finally, if the electrostatic speaker driver is enabled via its switch, located on the front panel, signals A and B are output from the mini-DIN ports located on the RZ6 front panel.
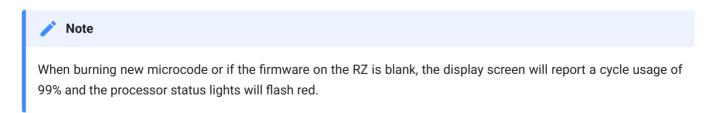
RZ6 Features

DSP Status Lights

PROCESSORS

These LEDs report the status of the multiprocessor's individual DSPs and will be lit solid green when the corresponding DSP is installed and running. The corresponding LED will be lit dim green if the cycle usage on a DSP is 0%. If the demands on a DSP exceed 99% of its capacity on any given cycle, the corresponding LED will flash red (~1 time per second). For QZDSPs, the LED indicates levels for the core with the highest cycle usage.

Front Panel Display Screen

```
Idle   u1   u2              All
Cyc.    0    0               0%
```

MODE

The front panel display screen reports detailed information about the status of the system. The top line reports the system mode, Run!, Idle, or Reset. The second line reports the user's choice of status indicators for each DSP followed by an aggregate value.

The user can cycle through the various status indicators using the Mode button to the bottom right of the display. Push and release the button to change the display or push and hold the button for one second then release to automatically cycle through each of the display options. The display screen may also report system status such as booting status (Reset).

> ✏ **Note**
>
> When burning new microcode or if the firmware on the RZ is blank, the display screen will report a cycle usage of 99% and the processor status lights will flash red.

Indicator	Description
Cyc	Cycle usage. For QZDSPs, the highest core cycle usage is shown
Bus%	Percentage of internal device's bus capacity used
I/O%	Percentage of data transfer capacity used
DAC	Displays the current analog attenuator setting. Also displays bars according to the RMS level of DAC A and B using a logarithmic scale **Note:** Eight solid bars denote that the signal on DAC A or B is clipping.
ADC	Displays bars according to the RMS Level on ADC A and B using a logarithmic scale. **Note:** Eight solid bars denote that the signal on ADC A or B is clipping.

Onboard Analog I/O and Optional Amplifier Input

The RZ6 is equipped with onboard analog I/O and attenuators. It may also include a fiber optic port for Medusa preamplifier input.

The table below provides a quick overview of these I/O features and how they must be accessed during experiment design.

Analog I/O	Description	Synapse Access	RPvdsEx Access
In-A and In-B	Analog Inputs	ADC Tab	RZ6_AudioIn macro
Out-A and Out-B	Analog Outputs	DAC Tab	RZ6_AudioOut macro
Atten-A and Atten-B	Programmable Attenuators	DAC Tab	RZ6_AudioOut macro
Optical In	Medusa PreAmp Input	RAn Hal	RZ6_AmpIn (for RA4PA) or Medusa4Z_Input macro

Onboard Analog Inputs

The RZ6 is equipped with two channels of 24-bit sigma-delta A/D converters. See RZ6 Technical Specifications for more information.

Analog signals can be input through several connectors on the RZ6 front panel.

Channel A has three possible sources:

- MIC-A (XLR microphone input)
- DIFF-A (¼" TRS microphone input)
- BNC labeled In-A

Channel B uses only the BNC labeled In-B:

> 🔥 **Important**
>
> Use only one input for channel A at a time. Attempting to input signals from multiple sources will produce an erroneous signal.

A and B Microphone Amplifier

An onboard two channel amplifier provides gain for the onboard analog input signals (MIC-A, DIFF-A, In-A, and In-B). The switch located to the left of the gain control knob allows the current gain setting to be applied (if set to Amp) or bypassed completely (if set to Byp).
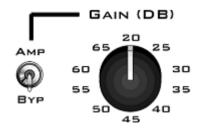
> 🔥 **Important**
>
> When the gain is enabled, analog input signals MIC-A and DIFF-A are differential. Since the differential signals are summed a signal gain of 6 dB will be inherently applied. If the amplifier is bypassed, common mode rejection is disabled.

> ✏️ **Note**
>
> To prevent clipping caused by a DC offset, the amplifier is AC coupled when the gain amplification is in use.

Gain

The front panel gain control knob can be used to the control overall signal level of both channels from 20 to 65 dB in 5 dB steps.

Fiber Optic Port - Optional

The RZ6-A-P1 acquires digitized signals from a Medusa preamplifier over a fiber optic cable. The port can be used with the RA4PA or Medusa4Z to input up to 4 channels.

The fiber optic port (devices with serial number 1007 and greater) can also support the HTI3 Head Tracker Interface.

Fiber Oversampling (preamp input)

Signals are digitized on the Medusa preamplifier at a maximum sampling rate of ~25 kHz, however, the fiber optic port on the RZ6 can oversample the digitized signals up to 8X or ~200 kHz. This will allow the RZ6 to run a DSP chain at ~200 kHz and still sample data acquired through an optically connected preamplifier.

Oversampling is performed on the RZ6. The signals being acquired will still be sampled at ~25 kHz on the preamplifier. This means that, even with oversampling, signals acquired by an optically connected preamplifier are still governed by the bandwidth and frequency response of the preamplifier.

Onboard Analog Outputs

The RZ6 is equipped with two channels of 24-bit sigma-delta D/A converters. See RZ6 Technical Specifications for more information. Analog signals are output through a variety of connectors on the RZ6 front panel.

Programmable Attenuation

The RZ6 has two channels of programmable attenuation for precision control of analog output signal levels over a wide dynamic range.

Programmable attenuation in the RZ6 is achieved using both analog and digital attenuation methods. The device supports analog attenuation values of 0, 20, 40, and 60 dB. Attenuation values which lie in-between or exceed 60 dB are handled using digital attenuation.

For example, if you set an attenuation value of 66 dB, the analog attenuator will be set to 60 dB and the remaining 6 dB of attenuation will be applied by scaling the digital signal on the processor before it goes to the DAC.

For the best results, you should use the maximum D/A voltage range and use the attenuators to reduce the output to the target voltage.

Manual Attenuator

The RZ6 includes another level of analog attenuation that can be controlled manually via the attenuator control knob from 0 to 27 dB in increments of 3 dB.

Manual attenuation is applied to both channels before the signals are output on any of the front panel connectors and is therefore applied in addition to any programmable attenuation.
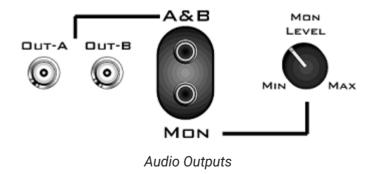
Analog Output via BNCs

DAC channels A and B are output to BNCs labeled Out-A and Out-B after attenuation has been applied. These outputs use a stereo power amplifier to drive TDT's MF1 multi-function speakers.

A single signal generated or input from any of the RZ6 analog inputs can be ganged to reduce the spectral variation in power of the transducer across all frequencies. To do this, configure your signal to output from both DAC channels and connect your transducer to both channels.

Stereo Headphone Output

DAC channels A and B are also available as a stereo headphone output through two ⅛" audio jack connector ports (channel A is the left stereo output and channel B is the right stereo output). The port labeled A&B (top) provides a stereo headphone output suitable for experimental paradigms while the port labeled Mon (bottom) can be controlled by the Mon Level knob located directly to the right, making it more suitable for monitoring the experiment.

Audio Outputs

> ✏️ **Note**
>
> All outputs use stereo power amplifiers
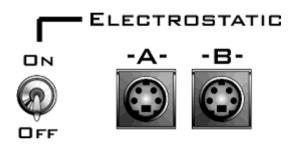
Monitor Speaker

The RZ6 is equipped with an onboard monitor speaker, provided for audio monitoring of a single channel. A switch located directly to the left of the monitor speaker is used to select between DAC channels A and B or to disable the monitor speaker. The monitor speaker output level is controlled by the Mon Level knob located directly to the right of the monitor stereo output.

Electrostatic Speaker Output

An onboard two channel broadband electrostatic speaker driver is provided, allowing direct connection of TDT's ES series electrostatic speakers. The driver produces flat frequency responses reaching far into the ultrasonic range, can drive two ES series speakers, and is powered using the onboard power supply. A switch located directly to the left of the two 4-pin, mini-DIN connectors is used to enable or disable output of DAC channels A and B.

> ✏️ **Note**
>
> The electrostatic speaker driver is designed to work exclusively with TDT's electrostatic series speakers. Do NOT attempt to use any other speaker.

> 🔥 **Important**
>
> If the electrostatic speaker driver is not being used, make sure that the ON/OFF switch is in the OFF position to reduce noise on the RZ6 analog I/O.

Digital I/O

The digital I/O ports include 24 bits of programmable I/O. The digital I/O is divided into three bytes (A, B, and C) as described in the chart below. All digital I/O lines are accessed via the 25-pin connector on the front of the RZ6. Earlier versions (serial number <2000) were limited to 8 bits. See RZ6 Technical Specifications for the DB25 pinout.

The digital I/O is configured in the Synapse RZn Hal.

Digital I/O	Description	DB25	BNCs	Notes
Byte A	bits 0 - 7	Yes	No	byte addressable
Byte B	bits 0 - 7	Yes	No	byte addressable
Byte C	bits 0 - 7	Yes	No	bit addressable

The data direction for the Digital I/O is also configured in the Synapse RZn Hal, or in RPvdsEx with the RZ6_Control macro.

The RZ digital I/O ports have different voltage outputs and logic thresholds depending on the type. Below is a table listing the different voltage outputs and thresholds for both types.

Digital I/O Type	Output High	Output Low	Input High	Input Low
Port A & Port B	5 V	0 V	>=2.5 V	0-2.45 V
Port C	3.3 V	0 V	>=1.5 V	0-1.4 V

LED Indicators

The RZ5D has 16 LED indicators for the analog and digital I/O located directly below the display screen and DSP status LEDs.

Digital I/O

These LEDs indicate the state of the 8 bit-addressable I/O of byte C.

Light Pattern	Description
Dim Green	Bit is configured for output and is currently a logical low (0)
Solid Green	Bit is configured for output and is currently a logical high (1)
Dim Red	Bit is configured for input and is currently a logical low (0)
Solid Red	Bit is configured for input and is currently a logical high (1)

Analog Input - ADC LED Indicators

The ADC LED indicators are labeled and located at the top right of the RZ6 front panel. The LEDs indicate the level of the signals on ADC channels A and B. This provides a useful indicator for adjusting the gain and to detect and prevent clipping. The following table describes the LED indicators' operation.

LEDs Lit	Description
4	Input is <=-6 dB down from max input voltage
3	Input is between -6 dB and -12 dB down from max input voltage
2	Input is between -12 dB and -25 dB down from max input voltage
1	Input is between -25 dB and -50 dB down from max input voltage

Fiber Optic Indicator

A single green LED indicator next to the fiber optic input port on the RZ6-A-P1 lights when a Medusa preamplifier is correctly synced with the RZ6.

RZ6 Technical Specifications

> ✎ **Note**
>
> The RZ6 can be equipped with a fiber optic input port and used with a four channel Medusa preamplifier. See the preamplifier's technical specifications for A/D converters.

DSP	Up to four standard DSPs and/or quad-core (QZDSP)
	DSP: 400 MHz DSPs, 2.4 GFLOPS peak per DSP
	QZDSP: Four 400 MHz DSPs, 2.4 GFLOPS per core
Memory	64 MB SDRAM per standard DSP
	256 MB DDR2 RAM per core, four cores per QZDSP
Digital I/O	8 programmable bits: 3.3 V (5.0 V max input), 25 mA max load
	2 programmable bytes (16 bits): 5.0 V (6.0 V max input), 35 mA max load
Fiber Optic Ports	Optional Input available on RZ6-A-P1 only. Supports:
	- Medusa4Z preamplifier (serial number 2400 and greater)
	- 4-channel RA4PA preamplifier
	- HTI3 Head Tracker Interface (serial number 1007 and greater)

D/A	2 channels, 24-bit sigma-delta
Sample Rate	Up to 195312.50 Hz
Frequency Response	DC - 0.44 * Fs (Fs = sample rate)
Voltage Out	±10.0 V
S/N (typical)	115 dB (20 Hz - 80 kHz at 5 Vrms)
THD (typical)	-90 dB (1 kHz output at 5 Vrms)
Sample Delay	31 (serial numbers >2000)
	47 (serial numbers <2000)
Output Impedance	1 Ohm

A/D	2 channels, 24-bit sigma-delta
Sample Rate	Up to 195312.50 Hz
Frequency Response	DC - 0.44 * Fs (Fs = sample rate)
Voltage In	±10.0 V
S/N (typical)	115 dB (20 Hz - 80 kHz at 5 Vrms)
THD (typical)	-90 dB (1 kHz output at 5 Vrms)
Sample Delay	66 samples
Input Impedance	10 kOhms

A and B Microphone Amplifier	Single setting for both channels
High Pass Corner Frequency	3.6 Hz (Active only if the Amplifier is enabled)
Gain Settings	20 to 65 dB
Gain Step Size	5 dB

Programmable Attenuation	2 channels
Switching Time	1 sample
Settling Time	3 us
Transient Voltage	~370 mV
Hardware Attenuation Settings	0, 20, 40, 60 dB

Manual Attenuation	Single setting for both channels
Attenuation Settings	0 to 27 dB
Attenuation Step Size	3 dB

Output Amplifier	2 channels
Spectral Variation	<0.1 dB from 50 Hz to 200 kHz
Signal Noise	115 dB (20 Hz to 80 kHz)
THD	<0.02% at 1 Watt from 50 Hz to 100 kHz
Noise Floor	20 uVrms
Power Output	0.75 W/channel into 5.5 ohms

Headphone Output	2 channels
Output Impedance	1 Ohm
Power Output	0.75 W/channel into 5.5 ohms
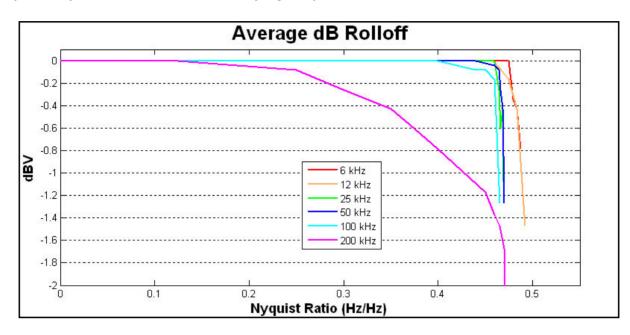
Electrostatic Speaker Output	2 channels

> ✏️ **Note**
>
> For further information on speaker specifications, see ES1/EC1 Technical Specifications and MF1 Technical Specifications.
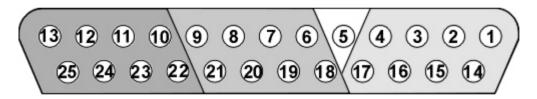
D/A dB Rolloff Diagram

This graph shows the dB rolloff for the RZ6 with varying sampling frequencies for the D/A. The sample delay remains constant for varying frequencies.

DB25 Digital I/O Pinout

Pin	Name	Description	Pin	Name	Description
1	C0	Port C Bit Addressable	14	C1	Port C Bit Addressable
2	C2		15	C3	
3	C4		16	C5	
4	C6		17	C7	
5	GND	Digital I/O Ground	18	A0	Port A Word Addressable
6	A1	Port A Word Addressable	19	A2	
7	A3		20	A4	
8	A5		21	A6	
9	A7		22	B0	Port B Word Addressable
10	B1	Port B Word Addressable	23	B2	
11	B3		24	B4	
12	B5		25	B6	
13	B7				

If using a PP24 Patch Panel, see PP24 to RZ6 Digital I/O.

RZ-UDP Communications Interface

RZ2 Processor Back side with RZ-UDP Installed

RZ-UDP Overview

The RZ Communications Interface (RZ-UDP-20) is an optional interface for RZ processor devices that includes a UDP Ethernet connection and a serial port connection.

The serial port can support baud rates up to 115200. The port is a standard 9-pin RS232 connection located on the back of the RZ. The RS232 port can be directly connected to any device that communicates via serial port, such as head trackers, eye trackers, or a PC.

> ✏ **Note**
>
> If the RZ has four optical DSP cards, the serial port is not available.

The UDP interface is designed to transfer up to 200 data values at low rates to or from a PC. The PC may be directly connected through a dedicated Ethernet card located elsewhere on the user's network, or even in a remote location connected via the Internet. The RZ UDP interface is located on the back panel of the RZ processor and accepts a standard Ethernet cable.

Like all network devices, the RZ UDP interface utilizes several network parameters such as a unique network address, appropriate network mask, and optionally a gateway (if operating across networks). The RZ UDP Ethernet interface supports the DHCP (Dynamic Host Configuration) protocol for automatic configuration of these network parameters, but these

parameters may also be set manually, as described in Configuring the UDP. The type and structure of data for the serial port must be manually configured through the same network interface.
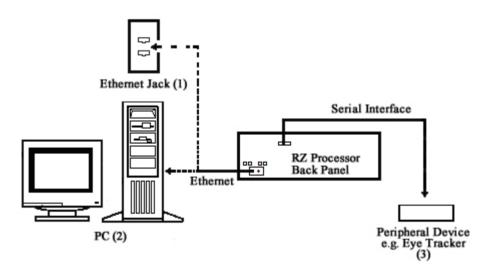
> **✎ Note**
>
> The RZ-UDP-20 is an updated version of the RZ-UDP-10 which had only an Ethernet interface. Configuration of the Ethernet interface is the same for both versions.

RZ-UDP Basics

Setting-Up Your Hardware

To setup the UDP Ethernet interface, connect your Ethernet cable directly to a PC Ethernet port or standard Ethernet wall jack. For more information on setting up or configuring the RZ processor see the System 3 Installation Guide.

The diagram above illustrates the possible connections from the RZ processor to an active network (1) or PC (2), and an optional serial connection to a peripheral device (3).

> **✎ Note**
>
> If you are only using the serial interface, you will still need a UDP Ethernet connection to configure the serial interface through the web interface. See Configuring the UDP through the Web Interface for more information.
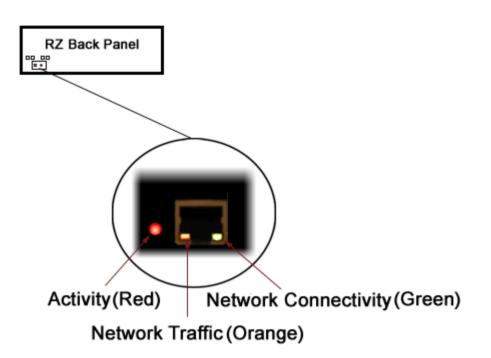
Programming Configuration

Synapse has built-in objects for the Processing Tree to send and receive data from the UDP interface. These must be added to your Hardware Rig in Synapse and then simply connect the desired signal stream to the UDP object. See the Synapse Manual for more information.

For RPvdsEx circuit design, two macros designed for the UDP Ethernet interface and two macros for the serial interface are installed here:

```
C:\TDT\RPvdsEx\Macros\Device\UDP Ethernet\
```

Status LEDs

The following table lists the possible status indicators for the UDP Ethernet interface.

Status	Green LED	Orange LED	Red LED
Off	No network connectivity	No network traffic detected	Remote address set, no activity
Blinking slowly ~1 Hz		Light network traffic is present	Power connected, waiting for remote address to be set
Blinking rapidly or solid glow >=2 Hz	Link connected	Heavy network traffic present	Packet activity present (send or receive)

UDP Configuration

The UDP interface has a unique IP address and network mask.

DHCP protocol automatically assigns IP addresses to devices on the network. The UDP interface relies primarily on dynamic mode for its IP configuration.

The UDP interface has a unique MAC address. You may need to know the MAC address for the UDP interface if you are connecting this device to the building network, so the IT department can let the UDP interface on the network. See Direct Connection to a PC for instructions on connecting a PC directly to the UDP interface so you can get the MAC address through the UDP web interface.

Background Information

UDP or "User Datagram Protocol" is a core protocol of the Internet Protocol suite or more commonly known as the TCP/IP protocol suite. UDP allows programs and networked computers to send datagrams or data organized in a specific structure (commonly referred to as a packet).

> ✏️ **Note**
>
> The UDP protocol is considered "connectionless" since devices send data to a defined IP address and are not actively connected to the destination device or PC. As such, the UDP Ethernet interface will send or receive data from the last IP address it is configured to communicate with.

When information from a data protocol (UDP or TCP) is sent, the information may get lost or delayed along the way. UDP protocol allows time critical data to be transmitted with very low latency since UDP protocol does not implement data tracking. Conversely, when TCP detects that information has been lost or received out of order, it resends the suspect information. This is insufficient for time dependent data found in most neuroscience applications.

> ✏️ **Note**
>
> The UDP protocol does not account for data received out of order.

Initialization

Upon initializing, the UDP interface will attempt to locate a DHCP server to dynamically assign an IP address to the device. If a DHCP server is available, a dynamically allocated IP address is assigned to the interface. If no DHCP server responds, the device falls back on the following static IP configuration:

IP Address: 10.1.0.100

IP Mask: 255.0.0.0

Gateway: 10.1.0.1

NetBIOS Name

You can connect to the UDP interface with either the IP address or the NetBIOS name, similar to how you can access computers on your network by name or IP address. The default NetBIOS name associated with the IP address is set by TDT and has the following naming structure:

TDT_UDP_MD_XXXX	
M	the model of the device, e.g. '2' for an RZ2, '5' for an RZ5, 'D' for an RZ5D
D	the number of RZ processor DSPs
XXXX	last 4 digits the RZ processor device serial number

For Example, an RZ2-4 (4 DSP) with a serial number of 1234 uses a NetBIOS name of `TDT_UDP_24_1234`. An RZ5D with a serial number of 1011 uses a NetBIOS name of `TDT_UDP_D3_1011`.

> ✏️ **Note**
>
> Devices equipped with a UDP interface that have a serial number less than 2012 use a different NetBIOS name format. Use the IP address instead.

Although a default NetBIOS name is assigned. The name can be changed using the UDP Web Interface, see Configuring the UDP through the Web Interface for more information.

> ✏️ **Note**
>
> When connecting the RZ, be sure the network mask is set to a Class C or smaller network. A Class A network mask (255.0.0.0) will disable NetBIOS naming on the PC Ethernet interface. In such cases, the IP address of the UDP Ethernet interface must be specified instead.

Configuring the UDP through the Web Interface

Every RZ UDP interface contains a minimal web server which is used to configure the UDP and serial interfaces. Configuration options can be set here if no DHCP server is available. If a DHCP server exists, the NetBIOS name associated with the dynamically assigned IP address can be configured here.

> ✏️ **Note**
>
> The web interface is only enabled for one minute after powering up the RZ, unless it is in use, in which case it remains enabled until the RZ is turned off. Loading pages through the web interface while collecting data is discouraged and may cause packet loss.

To connect to the UDP Ethernet interface server:

1. Make sure there is an active connection from the PC to the UDP Ethernet port on the back of the RZ then open an Internet browser such as Mozilla Firefox.
2. Enter the device's IP address (if known) as the web address (e.g. http://10.1.0.100) or the NetBIOS name as the web address (e.g. TDT_UDP_0000000).

Introduction Page
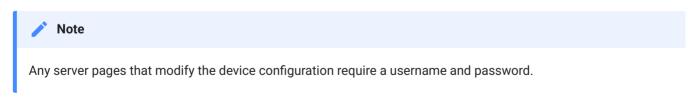
The Introduction page provides basic information, including the default username and password. The login information can be changed on the Authentication page.

Authentication Page

The Authentication page allows users to change their username and password provided they enter the currently set username and password.

> ✎ **Note**
>
> Any server pages that modify the device configuration require a username and password.

Default Username: admin

Default Password: pw

Network Configurations Page

This page contains settings for configuring the UDP interface. To change the network configuration, click the **Networking** link on the left.

Current Network Value

Current Network Value	
This section shows the current network values.	
IP Address:	10.10.10.106
Subnet Mask:	255.255.255.0
Gateway Address:	10.10.10.1
MAC Address:	0.4.163.0.0.0

Network Settings

This area contains settings for configuring the UDP interface in the event that no DHCP server is detected.

Network Settings

The IP, Subnet and Gateway addresses are only used in the following situations:
- When DHCP is disabled
- When DHCP is enabled, but there is no DHCP server available on the network
- For the network bootloader

If DHCP is enabled and available on the network, all these values will be obtained from the DHCP server.

IP Address:	10	1	0	100		
Subnet Mask:	255	0	0	0		
Gateway Address:	10	1	0	100		
MAC Address:	0	4	163	0	0	0

> ✏ **Note**
>
> These settings are reserved for connections that cannot locate a DHCP server. If no DHCP server can be detected contact your network administrator for applicable settings. If the 'Enable DHCP' check box is checked (see Parameters below), the "IP Address", "Subnet Mask", and "Gateway Address" values are overridden and automatically configured by the DHCP server if available.

Parameters

This area contains settings for enabling DHCP or renaming the NetBIOS name.

The Update and Reset button saves the current configuration settings and performs a soft reset of the UDP interface to load the current settings.

> ✏️ **Note**
>
> The NetBIOS name can be no greater than 15 characters long and cannot contain spaces or the following characters: / : * ? " ; | -

> ✏️ **Note**
>
> A reset circuit is provided with the TDT driver installation and can be found in:
>
> ```
> C:/TDT/RPvdsEx/Support/
> ```
>
> Running this circuit on the device with the UDP interface will reset the NetBIOS name to the factory default setting described in NetBIOS Name.

Direct Connection to a PC

The UDP interface can be connected directly to a PC or laptop. Once connected, several steps are required in order for the PC to recognize to the UDP interface connection. This method may be performed on any operating system which supports TCP/IP.

To initialize the PC for a direct connection in Windows 10:

1. Physically connect the UDP interface and the PC via an Ethernet cable.

2. Open **Control Panel** then double-click **Network and Sharing Center**.

3. Click the desired connection link (this is usually a Local Area Connection).

4. In the status dialog, click the **Properties** button.

5. In the item list, select Internet Protocol (TCP/IP) or if there are multiples, select Internet Protocol (TCP/IPv4).

6. Click the **Properties** button.

7. Select **Use the following IP address** and enter these values:

IP address: 10.1.0.x, where x can be any value, 1 to 254, except 100

Subnet mask: 255.255.255.0

Default gateway: Leave empty

8. Click **OK**.

The UDP interface connection should now be recognized by the PC. Cycle power on the RZ device, the IP address of the RZ will be 10.1.0.100.

Serial Configuration Page

> ✏️ **Note**
>
> If the RZ has four optical DSP cards, the serial port is not available.

Latest Data Read from Serial Port

If any data has been sent to the RZ serial port, the latest value will be displayed in this area. ASCII characters represent each byte.

Settings for enabling the serial port, setting baud rate, setting data type and command formats are located in the Serial Port Settings area.

Parameters

The user can enable/disable the serial port, specify the baud rate, and select from a list of preset values.

Data Type

Big vs Little Endian

If the device attached to the RS232 connection sends the lower byte before the upper byte, set this to Little Endian. Otherwise, use Big Endian.

8 vs 16 vs 24 vs 32 bit words

This field specifies the length of the data words that the device attached to the RS232 connection is sending. If the data being received is less than 32 bits in length, it is 0 padded out to 32 bits.

Response Format

This area contains configuration settings for the data received from the peripheral device. As data is received over the RS232 connection, it is matched against a user-specified sequence of header bytes at user specified intervals. For example, the user could set the connection to match two specific header bytes, process the next four bytes as data and then start the process over again.

Frame Length

Enter the total length of a 'frame' of data, including any header bytes. In the example shown in the image above, three channels of 32 bit data are being sent, for a total of 12 data bytes (32 bits = 4 bytes). In addition, there are 8 'header' bytes that the user wants to synchronize with, bringing the total frame byte count to 20. The Frame Length, the word size, and the size of the header bytes are used to determine the number of channels being sent and which channel each data byte belongs to.

Header Format

If this field is empty, no synchronization will occur, and everything sent over the RS232 connection will be processed. Otherwise, the RZ will look for the specified sequence of bytes at the beginning of each frame. The user can enter a decimal value or any ASCII character in single quotes (e.g. 'A'). The '*' character is reserved as a wildcard character that will match anything.

> ✏️ **Note**
>
> If the received data/headers do not match the expected format, they are discarded and all synchronization information is reset. The RZ will then wait until 10 consecutive successful synchronizations before processing any further data bytes.

Commands

This area is used to configure any commands that the RZ needs to send over the serial port. Use this section if the peripheral device connected to the RS232 accepts special requests, such as an initialization command, start/stop command, or reset command.

Command Groups

The format of this section is similar to the header format. The user can enter a decimal value or any ASCII character in single quotes, but the '*' no longer takes on any special meaning here. Each of the command groups is tied to a trigger in the RZ_Serial_Rec or RZ_Serial_Send macros. When triggered, the specified sequence of bytes/characters will be sent over the RS232 connection.

Configuring the UDP Interface on the RZ

Synapse has a built-in object for the Processing Tree to stream packets to/from the UDP interface. This must be added to your Hardware Rig in Synapse by right-clicking on the RZ in the Rig Editor. See the Synapse Manual for more information.

> ✏️ **Note**
>
> For RPvdsEx circuit design (OpenEx users), the TDT drivers installs the UDP circuit macros in `C:\TDT\RPvdsEx\Macros\Device\UDP Ethernet\` . See the Legacy System 3 Manual for circuit design.

> ✏️ **Note**
>
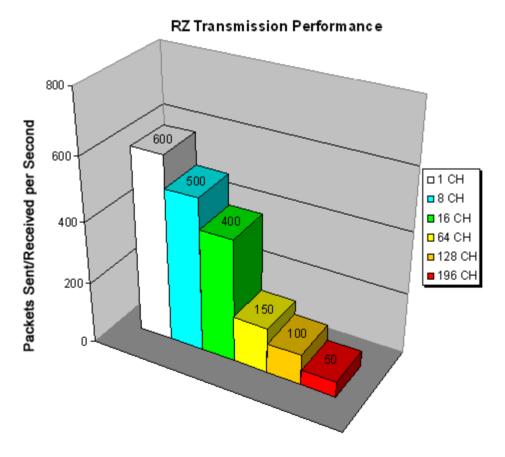> The RS232 serial port must use the RZ_Serial_Rec or RZ_Serial_Send macros in RPvdsEx.

Programming Guide

Wrapper classes and demo files for MATLAB and Python are in the RZUDP Programming Guide A C# implementation can be found on github. A C++ example is available on request.

UDP Interface Performance

The UDP interface is a 10Mb Ethernet interface, but the usable bandwidth is significantly lower due to limitations of the Ethernet hardware. A graph below displays the expected throughput for different numbers of packets sent or received per second depending on the number of channels transmitted on an RZ processor.

The bandwidth for transmitting data from an RZ through the UDP interface decreases depending on the width (or number of channels) of packets sent or received. Transmission of a single packet (single channel) provides a high amount of data resolution since the packets are transmitted at a much higher rate and would respond quickly to abrupt changes in value.

Transmitting multiple packets (large number of channels) allows more information to be sent in parallel but reduces data resolution.

Relative Performance

A typical application might involve sending a packet size of 16 channels 100 times per second or a packet size of 100 channels 10 times per second. As shown in the diagram above, the UDP interface will be able to send a packet size of 16 channels 400 times per second or a packet size of 128 channels 100 times per second.

As a result, the UDP performance is relative to the size of the packet, dictated by the number of channels transmitted.

Typical RZ Transmission Performance with the RZUDP-20 Table

The table below displays the expected throughput for different numbers of packets sent or received per second depending on the number of channels transmitted on an RZ processor.

Number of Channels (32-bit Words)	Packets Sent/Received per Second
1	600
8	500
16	400
32	300
64	150
128	100
192	50

RZ-UDP Technical Specifications

Compatible RZ	RZ2, RZ10, RZ10x, RZ5, RZ5P, RZ5D
Interfaces	Standard Ethernet (for direct connections to a PC an Ethernet crossover cable is required) RS-232 Serial Port (9-Pin)
Ethernet Speed	10 Mbps
Serial Speed	115,200 bits/sec
Transfer Rates	Dependent on data packet size (see Relative Performance table above)

Appendix I: UDP Test Application

A software test application installs with the TDT Drivers and can be used to send or receive packets from an RZ UDP interface. The UDP Test Application installs to:

```
C:\TDT\RPvdsEx\Examples\RZ UDP\
```

Running the Application

Once the application is running, connect to a UDP interface for sending or receiving packets from an RZ processor. Packets can be loaded, saved, and edited. Additionally, the packet format can be converted to double or integer format.

To create a new packet:

1. Double-click anywhere in the packet window to access the **Edit Values** dialog box.

   or

   Right-click the packet window to access the **Packet Dialog** menu.

2. Select the **New Packet** option. This prompts the **Edit Values** dialog box.

To edit an existing packet:

1. Select the desired packet and right-click to access the **Packet Dialog** menu.

2. Select the **Edit Packet** option. This prompts the **Edit Values** dialog box.

To convert the UDP Test Application packet format:

1. Right-click the packet window to access the **Packet Dialog** menu.

2. Select **Convert To**.

3. Select the desired format for the selected packet.

Example: Using the UDP Test Application

In this example we will send packets from the PC to an RZ through the UDP interface.

To establish a connection to the RZ:

1. First, run the UDP Test Application by double-clicking the **UDPTestApplication.exe** icon.

2. Enter the **NetBIOS** name or **IP address** of the RZ processor you wish to send a packet to in the **Device Address** text box.

3. Click the **Check** button.

A connection is established and the status bar indicates a device has been found. Packets may now be received or sent from this RZ processor.

To send a data packet to the RZ processor:

1. Double-click anywhere in the UDP Test Application packet window.

or

Right-click to bring up a selection dialog box and select **New Packet**.

This prompts a dialog box where values can be edited.

2. Click the **Doubles** radio button and enter "**1234**".

3. Click **OK**.

   The configured data packet is shown in the UDP Test Application packet window.

4. Click the **Send All** button to send all data packets to the RZ processor.

   or

   Send an individual packet by right-clicking on the desired packet and selecting **Send Packet** from the Packet Dialog menu.

To receive a data packet sent from the RZ processor:

1. First, run the UDP Test Application by double-clicking the **UDPTestApplication.exe** icon.

2. Enter the **NetBIOS** name or **IP address** of the RZ processor you wish to send a packet to in the **Device Address** text box.

3. Click the **Check** button.

4. Click the **Receive** button.

   The button changes to **Stop** in order to notify that it is waiting for a data packet to be sent from the RZ processor. Data packets are sent through the Synapse UDPSend Hal, or from RPvdsEx using the RZ_UDP_Send macro.

5. At this time you may configure the circuit to send a data packet from the RZ processor to the UDP Test Application.

   Once received, the data packet will be displayed in the UDP Test Application packet window. The Source column will display the IP address the data packet was received from while the Data column displays the data packet itself.

Appendix II: Network Structure

In order to understand how the UDP interface works, a basic understanding of Internet Protocol (IP) networking is required. As mentioned above, all network devices require a unique network address, appropriate network mask, and if communicating between networks, a gateway. Data in IP networks is organized into discrete packets for transmission or reception. For our purposes, the packet size is equivalent to the number of channels being transmitted or received.

Network Address

All network devices utilize a network address commonly referred to as the "IP address". The IP address is a unique address given to any networked device and consists of four hexadecimal values that are used to locate a device from within a network. Multiple devices that are located within a common network use similar IP addresses.

For example:

Several office computers are connected to a network within an office.

IP address Computer 1: 192.86.100.10

IP address Computer 2: 192.86.100.11

IP address Computer 14: 192.86.100.23

As shown above, IP addresses share a common prefix when located on a common network.

Dynamic Host Configuration Protocol (DHCP), for instance, requires that broadcasts be used to dynamically assign a unique IP address to computers on a network.

MAC Address

A device's MAC address or "Media Access Control" address is a unique number that acts like a name for a particular network adapter. On a shared medium such as Ethernet, this address is generally assigned to the hardware when it is constructed, but may be manually modified in the UDP Interface.

For example:

The network cards in two different computers will have different MAC addresses, as would an Ethernet adapter and a wireless adapter in the same computer.

The DHCP Protocol

DHCP or "Dynamic Host Configuration Protocol" is a protocol used by networked devices (clients) to obtain various parameters necessary for the clients to operate in an Internet Protocol (IP) network. By using this protocol, system administration workload greatly decreases, and devices can be added to the network with minimal or no manual configuration.

DHCP automates the assignment of IP addresses, subnet masks, default gateway, and other IP parameters. Three modes for allocating IP addresses exist: dynamic, reserved, and manual. The UDP interface relies primarily on dynamic mode for its IP configuration.

Dynamic

In dynamic mode a client is provided with a temporary IP address for a given length of time. This length of time is dependent on the server configuration and may range from a long time (months) to several hours.

The current IP address can be renewed at any time by the DHCP client. This renewal is used by properly functioning clients to maintain the same IP address throughout their connection to a network.

Appendix III: The UDP Protocol

UDP or "User Datagram Protocol" is a core protocol of the Internet Protocol suite or more commonly known as the TCP/IP protocol suite. UDP allows programs and networked computers to send datagrams or data organized in a specific structure (commonly referred to as a packet).

> ✏️ **Note**
>
> The UDP protocol is considered "connectionless" since devices send data to a defined IP address and are not actively connected to the destination device or PC. As such, the UDP Ethernet interface will send or receive data from the last IP address it is configured to communicate with.

When information from a data protocol (UDP or TCP) is sent, the information may get lost or delayed along the way. UDP protocol allows time critical data to be transmitted with very low latency since UDP protocol does not implement data tracking. Conversely, when TCP detects that information has been lost or received out of order, it resends the suspect information. This is insufficient for time dependent data found in most neuroscience applications.

> ✏️ **Note**
>
> The UDP protocol does not account for data received out of order.

The UDP Packet Structure

All data sent or received by the UDP Ethernet interface is in the form of a packet. Every packet has a standard structure which includes a 4 byte header followed by n x 4 bytes of data, where n is the total number of channels.

> ✏️ **Note**
>
> The term packet refers to a header and number of single sample values sent. Each channel sends a single sample. The packet size is therefore equivalent to the number of channels and is measured in 32-bit words.

For Example:

Sending 16 channels (a packet size of 16, 32-bit words) will produce a packet of 68 bytes.

4 byte header + (16 channels x 4 bytes) = 68 bytes.

Header Format

The packet header precedes a new packet and stores information about the packet and its intended command for the UDP interface. The structure for the packet header is shown below.

4 Byte Packet Header (32 bits)

| 0x55 | 0xAA | Cmd | Num |

The upper two bytes, "55AA" are reserved and required by hardware. The lower two bytes are used for specifying a UDP command (Cmd) and the number of 4 byte data packets (Num) that are to be expected following the header. For all data samples, "Cmd" must be set to 0.

For Example:

The previous example which sent a packet size of 16 channels would use the 32-bit header:

| 0x55 | 0xAA | 0x00 | 0x10 |

Where the "Num" value 0x10 = 16 (the number of channels).

UDP Interface Commands

There are 4 commands that can be specified for the header byte labeled "Cmd".

Name	Hex Code	Description
DATA_SEND	0x00	Data is being sent, the byte labeled "Num" contains the number of data packets following the current header.
GET_VERSION	0x01	Retrieve the protocol version supported by the UDP interface.
SET_REMOTE_IP	0x02	Sets the target for receiving packets from the RZ. The IP and port of the machine sending this packet will be used as the new target.
FORGET_REMOTE_IP	0x03	Clears the target IP and port, thereby stopping the flow of packets. ## UDP Circuit Design

Appendix IV: Serial Circuit Design

Access to the Serial interface is provided through two RPvdsEx macros: RZ_Serial_Send and RZ_Serial_Rec. Both macros operate on multi-channel data and can be configured to specify the number of channels. This channel count corresponds to the size of the underlying serial stream.

RZ_Serial_Rec Macro
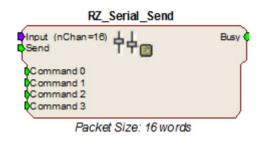
The RZ_Serial_Rec macro is used to receive serial data from the RS232 connection and can also be triggered to send preset commands over the RS232 connection. The number of channels received by the hardware is set in the web configuration. Make sure the packet size set in the macro is at least as large as the value set in the web configuration, otherwise some channels will have missing or incorrect data. If packet size is larger than the number of channels being sent, any excess channels will simply read 0.
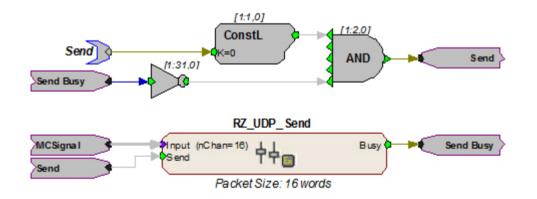
RZ_Serial_Send Macro

Use the RZ_Serial_Send macro to send more than just the pre-configured commands over RS232. If using both the RZ_Serial_Rec and RZ_Serial_Send in the same circuit you must disable the Commands in the RZ_Serial_Rec macro options.

Sending Data Construct

Data is sent whenever the "Send" input receives a rising trigger (logic high (1)). The duration of the busy signal is then dependent on the number of channels to send (packet size). Each logic high pulse sent to the send input results in one send packet request. This means that each packet sent results in one sample sent per channel.

In this construct, the parameter tag "Send" is used to enable data transmission. The Send input on the RZ_UDP_Send macro is only pulsed when the Send parameter tag is high (1) and the macro is not already sending a packet (Busy = low (0)). Data is input from the HopIn component labeled MCSignal.
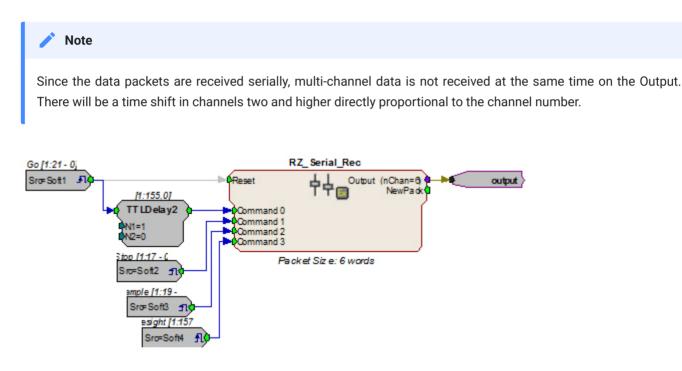
> ✏️ **Note**
>
> To modify the number of channels sent, (packet size) edit the Packet Size parameter found in the RZ_UDP_Send macro setup properties.

Receiving Scalar Data Construct

When data is received, the NewPack signal will output a logic high (1) denoting that a packet header has been found. As data is being received, the Busy signal will output a logic high (1) and as soon as the header has been received, NewPack will go low (0). The Busy signal will then remain high until the entire packet has been received. The duration of the busy signal is then dependent on the number of channels to send (packet size). Each high duration of the Busy signal results in one received packet. This means a single packet received results in one sample received per channel.

If reset goes high (1) at any time, receiving data is halted and the macro will wait until a new header is found. Any data that was received will still be available on the multi-channel output.

> ✏️ **Note**
>
> Since the data packets are received serially, multi-channel data is not received at the same time on the Output. There will be a time shift in channels two and higher directly proportional to the channel number.

In this circuit construct, software triggers are used to send commands to the peripheral device (head tracker). The multi-channel output contains the tracking information and can be further processed and/or stored to the data tank.

2. RX Processors

RX8 Multi I/O Processor

RX8 Overview

The RX8 is a high channel count, high sample rate analog I/O system which provides a maximum of 24 channels of analog I/O and generates a maximum sampling rate of 100 kHz per channel. Each bank of four or eight channels of I/O is user configurable with either PCM or sigma-delta converters. The 24-bit sigma-delta converters are ideal for audio applications. The 16-bit PCM analog converters have an excellent dynamic range and almost no group delay. These converters are excellent for acquiring signal information and controlling external devices, such as motors.

The RX8 is equipped with either two or five 100 MHz, 1600 MFLOPS Sharc DSPs and can control audio feedback systems or motor controls in real-time. Built in digital filters, waveform generators, and logic control components give end users the ability to design and control virtually any presentation system.

Power and Communication

The RX8 mounts in a System 3 zBus Powered Device Chassis (ZB1PS) and communicates with the PC using the Optibit (PO5/FO5) PC interface. The ZB1PS is UL compliant, see the ZB1PS Operations Manual for power and safety information.

Software Control

Software control is implemented with circuit files developed using TDT's RP Visual Design Studio (RPvdsEx). Circuits are loaded to the processor through TDT run-time applications or custom applications. This manual includes device specific information needed during circuit design. For circuit design techniques and a complete reference of the RPvdsEx circuit components, see the RPvdsEx Manual.

RX Architecture

Each RX multiprocessor device is equipped with either two or five digital signal processors (DSPs). The multi-DSP architecture allows processing tasks to be distributed across multiple processors and enables data to be transferred to the PC quickly and efficiently. The DSPs include one master and one or four auxiliary DSP(s). 128 MB SDRAM of system memory is shared by all DSPs. When designing circuits the maximum number of components for each RX DSP is 256.

Each DSP communicates with an internal bus to send and receive information from the I/O controller and the shared memory. The master DSP supervises overall system boot up and operation. The master DSP also acts as the main data interface between the zBus (host PC) and the multi-DSP environment.
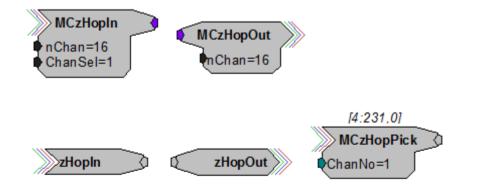
Because the zBus communicates only with the master processor, these devices operate most efficiently when the circuit related processing tasks assigned to the master DSP are minimized, allowing more processor power (cycles) for communication and overhead tasks.

The RX8 contains two DB25 connectors for interfacing with 24 bits of digital I/O and 24 channels of analog I/O.

Distributing Data Across DSPs

In RPvdsEx data can be transferred between each of the auxiliary DSPs as well as the master DSP using zHop components.

Components such as MCzHopIn and MCzHopOut can be used for multi-channel signals while components such as zHopIn, zHopOut, and MCzHopPick are used with single- channel signals. Up to 126 pairs can be used in a single RPvdsEx circuit.

Bus Related Delays

The zHop Bus introduces a single sample delay. However, this delay is taken care of for the user in OpenEx when Timing and Data Saving macros are used.

See "MultiProcessor Circuit Design" in the RPvdsEx Manual for these and other multiprocessor circuit design techniques.

RX8 Features

DSP Status Displays
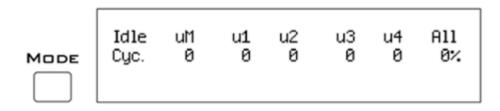
All high performance RX multiprocessors include status lights and a display screen to report the status of the individual processors.

Status Lights

Up to five LEDs report the status of the multiprocessor's individual DSPs. When the device is turned on, they will glow steadily. If the demands on a DSP exceed 99% of its capacity on any given cycle, the corresponding LED will flash very rapidly (~3 times per second).

Front Panel Display Screen

The front panel display screen reports detailed information about the status of the system. The display includes two lines. The top line reports the system mode, Run! or Idle, and displays heading labels for the second line. The second line reports the user's choice of status indicators for each DSP followed by an aggregate value.

The user can cycle through the various status indicators using the Mode button to the left of the display. Push and release the button to change the display or push and hold the button for one second then release to automatically cycle through each of the display options. The

display screen may also report system status such as booting status (Booting DSP) or alert the user when the device's microcode needs to be reprogrammed (Firmware Blank).

Status Indicators

Cyc	cycle usage
Ovr	processor cycle overages
Bus%	percentage of internal device's bus capacity used
I/O%	percentage of data transfer capacity used

> 🔥 **Important**
>
> The status lights will flash (~3 times a second) to alert the user when a device goes over the cycle usage limit, even if only for a particular cycle. This helps to identify periodic overages caused by components in time slices.

Bits Lights

The RX8's eight Bits lights are user configurable. By default the Bits lights indicate the logic level (lit when high) for the eight bit-addressable digital I/O lines. The Bits lights can also act as logic level lights for any of the other bytes of digital I/O.

Analog Input/Output

The RX8 can have a maximum of 24 channels of analog I/O accessed via the 25-pin connector on the front panel. Each bank of up to eight channels of I/O is user configurable with either PCM or sigma-delta converters.

Sigma-delta converters provide superior conversion quality and extended useful bandwidths, at the cost of an inherent fixed group delay. When equipped with sigma-delta, the RX8 DAC Delay is 23 samples and the RX8 ADC Delay is 47 samples.

This device can sample at rates up to ~100 kHz. For additional information on sampling rates for both PCM and sigma-delta converters, see Realizable Sampling Rates for the RX8.

> 🔥 **Important**
>
> Because of device timing constraints at higher sampling rates, only the first 23 channels of analog I/O are processed when operating the RX8 at ~100 kHz.
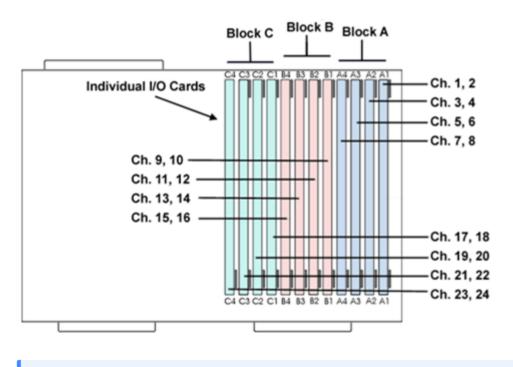
The analog I/O of each device is custom configured at the factory. Problems will arise if end users do not carefully note the configuration of their RX8 device. This topic provides information about configurations and channel numbering. The RX8's analog I/O channels are accessed via a 25-pin connector on the front panel. If you know what channel numbers your device uses, See RX8 Technical Specifications or the Analog I/O pinout diagram.

Organization of Analog I/O Blocks

The RX8 has three blocks of I/O ports. Each block can house up to eight channels for a total of 24 channels of analog I/O. Blocks can only be filled by analog I/O modules of the same type.

For example:

A block can be configured with all D/A's or all A/D's, but not a mixture of D/A's and A/D's. In addition, the D/A's and A/D's must be of the same type (either PCM or sigma-delta).

> ✏ **Note**
>
> Block C can only be configured with D/A output channels
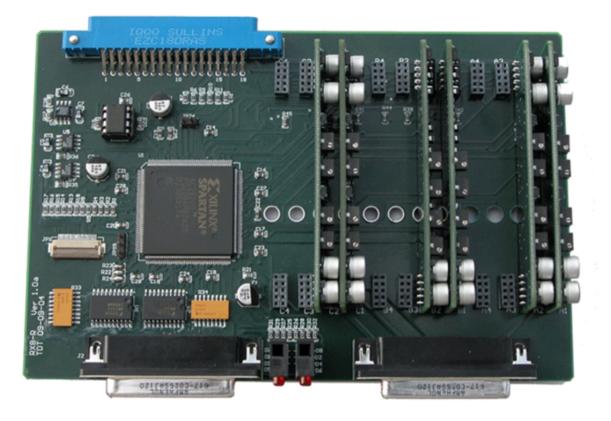
Channel Numbers

Starting with block A and ending with block C, channels are numbered sequentially from 1 to 24. The channel numbering is independent of whether the analog I/O board is an input or output.

For example:

The analog I/O of an RX8 that has four A/D's in the first two slots of Block A and four D/A's in the first two slots of Bank C, would be accessed with the A/D's as channels 1-4 and the D/A's as channels 17-20.

The photo below shows one possible configuration of the RX8's I/O boards. This configuration uses channels 1-4, 9-12, and 17-20.

Digital I/O

The RX8 processor includes 24 bits of programmable I/O in two eight bit word- addressable bytes and eight bits of bit-addressable I/O. Digital I/O lines are accessed via the 25-pin connector on the front panel and can be configured as inputs or outputs. See the "Digital I/O Circuit Design" section of the RPvdsEx Manual for more information on programming the digital I/O.

> ⚠️ **Caution**
>
> The first eight bits of bit-addressable digital I/O on RX devices are unbuffered. When used as inputs, overvoltages on these lines can cause severe damage to the system. Never send a signal with amplitude greater than five volts into any digital input.

Configuring the Programmable I/O Lines

Each of the eight bit-addressable bits can be independently configured as inputs or outputs. The digital I/O lines can be configured as inputs or outputs in groups of eight bits - that is as byte A and byte B. Note, however, that the bytes must be addressed as if part of a word, not as individual bytes. See "Addressing Digital Bits In A Word" in the RPvdsEx Manual for more information.

By default, all bits are configured as inputs. This default setting is intended to prevent damage to equipment that might be connected to the digital I/O lines. The user can configure the bits in the RPvdsEx configuration register. The configuration register is also used to determine what the eight front panel Bits lights represent.

To access the bit configuration register:

1. Click the Device Setup command on the Implement menu.

2. In the Set Hardware Parameters dialog box, click the Device Type box and select RX8 Multi-Chan I/O from the list.

   The dialog expands to display the Device Configuration Register.

3. Click Modify to display the Edit I/O Setup Control dialog box.

   In this dialog box, a series of check boxes are used to create a bitmask that is used to program all bits.

4. To determine the desired value, select or clear the check boxes according to the table below. By default, all check boxes are cleared (value = 0). Selecting a check box sets the corresponding bit in the bitmask to one.

5. When the configuration is complete, click OK to return to the Set Hardware Parameters dialog box.

Bit #	Description
0-7	Each of these bits controls the configuration of one of the eight addressable bits as inputs or outputs. Setting the bit to one will configure that bit as an output
8-9	Each of these bits controls the configuration of one of the two addressable bytes as inputs or outputs. Setting the bit to one will configure that byte as an output. Bit 8 controls byte A, and Bit 9 controls byte B
10-11	Not used
12-14	Create a bit code that determines how the front panel Bits lights are used, see table below.
15	Not used

Bit Codes for Controlling the Bit Lights (Boxes 12-14)

By default, check boxes 12 -14 in the Edit I/O Setup Control dialog box (previous diagram) are cleared to create the bit code 000. This configures the eight front panel Bits lights to act as activity lights (glow when high) for the eight bit addressable digital I/O lines. The Bits lights can also be configured to provide information about amplifier status or act as activity lights for any of the other four bytes of digital I/O.

Bit Flags	Bits set to 1	Bit Lights Used For ...
000	None	Logical level lights for bit-addressable I/O lines
100	14	Logical level lights for byte A
101	12, 14	Logical level lights for byte B

The XLink is not supported at this time.

Realizable Sampling Rates for the RX8

PCM converters support a broad range of sampling rates up to the maximum of ~100 kHz. Realizable sampling rates can easily be determined in the device set-up dialog in RPvdsEx.

Sigma-Delta converters support a more limited set of sampling rates as shown in the table below. When using Sigma-Delta converters, the user must ensure a valid sampling rate is set for the device.

> ✏️ **Note**
>
> The Check Realizable button in the device set-up dialog in RPvdsEx is used to calculate the true sampling rate of the system when an arbitrary sampling rate is used. This rate is based on the PCM converters. If your RX8 contains any sigma-delta converters you must use the following values for arbitrary sampling rates.

Supported Arbitrary Sample Rates for Sigma-Delta Converters

Standard Rate	Actual/Arbitrary Rate (Hz)	Standard Rate	Actual/Arbitrary Rate (Hz)
6 kHz	6103.515625	25 kHz	24414.0625
	6975.45		27901.79
	8138.025		32552.08
	9765.63		39062.50
12 kHz	12207.03125	50 kHz	48828.125
	13950.89		55803.57
	16276.04		65104.17
	19531.25		78125.00
		100 kHz	97656.25

RX8 Technical Specifications
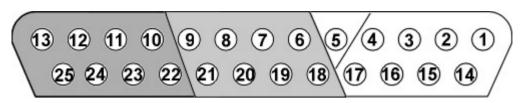
DSP	Two or Five 100 MHz Sharc ADSP 21161, 600 MFLOPS Peak
Memory	128 MB SDRAM shared
Digital I/O	8 programmable bits: 3.3 V (5.0 V max input), 25 mA max load 2 programmable bytes (16 bits): 5.0 V (6.0 V max input), 35 mA max load
D/A	**Up to 24 channels, 16-bit PCM or 24-bit sigma-delta**
Sample Rate	Up to 97.65625 kHz*
Frequency Response	DC - 0.44 * Fs (Fs = sample rate)
Voltage Out	±10.0 V, 175 mA max load
S/N (typical)	Sigma-delta: 97 dB (20 Hz - 20 kHz at 9.9 V) PCM: 80 dB (20 Hz - 20 kHz at 9.9 V)
THD (typical)	Sigma-delta: -84 dB (1 kHz output at 5 Vrms) PCM: -70 dB (1 kHz output at 5 Vrms)
Sample Delay	Sigma-delta: 23 samples PCM: 4 samples
Output Impedance	10 Ohms
A/D	**Up to 16 channels, 16-bit PCM or 24-bit sigma-delta**
Sample Rate	Up to 97.65625 kHz*
Frequency Response	Sigma-delta: DC - 0.44 * Fs (Fs = sample rate) PCM: DC - 7.5 kHz (3 dB corner, 2nd order, 12 dB per octave)
Voltage In	±10.0 V
S/N (typical)	Sigma-delta: 97 dB (20 Hz - 20 kHz at 10 V) PCM: 80 dB (20 Hz - 20 kHz at 10 V)
THD (typical)	Sigma-delta: -84 dB (1 kHz output at 5 Vrms) PCM: -65 dB (1 kHz output at 5 Vrms)
Sample Delay	Sigma-delta: 47 samples PCM: 4 samples
S/N (typical)	82 dB (20 Hz - 20 kHz at 9.9 V)
Input Impedance	10 kOhms

* Because of device timing constraints at higher sampling rates, only the first 23 channels of analog I/O are processed when operating the RX8 at 100 kHz. See Realizable Sampling Rates for the RX8 for a list of supported sampling rates.

DB25 Connector Pinouts
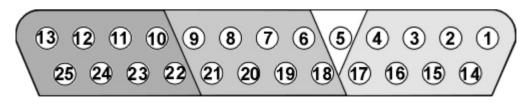
TDT Recommends accessing the RX8 I/O via a PP24 patch panel.

Analog I/O

Pin	Name	Description	Pin	Name	Description
1	A1	Analog A bank	14	A2	Analog A bank
2	A3		15	A4	
3	A5		16	A6	
4	A7		17	A8	
5	AGND	Analog Ground	18	A9	Analog B bank
6	A10	Analog B bank	19	A11	
7	A12		20	A13	
8	A14		21	A15	
9	A16		22	A17	Analog C bank
10	A18	Analog C bank	23	A19	
11	A20		24	A21	
12	A22		25	A23	
13	A24				

Digital I/O

Pin	Name	Description		Pin	Name	Description
1	C0	Port C Bit Addressable		14	C1	Port C Bit Addressable
2	C2			15	C3	
3	C4			16	C5	
4	C6			17	C7	
5	GND	Digital I/O Ground		18	A0	Port A Word Addressable
6	A1	Port A Word Addressable		19	A2	
7	A3			20	A4	
8	A5			21	A6	
9	A7			22	B0	Port B Word Addressable
10	B1	Port B Word Addressable		23	B2	
11	B3			24	B4	
12	B5			25	B6	
13	B7					

3. RP Processors

RP2.1 Real-Time Processor

RP2.1 Overview

The RP2.1 real-time processors consist of an Analog Devices Sharc floating point DSP with surrounding analog and digital interface circuits to yield a powerful programmable signal-processing device capable of handling a variety of tasks.

Power and Communication

The RP2.1 mounts in a System 3 zBus Powered Device Chassis (ZB1PS) and communicates with the PC using any of the zBus PC interfaces. The ZB1PS is UL compliant, see the ZB1PS Operations Manual for power and safety information.

Software Control

Software control is implemented with circuit files developed using TDT's RP Visual Design Studio (RPvdsEx). Circuits are loaded to the processor through TDT run-time applications or custom applications. This manual includes device specific information needed during circuit design. For circuit design techniques and a complete reference of the RPvdsEx circuit components, see the RPvdsEx Manual.

Features

Memory

The RP2.1 comes with 32 MB of memory for data storage and retrieval.

Digital Input/Output Bits
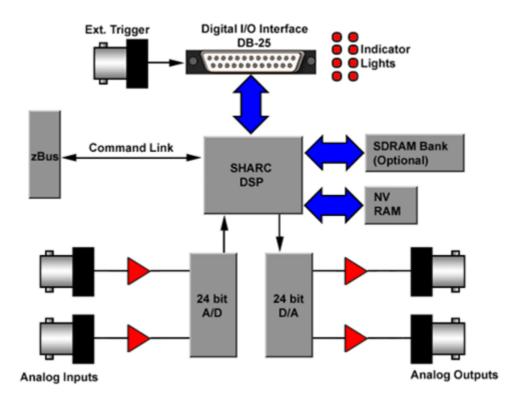
The digital I/O circuits include eight bits of digital input and eight bits of digital output that are accessed on the 25 pin connector on the front of the RP2.1. The bits of these ports can be programmed individually or as a 'digital word' and used in a variety of ways within the RP2.1 processing circuit, including implementing triggers, timing trigger responses, and lighting LEDs. The first four bits of the digital inputs and digital outputs as well as the Trigger/Enable input are mapped to LED indicators on the front panel of the RP2. There is an additional TRIG input BNC on the front panel.

D/A and A/D

The RP2.1 is equipped with two channels of 24-bit, 200 kHz sigma-delta D/A and two channels of 24-bit, 200 kHz sigma-delta A/D. Sigma-Delta converters provide superior conversion quality and extended useful bandwidths, at the cost of an inherent fixed group delay. See RP2.1 Technical Specifications for the group delay of each device.

Hardware

The 32 MB of SDRAM are used for storage of long stimulus waveforms and acquired data. All of the RPvdsEx buffer components, used to build circuits for the RP2, utilize the SDRAM memory. The RP2.1 communicates with and is programmed through the zBus.
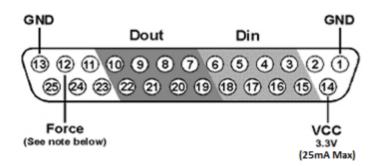
The RP2.1 is interfaced to the analog world via a two channel 24-bit analog to digital converter and a two channel 24-bit digital to analog converter. The RP2 system's I/O buffer handles ±10 V signals with excellent signal to noise performance. The RP2 contains a 100 kHz (50 kHz BW) A/D and a 200 kHz (100 kHz BW) D/A, while the RP2-5 has a 50 kHz (25 kHz BW) A/D and D/A. Both devices allow for user programmable sampling rates from the specified maximum down to 6.25 kHz. A special calibration program is used to calibrate the RP2's analog I/O offering very small gain and DC offset errors.

RP2.1 Technical Specifications

DSP	50 MHz Sharc 21065, 150 MFLOPS
Memory	32 MB SDRAM
Digital I/O	8 input bits, 8 output bits, 1 TRIG input: 3.3 V (5.0 V max input), 25 mA max load
System Reset	Force input (see the section below on how to reset)
D/A	**2 channels, 24-bit sigma-delta**
Sample Rate	Up to 195.3125 kHz
Frequency Response	DC - 0.44 * Fs (Fs = sample rate)
Voltage Out	±10.0 V, 175 mA max load
S/N (typical)	105 dB (20 Hz to 20 KHz), 95 dB (20 Hz to 50 KHz)
THD (typical)	-95 dB for 1 KHz output at 5 Vrms
Sample Delay	30 samples
Output Impedance	10 Ohms
A/D	**2 channels, 24-bit sigma-delta**
Sample Rate	Up to 195.3125 kHz
Frequency Response	DC - 0.44 * Fs (Fs = sample rate)
Voltage In	±10.0 V
S/N (typical)	105 dB (20 Hz to 20 KHz), 95 dB (20 Hz to 50 KHz)
THD (typical)	-95 dB for 1 KHz input at 5 Vrms
Sample Delay	65 samples
S/N (typical)	82 dB (20 Hz - 20 kHz at 9.9 V)
Input Impedance	10 kOhms

DB25 Connector Pin Out

Pin	Name	Description	Pin	Name	Description
1	GND	Ground	14	VCC	3.3 V (25 mA Max)
2	NA	Not Used	15	DI0	Digital Input Bits
3	DI1	Digital Input Bits	16	DI2	
4	DI3		17	DI4	
5	DI5		18	DI6	
6	DI7		19	DO0	Digital Output Bits
7	DO1	Digital Output Bits	20	DO2	
8	DO3		21	DO4	
9	DO5		22	DO6	
10	DO7		23	NA	Not Used
11	NA	Not Used	24	NA	
12	Force	Used to reset the RP2.1	25	NA	
13	GND	Ground			

> ✏️ **Note**
>
> TDT recommends the PP16 Patch Panel for accessing digital I/O.

> 🔥 **Important**
>
> Force is used to reset the RP2.1, including deleting the device's microcode. It has no function in data acquisition or manipulation.

To reset the device:

1. Connect a wire (or paper clip) from pin 12 to pin 13 on the Digital I/O port.

2. Use the desktop short cut to run zBusMon.

3. With pins 12 and 13 shorted, click the 'Reboot System!' button. The RP2.1 will appear as a 'G21' device.

4. Right-click on the G21 and select 'Program G21'.

5. In the System3 Device Programmer window, click the Browse button next to the uCode File field and select RP21.dxe.

6. Remove the short from pins 12 and 13, and click the 'Program Device!' button. Do not use your computer until the device reprogramming is complete (approximately four minutes).

4. PZ Preamplifiers

PZ5 NeuroDigitizer

PZ5 Overview

The PZ5 is a multi-modal NeuroDigitizer suitable for recording a broad range of biological potentials. Its analog input boards combine the functionality of the PZ2 and PZ3 amplifiers in a single device that can be used for both high and low impedance input signals simultaneously. The PZ5 may also include digital input boards for inputting signals from TDT's ZD or OD Intan-based digitizing headstages, or an Intan RHD2000 amplifier board with up to 128 channels.

Analog input boards oversample the signal with very fast instrumentation grade converters. TDT's custom hybrid A/D circuit yields 28 bits of resolution and unparalleled dynamic range. Optional DC coupling offers zero phase distortion across the signal bandwidth. Sampling rate and down-sampling filters can be optimized on each logical amplifier for the intended input type to optimize signal fidelity. The ±500 mV input range is large enough to accept any biological potential and most stimulus artifacts without saturating.

The PZ5 analog inputs are organized into 16-channel banks. Each bank is electrically isolated, meaning the ground and reference channels are not inherently shared between banks. Multiple banks can be grouped into a single logical amplifier that shares the same settings and ground/reference among each bank in the logical amplifier. There are several different referencing modes; each logical amplifier can use the ground as a reference, use a shared reference, use a unique reference on each bank or implement full per-channel differential referencing.

Digital inputs are used exclusively with RHD2000 series amplifier boards and SPI Interface Cables, available from Intan Technologies. Each input serves as a bank of channels and may be up to 128 channels, depending on the connected amplifier board. Each digital board can be its own logical amplifier, isolated from the other boards, or be grouped with other digital boards in a larger logical amplifier configuration.

A touchscreen interface provides immediate preview of inputs, impedance checking and real-time control and configuration options for each amplifier bank.

The PZ5 is available in 32, 64, 96, or 128 analog channel models. The PZ5 is also available with 2 or 4 digital inputs and models that combine 32 or 64 analog input channels with 2 or 4 digital inputs. The PZ5 can support a total of up to 128 analog channels or up to 256 digital channels or up to 256 mixed channel types. The total number of channels is generally reduced to 128 at higher sampling rates, up to 50 kHz. See Sampling Rate and Digital Input Channels for more information.

> ✏️ **Note**
>
> To record at ~50 kHz on 128 or more channels, see PZ5 Software Control for more information.
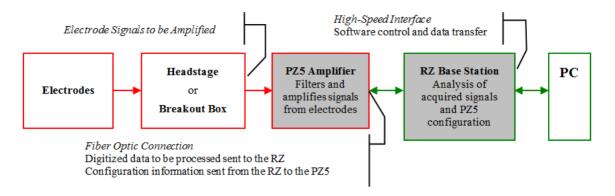
System Hardware

The PZ5 accepts inputs from a variety of electrode/headstage combinations via the back-panel. Each analog board has a mini-DB26 connector that accepts 16 recording channels (or 8 differential channels) along with ground and reference. Digital boards have a 12-pin Omnetics connector for Intan headstages and can accept up to 128 digital channels each. The PZ5 can return at most 256 recording channels to the RZ base station.

Analog signals are digitized and transmitted to the RZ base station for further processing via a single fiber optic connection. Configuration information is also sent from the RZ to the PZ5 across the fiber optic connection. The PZ5 can connect to the 'PZ Amplifier' input on an RZ2 base station, or directly to any RZDSP-P card or optical QZDSPO quad card on any RZ base station.

A standard recording configuration includes electrodes appropriate to the input signals, a breakout box or one or more Z-Series headstages (such as ZC32), a PZ5 and an RZ base station.

The diagram below illustrates this flow of data and control information through the analog system.

PZ5 Data and Control Flow Diagram

Hardware Setup
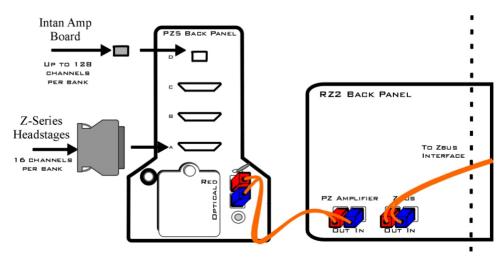
TDT recommends fully charging the PZ5 before use. The PZ5 battery charger connects to the round female connector located on the back panel.
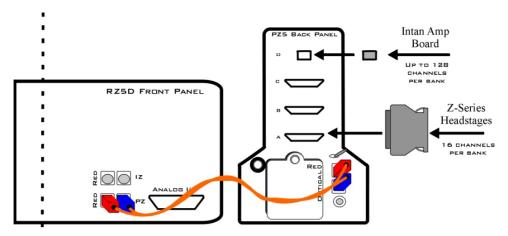
> 🔥 **Important**
>
> To avoid introducing EMF noise, DO NOT connect the charger to the PZ5 while collecting data.

A 5-meter paired fiber optic cable is included to connect the PZ5 to the base station. The connectors are color coded and keyed to ensure proper connections.

The diagram below illustrates the connections necessary for PZ5 operation.

System Connection Diagram for PZ5 with RZ2

System Connection Diagram for PZ5 with RZ5D

Connecting Headstages and Electrodes

Analog signals are input via multiple mini-DB26 connectors on the PZ5 back panel. For high impedance recordings, one or more Z-Series headstages can be connected to the input connectors on the PZ5 back panel. For low impedance recordings, an S-BOX input splitter or LI-CONN low-impedance connector can be used. Alternately, custom connectors and a breakout box with a male mini-DB26 connector can be used. If using custom connectors, see Pinout Diagrams.

Digital signals are input via Intan connectors on the PZ5 back panel.

Powering ON/OFF

To turn the PZ5 on, move the toggle switch located on the back panel of the PZ5 to the ON position.

Physical Amplifier

All PZ5 analog input channels are organized into groups of 16 channel banks, with each bank corresponding to a rear panel headstage connector (labeled alphabetically from bottom to top) and a front panel LED display.

Digital input channels are associated with a digital board corresponding to a rear panel digital input connector (labeled from bottom to top following, alphabetically, any analog input connectors). Each digital board is a bank that can comprise 16, 32, 64, 96, or 128 channels, depending on the connected Intan amplifier board(s).

Each bank is electrically isolated and can be independently configured or grouped with other banks and defined as a logical amplifier. Analog and digital boards cannot be combined together.
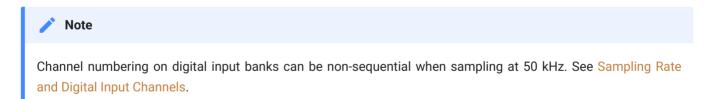
Logical Amplifiers
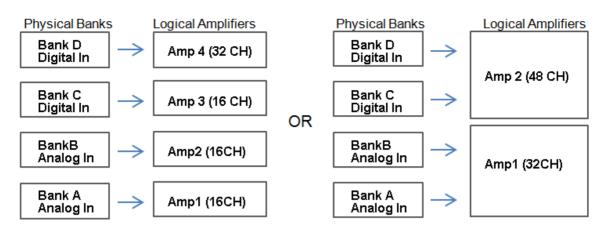
Though each bank has its own ground and reference, a single ground and reference can also be defined and shared across all banks of the logical amplifier. See Analog Recording Reference Modes for analog input banks.

Two Possible Logical Amplifier Configurations for a PZ5-0-64 64 Channel (all analog input)

Digital boards can be configured individually or grouped to share a single ground and use common filter settings and sampling rate.

> ✏️ **Note**
>
> Channel numbering on digital input banks can be non-sequential when sampling at 50 kHz. See Sampling Rate and Digital Input Channels.

Two Possible Logical Amplifier Configurations for a PZ5-64-2 (with two digital inputs)

Logical amplifier configurations can be defined using the front panel interface (see PZ5 Touchscreen), in Synapse, or in RPvdsEx using the PZ5_Control macro. The PZ5-0-32 model can have a maximum of two logical amplifiers configured. All other PZ5s can have a maximum of four logical amplifiers.

Analog Recording Reference Modes

The PZ5 supports four referencing modes for each analog input logical amplifier: Local, Shared, None and Differential. See Pinout Diagrams.

Reference Mode	Description
Local	Each bank of channels in a logical amplifier uses its own reference input (pin 5) as the reference for that bank
Shared	The reference (pin 5) of the first bank of the logical amplifier acts as a reference for all banks in the logical amplifier
None	The references for all banks of a logical amplifier are tied to the Ground (pins 13, 15, and 16).
Differential	The inputs in each bank of the logical amplifier are paired; odd channels serve as recording (+) channels and each even channel is used as an individual reference (-) channel for the preceding odd channel. No connections should be made to pin 5.

Sampling Rate and Onboard Filters

The sampling rate of each logical amplifier is adjustable (max 50 kHz, min 750 Hz) and should be set to a value appropriate for the signal of interest. Reducing the sampling rate when acquiring low-frequency analog signals yields higher bit resolution and improved signal-to-noise. Use the Amp Type Presets as a guide for determining what sampling rate to use for each logical amplifier.

The onboard down-sampling filters are used to further reduce the noise from frequencies above the band of interest and can be set to a percentage of the sampling rate (max 45%, min 10%). Adjusting the sampling rate and filter for each logical amplifier to match your desired signal gives you the best possible signal fidelity.

Sampling Rate and Digital Input Channels

When a logical amplifier contains digital inputs, the sampling rate should be set to a value appropriate for the connected Intan amplifier board. Sampling rates at or above 50 kHz reduce the number of channels available on the amplifier boards.

At 50 kHz the 32 channel amplifier board is limited to 20 channels and the 64 and 128 channel boards are limited to 40 channels, at the time of this writing. The maximum aggregate number of channels is 256 channels at up to 25 kHz, or 128 channels at up to 50 kHz.

It is also important to note that, while the Intan board channel numbers are normally sequential and offset by the number of analog inputs in the amplifier, sampling at or above 50 kHz may also affect channel numbering.

At 50 kHz the native channel numbers per board are 1-20 and 33-52. These channel numbers are then offset by the number of channels existing in the lower banks of the PZ5. Also see Input Connectors.

Amp Type Presets

Amp Icon	Amp Label	Default Settings
	EMG	Electromyography Referencing: Diff (true differential) Coupling: AC Sample Rate: 750 Hz
	EEG	Electroencephalography Referencing: Shared Coupling: AC Sample Rate: 750 Hz
	LFP	Local Field Potentials Referencing: Shared Coupling: AC Sample Rate: 3 kHz
	SU	Single Unit Referencing: Local Coupling: AC Sample Rate: 25 kHz
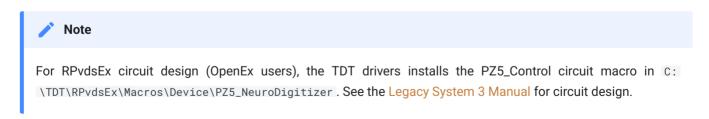
The PZ5 touchscreen interface uses representative diagrams to enable users to identify the configuration of the amplifier at a glance. The table below explains the parts of the diagram and what each represents.

PZ5 Signal/Reference Diagram

PZ5 Software Control

All PZ5 configuration and control of data acquisition is managed through Synapse. The PZ5 object configures the analog and digital headstage recording inputs. Please see the Synapse Manual for more information.

> ✏️ **Note**
>
> For RPvdsEx circuit design (OpenEx users), the TDT drivers installs the PZ5_Control circuit macro in `C: \TDT\RPvdsEx\Macros\Device\PZ5_NeuroDigitizer` . See the Legacy System 3 Manual for circuit design.

Recording 128 Channels at 50 kHz

Due to the PZ5's high bit resolution and recording capabilities, data should always be stored as 32-bit floating point. However, when storing 128 channels at 50 kHz sampling rate, you must use the Short (16 bits) format due to bandwidth constraints. This means the data will be scaled and converted into an integer before storage, which narrows the dynamic range of the acquired signals. In this case, all DC offsets must be removed before the data is stored. You can either filter out the DC offset with a Neural Stream Processor gizmo in Synapse or use AC coupling on the logical amplifier if you are storing the raw signal direct from the PZ5.

PZ5 Touchscreen

The PZ5 touchscreen can be used to add logical amplifiers, check impedance, preview waveforms in real-time. It also provides access to the PZ5 settings, such as the screen auto lock and auto sleep features, as well as tools for viewing system information, such as battery status, and updating the device software.

Main Configuration Screen

The main configuration screen includes the following:

Touchscreen Icon	Description
	All logical amplifiers that have been defined are represented on the right side of the screen and labeled in logical order from bottom to top. For example, 2:DIG is the second logical amplifier and is configured for a digital headstage. In the illustration above, this would correspond to the back panel input connector labeled 'B'. See PZ5 Software Control.
	Display the System Setup Screen
	Toggle LED Indicators on or off. See Clip Warnings and Activity Display for more information.
	Display battery status information. A lightning bolt through the icon indicates that the PZ5 is charging. See Battery Status for more information.
	Lock to protect configuration settings. Unlock to allow changes to the configuration.
	Create a new logical amplifier. As logical amplifiers are added they appear on the Main Configuration screen. See Manual Configuration.
	PZ5 bank icons are color coded to indicate current configuration of each bank. A red outline indicates that the bank is configured as part of a logical amplifier but no headstage is currently detected on that bank. A gray bar indicates that the bank is not configured. Digital input boards are overlaid with a digital signal representation.

Impedance Checking Screen

> 🔥 **Important**
>
> The impedance checking feature of the PZ5 can and should only be used with a passive headstage or direct connection to the electrodes.

 Enter the Impedance Checking screen by touching this icon on an existing logical amplifier on the Main Configuration screen. The logical amplifier number and amp type are displayed in the top-left corner, for example 1:EEG.

Select the type of connections to measure (Probing options) and choose a target impedance value (Target) to color code the measured impedance value text. During impedance checking, All connections in the selected set are tested in parallel and the impedance is color-coded relative to the user-defined target impedance.

A limited set of channels are visible at any one time. Swipe vertically on the touchscreen to scroll the visible channels.

Settings include:

Setting	Description
Target	Select the target impedance from a drop down list (1 kOhms -100 kOhms). This is used to color the impedance value text during/after probing. Impedance values above the target are colored red, values <75% below the target are green and all other values are yellow.
Freq.	Set the probe signal frequency from a drop down list. The frequency is adjustable from 35 Hz, 70 Hz, 140 Hz, 280 Hz, 560 Hz, 1120 Hz, and 2240 Hz. This feature is only selectable in daughter board firmware v1.3 and above, and PZ5 software v1.1.1 and above. The frequency is fixed at 140 Hz in prior versions.
Probing	(Analog input amps only) Select the set of connections to measure. The available options in this list change depending on the logical amp referencing mode. See table below.
Sort Button	Toggle button that displays the channels with the largest variation from the target impedance at the top of the screen
Auto Button	Toggle button that cycles through each probing option every second
Next Button	Select to advance to the next probing option set

Ref Mode	Probing Options
Differential	**Inp(+)** for the positive input channels and **Inp(-)** for the differential channels
Local	**Input** for all the input channels, **Ref** for the reference impedance to ground, and **AltRef** to test the alternative reference (pin 13, see Pinout Diagrams)
Shared	**Input** for all the input channels, **Ref** for the reference impedance to ground, and **Gnd** to test the ground impedance
None	**Input** for all the input channels

Waveform Display Screen

Enter the Waveform Display screen by touching this icon on an existing logical amplifier on the Main Configuration Option screen. The displayed waveform is decimated for plotting and high pass filtered so all channels can be shown on the same voltage scale. If the logical amplifier is DC Coupled, the DC offset is displayed as a value on the right side of each plot line (in mV).

Waveform Display Touchscreen Controls

> 🔥 **Important**
>
> To return to the Main Configuration screen, swipe three fingers across the screen in any direction. On the Main Configuration screen, a three finger swipe will turn off the display.

Manual Configuration

The logical amplifier configuration defined in Synapse is sent to the PZ5 and applied when the recording begins. However, the touchscreen interface can also be used to configure logical amplifiers on-the-fly.
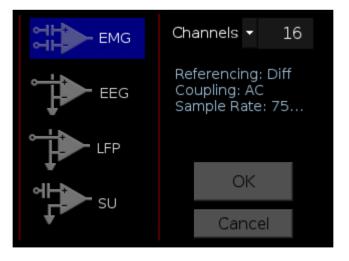
For analog amplifiers, touch the **+** icon to add a logical amplifier. Set the Amp Type and number of channels in the screen that follows. See Amp Type Selection Screen for more information. Adjust amplifier configuration options in the next screen. See Configuration Options Screen for more information.

For digital amplifiers, the **+** icon has a square wave through it. Set the number of digital boards to include in the logical amplifier and the amplifier configuration options in the screen that follows. See Configuration Options Screen for more information.

Amp Type Selection Screen

Enter the Amp Type Selection screen by touching the **+** icon on the Main Configuration screen or by touching the **Amp Type** button on the Configuration Options Screen for an existing logical amplifier.
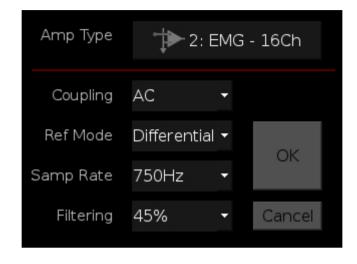
Select the Amp Type and set the number of channels in the logical amplifier (by banks of 16 channels for analog amplifiers).

Configuration Options Screen

Enter the Configuration Options screen after selecting the Amp Type when adding a new logical amplifier, or by touching the Amp Icon on an existing logical amplifier on the Main Configuration screen.

Analog Input Amp Settings

Each Amp Type includes preset values for each setting. The Configuration Options Screen lets you modify them.

Setting	Description
Coupling	Choose AC or DC. AC coupling implements a high pass filter with ~0.4 Hz cutoff frequency
Ref Mode	Choose Local, Shared, None, or Differential Reference Mode. See Analog Recording Reference Modes for more information
Samp Rate	Set the Sampling Rate to match the desired frequency band of your incoming signals (or leave at 'System Rate' if you are unsure). Options include: 750 Hz, 1.5 kHz, 3 kHz, 6 kHz, 12 kHz, 25 kHz, 50 kHz. By default, the sampling rate matches that of the RZ.
Filtering	Select a cutoff frequency for the anti-aliasing filter, as a percentage of the sampling rate. Choose from a list of values: 45%, 35%, 25%, 15%, or 10%
Ext. Ground	Press 'More' button to access this. Set to Yes to connect this logical amplifier ground to the external ground plug on the physical PZ5 device. **Caution:** When using multiple sub-amps make sure they aren't all sharing the External Ground connection or else they won't be isolated!

Digital Input Settings

Setting	Description
Ext. Ground	Set to Yes to connect this logical amplifier ground to the external ground plug on the physical PZ5 device. **Caution:** When using multiple sub-amps make sure they aren't all sharing the External Ground connection or else they won't be isolated!
HP Filt	Select a cutoff frequency for the highpass filter
Samp Rate	Choose a sampling rate from a list of values. Auto means it runs at whatever the RZ sampling rate is
LP Filt	Select a cutoff frequency for the lowpass filter. Auto means it is matched to the sampling rate automatically. See table below.

PZ5 Sampling Rate	LP Auto Filter
750 Hz	300 Hz
1.5 kHz	750 Hz
3 kHz	1.5 kHz
6 kHz	3 kHz
12 kHz	5 kHz
25 kHz	10 kHz

Battery Status

 Press the Battery Status icon to display battery information:
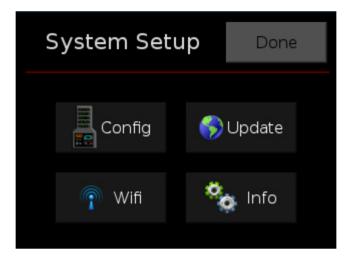
Setting	Description
Charging	Indicates if the charger is plugged into the PZ5 (Yes/No)
Voltage	Current voltage level of the battery pack
Level	% battery life remaining.
Endurance	Estimated time of battery life remaining

> ✏ **Note**
>
> The Battery Level is also mirrored on the RZ2 LCD display when the PZ5 is connected to the PZ Amplifier port on the back of the RZ2.

System Setup Screen

The System Setup screen is displayed by touching the PZ5 logo on the top-left of the Main Configuration screen.

Button	Description
Config	Open the System Configure screen
Update	Update onboard software over the Internet
Wifi	Connect to a wireless network for system updates
Info	Open the device System Info screen to view version numbers for various hardware, software and firmware components

System Configure Screen

The System Configure screen is displayed by touching Config on the System Setup screen.

Setting	Description
Boot Amp	Select the default logical amplifier settings when the PZ5 is first powered on. See table below.
Autolock	Select an option to lock the configuration screen after 1, 2 or 5 min of screen inactivity or select Never to turn off autolocking
Autosleep	Select an option to turn off the screen after 5, 10 or 30 min of screen inactivity or select Never to turn off autosleep
Brightness	Select High, Medium, or Low to set touchscreen brightness
Wireless	Enable/disable the wireless connection

Boot Amp	Description
None	Boots with no logical amplifiers specified
PZ2	All banks configured as one Single Unit amplifier
PZ3	All banks configured as one EEG amplifier
PZ3 Diff	All channels configured as one EEG amplifier in differential referencing mode
Last	Reboots into the last used configuration
Smart	Does not overwrite any existing logical amplifier configuration on boot. For example, if you configure the logical amplifiers in Synapse before the PZ5 boots then the PZ5 will NOT overwrite that configuration. If the PZ5 boots and NO logical amplifiers are configured it will behave the same as Last.

System Info Screen

The System Info screen is displayed by touching Info on the System Setup screen. Use the scroll bar to see all of the version numbers.

Information	Description
Device	PZ5 model number (e.g. PZ5-0-32)
Software version	Currently installed version of onboard software
Firmware version	Currently installed version of firmware
Hardware version	Version of hardware
Battery	Date and capacity of last battery calibration (in mAhr)

Advanced Button

Password protected settings for TDT use only at this time.

System Update Screen

The system updater connects to a TDT server to download the latest PZ5 software and automatically update the device. This requires an active and configured Internet connection. The PZ5 provides two options for network connection: WiFi and Ethernet. The WiFi connection can be configured on the Wireless Networks Screen, see below. The Ethernet port is located on the back panel.

The System Update screen is displayed by touching Update on the System Setup screen.

> 🔥 **Important**
>
> The update process can take up to an hour to complete. Make sure the PZ5 battery charger is plugged in during the update.

Wireless Networks Screen

The Wireless Networks screen is displayed by touching WiFi on the System Setup screen. Available networks that have been used or previously configured are displayed in the main area of the screen. Selecting a network from the list displays network information and enables the user to connect to the network, forget the network, or cancel configuration of the network.

The wireless icon shows if the wireless feature is enabled or disabled. A red 'x' will appear through the icon if wireless is disabled. Enable/disable wireless through the System Configure Screen.

Setting	Description
Show All	Shows all networks, including networks that have not been previously used or configured
IP Addr	Displays current IP Address when connected to a network

PZ5 Features

Status LED

The status LED above the touchscreen indicates the PZ5 connection and charging status.

Green LED	Device Status
Solid	Connected
Slow flash (~1 every three seconds)	Connected and charging
Rapid flash (~1 per second)	Not connected

Clip Warnings and Activity Display

The front panel LEDs can be used to indicate spike activity and/or clip warning for analog input channels. They can be configured under software control using the PZ5 gizmo in Synapse, or under manual control using the toggle switch on the PZ5 touchscreen.

LED Indicators (analog)

When enabled, LEDs for each channel are lit green to indicate activity or red to indicate a clip warning. The top row indicates the odd channels (left to right). The bottom row indicates the even channels.

Green: Activity

Red: Clip Warning

> ✏️ **Note**
>
> The LED indicators are also mirrored on the RZ2 LCD display when the PZ5 is connected to the PZ Amplifier port on the back of the RZ2.

Clip Warning

Analog clipping occurs when the input signal is too large. When the input to a channel is within 3 dB of the PZ5's maximum voltage input range the LED for the corresponding channel is lit red to indicate that clipping may occur.

Activity

When configured to indicate activity, LEDs are lit green whenever a unit (spike) occurs on the corresponding channel. The sensitivity threshold for the green LED is ~200 uV.

LED Indicators (digital)

LEDs that represent digital input boards, indicate the number of input channels with each LED indicating 16 channels. For example, four LEDs indicates 64 input channels have been detected on that connection.

External Ground

The external ground is optional and should only be used in cases where the subject occasionally contacts a metal surface that isn't tied to the animal ground, such as a lever press. When contact is made, a ground loop is formed that temporarily adds extra noise to the system. Grounding this metal surface directly to the TDT hardware removes this ground loop at the cost of raising the overall noise floor a small amount.

A banana jack located on the back of the PZ5 provides connection to common ground. Any logical amplifier configured through the PZ5 touchscreen has this shorted by default. The PZ5 gizmo in Synapse allow you to float that ground connection on individual sub-amplifiers.

An external grounding cable kit is included with the PZ5. Each kit includes: one male banana plug to male banana plug pass through and one male banana plug to alligator clip pass through. These cables also include ferrite beads to remove any potential RF noise that might travel through the cable. For best results position the ferrite bead close to the source of the RF noise.

Battery Overview

The PZ5 features a 32 Amp-hour Lithium ion battery pack.

Charging the Batteries

Operate the PZ5 with the charging cable disconnected. An external battery pack (PZ-BAT) or external charger and extra battery (PZ5-BAT) is available for longer battery life and extended recording sessions. See PZ-BAT and PZ5-BAT.

PZ5 Technical Specifications

Analog Inputs

Analog A/D Input	Up to 8 cards (128 channels), hybrid
Maximum Voltage In	±500 mV
Gain	2x
A/D Sample Rate	Up to 48828.125 Hz (adjustable in steps of approximately 750, 1500, 3000, 6000, 12000, 25000, 50000 Hz)^
Frequency Response	DC coupled: 0 Hz - 0.45*Fs AC coupled: 0.4 Hz - 0.45*Fs
S/N (typical)	104 dB, single unit, Fs = 25 kHz, 300-7000 Hz 116 dB, differential, Fs = 750 Hz, 0.4-300 Hz
DC offset	<±10 uV
Input Referred Noise	Single Ended: 3.0 uVrms, 300-7000 Hz, 25 kHz Differential: 0.75 uVrms, 0.4-300 Hz, 750 Hz
Distortion (typical)	<1%
Input Impedance	AC coupled: 100 kOhm DC coupled: 20 MOhm

^Note: If recording at ~50 kHz on 128 channels, see PZ5 Software Control for more information.

Analog Input Sample Delay

Depends on PZ5 and RZ processor sample rates. All units in samples.

PZ5 rate	RZ @ 25 kHz	RZ @ 12 kHz
25 kHz	22	N/A
12 kHz	40	23
6 kHz	76	42
3 kHz	141	79
1.5 kHz	270	152
750 Hz	543	295

Digital Inputs

RHD2000 series amplifier boards and SPI interface cables are used in TDT's ZD and OD Intan-based digitizing headstages. They are available from Intan Technologies.

> 🔥 **Important**
>
> The specifications below are dependent on the amplifier board. See Intan RHD2000 series website for latest, full performance specifications.

Digital Headstage Input	Up to 8 cards (256 channels), 1 input per card
Sampling Rates	Up to 25 kHz
Frequency Response	0.1 Hz - 10 kHz
Input Range	±5 mV with ZD, OD, and other Intan-based digitizing headstages
Allowable DC Offset	±0.4 V
Sample Delay	5 samples

General

|	
Battery Capacity	32 Ahr
Battery	8-10 hours to charge to 95% capacity, 14 hours to fully charge. Battery life runtime: 2 active boards ~50 hrs 4 active boards ~35 hrs 6 active boards ~27 hrs 8 active boards ~22 hrs
Charger	External 12 V, 2.5 A power supply, center negative
Indicator LEDs	Up to 128 status/clip warning/digital input channel count
Fiber Optic Cable	5 meters standard, cable lengths up to 20 meters.
Ethernet Port	100 Mbps
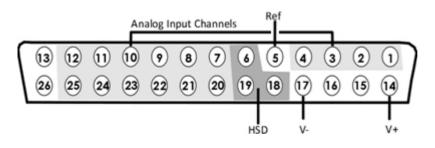
Input Connectors

The PZ5 has up to eight 26-pin headstage connectors (analog) or up to four 12-pin Omnetics nano connectors (digital) on the back of the unit. The connectors are labeled alphabetically from bottom to top. Each connector carries signal for one bank of channels with ground and reference. The corresponding channel numbers depend on 1) the reference mode configurations or number of channels in a connected digital amplifier board and 2) the position of the bank in a logical amplifier.

For simplicity sake, the diagrams below assume channels for that connector begin with channel 1. For example, A1 - A16 represent the 16 channels coming from the connected headstage. The user must increment the channel numbers by 16 (or 8 if in Differential mode) according to the mode and position of the connector. So, for the connector labeled 'A', A1 is channel 1 while on the connector labeled 'B', A1 may be channel 17.

Pinout Diagrams

Local, None or Shared Reference Mode

Pin	Name	Description	Pin	Name	Description
1	A1	Analog Input Channels	14	V+	Positive Voltage (+2.5 V)
2	A2		15	GND	Ground
3	A3		16	GND	
4	A4		17	V-	Negative Voltage (-2.5 V)
5*	Ref*	Reference*	18	HSD	Headstage Detect
6	HSD	Headstage Detect	19	HSD	
7	A5	Analog Input Channels	20	A6	Analog Input Channels
8	A7		21	A8	
9	A9		22	A10	
10	A11		23	A12	
11	A13		24	A14	
12	A15		25	A16	
13	^	See notes below	26	NA	Not Used

> ✏️ **^Note**
>
> In Local reference mode, Pin 13 is AltRef. Otherwise, Pin 13 is Ground.

* In Shared reference mode, only Pin 5 of the first bank of the logical amplifier is connected. It is shared internally among the other banks of the logical amplifier.

* In None reference mode, Pin 5 is not connected.

Differential Reference Mode

> ✏️ **Note**
>
> There are 8 (+) channels and 8 (-) channels per DB26 connector. Subsequent banks are indexed by an additional 8 channels.

Pin	Name	Description		Pin	Name	Description
1	A1(+)	Analog Input Channel		14	V+	Positive Voltage (+2.5 V)
2	A1(-)	Differential Analog Input Channel		15	GND	Ground
3	A2(+)	Analog Input Channel		16	GND	
4	A2(-)	Differential Analog Input Channel		17	V-	Negative Voltage (-2.5 V)
5	NA	Not Used		18	HSD	Headstage Detect
6	HSD	Headstage Detect		19	HSD	
7	A3(+)	Analog Input Channels		20	A3(-)	Differential Input Channels
8	A4(+)			21	A4(-)	
9	A5(+)			22	A5(-)	
10	A6(+)			23	A6(-)	
11	A7(+)			24	A7(-)	
12	A8(+)			25	A8(-)	
13	GND	Ground		26	NA	Not Used

> ✏️ **Note**
>
> See Tech Note 0896 before attempting to make any custom connections.

Digital Connectors

The digital input connector is a self-aligning 12-pin Omnetics PZN-12 polarized nano connector that mates directly to an Intan RHD2000 SPI interface cable.

PZ5M Medically Isolated NeuroDigitizer

PZ5M Overview

The PZ5M is a multi-modal NeuroDigitizer, suitable for recording a broad range of biological potentials, combining the functionality of high and low impedance amplifiers in a single device. The device is battery operated with alternative Mains power, used primarily for charging, with full biomedical isolation for subject safety. The rack-mountable PZ5M-512 can be used for simultaneous input of EEG, EMG, LFP and Single Unit signals.

Analog input boards oversample the signal with very fast instrumentation grade converters. TDT's custom hybrid A/D circuit yields 28 bits of resolution and unparalleled dynamic range. Optional DC coupling offers zero phase distortion across the signal bandwidth. Sampling rate and down-sampling filters can be optimized on each logical amplifier for the intended input type to optimize signal fidelity. The ±500 mV input range is large enough to accept any biological potential and most stimulus artifacts without saturating.

The PZ5M analog inputs are organized into multiple banks of 64 channels. Each bank is electrically isolated, meaning the ground and reference channels are not inherently shared between banks. Multiple banks can be grouped into a single logical amplifier that shares the same settings and ground/reference across each bank in the logical amplifier. There are several different referencing modes; each logical amplifier can use the ground as a reference, use a shared reference, use a unique reference on each bank or implement full per-channel differential referencing.

A touchscreen interface provides immediate preview of inputs, impedance checking and real-time control and configuration options for each amplifier bank.

The PZ5M is available in 256 channel (PZ5M-256) or 512 channel (PZ5M-512) models. The total number of channels is generally reduced by half at 50 kHz sampling rates, See PZ5M Software Control for more information.
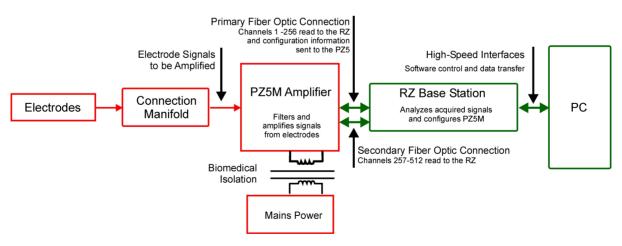
System Hardware

The PZ5M accepts inputs from a variety of electrode/headstage combinations via the back-panel connectors. It includes up to eight DB80 connectors, each with 64 recording channels (or 32 differential channels) along with ground and reference.

Analog signals are digitized and transmitted to the RZ base station for further processing via a fiber optic connection. Configuration information is also sent from the RZ to the PZ5M across the fiber optic connection. The PZ5 can connect to the 'PZ Amplifier' input on an RZ2 base station, or directly to any RZDSP-P card or optical QZDSPO quad card on any RZ base station.

The PZ5M-512 uses two of these connections, each transferring data for up to 256 channels. The PZ5M-256 only requires a single connection, but includes a second connection that duplicates the data for more parallel processing if necessary.

A standard recording configuration includes electrodes appropriate to the input signals, a breakout box / connection manifold or one or more Z-Series headstages, a PZ5M and an RZ2 processor.

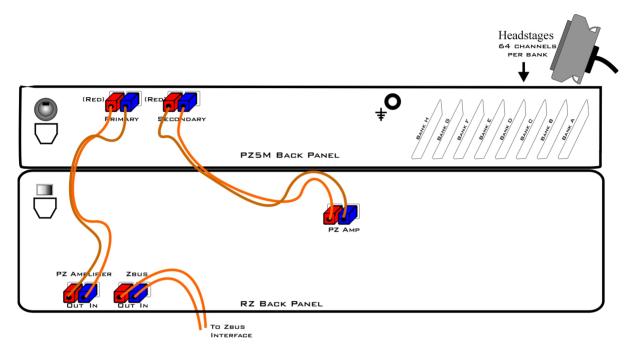The diagram below illustrates this flow of data and control information through the system.

PZ5M Data and Control Flow Diagram

Hardware Setup

Up to two 5-meter paired fiber optic cables (up to 256 channels per duplex cable) are included to connect the PZ5M to the base station. The connectors are color coded and keyed to ensure proper connections.

The diagrams below illustrate the connections necessary for PZ5M operation.

System Connection Diagram for PZ5M-512 with RZ2

Two fiber optic ports are available on the back panel for transferring digitized channels to the RZ device. The first 256 channels are handled by the Primary fiber optic port and the second 256 channels (257-512) are handled by the Secondary fiber optic port. The Primary port also receives the configuration information from the RZ2.

The PZ5M can connect to the 'PZ Amplifier' input on an RZ2 base station, or directly to any RZDSP-P card or optical QZDSPO quad card on any RZ base station.

Connecting Headstages and Electrodes

Analog signals are input via multiple mini-DB80 connectors on the PZ5M back panel. For high impedance recordings, most users will connect to the input connectors on the PZ5M back panel using a ZC64 headstage or a connection manifold.

For low impedance recordings, users will likely use custom cables, typically to an S-BOX splitter box with touchproof connectors. If using custom connectors, see Pinout Diagrams.

Powering ON/OFF

The PZ5M has both an onboard battery and a connection to mains power.

The small square button on the face of the PZ5M by the touchscreen turns the PZ5M on/off. Press and hold the front panel power button for one second to turn the PZ5M on or off.

The switch on the back of the PZ5M connects mains power. For shorter recordings, disconnect the AC power cable and turn the mains power switch off. Only turn it on to recharge the batteries in between recordings. For longer recordings, mains power will power the PZ5M and charge the batteries simultaneously.

> 🔥 **Important**
>
> If the PZ5M power circuit doesn't detect the power (from power cord) when set to charge, charging is not engaged. Be sure the device is plugged in before you switch to charging.
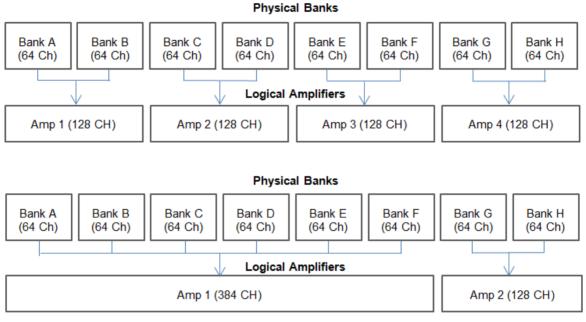
See Power Status LEDs for more information.

Physical Amplifier

All PZ5M channels are organized into banks, with each bank corresponding to a group of 64 channels, a rear panel headstage connector (labeled alphabetically), and a front panel LED displays. Each bank is electrically isolated and can be independently configured or grouped with other banks and defined as a logical amplifier.

Logical Amplifiers

Though each bank has its own ground and reference, a single ground and reference can also be defined and shared across all banks of the logical amplifier. See Reference Modes for more information.

Physical Banks

| Bank A (64 Ch) | Bank B (64 Ch) | Bank C (64 Ch) | Bank D (64 Ch) | Bank E (64 Ch) | Bank F (64 Ch) | Bank G (64 Ch) | Bank H (64 Ch) |

Logical Amplifiers

| Amp 1 (128 CH) | Amp 2 (128 CH) | Amp 3 (128 CH) | Amp 4 (128 CH) |

Physical Banks

| Bank A (64 Ch) | Bank B (64 Ch) | Bank C (64 Ch) | Bank D (64 Ch) | Bank E (64 Ch) | Bank F (64 Ch) | Bank G (64 Ch) | Bank H (64 Ch) |

Logical Amplifiers

| Amp 1 (384 CH) | Amp 2 (128 CH) |

Two Possible Logical Amplifier Configurations

Logical amplifier configurations can be defined using the front panel interface (see PZ5M Touchscreen), in Synapse, or in RPvdsEx using the PZ5M_Control macro. The PZ5M can have a maximum of four logical amplifiers.

Reference Modes

The PZ5M supports four referencing modes for each analog input logical amplifier: Local, Shared, None and Differential. See Pinout Diagrams.

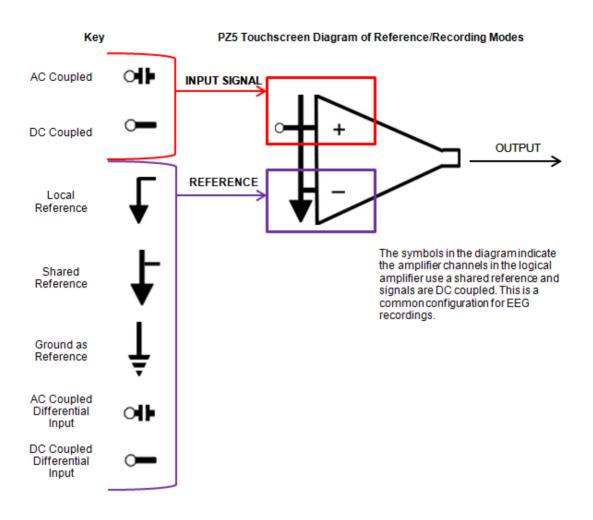| Reference Mode	Description
Local	Each group of 32 channels in a logical amplifier uses its own reference input (pin 5) as the reference for that bank
Shared	The reference (pin 5) of the first bank of the logical amplifier acts as a reference for all banks in the logical amplifier
None	The references for all banks of a logical amplifier are tied to the Ground (pins 13, 15, and 16).
Differential	The inputs in each bank of the logical amplifier are paired; odd channels serve as recording (+) channels and each even channel is used as an individual reference (-) channel for the preceding odd channel. No connections should be made to pin 5.

Sampling Rate and Onboard Filters

The sampling rate of each logical amplifier is adjustable (max 50 kHz, min 750 Hz) and should be set to a value appropriate for the signal of interest. Reducing the sampling rate when acquiring low-frequency analog signals yields higher bit resolution and improved signal-to-noise. Use the Amp Type Presets as a guide for determining what sampling rate to use for each logical amplifier.

The onboard down-sampling filters are used to further reduce the noise from frequencies above the band of interest and can be set to a percentage of the sampling rate (max 45%, min 10%). Adjusting the sampling rate and filter for each logical amplifier to match your desired signal gives you the best possible signal fidelity.

Amp Type Presets

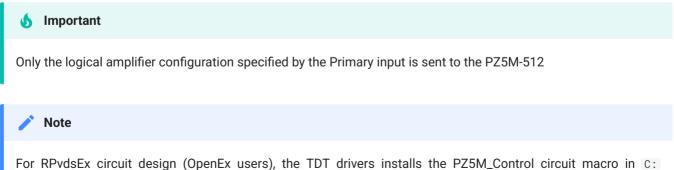| Amp Icon	Amp Label	Default Settings
	EMG	Electromyography Referencing: Diff (true differential) Coupling: AC Sample Rate: 750 Hz
	EEG	Electroencephalography Referencing: Shared Coupling: AC Sample Rate: 750 Hz
	LFP	Local Field Potentials Referencing: Shared Coupling: AC Sample Rate: 3 kHz
	SU	Single Unit Referencing: Local Coupling: AC Sample Rate: 25 kHz

The PZ5M touchscreen interface uses representative diagrams to enable users to identify the configuration of the amplifier at a glance. The table below explains the parts of the diagram and what each represents.

PZ5M Signal/Reference Diagram

PZ5M Software Control

All PZ5M configuration and control of data acquisition is managed through Synapse. The PZ5 object configures the analog and digital headstage recording inputs. Please see the Synapse Manual for more information.

> 🔥 **Important**
>
> Only the logical amplifier configuration specified by the Primary input is sent to the PZ5M-512

> ✏️ **Note**
>
> For RPvdsEx circuit design (OpenEx users), the TDT drivers installs the PZ5M_Control circuit macro in `C:\TDT\RPvdsEx\Macros\Device\PZ5_NeuroDigitizer` . See the Legacy System 3 Manual for circuit design.

Recording 128 Channels at 50 kHz

Due to the PZ5M's high bit resolution and recording capabilities, data should always be stored as 32-bit floating point. However, when storing 128-256 channels at 50 kHz sampling rate, you must use the Short (16 bits) format due to bandwidth constraints. This means the data will be scaled and converted into an integer before storage, which narrows the dynamic range of the acquired signals. In this case, all DC offsets must be removed before the data is stored. You can either filter out the DC offset with a Neural Stream Processor gizmo in Synapse or use AC coupling on the logical amplifier if you are storing the raw signal direct from the PZ5M.

PZ5M Touchscreen

The PZ5M touchscreen can be used to add logical amplifiers, check impedance, preview waveforms in real-time. It also provides access to the PZ5M settings, such as the screen auto lock and auto sleep features, as well as tools for viewing system information, such as battery status, and updating the device software.

Main Configuration Screen

The main configuration screen includes the following:

Touchscreen Icon	Description
	All logical amplifiers that have been defined are represented on the right side of the screen and labeled in logical order from bottom to top. For example, 2:EMG is the second logical amplifier. In the illustration above, this would correspond to the back panel input connector labeled 'B'. See PZ5M Software Control.
	Display the System Setup Screen
	Toggle LED Indicators on or off. See Clip Warnings and Activity Display for more information.
	Lock to protect configuration settings. Unlock to allow changes to the configuration.
	Create a new logical amplifier. As logical amplifiers are added they appear on the Main Configuration screen. See Manual Configuration.
	PZ5M bank icons are color coded to indicate current configuration of each bank. A red outline indicates that the bank is configured as part of a logical amplifier but no headstage is currently detected on that bank. A gray bar indicates that the bank is not configured. Digital input boards are overlaid with a digital signal representation.

Impedance Checking Screen

> 🔥 **Important**
>
> The impedance checking feature of the PZ5M can and should only be used with a passive headstage or direct connection to the electrodes.

 Enter the Impedance Checking screen by touching this icon on an existing logical amplifier on the Main Configuration screen. The logical amplifier number and amp type are displayed in the top-left corner, for example 1:EEG.

Select the type of connections to measure (Probing options) and choose a target impedance value (Target) to color code the measured impedance value text. During impedance checking, All connections in the selected set are tested in parallel and the impedance is color-coded relative to the user-defined target impedance.

A limited set of channels are visible at any one time. Swipe vertically on the touchscreen to scroll the visible channels.

Settings include:

Setting	Description
Target	Select the target impedance from a drop down list (1 kOhms -100 kOhms). This is used to color the impedance value text during/after probing. Impedance values above the target are colored red, values <75% below the target are green and all other values are yellow.
Freq.	Set the probe signal frequency from a drop down list. The frequency is adjustable from 35 Hz, 70 Hz, 140 Hz, 280 Hz, 560 Hz, 1120 Hz, and 2240 Hz. This feature is only selectable in daughter board firmware v1.3 and above, and PZ5M software v1.1.1 and above. The frequency is fixed at 140 Hz in prior versions.
Probing	(Analog input amps only) Select the set of connections to measure. The available options in this list change depending on the logical amp referencing mode. See table below.
Sort Button	Toggle button that displays the channels with the largest variation from the target impedance at the top of the screen
Auto Button	Toggle button that cycles through each probing option every second
Next Button	Select to advance to the next probing option set

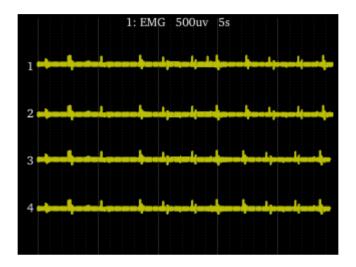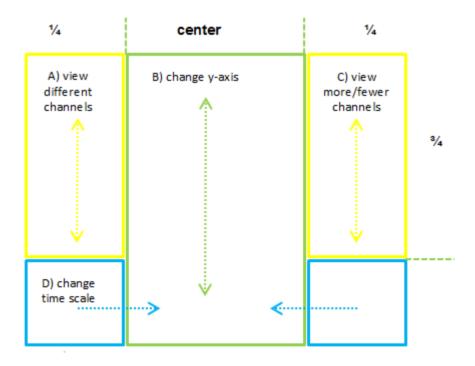| Ref Mode	Probing Options
Differential	**Inp(+)** for the positive input channels and **Inp(-)** for the differential channels
Local	**Input** for all the input channels, **Ref** for the reference impedance to ground, and **AltRef** to test the alternative reference (pin 13, see Pinout Diagrams)
Shared	**Input** for all the input channels, **Ref** for the reference impedance to ground, and **Gnd** to test the ground impedance
None	**Input** for all the input channels

Waveform Display Screen

Enter the Waveform Display screen by touching this icon on an existing logical amplifier on the Main Configuration Option screen. The displayed waveform is decimated for plotting and high pass filtered so all channels can be shown on the same voltage scale. If the logical amplifier is DC Coupled, the DC offset is displayed as a value on the right side of each plot line (in mV).

Waveform Display Touchscreen Controls

> 🔥 **Important**
>
> To return to the Main Configuration screen, swipe three fingers across the screen in any direction. On the Main Configuration screen, a three finger swipe will turn off the display.

Manual Configuration

The logical amplifier configuration defined in Synapse is sent to the PZ5M and applied when the recording begins. However, the touchscreen interface can also be used to configure logical amplifiers on-the-fly.

Touch the **+** icon to add a logical amplifier. Set the Amp Type and number of channels in the screen that follows. See Amp Type Selection Screen for more information. Adjust amplifier configuration options in the next screen. See Configuration Options Screen for more information.

Amp Type Selection Screen

Enter the Amp Type Selection screen by touching the **+** icon on the Main Configuration screen or by touching the **Amp Type** button on the Configuration Options Screen for an existing logical amplifier.

Select the Amp Type and set the number of channels in the logical amplifier (by banks of 64 channels for analog amplifiers).

Configuration Options Screen

Enter the Configuration Options screen after selecting the Amp Type when adding a new logical amplifier, or by touching the Amp Icon on an existing logical amplifier on the Main Configuration screen.
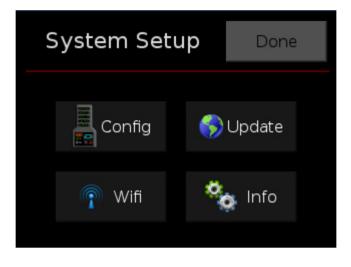

Analog Input Amp Settings

Each Amp Type includes preset values for each setting. The Configuration Options Screen lets you modify them.

Setting	Description
Coupling	Choose AC or DC. AC coupling implements a high pass filter with ~0.4 Hz cutoff frequency
Ref Mode	Choose Local, Shared, None, or Differential Reference Mode. See Reference Modes for more information
Samp Rate	Set the Sampling Rate to match the desired frequency band of your incoming signals (or leave at 'System Rate' if you are unsure). Options include: 750 Hz, 1.5 kHz, 3 kHz, 6 kHz, 12 kHz, 25 kHz, 50 kHz. By default, the sampling rate matches that of the RZ.
Filtering	Select a cutoff frequency for the anti-aliasing filter, as a percentage of the sampling rate. Choose from a list of values: 45%, 35%, 25%, 15%, or 10%
Ext. Ground	Press 'More' button to access this. Set to Yes to connect this logical amplifier ground to the external ground plug on the physical PZ5M device. **Caution:** When using multiple sub-amps make sure they aren't all sharing the External Ground connection or else they won't be isolated!

System Setup Screen

The System Setup screen is displayed by touching the PZ5 logo on the top-left of the Main Configuration screen.

Button	Description
Config	Open the System Configure screen
Update	Update onboard software over the Internet
Wifi	Connect to a wireless network for system updates
Info	Open the device System Info screen to view version numbers for various hardware, software and firmware components

System Configure Screen

The System Configure screen is displayed by touching Config on the System Setup screen.

Setting	Description
Boot Amp	Select the default logical amplifier settings when the PZ5 is first powered on. See table below.
Autolock	Select an option to lock the configuration screen after 1, 2 or 5 min of screen inactivity or select Never to turn off autolocking
Autosleep	Select an option to turn off the screen after 5, 10 or 30 min of screen inactivity or select Never to turn off autosleep
Brightness	Select High, Medium, or Low to set touchscreen brightness
Wireless	Enable/disable the wireless connection

Boot Amp	Description
None	Boots with no logical amplifiers specified
PZ2	All banks configured as one Single Unit amplifier
PZ3	All banks configured as one EEG amplifier
PZ3 Diff	All channels configured as one EEG amplifier in differential referencing mode
Last	Reboots into the last used configuration
Smart	Does not overwrite any existing logical amplifier configuration on boot. For example, if you configure the logical amplifiers in Synapse before the PZ5 boots then the PZ5 will NOT overwrite that configuration. If the PZ5 boots and NO logical amplifiers are configured it will behave the same as Last.

System Info Screen

The System Info screen is displayed by touching Info on the System Setup screen. Use the scroll bar to see all of the version numbers.

Information	Description
Device	PZ5M model number (e.g. PZ5M-512)
Software version	Currently installed version of onboard software
Firmware version	Currently installed version of firmware
Hardware version	Version of hardware
Battery	Date and capacity of last battery calibration (in mAhr)

Advanced Button

Password protected settings for TDT use only at this time.

System Update Screen

The system updater connects to a TDT server to download the latest PZ5M software and automatically update the device. This requires an active and configured Internet connection. The PZ5 provides two options for network connection: WiFi and Ethernet. The WiFi connection can be configured on the Wireless Networks Screen, see below. The Ethernet port is located on the back panel.

The System Update screen is displayed by touching Update on the System Setup screen.

> 🔥 **Important**
>
> The update process can take up to an hour to complete. Make sure the PZ5 battery charger is plugged in during the update.

Wireless Networks Screen

The Wireless Networks screen is displayed by touching WiFi on the System Setup screen. Available networks that have been used or previously configured are displayed in the main area of the screen. Selecting a network from the list displays network information and enables the user to connect to the network, forget the network, or cancel configuration of the network.

The wireless icon shows if the wireless feature is enabled or disabled. A red 'x' will appear through the icon if wireless is disabled. Enable/disable wireless through the System Configure Screen.

Setting	Description
Show All	Shows all networks, including networks that have not been previously used or configured
IP Addr	Displays current IP Address when connected to a network

PZ5M Features

Power Status LEDs

A battery power button located above the front panel touchscreen interface turns on/off battery power and the adjacent row of small LEDs reports power type and level. The first LED (from left) indicates whether the devices is being powered from mains or batter power.

LED Color	Status
Green	the device is using mains power and the battery is charging.
Red	the device is using battery power. To use battery power, turn off Mains power using the switch on the back panel.

The four LEDs on the right end of the row indicate the power level of the battery.

The LED between the Power Mode LED and the Power Level LEDs is not used at this time.

Battery Operation and Charging

The digitizer has an onboard, 240 Wh battery for device operation. The battery charges whenever the Mains power is connected and the Mains power switch is in the on position. The battery power button may be on or off.

Clip Warnings and Activity Display

The front panel LEDs can be used to indicate spike activity and/or clip warning. They can be configured under software control using the PZ5 gizmo in Synapse, or under manual control using the toggle switch on the PZ5M touchscreen.

LED Indicators

When enabled, LEDs for each channel are lit green to indicate activity or red to indicate a clip warning.

Green: Activity   Red: Clip Warning

> ✏️ **Note**
>
> The LED Indicators for the first 256 channels are also mirrored on the RZ2 LCD display when the PZ5M is connected to the PZ Amplifier port on the back of the RZ2.

Clip Warning

Analog clipping occurs when the input signal is too large. When the input to a channel is within 3 dB of the PZ5M's maximum input range the LED for the corresponding channel is lit red to indicate that clipping may occur.

Activity

When configured to indicate activity, LEDs are lit green whenever a unit (spike) occurs on the corresponding channel. The sensitivity threshold for the green LED is ~200 uV.

External Ground

The external ground is optional and should only be used in cases where the subject occasionally contacts a metal surface that isn't tied to the animal ground, such as a lever press. When contact is made, a ground loop is formed that temporarily adds extra noise to the system. Grounding this metal surface directly to the TDT hardware removes this ground loop at the cost of raising the overall noise floor a small amount.

A banana jack located on the back of the PZ5M provides connection to common ground. Any logical amplifier configured through the PZ5M touchscreen has this shorted by default. The PZ5 gizmo in Synapse allow you to float that ground connection on individual sub-amplifiers.

An external grounding cable kit is included with the PZ5M. Each kit includes: one male banana plug to male banana plug pass through and one male banana plug to alligator clip pass through. These cables also include ferrite beads to remove any potential RF noise that might travel through the cable. For best results position the ferrite bead close to the source of the RF noise.

PZ5M Technical Specifications

A/D Input	Up to 512 channels, hybrid
Maximum Voltage In	±500 mV
Gain	2x
A/D Sample Rate	Up to 48828.125 Hz (adjustable in steps of approximately 750, 1500, 3000, 6000, 12000, 25000, and 50000 Hz)^
Frequency Response	DC coupled: 0 Hz - 0.45*Fs AC coupled: 0.4 Hz - 0.45*Fs
S/N (typical)	104 dB, single unit, Fs = 25 kHz, 300-7000 Hz 116 dB, differential, Fs = 750 Hz, 0.4-300 Hz
DC offset	<±10 uV
Input Referred Noise	Single Unit: 3.0 uVrms, 300-7000 Hz, 25 kHz Differential: 0.75 uVrms, 0.4-300 Hz, 750 Hz
Distortion (typical)	<1%
Input Impedance	AC coupled: 100 kOhm DC coupled: 20 MOhm
Indicator LEDs	Up to 512 status/clip warning
Fiber Optic Cable	5 meters standard (2), cable lengths up to 20 meters Note: If longer cable lengths are required, contact TDT.
Ethernet Port	100 Mbps
Battery	240 Wh 20 hours to fully charge 16-18 hours to charge to 95% capacity 5.5 hour runtime (with every bank active)

^Note: If recording at ~50 kHz on 128-256 channels, see PZ5M Software Control for more information.

Analog Input Sample Delay

Depends on PZ5M and RZ processor sample rates. All units in samples.

PZ5M rate	RZ @ 25 kHz	RZ @ 12 kHz
25 kHz	22	N/A
12 kHz	40	23
6 kHz	76	42
3 kHz	141	79
1.5 kHz	270	152
750 Hz	543	295

Input Connectors

PZ5M NeuroDigitizers has up to eight headstage connectors on the back of the unit. Each connector carries input signals and some combination of ground(s) and reference(s).
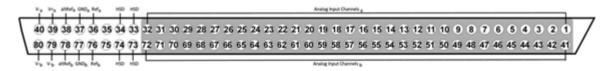
Pinout Diagrams

The PZ5M connectors are labeled alphabetically from right to left. The corresponding channel numbers depend on 1) the reference mode configuration and 2) the position of the bank in a logical amplifier.

For simplicity sake, the diagrams below assume channels for that connector begin with channel 1. For example, in the first pinout below A1 - A32 represent the first 32 channels coming from the headstage connected to the mini-DB80. Channels numbers should be incremented according to connector position.

The left and right row on each connector is electrically separate, but represents a single block of channels that can be defined as a logical amplifier or as part of a larger logical amplifier. As a result, ground and references are duplicated for left(a) and right(b) rows.

Local, None or Shared Reference Mode

Pin	Name	Description	Pin	Name	Description
1	A1	Analog Input Channels	41	A33	Analog Input Channels
2	A2	(1-32)	42	A34	(33-64)
...	...	...	...	...	...
31	A31		71	A63	
32	A32		72	A64	
33	HSD	Headstage Detect	73	HSD	Headstage Detect
34	HSD	Headstage Detect	74	HSD	Headstage Detect
35	NA	Not Used	75	NA	Not Used
36*	Refa*	Reference for ch 1-32*	76*	Refb*	Reference for ch 33-64*
37	GNDa	Ground for ch 1-32	77	GNDb	Ground for ch 33-64
38	^	See notes below	78	^	See notes below
39	V+a	Positive Voltage (+2.5 V)	79	V+b	Positive Voltage (+2.5 V)
40	V-a	Negative Voltage (-2.5 V)	80	V-b	Negative Voltage (-2.5 V)
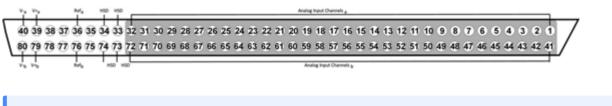
> ✏️ **^Note**
>
> In Local reference mode, Pin 38 is AltRefa and Pin 78 is AltRefB. Otherwise, Pin 38 is GNDa and Pin 78 is GNDb.

* In Shared reference mode, only Pin 36 of the first bank of the logical amplifier is connected. It is shared internally among the other banks of the logical amplifier.

* In None reference mode, Pin 36 and Pin 76 are not connected.

Differential Reference Mode

> ✏️ **Note**
>
> There are 32 (+) channels and 32 (-) channels per mini-DB80 connector. Subsequent banks are indexed by an additional 32 channels.

Pin	Name	Description	Pin	Name	Description
1	A1(+)	Analog Input Channels	41	A17(+)	Analog Input Channels
2	A1(-)	(1-16)	42	A17(-)	(17-32
3	A2(+)		41	A18(+)	
4	A2(-)		42	A18(-)	
...	...	...	...	...	...
29	A15(+)		69	A31(+)	
30	A15(-)		70	A31(-)	
31	A16(+)		71	A32(+)	
32	A16(-)		72	A32(-)	
33	HSD	Headstage Detect	73	HSD	Headstage Detect
34	HSD	Headstage Detect	74	HSD	Headstage Detect
35	NA	Not Used	75	NA	Not Used
36	NA	Not Used	76	NA	Not Used
37	GNDa	Ground for ch 1-32	77	GNDb	Ground for ch 33-64
38	GNDa		78	GNDb	
39	V+a	Positive Voltage (+2.5 V)	79	V+b	Positive Voltage (+2.5 V)
40	V-a	Negative Voltage (-2.5 V)	80	V-b	Negative Voltage (-2.5 V)

Contact TDT technical support support@tdt.com before attempting to make any custom connections.

PZ-BAT External Battery Pack for the PZ Amplifiers

PZ-BAT Overview

The PZ-BAT external battery pack is used with a PZ amplifier for long recording sessions. It provides 42 AmpHours and requires 8-10 hours to charge to 95% capacity and 14 hours to fully charge.

Charging the Batteries

A 100-240 VAC, 50-60HZ 2A(MAX) power connection socket is on the back or the PZ-BAT. Connect to AC power to charge.

Using the External Battery Pack

The DC power output cable on the front panel can be connected directly to the round female charger socket on the back panel of a PZ amplifier.

Set the three position switch on the front of PZ amplifier to either the A or B position to power on the PZ amplifier. When the PZ-BAT is connected the PZ's Battery Status LEDs will behave as if the internal batteries are charging.

> 🔥 **Important**
>
> To avoid introducing EMF noise, DO NOT connect the PZ-BAT to AC power while connected to a PZ amplifier that is collecting data.

PZ-BAT Technical Specifications

The internal charger is 6 V, 3 A power supply.

Battery performance:

# of Ch	Duration
32	55 hrs
64	46 hrs
96	40 hrs
128	34 hrs
256	21 hr

> ✏️ **Note**
>
> All time values are typical.

PZ5-BAT External Charger

PZ5-BAT Overview

The PZ5-BAT is an external battery charger for the PZ5 or SIM's 32 Ahr Lithium-ion user-serviceable battery pack. The PZ5-BAT unit is comprised of an off-the-shelf programmable charger that has been pre-programmed for use with the PZ5 battery pack, and a custom connector cable.

Using the Charger

The instructions below are the same for both the PZ5 and SIM devices.

Remove the Battery pack
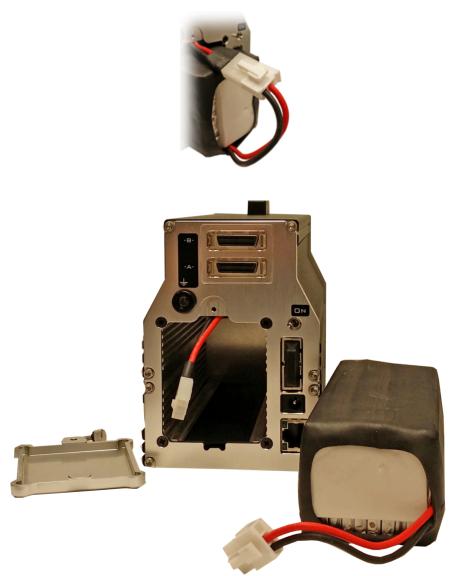
Before using the external charger, you will often need to remove the battery pack from the device. The PZ5 battery cover is located on the back side and is held on by a single thumbscrew at the top and a simple notch at the bottom.

1. Unscrew the thumbscrew then lift and pull away the battery cover.
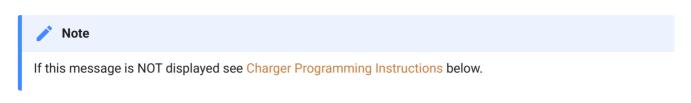
2. The connector between the batter pack and the device will be immediately visible. Press down on the tab to release the connection then gently pull the battery pack free from the device.

Charge the Battery

1. Power on the charger by plugging it in to AC power with the provided cable.

   Upon power up, verify the display reads "LiPo CHARGE" on the first line and then "3.5A" and "3.7V(1S)" on the second line.

   > ✏️ **Note**
   >
   > If this message is NOT displayed see Charger Programming Instructions below.

2. Plug the battery pack into the charger using the custom connector cable.

3. Press and hold the **ENTER (Start)** button to begin. The charger will check the battery to verify that it is okay to charge.

4. When the check is complete, press the **ENTER (Start)** button again to CONFIRM and then it will begin to charge.

5. Charging will stop (no numbers changing on the display) when the battery pack is fully charged.

Install a Battery Pack

While the battery pack is charging you can install an alternate pack in the PZ5, or when charging is complete re-install the charged pack.
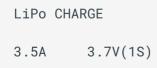
1. Connect the pack's cable to the PZ5 cable. The connectors are keyed to prevent miswiring and snap in place when securely connected.

2. Gently slide the battery into the unit. Ensure that the cable is tucked inside the opening.

3. Line-up the tabbed end of the cover with the notch at the bottom of the opening and slide it into position.

4. Use the thrumbscrew to securely attach the cover.

Charger Programming Instructions

When powering on the charger the display should read:

```
LiPo CHARGE

3.5A     3.7V(1S)
```

If the expected message is not displayed, the settings may have been erroneously changed and it may be necessary to re-program the unit.

Before re-programming, try pressing the **ENTER (Start)** button. If the display changes to display the beginning message above, return to the .

To program the charger:

1. Upon power up, press and hold the **BATTERY TYPE** button until the display reads, **"PROGRAM SELECT LiPo BATT"** then press the **ENTER (Start)** button.

2. Verify the display reads "LiPo CHARGE" on the first line and then "3.5A" and "3.7V(1S)" on the second line.

3. If the display does not read 3.5A, then press the **ENTER (Start)** button to change the charge rate. Press the **'+'** plus or **'-'** minus Status buttons to adjust the value to **3.5A**. When 3.5A is displayed, press the **ENTER (Start)** button.

4. Verify that **"3.7V"** is blinking. If not, use the **'+'** plus or **'-'** minus Status buttons to adjust the value to 3.7V and then press the **ENTER (Start)** button.

```
LiPo CHARGE

3.5A     3.7V(1S)
```

5. Press the **BATTERY TYPE** button until the display reads, "USER SET PROGRAM". Then press the **ENTER (Start)** button.

```
USER SET

    Program->
```

6. Press the '-' minus Status button (4 times) until the screen reads "SAFETY TIMER".

7. Press the **ENTER (Start)** button and then press the '+' plus Status button to set the timer to "OFF".

8. Press the **ENTER (Start)** button twice and verify that "OFF" is no longer flashing.

```
SAFETY TIMER

OFF 120min
```

9. Press the '+' plus Status button (once) until the screen reads "CAPACITY CUT-OFF"

10. Press the **ENTER (Start)** button twice and then press the '+' plus Status button to change the capacity to "40000 mAh".

```
CAPACITY CUT-OFF

OFF  40000mAh
```

11. Press the **ENTER (Start)** button and verify that "40000" is no longer flashing.

12. Press the **BATTERY TYPE** button (twice) until the display reads, "PROGRAM SELECT LiPo BATT". Then press **ENTER (Start)** button.

13. Verify the screen displays the following:

```
LiPo CHARGE

3.5A    3.7V(1S)
```

14. The charger is ready to use.

5. Medusa Preamplifiers

Medusa4Z BioAmp

Medusa4Z Overview

The Medusa4Z is a four-channel, referential, low-noise digital bioamp targeted for use in low-channel-count, low-impedance neurophysiology recordings, such as ABR, EEG, EMG, or EKG signals. The bioamp digitizes one or four channels at acquisition rates of approximately 3 kHz, 6 kHz, 12 kHz, or 25 kHz, and the amplified digital signal is sent to the base station via a noiseless fiber optic connector.

Connections to the subject (four channels, reference, and ground) are made with six standard 1.5 mm touchproof safety connectors.

- It is powered by a 5 AmpHr Li-Poly battery that provides up to 30 hours of continuous data acquisition in single-channel mode and up to 24 hours in four-channel mode.

- It includes impedance testing functionality for each of the four recording channels as well as the reference electrode.

- The user interface has 8 buttons and a 16 x 2 character LCD display screen. It lets you select performance characteristics of the preamplifier and shows battery and signal level.

- A complete charge from a dead battery can be achieved in under 8 hours with the included charger.

Medusa4Z Features

The Medusa4Z has the option to be run in single-channel mode or four-channel mode. When in single channel mode, channels 2-4 are powered down and isolated from the reference line. Running in single-channel mode will provide slightly better performance and longer battery life.

There are selectable Sampling Frequency options of ~3 kHz, ~6 kHz, ~12 kHz, or system rate (maximum ~25 kHz). Users will find that using the lowest practical rate improves noise performance.

When testing the impedance of the probes, users can select frequencies of 100 Hz, 300 Hz, 500 Hz, or 1 kHz.

A user-selectable digital highpass filter has adjustable options that are: Off, 1 Hz, and 3 Hz. The hardware has a fixed analog highpass at 0.3 Hz.

An Auto Shutdown feature has three modes: Never, 1 hour, 3 hours, or 5 hours. If no buttons are pressed after this interval, then the device will automatically power down. If no optics are detected, the Medusa4Z will also shutdown. Before shutting down, the blue POWER LED will blink fast to indicate that time has expired. Pressing any key will reset the counter.

Analog Input Channels

The Medusa4Z Preamplifier acquires signals with 16-bit PCM ADCs. The signals are oversampled before conversion to remove aliasing of high frequency RF signals. This allows users to acquire at lower sampling rates (down to 3 kHz) with improved signal-to-noise quality in that range and no aliasing. The Medusa4Z can also acquire data in High-Resolution mode which uses 24-bit PCM ADCs. This is controlled by the base station (RZ, RX) to which the Medusa4Z is connected. The change occurs by modifying the underlying circuit running on the base station in Synapse or BioSigRZ. This is the handled by default in Synapse v92 and above, and BioSigRZ v5.7.5 and above. In TDT Drivers v92 and above there is a RPvdsEx circuit macro available in: `C:\TDT\RPvdsEx\Macros\Device\Medusa4Z_Bioamp`.

Electrode Connectors

Plug the electrodes directly into the standard 1.5 mm touchproof connectors on the side of the Medusa4Z.

Impedance Checking

The impedance checker on the Medusa4Z provides a simple check of the channel impedance relative to ground. To check the impedance level, press the button next to the channel indicator (e.g. CHAN-1). The impedance between channel and ground will be shown on the screen. The REF impedance button checks the impedance between the reference and the ground. Impedance checking frequency options are 100 Hz, 300 Hz, 500 Hz, and 1 kHz. These are settable on the user interface.

LCD Screen

The LCD screen shows the current sampling rate, battery level, and signal level indication on the active channels.

Use the SETUP button to cycle through available settings and use the OPTION button to change the currently selected setting. Settings include:

Active Channels: Single or Four Channel

Sample Frequency: ~3 kHz, ~6 kHz, ~12 kHz, System Rate (up to ~25 kHz). Match this to the desired frequency range of your acquired signal (maximum frequency captured will be ~45% of selected sample frequency). Note that lower sampling rates will have improved signal-to-noise, but they will also have longer sample delays. Please refer to the See Medusa4Z PreAmp Technical Specifications. for more information.

Probe Frequency: 100 Hz, 300 Hz, 500 Hz, 1 kHz. Choose the default frequency used for the impedance checker.

Highpass Filt: Off, 1 Hz, 3 Hz. Set the highpass filter cutoff frequency on the input signals. 'Off' is a 0.1 Hz filter. Note that there is a fixed 0.3 Hz highpass analog filter on the inputs.

Auto Shutdown: Never, 1 hr, 3 hr, 5 hr. After a period of inactivity the Medusa4Z will shut itself down to preserve power. This prevents dead batteries from accidentally leaving the unit on overnight.
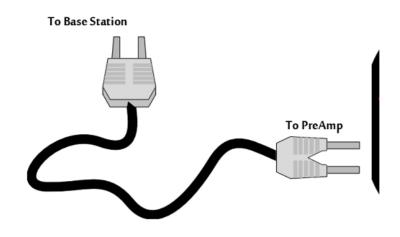
Base Station Connector - Optical

Use the provided fiber optic pair (black cable, white connectors) to connect the OPTICAL port on the preamplifier to the optical input port on the base station.

The duplex fiber optic cable has identical one-piece connectors at each end. There is a V-shaped groove on one side of the connector and a raised rectangle on the other. As shown in

the image below, plug the connector into the RZ6 port with the raised rectangle side up. Plug the connector into the preamplifier with the V-shaped groove up.

Medusa4Z Connection Diagram

Power

The POWER button on the face of the Medusa4Z powers it on. Press and hold the button to power it off. Press the power button momentarily to go to the home screen from anywhere or to reset the power down timer.

Do not use the recessed slide power switch (ON OFF (RESET)) on the side of the device unless you need to reset all settings to factory default, or if you are storing the Medusa4Z for an extended period of time and want to completely disconnect the battery. The OPTICAL fiber connector at the right will be illuminated when the amplifier is on.

Power Requirements

The lithium battery charges in four hours. Keeping the battery charger connected to the amplifier does not affect the battery life. However, the charger will significantly increase the noise of the system if it is plugged in while an experiment is running. A 12 Volt battery charger is included with the amplifier. The supplied charger tip is center negative. However, tip polarity can be positive or negative if the charger needs to be replaced.

> ✏️ **Note**
>
> If the Medusa4Z is powered on while charging, the charge circuit will halt when the battery is full. It will resume charging when the battery runs down to ~90%.

The lithium battery supplied with the system cannot be removed. If battery life longer than 30 hours is required, an external battery pack can be connected to the voltage inputs of the charger. TDT recommends a 6 V (minimum) to 12 Volt (maximum) battery, such as lead acid batteries used for motorized wheel chairs. Contact TDT for more information.

Medusa4Z Technical Specifications

A/D	Up to 4 channels Standard Mode: 16-bit PCM High-Resolution Mode: 24-bit PCM
Sample Rate	~3 kHz, ~6 kHz, ~12 kHz, or ~25 kHz
Maximum Voltage In	±10 mV
Gain	100x
Frequency Response	3 dB 0.3 Hz - 0.45*Fs (with no additional high-pass filter selected)
Highpass Filter	0.3 Hz, 1 Hz, or 3 Hz
Anti-Aliasing Filtering	45% sampling rate
S/N (typical)	80 dB
Input Impedance	100 kOhm
Battery	Li-Poly Battery 5000 mAh single-channel mode: 30 hour runtime four-channel mode: 24 hour runtime 1000 cycles of charging, not removable by user
Charger	6-16 V DC, >1 A, center-positive or center-negative
Fiber Optic Cable	5 meters standard, maximum cable length 12 meters

Input Referred Noise

Depends on Medusa4Z sample rate and electrode impedance. All units in uVrms.

Medusa4Z rate	shorted	3 kOhm	10 kOhm
3 kHz	0.15	0.3	0.5
6 kHz	0.25	0.4	0.7
12 kHz	0.3	0.6	1.0
25 kHz	0.4	0.9	1.4

Sample Delay

Depends on Medusa4Z and RZ processor sample rates. All units in samples.

Medusa4Z rate	RZ 200 kHz	RZ 100 kHz	RZ 50 kHz	RZ 25 kHz	RZ 12 kHz	RZ 6 kHz
25 kHz	181	89	45	24	N/A	N/A
12 kHz	322	165	82	42	24	N/A
6 kHz	590	299	150	75	42	24
3 kHz	1140	571	286	145	76	42

RA16PA/RA4PA Medusa PreAmps

Medusa Overview

The Medusa Preamplifiers are low noise digital bioamplifiers and are available with either PCM or Sigma-Delta ADCs. The system amplifies and digitizes up to 16-channels of analog signal at a 24.414 kHz sampling rate. The amplified digital signal is sent to the base station via a noiseless fiber optic connector.

- Digitizes either four or 16 channels at acquisition rates of approximately 6, 12, or 25 kHz.

- Connects to the headstage via a DB25 connector.

- Powered by a Lithium-ion battery that provides 20 hours of continuous data acquisition in 16-channel mode and 30 hours of operation in 4-channel mode.

- Clip warning lights indicate when any signal is -3 dB from the preamplifier's maximum voltage input.

Medusa Features

Analog Acquisition Channels

The RA16PA and RA4PA standard Medusa Preamplifiers acquire signals using 16-bit PCM ADCs, which provide quality acquisition with minimal delay. The RA16SD and RA4SD use Sigma-Delta ADCs, which have several characteristics that improve signal quality. Oversampling of the signal before conversion removes aliasing of high frequency RF signals.

RA16SD testing indicates that signals greater than 150% of the Nyquist frequency are removed from the signal. This allows users to acquire at lower sampling rates (6 kHz) without worry of significant aliasing. In addition, each converter also has a two pole anti-aliasing filter (12 dB per Octave) at 7.5 kHz. However, the sigma-delta ADC's have a fixed group delay of 20 samples (compared to four samples for the RA16PA). When using the RA16SD this group delay must be taken into account when the data is displayed or acquired (for example, adding a SampDelay to the RPvdsEx circuit).

Clip Warning Lights

When the input to a channel is greater than -3 db from the preamplifier's maximum voltage input, a light on the top of the amplifier is illuminated. The first column of lights corresponds to channels 1-8 and the second column corresponds to channels 9-16. The clip warning light indicator can be turned off by flipping a switch on the end of the amplifier.

Power Light

The power light is in the top corner of the amplifier. It is illuminated when the device is on. It flashes quickly if the battery is low. It flashes slowly while the battery is charging. Note: The flashing LED indicator is only available when the amplifier is powered on and connected to a powered base station.

Headstage Connector
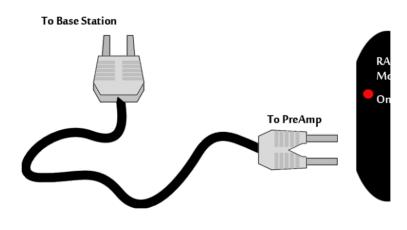
The headstage connector is a 25-pin (16-channel) connector. Information on the pin inputs is provided with the technical specifications.

Base Station Connector - To Base

Use the provided fiber optic pair (white connectors) to connect the To Base port on the preamplifier to the optical input port on the base station.

The duplex fiber optic cable has identical one-piece connectors at each end. There is a V-shaped groove on one side of the connector and a raised rectangle on the other. As shown in the image above, plug the connector into the RZ6 port with the raised rectangle side up. Plug the connector into the preamplifier with the V-shaped groove up.

Medusa PreAmp Connection Diagram

Power

A switch on the back powers up the amplifier. The fiber connector at the right will be illuminated when the amplifier is on.

LEDs

This switch turns the clip warning lights on top of the amplifier on or off.

Power Requirements

The Lithium-ion batteries charge in four hours. Keeping the battery charger connected to the amplifier does not affect the battery life. However, the charger will significantly increase the noise of the system if it is plugged in while an experiment is running. A 6 volt battery charger is included with the amplifier. The charger tip is center negative. If it is necessary to replace the charger make sure that the power supply has the correct polarity.

The Li-ion battery supplied with the system cannot be removed. If battery life longer than 30 hours is required, an external battery pack can be connected to the voltage inputs of the charger. TDT recommends a 6 Volt (minimum) to 9 Volt (maximum) battery, such as lead acid batteries used for motorized wheel chairs. See Tech Note #0256 for more information.

RA16PA/RA4PA Technical Specifications

Includes specifications for the RA4PA, RA16PA, and RA16SD Medusa Preamplifiers.

A/D	RA4PA: 4-channels 16-bit PCM
	RA16PA: 16-channels 16-bit PCM
	RA16SD: 16-channels 16-bit sigma-delta
Sample Rate	6, 12, or 25 kHz
Maximum Voltage In	RA4PA and RA16PA: ±4 mV
	RA16SD: ±5 mV
Frequency Response	3 dB 2.2 Hz - 7.5 kHz
Highpass Filter	2.2 Hz
Anti-Aliasing Filtering	RA4PA and RA16PA: 7.5 kHz (3 dB corner, 1st order, 6 dB per octave)
	RA16SD: 7.5 kHz (3 dB corner, 2nd order, 12 dB per octave)
S/N (typical)	RA4PA and RA16PA: 60 dB
Input Referred Noise	rms 3 uV bandwidth 300 - 3000 Hz
	6 uV bandwidth 30 - 5000 Hz
Group Sample Delay	RA4PA and RA16PA: See below
	RA16SD: 20 Samples
Input Impedance	100 kOhms
Power Requirements	500 mA while charging, 60 mA once charged
Battery	Li-ion Battery 1950 mAh, 20-25 hour runtime
	1000 cycles of charging, not removable by user
Charger	6-9 V DC, >500 mA, center negative
Fiber Optic Cable	5 m standard, maximum cable length 12 m

Sample Delay
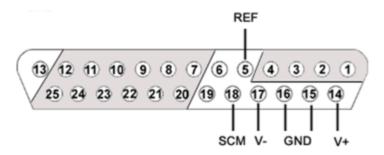
RA4PA and RA16PA sample delay depends on RZ processor sample rates. All units in samples.

RZ rate	Delay
200 kHz	36
100 kHz	18
50 kHz	4
25 kHz	4
12 kHz	4
6 kHz	4

Pinout Diagrams

16- and 4-channel pinouts (all models built after 2002):

Pin	Name	Description		Pin	Name	Description
1	A1	Analog Input Channels		14	V+	Positive Voltage (+1.4 V)
2	A2			15	GND	Ground
3	A3			16	GND	Ground
4	A4			17	V-	Negative Voltage (-1.4 V)
5	Ref	Reference		18	HSD	Headstage Detect
6	DNC	Do Not Connect		19	HSD	
7	A5	Analog Input Channels		20	A6	Analog Input Channels
8	A7			21	A8	
9	A9			22	A10	
10	A11			23	A12	
11	A13			24	A14	
12	A15			25	A16	
13	DNC	Do Not Connect				

RA8GA Adjustable Gain PreAmp

RA8GA Overview

The RA8GA acquires and digitizes multi-channel data from a variety of analog voltage sources such as eye-trackers, amplifiers (including Grass, Axon, and WPI amplifiers), PH meters, and temperature sensors. The RA8GA digitizes up to eight channels at acquisition rates of 6, 12, or 25 kHz. All channels have a variable group gain setting of 10 Volts, 1 Volt, or 100 millivolts. The system has a bandwidth to DC, which allows users to acquire low frequency DC signals. In addition a two-pole low pass filter (12 dB per Octave) is set at 7.5 kHz.

Power and Interface

The device is powered via the System 3 zBus (ZB1PS) and requires an interface to the PC. If the RA8GA is housed in one of several ZB1PS chassis in your system, ensure that it is connected in the interface loop according to the installation instructions: Gigabit, Optibit, or USB Interface.

RA8GA Features

Max Input Lights

The Active light flashes once a second when the preamplifier is not connected to a base station. It glows steady when it is properly connected.

The 10 V, 1 V, and 0.1 V lights indicate the current acceptable voltage range. If the signal input reaches -6 dB from the maximum input for the selected range, a clip warning light on the base station will be lit. On RX5 or RX7 processors the LED located next to the fiber optic input port serves as the clip warning light.

Range Select Button
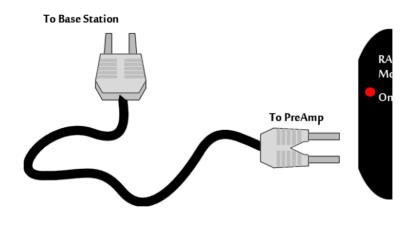
All channels use a group adjustable gain control i.e. all channels are either ±1 Volt, 10 Volts, or 0.1 Volt. A Range Selection button adjusts the gain setting among the following voltages: 0.1X gain = ±10 V, 10X gain = ±100 mV, 1.0X gain = ±1 V. Press the button to scroll through the available voltage ranges. Max input lights located to the left of the button, indicate the current selection.

To Base

The **To Base** connector is used to connect the device to the base station (such as RZ5, RZ2) using a fiber optic cable pair. One end of the fiber optic cable connects to the device using this connection pair and the other end connects to the input on the base station.

Connecting the Base Station to the Preamplifiers

To make the connection, plug one end of the cable into one of the fiber optic connectors as shown below and connect the other end of the cable to the fiber optic port on the base station. Both ends of the cable are the same but the two sides of the connector are different. See the diagram below to determine the correct way to make the connection for each device.

Medusa PreAmp Connection Diagram

Analog Input

Each Preamp comes with eight channels of analog input. Each analog input uses 16-bit PCM parts for high quality signal conversion. See the Technical Specifications for a Pinout Diagram for the 25-pin Analog Input connector.

A PP16 patch panel can be used to simplify connection to the preamplifier's analog inputs. A ribbon cable connects the RA8GA Analog I/O connector to the RA16 connector on the back of the PP16 allowing acquisition of signals via the first eight BNC connectors on the front of the PP16.

RA8GA Gain Settings

Gain	Voltage	DSP Scale Factor
0.1	±10 V	1700
1.0	±1 V	170
10.0	±0.1 V	17

Accounting for Gain Settings on the DSP

The output from a RA8GA generates a floating-point value of between ±6 mV. A scale factor must be used in order for the acquired signal to display the correct voltage. The scale factor for each gain setting is listed in the table above. The Synapse RAn Hal accounts for this for you. If using RPvdsEx to read the data, the scale factor should be added after the channel input (ADCIn).
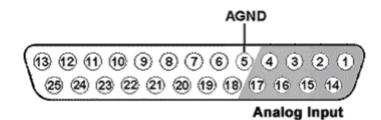
The following example shows an RPvdsEx circuit segment that adds the scale factor for a ±1 V input range:

RA8GA Technical Specifications

A/D	8-channels 16-bit PCM
Maximum Voltage In	Variable gain settings allow ±10 V, ±1 V or ±100 mV
Frequency Response	DC - 7.5 kHz (2nd order 12 dB per octave)
S/N (typical)	70 dB (±1 V @ 1 kHz) at ±1 V Gain Setting
THD (typical)	0.01%
A/D Sample Rate	6, 12, or 25 kHz
Cross Talk	<-70 dB (DC - Nyquist)
Input Impedance	10 kOhm
Offset	<5 mV, ±10 V range
	<3 mV, ±1 V or ±100 mV range

Analog Input Pinout Diagram

Pin	Name	Description		Pin	Name	Description
1	A1	Analog Input Channels		14	A2	Analog Input Channels
2	A3			15	A4	
3	A5			16	A6	
4	A7			17	A8	
5	GND	Ground		18	NA	Not Used
6	NA	Not Used		19	NA	
7	NA			20	NA	
8	NA			21	NA	
9	NA			22	NA	
10	NA			23	NA	
11	NA			24	NA	
12	NA			25	NA	
13	NA					

6. Test Signal Generators
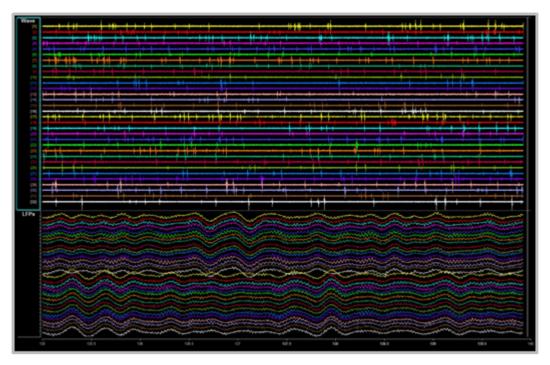
FB128 Neural Simulator

Overview

The FB128 Neural Simulator is a tool for testing experimental paradigms during the design phase and debugging problems when they arise. The compact, battery operated device simulates neurological waveforms or sine waves that can be output directly to a ZIF-Clip headstage. The FB128-OMN version includes connections for a 16 channel and 32 channel Omnetics headstage as well.

Neurological simulations consist of an LFP component and spike components. Eight unique spike waveform shapes are used depending on the mode. Up to 128 channels can be output (up to 96 unique).

32 channels from FB128 - filtered for Spike (top) and LFP (bottom) waveforms

The simulator can operate in eight different modes and includes an inhibitory/excitatory option for even more output variations. The simulation modes are listed on the face of the module and LEDs indicate which is active. Operational buttons or switches, a TTL input, and a charger input are positioned on one end of the module and output connectors for headstage connection are positioned on the other.
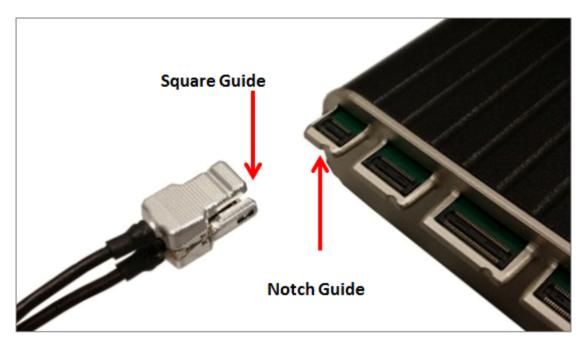
Hardware Set-up

When using the FB128 to test your protocol or recording hardware, set-up the recording part of your system as you would during your experiment with the FB128 in place of the subject and electrodes.

ZIF Connectors

Four output connectors are positioned side-by-side at one end of the simulator. One for each size of ZIF-Clip headstages, including one connector for the ZC16/ZC32/ZD32 and one each for the ZC64/ZD64, ZC96/ZD96, and ZC128/ZD128.

Connect the headstage to the appropriate connector just as you would connect it to an electrode or adapter. First, line up the square guide on the headstage with the notch on the probe connector. Hold it firmly open at the wire end of the connector until it is fully in position then clamp it firmly in place.

ZC32 and FB128

> ⚠ **Caution**
>
> Failure to hold the clip open until it is fully in position can cause damage to the headstage connectors.

Omnetics Connectors

The FB128-OMN has 16- and 32-channel Omnetics connectors for LP16CH-Z and LP32CH-Z style headstages.
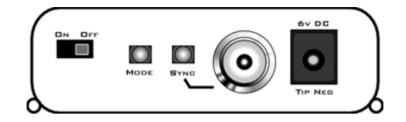
Connect the headstage to the appropriate connector just as you would connect it to an electrode or adapter. Line up the label on the Omnetics connector on the headstage with the arrow on the probe connector.

LP16CH-Z and FB128-OMN

Simulation Modes

The Mode button, is positioned on the end opposite the output connectors.
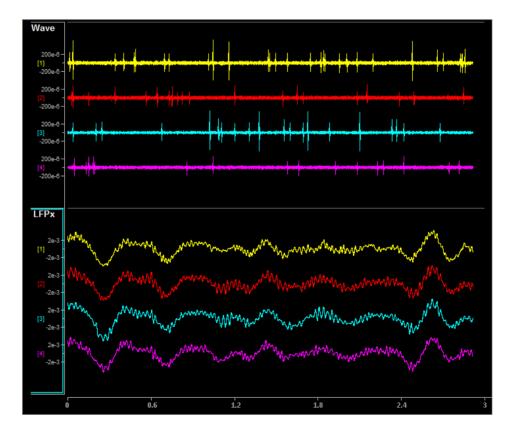
To cycle through the operating modes:

  • Briefly press the **Mode** button. The active mode is indicated by a lit LED on the face of the module. If you press too long and the LED is blinking, you are in Channel Mapping Mode. See Channel Mapping Mode.

NORMAL

Neurological waveforms, including spike waveforms and LFP.
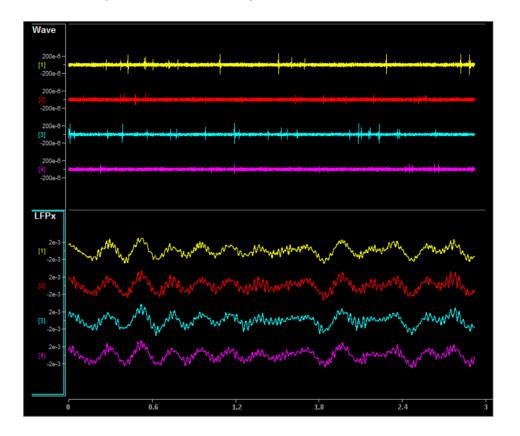
Pictured waveforms were generated by the FB128 and plotted in Synapse with the following settings:

Wave Filter Settings: High Pass: 300 Hz, Low Pass: 5000 Hz

LFPx Filter Settings: High Pass: 0 Hz, Low Pass: 300 Hz

HASH

NORMAL mode but with spikes scaled down by a factor of 2.
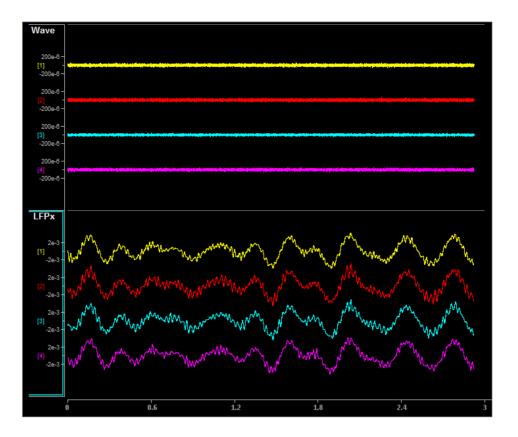
Pictured waveforms were generated by the FB128 and plotted in Synapse with the following settings:

Wave Filter Settings: High Pass: 300 Hz, Low Pass: 5000 Hz

LFPx Filter Settings: High Pass: 0 Hz, Low Pass: 300 Hz

LFP ONLY

NORMAL with spikes scaled to zero.
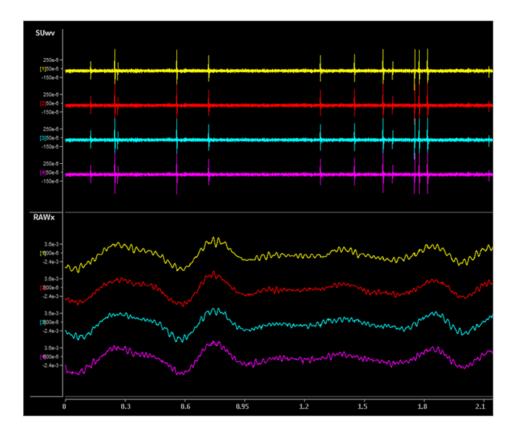
Pictured waveforms were generated by the FB128 and plotted in Synapse with the following settings:

Wave Filter Settings: High Pass: 300 Hz, Low Pass: 5000 Hz

LFPx Filter Settings: High Pass: 0 Hz, Low Pass: 300 Hz

TETRODE

Neurological LFP waveforms with spikes--where spikes on each group of four channels fire synchronously. Channels 1-4 fire together, channels 5-8 fire together, and so forth.

Shown: Tetrode + Excitatory Mode

Pictured waveforms were generated by the FB128 and plotted in Synapse with the following settings:

SUwv Filter Settings: High Pass: 300 Hz, Low Pass: 5000 Hz

RAWx Filter Settings: Unfiltered
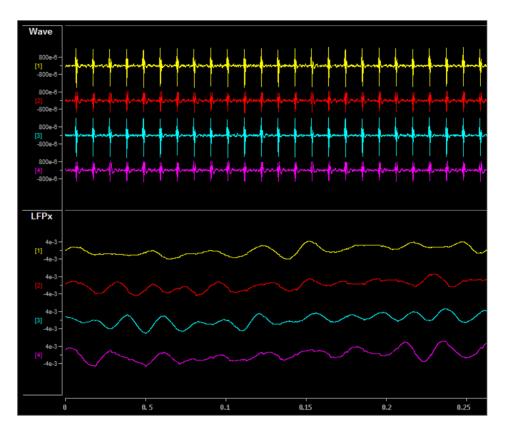
> 🔥 **Important**
>
> To better view Tetrode mode (as pictured above) the channels must be re-mapped.
>
> For Synapse users, use the Channel Mapper gizmo. Choose TDT > Electrode > then FBnTET to match your channel count.
>
> For RPvdsEx / OpenEx users, the map for each ZIF-Clip headstage is included in FB128Tetrode.rcx, which is bundled in the RPvdsEx zipped examples on the TDT Website at: https://www.tdt.com/files/examples/RPvdsExExamples.zip.

SYNC 100 Hz

Neurological LFP waveforms with spikes on all channels firing synchronously at 100 Hz fixed rate. The spikes in this mode are always the same shape.

Pictured waveforms were generated by the FB128 and plotted in Synapse with the following settings:

Wave Filter Settings: High Pass: 300 Hz, Low Pass: 5000 Hz

LFPx Filter Settings: High Pass: 0 Hz, Low Pass: 300 Hz

TONE 30 Hz

30 Hz sine wave at approximately ±700 uV on all channels.

TONE 1000 Hz

1000 Hz sine wave at approximately ±70 uV on all channels (actual frequency is ~763 Hz).

TONE REF

100 Hz sine wave at approximately ±700 uV on Reference channel only. All other channels output 0. Because the reference is subtracted from all channels, the sine wave should be visible on all channels.
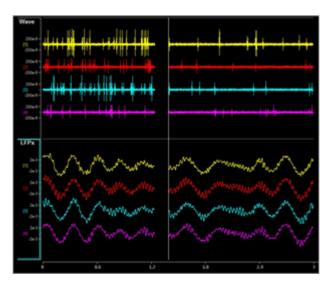
> ✏️ **Note**
>
> Reference lines are connected to Ground (0 V) for all modes except TONE REF.

Inhibitory/Excitatory Mode

An inhibitory/excitatory mode can be used in conjunction with all spike modes (NORMAL, HASH, TETRODE, and SYNC 100 Hz). When enabled, the base neurological waveforms (LFP) remain the same but some spike shapes are inhibited (fire less often) while others are excited (fire more often).

The Inhibitory/Excitatory mode can be activated by holding down the Sync button or it can be controlled programmatically by sending a TTL high to the Sync BNC connector. When using the Sync input, the mode change can also be timestamped in Synapse, which is helpful when testing event-related spike changes and verifying that histogram plots are working correctly.

Normal + Excitatory Mode vs Normal Mode

Pictured waveforms were generated by the FB128 and plotted in Synapse with the following settings:

Wave Filter Settings: High Pass: 300 Hz, Low Pass: 5000 Hz

LFPx Filter Settings: High Pass: 0 Hz, Low Pass: 300 Hz

Channel Mapping Mode

Starting with serial number 2000, the FB128 includes a diagnostic mode that presents a unique waveform on every channel. This is useful for mapping channels or for detecting shorts on the headstage.
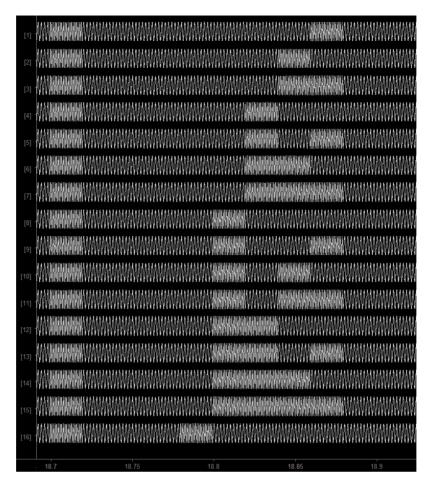
Press and hold the MODE button on the FB128 until the LED starts flashing, which indicates the FB128 is in channel mapping mode. Each channel plays a frequency encoded waveform that creates a unique binary pattern that can be mapped to channel number. See the image below.

Briefly press the MODE button again to cycle through the available channel count options until it matches the headstage you are testing.

Flashing LED	Channel Map Mode
NORMAL	ZIF 16-32 Channels
HASH	ZIF 64 Channels
LFP ONLY	ZIF 96 Channels
TETRODE	Lower 64 Channels of ZIF 128 Channel connector
SYNC 100Hz	Upper 64 Channels of ZIF 128 Channel connector
TONE 30Hz	Omnetics 16 Channels*
TONE 1000Hz	Omnetics 32 Channels*

* If using a ZIF headstage with a ZCA-OMN adapter, use the Mapper gizmo in Synapse and select the appropriate Omnetics adapter from the "TDT" category of maps.

Power cycle the FB128 to exit Channel Mapping Mode.

FB128 Channel Mapping Mode Output

Power

The FB128 is powered by a 1950 mAh battery with a 10-hr life. A 6 Volt charger (tip negative) is supplied for charging.

FB128 Technical Specifications

Output	±10 mV
Battery	1950 mAh
Battery life	10 hr runtime, time to charge 2.5 hr
Charger	6 V (tip negative)

7. Subject Interface

SIM Subject Interface Module

SIM Device Overview

The Subject Interface Module (SIM) is a multi-modal stimulator and neurodigitizer suitable for recording a broad range of biological potentials. Multiple banks of high-fidelity stimulation can be combined with the same high-fidelity analog and digital input boards used in the PZ5 amplifier.

The SIM supports up to eight banks that can be configured with stimulation, analog acquisition, or digital headstage acquisition boards.

It connects to a DSP-M or optical quad DSP card in any RZ processor and is controlled by TDT's Synapse software.

The IZV stimulator boards converts digital waveforms into analog waveforms as part of a computer-controlled neural microstimulator system that delivers user-defined stimuli through up to 128 electrodes. The IZV can output either a voltage-controlled waveform or a current-controlled waveform and provides feedback of the actual voltages delivered to the electrodes.

Each stimulation board has four 'voices' that can supply up to 5 mA per channel with 10 nA resolution and ±15 V compliance. Voices can be programmatically connected to the same stimulation channel to increase output current to up to 20 mA on a single channel per board. Stimulation boards can be harnessed together to increase compliance voltage beyond the ±15 V range for high voltage, single-channel stimulation.

The SIM analog boards can record high and low impedance input signals simultaneously. Analog input boards oversample the signal with very fast instrumentation grade converters. TDT's custom hybrid A/D circuit yields 28 bits of resolution and unparalleled dynamic range. Optional DC coupling offers zero phase distortion across the signal bandwidth. Sampling rate and down-sampling filters can be optimized on each logical amplifier for the intended input type to optimize signal fidelity. The ±500 mV input range is large enough to accept any biological potential and most stimulus artifacts without saturating.

The analog input and stimulator outputs are organized into 16-channel boards. Each bank is electrically isolated, meaning the ground and reference channels are not inherently shared

between banks. Multiple banks can be grouped into a single logical amplifier/stimulator that shares the same settings and ground/reference among each bank in the logical amplifier/stimulator.

For analog recording, there are several different referencing modes; each logical amplifier can use the ground as a reference, use a shared reference, use a unique reference on each bank or implement full per-channel differential referencing.

The SIM may also include digital input boards for inputting signals from an Intan RHD2000 amplifier board and SPI Interface Cables, with up to 128 channels per digital board. Each digital board can be its own logical amplifier, isolated from the other boards, or be grouped with other digital boards in a larger logical amplifier configuration.

A touchscreen interface provides system information and remote arming of the stimulator boards.

SIM devices are available in 2, 4, or 8 bank models. The SIM can support a total of up to 128 analog channels, up to 256 digital channels, up to 128 stimulation channels (32 simultaneously), or up to 256 mixed channel types. The total number of channels is generally reduced to 128 at higher sampling rates, up to 50 kHz. See See Sampling Rate and Digital Input Channels for more information.

System Hardware

A typical system consists of a Subject Interface and an RZ processor equipped with a specialized DSP (RZDSP-M) and additional fiber optic connector on the back panel.

The Subject Interface connects to the fiber optic port labeled 'To SI' on the back of an RZ base station configured with a DSP-M card or optical QZDSPO quad card. Configuration information is sent from the RZ to the SI across the fiber optic connection.
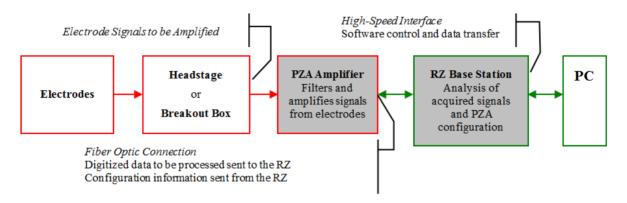
Recording (PZA and PZD)

The Subject Interface accepts inputs from a variety of electrode/headstage combinations via the back-panel. Each analog board (PZA) has a mini-DB26 connector that accepts 16 recording channels (or 8 differential channels) along with ground and reference. Digital boards (PZD) have a 12-pin Omnetics connector for Intan headstages and can accept up to 128 digital channels each. The Subject Interface can return at most 256 recording channels to the RZ base station.

Analog signals are digitized and transmitted to the RZ base station for further processing via a single fiber optic connection.

A standard recording configuration includes electrodes appropriate to the input signals, a breakout box or one or more Z-Series headstages (such as ZC32), a Subject Interface and an RZ base station.

The diagram below illustrates this flow of data and control information through the analog system.
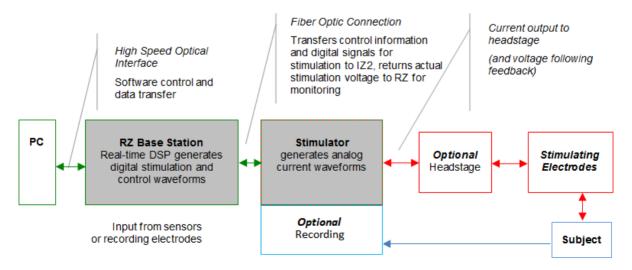

PZA Data and Control Flow Diagram

Stimulation (IZV)

The Subject Interface has 16 channels per bank (mini-DB26 connector) and ground.

The diagram below illustrates this flow of data and control information through the stimulator system.
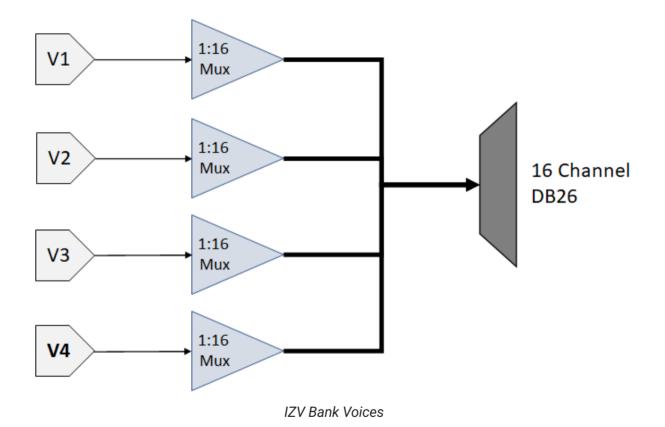
IZV Data and Control Flow Diagram

In current controlled mode, the driving voltage is adjusted based on the electrode impedance. Analog-to-digital (A/D) converters read the output voltage on the stimulating channels and send that information back to the RZ for monitoring.
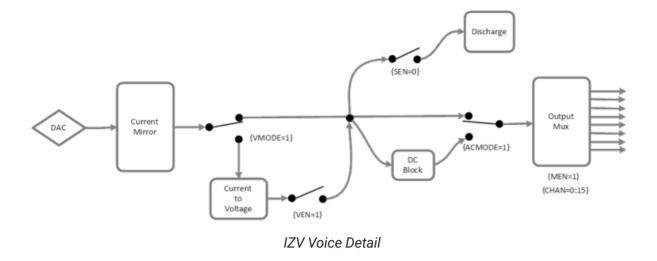
The Stimulator System

The IZV stimulator can deliver arbitrary waveforms of up to 20 kHz bandwidth. Each channel uses PCM D/As to ensure minimal sample delays.
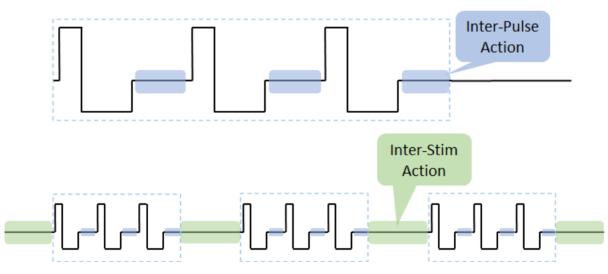
Each IZV bank has four unique hardware "voices" that can be sent to any of its 16 channels, so four independent channels can stimulate on any given sample of the real-time clock on each bank. You can assign multiple voices to the same channel to increase maximum current for one or two channels at a time.

IZV Bank Voices

Each voice starts with a low voltage waveforms from the D/A converters. This is converted to constant voltage or constant current waveforms. An optional DC Block (RC circuit) removes any constant DC current from the output. You can also switch passive discharge shunts to remove excess voltage in between stim pulses.

IZV Voice Detail

The signal path switches can be flipped on each sample of the real-time processor controlling the IZV. The Electrical Stim Driver gizmo in Synapse is typically used to send the control signals to the IZV gizmo. The Electrical Stim Driver controls what happens between pulses in a burst (Inter-Pulse Action) and between bursts (Inter-Stim Action). The four options are described below.
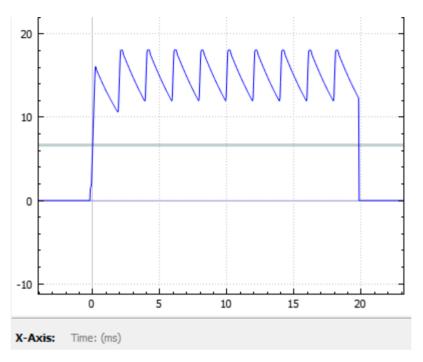
IZV Inter-Stim and Inter-Pulse time periods

Option	Description
Channel Hold	Electrode remains connected to voice output (zero current / voltage)
Channel Release	Electrode is disconnected from voice output (open circuit)
Discharge	Electrode is switched to 10K discharge impedance
Ground	Electrode is switched to low impedance ground (voltage mode 0 V)
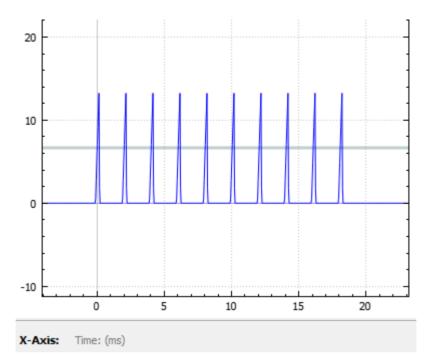
Channel Release minimizes any potential charge collection in between bursts, but switching it in between short pulses is not recommended. Therefore the default configuration is Channel Hold for the Inter-Pulse Action and Channel Release for the Inter-Stim Action.

One common use case is DBS where two electrodes use a 'local ground'; essentially the second channel acts as the return path. You might see charge build up on the electrodes and not get the desired waveform. The output voltage might look something like this:

Inter-Stim Action set to Channel Hold

Use *Discharge* in between pulses and *Channel Release* (open circuit) in between bursts to get rid of the excess charge on the electrode. The output voltage for that same stimulation pattern then looks like this:

Inter-Stim Action set to Discharge

Safety

When Safety Mode is enabled in Synapse, the SIM must be armed by the user before any current can flow. The hardware ensures that maximum output current is not exceeded. The SIM is battery powered and thus isolated from any mains power.

Physical Amplifier
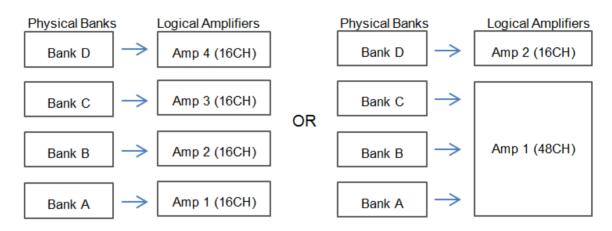
All SIM analog input channels are organized into groups of 16 channel banks, with each bank corresponding to a rear panel headstage connector (labeled alphabetically from bottom to top) and a front panel LED display.

Digital input channels are associated with a digital board corresponding to a rear panel digital input connector (labeled from bottom to top following, alphabetically, any analog input connectors). Each digital board is a bank that can comprise 16, 32, 64, 96, or 128 channels, depending on the connected Intan amplifier board(s).

Each bank is electrically isolated and can be independently configured or grouped with other banks and defined as a logical amplifier. Analog and digital boards cannot be combined.

Logical Amplifiers/Stimulators

Though each bank has its own ground and reference, a single ground and reference can also be defined and shared across all banks of the logical amplifier. See Analog Recording Reference Modes for analog input banks.

Two Possible Logical Amplifier Configurations for an SI4 64-Channel Subject Interface (all analog input)

Digital boards can be configured individually or grouped to share a single ground and use common filter settings and sampling rate.

> ✏️ **Note**
>
> Channel numbering on digital input banks can be non-sequential when sampling at 50 kHz. See Sampling Rate and Digital Input Channels.

Two Possible Logical Amplifier Configurations for an SI4 with two analog cards and two digital input cards

Logical amplifier configurations are defined in Synapse software. In the same manner, IZV stimulator banks can also be grouped into logical stimulators and this is controlled in Synapse.

Analog Recording Reference Modes

The SIM PZA boards support four referencing modes for each logical amplifier: Local, Shared, None and Differential. See Pinout Diagrams.

Reference Mode	Description
Local	Each bank of channels in a logical amplifier uses its own reference input (pin 5) as the reference for that bank
Shared	The reference (pin 5) of the first bank of the logical amplifier acts as a reference for all banks in the logical amplifier
None	The references for all banks of a logical amplifier are tied to the Ground (pins 13, 15, and 16).
Differential	The inputs in each bank of the logical amplifier are paired; odd channels serve as recording (+) channels and each even channel is used as an individual reference (-) channel for the preceding odd channel. No connections should be made to pin 5.

Sampling Rate and Onboard Filters

The sampling rate of each logical amplifier is adjustable (max 50 kHz, min 750 Hz) and should be set to a value appropriate for the signal of interest. Reducing the sampling rate when acquiring low-frequency analog signals yields higher bit resolution and improved signal-to-noise. Use the Base Type presets as a guide for determining what sampling rate to use for each logical amplifier.

The onboard down-sampling filters are used to further reduce the noise from frequencies above the band of interest and can be set to a percentage of the sampling rate (max 45%, min 10%). Adjusting the sampling rate and filter for each logical amplifier to match your desired signal gives you the best possible signal fidelity.

Sampling Rate and Digital Input Channels

When a logical amplifier contains digital inputs, the sampling rate should be set to a value appropriate for the connected Intan amplifier board. Sampling rates at or above 50 kHz reduce the number of channels available on the amplifier boards.

At 50 kHz the 32 channel amplifier board is limited to 20 channels and the 64 and 128 channel boards are limited to 40 channels, at the time of this writing. The maximum aggregate number of channels is 256 channels at up to 25 kHz, or 128 channels at up to 50 kHz.

It is also important to note that, while the Intan board channel numbers are normally sequential and offset by the number of analog inputs in the amplifier, sampling at or above 50 kHz may also affect channel numbering.

At 50 kHz the native channel numbers per board are 1-20 and 33-52. These channel numbers are then offset by the number of channels existing in the lower banks of the SIM. Also see Input Connectors.

SIM Software Control

All SIM configuration and control of data acquisition is managed through Synapse. The PZA and PZD objects configure the analog and digital headstage recording inputs, and the IZV object controls the stimulator outputs. Please see the Synapse Manual for more information.

Recording 128 Channels at 50 kHz

Due to the SIM's high bit resolution and recording capabilities, analog input data should always be stored as 32-bit floating point. However, when storing 128 channels at 50 kHz sampling rate, you must use the Short (16 bits) format due to bandwidth constraints. This means the data will be scaled and converted into an integer before storage, which narrows the dynamic range of the acquired signals. In this case, all DC offsets must be removed before the data is stored. You can either filter out the DC offset with a Neural Stream Processor gizmo in Synapse or use AC coupling on the logical amplifier if you are storing the raw signal direct from the SIM.
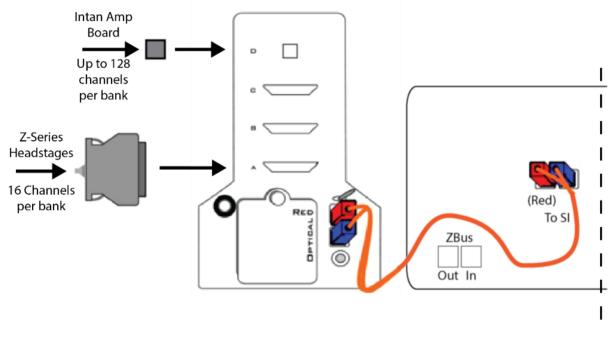
Hardware Setup

TDT recommends fully charging the SIM before use. The SIM battery charger connects to the round female connector located on the back panel.

> 🔥 **Important**
>
> To avoid introducing EMF noise, DO NOT connect the charger to the SIM while collecting data.

A 5-meter paired fiber optic cable is included to connect the Subject Interface to the base station. The connectors are color coded and keyed to ensure proper connections.

The diagram below illustrates the connections necessary for PZA or PZD operation.

System Connection Diagram for PZA or PZD with RZ2

Connecting Headstages and Electrodes

Analog signals are input via multiple mini-DB26 connectors on the SIM back panel. For high impedance recordings, one or more Z-Series headstages can be connected to the input connectors on the PZA back panel. For low impedance recordings, an S-BOX input splitter or LI-CONN low-impedance connector can be used. Alternately, custom connectors and a breakout box with a male mini-DB26 connector can be used. If using custom connectors, see Pinout Diagrams.

Digital signals are input via Intan connectors on the SIM back panel.

Powering ON/OFF

To turn the Subject Interface on, move the toggle switch located on the back panel of the SIM to the ON position.

Using the SIM Front Panel Display
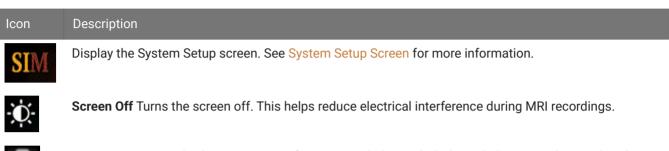
The front display is a touchscreen interface for monitoring the status of SIM banks as well as arming IZV stimulators. Banks are color coded by card type. Blue is a PZA analog recording card, Green is a PZD digital recording card, and Purple is an IZV Stimulator card. Each card box maps, in order, to the right- hand buttons on the front face of the SIM.

Main Configuration Screen

The Main Configuration screen provides a touchscreen interface for monitoring SIM banks. It also provides access to the SIM device settings, such as the screen brightness, as well as tools for viewing system information, such as battery status, and updating the device software.

The main configuration screen includes the following:

Icon	Description
	Display the System Setup screen. See System Setup Screen for more information.
	Screen Off Turns the screen off. This helps reduce electrical interference during MRI recordings.
	Battery Status Display battery status information. A lightning bolt through the icon indicates that the SIM is charging.

When the SIM is configured in Synapse, the Phys<->Logic button switches between displaying individual bank information and organizing them by logical amplifier/stimulator.

Press on the bank (or press the corresponding bank button on the right side of the SIM) to show more information about that bank and how it is configured. For amplifier cards, this includes how the reference is configured. For stimulator cards, this includes the maximum compliance voltage and also an interface to Arm the device, if Remote Arming is enabled in Synapse.

Battery Status

 Press the Battery Status icon to display battery information:
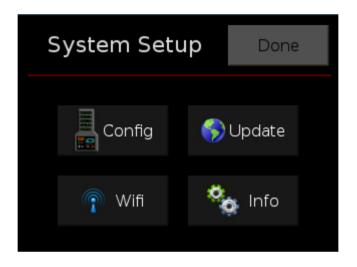
Setting	Description
Charging	Indicates if the charger is plugged into the SIM (Yes/No)
Voltage	Current voltage level of the battery pack
Level	% battery life remaining
Endurance	Estimated time of battery life remaining

> ✏️ **Note**
>
> If the SIM is left on charger for more than 3 hours after the battery is 100% full, the internal charging circuit will turn off (and the lightning bolt icon will disappear) until either the battery drops to 80% or you disconnect / reconnect the charger.

System Setup Screen

The System Setup screen is displayed by touching the SIM logo on the top-left of the Main Configuration screen.

Settings include:

Setting	Description
Config	Open the System Configure screen
Update	Update onboard software over the Internet
Wifi	Connect to a wireless network for system updates
Info	Open the device System Info screen to view version numbers for various hardware, software and firmware components

System Configure Screen

The System Configure screen is displayed by touching Config on the System Setup screen.

Settings include:

Setting	Description
Brightness	Select High, Medium, or Low to set touchscreen brightness
Wireless	Enable/disable the wireless connection

System Info Screen

The System Info screen is displayed by touching Info on the System Setup screen. Use the scroll bar to see all of the version numbers.

Information displayed includes:

Setting	Description
Device	SIM model number (e.g. SIM10-4)
Software version	Currently installed version of onboard software
Firmware version	Currently installed version of firmware
Hardware version	Version of hardware
Battery	Date and capacity of last battery calibration (in mAhr)

Advanced Button

Password protected settings for TDT use only at this time.

System Update Screen

The system updater connects to a TDT server to download the latest SIM software and automatically update the device. This requires an active and configured Internet connection. The SIM provides two options for network connection: WiFi and Ethernet. The WiFi connection can be configured on the Wireless Networks screen, see below. The Ethernet port is located on the back panel.

The System Update screen is displayed by touching Update on the System Setup screen.

> 🔥 **Important**
>
> The update process can take up to an hour to complete. Make sure the SIM battery charger is plugged in during the update.

Wireless Networks Screen

The Wireless Networks screen is displayed by touching WiFi on the System Setup screen. Available networks that have been used or previously configured are displayed in the main area of the screen. Selecting a network from the list displays network information and enables the user to connect to the network, forget the network, or cancel configuration of the network.

The wireless icon shows if the wireless feature is enabled or disabled. A red 'x' will appear through the icon if wireless is disabled. Enable/disable wireless through the System Configure Screen.

Setting	Description
Show All	Shows all networks, including networks that have not been previously used or configured
IP Addr	Displays current IP Address when connected to a network

SIM Features

Status LED

The status LED above the touchscreen indicates the Subject Interface connection and charging status.

Green LED	Device Status
Solid	Connected
Slow flash (~1 every three seconds)	Connected and charging
Rapid flash (~1 per second)	Not connected

Clip Warnings and Activity Display

The front panel LEDs can be used to indicate spike activity and/or clip warning for analog input channels. They can be configured under software control using the PZA, PZD, and IZV gizmos in Synapse.

LED Indicators (stimulator)

The stim LEDs are located on the front plate of the SIM and indicate the voltage at the corresponding electrode site. The stim LED will turn green when a channel has greater than ±150 mV at the output and will turn red when a channel output is beyond ±10 V.

If Safety Mode is enabled, four RED leds indicate a fault state. Four green LEDs indicate it is ready to be armed.

LED Indicators (analog)

LEDs for each channel are lit green to indicate activity or red to indicate a clip warning. The top row indicates the odd channels (left to right). The bottom row indicates the even channels.

Green: Activity

Red: Clip Warning

Clip Warning

Analog clipping occurs when the input signal is too large. When the input to a channel is within 3 dB of the SIM's maximum voltage input range the LED for the corresponding channel is lit red to indicate that clipping may occur.

Activity

When configured to indicate activity, LEDs are lit green whenever a unit (spike) occurs on the corresponding channel. The sensitivity threshold for the green LED is ~200 uV.

LED Indicators (digital)

LEDs that represent digital input boards, indicate the number of input channels with each LED indicating 16 channels. For example, four LEDs indicates 64 input channels have been detected on that connection.

External Ground

The external ground is optional and should only be used in cases where the subject occasionally contacts a metal surface that isn't tied to the animal ground, such as a lever press. When contact is made, a ground loop is formed that temporarily adds extra noise to the system. Grounding this metal surface directly to the TDT hardware removes this ground loop at the cost of raising the overall noise floor a small amount.

A banana jack located on the back of the SIM provides connection to common ground. The PZA, PZD, and IZV gizmos in Synapse allow you to float that ground connection on individual sub-amplifiers / sub-stimulators.

An external grounding cable kit is included with the SIM. Each kit includes: one male banana plug to male banana plug pass through and one male banana plug to alligator clip pass through. These cables also include ferrite beads to remove any potential RF noise that might travel through the cable. For best results position the ferrite bead close to the source of the RF noise.

Battery Overview

The SIM features a 32 Amp-hour Lithium ion battery pack.

Charging the Batteries

Operate the SIM with the charging cable disconnected. An external battery pack (PZ-BAT) or external charger and extra battery (PZ5-BAT) is available for longer battery life and extended recording sessions. See PZ-BAT and PZ5-BAT.

SIM Technical Specifications

Stimulator Output

Stimulator Output	Up to 8 cards
Stim Output Channels	16 per card
Stim Output Voices	4 per card
Stim Compliance Voltage	Up to ±15 V* (user selectable from 15, 10, 7, 5, 3, 1.5, 1.0, 0.5 V) ±5 mA per voice, up to 3 kOhm load+
Stim Output Resolution	Voltage Mode: 100 uV Current Mode: 10 nA
DC Offset Current	Active channel: <100 nA Open channel: <1 nA
Stim Sample Delay	7 samples
Monitor Delay	3 samples

PZA Analog Inputs

Analog A/D Input	Up to 8 cards (128 channels), hybrid
Maximum Voltage In	±500 mV
Gain	2x
A/D Sample Rate	Up to 48828.125 Hz (adjustable in steps of approximately 750, 1500, 3000, 6000, 12000, 25000, 50000 Hz)^
Frequency Response	DC coupled: 0 Hz - 0.45*Fs AC coupled: 0.4 Hz - 0.45*Fs
S/N (typical)	104 dB, single unit, Fs = 25 kHz, 300-7000 Hz 116 dB, differential, Fs = 750 Hz, 0.4-300 Hz
DC offset	<±10 uV
Input Referred Noise	Single Ended: 3.0 uVrms, 300-7000 Hz, 25 kHz Differential: 0.75 uVrms, 0.4-300 Hz, 750 Hz
Distortion (typical)	<1%
Input Impedance	AC coupled: 100 kOhm DC coupled: 20 MOhm

^Note: If recording at ~50 kHz on 128 channels, see SIM Software Control for more information.

Analog Input Sample Delay

Depends on SIM and RZ processor sample rates. All units in samples.

SIM rate	RZ @ 25 kHz	RZ @ 12 kHz
25 kHz	22	N/A
12 kHz	40	23
6 kHz	76	42
3 kHz	141	79
1.5 kHz	270	152
750 Hz	543	295

General

Battery Capacity	32 Ahr
Battery	8-10 hours to charge to 95% capacity, 14 hours to fully charge. Battery life runtime: 2 active boards ~50 hrs 4 active boards ~35 hrs 6 active boards ~27 hrs 8 active boards ~22 hrs
Charger	External 12 V, 2.5 A power supply, center negative
Indicator LEDs	Up to 128 status/clip warning/digital input channel count
Fiber Optic Cable	5 meters standard, cable lengths up to 20 meters.
Ethernet Port	100 Mbps

* Note: Higher compliance voltages can be attained by wiring stimulus banks together

+ Note: Higher current outputs can be attained by targeting the same channel with multiple voices

PZD Digital Inputs

RHD2000 series amplifier boards and SPI interface cables are used in TDT's ZD and OD Intan-based digitizing headstages. They are available from Intan Technologies.

> 🔥 **Important**
>
> The specifications below are dependent on the amplifier board. See Intan RHD2000 series website for latest, full performance specifications.

Digital Headstage Input	Up to 8 cards (256 channels), 1 input per card
Sampling Rate	Up to 25 kHz
Frequency Response	0.1 Hz - 10 kHz
Input Range	±5 mV with ZD, OD, and other Intan-based digitizing headstages
Allowable DC Offset	±0.4 V
Sample Delay	5 samples
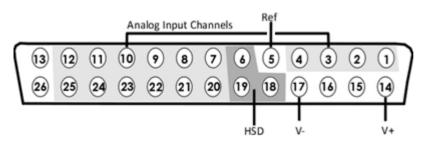
Input Connectors

The SIM Subject Interface has up to eight 26-pin headstage connectors (analog) or up to four 12-pin Omnetics nano connectors (digital) on the back of the unit. The connectors are labeled alphabetically from bottom to top. Each connector carries signal for one bank of channels with ground and reference. The corresponding channel numbers depend on 1) the reference mode configurations or number of channels in a connected digital amplifier board and 2) the position of the bank in a logical amplifier.

For simplicity sake, the diagrams below assume channels for that connector begin with channel 1. For example, A1 - A16 represent the 16 channels coming from the connected headstage. The user must increment the channel numbers by 16 (or 8 if in Differential mode) according to the mode and position of the connector. So, for the connector labeled 'A', A1 is channel 1 while on the connector labeled 'B', A1 may be channel 17.

Pinout Diagrams

Local, None or Shared Reference Mode

Pin	Name	Description		Pin	Name	Description
1	A1	Analog Input Channels		14	V+	Positive Voltage (+2.5 V)
2	A2			15	GND	Ground
3	A3			16	GND	Ground
4	A4			17	V-	Negative Voltage (-2.5 V)
5*	Ref*	Reference*		18	HSD	Headstage Detect
6	HSD	Headstage Detect		19	HSD	
7	A5	Analog Input Channels		20	A6	Analog Input Channels
8	A7			21	A8	
9	A9			22	A10	
10	A11			23	A12	
11	A13			24	A14	
12	A15			25	A16	
13	^	See notes below		26	NA	Not Used

> ✏️ **^Note**
>
> In Local reference mode, Pin 13 is AltRef. Otherwise, Pin 13 is Ground.

* In Shared reference mode, only Pin 5 of the first bank of the logical amplifier is connected. It is shared internally among the other banks of the logical amplifier.

* In None reference mode, Pin 5 is not connected.

Differential Reference Mode

> ✏️ **Note**
>
> There are 8 (+) channels and 8 (-) channels per DB26 connector. Subsequent banks are indexed by an additional 8 channels.

Pin	Name	Description	Pin	Name	Description
1	A1(+)	Analog Input Channel	14	V+	Positive Voltage (+2.5 V)
2	A1(-)	Differential Analog Input Channel	15	GND	Ground
3	A2(+)	Analog Input Channel	16	GND	
4	A2(-)	Differential Analog Input Channel	17	V-	Negative Voltage (-2.5 V)
5	NA	Not Used	18	HSD	Headstage Detect
6	HSD	Headstage Detect	19	HSD	
7	A3(+)	Analog Input Channels	20	A3(-)	Differential Input Channels
8	A4(+)		21	A4(-)	
9	A5(+)		22	A5(-)	
10	A6(+)		23	A6(-)	
11	A7(+)		24	A7(-)	
12	A8(+)		25	A8(-)	
13	GND	Ground	26	NA	Not Used

> ✏️ **Note**
>
> See Tech Note 0896 before attempting to make any custom connections.

Digital Connectors

The digital input connector is a self-aligning 12-pin Omnetics PZN-12 polarized nano connector that mates directly to an Intan RHD2000 SPI interface cable.

Stimulator Connectors

Pin	Name	Description		Pin	Name	Description
1	A1	Analog Output Channels		14	Digital Data	
2	A2			15	GND	Ground
3	A3			16	HV Ctrl	
4	A4			17	Digital Data	
5	Digital Clock			18	VCC	
6	HSD	Headstage Detect		19	HSD	Headstage Detect
7	A5	Analog Output Channels		20	A6	Analog Output Channels
8	A7			21	A8	
9	A9			22	A10	
10	A11			23	A12	
11	A13			24	A14	
12	A15			25	A16	
13	V+	+20 V		26	V-	-20 V

> ✏️ **Note**
>
> See Tech Note 0896 before attempting to make any custom connections.

8. Stimulators

IZ2M/IZ2MH Medically Isolated Stimulator
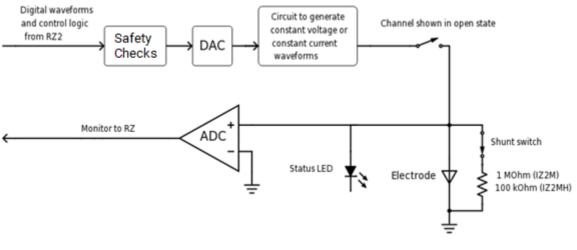
IZ2M/IZ2MH Overview

As part of a computer-controlled neural stimulator system, the IZ2M/IZ2MH outputs constant-current stimulation across multichannel electrodes and provides feedback of actual voltages delivered to the electrode. The stimulator converts user-defined digital waveforms to analog current and provides high precision electrical stimulus control. With up to 64 channels, the IZ2MH delivers a maximum of 3 mAmps (300 uAmps for the IZ2M) of current per electrode up to 12 V on up to ten electrodes simultaneously. The device is battery operated with alternative Mains power, used primarily for charging. Full medical grade isolation between the mains power and the electrode outputs ensures electrical isolation, and additional safety features ensure safe operation at all times.

Stimulation

The stimulator can deliver arbitrary waveforms at up to 50 kHz sampling rate. Each channel uses PCM D/As to ensure sample delays of only 4 samples and square edges on pulse stimulation waveforms. Stimulation control waveforms for each electrode channel are first defined on the RZ base station and digitally transmitted to the stimulator. Special circuitry on the stimulator converts voltage waveforms from the D/A converters to constant current waveforms as shown in the diagram below.

Stimulator Diagram
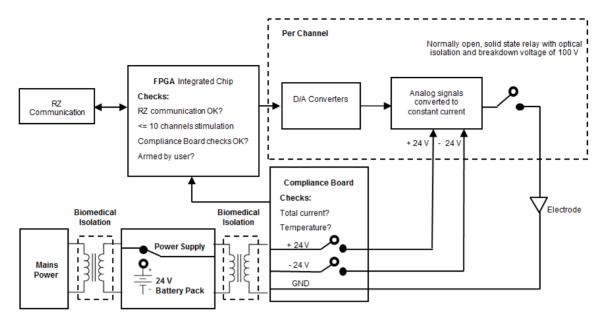
The driving voltage is adjusted according to Ohm's law (V=IR), where I is the desired stimulation current and R is the electrode impedance. Eight analog-to- digital (A/D) converters read the output voltage and send that information back to the RZ for monitoring.

Individual channels can be open circuited. A shunt resistor to ground can be applied to all channels (100 kOhm for IZ2MH and 1 MOhm for the IZ2M). This is most useful for electrodes with very high impedance at DC that would normally produce large quiescent DC voltages.

Safety

The IZ2M/IZ2MH's robust safety profile includes both software and hardware components. Control software ensures that the device always boots in safe-mode, meaning all channels power up by default with their relays open. The relays are kept open until the device finishes booting, passes all internal safety checks, and is armed by the user. This ensures absolutely zero current can flow until proper software control is established. During operation, control software ensures that no more than 10 of the channels can be enabled for stimulation at the same time and that maximum output current is not exceeded.

At the hardware level, the stimulator features an air flow system to regulate temperature and a power supply monitoring system. These systems are controlled on an independent compliance board that will not allow stimulation currents to flow unless all safety checks are met. An ARM/ STOP button allows for manual safety override.
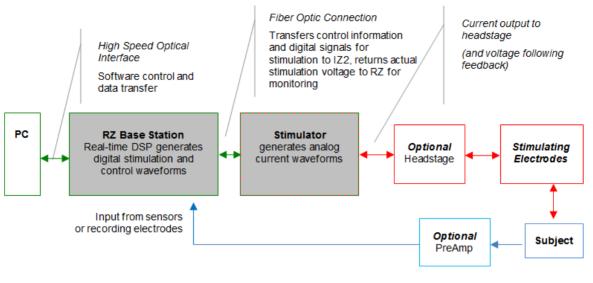
IZ2M/IZ2MH Functional Safety Diagram

The stimulator's power supply has been validated to ensure 4,000 volts of isolation between the input and output, 1,500 volts of isolation between the input and ground, and 500 volts of isolation between the output and ground. Safety approvals for the power supply include the following: UL60601-1, EN60601-1, CSA C22.2 No. 601.1 CE Mark LVD.

The Stimulator System

A typical system consists of an RZ processor equipped with a specialized DSP (RZDSP-I or QZDSPO) and additional fiber optic connector on the back panel.

The block diagram below illustrates the functionality of the system.

High Speed Optical Interface

Software control and data transfer

Fiber Optic Connection

Transfers control information and digital signals for stimulation to IZ2, returns actual stimulation voltage to RZ for monitoring

Current output to headstage

(and voltage following feedback)

PC

RZ Base Station
Real-time DSP generates digital stimulation and control waveforms

Stimulator
generates analog current waveforms

Optional Headstage

Stimulating Electrodes

Input from sensors or recording electrodes

Optional PreAmp

Subject

Multichannel Stimulator System Diagram

Stimulation control waveforms for each electrode channel are first defined on the RZ base station and digitally transmitted over a fiber optic cable to the stimulator. On the stimulator, specialized circuitry for each electrode channel generates an analog voltage waveform. Analog-to-digital (A/D) converters read the output voltage for a chosen bank of 8 channels and send that information back to the RZ for monitoring.
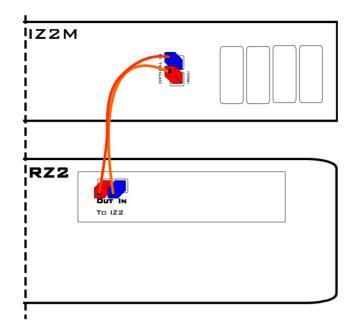
Hardware Set-up

To connect the system hardware:

Ensure that the TDT drivers, PC interface, and RZ and zBus devices are installed, setup, and configured according to the installation guide provided with your system.

Connect to RZ Base Station

Connect the stimulator to the base station using the provided duplex fiber optic cable.

Connect the fiber optic cable from the stimulator's fiber optic port labeled Fiber to the fiber optic port labeled To IZ2 on the back side of the RZ. Use the RED labels to match up the color coded fiber connectors and be sure to line up the notch and keys on each.

Connect electrodes

Connect the DB26 output connectors on the stimulator to the stimulating electrodes using your preferred method, such as direct wiring or a custom pass through connector (available from TDT). See IZ2M/IZ2MH Stimulator Technical Specifications for pinouts.

Power on

Power on the RZ base station, then power on the stimulator by pressing and holding the small square button to the left of the status lights. After one second, release the button.

The stimulator is powered on using battery for operation.

> 🔥 **Important**
>
> The IZ2M/IZ2MH uses mains power for charging. Connect the power connector on the back panel to a mains power outlet, using the provided AC power cable. The battery is always charging when the mains power switch is in the ON position, regardless of whether the IZ2M/IZ2MH is turned on.

When battery power is turned on, the blue LED on the mains power switch, to the right of the status button, will be lit even when the mains power is off (used to indicate temperature). Verify whether mains power is on or off by looking at the position of the switch and by looking

at the left-most power status LED. It will be red when the device is using battery power or green when the device is using Mains power.

The hardware is ready for use

If using the system with other devices, or preamplifiers, see the documentation for those devices for hardware connection information.

Arming Sequence

Before the stimulator can be armed the RZ2 must be connected to the stimulator and powered on. If the stimulation circuit is loaded and running, it MUST not be actively sending stimulus signals on any channels.

The instructions below provide step-by-step sequence and more detail about each stage of device operation.

Step one. Boot - turn power on

When the device is powered on (see above) the blue LED blinks until the device comes up to optimal temperature. This can take up to 10 minutes. If no faults are found at start-up, the stimulator may be armed before optimal temperature is reached (not recommended).

If a safety fault condition is found at start-up; the blue LED will blink at 1 Hz and the yellow LED will be off.

If a communication error occurs, such as no signal detected from the RZ device, is found, or the RZ is trying to actively stimulate, the yellow Ready LED will blink.

When all safety checks have passed both the blue (mains power) and yellow (Ready) LEDs will be lit (no flashing). The device is ready to arm.

Step two. ARM - hold down the Start/Stop button for 3 seconds

When the red LED flashes the Start/Stop button may be released and the red (Armed) LED will remain lit. If any fault is detected the red LED will not come on (or turn off) and the blue LED will begin to blink at 1 Hz.

Step three. Stimulate - send stimulation (up to 10 channels) from the RZ processor

Once the device is armed, it is under the control of the RZ processor. If the RZ is not actively controlling the IZ2M, the default state is channels are closed and output set to zero current.

The stimulator will deliver stimulation to the subject whenever stimulation signals are received from the RZ processor.

The stimulator faults and returns to safe mode (all channels open/no voltage output possible) if any of the below occurs:

- Stimulation is attempted on more than 10 channels.

- More than 100 mA total output is detected by the compliance board. Note: It is not possible to reach 100 mA under normal software controlled conditions.

- IZ2_Control macro in RPvdsEx is set to Voltage mode instead of Current mode.

See your software documentation for end user applications.

Step four. STOP - press Start/Stop button

The user can press the Start/Stop button at any time to stop stimulation immediately and revert to safe mode.

Status LEDs

A blue LED is located on the on/off switch on the right side of the stimulator's front panel. It reports power on/off state and indicates temperature and over voltage faults. On the left side of the device, there is a Start/Stop button for arming the device with adjacent yellow (Ready) and red (Armed) LEDs that report any communication errors and armed status. Between the Battery on/off button and the Mains on/off switch there is a row of power status LEDs.

The chart below compiles the various stages of operation and blue, yellow, red LED status for each.

LEDs	Blue	Yellow	Red
Power on (Safe Mode)	blink (1 Hz - 50/50)	off	off
Ready to ARM	solid (w/temp flash*)	solid	off
Arming	solid (w/temp flash*)	solid	blink
Ready to Stim (Armed)	solid (w/temp flash*)	solid	solid
Safety Fault	blink (1 Hz - 50/50)	off	off
Communication Failure	solid	blink	off
Safety Fault and Communication Error	blink (1 Hz - 50/50)	off	off

* The Blue LED is primarily used to indicate power on/off and safety ok/fault. However, when the IZ2M/IZ2MH is actively stimulating (no faults) it also indicates temperature deviation from optimal by blinking off (short off duration) with the frequency of the off blink indicating the number of degrees off from optimal.

Power Status LEDs

Immediately to the left of the mains power button there is a row of small LEDs. The first LED (from left) indicates whether the devices is being powered from mains or battery power.

LED Color	Status
Green	the device is using mains power and the battery is charging
Red	the device is using battery power

The four LEDs on the right end of the row indicate the power level of the battery.

# of LED's Lit	Battery Power Level
4	Fully charged
3-2	Not fully charged
1	Critically low, charge immediately

The LED between the Power Mode LED and the Power Level LEDs is not used at this time.

Testing the System

The IZ2M includes a resistor block that is used to verify stimulation output. The RB100 is a 100 kOhm resistor block that is included with the IZ2M. The RB10 is a 10 kOhm resistor block that is included with the IZ2MH. In Synapse, use the impedance test built into the IZ2n HAL object at run time to verify that the correct impedance is measured. Download the test files and instructions from https://www.tdt.com/files/tech/IZ2ImpedanceTest.zip.

IZ2M/IZ2MH Features

Analog Outputs (Stim Outputs)

The analog output channels are arranged in sixteen-channel banks.

Stim Lights

The Stim Lights are located on the front plate of the IZ2M/IZMH and are labeled by channel number. Each LED indicates the voltage at the corresponding electrode site. The Stim Light will turn green when a channel has greater than ±150 mV at the output and will turn red when a channel output is beyond ±10 V.

Fiber Optic Port (Fiber)

The fiber optic input port provides an isolated connection to the RZ base station. One end of the fiber optic cable connects to the stimulator fiber optic input port (labeled Fiber) and the other end connects to the fiber optic input port (labeled 'To IZ') on the front panel of a RZ5D or the back panel of other RZ base stations. See Hardware Set-up connection diagram.

Battery Operation and Charging

The stimulator has an onboard, 240 Wh battery for device operation. The battery charges whenever the Mains power is connected and the Mains power switch is in the on position.

Software Control

Synapse
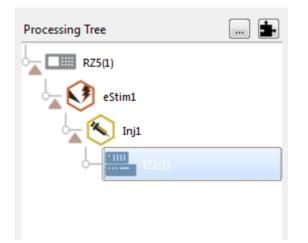
Operation of the stimulator system is controlled by an IZ2 object in the Synapse Rig and Processing Tree. Consult the Synapse Manual for more detailed information on general Synapse use.

Ensure that hardware your rig is properly set up in the Rig Editor (Menu > Edit Rig) and you have the required elements: RZ processor, RZDSP-I (or QZDSPO with optics) and IZ2 stimulator.

> 🔥 **Important**
>
> Make sure the IZ2 object has the correct model selected (IZ2M or IZ2MH) and channel count.

A typical electrical stimulation experiment includes an Electrical Stimulation gizmo to generate monophasic or biphasic pulses, then a Signal Injector gizmo which routes this single channel signal to one or more channels in a multi- channel stream and determines what the non-stim channels are doing (typically set to "IZ2 Open" mode), and then this multi-channel stream connects to the IZ2 object to control all channels on the IZ2 at once.

Important Experiment Design Considerations

Sampling Rate

The IZ2M/IZ2MH can control 64 channels at up to 50 kHz. The stimulator sampling rate is the same as the sampling rate of the circuit running on the RZ device, so the maximum sampling rate of the stimulator is also limited to the maximum sampling rate of the type of RZ device controlling it.

Signal Resolution

Signal resolution is dependent on the sampling rate used. PCM D/A converters allow users to generate precise pulsed signals, including square waves with durations of only 1 sample.

Designing the Stimulus Signal

The IZ2M/IZ2MH Stimulator system offers flexible stimulus delivery capable of generating complex patterns of pulses or arbitrary waveforms.

This allows you to make use of the full range of the stimulation gizmos in the Synapse library, or create your own user gizmo for custom stimulation patterns.

The Signal Injector gizmo provides default values for the non-stimulating channels. This can be zero current or open circuit for the IZ2M/IZ2MH. Use the IZ2 object settings to enable the shunt resistors on all channels and to toggle voltage or current mode.

Ensure no more than ten channels have non-zero stimulus.

Monitoring the Stimulation

Eight PCM A/D converters on the stimulator monitor the actual output voltage for a chosen bank of channels and send that information back to the RZ. This information is available from the output of the IZ2_Control macro. The MonBank macro input specifies which bank of eight channels is updating on the Monitor output (the rest of the channels of the Monitor output will be latched). A zero indicates that the first bank of eight is monitored.
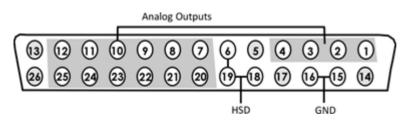
> ✏️ **Note**
>
> The onboard A/D converters provide the feedback clip at ±20 V, which is higher than any possible output.

IZ2M/IZ2MH Stimulator Technical Specifications

Stimulus Output Channels	32 or 64
Sampling Rate	Up to 48828.125 Hz
Stimulus Output Voltage	±12 V
Stimulus Output Current	IZ2M: ±300 uA up to 40 kOhm load
	IZ2MH: ±3 mA up to 4 kOhm load
Offset Current	<100 nA on active channels and <3 nA on open channels
Battery	240 Wh
	20 hours to fully charge
	16-18 hours to charge to 95% capacity
	7.5 hour runtime

Mini-DB26 Connector Pinouts for the IZ2M/IZ2MH

Stim Output Connector

Pin	Name	Description	Pin	Name	Description
1	A1	Analog Output Channels	14		Digital Strobe
2	A2		15	GND	Ground
3	A3		16	GND	Ground
4	A4		17		Digital Data
5		Digital Clock	18	HSD	Headstage Detect
6	HSD	Headstage Detect	19	HSD	
7	A5	Analog Output Channels	20	A6	Analog Output Channels
8	A7		21	A8	
9	A9		22	A10	
10	A11		23	A12	
11	A13		24	A14	
12	A15		25	A16	
13	V+	+20 V	26	V-	-20 V

> ✏️ **Note**
>
> See Tech Note 0896 before attempting to make any custom connections.

9. Audio Devices

ED1 Electrostatic Speaker Driver

Overview

The ED1 is a broadband electrostatic driver that produces incredibly flat frequency responses reaching far into the ultrasonic range. The ED1 is designed to drive TDT's ES1 and EC1 electrostatic speakers only.

The ED1 is a TDT System 3 device, and receives power from the zBus. It's two input BNCs accept input signals up to 10 V, though using 4 V maximum is recommended for longest speaker life. The front panel gain control controls overall signal level of both channels from 0 to -27 dB attenuation in 3 dB steps. ED1 output is via two 4-pin, mini-DIN connectors, which carry both bias and signal voltages.

While the ED1 will accept a 10 V input, it is possible to overdrive an ES1 when the ED1 is on the maximum gain setting. Always check that the output signal is not distorted. If the signal is distorted, turn down the gain on the ED1 until the distortion disappears. Both SigCalRP and BioSigRZ software measure the frequency response and Total Harmonic Distortion (THD) of the ES1/EC1 speaker. They also generate a normalization curve that can be used to flatten the frequency response of the ES1.

Power

The ED1 Electrostatic Speaker Driver is powered via the System 3 zBus (ZB1PS). No PC interface is required.

ED1 Technical Specifications
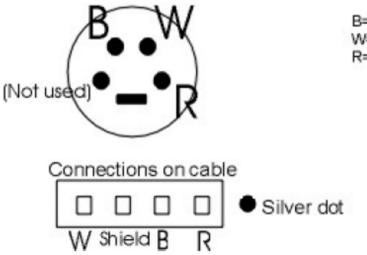
Input Signal Range	±10 V peak into ED1, ±4 V recommended
Gain	0 dB to -27 dB on both channels, in 3 dB steps
Input Impedance	10 kOhm
Output Impedance	1 kOhm

> ✏️ **Note**
>
> For further information, see EC1/ES1 Electrostatic Speaker.

ED1 Pinouts

Connections on ED1 (front view)

B= Black: signal voltage
W= White: opposite signal voltage
R= Red: Bias voltage

(Not used)

Connections on cable

● Silver dot

W Shield B R

HB7 Headphone Buffer

Overview

The HB7 headphone buffer is used to amplify signals for headphones. The HB7 is a two channel device. The outputs include both a stereo headphone jack and Left and Right BNC connectors. The output level can be controlled with a Gain knob, and there is a Differential switch that allows the LEFT input to be output to the Left and Right outputs resulting in an additional 6 dB of gain.

Power

The HB7 Headphone Buffer is powered via the System 3 zBus (ZB1PS). No PC interface is required.

Features

Inputs

The HB7 has two inputs for signals up to ±10 V, accessed through front panel BNC connectors labeled LEFT and RIGHT.

Outputs

The outputs include both a stereo headphone jack labeled PHONO and Left and Right BNC connectors.

> ✏️ **Note**
>
> When monitoring both output channels with only one input connected, users should short the unused input channel to ensure maximum channel separation.

Gain

A single GAIN knob provides control over the signal output level in 3 dB steps from 0 to -27 dB.

AC/DC Switch

The AC/DC switch can be used to switch from DC coupling to AC coupling mode. In AC coupling mode, a 0.5 Hz high pass filter is applied to the signals.
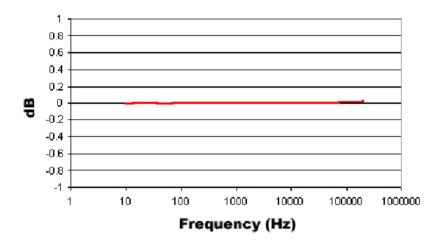
DIFF Switch
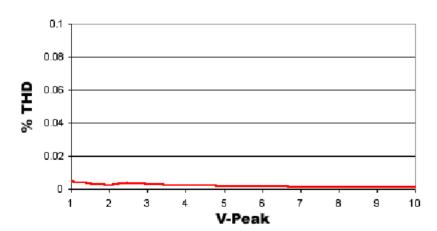
The DIFF switch will switch to a differential output mode that gives 6 dB of additional gain when connected to a speaker. When DIFF is switched on (the switch in the up position), the left channel input goes to both the left and right channels and is inverted on the right channel (the right input BNC is not used). The differential output will usually only be used with speakers, not headphones. To connect the speaker, connect the left output to one pole of the speaker and the right output to the other pole of the speaker (neither ground of the left nor right output will be connected).

HB7 Technical Specifications

Input Signal Range	±10 V peak
Power Output	0.12 W into 4 Ohms, 0.25 W into 8 Ohms, 1.0 W into 32 Ohms
Spectral Variation	<0.1 dB from 10 Hz to 200 kHz
Signal/Noise	117 dB (20 Hz to 80 kHz)
Noise Floor	9.2 uVrms
THD	<0.0002% (1 kHz tone, ±7 V peak)
Corner Frequency	0.5 Hz (AC-Coupled Mode)
Input Impedance	10 kOhm
Output Impedance	5 Ohm
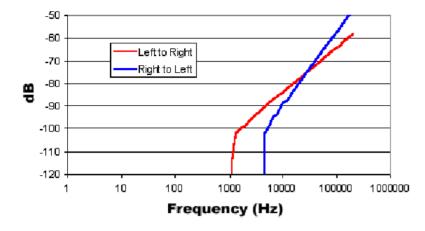
HB7 Frequency Response

HB7 Total Harmonic Distortion

HB7 Crosstalk

MA3 Microphone Amplifier

MA3 Overview

The MA3 is a two-channel microphone amplifier for auditory scientists. This high-quality low-cost system is designed for use with both ¼" audio jack microphones and balanced XLR inputs for optimum impedance and noise characteristics. The MA3 can provide a bias voltage for microphones that require it. Two BNC connectors provide analog output. A variable gain knob provides amplification from 10 dB to 55 dB in 5 dB steps. A toggle switch provides 20 dB of additional gain for over 5000x total amplification.

Power

The MA3 Microphone Amplifier is powered via the System 3 zBus (ZB1PS). No PC interface is required.

MA3 Features

Inputs

The MA3 comes with three inputs: an XLR microphone input and two ¼" TRS connector inputs. Signals from two microphones can be amplified simultaneously.

Bias

The Bias switch produces a bias voltage for microphones that require it.

Gain Control

The gain control amplifies the microphone input in 5 dB steps from 10-55 dB (~3x - ~560x). The Gain Switch adds an additional 20 dB (10x) of gain for a maximum amplification of ~5600x.
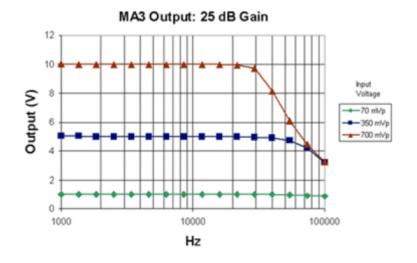
Outputs

Two BNC outputs give easy connection to any TDT System 3 device. The maximum voltage output is ±10 Volts. Clip lights indicate and overvoltage on the signal output.
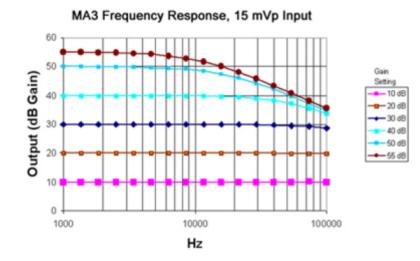
MA3 Technical Specification

Input Signal Range	±10 V peak
-3 dB Bandwidth	200 kHz @ 40 dB gain
Gain Accuracy	±1 dB
Spectral Variation	1 dB from 20 Hz to 20 kHz
Signal/Noise	110 dB (20 Hz to 30 kHz at 9.9 V)
Noise Floor	9.2 uVrms
THD	<0.002% (1 kHz tone, ±7 V peak)
Input Impedance	600 Ohm
Output Signal Range	±10 V peak
Bias Voltage	10 V, 150 mA max, superimposed onto microphone
Output Impedance	5 Ohm

MA3 Output

MA3 Output: 25 dB Gain

MA3 Frequency Response

MA3 Frequency Response, 15 mVp Input

PA5 Programmable Attenuator

Overview

The PA5 Programmable Attenuator is a precision device for controlling signal levels over a wide dynamic range, providing 0 to 120 dB of attenuation for signals up to 100 kHz in frequency. The device is fully programmable; however, simple manual operation is also available using front panel controls.

When used programmatically, the module may be controlled via TDT's ActiveX Controls in any programming environment that supports ActiveX controls, such as MATLAB, Python, or LabVIEW. For information about how to control the module programmatically, see the ActiveX Reference Manual.

When used in manual operation, the attenuation level is adjusted in two modes of operation:

- In **Atten** mode, the attenuation level of the signal can be adjusted from 0 to 120 dB in increments of 0.1 dB.
- **UserAtt** mode applies user-programmed parameters to adjust the attenuation level. Before using the UserAtt mode, attenuation parameters must be set up using the UserOps menu.

Power and Interface

The PA5 Programmable Attenuator is powered via the System 3 zBus (ZB1PS). and requires an interface to the PC (Gigabit, Optibit, or USB). Ensure that the ZB1PS chassis housing the PA5 is connected in the interface loop according to the installation instructions for the interface in use.

> 🔥 **Important**
>
> The chassis housing the PA5 must be powered and connected to a PC via the PC interface for BOTH manual and programmed operation.

Features

Display

Displays the current level of attenuation being applied to the signal or displays the manual operations menu. During manual operation it is used to set up user-defined attenuation parameters and to obtain descriptions for menu items. See PA5 Display Icons for more information.

(ESC) Button

Exits the manual operations menu items without accepting changes.

SELECT (ENTER) Knob

During manual operation, allows the user to adjust the attenuation applied to the signal. In addition, it allows the user to scroll through the manual operation menus, set up user-defined attenuation parameters, and access descriptions of menu item.

Turn the Select knob to adjust attenuation or view menus. Press and release the knob to make a selection. The module must be in Atten or UserAtt mode to manually adjust attenuation. See PA5 Manual Operation for more information.

INPUT BNC

Source signal input. The maximum input voltage is ±10 V peak.

OUTPUT BNC

Attenuated signal output.

PA5 Manual Operation

> 🔥 **Important**
>
> The PA5 is powered via the zBus and must be connected to the PC via an interface module during manual operation.

In manual operation, the PA5 is operated using front panel controls. The menu options are viewed by turning the Select knob and entered by pressing and releasing the knob. The module must first be set to Attn or UserAtt mode to manually adjust attenuation.

To access a menu:

- Turn the knob until the name of the desired menu appears on the display, then press and release the knob. The module has two levels of menus.

  Top-level menu items are indicated by a single filled box in the upper left corner of the menu display, and sub-menus are indicated with an additional indicator box for each level. Only the UserOps menu item has sub-menu items. See PA5 Display Icons for more information.

For a definition of each menu item:

- Turn the **Select** knob until the name of the menu appears on the display, then press and hold down the **Select** knob. A description of the menu function will scroll across the display.

To exit a menu without changing settings:

- Press and release the **ESC** button.

Operation in Atten Mode

In **Atten** mode, the user sets the desired level of attenuation with the Select knob. When the unit is powered on, it defaults to the Atten mode with 0.0 dB of attenuation.

To use Atten mode:

1. Turn the **Select** knob until **Atten** appears on the display, then press and release the **Select** knob.

A small letter "A" appears in the upper left corner of the display, indicating the unit is in **Atten** mode, and a decibel reading appears on the right side of the display. See PA5 Display Icons for more information.

2. Turn the **Select** knob to adjust attenuation in 0.1 dB increments.

Operation in UserAtt Mode

In **UserAtt** mode, the user can adjust the attenuation level of the signal using user-programmed parameters available in the UserOps menu. Users can also save common parameter configurations in the PA5's nonvolatile memory. See Using Preset Configurations for more information.

To use **UserAtt** mode:

1. Turn the **Select** knob until **UserAtt** appears on the display, then press and release the **Select** knob.

   A small letter "U" appears in the upper left corner of the display, indicating the unit is in **UserAtten** mode, and a decibel reading appears on the right side of the display. See PA5 Display Icons for more information.

2. Turn the **Select** knob to adjust attenuation according the current user programmable parameters (available in the **UserOps** menu). The default settings include a step size of 3.0 dB and dynamic update mode.

   > ✏️ **Note**
   >
   > When the **Update** attenuation parameter is set to **Manual**, the intensity of the display will dim as the user turns the knob. This indicates that the changes have not been applied to the output signal. The user must press and release the **Select** knob to apply attenuation changes to the output signal.

To access the UserOps menu:

1. Turn the **Select** knob until **UserOps** appears on the display.

2. Press and release the **Select** knob.

3. Set the **UserOps** parameters as desired.

   To set parameters such as step size (StpSize), update mode (Update), minimum attenuation (AbsMin), base attenuation (BaseAtt), and reference value (Refrnce); turn the **Select** knob to the desired value and then press and release to save changes.

4. To exit any menu without saving parameter changes, press and release the **ESC** button before the settings are saved.

About UserAtten Mode Parameters

In **UserAtten** Mode, the user may set parameters such as step size (**StpSize**), update mode (**Update**), and minimum attenuation (**AbsMin**). The scale can be adjusted using the base attenuation (**BaseAtt**) and reference value (**Refrnce**) parameters. Both base attenuation and reference can be used simultaneously, producing an actual attenuation equal to (**Refrnce** + **BaseAtt** - **{dial setting}**). See PA5 Manual Operation for more information.

BaseAtt - Base Attenuation

Adds a fixed attenuation value, shifting the scale down and allowing attenuation to be displayed relative to this base level (useful for calibrating signals played over varying transducers). See Setting Base Attenuation, for more information.

StpSize - Step Size

Sets the increments in which attenuation is applied to the signal when using the **Select** knob.

Refrnce - Reference

Sets a reference value used to "flip" the scale of the display (useful for displaying actual signal level on the front panel of the PA5). May be used only when the intensity of the input signal is known. See Setting a Reference Value for more information.

Update - Update

Determines whether attenuation changes dynamically as the selector knob is turned or only after pressing enter to select the current value.

AbsMin - Minimum Attenuation

Sets the minimum level of attenuation the user can apply to the signal (to avoid accidentally presenting excessively loud signals).

PA5 Manual Operation Menus

To access a menu:

- Turn the knob until the name of the desired menu appears on the display, then press and release the knob. The module has two levels of menus.

  Top-level menu items are indicated by a single filled box in the upper left corner of the menu display, and sub-menus are indicated with an additional indicator box for each level. Only the **UserOps** menu item has sub-menu items.

For a definition of each menu item:

- Turn the Select knob until the name of the menu appears on the display, then press and hold down the Select knob. A description of the menu function will scroll across the display.

To exit a menu without changing settings:

- Press and release the **ESC** button.

PA5 Top Level Menu

Atten

Sets attenuation from 0.0 to 120.0 dB in 0.1 dB increments. The default setting is 0.0 dB. When Atten is in use, the letter "A" appears on the left side of the display, while the attenuation level appears on the right side of the display.

UserAtt

Sets attenuation based on UserOps settings. Before use, attenuation parameters must be set up via the UserOps sub-menus (see below). The default setting is 0.0 dB. When UserAtt is in use, the letter "U" appears on the left side of the display, while the attenuation level appears on the right side of the display.

UserOps

Access UserOps submenu:

BaseAtt

Sets a fixed level of attenuation as a reference. The default setting is 0.0 dB and the range is 0 to 100.0 dB. When BaseAtt is set, a "+" symbol appears on the left side of the display.

When used, the attenuation level displayed is relative to BaseAtt. For example, with BaseAtt set to 60.0 dB, the attenuation level will be display from -60.0 dB to 60.0 dB.

StpSize

Sets the increments of attenuation. The default setting is 3.0 dB, and the range is 0.1 to 60.0 dB.

Refrnce

Changes the display so it shows the output signal intensity rather than the attenuation level. This function may be used only when the input signal strength is known. When Refrnce is set, the letter "R" appears on the left side of the display. The default setting is 0.0, and the range is ±300.0.

For example, when Refrnce is set to 136 and the attenuation level set to 0.0 dB, the display shows 136.0. When the attenuation level is adjusted to 30.0 the display shows 106.

Update

Determines when attenuation is applied to the signal. When set to Dynamic, attenuation is applied as the Select knob is turned. When set to Manual, attenuation is applied after the Select knob is pressed and released. The default setting is Dynamic.

Note that when Update is set to Manual, the attenuation level on the display changes as the Select knob is turned, but the attenuation is not applied to the signal until the Select knob is pressed and released. In this mode, the intensity of the display dims to indicate that the attenuation has not been applied to the signal.

MinAttn

Sets the minimum attenuation level for the UserAtt mode. This is used to avoid signals that are too loud for the subject or equipment. The default value is 0.0 dB and its range is 0.0 to 100.0 dB.

Note that setting this parameter limits the range of possible attenuation levels. For example, when it is set to 30.0 dB, the range of attenuation is 30 db to 120 dB. Access UserOps submenu.

Load PS

Loads one of four preset UserAtt configurations from non-volatile memory. See Save PS (Below). The default is 1 and its range is 1 to 4.

Save PS

Saves the current UserAtt configuration in one of four non-volatile memory buffers. This permits the user to save commonly used UserAtt configurations. The default is 1 and its range is 1 to 4.

To save a configuration, first ensure that all UserAtt parameters are set as desired then turn the Select knob until the desired memory location is displayed, and press the Select knob. Saving appears on the display. The preset is ready of use.

Reset

Resets all menu items, including presets, to their default conditions.

Confirm

The user must confirm the reset by pressing and releasing the Select knob. While the module is resetting, Reseting appears on the display.

To exit without resetting, turn the Select knob until Cancel appears on the display and then press and release the Select knob, or press the Esc button.

Cancel

Cancels the reset.

Setting Base Attenuation

When operating the PA5 manually in User Attenuation (UserAtt) mode, the Base Attenuation (BaseAtt) parameter can be used to apply a fixed attenuation level to the signal. Any additional attenuation to the signal is displayed relative to this base level within a range of 0 to 120 dB. For example: if the BaseAtt is set to 6 dB, when the user sets the attenuation to 3 dB the actual attenuation applied is 9 dB. This feature can be used to calibrate a number of different experimental setups, attenuating each by a different base attenuation so as to provide identical signal levels when each is set to 0.0 dB UserAtt.

When this feature is in use, a "+" symbol is displayed on the left side of the display. Note that the Base Attenuation and Reference parameters can be used simultaneously. When both of these features are in use, the letter "R" and a "+" symbol are displayed on the left side of the display. See PA5 Display Icons for more information.

To set the base attenuation:

1. Access the **UserAtt** mode, by turning the **Select** knob until **UserAtt** appears on the display, then pressing and releasing the knob.

2. Access the **UserOps** menu, and turn the **Select** knob until **BaseAtt** appears on the display.

3. Press and release the **Select** knob. 0.0 dB appears on the display.

4. Turn the **Select** knob until the display shows the desired level of attenuation.

5. Press and release the **Select** knob. The level is saved and **BaseAtt** appears on the display.

6. To exit the **UserOps** menu, press and release the **ESC** button again.

Setting a Reference Value

The Reference parameter is used to display the intensity of the output signal. This parameter can be used only when the strength of the input signal is known. This serves to "flip" the scale, displaying larger numbers for smaller attenuation values.

When in use, a letter "R" is displayed on the left side of the display. Note that the Base Attenuation and Reference parameters can be used simultaneously. When both of these features are in use, the letter "R" and a "+" symbol are displayed on the left side of the display. See PA5 Display Icons for more information.

To set the Reference parameter:

1. Access the **UserOps** menu, and turn the **Select** knob until **Refrnce** appears on the display.

2. Press and release the **Select** knob. **0.0 dB** appears on the display.

3. Turn the **Select** knob until the display shows the desired level.

4. Press and release the **Select** knob. The reference is saved.

5. To exit the **UserOps** menu, press and release the **ESC** button.

Using Preset Configurations

The PA5 Programmable Attenuator allows users to save four unique User Operation configurations that may be used in UserAttn mode. These configurations may include any of the UserOps parameters (such as step size, base attenuation, and minimum attenuation). Before a configuration can be loaded, it must be set up via the UserOps menu and saved via the SavePS menu.

Saving Preset Configurations

> ⚠️ **Warning**
>
> This procedure overwrites the contents of the selected preset location. Be certain that the existing configuration is not needed before continuing.

Before a configuration can be saved, it must be set up via the UserOps menu. Once the configuration is set up as desired, save the configuration by performing the following:

1. At any top-level menu, turn the **Select** knob until **SavePS** appears on the display.

2. Press and release the **Select** knob. **Preset-1** appears on the display.

3. Turn the **Select** knob until the desired preset location is displayed and then press and release the **Select** knob.

   Saving appears on the display and then **Atten** appears on the display.

   The configuration is saved.

Loading Preset Configurations

When a configuration has been set up via the UserOps menu and saved via the SavePS menu, load the configuration by performing the following:
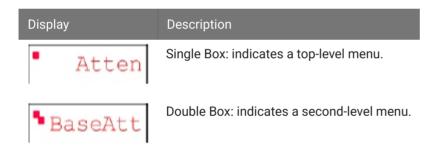
1. Turn the **Select** knob until **LoadPS** appears on the display.

2. Press and release the **Select** knob. **Preset-1** appears on the display.

3. Turn the **Select** knob until the desired preset location is displayed, and then press and release the **Select** knob.

   Loading appears on the display and then **Atten** appears on the display.

   The configuration is loaded.

PA5 Display Icons

Menu Level Icons

Display	Description
■ Atten	Single Box: indicates a top-level menu.
■ BaseAtt	Double Box: indicates a second-level menu.
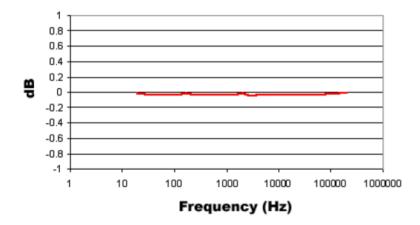
Attenuation Mode Icons
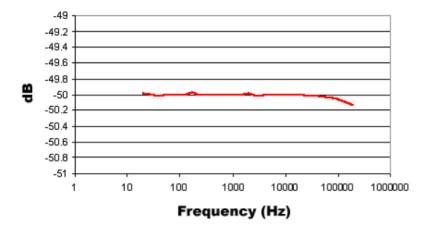
Display	Description
A 1.0dB	A: Normal Attenuation Mode
U 3.0dB	U: User Attenuation Mode
U+ 3.0dB	U+: User Attenuation Mode. Base attenuation value set.
R 3.0dB	R: User Attenuation Mode. Reference level set.
R+ 3.0dB	R+: User Attenuation Mode. Base attenuation value and reference level set.

PA5 Technical Specifications

Input Signal Range	±10 V peak
Frequency Range	DC - 200 kHz
Attenuation Range	0.0 to 120.0 dB
Attenuation Resolution	0.1 dB
Attenuation Accuracy	0.05 dB
Spectral Variation	<0.04 dB (20 Hz to 80 kHz)
Offset	<10 mV
Signal/Noise	113 dB (20 Hz to 80 kHz at 9.9 V)
Noise Floor	16 uVrms (20 Hz to 80 kHz)
THD	<0.003% (1 kHz tone ±7 V peak, 0 dB attenuation)
Attenuation Settling Time	5 ms
Switching Transient	<8 mV (0 Hz to 80 kHz)
Input Impedance	10 kOhm
Output Impedance	10 Ohm
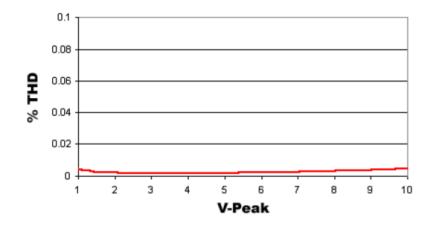
PA5 Frequency Response

PA5 Frequency Response with 50 dB Attenuation

PA5 Total Harmonic Distortion

SA1 Stereo Amplifier

SA1 Overview

The SA1 is a power amplifier for the zBus that delivers up to 3 watts of power to speakers. It has excellent channel separation combined with low noise and distortion. The frequency response is flat from 50 hertz to 200 kilohertz. Gain can be varied over a 27 dB range in 3 dB increments.

Power

The SA1 Stereo Amplifier is powered via the System 3 zBus (ZB1PS). No PC interface is required.

SA1 Features

Inputs

There are two inputs (±10 V maximum) that connect through BNC's labeled IN-1 and IN-2.

Outputs
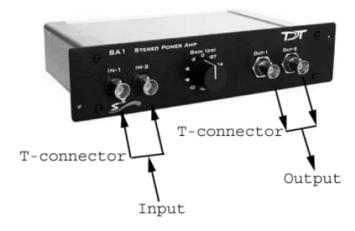
The outputs are two (OUT-1 and OUT-2) BNC connectors.

Gain

A single GAIN knob provides control over the signal output level in 3 dB steps from 0 to -27 dB. It attenuates both output channels.

Ganged Output Mode

A ganged output mode gives 6 dB of additional gain when connected to a speaker. Split the signal to the input; send one to the IN-1 and the other to IN-2. Take the outputs from OUT-1 and OUT-2 and combine them to boost the gain.

SA1 Technical Specifications

Input Signal Range	±10 Vpeak
Power Output	1.5 W/channel into 5.5 ohm, 4 W with ganged output
Spectral Variation	<0.1 dB from 50 Hz to 200 kHz
Signal/Noise	116 dB (20 Hz to 80 kHz)
THD	<0.02% at 1 Watt from 50 Hz to 100 kHz
Noise Floor	10.5 uVrms
Input Impedance	10 kOhm
Output Impedance	0.6 ohm, 0.3 ohm ganged

SA8 Eight Channel Power Amplifier

SA8 Overview

The SA8 is an eight-channel power amplifier that delivers up to 1.5 watts of power per speaker to up to eight speakers. The unit features high channel separation with low cross talk combined with low noise and distortion. The gain for all eight channels can be set to 0, -6, -10 or -13 dB.

Power

The SA8 Power Amp is powered via the System 3 zBus (ZB1PS). No PC interface is required.

SA8 Features

Inputs

There are eight available inputs located on the DB9 connector on the front panel of the SA8.

Outputs

The eight output channels are accessible via the DB25 connector and are arranged for optional direct connection to a PP16 Patch Panel. For easy wiring and connection to a wide variety of transducers, the eight outputs are duplicated on the DB25 and sufficient ground pins are provided to allow for connections requiring a single ground for all channels or paired grounds for each channel.

See Mapping SA8 Analog Outputs to PP16 Connectors for more information on easy access to SA8 output channels via the patch panel.

Gain
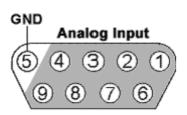
The gain is controlled by two toggle switches on the front panel of the SA8. The following table describes the selectable gain values.

Left Toggle	Right Toggle	dB Gain
Up	Up	0
Up	Down	-6
Down	Up	-10
Down	Down	-13

SA8 Technical Specifications
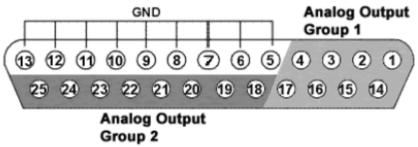
Input Signal Range	±10 V peak
Power Output	5 W total into 5.5 ohm loads, split across all connected channels
Spectral Variation	<0.1 dB from 50 Hz to 200 kHz
Signal/Noise	116 dB (20 Hz to 80 kHz)
THD	<0.02% at 1 W from 50 Hz to 100 kHz
Noise Floor	10.5 uVrms
Input Impedance	10 kOhm
Output Impedance	2 ohms
Cross Talk	<-60 dB

Analog Input Pinout

Pin	Name	Description		Pin	Name	Description
1	A1	Analog Input Channels		6	A2	Analog Input Channels
2	A3			7	A4	
3	A5			8	A6	
4	A7			9	A8	
5	GND	Ground				

Analog Output Pinout

Pin	Name	Description		Pin	Name	Description
1	A1	Analog Output Channels		14	A2	Analog Output Channels
2	A3	(Group 1)		15	A4	(Group 1)
3	A5			16	A6	
4	A7			17	A8	
5	GND	Ground		18	A1	Analog Output Channels
6	GND			19	A2	(Group 2)
7	GND			20	A3	
8	GND			21	A4	
9	GND			22	A5	
10	GND			23	A6	
11	GND			24	A7	
12	GND			25	A8	
13	GND					

SM5 Signal Mixer

SM5 Overview

The SM5 is a three-channel signal mixer. The relative contribution of the three inputs to the final output can be adjusted using a variable gain for two of the inputs. In addition, the signal on the two adjustable channels can be inverted before addition. The input signal range is ±10 V for each channel, with the additional caveat that the amplified signal for each channel may not exceed ±10 V without clipping. The range for the summed output is ±10 V.

Power

The SM5 Signal Mixer is powered via the System 3 zBus (ZB1PS). No PC interface is required.

SM5 Features

The SM5 Signal Mixer is a three-channel weighted summer with variable input weighting and channel inverting.

Inputs

Three signals input channels (A, B, and C), with a range up to ±10 V peak, are accessed through front panel BNC connectors. Input channels A and B are multiplied by a weighted, signed constant, K, before being added to the final output. The weighting range for these two channels is adjustable from -20 dB to +20 dB (i.e. |K| = 0.1 to 10) using a GAIN knob on the front panel. The sign of K for channels A and B can also be selected using front panel toggle switches, labeled INV-A and INV-B.

If an input is not being used, it should be grounded by attaching a shorted BNC cable. This will prevent unwanted noise from being added to the output.
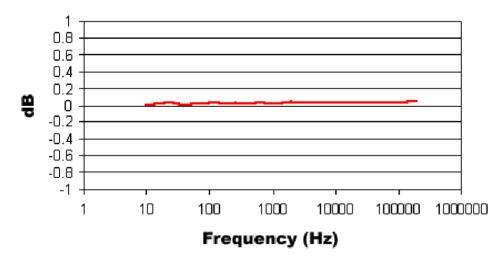
Clipping

The variable weighting provides a great deal of flexibility in input and output signals. However, care should be taken to avoid clipping any signal component. The SM5 output signal = (Ka*A) + (Kb*B) + C is limited to ±10 V peak. In addition, the raw inputs, A, B, and C, as well as the weighted inputs, Ka*A, and Kb*B, are limited to ±10 V peak.
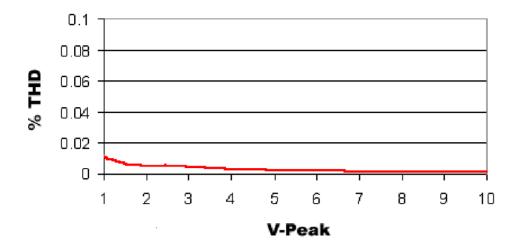
SM5 Technical Specifications

Input Signal Range	±10 V peak
Weighting Range	-20.0 to +20.0 dB
Max Output	±10 V
Spectral Variation	<0.1 dB from 10 Hz to 200 kHz
S/N (typical)	111 dB (20 Hz to 80 kHz)
THD	<0.002% (1 kHz tone ±7 V peak)
Noise Floor	19 uVrms
Output Impedance	20 Ohm
Input Impedance	10 kOhm
Inversion	Channels A & B

SM5 Frequency Response

SM5 Total Harmonic Distortion

10. iCon Behavioral Platform

iCon Behavioral Control Interface

The iCon is a behavioral control interface designed to support easy or complex behavioral experiments. It has interchangeable analog and digital modules to fit the needs of any experimental paradigm. It can control most third-party behavioral chambers with TDT's Synapse software — resulting in high-bandwidth, precision control of behavioral hardware with real-time signal monitoring.

The iCon interface comes in two different versions:

- The "iCon" has an optical communication port ("iCon") to interface to an RZ processor with a DSP-M card. The iCon runs at the RZ system sampling rate, up to a maximum 50 kHz.
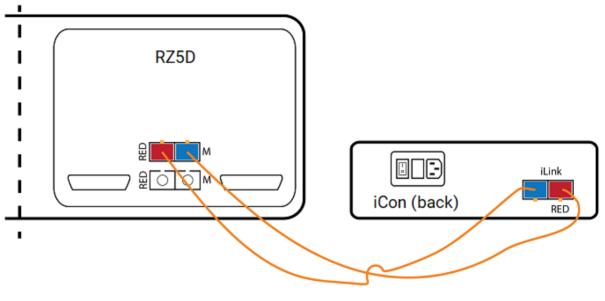
- The "iConZ" has a USB 3 connector ("iConZ") to connect directly to a PC or laptop. The iConZ has its own onboard digital signal processors (DSPs) and supports ~6 kHz sampling rate, though modules such as the iMn support higher sampling rate onboard processing. These built-in DSPs will appear as an "RZ3" in zBusMon and Synapse software.

The iCon is available with two (iCon-2/iConZ-2), four (iCon-4/iConZ-4), or six (iConZ-6 only) module slots.

Physical Setup
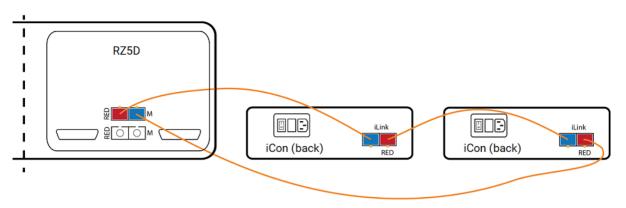
iCon

The iCon connects to a DSP-M or optical QZDSP card in your RZ processor.

Single iCon connected to a DSPM card in an RZ5D

You can connect multiple iCons to the same DSP interface card.

Two iCons connected to a single DSPM card in an RZ5D

iConZ

The iConZ connects to a USB 3 port on your PC or laptop.

iConZ connected to PC

You can connect one iConZ per computer. To use multiple iConZ interfaces simultaneously, you need one laptop per iConZ, or a dedicated iPac Workstation to manage up to eight at once.

Features

Power

The iCon is powered by an integrated switched-mode power supply. The power supply auto-detects your region's voltage setting and no further configuration is needed. The power switch is located on the back panel.

Status Light

The iCon front panel display Status light reports system connection information.

LED status	Description
solid red	no connection
solid green	connected and identified
blinking green	connected and experiment is running in Synapse
blinking red	Synapse is trying to access a module that doesn't exist, for example if your experiment is using a module that is not installed in the iCon

I/O Control

At the most basic the TDT iCon system can replace existing devices such as the Med Associates, Colburn or Lafayette systems that interface to a standard operant or behavioral box with input and output lines, where the output lines drive feeders, lick meters and other devices that require more than a digital trigger. At the more complex level the TDT system can be used to send and receive complex signals to control multiple hardware devices.

Replicating an Existing Behavioral Control System

The TDT system provides a unifying interface for sending and receiving behavioral information from a behavioral control box without the need for the external devices from these other companies.

iCon Control

The iCon can be controlled in the following ways:

1. Bi-directional real-time communication between the iCon and an RZ processor, running in Synapse.

2. Client software using the SynapseAPI to control the iCon outputs through Synapse.

3. Pynapse Python Coding Gizmo in Synapse controlling the iCon outputs and managing full behavioral state control.

The iCon object in Synapse lets you configure how the iCon modules are controlled (either through real-time signals on the RZ itself, client-controlled via the SynapseAPI, or directly integrated in a Pynapse gizmo) and how to route iCon input state changes for storage or further closed-loop processing.

Installation Notes

When adding modules to an existing iCon, note that:

1. The iV1 and iV2 can't be installed in the bottom slot of iCon-2, iConZ-2, iCon-4, iConZ-4, iConQZ-4, or iConQZ-6 devices.

2. The iX6, iX7, iV1, iV2, iD2, iA16, iA32, and any iMn device can't be installed in the bottom two slots of iConZ-6 devices.

The Synapse Rig will give you a warning if it detects a bad device configuration.

Module Removal Instructions

1. Turn the power switch on the back of the iCon to the Off position.

iCon4 with power switch off

2. Loosen the four thumbscrews on the sides of the iCon.
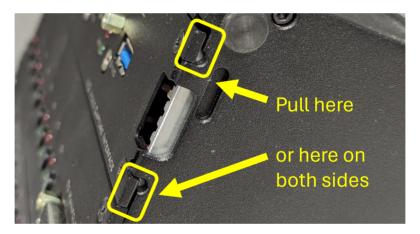
Location of thumbscrews on iCon4

3. Remove the side rails and set them aside.

iCon4 with side rails removed

4. With both hands, use the tabs on the module faceplate to pry straight out.

Location of module pull tabs

Example grip for removing the top module. Pull the module tabs on both sides while bracing against lower modules

If there is already an empty slot, modules can be removed by pulling on the faceplate lip

Removing a module next to an empty slot

iAn BioAmp

iA4 Differential BioAmp

iA4 Overview

The iA4 is a four-channel differential bioamp targeted for use in low-channel-count, low-impedance neurophysiology recordings such as ABR, EEG, EMG, or EKG signals. The bioamp digitizes up to four channels at acquisition rates of approximately ~750 Hz, ~1.5 kHz, ~3 kHz, ~6 kHz, ~12 kHz, ~25 kHz, or ~50 kHz. The amplified digital signal is sent through the iCon or iConZ interface.

Connections to the subject (up to four differential pairs and ground) are made with standard 1.5 mm touchproof safety connectors.

- Manual impedance check buttons simplify testing and debugging of connected electrodes
- Onboard LEDs provide live feedback of the recording (+) and indifferent (-) channel impedances and activity

iA4 Features

There are selectable Sample Rate options of ~750 Hz, ~1.5kHz, ~3 kHz, ~6 kHz, ~12 kHz, ~25 kHz, ~50 kHz or system rate (maximum ~50 kHz). Using the lowest practical rate for your application improves noise performance.

A user-selectable on-board highpass filter has adjustable options of 0.3 Hz, 1 Hz, 2 Hz, 4 Hz, 8 Hz, 16 Hz, 32 Hz, or 64 Hz.

For information on software control of the iA4 and all of its available features, see the Synapse Manual.

iA4 Clip Warnings and Activity Display

The status LEDs above each channel on the iA4 indicate channel activity and clip warning. LEDs for each channel are lit green to indicate an active channel and/or red to indicate a clip warning.

Clip Warning

Analog clipping occurs when the input signal is too large. When the input to a channel is within ~1.5 dB of the iA4's maximum voltage input range the LED for the corresponding channel is lit red to indicate that clipping may occur. This is ~±10.6 mV.

Activity

The activity LED is lit green whenever the channel is enabled.

iA4 Electrode Connectors

Plug the electrodes directly into the standard 1.5 mm touchproof connectors on the front of the iA4.

iA4 Impedance Checking

The impedance checker on the iA4 provides a simple check of the channel impedance relative to ground. The impedance check can either be controlled in Synapse software, or by pressing the **Imp** button on the front panel. The impedance between channel and ground will be shown on the LED indicators.

When controlling impedance check from Synapse, the available frequencies are 100 Hz, 300 Hz, 500 Hz, or 1 kHz. A 100 Hz probe frequency is used when manually pressing the **Imp** button on the front panel of the iA4.

The impedance check alternates between the (+) and (-) channel inputs every ~110 ms and displays the (+) input impedance on the top row of LEDs on the front of the device (red K-Ohms LED row) and the (-) input impedance in the bottom row (green K-Ohms LEDs).

When testing through Synapse software, all active channels are tested simultanously and the highest (+) and (-) impedance of all channels is shown in the K-Ohms LED top and bottom rows respectively.

iA4 Technical Specifications

A/D	Up to 4 channels, 24-bit PCM
Sample Rate	~750 Hz, ~1500 Hz, ~3 kHz, ~6 kHz, ~12 kHz, ~25 kHz, or ~50 kHz
Maximum Voltage In	±12.5 mV
Gain	100x
Frequency Response	3 dB 0.3 Hz - 0.45*Fs (with no additional high-pass filter selected)
Highpass Filter	0.3 Hz, 1 Hz, 4 Hz, 8 Hz, 16 Hz, 32 Hz, or 64 Hz single pole digital filter
Anti-Aliasing Filtering	45% sampling rate
S/N (typical)	80 dB
Input Impedance	100 kOhm

iA16 / iA32 BioAmp

iA16 / iA32 Overview

The iA16 / iA32 is a 16- or 32-channel bioamp with a single reference connection, targeted high-impedance neurophysiology recordings such as extracellular potentials. The bioamp digitizes up to 32 channels at acquisition rates of approximately ~750 Hz, ~1.5 kHz, ~3 kHz, ~6 kHz, ~12 kHz, ~25 kHz, or ~50 kHz. The amplified digital signal is sent through the iCon or iConZ interface.

Connections to the subject are made through mini DB26 connectors to standard headstages or splitter boxes.

• Onboard LEDs provide live feedback of the recording channel activity and impedances

iA16 / iA32 Features

There are selectable Sample Rate options of ~750 Hz, ~1.5kHz, ~3 kHz, ~6 kHz, ~12 kHz, ~25 kHz, ~50 kHz or system rate (maximum ~50 kHz). Using the lowest practical rate for your application improves noise performance.

A user-selectable on-board highpass filter has adjustable options of 0.3 Hz, 1 Hz, 2 Hz, 4 Hz, 8 Hz, 16 Hz, 32 Hz, or 64 Hz. It can also be disabled for DC Coupled recording.

For information on software control of the iA16 / iA32 and all of its available features, see the Synapse Manual.

iA16 / iA32 Activity Display

The channel LEDs are dim green when enabled. At ~25 kHz sampling rate and above, the channel indicators flash green when there is spike activity.

iA16 / iA32 Electrode Connectors

Plug a headstage into the DB26 connector(s) on the front of the iA16 / iA32.

iA16 / iA32 Impedance Checking

The impedance checker on the iA16 / iA32 provides a simple check of the channel impedance relative to ground. The impedance check can either be controlled in Synapse software, or by pressing the **Imp** button on the front panel. The impedance between channel and ground will be shown on the LED indicators.

When controlling impedance check from Synapse, the available frequencies are 100 Hz, 300 Hz, 500 Hz, or 1 kHz. A 100 Hz probe frequency is used when manually pressing the **Imp** button on the front panel of the iA4.

The impedance check alternates between the recording channels and reference channel every ~250 ms and displays the channel input impedances on the front panel LEDs.

iA16 / iA32 Technical Specifications

Analog Inputs

Analog A/D Input	Up to 32 channels, 24-bit PCM
Maximum Voltage In	±500 mV
Gain	2x
A/D Sample Rate	Up to 48828.125 Hz (adjustable in steps of approximately 750, 1500, 3000, 6000, 12000, 25000, 50000 Hz)^
Frequency Response	DC coupled: 0 Hz - 0.45*Fs AC coupled: 0.3 Hz - 0.45*Fs
S/N (typical)	104 dB, single unit, Fs = 25 kHz, 300-7000 Hz 116 dB, differential, Fs = 750 Hz, 0.4-300 Hz
DC offset	<±10 uV
Distortion (typical)	<1%
Input Impedance	AC coupled: 100 kOhm DC coupled: 20 MOhm

^Note: If recording at ~50 kHz on an iA32, only 16 channels are available.
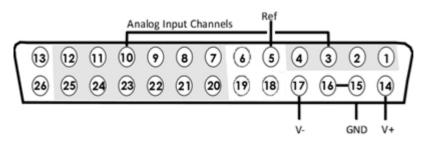
Input Connectors

The iA32 has two 26-pin headstage connectors (analog) on the front of the unit. The connectors are labeled alphabetically from top to bottom. Each connector carries signal for one bank of channels with ground and reference. The corresponding channel numbers depend on the reference mode configuration.

For simplicity sake, the diagrams below assume channels for that connector begin with channel 1. For example, A1 - A16 represent the 16 channels coming from the connected headstage. The user must increment the channel numbers by 16 (or 8 if in Differential mode) according to the mode and position of the connector. So, for the connector labeled 'A', A1 is channel 1 while on the connector labeled 'B', A1 may be channel 17.

Pinout Diagrams

Shared Reference Mode

Pin	Name	Description		Pin	Name	Description
1	A1	Analog Input Channels		14	V+	Positive Voltage (+2.5 V)
2	A2			15	GND	Ground
3	A3			16	GND	
4	A4			17	V-	Negative Voltage (-2.5 V)
5*	Ref*	Reference*		18	NA	Not Used
6	NA	Not Used		19	NA	
7	A5	Analog Input Channels		20	A6	Analog Input Channels
8	A7			21	A8	
9	A9			22	A10	
10	A11			23	A12	
11	A13			24	A14	
12	A15			25	A16	
13	NA	Not Used		26	NA	Not Used

* Pin 5 on both DB26 connectors on the iA32 are shorted together internally.

Differential Reference Mode

> ✏️ **Note**
>
> There are 8 (+) channels and 8 (-) channels per DB26 connector. Subsequent banks are indexed by an additional 8 channels.

Pin	Name	Description	Pin	Name	Description
1	A1(+)	Analog Input Channel	14	V+	Positive Voltage (+2.5 V)
2	A1(-)	Differential Analog Input Channel	15	GND	Ground
3	A2(+)	Analog Input Channel	16	GND	
4	A2(-)	Differential Analog Input Channel	17	V-	Negative Voltage (-2.5 V)
5	NA	Not Used	18	NA	Not Used
6	NA		19	NA	
7	A3(+)	Analog Input Channels	20	A3(-)	Differential Input Channels
8	A4(+)		21	A4(-)	
9	A5(+)		22	A5(-)	
10	A6(+)		23	A6(-)	
11	A7(+)		24	A7(-)	
12	A8(+)		25	A8(-)	
13	NA	Not Used	26	NA	Not Used

> ✏️ **Note**
>
> See Tech Note 0896 before attempting to make any custom connections.

iAn Sample Delay

Depends on iAn and RZ processor sample rates. All units in samples.

iAn rate	RZ @ 50 kHz	RZ @ 25 kHz	RZ @ 12 kHz	RZ @ 6 kHz
50 kHz	21	N/A	N/A	N/A
25 kHz	37	22	N/A	N/A
12 kHz	74	40	23	N/A
6 kHz	146	76	42	24
3 kHz	290	150	78	41
1.5 kHz	577	292	149	78
750 Hz	1154	580	294	150

iD2 Digital Headstage Interface

iD2 Overview

The iD2 is an interface to Intan-based digital headstages. It has two input connectors that can read up to 128 channels each, for a total of 256 channels. All raw data is streamed via USB 3 back to the computer running Synapse and recorded straight to disk.

- The iD2 includes impedance testing functionality for each headstage
- Onboard LEDs provide live feedback of the headstage connection and activity

iD2 Features

The iD2 has selectable sample rate options of ~750 Hz, ~1.5kHz, ~3 kHz, ~6 kHz, ~12 kHz, ~25 kHz or system rate (maximum ~25 kHz). Using the lowest practical rate for your application improves noise performance.

A plot-decimated (highly compressed) version of the raw signal is returned back to the processor and Synapse for visualization of all headstage channels. The plot decimated data consists of the max and min values of a short chunks of points. The rest of the chunk is thrown away. The data rate depends on the System rate and number of channels, but is usually ~300-1500 Hz. This is fine for monitoring the signal for activity and requires very low bandwidth, but is not useful for data analysis.

The plot decimated data can optionally be filtered on the iD2 itself. If the iD2 is running at ~6 kHz or above, you can enable a 100 Hz, 300 Hz, or 500 Hz filter on the device. At lower sampling rates, there is no filter available. At runtime, you can use the filter cutoff frequency as a highpass, as a lowpass, or disable it.

Up to 16 user-selectable channels are returned to the processor and Synapse at the full data rate for real-time processing and visualization.

All raw data is streamed back through the USB to the computer running Synapse.

For information on software control of the iD2 and all of its available features, see the Synapse Manual.

> 🔥 **Important**
>
> The iD2 USB Streaming capability is not compatible with the iPac and SynCon software.

Clip Warnings and Activity Display

The status LEDs above each port on the iD2 indicate headstage connectivity (green) and clip warning (red).

Clip Warning

Clipping occurs when the input signal is too large. When the voltage input to any channel is within ~0.5 dB of the iD2's maximum voltage input range, the LED for the corresponding port is lit red to indicate that clipping may occur. This is ~±4.7 mV.

Activity

The activity LED is lit whenever a headstage is detected on that port.

USB indicators

The USB status LEDs indicate connectivity and error status.

Error

The red Error LED is normally off. It starts blinking if the internal memory buffer gets to 75% full, indicating that there are possible issues transferring data. The LED turns solid red when the buffer is 90% full.

Active

The green LED comes on to indicate a valid USB connection. During preview/record the LED blinks slowly to indicate that data is streaming.

Headstage Connectors

Plug the Intan-based headstage directly into the 12-pin Omnetics connector. Each port supports up to 128 channels.

Impedance Checking

The impedance checker on the iD2 provides a simple check of the channel impedance relative to ground. The impedance check is controlled in Synapse software.

The available probe frequencies are 24 Hz, 48 Hz, 95 Hz, 191 Hz, 381 Hz, 763 Hz, 1526 Hz, or 3052 Hz.

The impedance check continuously loops through the banks of channels and updates the LEDs in Synapse.

iD2 Technical Specifications

RHD2000 series amplifier boards and SPI interface cables are used in TDT's ZD and OD Intan-based digitizing headstages. They are available from Intan Technologies.

> 🔥 **Important**
>
> The specifications below are dependent on the amplifier board. See Intan RHD2000 series website for latest, full performance specifications.
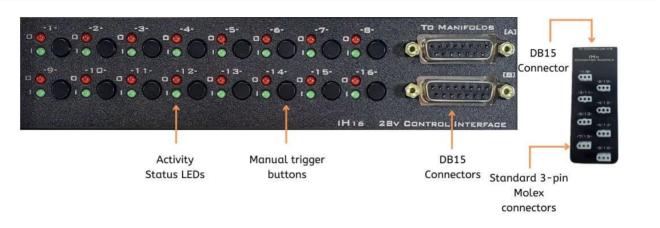
Digital Headstage Inputs	2 (256 channels)
Sampling Rate	Up to ~25 kHz
Frequency Response	0.1 Hz - 10 kHz
Input Range	±5 mV with ZD, OD, and other Intan-based digitizing headstages
Allowable DC Offset	±0.4 V
Focus Sample Delay	9 samples
USB Transfer Speed	>25 MB/sec (256 channels at ~25 kHz)
USB Sample Delay	0 samples

Digital Connectors

The digital input connector is a self-aligning 12-pin Omnetics PZN-12 polarized nano connector that mates directly to an Intan RHD2000 SPI interface cable.

iHn High Voltage Interface

Activity Status LEDs — Manual trigger buttons — DB15 Connectors — Standard 3-pin Molex connectors — DB15 Connector

The iH16 and iH8 modules feature 16 or eight bidirectional interface ports to directly control high-voltage (e.g. 28 V signal) cage elements including Med Associates, Lafayette, and Coulbourn. The iH8 and iH16 modules connect to an iHm, iH8-RJ25PLA/B, or iH8-RJ25A/B manifold via a DB15 cable. The manifold can be placed closer to the behavioral apparatus.

- Each interface port is configurable in Synapse as either inputs or outputs
- Manual trigger buttons on the front panel are used for testing / debugging connected behavioral components
- Status lights make it easy to monitor component activity during sessions

The 'O' LED lights when the port is driven by Synapse, and the 'I' LED lights when the port is driven by Synapse, by an external device, or by the manual button press.

An output port can source up to 1 A maximum. The maximum total output per iHn module is 1 A. The maximum total output per iCon is 3 A.

A previous 10 channel model (iH10) has Molex connectors directly on the face of the device.

For information on software control of the iHn modules, see the Synapse Manual.

Manifolds

The iHn comes with one or two manifolds, which interface with cage elements closer to the subject. They connect to the iHn via provided DB15 cables. There are two types of manifolds: the iHm Manifold has eight 3-pin Molex connectors and the iH8-RJ25A/B Manifolds and iH8-RJ25PLA/B Manifolds have eight 6-pin RJ25 connectors.

iHm Manifold

The iHM uses 1.57 mm diameter standard Molex pin and socket connectors.

iHm Manifold Molex Pinout

Pin	Name	Description
G	Ground	
S	Signal	Input or output signal
V+	+28 V	+28 V up to 1 A, 3 A max per iCon

As an **Input**, the Signal line floats to +28 V. Short the Signal line to ground to trigger it. As an **Output**, the Signal line floats by default and is shorted to 0 V when triggered.

iH8-RJ25PLA/B Manifold

The iH8-RJ25PLA/B manifolds feature 8 telephone-style 6-pin RJ25 ports to provide direct control of high-voltage (e.g. 28V signal) cage elements from Panlab.

- There are a total of 8 inputs and outputs combined per manifold

- The ports are configurable in Synapse as either inputs or outputs

- Each port has one input and two outputs

The numbers on the faceplate indicate which input channels and output channels are available on that connector. The outputs that are shared between ports are physically shorted together inside the iH8-RJ25. For example, Out 2 on the iH8-RJ25PLA is available on the first two ports and is controlled by the same signal from Synapse.

Similarly, inputs and outputs of the same number are shorted internally. For example, Out1 and In1 share the same signal from the iHn and you can't use both at the same time.
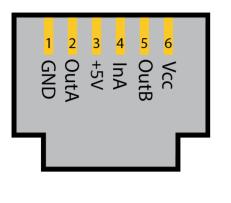
The iH8-RJ25PLA and iH8-RJ25PLB models are electrically identical, but have different channel numbering on the faceplate to match the A and B inputs on the iH16 module.

Typical Configurations

Device Type	Configuration
Up to 8 input-only devices	Connect each device to an RJ25 connector. Configure all 8 as inputs in Synapse
Up to 8 output-only devices	Connect each device to an RJ25 connector. Configure all 8 as outputs in Synapse
4 input-only and 4 output-only devices	Connect the inputs to In1, In3, In5, In7. Connect the outputs to Out2, Out4, Out6, Out8
4 devices with 1 input and 1 output each	Connect to In1 (Out5), In2 (Out6), In3 (Out7), In4 (Out8)

iH8-RJ25PLA/B Manifold Pinout

Pinout looking into the connector

Pin	Name	Description
1	GND	Ground
2	OutA	Output Signal A
3	+5V	
4	InA	Output Signal
5	OutB	Output Signal B
6	V+	+28 V up to 1 A, 3 A max per iCon

iH8-RJ25A/B Manifold

The iH8-RJ25A/B manifolds feature 8 telephone-style 6-pin RJ25 ports to provide direct control of high-voltage (e.g. 28V signal) cage elements from Coulbourn.

- There are a total of 8 inputs and outputs combined per manifold

- The ports are configurable in Synapse as either inputs or outputs

- Each port has one input and up to three outputs

The numbers on the faceplate indicate which input channels and output channels are available on that connector. The outputs that are shared between ports are physically shorted together inside the iH8-RJ25. For example, Out 6 on the iH8-RJ25A is available on the first two ports and is controlled by the same signal from Synapse.

Similarly, inputs and outputs of the same number are shorted internally. For example, Out1 and In1 share the same signal from the iHn and you can't use both at the same time.

The iH8-RJ25A and iH8-RJ25B models are electrically identical, but have different channel numbering on the faceplate to match the A and B inputs on the iH16 module.

Typical Configurations

Device Type	Configuration
Up to 8 input-only devices	Connect each device to an RJ25 connector. Configure all 8 as inputs in Synapse
Up to 8 output-only devices	Connect each device to an RJ25 connector. Configure all 8 as outputs in Synapse
4 input-only and 4 output-only devices	Connect the inputs to In1, In3, In5, In7. Connect the outputs to Out2, Out4, Out6, Out8
4 devices with 1 input and 1 output each	Connect to In1 (Out5), In2 (Out6), In3 (Out7), In4 (Out8)

iH8-RJ25A/B Manifold Pinout

Pinout looking into the connector

Pin	Name	Description
1	V+	+28 V up to 1 A, 3 A max per iCon
2	InA	Input Signal
3	OutA	Output Signal A
4	OutB*	Output Signal B*
5	OutC**	Output Signal C**
6	GND	Ground

> ✏️ **Note**

* Not available on connector 4 or 8
** Not available on connector 3, 4, 7, or 8
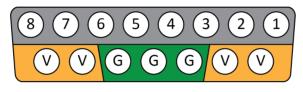
iHMSG

The iHMSG cable interfaces a third-party behavioral control box with the iHm manifolds. It has a DB25 on one end to connect to the third-party system, and two DB15s on the other end to connect to iHm manifolds. The DB15s are labeled "A" and "B" for the upper and lower bits.

DB15 Pinout

If you are not using a TDT manifold and are instead connecting directly to the iH8/iH16 DB15 port, here is the pinout:

iHn A pinout, looking into the connector

Pin	Name	Description	Pin	Name	Description
1	I/O 1	Input/Output 1	9	Vcc	+28 V up to 1 A, 3 A max per iCon
2	I/O 2	Input/Output 2	10	Vcc	
3	I/O 3	Input/Output 3	11	Gnd	Ground
4	I/O 4	Input/Output 4	12	Gnd	
5	I/O 5	Input/Output 5	13	Gnd	
6	I/O 6	Input/Output 6	14	Vcc	
7	I/O 7	Input/Output 7	15	Vcc	
8	I/O 8	Input/Output 8			

All Ground pins are shorted together. All Vcc pins are shorted together.

The B connector on the iH16 is identically wired, except Pins 1-8 are I/O 9-16.

iL24 Digital Logic Interface

The iL24 module can communicate with external behavioral components using 24 bits of 5 V or 3.3 V TTL logic signals. There are 12 input bits and 12 output bits. Each direction has 4 addressable bits and 1 addressable byte.

- There are four bit-wise inputs and four bit-wise outputs available with BNC connectors and status light for each

- The DB25 connector has access to all 24 addressable bits

- Two rows of 8 status LEDs on the front panel show the state of the word input and output bits

- The front panel switch toggles between +3.3 V and +5 V logic for all 24 bits of I/O on the iL24

- Each bit can source up to 6 mA maximum current
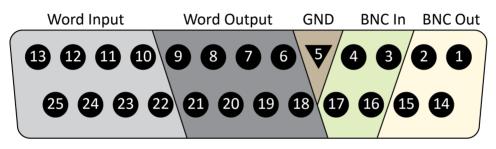
For information on software control of the iL24, see the Synapse Manual.

iL24m Manifold

The iL24 comes with a manifold of BNC connectors for easier access to the Word Input and Word Output bits.
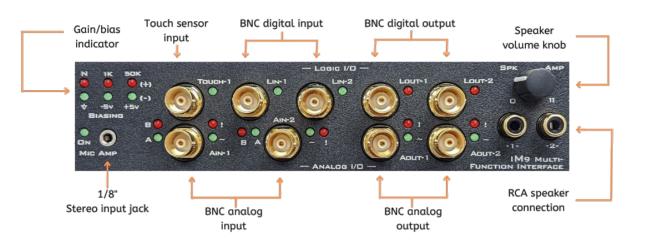
DB25 Pinout

iL24 pinout, looking into the connector

Pin	Name	Description	Pin	Name	Description
1	BO1	BNC Output	14	BO2	BNC Output
2	BO3		15	BO4	
3	BI1	BNC Input	16	BI2	BNC Input
4	BI3		17	BI4	
5	GND	Ground	18	DO0	Word Output
6	DO1	Word Output	19	DO2	
7	DO3		20	DO4	
8	DO5		21	DO6	
9	DO7		22	DI0	Word Input
10	DI1	Word Input	23	DI2	
11	DI3		24	DI4	
12	DI5		25	DI6	
13	DI7				

iMn Multi-Function Interface

The iM5, iM7, iM8, iM9, iM14, and iM15 have specialized I/O functions, including advanced audio processing critical for auditory behavioral experiments.

- Drive a speaker (e.g. MF1) directly up to 4W via an RCA connection.

- Record cage sounds via an embedded microphone amplifier.

- Connect with many common cage elements (e.g. touch sensors) via BNC ADC inputs and DAC outputs.

- Generate AM and FM stimulation (excludes iM10*)

* For information on the iM10, see iM10 Multi-Function Interface.

Feature Table

	Analog In	Analog Out	Digital In	Digital Out	Touch Inputs	Accessory Port
iM5	1	1	1	1	-	-
iM7	1	1	1	1	-	Medusa Amp
iM8	2	2	1	1	1	Medusa Amp
iM9	2	2	2	2	1	-
iM14	1	1	1	1	-	iH8 +28 V*
iM15	2	2	1	1	1	iH8 +28 V*

* The +28 V logic includes four output bits and four input bits.

For information on software control of the iMn and all of its available features, see the Synapse Manual.

Digital Inputs

The iMn has one or two +3.3 V TTL inputs.

Digital Outputs

The iMn has one or two +3.3 V TTL outputs that can source up to 6 mA maximum current.

Touch Inputs (Optional)

The iM8 and iM9 have a touch sensor input. This input has an independent ground. It uses a 750 nA current and triggers if the measured impedance between the input and ground is <=10 MOhm.

Analog Inputs

The iMn has up to two ±5 V analog inputs. The inputs have an optional microphone amplifier with 56.6 dB, 66.6 dB, or 76.6 dB gain and attack/release ratios of 1:500, 1:2000, 1:4000.

> ✏️ **Note**
>
> The input signals are inverted when using the microphone amp input.

The iMn analog inputs have adjustable input impedance and bias voltage. The options include:

Non-Inverting Input:

- Normal (10 kOhm to Ground)
- Positive Bias (1 kOhm to +5 V)
- Positive Bias (50 kOhm to +5 V)

Inverting Input:

- Ground
- Negative Bias (100 Ohm to -5 V)

• Positive Bias (100 Ohm to +5 V)

> ✏️ **Note**
>
> If the amplifier is enabled on an input channel, the bias setting is ignored and the defaults are used

> 🔥 **Important**
>
> DO NOT connect anything to the microphone input if you aren't using it.
> Do NOT connect anything to the BNC inputs when the microphone amp is enabled.

Each analog input has two LEDs. The top LED is a clip light that flashes if the input signal is >~4.75 V. The bottom LED is a signal LED that will light when that processed input triggers.

The iMn input processor runs at 400 kHz, independent of the RZ / iConZ sampling rate, for increased complex waveform processing of higher bandwidth signals. See the Synapse Manual for the full list of options.

Analog Outputs

The iMn generates a pre-programmed waveform when triggered. This includes DC Voltage, Tone, White Noise, Pink Noise, Square, Clock, PWM signal, or a user-defined waveform. Real-time amplitude and/or frequency modulation is possible. See the Synapse Manual for the full list of options.

The iMn-generated waveforms use a ±5 V amplitude. Apply up to 50 dB attenuation to each individual output, adjustable at run-time. The iMn onboard analog processor runs at 800 kHz, independent of the RZ / iConZ sampling rate, to achieve higher bandwidth signals than possible on the DSP.

The signals generated by Output 1 and Output 2 can be mixed to play out of a single speaker.

Each Output has two LEDs. The top LED is a clip light that flashes if the output signal is >=4.9 V. The bottom LED is a signal LED that will light when that output is enabled.

The RCA connectors can directly drive speakers. These connectors are driven differentially to provide more power. The RCA connectors should only be connected to speakers. If you are controlling an external amplifier then use the BNC output connectors.

Medusa4Z Input (Optional)

The iM7 and iM8 modules have a fiber optic input for a Medusa4Z Bioamp for up to four channels of ephys data. If the iMn module is inside an iConZ, the sampling rate is limited to ~6 kHz. For an iCon, the Medusa4Z can run at up to ~25 kHz sampling rate.
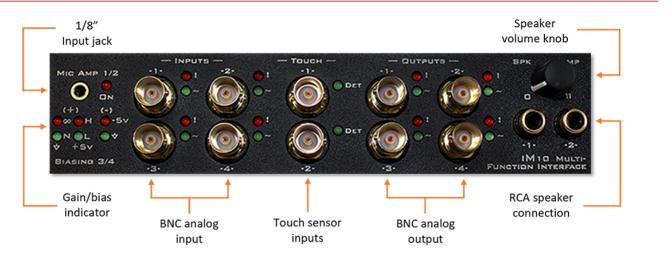
iHm Manifold Interface (Optional)

The iM14 and iM15 modules have a DB15 port that connects to an iHm manifold. There are four +28 V outputs that map to 1-4 on the manifold and four +28 V inputs that map to 5-8 on the manifold. See iHn High Voltage Interface for more information.

iMn Technical Specifications

Digital Inputs	Up to 3 inputs
Threshold Voltage	1.7 V
Input Delay	4 samples
Digital Outputs	Up to 2 outputs
Output Voltage	3.3 V, 6 mA max load
Output Delay	5 samples
D/A	Up to 2 channels
Sample Rate	Up to ~800 kHz
Voltage Out	±5 V
Output Impedance	10 Ohms
Output Delay	7 samples
A/D	Up to 2 channels
Sample Rate	Up to ~400 kHz
Frequency Response	DC - 0.45 * Fs (Fs = sample rate)
Voltage In	±5 V
Input Impedance	100 kOhms, adjustable. See Analog Inputs
Input Delay	6 samples

iM10 Multi-Function Interface

The iM10 has multiple specialized I/O functions, including advanced audio processing for auditory behavioral experiments.

- Drive a speaker (e.g. MF1) directly up to 4 W via an RCA connection.

- Record cage sounds via an embedded microphone amplifier.

- Connect with many common cage elements (e.g. touch sensors) via BNC ADC inputs and DAC outputs.

- Streamline setup with a range of embedded signal processing options.

The iM10 analog input / output range is ±5 V. The onboard analog processing runs at 400 kHz, independent of the RZ / iConZ sampling rate.

For information on software control of the iM10 and all of its available features, see the Synapse Manual.

Inputs

The iM10 has four analog inputs. Inputs 1 and 2 have a 50 kOhm input impedance and feature an optional microphone amplifier with 56.6 dB, 66.6 dB, or 76.6 dB gain and attack/release ratios of 1:500, 1:2000, 1:4000. When using the microphone amp input, note that the input signals are inverted.

> 🔥 **Important**
>
> Do not connect anything to the BNC Inputs 1 and 2 when the microphone amp is enabled, and do not connection anything to the microphone input if you aren't using it

Inputs 3 and 4 have a 10 kOhm input impedance by default with optional adjustable input impedance and bias voltage. Options are:

- 10 kOhm to Ground
- 1 kOhm (+5 V positive bias)
- 50 kOhm (+5 V positive bias)
- infinite input impedance

The inverting input (BNC shell) can either be tied to Ground or a -5 V negative bias.

Add up to 76.6 dB gain to the signal on each individual input.

Each Input has two LEDs. The top LED is a clip light that flashes if the input signal is >~4.75 V. The bottom LED is a signal LED that will light when that processed input triggers.

Touch Inputs

The iM10 has two touch sensor inputs. These have an independent ground. They use a 750 nA current and trigger if the measured impedance between the input and ground is <=10 MOhm.

Outputs

The iM10 has four analog outputs. The outputs have a 10 Ohm output impedance. Output a pre-programmed set of waveforms (DC Voltage, Tone, White Noise, Pink Noise, Square, Clock, or PWM), or a user-defined waveform. See the Synapse Manual for the full list of options.

Outputs 1 and 2 are paired. This means the choice of waveform shape for Output 2 can be limited depending on the selected waveform for Output 1. Also, the signals generated by Output 1 and Output 2 can be mixed to play out a single speaker.
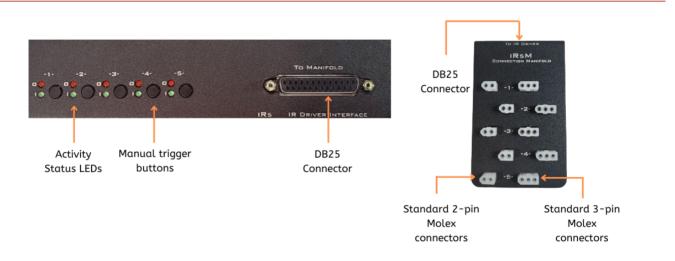
Likewise, Outputs 3 and 4 are also paired.

The iM10-generated waveforms use a ±5 V amplitude. Apply up to 50 dB attenuation to each individual output, adjustable at run-time.

Each Output has two LEDs. The top LED is a clip light that flashes if the output signal is >=4.9 V. The bottom LED is a signal LED that will light when that output is enabled.

The RCA connectors can directly drive speakers. These connectors are driven differentially to provide more. The RCA connectors should only be connected to speakers. If you are controlling an external amplifier then use the BNC output connectors.

iRn IR Driver Interface

Activity Status LEDs   Manual trigger buttons   DB25 Connector

DB25 Connector

Standard 2-pin Molex connectors   Standard 3-pin Molex connectors

The iR5/iR10 is a specialized interface for up to five or ten infrared sensor beams. This module has built-in power and logical connections to drive external IR sensors. It sends TTL events whenever the subject crosses the beam, without the need for any external signal processing.

- Manual trigger buttons for each IR port simplify testing and debugging

- Status lights for each IR beam monitor subject movement during sessions.

For information on software control of the iRn, see the Synapse Manual.

Manifolds

The iRn connects to a manifold via a DB25 cable.

iR5M Molex Manifold

iR5m-RJ RJ22 Manifold

iRSD38

The iRSD38 is a 38kHz IR driver and sensor combination that connects to the iR5m-RJ / iR10m-RJ manifolds to form a beam break. The drivers have a red band around them and the sensors have a blue band. The modules have two mounting holes for flathead #4 screws. Standard cable length is 42".

iRSD38 Sensor and Driver

Output Power

The IR LED output power is adjustable through Synapse software configuration (1-8). This adjusts an in-line resistor value from 4 kOhm to 500 Ohm. Power output depends on this power setting and the voltage drop of the LED. The table below shows the supply current for a typical IR LED with a 1.4 V voltage drop.
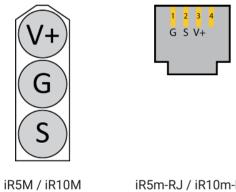
Setting	Supply Current (mA)
1	0.9
2	2.7
3	4.5
4	6.3
5	8.1
6	9.9
7	11.7
8	13.5

Sensor Input

The sensor power output has a 10 ohm resistor in line. The output voltage changes with the current draw as follows:

Current Draw (mA)	Voltage
1	3.29
3	3.27
10	3.2
30	3
100	2.3
300	0.3

Receiver Pinout

iR5M / iR10M   iR5m-RJ / iR10m-RJ
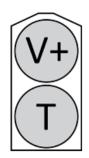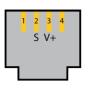
Pin	Name	Description
V+	Sensor power	+3.3 V with 10 Ohm in-line resistor
G	Ground	
S	Sensor	Sensor output

When the Sensor output is pulled low, it triggers the event.

Driver Pinout

iR5M / iR10M   iR5m-RJ / iR10m-RJ

Pin	Name	Description
V+	Driver voltage	+5 V output with a variable in-line resistor
T	Toggle line	Determines if power output is on

iS9 Aversive Stimulator

The iS9 generates small electrical currents for standard behavioral conditioning experiments, such as startle and Pavlovian fear response. Timing is precisely controlled for pairing the stim with other sensory cues or behavioral events. The iS9 is compatible with 3rd party behavioral boxes (Med Associates, Lafayette, and Harvard Apparatus).

- Deliver current from 0 mA – 2.5 mA in 0.01 mA steps to each of 9 metal floor grids in rapid succession.

- Detect spout licks with built-in touch sensors (decoupled at stimulation to avoid false responses).

- Detect null events when stimuli fail to reach the subject.

- Automatically time-stamp stimulus and behavioral event information for on- and off-line analysis.
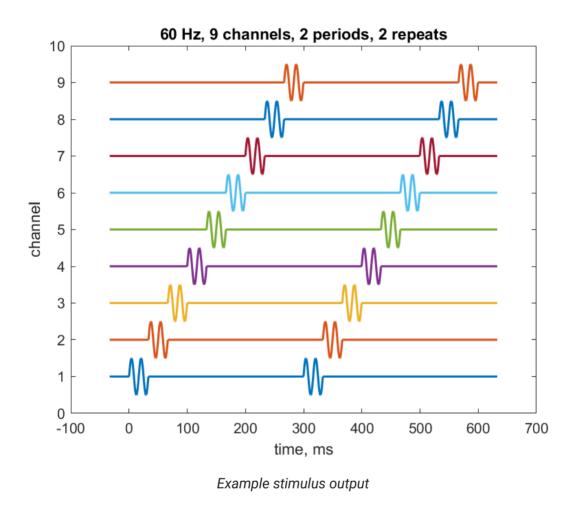
For information on software control of the iS9 and all of its available features, see the Synapse Manual.

iS9 Touch Inputs

The iS9 has two banana jack touch sensor inputs. They use a 750 nA current and trigger if the measured impedance between the input and ground is <=10 MOhm. The touch inputs are disabled during stimulation to avoid false detections.

iS9 Outputs

The iS9 outputs a specified current at 50 Hz or 60 Hz on up to 9 channels sequentially. Specify the desired duration of the waveform on each channel (in periods of the sine wave) and the number of times to repeat the entire scan (or on/off continuous).

Example stimulus output

These settings are all controlled in Synapse software. See the Synapse Manual for the full list of options.

Manual Operation

By default, the "Manual" button on the face of the iS9 presents a 1 mA, 1 period waveform, cycling all 9 channels continuously while pressed. During an experiment, the iS9 uses the stimulus parameters defined within Synapse.

Maximum Current: 2.5 mA into 50 kOhm load

The Pass/Fail LEDs indicate whether a subject was detected during the stimulation.

> 🔥 **Important**
>
> The output currents are calibrated to a 50 Ohm grid rod. The output does not scale linearly, so using a lower load may cause false positives on the 'Pass' LED because the voltage output is small

iVn Video Capture Interface

The iV1/iV2 iCon modules connect to USB3 cameras to record video frames synchronized with all behavioral, electrophysiology, fiber photometry, and other research data. Record video from up to two cameras simultaneously per iV2 module or one camera per iV1 module. The iV2 also features real-time subject tracking.

Camera Options

USB3CAM Kit for iV2

Each kit includes:

- One Basler ace 2 a2A1920-160ucBAS color camera w/ IR filter and lens
- A 3 meter locking USB cable and camera sync cable

USB3CAM_MONO

Each kit includes:

- One Basler ace 2 a2A1920-160umBAS monochrome camera and lens*
- A 3 meter locking USB cable and camera sync cable

* requires iV2 v1.3 firmware or above. See Software Updates

iV1_CAM Kit

Each kit includes:

- One Basler dart daA1920-30uc color camera and IR filter lens
- A 3 meter locking USB cable and camera sync cable

iV1_CAM_MONO Kit

Each kit includes:
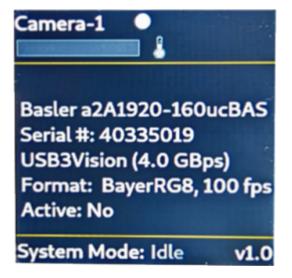
- One Basler dart daA1920-30um monochrome camera and lens
- A 3 meter locking USB cable and camera sync cable

Status Lights

Each camera has an Error and Active LED. All Err and Act LEDs will flash during the boot process, or if the iCon has no communication.

LCD Screen

Press the Info button to toggle between live view and camera information

Camera Information

Recording Status

Frame Buffer

Synapse triggers asynchronous frame grabs during acquisition. The iVn has an onboard 10 second frame buffer that allows it to catch up after periods of rapidly changing images. A small progress bar indicator on the LCD screen shows the state of this buffer. If it fills up, you will see Frame Errors in the Synapse run-time tab, indicating lost frames. The frame buffer is shared by both cameras on an iV2.

Temperature Indicator

Next to the status bar is a temperature sensor. Make sure the iCon housing the iVn has adequate room to dissipate heat.

Camera Status

LED status	Camera Status
hidden	no camera detected
gray	detected but not running
red	running with errors
yellow	running but not capturing frames
blue	running and capturing frames

Compression

The iVn streams data at a fixed bit rate, determined by the Compression Quality setting in Synapse. The value ranges from 1 to 5, which corresponds to 2.5 MB/minute to 22 MB/minute. Therefore the size of a 30-minute video ranges from ~75 MB to ~660 MB depending on this setting. The actual quality of each frame (pixelation) will depend on how much movement there is in the image, like you would see with any live camera feed streaming at a fixed bit rate.

Compression	MB/minute
1	2.5
2	3.7
3	7
4	14.5
5	22

The iVn generates mp4 files with three choices of encoding: H264, H265, MJPEG. The max FPS is limited by the choice of the encoder. H264 is around twice as efficient as H265 or MJPEG without a perceived difference in quality, so you can get twice the frame rate using H264.

iV2 Example Frame Rates

A single camera running on the iV2 using H264 encoding can record 1920 x 1200 @ 40 FPS, 1280 x 1024 @ 60 FPS, or 640 x 400 @ 200 FPS. If you're running two cameras per iV2, then cut those FPS numbers in half. Each camera can run at independent resolutions and frame rates.

iV1 Example Frame Rates

The iV1 camera can record at 1920 x 1080 @ 25 FPS, 1280 x 1024 @ 40 FPS, or 640 x 400 @ 120 FPS. There may be some frame errors during initial startup at higher frame rates.

IR Support

In addition to the monochrome camera options listed above, current users with the a2A1920-160ucBAS color camera can also optionally remove the IR filter from the camera itself following the instructions here.

Software Updates

In case the iVn needs a software update, here is the procedure:

1. Copy the files provided by TDT to a USB drive.

2. Insert the USB stick into the iVn.

3. The iVn will automatically update itself. After ~5 minutes, the iVn screen will indicate that it is finished.

4. Remove the USB drive, and the iVn will reboot itself to complete the process.

5. Verify that the new software version number is correct on the iVn screen.

Software Control

See the Synapse Manual for software control, including how to set up real-time subject tracking for iV2.

Converting MP4 to AVI

The iVn only records MP4 files. To convert MP4 to AVI, you can use FFmpeg. This example will convert all the MP4 files in a folder/subfolders into AVI files with similar quality.

1. Download FFmpeg (https://www.ffmpeg.org/download.html). On Windows, the latest version can be downloaded from this github link.

2. Extract the contents onto your hard drive. In the example below, FFmpeg was extracted onto the `D:\` drive, and the tanks that will be converted are located in the `D:\Tanks` directory.

3. Copy the code below into Notepad, adjust the "FFMPEG" and "SOURCE" variables as needed. Save it as MP4toAVI.bat on your desktop.

4. Close the MP4toAVI.bat file and then double-click it on your desktop to run the commands.

```
@echo off
setlocal enabledelayedexpansion
set FFMPEG=D:\ffmpeg-master-latest-win64-gpl\bin\ffmpeg.exe

REM Set the source folder path
set "SOURCE=D:\Tanks"

REM Loop through each MP4 file in the source folder and its subfolders
for /r "%SOURCE%" %%F in (*.mp4) do (
    REM Extract the base name of the file (without extension)
    set "basename=%%~nxF"

    REM Remove the .mp4 extension and add .avi
    set "outputfile=!basename:.mp4=.avi!"

    REM Construct the full path for the output file
    set "outputpath=%%~dpF!outputfile!"

    REM Output the input and output file names to the console
    echo Converting: %%F to !outputpath!

    REM Perform the conversion using FFmpeg
    %FFMPEG% -y -i "%%F" -vcodec copy -acodec copy "!outputpath!"
)

endlocal
```

iX6 Lux Optical Interface

iX6 Overview

The iX6 iCon module drives integrated LUX LEDs and records fluorescent responses for fiber photometry and optogenetics applications. It has three built-in current driver outputs for driving integrated LEDs directly, or external LEDs connected to an M8 cable. It has has two input slots for photosensors, M8, or BNC inputs, and an additional input slot for a power meter.

The Activity LEDs illuminate when the Lux components are powered on and active.

See the Lux hardware manual for more information and technical specifications.

See the Synapse Manual for software control.

iPac Multi-Node Behavioral Controller

iPac6 shown - iPac Includes Keyboard, Mouse, and Monitor (not shown)

iPac Overview

The iPac controls multiple behavioral cages from one workstation. Inside the box there is a master computer running four (iPac4), six (iPac6), or eight (iPac8) virtual machines. Each virtual machine is running a full Windows 10 or 11 operating system with TDT's Synapse software and has a direct connection to the iConZ Behavioral Controller Interface integrated *RZ3* processor via USB. The RZ3 processor includes two DSP cores which are optimized for real-time behavioral control.

The master computer runs an application called *iPacConsole* that connects to all iPac node virtual desktops. Each node runs a special version of Synapse called SynCon that connects to the RZ3 and attached iConZ. There is a 1 TB shared drive that serves as the TDT data storage for all the node computers.

Power and Interface

The iPac comes factory installed with USB 3 interface cards to connect to iConZ devices.

The power supply is auto-switching for 110 V or 220 V. Soft on/off buttons for the master computer are on the front panel and a hard power cutoff switch is on the back panel. The Master power button turns on all nodes and the Master. A brief press (<1 second) of the Master power button initiates Windows shutdown on the Master and all nodes.

Hardware Setup

Use the provided USB type C to A cables to connect the TDT iConZ devices to the iPac USB ports labeled Node-1 to Node-8. Multiple iConZ connections should be placed in order, starting with Node-1 at the top.

iConZ Connected to Node-1 on the iPac

iPac Features

Status Lights

iPac Front Panel LEDs

The Master LED is blue when powered on. The LEDs for each node indicate the following status information:

0-100%	
Solid Blue	Experiment progress of time elapsed (see note)
Error	
Solid Red	Error in communication between the master PC and a sub node
Blinking Red	Error in communication between node and SynCon During Preview mode to indicate no data is being saved
Active	
Solid Green	Node is active
Blinking Green	Preview or recording in progress

> ✏️ **Note**
>
> The blue progress LEDs can indicate several things depending on the experiment configuration:
>
> 1. If a progress bar Pynapse control named "Progress" has been created, the blue LEDs will show the value of that bar (0-100).
>
> 2. If using Session Mode Controls in Pynapse, the LEDs will indicate session progress.
>
> 3. If neither of the above are used, the LEDs will indicate elapsed time. If less than one hour has elapsed, each 20% increment represents 12 minutes. After one hour, each 20% increment represents two hours up to a maximum of 10 hours (100%).

Hard Drives

The Master PC system hard drive (C:) ships with Windows 10 or 11 and TDT's iPacConsole Software.

The Master shared drive (D:) is available to all the nodes. To connect to the shared drive from a node, navigate to the node's `Z:\` drive. It is used for saving data and subject/experiment sharing. See Tank Data Location and Sharing Experiments and Subjects below.

The shared drive is also accessible to other computers on the same network as the iPac. To navigate to the shared drive from another computer on the network, navigate to `\\IP{NNNN}-MASTER\Shared\` in Windows Explorer, where `{NNNN}` is the iPac serial number. If prompted, connect as user `iPacMaster` (default password is `tdt`).

Video Support

The iPac has four Mini DisplayPort outputs. It comes with a 34" ultra-wide monitor.

Input/Output Connections

The iPac includes one front panel USB 3.1 port for data transfer, and four USB 3.2 Gen 2 ports on the back for mouse, keyboard, and other USB devices. It includes Gigabit Ethernet ports for external networking. Two USB extension cables are included so the keyboard and mouse can be farther away from the iPac. The extension cables are not compatible with iConZ devices and should only be used for the mouse and keyboard.

Back Panel Connections

1. AC Power Cord Input

2. On/Off Switch

3. USB ports for mouse/keyboard

4. Ethernet ports

5. iConZ USB links

6. Mini DisplayPort Video Output

7. Covered DVI Port - *do not use*

> ✏️ **Note**
>
> The provided mouse and keyboard connect via the USB ports labeled "3" above. iConZ devices should ***only*** be used on USB ports labeled Node1-8, labeled "5" above.

iPac Master PC Technical Specifications

CPU	Intel 12th gen i7-12700k
Memory	64GB DDR5 RAM
Video	NVIDIA T1000 with 4x Mini DisplayPort
OS Hard Drive	1TB M.2 NVME - hosts Proxmox OS & all VMS
Data Storage	1TB SSD - Full passthrough storage drive for tanks shared via master VM
Operating System	SN >1015: Proxmox VE 7.4 running up to 9 instances of 64-bit Windows 11 SN <1016: Proxmox VE 7.4 running up to 9 instances of 64-bit Windows 10
Software	iPacConsole & SynCon
Network	Two Gigabit Ethernet port
USB	4x USB 3.2 Gen 2 ports (back) for keyboard and mouse, 1x USB 3.1 on front for data transfer
Keyboard	Das Keyboard Model S Mechanical Keyboard with two port USB hub
Mouse	Logitech G502 SE

iPac Operation

1. Press the master power on the front of the unit. This powers on the Master computer and all nodes.

2. A black Proxmox login page will be displayed first and will automatically log in after a short period of time. No input from the user is necessary here. Wait for the standard Windows login page and log in as user `iPacMaster` (the default password is `tdt`).

> 🔥 **Important**
>
> It is normal for the screen to remain black or on the Proxmox login screen for 5-10 minutes during boot. The iPac is continuing the startup process in the background. No user input is needed until the Windows login screen.

3. Launch **iPacConsole** after logging in. This is used to remotely connect to all the nodes. After launch, the nodes will begin connecting one by one. This example uses an iPac6:
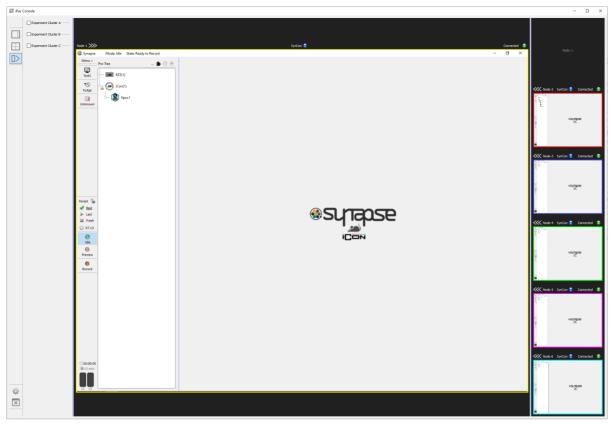
iPac6 With Disconnected Nodes

4. Click on the `<<<` symbol above a node to enlarge it.

iPac6 With Connected Nodes

The remote desktop status is shown at the upper right of each node screen. Clicking the connection status will disconnect a connected node or attempt to reconnect a disconnected node. Occasionally the connection may fail to initialize. If a node repeatedly fails to connect, try closing iPacConsole and starting it again, or rebooting the iPac.

5. Each node can be used like a standalone Windows computer connected to an iConZ. See SynCon Software below for more information.

6. Click the [X] icon on the lower left of iPacConsole to close it.

7. Safely shut down the entire system by briefly (<1 second) pressing the Master power button. This initiates a standard Windows shutdown on all nodes and the Master. Do not use the Windows start menu to shut down or restart, this will not turn off the hardware.

iPacConsole Settings

Click the gear icon on the bottom left toolbar to open the iPacConsole settings. Here you can change the screen resolution for each node.

iPacConsole Settings
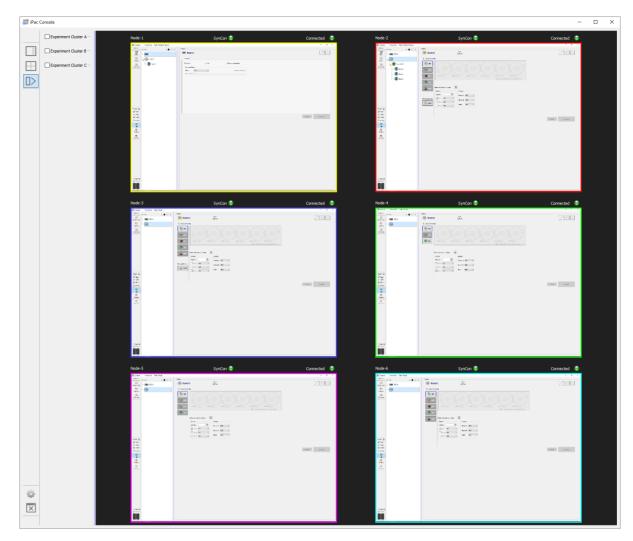
Node Desktop Layout

On the left toolbar of the iPacConsole there are node layout options. There are two default layouts to choose from. Nodes are ordered from left to right and from top to bottom.

	Single Focus Layout	Maximizes one of the nodes on screen
	All Focus Layout	Shows all the nodes equally sized
	Experiments	Show or hide experiments panel

iPacConsole All Focus Layout on iPac6

Using Experiment Clusters

Experiment clusters allow for up to three different experiments to be run at the same time across any combination of nodes and subjects.

1. Click the experiment cluster button ▯▷ on the left toolbar of iPacConsole to open the experiment cluster panel.

Experiment Cluster Options In iPacConsole

2. Select the checkboxes based on how many different experiments you want to run simultaneously.

3. Use the checkboxes to select the nodes you want to run the experiment. Nodes can only be assigned to one cluster at a time.

4. Select the experiment and subjects using the dropdown lists. The subject numbers correspond to the node numbers that were selected. Experiments and subjects created or

modified in any node will be available here once the automatic upload to the shared drive is complete. See Sharing Experiments and Subjects below.

    a. The rat icon next to a subject will be green when the node is ready to Preview or Record and blue while running. A grey icon indicates the subject is not available or an error has occurred.

5. Use the Preview and Record buttons will start running the selected experiment on all the selected nodes. This will automatically send the selected subjects and experiments to SynCon on the selected nodes. Separate experiment clusters can be started and stopped independently of one another.
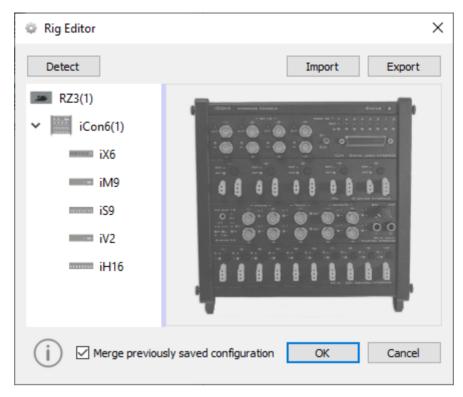
> ✏️ **Note**
>
> The experiments on each node are started sequentially and there may be a slight delay between the start of a recording from one node to another.

SynCon Software

SynCon is a special version of Synapse with the following key differences:

- Runs at 6 kHz sampling rate only
- Includes Base Synapse, Fiber Photometry, and Pynapse Coder Synapse Packages
- The rig contains only the RZ3 and detects the attached iCon modules

Rig Editor for a Single Node
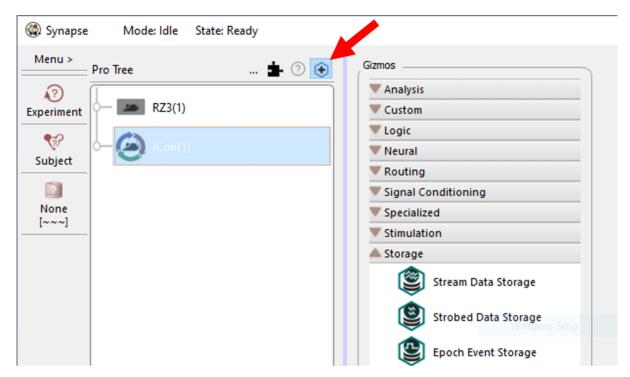
• Unnecessary preferences are removed from the menu. This includes:

  ◦ User accounts

  ◦ Clustering options

  ◦ Corpus options

Accessing SynCon Gizmos

By default, the gizmo panel in SynCon is hidden to maximize screen space. It can be opened by clicking the gizmo plus icon ⊕ above the processing tree.

Gizmo Panel Button Location

Tank Data Location

SynCon is configured to write its tank data to the shared drive on Master. Each node writes to this tank on the shared drive (`Z:\Tanks`).
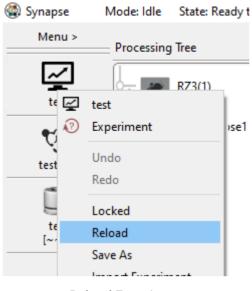
Node-1 Data Saving Preferences Menu

Temporary preview data will be written to `Z:\Tanks\Syncon_Previews\Node-{n}`, where `{n}` is the node number. Data stored here will be removed when the Preview ends.

Sharing Experiments and Subjects

Experiments and Subjects that are not marked as "Private" are shared between the nodes. When an experiment or subject changes on one node, it is written to the Shared folder on the master shared drive (`Z:\Shared\` from the node). Other nodes running Synapse see this and import the updated experiment or subject into their own database.

If other nodes already have that experiment selected, it will be cleared and can be re-loaded manually or by using the experiment cluster panel.

Reload Experiment

> 🔥 **Important**
>
> For experiment and subject sharing to work, ***do not*** start your experiment name with `Experiment` or the subject name with `Subject`.

Per-Node Experiment Configuration

Some iCon modules will require manual configuration in SynCon on each node they are attached to.

iVn

Each iVn camera requires a reference video. Instructions can be found in the iVn manual. This should be repeated for all cameras attached to a node. Video frame rate and resolution settings need to be set individually and do not sync between nodes.

11. Computer Workstations

WS4/WS8 Computer Workstation

Workstation Includes Keyboard and Mouse - Not Pictured

WS Overview

The TDT WS computer workstations are rack-mountable and purpose-built for research applications, experiment control and data analysis. Each WS is equipped with a TDT Optibit interface and comes pre-installed with TDT software.

The WS also includes at least one removable 1 TB hard drive. Additional storage drives are available from TDT.

The WS is available in two configurations. The WS8 is optimized for the most demanding applications, including high-channel count neurophysiology. The WS4 is targeted for less demanding applications, such as ABR and DPOAE testing with BioSigRZ software or fiber photometry. Both form factors include two Gigabit Ethernet network ports for integration with existing lab infrastructure or external device support.
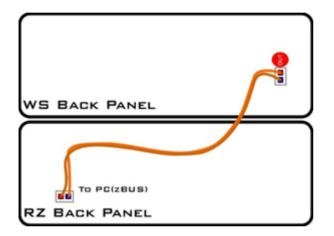
Power and Interface

The WS comes factory installed with an Optibit optical interface card.

The power supply is auto-switching for 110 V or 220 V. A soft on/off button is provided on the front panel and a hard power cutoff switch is provided on the back panel.
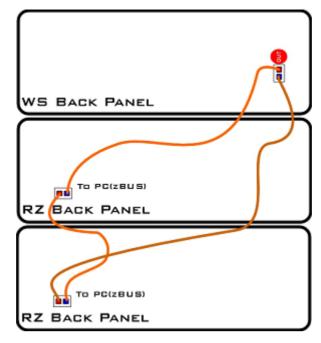
WS Hardware Setup

Use the provided duplex fiber optic patch cables (orange) to connect the WS's factory-installed optical interface card to a TDT processor device. The fiber optic ports on each device and the patch cables are color-coded and use key and notch connectors to ensure correct wiring.
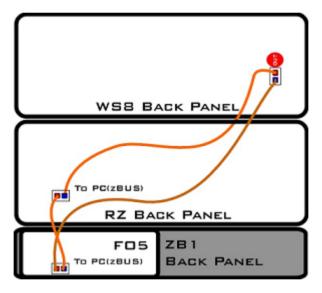
Connecting Multiple Devices
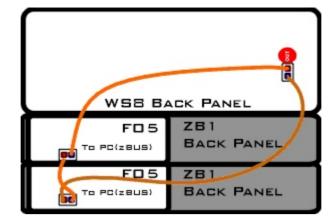
Multiple processors (or other interface-dependent devices mounted in a zBus chassis) can be connected to the WS's Optibit interface in a communications loop. The most common configuration consists of multiple RZ devices, such as multiple RZ2s used for processing higher-channel counts. The strands of the duplex cable can be separated as needed to make the required connections. See the diagrams below for additional configurations.

Multiple RZ Processors

Mixed RZ and RX or RP Processors

Multiple ZB1 Mounted Devices (RX, RP, PA5)

WS Features

LED Display

The LED display provides visual representation of system performance. The display includes 12 angled lines of LEDs representing percentage of performance capacity in use, from 0 - 100%, for each system element. Lines are labeled for quick identification and include indicators for the system elements listed below.

NET-A	Ethernet Port A
NET-B	Ethernet Port B
1-4	Processor Threads 1 - 4
5-8	Processor Threads 5 - 8 (WS8 only)
HDD	System Hard Drive
MEM	RAM Usage

System Hard Drive (C:)

The system hard drive is pre-loaded with 64-bit Windows 10 or 11 and TDT Software that was purchased with the system. For WS SN > 3000, the operating system is on an NVMe drive installed on the motherboard.

For WS devices with SN < 3000, it is labeled as the C: drive and is accessible from the front panel. This is a removable drive, but must be in place for system operation. A blue LED indicates connection and a purple LED indicates when the drive is being accessed.

Data (D: & E:)

The WS supports up to two removable data drives for storage of experiment data. The drives slots are accessible from the front panel and are labeled D: and E: (or DATA1 and DATA2). The standard system ships with one storage drive and additional drives may be purchased separately. Any 2.5" SATA hard drive is compatible. A blue LED indicates connection and a purple LED indicates when the drive is being accessed.

> ⚠️ **Caution**
>
> Do not remove or insert drives while the WS is running.

To remove/insert drives:

1. Turn off the WS.

2. Press upward on the silver button near the bottom of the drive door then lift the door up to open.

3. Pull the drive out or push it into place.

4. Close the drive door, pressing firmly until it snaps into place.

USB Ports

WS serial numbers 3000 and above include two front panel USB 3.2 ports, and four USB 3.2 ports on the back.

WS serial number 2000-3000 include one front panel USB 3.0 port, six USB 3.0 ports on the back, and two USB 2.0 ports on the back.

WS serial number <2000 include one front panel USB 2.0 port and four USB 3.0 ports on the back. See the Connector Panel diagram below for port location. Two USB extension cables are included so keyboard and mouse can be away from the WS.

Video Support

The WS8 and WS4 each include a high-performance video card. The WS8 (SN >3000) supports up to four monitors. The WS4 (SN >3000) supports up to three monitors. The latest WS models have a mini-Display Port to Display Port (DP) adapter and a DP-DP cable instead.

Input/Output Connections

The WS includes standard connections for keyboard, mouse, and audio input/output lines. Two Gigabit Ethernet ports and an RS232 type serial port are also provided.

Back Panel Connections

WS serial number 2000 and above

1. AC Power Cord Input

2. On/Off Switch

3. Connector Panel

4. Video Card with mini-DisplayPort*

5. PO5e Optical Card

6. Unavailable

7. Open PCIe x4, Half-Length Slot
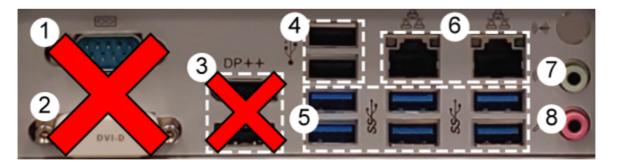
> ⚠️ **Warning**
>
> Do not connect to the motherboard video connections (labeled '3'). Only connect monitors to the graphics card (labeled '4').

> ✏️ **Note**

* Older WS models have DisplayPort (WS8 only), HDMI, and DVI. WS4 (SN >2000) built after approximately 29 June 2021 may have three mini-Display Port connectors instead. WS8 SN>3000 will have four.

Connector Panel

1. Serial (RS232) port	5. USB 3.0
2. DVI-D *	6. Gigabit Ethernet
3. Display Port / HDMI *	7. Audio Line Out
4. USB	8. Mic In

> ⚠️ **Warning**
>
> * Do not connect a monitor to the motherboard video connections (labeled '2' and '3'). Only connect monitors to the graphics card (labeled '4' in the Back Panel Connections).

WS8 Technical Specifications

CPU	SN >3000: Intel Core i7-12700K SN >2000: Intel Core i7-6700K SN <2000: Intel Core i7-3770
Memory	SN >3000: 32 GB DDR5-4400 SN >2000: 8 GB DDR4-2133 SN <2000: 8 GB DDR3-1600
Video Card	SN >3000: NVIDIA T1000 SN >2000: GeForce GTX 1050Ti with 4 GB GDDR5 SN <2000: GeForce GTX 650 with 2 GB RAM
OS Hard Drive	SN >3000: 1 TB NVMe SN <3000: 240 GB Solid State Drive (SSD)
Data Storage	SN >2000: 1 TB SSD, removable (1 included) SN <2000: 1 TB HDD, 7200 RPM, removable (1 included)
Network	Two Gigabit Ethernet ports
Power Supply	650 W
TDT Interface	SN >2000: PO5e card SN <2000: PO5 card
Open Slot	PCIe x4, half-length
Keyboard	Das Keyboard Model S Mechanical Keyboard with two port USB hub
Mouse	Logitech G502 SE
Operating System	64-bit Windows 10 or 11
Software	TDT Drivers, RPvdsEx, and other TDT software as requested

WS4 Technical Specifications

CPU	SN >3000: Intel Core i5-12400F SN >2000: Intel Core i5-6600K SN <2000: Intel Core i5-3570
Memory	SN >3000: 16 GB DDR5-4400 SN >2000: 4 GB DDR4-2133 SN <2000: 4 GB DDR3-1600
Video Card	SN >3000: NVIDIA T400 SN >2000: GeForce GT 1030 with 2 GB RAM Built after appox. 6/29/21: NVIDIA P400 or T400 with 2GB RAM SN <2000: GeForce GT 730 with 2 GB RAM
OS Hard Drive	SN >3000: 1 TB NVMe SN <3000: 240 GB Solid State Drive (SSD)
Data Storage	SN >2000: 1 TB SSD, removable (1 included) SN <2000: 1 TB HDD, 7200 RPM removable (1 included)
Network	Two Gigabit Ethernet ports
Power Supply	650 W
TDT Interface	SN >2000: PO5e card SN <2000: PO5 card
Open Slot	PCIe x4, half-length
Keyboard/Mouse	Microsoft USB Keyboard and Mouse
Operating System	64-bit Windows 10 or 11
Software	TDT Drivers, RPvdsEx, and other TDT software as requested

12. Data Streamers

RS3 Data Streamer

RS3 Overview

The RS3 Data Streamer is a specialized DSP that streams data directly from an RZ2 processor to the PC running Synapse through a USB3 cable. This bypasses the fiber optic connection, improving real-time performance and allowing you to acquire continuous data over several days or weeks.

Each RS3 card can stream up to 256 32-bit channels at rates up to ~25 kHz or 128 32-bit channels at ~50 kHz. Streamed data is stored as individual channels and can be stored in different numeric formats (16-bit integer, 32-bit float). Stored data can be easily reincorporated into the TTank data tank format for post processing, or processed on its own. Multiple RS3 cards can be installed in a single RZ2. An internal USB hub is provided to minimize external USB cable connections to the RZ2.

Hardware Requirements

The RS3 is installed internally on the RZ2 processor. The USB port is accessible on the back panel and must be connected to the same computer that is connected to the RZ2 with the provided locking cable
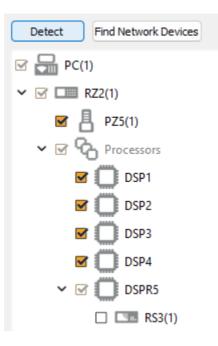
RS3 USB Port
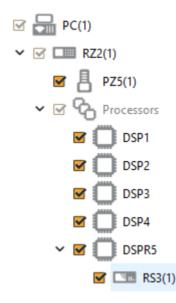
You can connect multiple RS3 cards to the same computer through separate USB cables. Alternatively, TDT provides a USB hub that is mounted inside the RZ2 to connect all of the RS3 cards to a single USB cable.

Synapse Setup

Software control is implemented in TDT's Synapse software. To add an RS3 in Synapse, go to Menu -> Edit Rig. With the RZ2 processor powered on and connected to the PC, click the 'Detect' button. If the Rig Editor sees a DSPR card, it will automatically add an RS3 object underneath it, like this:

By default the RS3 object is unchecked, which means it won't automatically be added to the Processing Tree when you create a new experiment. If you intend to use the RS3 for most of your experiments, check the box next to RS3 now.
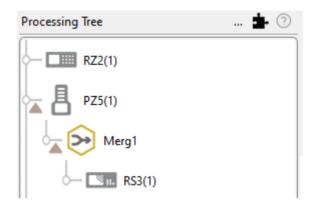
When you exit the Rig Editor, the RS3 will appear in the Processing Tree. Attach it directly to the PZ5 or PZA amplifier to stream the raw data.

RS3 connected to PZ5

Since there is one link in the Processing Tree per RS4 object, if you have the PZ5 or PZA configured with multiple subamplifiers and a single fiber optic to the RS4, you must first merge the subamplifier signals into one large multi-channel signal and connect that to the RS3.

RS3 connected to multiple subamplifiers

RS3 Options

The RS3 object configures data storage from the RS3 to the PC. The object provides settings for the number of channels, storage format, and decimation factor.

RS3 Options

By default, the RS3 uses the RZ2 device sampling rate. You can set a rate manually by clearing the **Sample Rate Max** check box to enable the slider. You can also select the data format and any scaling. If streaming from an analog PZ5 or PZA amplifier, the Float-32 format is recommended due to the large input range and high fidelity. If using a ZD digital headstage or PZ2 amplifier, Integer-16 format with Scaling set to 1e6 is preferred.

Phantom Store generates header information in the data tank. This is useful if you are reading the RS3 data with TDT applications through the tank server. However, this consumes extra hard disk space on your Synapse computer, so if you are going to read the files directly from the RS4 for your own custom analysis then leave this unchecked.

> 🔥 **Important**
>
> If you aren't using TDT applications to read the data saved on the RS3, you don't need to select **Phantom Store**.

Segment Files Every lets you split up the data files automatically at the specified interval. The new file will begin exactly one sample after the previous file. This is useful for long recordings where the user wants access to the raw data for parallel processing before the recording is over.

Run-time Monitor adds a runtime interface that warns you of data errors and USB connection issues, and shows data storage rates.

By default the data is stored in the same block folder as the rest of the recording. Use the **Store Location** option to point the RS3 data files to a different path.

Recording Sessions

When Synapse enters Preview or Record mode, the RZ2 begins streaming data to the RS3 card, and the RS3 begins transferring it to the PC. The Synapse software opens new files and starts saving the raw data to disk. For long recording sessions, the **Segment Files Every** option has several time options to periodically close the currently recorded files and open new data files. This partitions the recording into multiple smaller data files that may be easier to analyze if you are doing long multi- day recordings.

RS3 Storage Format

Data stored with the RS3:

- Contains an *.sev file for each channel recorded in the stream.

- Stores all of the channel data files in a single Data Tank folder.

- Contains a log text file with starting sample, ending sample, and any gaps in the data stream.

These SEV files are typically directly stored within the same local block folder as the rest of the Synapse data, but can be in a different location specified by the **Store Location** option. The SEV files can be read by any TDT application (if Phantom Store was enabled during the recording), or read directly with the MATLAB and Python SDKs.

Naming Convention

The file names include the tank, block, store name (typically RSn1), and channel number. For example, if you are recording channel 1 for the event RSn1 on Block-3 from DemoTank2 the RS3 will store in the following location and format:

```
D:\Tanks\DemoTank2\Block-3\DemoTank2-Block-3_RSn1_ch1.sev
```

> ✏️ **Segmented Files**
>
> When use the segmented files option, the exact length of each file will be a multiple of a fixed block size, based on the sampling rate. It will be as close as possible to the selected setting value (e.g. 1 hr, 4 hr, etc.), but will not be exact. It will be within ~0.1 seconds or so of the exact desired duration, and there will be no overlap in the data at the beginnings and ends of the files.
>
> The files will be named as follows:
>
> ```
> {TANK}_{BLOCK}_{STORE}_ch1.sev
> {TANK}_{BLOCK}_{STORE}_ch1-1h.sev
> {TANK}_{BLOCK}_{STORE}_ch1-2h.sev
> ...
> {TANK}_{BLOCK}_{STORE}_ch2.sev
> {TANK}_{BLOCK}_{STORE}_ch2-1h.sev
> {TANK}_{BLOCK}_{STORE}_ch2-2h.sev
> ...
> ```
>
> If using Phantom Store to use TDT TTank applications to read the data, only the first file chunk will be accessible because it matches the expected naming scheme.
>
> If you are reading the data with the MATLAB or Python SDKs then these segmented files are handled for you, with no concern to the user.

RS3 Technical Specifications

Port Speed	25 MB/sec (per card)

RS4 Data Streamer

Before You Begin

The RS4 firmware version is shown at the top center of the Ports tab on the touchscreen interface. TDT periodically releases firmware updates for the RS4. These are installed by connecting the RS4 to the Internet and pressing the **Update Firmware** button on the Config Tab. This connects the RS4 to the TDT web server to download and apply the update. Note that each update is incremental and you may need to perform the update process several times until the RS4 is up to date.

Recent critical firmware updates include:

- v1.22 / v2.7: added SFTP server for safer data transfer (see Accessing RS4 Storage)
- v2.9 / v3.1: added improved gap logging

The latest firmware version depends on the first number of your RS4 firmware version.

RS4 Version	Latest Firmware Version
1.x	v1.22
2.x	v2.9
3.x	v3.1

See the RS4 Important Changes for more a more detailed version history.

RS4 Overview

The RS4 Data Streamer is a high performance data storage array designed to save data directly from an RZ processor, without going through Synapse. This improves real-time performance and allows you to acquire continuous data over several days or weeks. The RS4 storage array is accessed over a network connection or to a USB storage device.

The RS4 can stream up to 1024 16-bit channels at rates up to ~25 kHz and fewer channels at rates up to ~50 kHz. Streamed data is stored as individual channels and can be stored in different numeric formats (16-bit integer, 32-bit float). Stored data can be easily reincorporated into the TTank data tank format for post processing, or processed on its own. The RS4 is available with either one or four streaming ports and four or eight terabytes (TB) of storage.

Power and Communication

The RS4 has an integrated switched-mode power supply that auto-detects your region's voltage setting. A switch on the back panel of the RS4 enables/disables the power supply.

The power button is located on the bottom right of the front panel of the RS4. Press it briefly to power on or initiate the shutdown.

> 🔥 **Important**
>
> Only power the RS4 down during an Idle state. Idle status can be checked in the Ports tab. Failure to power down during Idle status may result in the RS4 performing a file system check during the next boot process and possible data loss.

> ✏️ **Note**
>
> If the RS4 becomes unresponsive and fails to shutdown normally, you can shut the device down by holding the power button for longer than five seconds. This will force the device to shutdown. After a forced shutdown, the RS4 may perform a file system check.

The RS4 receives data through it's fiber optic ports located on the back panel of the device. This connects to a special DSP that installs in the RZ processor. These ports are color coded for correct wiring. See Hardware Requirements for setup information.

The RS4 has a touch screen interface for status displays and configuration options.

The front panel device status LEDs report hard drive and network activity.

Data Transfer Rate

The maximum data rate for each RS4 streaming port is 12.5 MB/s. This equates to streaming 256 channels of 16-bit integers at a sampling rate of ~25 kHz per streaming port, or 128 channels of 32-bit floats. With four ports available, up to 1024 channels of 16-bit integers can be streamed to the RS4.

> ✏️ **Note**
>
> When recording data it is important to compare the data rate calculated by Synapse to the actual data rate reported by the RS4. If the reported data rate in the RS4 is not similar to the calculated data rate in the macro, this may indicate a hardware problem. If so, contact TDT.

File System Check

Occasionally the RS4 will perform a file system check during the boot process. This is to ensure the integrity of the storage array and file system. You can view the progress of the file system check in the Status Tab.

> ✏️ **Note**
>
> The more files present on the storage array, the longer the file system check will take.
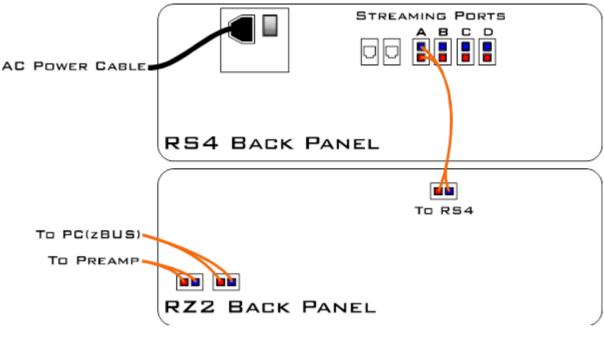
Hardware Requirements

Basic setup for the RS4 Data Streamer includes connection to one or more RZ processors via the orange fiber optic cable. Connect the RZ2 as illustrated in the following diagram.
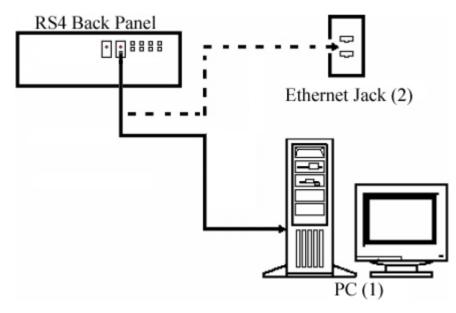
> 🔥 **Important**
>
> Make sure that all cables are connected before powering on the RS4. Make sure the RS4 is turned on *last*, after the RZ processor.

RS4 to RZ2 Connection Diagram

In the diagram above, a single RZ2 provides one streaming input to the RS4. For four port RS4-4 devices, the RZ may have multiple optical DSPs connected to the RS4 in order to stream even higher channel counts, or additional RZ devices can be connected to the same RS4 provided it has vacant streaming ports (B, C, or D) available. The RZ2 is also connected to a preamplifier and PC. The fiber optic cables are color coded to prevent wiring errors.

A network connection is not required but is strongly recommended for both controlling data file naming from Synapse and for accessing stored data quickly.

RS4 PC and Network Connection Diagram

The diagram above illustrates possible connections from the RS4 to a PC (1) or network (2). Connect the Ethernet cable to the RS4 port labeled Network.

Configuring the RS4

Storage Array Types

The hard drives in the RS4 can be configured in one of two RAID based storage array types Striped or Mirrored. A full disk reformat, including loss of data, is required when switching between the types. Each type has advantages and disadvantages and is suited for particular situations. The RS4 is formatted as a Mirrored array by default since this reformatting takes much longer (several hours).

Striped

Striped array types offer quick reformatting (several minutes), efficient data storage, and performs streaming tasks at the maximum transfer rate. This type does NOT protect against data drive failures and loss of a data drive will result in loss of data. This format is useful for those who wish to stream large amounts of data and are regularly backing up the data.

Mirrored

Mirrored array types duplicate the data across your available drives. This prevents data loss if any single drive fails. This reduces total available storage space by half. For older RS4s that use HDD drives, using Mirrored array may result in slower transfer speeds.

Mirrored arrays will prevent data loss if any single drive fails. RS4 devices that contain four data drives, in some cases, are protected if two of the four data drives fail.

The array will resync the drives periodically to ensure the copies are identical. The Array Status displays 'Resyncing' in the Status Tab. Do not attempt to save data to the RS4 while resyncing is occurring.

> ✏️ **Note**
>
> If the resyncing process is interrupted by a loss of power or shutdown of the system, it will resume to where it left off prior to the interruption.

Reformatting the RS4 Storage Array

To reformat the RS4 storage array:

1. Press the **Config** tab on the RS4 interface.

2. Press the **Reformat Array** button.

3. Press the desired array type or press Cancel to exit.

Network Access

The RS4 needs network access to the host computer for retrieving data after the recording and also so Synapse software can tell the RS4 how to name its files during the recording so they can be matched up later.

By default, the RS4 is set to dynamically receive an IP address from the DHCP server on the network it is connected to. If no DHCP server responds, the device falls back on Manual mode with the following default static IP configuration:

IP Address	Netmask
10.1.0.42	255.255.255.0

You can configure the IP address manually through the touchscreen interface. See Manual Configuration on the Status Tab.

There are two methods for networking to the RS4:

- Directly connecting to a PC

- Connection to a local area network

Direct Connection to a PC

Direct connection to a PC allows data on the RS4 to be viewed and modified through the standard Microsoft Windows file sharing protocol.

> 🔥 **Important**
>
> When using a Static IP, the RS4 Current IP must be set to "Configure Manually" using the touch screen interface.

To enable manual configuration:

1. Touch the **Status Tab** and then touch the **Current IP** field. This display the Network Configuration window.

2. Touch the **Configure Manually** check box and click OK to accept the default value.

Using Windows 10

To access the RS4 file system through a PC, running Windows 10:

1. You will have to configure the PC TCP/IP settings. Open Control Panel, then **Network and Sharing Center**, then **Change adapter settings**.

2. Double-click the desired connection (this is usually a Local Area Connection or Ethernet).

3. In the status dialog, click the **Properties** button.

4. In the item list, select **Internet Protocol (TCP/IP)** or if there are multiples, select **Internet Protocol (TCP/IPv4)**.

5. Click the **Properties** button.

6. Select **Use the following IP address** and enter these values:

   IP address: 10.1.0.x; where x can be any value, 1 to 254 except 42

   Subnet mask: 255.255.255.0

   Default gateway: Leave empty

7. Click **OK**. The RS4 can now be accessed by the PC at address 10.0.1.42 through this network connection.

Connecting Through a Network

Connection to a local area network also allows data to be viewed and modified through the standard Microsoft Windows file sharing protocol from any PC connected to the same network as the RS4.

Typically the RS4 will automatically have an IP address assigned to it. DHCP must be enabled on the network in order to access the RS4. If DHCP is disabled or not supported, you must connect the RS4 directly to a PC (see Direct Connection to a PC for more information).

To obtain the RS4 device address, press the **Ports** tab on the RS4 interface. The device address is displayed at the top of the page to the right of **Device Name** field.

> ✏️ **Note**
>
> If the RS4 does not automatically identify on a network, you can force it to reset its IP address by unplugging the Ethernet cable the plugging it in again.

> 🔥 **Finding the MAC Address**
>
> In some labs, the network administrator may require RS4 users to provide the device's MAC address.
>
> To find the MAC Address:
>
> 1. On the touchscreen interface, press the **Status** tab.
> 2. Press in the **Current IP** field. A Network Configuration dialog opens and the MAC address is displayed at the bottom of the pop-up window.
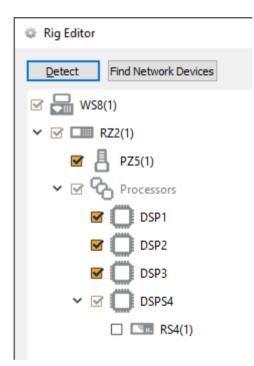
Synapse Setup
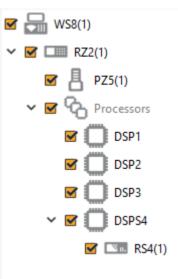
Software control is implemented in TDT's Synapse software. For OpenEx users, see the Legacy System 3 Manual.

To add an RS4 in Synapse, go to Menu -> Edit Rig. With the RZ processor powered on and connected to the PC, click the 'Detect' button. If the Rig Editor sees a DSPS card, it will automatically add an RS4 object underneath it, like this:

By default the RS4 object is unchecked, which means it won't automatically be added to the Processing Tree when you create a new experiment. If you intend to use the RS4 for most of your experiments, check the box next to RS4 now.
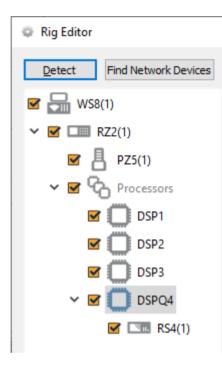
If the RS4 is powered on and connected to the PC through an Ethernet cable (see Network Access above), click **Find Network Devices** to have Synapse automatically find the available RS4 IP addresses on the network, and choose the address of your RS4 from the list. Synapse uses this information to send the tank and block name information to the RS4 so it can rename its files accordingly. For best results, choose the **Direct** communication method. This means Synapse will target the RS4 specifically with its rename packets, instead of broadcasting to all devices on the network.
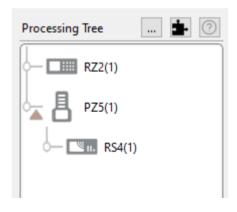
> 🔥 **Important**
>
> The RS4 object must be attached to the DSP in the RZ processor that is physically connected to the RS4 via fiber optic cables, in this case DSP-4. This could be a DSPS card or an optical QZDSP (QZDSPO) card.
>
> If using an optical QZDSPO the RS4 must be manually added to the rig. After the Autodetect, add the RS4 by right-clicking on the QZDSP and selecting 'Add RSn' from the list.
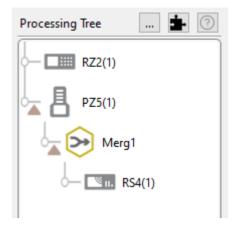
When you exit the Rig Editor, the RS4 will appear in the Processing Tree. Attach it directly to the PZ5 or PZA amplifier to stream the raw data to the RS4 drives.

RS4 connected to PZ5

Since there is one link in the Processing Tree per RS4 object, if you have the PZ5 or PZA configured with multiple subamplifiers and a single fiber optic to the RS4, you must first merge the subamplifier signals into one large multi-channel signal and connect that to the RS4.

RS4 connected to multiple subamplifiers

RS4 Options

The RS4 object configures data storage from the RZ to the RS4. The object provides settings for the number of channels, storage format, and decimation factor.

RS4 Options

By default, the RS4 uses the RZ device sampling rate. You can set a rate manually by clearing the **Sample Rate Max** check box to enable the slider. You can also select the data format and any scaling. If streaming from a PZ5 or PZA, due to the large input range and high fidelity, the Float-32 format is recommended. If using a PZ2, Integer-16 format with Scaling set to 1e6 is preferred.

Phantom Store generates header information in the data tank. This is useful if you are reading the RS4 data with TDT applications through the tank server. However, this consumes extra hard disk space on your Synapse computer, so if you are going to read the files directly from the RS4 for your own custom analysis then leave this unchecked.

Send SEV Rename Packets sends a UDP packet containing the tank and block name over the local network to the RS4, so that the RS4 can rename the data files correctly.

When **Phantom Store** is selected, **Send SEV Rename Packets** is selected for you.

> 🔥 **Important**
>
> If you aren't using TDT applications to read the data saved on the RS4, you don't need to select **Phantom Store** but you *absolutely* should select **Send SEV Rename Packets** so that the RS4 data is organized properly.

Use Large Buffer Size allocates more DSP memory to buffer the data before it is transferred to the RS4. This improves reliable when streaming very high bandwidth, high channel count data to multiple RS4 ports. The RS4 should be updated to v1.19 firmware or above to most effectively use this setting.

Recording Sessions

When Synapse enters Preview or Record mode, the RZ begins streaming data to the RS4. This initiates a recording period or session on the RS4. A session is defined as any length of continuous streaming data sent to an RS4 streaming port. Each streaming port on the RS4 can initiate a session and sessions may run concurrently.

If the RS4 sees data coming into a port, it opens new files and starts saving the raw data to disk. The RS4 otherwise doesn't know anything about Synapse state (Idle, Preview, Record). Synapse sends the RS4 information over the network via small UDP packets every 5 seconds. Each packet contains the tank and block name, so that the RS4 can rename the files appropriately. Make sure the **Send SEV Rename Packets** option is enabled in Synapse.

When data is no longer streaming to the port for a period of time longer than the **Rec Stop Timeout** setting, the session is concluded and a new session will begin when a new data stream is presented. This is set on the Config Tab. The default is 10 seconds but you may want to shorten that to 3 seconds.

For long recording sessions, the RS4 touchscreen configuration settings include an option to **Segment files every** with several time options to periodically close and reopen the session. This partitions the recording into multiple smaller data files that may be easier to analyze if you are doing long multi-day recordings. See Ports Tab for more information.

> 🔥 **Important**
>
> Before starting a new recording session, make sure the RS4 has stopped the previous session and the ports are Idle. Switching too quickly may cause the new data to be appended to the previous session data, or there could be a gap in the beginning of the new session data. This gap will be showing in the RS4 log file saved next to your data files. See RS4 Storage Format.

Accessing RS4 Storage

Data stored on the RS4 can be easily reincorporated into the TTank data format for post processing.

RS4 v2.x and 3.x devices

Enter the device name or IP address as shown in a windows address bar to access the RS4 file system.

Access RS4 file system in Windows Explorer

RS4 v1.x devices

The older RS4 devices use SMB 1.0 protocol, which is no longer supported by default in Windows 10. See Tech Note 0990 for more information.

For a more secure file transfer between the RS4 v1.x and Windows 10, use WinSCP.

WinSCP Setup

1. On the RS4, go to the Config -> Settings and make sure SFTP Data Access is set to 'Yes'.

2. On Windows, download and install WinSCP.

3. Launch WinSCP and set:

   • File protocol is `SFTP`

   • Host name is your `RS4 IP address`

   • User name is `tdtftp`

• Password is `tdt`

It should look like this when you are done, except the IP address will be different:

You can 'Save' this session information for future connections.

4. Click the 'Login' button. It will ask you to save the host key, click 'Yes'.

5. If successful, you will see the RS4 files on the right side. The 'data' folder is what you are used to seeing in your explorer window. Choose your local folder on the left side, then just drag/drop files or folders from the right side to the left side to initiate the transfer.

Access RS4 file system in WinSCP

> ⚠️ **Warning**
>
> Do not attempt to write to the RS4 storage array at any time while data is actively streaming. Doing so may corrupt data currently being stored.

RS4 Storage Format

Data stored on the RS4:

- Contains an *.sev file for each channel recorded in the stream.

- Does not contain other Data Tank file types (.tbk, .tdx, .tev, .tsq). These are saved into the data tank on your local machine

- Stores all of the channel data files in a single Data Tank folder.

- Contains a log text file with starting sample, ending sample, and any gaps in the data stream.

These SEV files can be copied directly into the local block folder and read by any TDT application (if Phantom Store was enabled), or read directly with the MATLAB and Python SDKs.
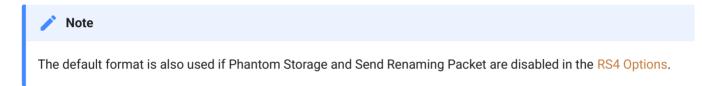
Naming Convention

When connected to an active network, TDT's Synapse software sends information to the RS4 via a broadcast UDP packet allowing it to properly name the streaming data sent to the RS4.

For example, if you are recording channel 1 for the event wavA on Block-3 from DemoTank2 the RS4 will store in the following location and format:

`\data\DemoTank2\Block-3\DemoTank2-Block-3_wavA_ch1.sev`
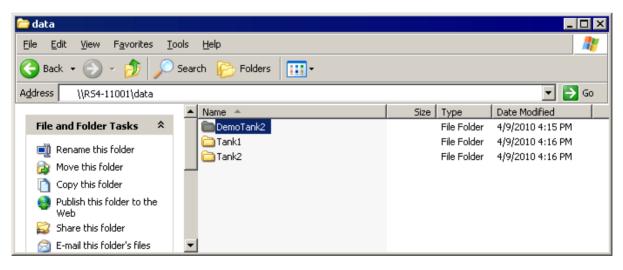
Without the Synapse network information the RS4 falls back to the default data format:

`\data\EventName-Year-Month-Day-Hour-Minute-Second\Unnamed_ch1.sev`

> ✏️ **Note**
>
> The default format is also used if Phantom Storage and Send Renaming Packet are disabled in the RS4 Options.

To move blocks to a Data Tank:

1. Access the RS4 file system on the local PC using the process described above in Accessing RS4 Storage.

2. Select the desired Data Tank.
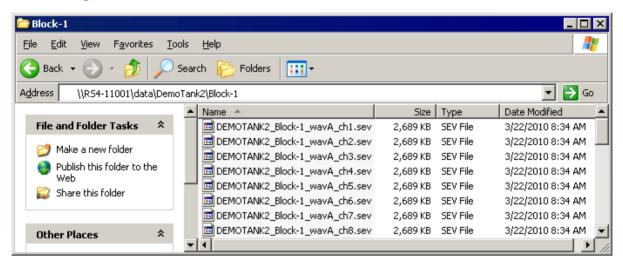
3. Copy the selected Data Tank to the local PC Data Tank.

4. If the Data Tanks share the same name, select **Yes to All** when asked to confirm possible merged folders. This will **not** overwrite data currently stored on the local drive since only the *.sev files and RS4 log files are copied.
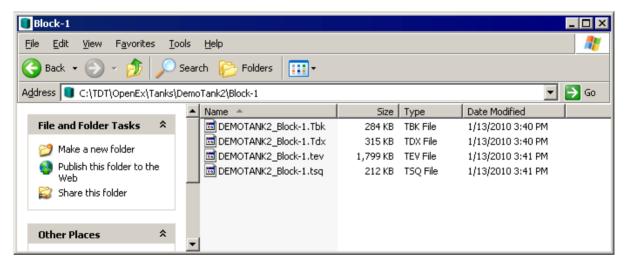
5. If you wish to move only a single block, copy the desired block and place it into the local PC Data Tank folder.

To move individual channels to a Data Tank:

1. Access the RS4 file system on the local PC using the process described above in Accessing RS4 Storage.

2. Copy and paste the desired file(s) to the local PC Data Tank folder.

3. Open the Data Tank you wish to move the data to by browsing to the block folder in the Data Tank folder on the local PC.

4. Copy and paste the desired data from the RS4 to the local PC.

> ✏️ **Note**
>
> Data sets containing a large number of channels, or long recording periods may take longer to display and process on the RS4 and will also lengthen the amount of time for file system checks. TDT recommends removing data that is no longer needed on the RS4. See Storage Tab for more information on deleting data.

LCD Touch Screen

The LCD touch screen reports information and allows configuration of available options.

Ports Tab

The Ports tab provides information for storage array streams, local storage rates, and storage size.

RS4-1 configured in Mirrored array mode

Firmware Version:

The currently installed firmware version number is displayed in the top center of the Ports tab. Compare this to the latest firmware version released by TDT, shown in Before You Begin, and perform Update Firmware if necessary.

Device Name:

Displays the assigned device name. This can be used to access the device over the network.

Name	Description
Port A, B, C, D	Information regarding the currently installed interface cards
Rate	The approximate current data transfer rate in MB/s. This rate incorporates overheads in the data transfer protocol and may differ slightly from the data rate calculated in Synapse
Amount Saved	The total amount of data saved to the storage array during the current recording session
Name	Displays the current session name. See Naming Convention for more information

Local Storage:

This area displays information relative to the currently installed array.

Name	Description
Array Status*	nTB - Active: Array is properly configured and its maximum storage space (nTB) is listed. Not Ready: No array is detected or the array is not yet ready
Percent Full	The percentage of space that has been used on the storage array
Will fill in approximately	An estimate of how much time it will take to fill the storage array with data based on the data rates for the current session(s)
Segment files every^	For long recordings, set a value to indicate when the RS4 should close the recording session and open a new session. This allows the user to access the raw data for parallel processing before the recording is over

---

✏️ **Array Size**

*Keep in mind that the total available storage is based on the amount of free disk space after system allocation. For example, although the RS4-4 specifications list 8 TB of storage space, 7.2 TB are actually available for data storage (in Striped array mode).

✏️ **Segmented Files**

^The exact length of each file will be a multiple of a fixed block size, based on the sampling rate. It will be as close as possible to the selected setting value (e.g. 1 hr, 4 hr, etc.), but will not be exact. It will be within ~0.1 seconds or so of the exact desired duration, and there will be no overlap in the data at the beginnings and ends of the files.

The files will be named as follows:

```
{TANK}_{BLOCK}_{STORE}_ch1.sev
{TANK}_{BLOCK}_{STORE}_ch1-1h.sev
{TANK}_{BLOCK}_{STORE}_ch1-2h.sev
...
{TANK}_{BLOCK}_{STORE}_ch2.sev
{TANK}_{BLOCK}_{STORE}_ch2-1h.sev
{TANK}_{BLOCK}_{STORE}_ch2-2h.sev
...
```

If using Phantom Store to merge the RS4 data with your other tank data, and you are using TTank to read the data, only the first file chunk will be accessible because it matches the expected naming scheme.

If you are reading the data with the MATLAB or Python SDKs then these files are handled for you.

Storage Tab

The Storage tab provides a list of folders (recording sessions) on the RS4. Items may be selected and deleted or moved and copied to a USB device. Status information for any connected USB Storage devices is displayed.

Local Storage:

Data items stored on the RS4 storage array are populated in the local storage list. Multiple items may be selected using press and drag.

USB Storage A, B:

Network data transfer is preferred. However, if network is not available, there are USB ports for data transfer. For RS4 v2.x devices, two USB 3.0 ports are available for data transfer. For RS4 v1.x, USB transfer is not recommend. The ports are USB 2.0 and are too slow for big file transfers.

When supported USB media is detected, the interface will display only the total space existing on the media as a reference. It does NOT display available space on the media.

> ✏️ **Note**
>
> TDT recommends that you do not attempt to copy or move files using the USB ports while a recording session is active.

Select item(s) from the local storage list and press the desired USB Storage connection indicator to prompt the copy/move dialog.

> ✏️ **Note**
>
> When moving or copying items the RS4 interface may become temporarily unresponsive.

Trash:

Select item(s) from the local storage list and press the Trash icon to permanently delete them. A dialog will prompt asking to confirm the deletion of the item(s).

Status Tab

System:

Displays the current usage and temperature for each processor core on the RS4 CPU. Also displays the approximate RPM for all three fans located inside of the RS4. Press **Current IP** to change the RS4 network configuration and see the MAC Address.

Storage Array:

Displays information about the state of the current storage array.

Name	Description
Active and mounted	Storage array is available and ready to store data
Active and not mounted	A supported storage array is available but is not configured to store data
Array was not found!	The system did not detect a supported storage array

The Progress Bar is active during:

- Reformatting: When reformatting a storage array, the progress completed (%) as well as the estimated amount of time remaining is displayed.

- Resyncing: If a mirrored array type has been formatted, the progress completed (%) as well as the estimated amount of time remaining for the Resync process is displayed. See Storage Array Types for more information.

- File System Check: If the RS4 is performing a file system check, the progress completed (%) and estimated amount of time remaining is displayed. During this time the status array will not be ready.

Check button

When the storage array is in mirrored configuration, a **Check** button appears at the bottom left corner. Pressing the **Check** button begins a disk check to see if the data on both images are identical. This process can take several hours. A progress bar and an estimated time to completion are displayed.

During this time the Ports tab will report that the array status is "Checking". No data access should occur during checking.

The button will stay depressed for the duration of the disk check. You can stop the disk check at any time by pressing the **Check** button again.

> 🔥 **Important**
>
> TDT recommends performing a disk check on a mirrored configuration every 7-30 days.

Data Ports:

Displays storage information for all installed memory buffers and any communication errors.

Name	Description
Memory Buffers (U/F/A)	Displays the number of memory buffers currently used, free, and allocated.
Communication Errors	Displays the current count of communication errors between the RS4 and RZ2. This value should be zero. If not, the current data session may contain gaps in the data, which will be written to the log file.
	If the count increases continuously at a high rate (>1500 errors per second), the RZ connected to that port might not be synchronized to the PCI card. Check the fiber optic connection from the RZ device to the PCI card and use zBusMon to confirm RZ to PC communication, and reboot both the RS4 and the RZ2.

View Log Window:

A log stores relevant messages and any communication errors encountered while the RS4 is in use. Click to open and view the log window. The log.txt file can be copied from the storage array for transfer to a PC.
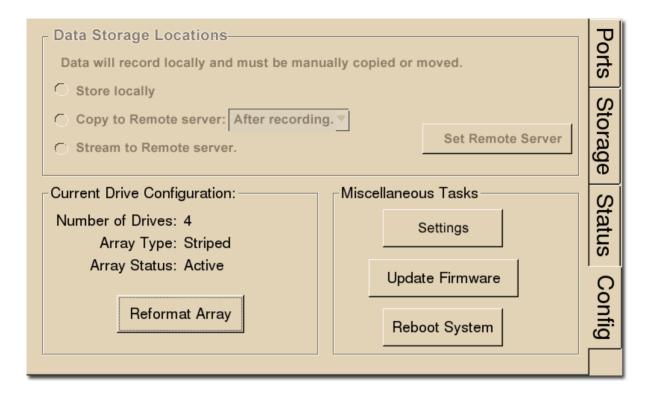
```
START: RS4 Log starting at 2010-04-04 21:36:30
Unmounting the file system...
Running: sudo /bin/umount /mnt/data
Stopping any existing array...
Running: sudo /sbin/mdadm --stop /dev/md0
Running: sudo /sbin/mdadm --stop /dev/md127
Running: sudo /sbin/mdadm --stop /dev/md126
Preparing the drives...
Creating the array...
```

Save   Done

> ✏️ **Note**
>
> Individual comments can be saved as well. Use standard drag techniques to highlight the desired comment(s) and click **Save** to write the selection to the log.txt file.

Config Tab

The Config tab provides options for reformatting the currently installed storage array, updating the RS4 firmware, and rebooting the system.

Data Storage Locations:

Not currently implemented.

Current Drive Configuration:

Displays information about the currently installed data drives.

Array Type	Description
Striped	Array is striped.
Mirrored (UUUU)	Array is mirrored. A "U" indicates that a drive is up and running, "_" indicates a drive failure that must be address immediately. Contact TDT.
Missing	No array type is detected. Try **Reformat Array** or contact TDT.

Status	Description
Preparing	Storage array is currently being reformatted
Resyncing	Storage array is being reformatted as a mirrored array and is currently resyncing the mirrored partitions. See Storage Array Types for more information
N/A	Storage array is not detected
Active	Storage array is detected and configured

Press **Reformat Array** to change the array type to Striped or Mirrored. Reformatting an array will erase all data contained in the array.

> ✏️ **Note**
>
> When reformatting an array, the interface may become temporarily unresponsive. Creating a Striped array is quick, but a Mirrored array can take a significant amount of time. It's best to do this overnight when there is some downtime.

Press **Settings** to set date and time and select unit of measure for temperature, along with gap detection settings.

The RS4 has built-in error detection - if it sees a small gap in data it logs the missing sample information in the log file but doesn't prematurely stop the recording. The **Rec Stop Timeout** setting determines how big of a gap there should be before it assumes it is a new recording and not an error state. After you stop a recording, the **Rec Stop Timeout** period must pass before the RS4 is Idle and ready to record again.

The RS4 makes audible beeps when recordings starts, recording stops (after the **Rec Stop Timeout** period has passed, and if gaps/errors are detected. This can be disabled.

TDT periodically releases updates to the software running on the RS4. Press **Update Firmware** to download any available updates from the TDT server. They will automatically install and ask you to reboot the RS4 when complete. The updates are incremental, so you might need to repeat this process until it says there are no more updates found. You can verify the updated firmware version on the Ports Tab.

> 🔥 **Important**
>
> The RS4 must have internet access to get these firmware updates. They cannot be done over USB or local network.

Troubleshooting

The following section provides examples and solutions to some of the errors that could be encountered while using the RS4 Data Streamer.

> ❓ **Device Will Not Power Up**
>
> Check the position of the power supply switch. If set to the "O" position the power supply is disabled. To enable, simply ensure that the switch is in the "1" position and attempt to power on the RS4. If the device does not power up after verifying that the power supply is enabled contact TDT.

❓ Can't Access the RS4 Storage Array

Check the Ethernet cable connection to ensure that the RS4 is connected to a network or PC using the Network Ethernet port located on the back panel of the RS4. See Hardware Requirements for connection diagrams.

If you are attempting to access the RS4 through a network, ensure that the server supports DHCP. If not, the RS4 will default to its static IP address (10.1.0.42). If you encounter this issue, see Direct Connection to a PC for information on how to access the RS4 using a direct connection to a PC.

❓ RS4 Interface Becomes Slow or Unresponsive

Researchers who use the Synapse preview mode extensively may find the interface to behave sluggishly. The RS4 does not throw out data recorded while in preview mode. Data recorded in preview mode is stored as unnamed data on the RS4 and is readily distinguishable from legitimate data recorded during an actual experiment. TDT recommends removing unnecessary data remaining on the storage array.

❓ RS4 Is Not Correctly Naming Data
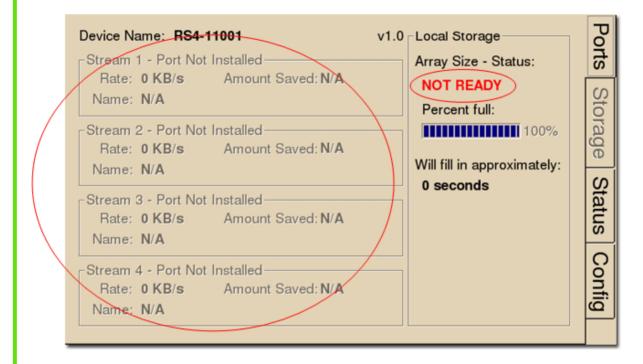
When connected to an active network, TDT's Synapse software sends information to the RS4 via a broadcast UDP packet allowing it to properly name the streaming data sent to the RS4. If the RS4 is powered on before connecting the necessary network cables it may default to the basic naming format:

```
\data\Event name-year-month-day-hour-minute-second\unnamed.sev
```

Power off the RS4, connect all the necessary cables then power the RS4 back on. See Network Access for more information.
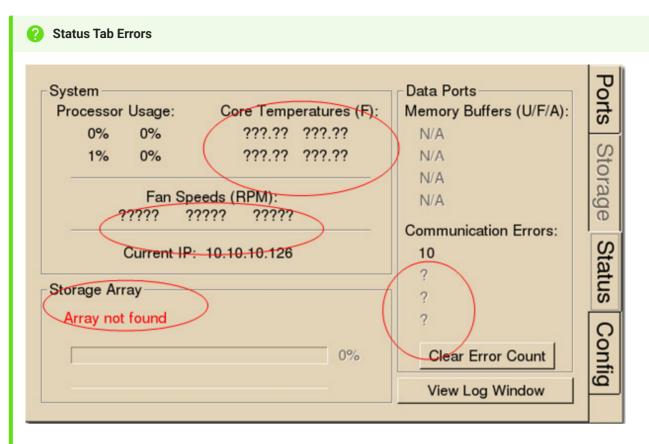
❓ Port Tab Errors

Below is an example of errors that can be encountered on the Port tab.

Ports that are not currently installed will be displayed in grayed out text. In most cases it is normal to see 3 of the 4 Streams disabled (since RS4 devices come installed with 1 or 4 data ports). Hardware failures can cause all ports to be grayed out. If you encounter this issue, contact TDT.

Array status messages will determine whether or not a storage array is currently installed properly. If the NOT READY status is displayed, the storage array may require reformatting (Check the Status tab for more details). See See Storage Array Types. for information on reformatting.

Status Tab Errors
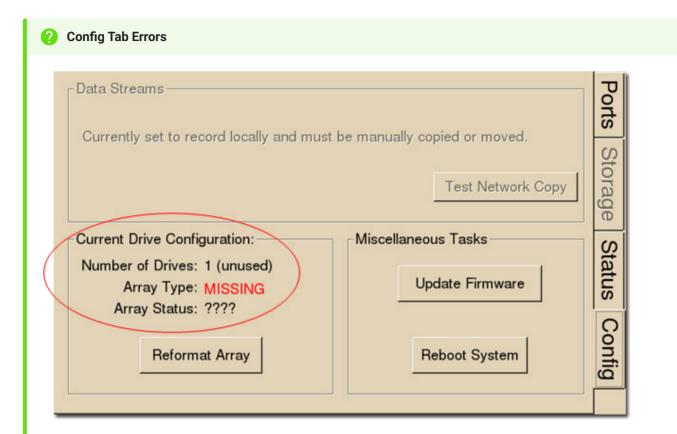
Temperature sensor failures will be displayed as ???.?? in the Status tab. If you encounter this issue, contact TDT.

Typical fan speed rates should be 1500 RPM and 3500 RPM under heavy processing loads. Fan failures will be displayed as ????? in the Status tab. If you encounter this issue, contact TDT.

Unformatted storage arrays will cause an Array not found status to be displayed. This may also be caused by disk drive failures within the RS4. You may attempt to reformat the storage array. See Storage Array Types for information on reformatting. If reformatting is not desired, contact TDT.

Communication errors are compiled per recording session for currently installed streaming ports and will indicate if a streaming port had a communication failure at some point during the session. Data recorded during the session may be invalid. Communication errors may result from wiring errors between the RZ2 and RS4. Cycling power on the RZ2(s) may fix the issue. Refer to the See RS4 to RZ2 Connection Diagram. for a proper wiring example. If the wiring is correct this may indicate a bad fiber optic cable that will need to be replaced.

❓ Config Tab Errors

Drive configuration errors may occur if the RS4 is unable to detect a properly formatted storage array. You may attempt to reformat the storage array. See Storage Array Types for information on reformatting. If reformatting is not desired, contact TDT.

> ✏️ **Note**
>
> If using a mirrored array type, drive failures will be displayed using an underscore.
>
> For Example, if drives 1 and 2 fail the Array Type will read:
>
> `Array Type:  Mirrored (__UU)`
>
> Data in these scenarios are most likely recoverable. If you encounter this issue contact TDT. You may attempt to recover the data by accessing the RS4 file system to move the data to a local PC prior to reformatting the array.

RS4 Technical Specifications

Processing Cores	4
Storage Array Size	4 TB (RS4-1) or 8 TB (RS4-4)
Storage Drive Type	HDD (All RS4-1, RS4-4 SN <1030)
	SSD (RS4-4 SN >=1030)
Streaming Ports	1 (RS4-1) or 4 (RS4-4)
Port Speed	12.5 MB/sec (per port)

RS4 Important Changes

2.9 / 3.1

- Added better gap logging for the 2.x and 3.x platforms

2.8

- Fixed issues when streaming at slower sampling rates

2.7 / 1.22

- Added SFTP access

1.21

- Added firewall

1.20

- Added option in Config dialog to disable RS4 beeping

1.19

- Make beeps through speaker when recording starts / stops, errors
- Save log file per port with recording start / stop and gap sample counters

1.15

- Better handle invalid streams on RS4 to cleanly stop sessions
- Invalid headers / footers resulted in the software being stuck in an infinite loop with "Flushing data files..." on the Ports tab

1.14

- Fixed file renaming problem triggered when renaming packets arrive in order

1.12

- Fixed static IP configuration

1.11

- Able to specify file truncating period, to prevent making extremely large files during an abnormally long recording

- Able to specify static IP

PO8e Streaming Interface for the RZ

PO8e Overview

The RZ PO8e interface is an optional interface for RZ processor devices and is designed to transfer high channel-count data to a PCI Express card interface (PO8e) for real-time processing in custom applications. The PO8e card can be in the same computer as the TDT system, or in a dedicated computer.

The RZ connects to the PO8e card via a special optical DSP (RZDSP-U) or optical quad (QZDSPO). The optical card has an interface located on the back panel of the RZ processor and connects to the PO8e via orange fiber optic cables provided with the system.
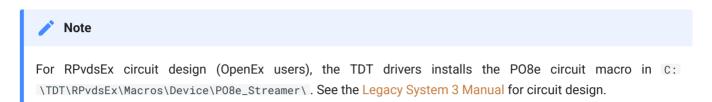
Data streamed through the PO8e is buffered at several points while the system copies it from the RZ to PC memory. When data is generated on the RZ unit and fed into the PO8e HAL object in Synapse Processing Tree (or the Stream_Remote_MC macro in RPvdsEx), this data is placed in a 10000 sample (per channel) FIFO buffer on the RZ processor. Data from this FIFO is transferred over the fiber optic link to the PO8e PCI Express card.

A shared library is provided (PO8eStreaming) along with a C/C++ interface for writing custom applications to collect data from the PO8e card in real-time. In the PO8eStreaming library a dedicated software thread actively attempts to read from the PCI Express card and places the transferred data into a RAM buffer. This structure allows the application program to query the API when convenient and read data in larger blocks. The RAM buffer is limited only by available memory, though the programmer should consume the data as soon as possible since this interface can transfer at rates up to ~12.5 MB/second.

See the PO8eStreaming programming guide for more information.

PO8e Installation

Synapse has a built-in object for the Processing Tree to stream data to the PO8e. This must be added to your Hardware Rig in Synapse and then simply connect the desired output stream to the PO8e object. See the Synapse Manual for more information.

> ✏️ **Note**
>
> For RPvdsEx circuit design (OpenEx users), the TDT drivers installs the PO8e circuit macro in `C:\TDT\RPvdsEx\Macros\Device\PO8e_Streamer\`. See the Legacy System 3 Manual for circuit design.
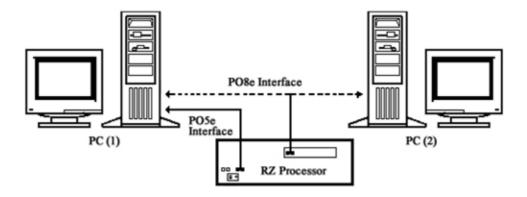
PO8e Hardware Requirements

Basic requirements include a paired fiber optic cable, an RZ processor equipped with the RZDSP-U or QZDSPO card.

The PO8e requires a Windows or Linux computer with a PCI Express slot.

Setting Up Your Hardware with the PO8e

In order to setup the RZ PO8e interface, connect the fiber optic cable from the RZ back panel to the PO8e card installed in the computer. The PO8e can be installed in the same computer as the PO5/e card or in a separate computer. For more information on setting up or configuring the RZ processor see the System 3 Installation Guide.

PO8e Connection Diagram

The diagram above illustrates the possible PO8e connections from the RZ processor to the TDT PC (1) or to a separate PC (2).

13. Lux Optical

Lux LEDs and Photosensors

Lux Overview

Lux optical components are modular plug-in light sources and photosensors. They include integrated LEDs, photosensors, M8 connectors for external LEDs, and BNC for voltage. They can be installed in an RZ10x or iX6 module.

The Lux components are held in place with two nylon screws. They are interchangeable, so you can swap LED colors at any time, upgrade from an external photosensor to a PS1 or PS2 integrated sensor, or interface with an external device with a BNC connector. In the case of lost Lux screws, do not replace them with metal screws. Please contact TDT support for replacement screw options.

> 🔥 **Important**
>
> Make sure the RZ10x or iX6 is powered off before changing the Lux components.

Lux Pod	Description
	Each Lux LED pod is colored with the closest visible color to the wavelength of light it emits. The Lux LEDs can occupy the left three slots of each Lux bank. The 465nm Lux LED is shown at left.
	The PS1 photosensor measures the fluorescence response from the subject. It can occupy the right two slots of each Lux bank.
	The PS2 photosensor is an upgraded version of the PS1 with a ~2x increase in signal-to-noise.
	The PM1 Power Meter measures the LED power received by the subject. It has built-in fluorescing material so it can also mimic a subject response for full end-to-end system testing. The PM1 can only occupy the slot on the far right of each Lux bank.
	The M8 connector is the default placeholder for the left three slots if LEDs aren't installed. It is used to drive an external third-party LED.
	The BNC connector can be swapped into any location on the Lux bank to connect to third party devices. It is the default placeholder for the right two slots if PS1/PS2/PM1s aren't installed.

> 🔥 **Important**
>
> The Lux LEDs, PS1, PS2, and PM1 have an FC connector with a small key that must be aligned to the fiber optic cable. This key is in the 10 o'clock position on all TDT optical Lux components.

See the Synapse Manual for RZ10x or Synapse Manual for iX6 for information on controlling the Lux drivers and reading the sensors.

Adding or Removing Lux Pods
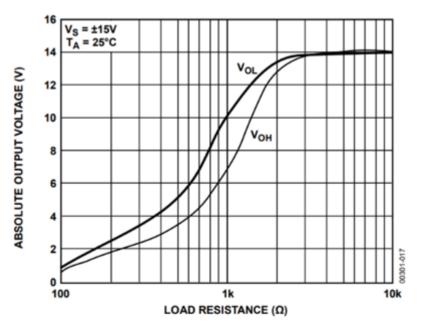
Before removing or installing any Lux pods, make sure the RZ10x or iX6 is powered off. Make sure that the pods are oriented with the text right side up and use the nylon screws that came with the system. If you have trouble holding the pod in the socket while screwing it in, you can connect a fiber optic cable to it to use as a kind of handle.

When finished, power on the unit. In Synapse, click the detect hardware button on the RZ10x LUX tab or the iX6 Options and verify that the new pods are detected properly.
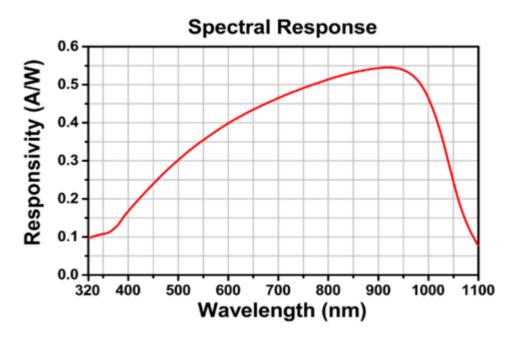
Lux Technical Specifications

LEDs	
Available Wavelengths	385 nm, 405 nm, 415 nm, 450 nm, 465 nm, 500 nm, 530 nm, 560 nm, 590 nm, 615 nm, 635 nm, 850 nm, 940 nm, 5K
Current Range	RZ10x: 2 mA - 1000 mA iX6: 2 mA - 500 mA
PS1/PS2	
Bandwidth	DC - 700 Hz
Wavelength Range	320 nm - 1100 nm
Gain	1e10
PM1	
Bandwidth	DC - 3000 Hz
Wavelength Range	320 nm - 1100 nm
Gain	6.5e4

BNC Output Pod	*RZ10x only
Output Channels	Up to 6 channels, 16-bit PCM
Sample Rate	Up to 48828.125 Hz
Frequency Response	DC - 0.44*Fs (Fs = sample rate)
Voltage Out	±10.0 V, 6 mA max load
S/N (typical)	82 dB (20 Hz - 20 kHz at 9.9 V)
Output Impedance	See below
BNC Input Pod	
Input Channels	iX6: up to 2 channels, 16-bit PCM RZ10x: up to 4 channels, 16-bit PCM
Sample Rate	Up to 48828.125 Hz
Frequency Response	DC - 7.5 kHz (2nd order, 12 dB per octave)
Gain	RZ10x: 1x iX6: 1.7x
Scale Factor	RZ10x: 1x iX6: -10x
Voltage In	RZ10x: ±10.0 V iX6: ±2.2 V
S/N (typical)	82 dB (20 Hz - 20 kHz at 9.9 V)
Input Impedance	10 kOhms (impedance of input connection will appear to be ~400 Ohm higher)

Lux BNC Pod Output Impedance

PS1, PS2, and PM1 Responsivity

Lux Optical Manifolds

Lux Manifold Overview
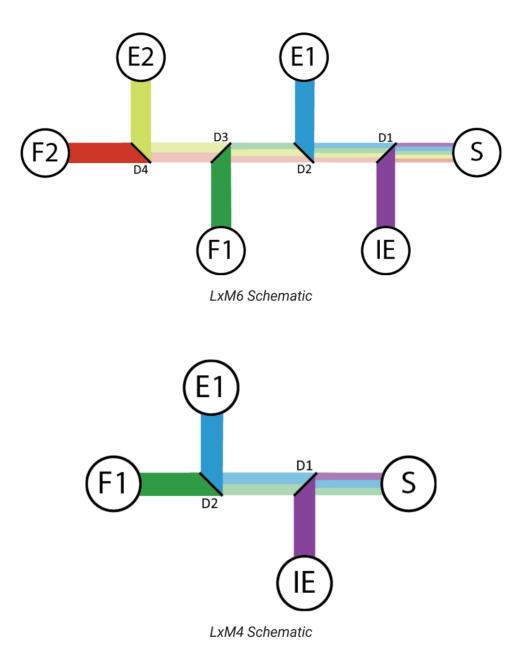
The Lux manifold is a modifiable beam filter that consists of a series of dichroic mirrors and light filters for fiber photometry and optogenetic stimulation.

Each Manifold is custom configured for standard optical sensors, like GCaMP, RCaMP, dLight, GRAB, and SnFR. However, the Lux manifold was specifically designed to easily swap the sensor filters to match the best isosbestic, excitation, and emission spectra of your biosensor.

Part Numbers:

- LxM4-405 - Lux 4-Port Optical Manifold with 405 nm IE Standard
- LxM4-415 - Lux 4-Port Optical Manifold with 415 nm IE Standard
- LxM6-405 - Lux 6-Port Optical Manifold with 405 nm IE Standard
- LxM6-415 - Lux 6-Port Optical Manifold with 415 nm IE Standard
- LxM6-GRAB - Lux 6-Port Optical Manifold with 430 nm IE Standard

Light Pathway

LxM6 Schematic

LxM4 Schematic

Available Filters

Here are the possible filters for each port. Each port is labeled with the port name and its center-bandwidth spec. In the case of the F2 port without any light filter, it is labeled "F2 -".

Filter Port	Center-Bandwidth (FWHM) (nm)	Total Bandwidth (FWHM) (nm)
IE	405-10	400-410
	415-10	410-420
	430-10^	425-435^
E1	472-35	455-490
	494-25^	482-507^
F1	520-41	500-541
	534-25^	522-547^
E2	560-10	550-570
F2	614-52	588-640
	607-36	589-625
	No Filter	

Dichroic Mirror	Cutoff (nm)	
D1	435	
D2	482	
	495^	
D3	552	
D4	562	

^ LxM6-GRAB defaults

The dichroic mirrors are fixed per device, but the optical filter ports are swappable. The back plate of the LxM can be removed and the optical filters can be swapped as needed with a compatible filter. Contact TDT Tech Support for assistance.

> 🔥 **Important**
>
> The Lux components have an FC connector with a small key that must be aligned to the fiber optic cable. This key is in the 12 o'clock position on all Lux Manifold components.

See the Fiber Photometry User Guide for information on making optical connections.

14. Microphones

DPM1 Distortion Probe Microphone System

Overview

The DPM1 Distortion Probe Microphone System measures distortion product otoacoustic emissions (DPOAE). It consists of a battery-powered signal conditioner and the probe microphone itself. It operates in the 1 kHz to 40 kHz range and can detect low intensity signals in the range of 0 dB SPL.

The provided cable and ear tip carry the response from the microphone into the system via a front panel BNC output. The microphone tip also has two small tube-connectors to carry the stimuli to the subject's ear. Slide the closed-field speaker tubes over these small stainless steel tubes, ensuring a snug fit.

A full system typically includes an RZ6 processor to generate two channels of stimuli and record one, and two closed-field speakers such as the MF1 or EC1 speakers. The speakers connect to two small stainless steel tube-connectors which carry the stimuli to the subject's ear.

Microphone Kit

The DPM1 system kit includes:

- DPM1_MIC - Microphone for Distortion Probe Microphone System

- DPM1_SC - Signal Conditioner for Distortion Probe Microphone System

- Four 9 V batteries

- Assorted ear tips:

    ◦ Four each 4 mm, 5 mm, 6 mm

    ◦ Two each 8 mm, 10 mm, 13 mm, 16 mm

- Four 10 cm pieces of PVC tubing: 1/16" ID, ⅛" OD, 1/32" wall

Power

The DPM1_SC is powered by two 9V batteries. Alkaline batteries are recommended. The "Bat Test" button on the front of the SPM1_SC checks the battery level and lights the green "OK" LED when it is acceptable.

> 🔥 **Important**
>
> The Battery Test is only accurate with the DPM1_SC powered OFF

Cable Connection

The tubing will transfer the signal best when it is kept straight. Note that the system performance is dependent on the coupling system used and the ear of the animal. Users should test the device under experimental conditions to ensure it meets their requirements. If using BioSigRZ software, see the DPOAE Guide for calibration tips. Technical Specifications measured under specific controlled conditions are provided for comparison purposes.

Routine Care and Maintenance

Inspect the microphone tip for visual damage or obstruction of the speaker and microphone holes prior to use. The microphone tip can occasionally get clogged up with ear wax. DO NOT stick pins or other sharps into the microphone tip as it could cause damage or push the occlusion farther into the microphone cavity. Instead, TDT recommends adding a 3-4 mm of isopropyl to a dish and swirling the tip of the microphone in the alcohol. This dissolves the wax in many cases. If there is still debris clogging the microphone hole, contact TDT for an RMA for repair.
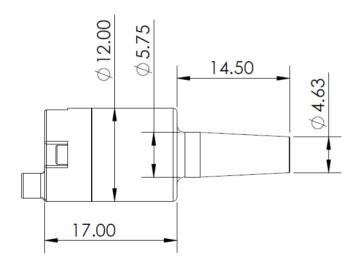
The outside of the DPM1 can be wiped down with isopropyl to sanitize it after each use.

DPM1 Technical Specifications

Microphone and Amplifier	
Gain	29 dB
Total Sensitivity	600 mV per Pascal (-4 dBV)
Undistorted output	108 dB SPL (3 V max)
Noise Floor @1kHz (1 Hz BW)	3 uV (-17.5 dB SPL)
Frequency Response	±2.5 dB from 3 kHz to 40 kHz
Output Impedance	<1 ohm
General	
Power	Two 9V alkaline batteries*
Microphone cable	0.75 m shielded 3-conductor
Diameter of speaker tubes	0.054" outer diameter

> ✏️ **Note**
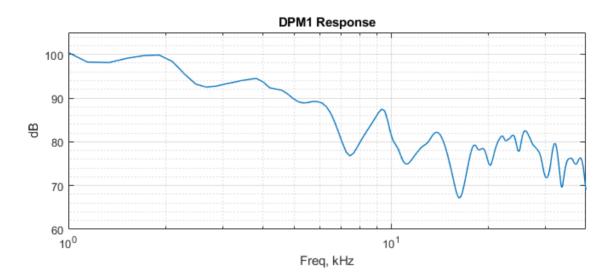
*Rechargeable batteries are NOT recommended

Microphone Tip Dimensions (all values in mm)

Frequency Response

The results of the calibration will vary depending on the type of ear to which the microphone is coupled and the length of the tube that is coupled to the ear. This curve is provided as representative of the type of response that may be obtained in a closed field.

Example Closed-field Frequency Response

Every experimental setup is unique. It is important to calibrate the response of the speaker in each experimental setup.

15. Motorized Commutators

ACO32/ACO64 Motorized Commutators

Overview

The ACO32 and ACO64 (Active Commutator with Optogenetic stimulation) are motorized commutators that actively track rotation on a headstage cable connected to an awake, behaving subject. They spin the motor to compensate, eliminating turn-induced torque at the subject's end of the cable. The commutator is typically used for systems acquiring neural recordings from up to 32 or 64 channels when using a PZ5 analog amplifier or up to 256 channels or 512 channels when using ZD digital headstages and a PZ5 digital amplifier.

Built-in electrical shielding ensures an ultra-quiet environment for recording and lightweight cables and connectors minimize the torque caused by subject motion. Pushbuttons allow for optional manual control of the commutator motor, and an input BNC can be used to inhibit the motor during critical recording periods. A banana jack provides access to ground, so that users can connect the commutator ground to an external ground, such as a Faraday cage, to minimize ground loops.

Optionally, a fiber optic rotary joint with single-channel optical fiber assembly may be added (shown above) to allow optical targeting and excitation on neural circuits for artifact free stimulation. The optical assembly is user serviceable to allow for easy optical fiber replacement.

Part numbers:

ACO32 - 32 Channel Commutator

ACO64 - 64 Channel Commutator

FORJ - Fiber Optic Rotary Joint and Fiber Optic Cable

Power and Interface

The ACO32 has a rechargeable 1950 mAh Li-ion Battery. The ACO64 has a 3900 mAh battery. A 6-9 V, 3A, center negative adapter (one provided) charges the device. Low battery status is reported only by a decrease in rotational speed.

ACO32 Hardware Setup

The commutator is mounted above the subject. A PZ preamplifier is connected to the DB26 connectors marked A and B on the face of the commutator. A headstage (with splice connector) and a splice-to-splice adapter are connected to the interface receptacles on the connector module. See Headstage Connections below for more information on this connection.

See ACO32 Dimensions for mounting dimensions.
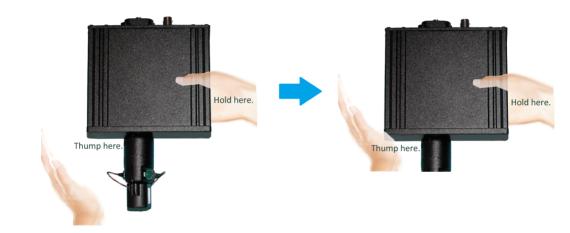
> **✎ Note**
>
> The motor in the ACO32 commutator is attached to a plate designed to allow it to be disengaged for testing and troubleshooting noise issues. The plate may slide out of normal position during shipping or anytime the commutator is turned upside down.
>
> If the motor is not engaged, you can turn the bottom section of the rotating shaft, but the rest of the shaft does not follow.
>
> To reengage the motor:
>
> 1. Hold the commutator with the faceplate up.
> 2. Grip one side of the commutator.
> 3. Bring the commutator down to thump the bottom corner with the heel of your palm, as shown below.
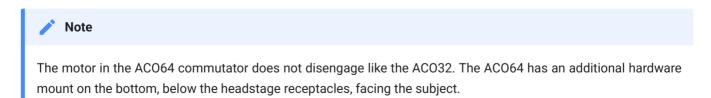
ACO64 Hardware Setup

The ACO64 commutator is analogous to the ACO32 and also typically mounted above the subject. A PZ preamplifier is connected to the DB26 connectors marked A, B, C, and D on the face of the commutator. A headstage (with splice connector) and a splice-to-splice adapter are connected to the interface receptacles on the connector module. See Headstage Connections below for more information on this connection.

See ACO64 Dimensions for mounting dimensions.

> **✎ Note**
>
> The motor in the ACO64 commutator does not disengage like the ACO32. The ACO64 has an additional hardware mount on the bottom, below the headstage receptacles, facing the subject.

Features

LEDs

The four indicator LEDs on the front panel indicate power, the status of the Inhibit BNC input, clockwise rotation and counterclockwise rotation.

P	Power (~0.5 Hz flash when on)
I	Inhibit
↺	Counterclockwise rotation
↻	Clockwise rotation

Manual Rotational Buttons

The commutator features both clockwise and counterclockwise manual rotational buttons. When pressed, these buttons will rotate the commutator at approximately 18 RPM. Pressing either of these buttons also overrides the current rotational state of the commutator.

Inhibit BNC

During critical recording periods it may be necessary to prevent rotation to ensure signal integrity. A logical low (0) on the Inhibit BNC will prohibit any rotation initiated by either the sensors on the commutator or the manual rotational button.
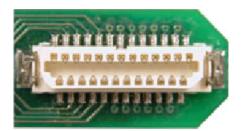
External Ground

A banana jack located on the face (GND) provides connections to common ground on the commutator.
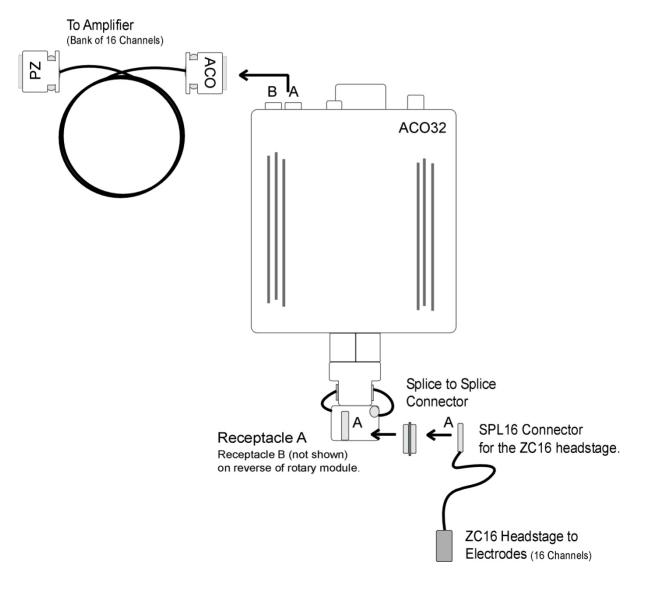
The external ground is optional and should only be used in cases where the subject must occasionally make contact with a metal surface that isn't tied to the animal ground, such as a lever press. When contact is made, a ground loop is formed that temporarily adds extra noise to the system. Grounding this metal surface directly to the TDT hardware removes this ground loop at the cost of raising the overall noise floor a small amount.

A cable kit is provided to ensure cables used with the external ground are suitable for this use. Each kit includes: one male banana plug to male banana plug pass through and one male banana plug to alligator clip pass through. These cables also include ferrite beads to remove

any potential RF noise that might travel through the cable. For best results position the ferrite bead close to the source of the RF noise.

Headstage Connections

Two or four interface receptacles are positioned on the rotary interface module. The receptacles are labeled to correspond to the DB26 connectors on the face. The ACO32 uses 'A' and 'B' labels, the ACO64 uses 1 to 4 silver marks on the receptacles. TDT offers headstages and connectors with a mate for these receptacles.

The diagram above shows the ACO32 connection for the A subset of channels:

- from headstage (with SPL16 analog or SPL16-D digital connectors)

- to splice-to-splice connector

- to commutator receptacle

- to amplifier connection cable.

Channel numbers correspond to the amplifier bank of channels to which the cable is connected. For example, if the 'A' connector is connected to Bank 'A' on the PZ5 preamplifier, channels are numbered 1 - 16.

Amplifier Connections

The ACO commutator interfaces with a PZ amplifier via two or four DB26 connectors, 16 analog channels each) on the face. Adapter cables may also be used for connections to Medusa Preamps.

See ACO Technical Specifications for connector pinout.

Fiber Optic Rotary Joint

The fiber optic rotary joint (FORJ) assembly is an available add-on component. It includes an FC/FC optical fiber connector accessible on the commutator face and a single channel optical fiber threaded through the module. The default fiber optic cable included with the system is 200 um core diameter, 0.22 NA, with a 1.25 mm OD metal ferrule. FORJ is also compatible with branched optical fibers of up to four bundles in the ACO64.

Replacing the Optical Fiber (ACO32)

The FORJ assembly can be removed and re-installed by the user to replace the optical fiber.

To remove a currently installed FORJ:

1. Use a 3/32" Allen hex driver to remove the two screws securing the fiber optic rotary joint to the commutator face.

2. Use the hex driver to remove two screws securing the encoder clamping plates.

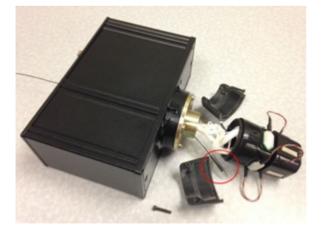3. Carefully pull the FORJ away from the commutator face until the fiber is free.
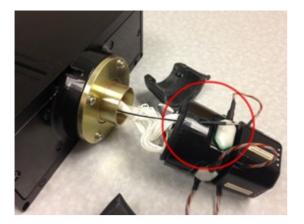

4. Disconnect the fiber from the joint.
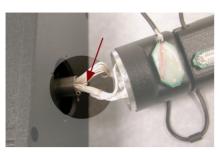
5. Replace the fiber.

To install the FORJ:

1. Insert metal cannula end of fiber into center of gear inside of ACO32.

2. Slowly push fiber through hole until the end appears among the wires on the other side of the ACO32.
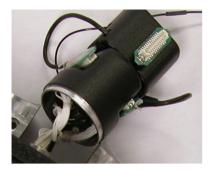
3. Using a pair of tweezers, carefully pull the end of the fiber and insert it into the hole next to the encoder.

4. Pull the end of the fiber through the hole and insert it through the hole in the groove of the connector module.

5. Leave enough slack in the section of fiber between the encoder and connector modules to match the loop of the other wires. A small lightweight tie can be loosely attached to hold the fiber adjacent to the wires.

6. Connect the FC/PC connector end of the fiber to (the smaller section of) the fiber optic rotary joint.

7. Slowly pull all of the excess fiber through the ACO32 until the FC/PC connector is inside the ACO32 and the fiber optic rotary joint plate can be attached to the ACO32 plate.

8. Attach the encoder clamping plates back onto the ACO32 shaft by tightening the two screws.

The plate should be just below body of the ACO32 and the encoder body should sit snuggly inside the lip of the clamping plates. Be careful not to pinch any wires or the fiber as the plates are tightened together.

> ✏️ **Note**
>
> If a FORJ is not used, the through-hole can be used for other related applications (e.g. fluid delivery system). Contact TDT for more details or assistance.

Change Kits

TDT provides two kits for users removing or adding a FORJ after initial purchase.

If you purchased the ACO32 or ACO64 without a FORJ and then add one, use the kit below to mount the new optics to the ACO32 or ACO64 faceplate.

If you purchased the ACO32 or ACO64 with a FORJ and wish to remove it, use the kit below to cover the opening where the FORJ was previously mounted.

> ✎ **Note**
>
> The two configurations use different screws, so be sure to save all screws.

Replacing the Optical Fiber (ACO64)

The FORJ assembly can be removed and re-installed by the user to replace the optical fiber.

To remove a currently installed FORJ:

1. Use a 3/32" Allen Hex driver to remove the two screws securing the fiber optic rotary joint to the commutator face.

2. Use the hex driver to remove the two screws securing the encoder clamping plates.

3. Carefully pull the FORJ away from the commutator face until the fiber is free.

4. Disconnect the fiber from the joint.

5. Replace the fiber.

To install one optical fiber in the FORJ:

1. Insert metal cannula end of the fiber into center of gear inside the ACO64.

2. Slowly push fiber through hole until the end appears among the wires on the other side of the ACO64. Carefully pull the wire through the slip ring.

3. Insert and guide the fiber through a hole in the encoder cover, then pull through.

4. Secure the two encoder clamping shells back onto the ACO64 shaft by inserting and tightening the two screws.
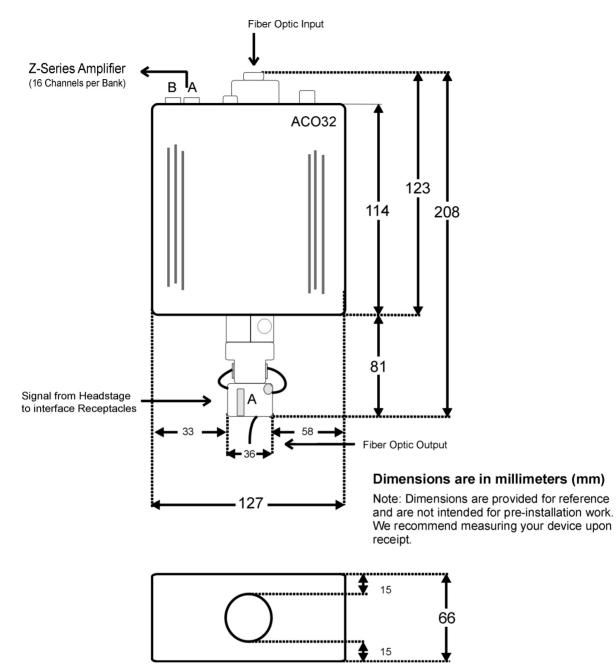
5. The plate should be just below the body of the ACO64 and the encoder body should sit snugly inside the lip of the clamping plates. Be careful not to pinch any wires or the fiber as the plates are tightened together.
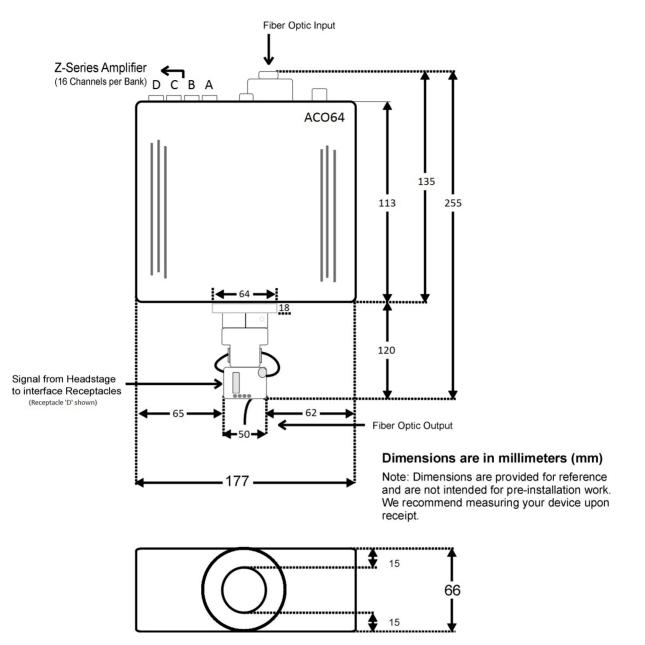
ACO Technical Specifications

Channels	ACO32 with analog PZ5 or PZA: up to 32 analog channels ACO32 with digital PZ5 or PZD: up to 256 digital channels ACO64 with analog PZ5 or PZA: up to 64 analog channels ACO64 with digital PZ5 or PZD: up to 512 digital channels
Signal/Noise	120 dB (20 Hz to 25 kHz)
RPM (approx)	18
Digital Inputs	1 Inhibit
Power Consumption	ACO32 and ACO64 quiescent: 35 mA ACO32 rotating: 65 mA ACO64 rotating: 75 mA
Run time	ACO32: ~20 hr ACO64: ~40 hr
Power Supply	ACO32: 1950 mAh Li-ion battery. 1000 cycles of charging. ACO64: 3900 mAh Li-ion battery. 1000 cycles of charging. Charger 6-9 V, 3A, center negative. Battery charges in 3-4 hours.
Mass	ACO32: ~917g ACO32 with FORJ: ~957g ACO64: ~1372g ACO64 with FORJ: ~1412g

ACO32 Dimensions

Fiber Optic Input

Z-Series Amplifier
(16 Channels per Bank)

B A

ACO32

123
114
208
81

Signal from Headstage
to interface Receptacles

33
58
36

Fiber Optic Output

127

Dimensions are in millimeters (mm)

Note: Dimensions are provided for reference
and are not intended for pre-installation work.
We recommend measuring your device upon
receipt.

15
66
15

ACO64 Dimensions

Dimensions are in millimeters (mm)

Note: Dimensions are provided for reference and are not intended for pre-installation work. We recommend measuring your device upon receipt.

Interface Receptacles

The interface receptacle diagram shows how the pins on each receptacle map to the pins on the associated DB26 connector on the face of the commutator. See pinouts below for the appropriate model.
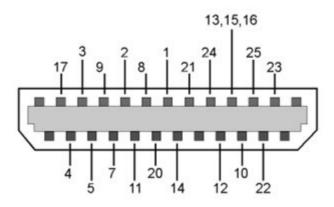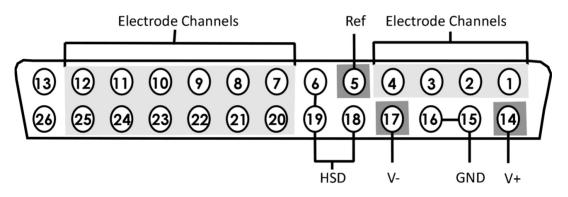
Diagram reflects pin numbers (not channel numbers).

For information on making custom connections to the commutator, see Tech Note TN0896.

ACO32 and ACO64 Amplifier Connector Pinout

Connectors are labeled A and B on ACO32 and A, B, C, D on ACO64. Electrode channels below are relative to the electrode/headstage connected to the corresponding interface receptacle.

Pin	Name	Description		Pin	Name	Description
1	E1	Electrode Channels		14	V+	Positive Voltage
2	E2			15	GND	Ground
3	E3			16	GND	
4	E4			17	V-	Negative Voltage
5	Ref	Reference		18	HSD	Headstage Detect
6	DNC	Do Not Connect		19	HSD	
7	E5	Electrode Channels		20	E6	Electrode Channels
8	E7			21	E8	
9	E9			22	E10	
10	E11			23	E12	
11	E13			24	E14	
12	E15			25	E16	
13	DNC	Do Not Connect		26	DNC	Do Not Connect

> ✏️ **Note**
>
> When mapping channel numbers for recording purposes, the preamplifier connections must be taken into account. The first channel as labeled above is relative to the amplifier bank of channel numbers connected. If connector 'B' on the ACO32 is connected to Bank B on the preamplifier, E1 is channel 17.

> 🔥 **Important**
>
> When using digital headstages and a PZ5 or PZD, channel mapping is handled by the PZ5 or PZD and channels will be ordered consecutively beginning with Connector 'A' on the commutator.

16. PC Interfaces

PO5/PO5e/PO5c/FO5 Optibit Interface

PO5 Interface Card

PO5e Interface Card

PO5c Interface Card

Optibit Overview

The Optibit system (Optical Gigabit) is designed for users that require high-speed real-time control of System 3 devices or precise system-wide device synchronization. The Optibit interface consists of a PCI card (PO5), PCIe card (PO5e), or PCI Cluster card (PO5c) that must be installed in the computer and one or more Optibit-to-zBus interface modules (FO5) that mount in the rear slot of a zBus device chassis or is built into RZ Processors. When using the Optibit interface, all devices are automatically phase locked to a single clock.

Part Numbers:

PO5 - Optical PCI Card for Optibit Interface

PO5e - Optical PCI Express Card for Optibit Interface

PO5c - Direct PCI Interface for Cluster Computing

FO5 - Optibit to zBus Interface

Fiber Optic Connection

Devices are connected in a simple loop using provided high speed noise immune fiber optic cabling. See the System 3 Install Guide for installation instructions. For setting up the PO5c card in Synapse, see Cluster Processing with Synapse.

FO5 Status LEDs
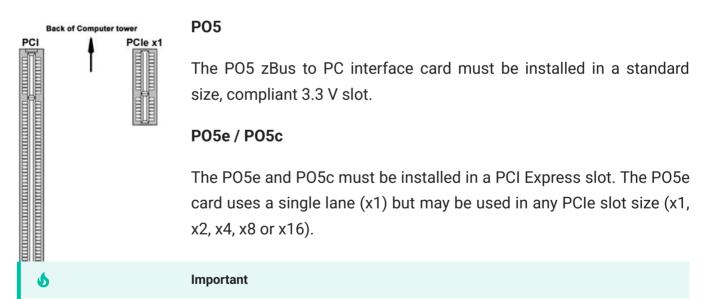
Four status LEDs on the face of the FO5 indicate the connection status of the interface.

Connected   The Connected LED is lit when the interface is powered on and the fiber optic cable labeled IN is connected properly. Although the Connected LED will light if only the IN cable is connected, both cables have to be connected properly for communication to take place.

Identified   The Identified LED lights when a software signal sent from the PC is recognized by the interface. This takes place when launching TDT software such as zBUSMon or running a Synapse experiment.

Activity   The Activity LED is lit when data is being sent to or from the TDT hardware.

Error   The Error LED lights when there is a connection or communication error. For example, this LED will light if the fiber optic cables are not connected properly.

PO5/PO5e/PO5c Technical Specifications
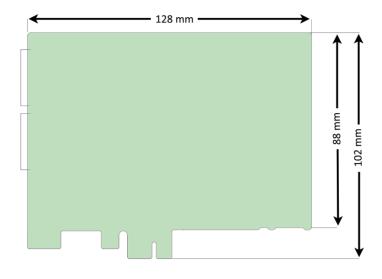
Interface transfer rates vary by transfer type and device. See Interface Transfer Rates for more information.

Below is a diagram of the compatible PCI and PCIe slots used with the PO5 and PO5e/PO5c Optibit Interface cards.

PO5

The PO5 zBus to PC interface card must be installed in a standard size, compliant 3.3 V slot.

PO5e / PO5c

The PO5e and PO5c must be installed in a PCI Express slot. The PO5e card uses a single lane (x1) but may be used in any PCIe slot size (x1, x2, x4, x8 or x16).

> 🔥 **Important**
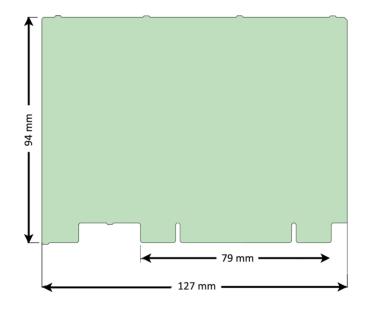
Do not attempt to install in low-profile PCI slots. While low profile and standard PCI cards maintain the same electricals, protocols, PC signals, and software drivers as standard PCI expansion cards, the low profile bracket is not compatible with standard card size.

Fiber Optics

Standard cable length is 5 meters. Longer cables (up to 30 meters) are available on request.

PO5e and PO5c dimensions

PO5 dimensions

UZ3 USB 3.0 Interface for Optibit

UZ3 Interface

UZ3 Overview

The UZ3 is a fiber optic interface to a high speed USB 3.0 port on your laptop or PC. It can connect to one or more RZ Processors. RX, RP, and PA5 devices are supported in v98 and above. BioSigRP does not support UZ3.

A USB Type C-C cable and C-A cable are included.

Part Number: UZ3 - USB 3.0 Interface

UZ3 Technical Specifications
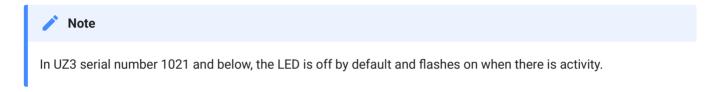
Interface transfer rates vary by transfer type and device. See Interface Transfer Rates for more information.

The UZ3 can handle roughly 50-75% of the data rate of the PO5/PO5e card and should not be used for high channel count applications. The actual maximum rate is dependent on your PC specs.

The status LED is on by default when connected and flashes off when there is transfer activity.

UZ3 status LED

> ✏️ **Note**
>
> In UZ3 serial number 1021 and below, the LED is off by default and flashes on when there is activity.

Do not use with a USB 2.0 port. Use zBUSMon software to measure the transfer rate to see if you are getting high speed data transfer.

The UZ3 dimensions are 31 x 21 x 106 mm.

UZ2 USB 2.0 Interface

UZ2 Interface

Overview

The USB 2.0 zBus Interface mounts in the rear bay of a zBus device chassis and handles communication and data transfer between your computer and zBus mounted programmable devices, such real-time processors or programmable attenuators. Most nonprogrammable devices, such as speaker drivers or signal mixers, do not require an interface.

You will need a USB 2.0 port available on the host PC for each UZ2 in a multi-chassis system. We recommend upgrading to an Optibit interface if your system requires more than three chassis.

> ✏️ **Note**
>
> If using the USB 2.0 interface on a 64-bit operating system, you must install version 76 TDT drivers or greater.

Connecting the UZ2

The UZ2 connects to your computer with standard USB 2.0 A to B cables (provided with each module). Interface drivers are bundled with the TDT Drivers and will be installed when the device is connected to the host computer for the first time. The UZ2 can be safely connected or unconnected while the computer is running.

> 🔥 **Important**
>
> Wait 10 seconds after devices have gone through the boot sequence or 30 seconds after turning on devices (with the computer already running) before running applications that use TDT devices. We also recommend using zBUSMon to verify the logical order of devices before beginning any experiment. See Boot Up Sequence for more information.

Sync

The Sync input allows users to synchronize several modules that are mounted in different device chassis. Each USB module has its own clock. Clocks on multiple USB devices will drift relative to each other. The Sync line uses the clock from one USB module, the parent, to synchronize the clocks across all zBus device chassis.

To connect several zBus chassis, one module (the highest logical module) is designated as the parent and the other clocks are children of the master clock. Connect the Sync Out of the parent clock to the Sync In of the child with a short patch cable. To connect several device chassis, daisy-chain the connections between the child chassis. When the Sync lines are connected correctly the LED to the left of the Sync connectors should be lit on each child device. The LED on the parent will remain unlit. The LED should only flash when the Sync lines are not connected.

Sync LEDs	Indicates
Flashing (on child)	Connected incorrectly
Parent device not lit and child devices lit	Connected correctly
No devices lit	Not synced to any device

Logical Order of Devices

The logical order of devices is determined each time the zBus chassis are powered on. You can verify the current logical order using the zBUSMon utility.

Boot Up Sequence

The boot up sequence for the USB 2.0 interface is driven from the PC and follows the communication protocol described below.

The first time the hardware is turned on:

1. A device driver is loaded to the interface. Depending on your operating system, the PC might beep to indicate that the device driver has been loaded.

2. A second set of drivers will be loaded and the devices will reboot.

3. The TDT hardware is queried to determine the logical order of the devices and zBus chassis.

> 🔥 **Important**
>
> If the zBus is accessed during step 3, the devices will fail to ID. To ensure that step 3 is completed, wait 10 seconds after the devices have rebooted (step two) before loading any TDT application or viewing the devices in zBUSMon. If the hardware fails to identify, power down the TDT hardware and restart it.

UZ2 Technical Specifications

Interface transfer rates vary by transfer type and device. See Interface Transfer Rates for more information.
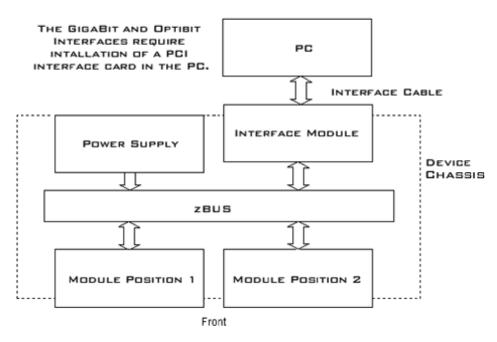
ZB1PS Powered zBUS Device Chassis

Overview

zBUS is TDT's high-speed, low-noise bus for System 3 modules. The bus is integrated into a device chassis, which serves as a rack mountable housing for most modular devices in the System 3 line, excluding the RZ processors which have their own built-in power supply and computer interface.

As shown in the functional diagram below, the bus distributes communication and power throughout the system.

zBUS Functional Diagram
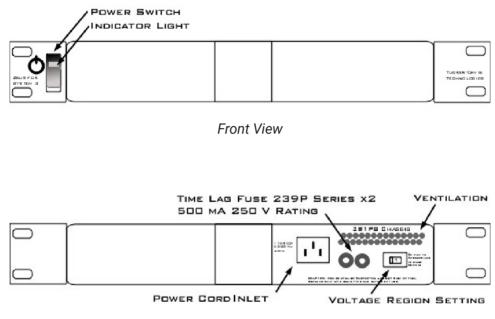
One or two modular devices can be mounted in the chassis' front bays, providing easy access to front panel connections. An interface module can be mounted in the second rear bay for chassis housing a programmable device. Multiple chassis can be interfaced for custom system configurations and individual modules can be added or removed as needed.

Power Supply

The ZB1PS chassis features an onboard, switchable (115 V / 220 V) power source. The power supply is integrated into the chassis and cannot be removed. A small fan is located inside of the power supply and provides cooling while the power supply is active.
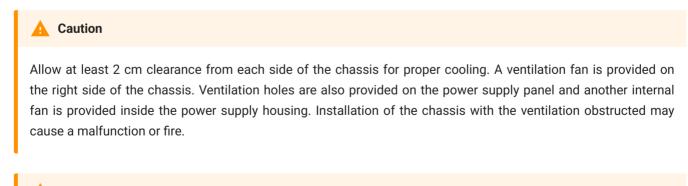
See the ZBPS1 Operations Manual for power and safety information.

Using the ZB1PS

Front View

Back View

Applying Power to the Chassis

> ⚠ **Caution**
>
> Allow at least 2 cm clearance from each side of the chassis for proper cooling. A ventilation fan is provided on the right side of the chassis. Ventilation holes are also provided on the power supply panel and another internal fan is provided inside the power supply housing. Installation of the chassis with the ventilation obstructed may cause a malfunction or fire.

> ⚠ **Caution**
>
> Use only the supplied power cord.

To turn the ZB1PS on:

1. Position the chassis so that both the power switch and power cord may be accessed easily.

2. Ensure that the power switch is off then connect the power cord.

3. Ensure that the voltage region switch is set correctly. For standard outlets in the United States it should be switched to 115 V.

4. Turn the power switch on. The power switch's green LED should be illuminated.

The Indicator Light

A front panel switch turns on the chassis power supply and includes an indicator light. The power switch's green LED will illuminate when the chassis is switched on. The light will flash rapidly when it receives a command from software and slowly to indicate a communications error (check all cable connections).

Disconnecting Power from the Chassis

> ⚠ **Caution**
>
> When removing the power cord from either the power supply or socket outlet, grasp the plug, not the cord, in order to avoid damaging the cable.

To disconnect the ZB1PS:

1. Turn off the power switch.

2. Disconnect the power cord from the power supply.

3. Disconnect the power cord from the wall socket plug.

Adding and Removing Modules

Before adding or removing modules, make sure the ZB1PS is powered off.

To remove a module from the chassis:

1. Unscrew the two thumb screws on the corner of the module faceplate.

2. Pull straight out on the front-panel BNC connectors. A BNC 'T' connector makes a great handle for removing zBUS devices.

To add a module to a chassis:

1. Insert the module into an empty bay and push straight back until it seats onto the connector.

2. Hold the module in place with the thumb screws.

ZB1PS Technical Specifications

Chassis	
Height	1U
Width	Standard 19" (482.6 mm) rack mount
Power Supply (Integrated)	
Maximum Working Voltage	HI to earth ground 230 V max LO to earth ground 230 V max
Main Voltage Rating	115/230 V, 50/60 Hz, 40 VA AC
Installation Category	CAT II
Environmental	
Operating Temperature	0°C to 45°C
Storage Temperature	5°C to 40°C
Humidity	80% for temperatures up to 31°C, decreasing linearly to 50% RH at 40°C
Maximum Altitude	2,000 m
Pollution Degree	2 (Indoor use only)
Power Supply Fuses	
Time Lag Fuse 239P Series	2 fuses
Operating Temperature	-55°C to 125°C
Ampere Rating	0.500 A
Voltage Rating	250 V
Interrupting Rating	10,000 amperes at 125 VAC, 0.7-0.8 power factor 35 amperes at 250 VAC, 0.7-0.8 power factor

Interface Transfer Rates

Transfer rates depend on a number of factors, including the device accessed the type of transfer, and cycle usage.

The table below includes typical transfer rates for the Optibit and USB interfaces at a 50% cycle usage with RP/RX and RZ devices.

Interface	Transfer Type	RP	RX	RZ
PO5/PO5e/FO5	Read	1.5	4.0	8.0
	Write	1.0	1.0	8.0
UZ3	Read	NS	NS	6.0 *
	Write	NS	NS	6.0 *
UZ2	Read	1.5	1.5	NS
	Write	1.0	1.0	NS

Transfer rates are in MB/s. NS: Not Supported
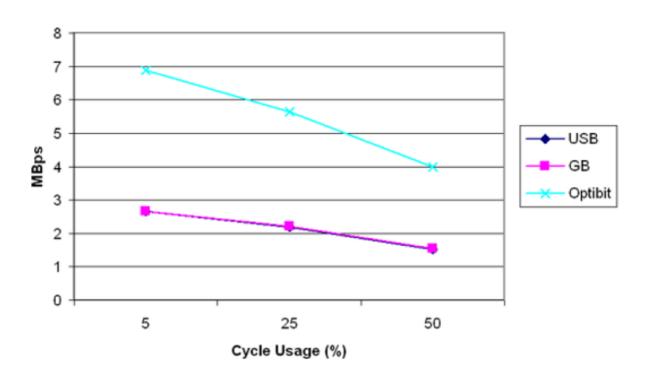
* UZ3 transfer rates are highly dependent on the specs of the computer.

Because of the overhead required to poll the hardware or run single commands with the USB interface, users should be aware of the following relationships when performing small data transfers with the UZ2.
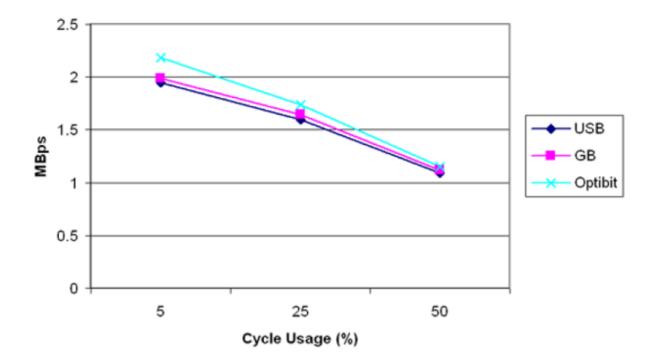
Interface	Transfer Type	RP/RX
UZ2	Snippet Transfers (~100)	0.3 MB/s
	Single Commands	1000 Commands/s

Cycle Usage and Large Transfers

The following graphs show how the cycle usage affects the transfer rate for large transfers with the Optibit, Gigabit, and USB 2.0 interfaces with an RX device. The data was collected using a buffer size of 1,000,000 for the Read Tag and Write Tag commands. The transfer rates were tested using both the RP2.1 (a single processor device) and only the main processor of an RX6 and using circuits generating cycle usages of 5, 25, and 50 percent.

Read Tag (Buffer Size = 1000000)

Write Tag (Buffer Size = 1000000)

17. Signal Routing

PP24 Patch Panel

Overview

The PP24 Patch Panel provides front panel BNC connections for easy access to the digital and analog inputs and outputs of the RZ and RX processors.

> ✏ **Note**
>
> If using the RP2.1 or RA16BA processors, Power Multiplexer (PM2R), or Power Amplifier (SA8), use the PP16 Patch Panel instead.

Adjustable Positioning

The PP24 comes with either an RX CONN or RZ CONN PCB adapter to match your processor type.
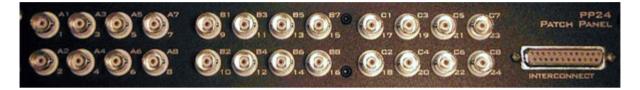
The PP24 has a 25-pin connector on the front panel. The RX CONN PCB Adapter connects the PP24 to an RX device positioned either directly above or directly below the PP24. The RZ CONN connects an RZ processor positioned above the PP24. Loosen the four thumbscrews (one on each corner of the PP24 front panel) to slide the BNC array into the correct position to align the connector with the target device.

> ⚠️ **Caution**
>
> The thumbscrews should never be completely removed. Avoid loosening the thumbscrews too far.

Mapping the Inputs and Outputs for Each Device

The PP24 consists of 3 banks of BNC connectors, Bank A, B, and C. Each of the banks is labeled 1-8 within the set and each BNC is also numbered as part of the entire group from 1 - 24.
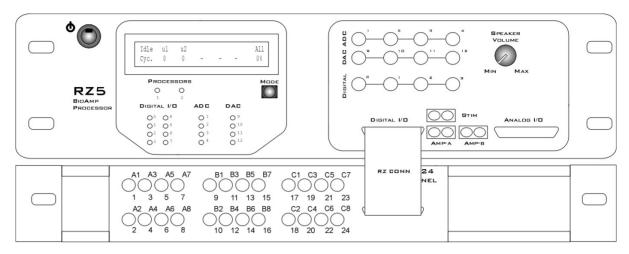
The following table shows the configuration of the BNC connectors for each I/O connector of the RX and RZ devices.

Device & Connector	A1 - A8	B1 - B8	C1 - C8
RZ5, RZ5D, RZ5P, RZ6, RZ10x Digital I/O Connector	Digital I/O Port C Bits 0-7	Digital I/O Port A Bits 0-7	Digital I/O Port B Bits 0-7
RZ2 Digital I/O Connector	Digital I/O Port C Bits 0-7	Digital I/O Port A Bits 0-7	Digital I/O Port B Bits 0-7
RX5, RX6, RX7, RX8 Digital I/O Connector	Bit Addressable Digital I/O Bits 0-7	Digital I/O Byte A Bits 0-7	Digital I/O Byte B Bits 8-15
RX5, RX7 Multi I/O Connector	Analog Outputs A2, A4, A6, A8 = Channels 1-4 A1, A3, A5, A7 = Not Used	Digital I/O Byte C Bits 16-23	Digital I/O Byte D Bits 24-31
RX8 Analog I/O Connector	Analog I/O Block A Channels 1-8	Analog I/O Block B Channels 9-16	Analog Output Block C Channels 17-24

For more information, see the diagrams for the desired device below.

RZ5, RZ5D, RZ5P, RZ6, RZ10x Digital I/O

The PP24 is mounted below the RZ.

RZ5, RZ5D, RZ5P, RZ6, RZ10x Digital I/O connection to the PP24
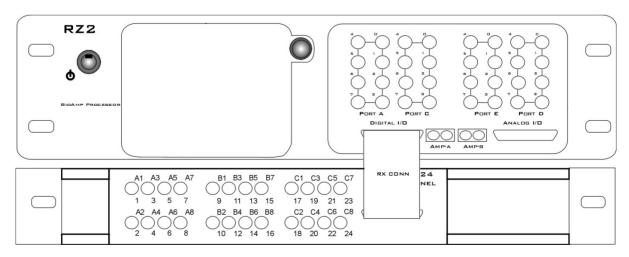
A1 - A8	B1 - B8	C1 - C8
Digital I/O	Digital I/O	Digital I/O
Port C Bits 0-7	Port A Bits 0-7	Port B Bits 0-7
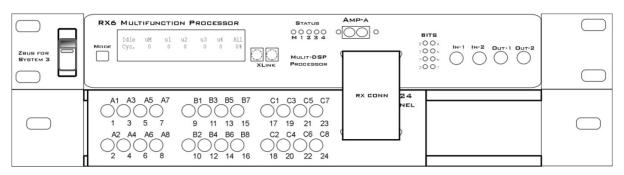
RZ2 Digital I/O

The PP24 is mounted below the RZ2. Ports A & C are available on the RZ2 front panel BNCs. Port B is only accessible through the DB25 connector.

RZ2 Digital I/O connection to the PP24

A1 - A8	B1 - B8	C1 - C8
Digital I/O Port C Bits 0-7	Digital I/O Port A Bits 0-7	Digital I/O Port B Bits 0-7

RX5 or RX7 I/O

The PP24 can be mounted above or below the RX5.

RX5 and RX7 Digital I/O connections to the PP24

A1 - A8	B1 - B8	C1 - C8
Bit Addressable Digital I/O Bits 0-7	Digital I/O Byte A Bits 0-7	Digital I/O Byte B Bits 8-15

RX5 and RX7 Multi I/O connections to the PP24.

A1 - A8	B1 - B8	C1 - C8
Analog Outputs A2, A4, A6, A8 = Channels 1-4 A1, A3, A5, A7 = Not Used	Digital I/O Byte C Bits 16-23	Digital I/O Byte D Bits 24-31

RX6 Digital I/O

The PP24 can be mounted above or below the RX6.
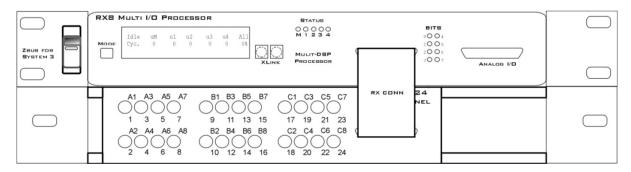
RX6 Digital I/O connection to the PP24

A1 - A8	B1 - B8	C1 - C8
Bit Addressable Digital I/O Bits 0-7	Digital I/O Byte A Bits 0-7	Digital I/O Byte B Bits 8-15

RX8 I/O

The PP24 can be mounted above or below the RX8.

RX8 Digital I/O connection to the PP24

A1 - A8	B1 - B8	C1 - C8
Bit Addressable Digital I/O Bits 0-7	Digital I/O Byte A Bits 0-7	Digital I/O Byte B Bits 8-15

RX8 Analog I/O connection to the PP24

A1 - A8	B1 - B8	C1 - C8
Analog I/O Block A Channels 1-8	Analog I/O Block B Channels 9-16	Analog Output Block C Channels 17-24

PP16 Patch Panel

The PP16 Patch Panel provides convenient BNC connections for easy access to the digital and analog inputs and outputs of a variety of System 3 devices. Originally designed for use with the RP2 Real-time Processor, RA16 Medusa Base Station, and RV8 Barracuda; the PP16 back edge is equipped with a nine pin and three 25-pin connectors, which have been marked with the corresponding device label.

To connect the PP16 to a device:

Connect the male end of the 25-pin ribbon cable to the desired module and connect the female end to the correct PP16 input according to the following table.

PP16 Device Connectors

PP16 Device Connectors and supported devices:

RA16 25 Pin	**RP2** 25 Pin
RA16BA ● RA8GA ● SA8	RP2 ● RP2.1 ● PM2R
RX5 ● RX6 ● RX7 ● RX8	
RZ2 ● RZ5 ● RZ5P ● RZ5D ● RZ6 ● RZ10x	

Mapping the Inputs and Outputs for Each Device

Each device has a unique input and output configuration. The table below shows the configuration of the BNC connectors.
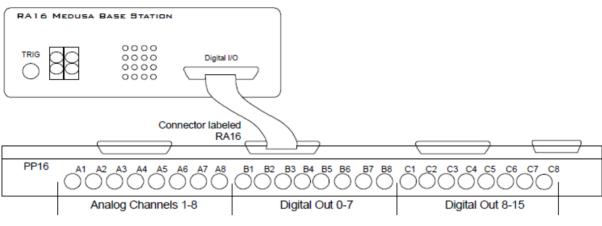
Device & Connector	A1-A8	B1-B8	C1-C8
RP2 / RP2.1 Digital I/O Connector	Digital Inputs Bits 0-7	Digital Outputs Bits 0-7	C1=3.3 V (max 1 mA)
RA16BA Analog/Digital I/O Connector	Analog Outputs Channels 1-8	Digital Outputs Bits 0-7	Digital Outputs Bits 8-15
RA8GA Analog I/O Connector	Analog Input Channels 1-8	Not Used	Not Used
PM2R Signal Out Connector	Analog Output Channels 0-7	Analog Output Channels 8-15	Not Used
SA8 Power Outputs Connector	Analog Output Channels 1-8	Analog Output Signal and Ground: Channels 1-4	Analog Output Signal and Ground: Channels 5-8

The PP16 can also be used with the RX and RZ devices, however, the PP24 Patch Panel is recommended.

Device & Connector	A1 - A8	B1 - B8	C1 - C8
RZ5, RZ5D, RZ5P, RZ6, RZ10x Digital I/O Connector	Digital I/O Port C Bits 0-7	Digital I/O Port A Bits 0-7	Digital I/O Port B Bits 0-7
RZ2 Digital I/O Connector	Digital I/O Port C Bits 0-7	Digital I/O Port A Bits 0-7	Digital I/O Port B Bits 0-7
RX5, RX6, RX7, RX8 Digital I/O Connector	Bit Addressable Digital I/O Bits 0-7	Digital I/O Byte A Bits 0-7	Digital I/O Byte B Bits 8-15
RX5, RX7 Multi I/O Connector	Analog Outputs A2, A4, A6, A8 = Channels 1-4 A1, A3, A5, A7 = Not Used	Digital I/O Byte C Bits 16-23	Digital I/O Byte D Bits 24-31
RX8 Analog I/O Connector	Analog I/O Block A Channels 1-8	Analog I/O Block B Channels 9-16	Analog Output Block C Channels 17-24

Mapping RA16BA I/O

The diagram below maps the RA16BA Digital I/O connection to the PP16.

RA16BA to PP16 Connection Diagram

Mapping RP2/RP2.1 I/O
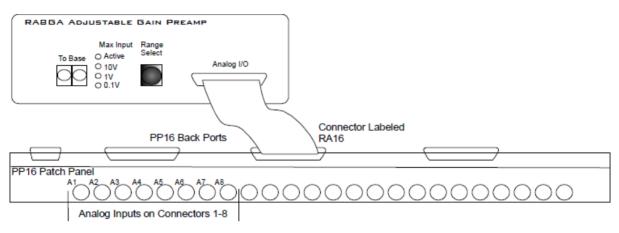
The diagram below maps the RP2 Digital I/O connection to the PP16. The last seven BNC connectors are not used. BNC C1 maps to VCC 3.3.

RP2.1 to PP16 Connection Diagram

Mapping RA8GA
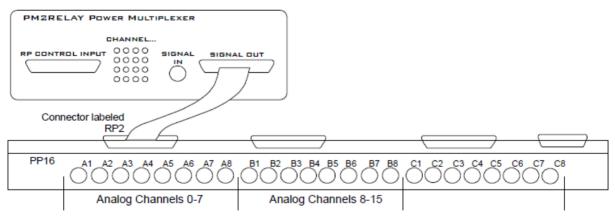
A PP16 patch panel can be used to simplify connection to the preamplifier's analog inputs. A ribbon cable can be connected from the RA8GA Analog I/O connector to the RA16 connector on the back of the PP16 allowing acquisition of signals via the first eight BNC connectors on the front of the PP16.

RA8GA to PP16 Connection Diagram
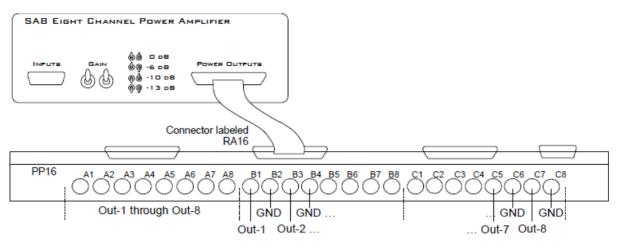
Mapping PM2R I/O

The diagram below maps the PM2R signal out connection to the PP16.

PM2R to PP16 Connection Diagram

Mapping SA8 Analog Outputs

SA8 to PP16 Connection Diagram

PM2Relay Power Multiplexer

Overview

The PM2Relay (PM2R) is a 16 channel multiplexer for delivering powered and unpowered signals to a device. When coupled to a power amplifier such as the SA1, the PM2R can transfer several watts of power to standard four ohm and eight ohm speakers.

The PM2R is designed to be used as a "de-multiplexer", that is, one input switched to 16 possible outputs. However, it can also be used as a straight multiplexer (16 inputs to one output). This is accomplished by sending signals in to the 16 "signal out" channels. The selected channel will be output on the "signal in" channel. Users that are doing this should be very careful, as it is easy to exceed the maximum input values when sending in 16 input signals. The aggregate input of all signals should never exceed two amps, or 15 volts, because severe damage can be caused to the module.

Each RZ/RX/RP processor can control up to four PM2R devices and each PM2R can have one active channel. Therefore, a maximum of four signals can be played out simultaneously when using four PM2Rs.

To connect to a System 3 module, attach the 25-pin, blue ribbon cable from the processor device to the PM2R. Connect your powered signal source to the Signal In. Connect the signal out to the 'RP2' connection on the PP16 Patch Panel, or your own connectors. The channel outs on the PP16 from the left to right, correspond to the 16 channels (0-15) on the device.

Power

The PM2R Power Multiplexer is powered via the System 3 zBus (ZB1PS). No PC interface is required.

PM2R Features

The PM2R uses a bit pattern code to control the output of a powered signal to one of sixteen output channels. The powered signal can come from any power amplifier such as the RZ6 processor, SA1 Stereo Amplifier or the HB7 Headphone Buffer. The PM2R is designed to use a bit-code pattern from any RZ, RX, or RP real-time processor.

RP Control Input

The male DB25 connector on the left is the interface to the Digital port on the processor. A blue ribbon connector is used to directly connect the processor and the PM2R. The PM2R uses 8 bits of digital I/O. If you need access to the other digital I/O on your device, a custom cable may be required.

Signal In

The BNC connector is the powered signal input. The maximum power input is a two amp, 15 volt continuous signal or approximately 30 watts of continuous power.

Signal Out

The female DB25 connector on the right is the interface for the powered signal output. Users can also connect the PM2R output to the patch panel (PP16) connector labeled for the 'RP2' for easy BNC access to the powered signal.

Channel...

Sixteen LEDs indicate which channel is active. One channel can be active at a time. It is also possible to inactivate all channels.

Bitcode Pattern

The bitcode pattern from the RP2 consists of an 8-bit word that contains the following information; the device ID, the channel ID, and a set-bit. A final bit shuts off all channels. To control the PM2R, generate the bitcode pattern associated with the device and channel then send out the set-bit to change the channels. Be aware that the relays on the PM2R have a transition time of around one millisecond.

Bits 0 - 3	identify the channel number. 0000 is channel 0, 1111 is channel 15.
Bits 4 and 5	identify the device number. 00 is device 0, 11 is device 3. The device number is set internally for each PM2R and allows for a single processor to control up to four PM2R modules. If only one PM2R is being used, it is device number 0.
Bit 6	the set-bit. When this bit is set high, the channel and device from the previous six bits is activated.
Bit 7	deactivates all channels across only the specified device.

> ✏️ **Note**
>
> Make sure to put a delay of one sample between setting the channel number and turning the channel on. Trying to do both at the same time will not work correctly. For example, send "00000111" to select channel 7, and then send "01000000" one sample later to turn the channel on.

Controlling Signal Presentation
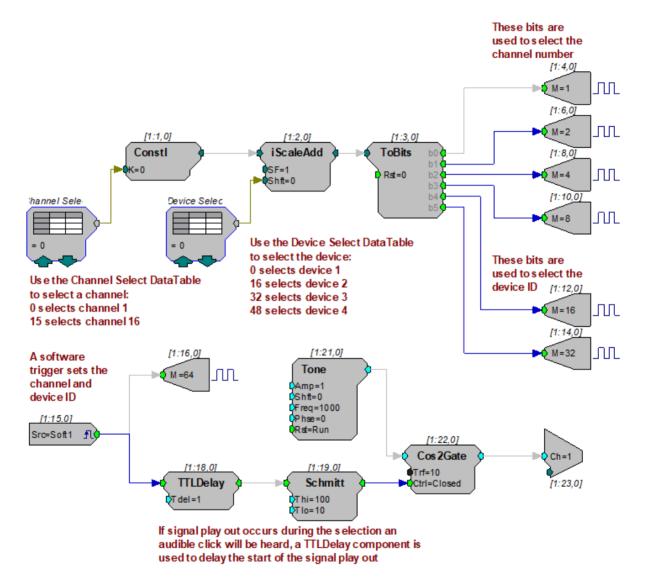
The circuits described here use typical techniques for controlling the signal presentation when using a PM2R. These circuits have been designed as tutorials and will need to be modified to meet the needs of the individual researcher.

Controlling the PM2R with BitOuts

In this example several BitOuts are used to control the PM2R from within RPvdsEx. The bit pattern is generated by two DataTable components. DataTables are commonly used to send values from the PC to the RP devices. While working in RPvdsEx, the selection can be changed by clicking the green up and down arrows near the bottom edge of the components. The first DataTable (Channel Select) stores the values for the channel number. Channel numbers start at zero and go to fifteen. Each processor is capable of controlling up to four PM2R devices. The second DataTable (DeviceSelect) stores the values for the device ID. The values in the table are 0 (device 0), 16 (device 1), 32 (device 2), and 48 (device 3). The iScaleAdd is used to add the integer values from both tables and the ToBits component changes the resulting

integer to the bitcode pattern. The first four bits are used to select the channel number and the last two bits are used to select the device ID.
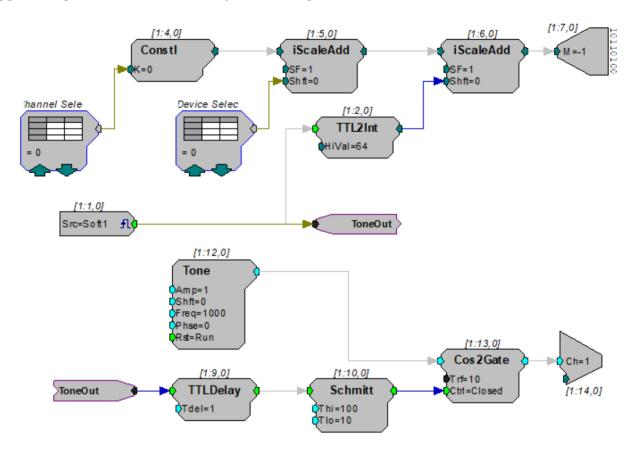
A software trigger is used to change devices and initiate a tone burst of 100 milliseconds duration. The software trigger causes the Schmitt trigger to open a gate for 100 milliseconds. The Schmitt trigger is delayed by one millisecond relative to the channel select. This removes the transient associated with the relays.

An example circuit for using the RZ6 to control the PM2R installs with TDT drivers to `C:\TDT\RPvdsEx\Examples\PM2rRZ6.rcx`.

Controlling the PM2R with WordOut

In this example a WordOut is used to control the PM2R (via an RP2.1) from within RPvdsEx. This simplified format decreases cycle usage. An additional iScaleAdd is required because the BitOut and WordOut components function differently and should not be used in the same circuit. As before, a software trigger initiates the start of the stimulus presentation. The triggered signal adds 64 to the output to change the channel.
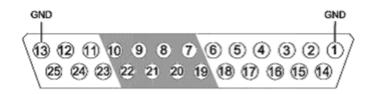
Controlling the PM2R from a run-time application

The examples described here could easily be modified to allow control from run- time applications. Parameter tags can be included and used in other applications such as BioSigRP, OpenEx, or Synapse.

PM2R Technical Specifications
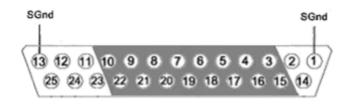
Switching Mode	Single 1-to-16, 16-to-1
Switching Time	2 ms
Input/output Level	±15 V
Channel Cross-Talk	<-80 dB
S/N (typical)	90 dB
Maximum Allowable Current	2 A continuous

RP Control Input - DB25 Pinout

Pin	Name	Description		Pin	Name	Description
1	GND	Ground		14	NA	Not Used
2	NA	Not Used		15	NA	
3	NA			16	NA	
4	NA			17	NA	
5	NA			18	NA	
6	NA			19	D0	Digital Input Bits
7	D1	Digital Input Bits		20	D2	
8	D3			21	D4	
9	D5			22	D6	
10	D7			23	NA	Not Used
11	NA	Not Used		24	NA	
12	NA			25	NA	
13	GND	Ground				

Signal Output - DB25 Pinout

Pin	Name	Description		Pin	Name	Description
1	SGND	Signal Ground		14	NA	Not Used
2	NA	Not Used		15	A0	Analog Output Channels
3	A1	Analog Output Channels		16	A2	
4	A3			17	A4	
5	A5			18	A6	
6	A7			19	A8	
7	A9			20	A10	
8	A11			21	A12	
9	A13			22	A14	
10	A15			23	NA	Not Used
11	NA			24	NA	
12	NA			25	NA	
13	SGND	Signal Ground				

18. Speakers

EC1/ES1 Electrostatic Speaker

Overview

TDT Electrostatic Speakers (Patent No. US 6,842,964 B1) are designed specifically for ultrasonic signal production. The electrostatic design offers a thin, flexible membrane with an extremely low moving mass. Unlike conventional speakers, these speakers distribute the driving signal homogeneously over the surface of the membrane. These factors produce a small, lightweight speaker with an excellent ultrasonic response and very low distortion. Available with or without a coupler, both models are easy to position and are particularly well suited for studies with small animals that have hearing in the ultrasonic range.

Part Numbers (Patent No. US 6,842,964 B1):

ES1 - Free Field Electrostatic Speaker

EC1 - Electrostatic Speaker-Coupler Model

Cable Connection

The ES1 and EC1 electrostatic speakers work exclusively with the ED1 Electrostatic Speaker Driver. Input is via a 4-pin, mini-DIN connector, which carries both bias and signal voltages from the speaker driver. Connection to the speaker driver is through a standard 6.1 m long cable. Other cable lengths can be special ordered, but will affect the speaker's frequency response. The speakers come fully enclosed to eliminate access to the high-voltage bias and driving signals. A 3.175 mm mounting hole at the base of the speaker accepts a standard 4-40 standoff. See ED1 Electrostatic Speaker Driver for information about gain settings.

The orientation of the cable connection is indicated with dots on the cable connector and on the speaker. The cable should be connected so that the dot on the cable faces towards the speaker.

When connecting the cable, ensure that the four pin connectors are fully seated on the speaker and the speaker driver. When the cable is repeatedly moved during the experiment, periodically check that the connectors are fully seated.

EC1 Coupled Electrostatic Speaker

The EC1 includes a small piece of ⅛" O.D. Tygon tubing coupled to the output. The tubing will transfer the signal best when it is kept straight. Note that the speaker performance is dependent on the coupling system used and the ear of the animal. Users should test the device under experimental conditions to ensure it meets their requirements. If using BioSigRZ software, see the ABR Guide or DPOAE Guide for calibration tips. Technical Specifications measured under specific controlled conditions are provided for comparison purposes.

Maximizing the Life of the Speakers

The TDT electrostatic speakers are designed to operate with input signals between 4 kHz and 110 kHz. Playing signals below 4 kHz causes a large amount of harmonic distortion that degrades the operation of the speakers over time, causing a decreased power output across all frequencies. Although the speakers won't clip until ±10 V, presenting continual input voltage over ±4 V will reduce speaker lifespan.

Broadband Signals

When using broadband signals, limit the amount of energy in the low frequency ranges whenever possible. For example, band-limiting noise stimuli with a high pass filter at 4 kHz or above (the higher the better for the life of the speakers) and limiting complex harmonic signals, such as frequency sweeps, to frequencies above 4 kHz can increase the effective life of the speakers.

Click Stimuli

ABR experiments in both human and mouse studies typically use a 100 microsecond click stimuli, which has most of its energy in the 2 kHz to 8 kHz range. Because click stimuli are short impulses that generate signals across a broad frequency range, band limiting the frequencies is not feasible. TDT recommends that users attenuate the click stimuli so as to minimize the potential effects on the speaker. Also note that the shorter the stimuli the flatter the frequency response and the greater the energy in the higher frequencies. Moreover, the shorter the duration of the click the less total energy it has (for a given voltage).

Routine Care and Maintenance

Inspect speakers for visual damage or obstruction of the speaker holes prior to use. If there is damage to the copper shield around the components next to the connector or debris clogging the speaker holes, contact TDT for an RMA for repair.
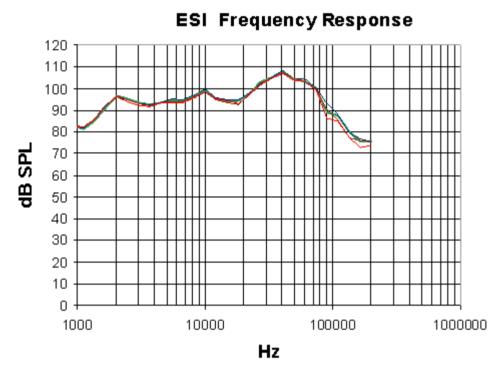
> ⚠️ **Caution**
>
> NEVER attempt to clean the holes in the baseplate of the speaker. Doing so can puncture the speaker membrane.
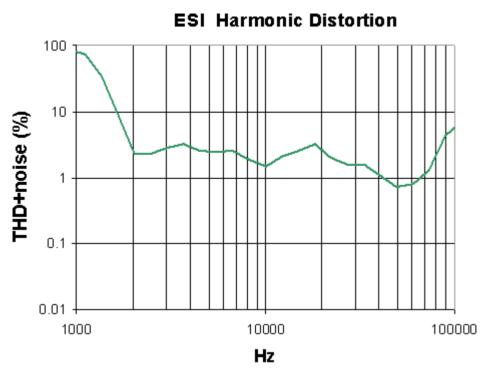
When using the EC1, check the end of the Tygon tubing for cerumen and other debris and clean as necessary.

ES1 Technical Specifications

Frequency Response	±11 dB from 4 kHz to 110 kHz
Weight	22 g
Dimensions	3.8 cm outside diameter x 2.6 cm deep
Typical Output (10 V peak input)	95 dB SPL at 10 cm, 5 kHz signal
Total Harmonic Distortion	<3%, 2 kHz - 110 kHz, 4 Vp input

Free-field Frequency Response of Four Speakers at 10 cm

Harmonic Distortion at 4 V Peak

Noise as well as harmonic distortion is measured. Lower signal levels (e.g. above 75 kHz shown above) have higher THD+noise because of lower signal to noise ratios. When measured at higher signal levels, the THD above 75 kHz is actually <3% up to 110 kHz.

EC1 Technical Specifications
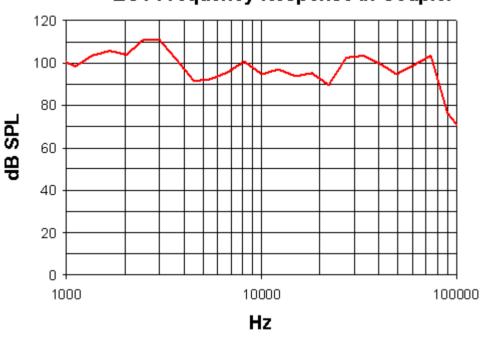
Frequency Response	±9 dB from 4 kHz to 110 kHz
Weight	22 g
Dimensions	3.8 cm outside diameter x 2.6 cm deep
Typical Output	90 dB SPL, 5 kHz signal*
	Every experimental setup is unique. It is important to calibrate the response of the speaker in each experimental setup.
Total Harmonic Distortion	*Every experimental setup is unique. It is important to calibrate the response of the speaker in each experimental setup.*

Frequency Response in Plexiglas Coupler

*Measurements were made in a 1 cm x 0.5 cm coupler with a 20 cm length of 2.4 mm i.e. tubing attached to the fitting of the EC1. 4 V peak input tones were tested and frequency response was measured with a calibrated pressure microphone.

The results of the calibration will vary depending on the type of ear to which the speaker is coupled and the length of the tube that is coupled to the ear. This curve is provided as representative of the type of response that may be obtained in a closed field.

In this case, the low end of the response (<5 kHz) is enhanced over the free- field response while the high end of the response (>80 kHz) is attenuated.

Every experimental setup is unique. It is important to calibrate the response of the speaker in each experimental setup.

> 🔥 **Important**
>
> Modifying the EC1 or ES1 can result in unexpected changes in the transfer function. All modifications to the EC1 or ES1 should be performed by TDT. If you need to be 30-60 dB lower than specifications, or if you have one of these devices, contact TDT for assistance.

MF1 Multi-Field Magnetic Speakers

Overview

TDT Multi-Field Magnetic Speakers offer high output and fidelity over a wide bandwidth and deliver more power at lower frequencies than our electrostatic speakers. They are well-suited for laboratory species with lower frequency hearing and for noise exposure studies.

A detachable tip allows them to be configured for either free-field or closed-field use. The closed-field configuration uses an internal parabolic cone designed to maximize output and minimize distortion. The tip is tapered to hold ⅛" O.D. PVC tubing. The mono speaker comes with two 10 cm tubes and the dual speaker set comes with four 10 cm tubes.

> ✏️ **Note**
>
> An Ear Tip for direct application (no tubing required), is also available.

Speakers feature a rugged aluminum housing and a built-in, 8-32 threaded hole for standard laboratory mounting hardware. The mono speaker includes an aluminum stand and the dual speaker set includes a variety of aluminum mount/base fittings for easier positioning.

Each MF1 kit (serial number >1200) also includes a USB drive containing several speaker-specific closed field and free field calibration curves (TCF files) made during final testing at TDT. These files are used with the BioSigRZ software. When using the MF1 speakers above 30

kHz in free field mode, TDT recommends using the speaker-specific TCF files in place of the generic speaker curves provided in the BioSigRZ installation (stored by default in `C:\TDT\BioSigRZ\TCF\`).

The speakers can be driven directly from the RZ6 or using TDT's SA1 or SA8 stereo amplifiers.

Part Numbers:

MF1-M - Mono, single speaker

MF1-S - Stereo, two speakers

Multi-Field Configurations

The MF1 speaker consists of the free-field speaker and a closed-field adapter - a tapered tip and line filter for closed-field use. An RCA to BNC adapter and stand are also provided.

Using the MF1 for Free Field Operation

The MF1 main speaker component can be used for free-field sound production. The speaker can be connected to the source via an RCA connector located on the back of the MF1 housing. If using the stereo amplifier built into the RZ6, simply connect the supplied RCA cable from the MF1 to one of the output BNC connectors on the RZ6 using the supplied RCA to BNC adapter.

> ⚠️ **Caution**
>
> When the speaker is configured for free field use, be careful to avoid touching the exposed speaker membrane.
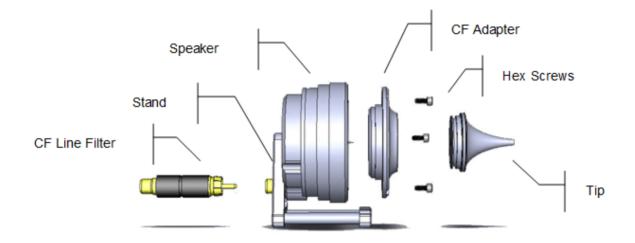
Configuring the MF1 for Closed Field Operation

For closed-field operation, the Close Field adapter is attached to the face of the speaker using three hex screws. A parabolic tip is be mounted in the recessed socket on the closed-field adapter and is held securely in place by an o-ring at the base of the tip.

The speaker can be connected to the source via an RCA connector located on the back of the MF1 housing. If using the stereo amplifier built into the RZ6, simply connect the supplied RCA cable from the MF1 to one of the output BNC connectors on the RZ6 using the supplied RCA to BNC adapters.

> 🔥 **Important**
>
> When using the MF1 in the closed-field configuration the supplied CF line filter must be installed between the BNC to RCA adapter and the RCA cable. This filter minimizes distortion at lower frequencies in the closed-field.

To configure the MF1 for closed-field:

1. Ensure black o-ring is in place on back of CF adapter, as shown.

   Attach the CF adapter to the front of the speaker using three of the provided ¼ x 4-40 hex screws.

2. Ensure the blue o-ring is in place at the base of the desired tip, as shown.

3. Insert one of the tips into the groove on the CF adapter. Ensure the tip is bottomed in its socket. If using the tube tip, gently insert the tube into the narrow end of the tip.

Speaker with CF Adapter

Groove for Tip

3mm Tube Tip

Blue O-ring
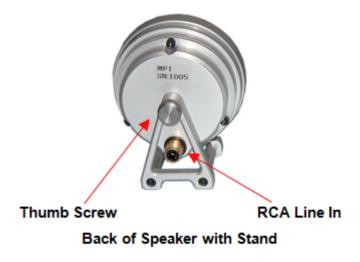
4. Attach a BNC to RCA adapter to the BNC amplifier port of your source device.

   Attach the CF filter to the RCA cable.

CF Filter For Closed Field Configuration Only

If desired, the provided stand can be attached to the speaker using a thumbscrew.

   • Connect the MF1 to the amplifier using the RCA cable (with CF filter attached).

Thumb Screw   **RCA Line In**

Back of Speaker with Stand
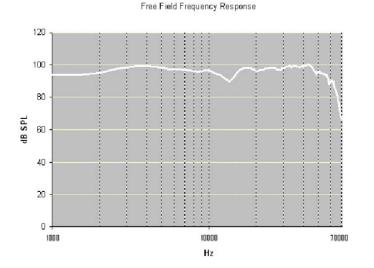
Closed-Field Speaker Design Considerations

When using the closed-field configuration for experiments, the provided PVC tubing will transfer the signal best when it is kept straight. Note that the speaker performance is dependent on the coupling system used and the ear of the subject. All speaker configurations should be calibrated to your specific configuration. Technical specifications measured under specific controlled conditions are provided for comparison purposes. If using BioSigRZ software, see the ABR Guide or DPOAE Guide for calibration tips.
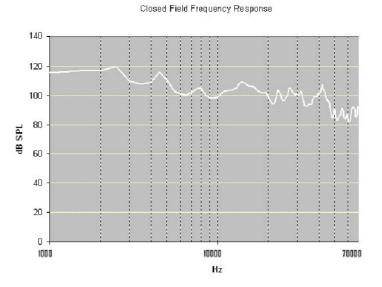
MF1 Technical Specifications

Weight	Free Field: ~216g Closed Field: ~277g
Outside Diameter	6.6 cm
Depth	Free Field: 3.6 cm w/Tube Tip: 6.8 cm w/Ear Tip*: 7.1 cm
Typical Output (±1 V peak input)	Free Field: 87 dB SPL at 10 cm Closed Field: 100 dB SPL in 0.1 cc coupler
THD	<=1% from 1 kHz to 50 kHz
Impedance	4 Ohms
Max driving power	75 W (for third party amps)

* Available on request.

Free field measurements typical at 10 cm using ±1 V input

Closed Field Frequency Response

Closed field measurements typical for approx 0.1 cc eartip coupler using ±1 V input

MS2 Monitor Speaker

MS2 Overview

The MS2 Monitor Speaker is used as an audio monitor for signals up to ±10 V. The MS2 output level is controlled manually using a 1-turn potentiometer on the front panel interface. Maximum output is greater than 90 dB SPL at 10 cm. The frequency response ranges from 300 Hz to 20 kHz. A typical use of the MS2 is for audio monitoring of electrophysiological potentials.

Power

The MS2 Monitor Speaker is powered via the System 3 zBus (ZB1PS). No PC interface is required.

MS2 Features

Manual control is via a single LEVEL knob, which provides control over the signal output level. The MS2 has one input channel for signals up to ±10 V, accessed through a front panel BNC connector
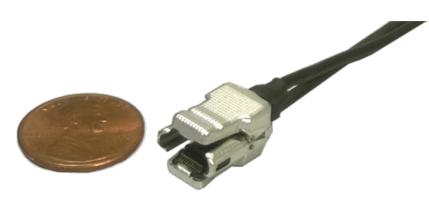
The MS2 is useful for monitoring the output signal that may be going to headphones in a soundproof room and for monitoring physiological signals that are being acquired, such as neurophysiology recordings.

MS2 Technical Specifications

Input Signal Range	±10 V peak
Max Output	>90 dB SPL at 10 cm
Input Impedance	10 kOhms

19. Headstages

ZIF-Clip® ZC Analog Headstages

32-Channel ZIF-Clip® Headstage

ZIF-Clip® ZC Overview

ZIF-Clip® standard headstages are analog headstages recommended for use with probe impedance that range from 20 Kohm to 5 Mohm. They are designed to connect directly to a PZ preamplifier/neurodigitizer but may be connected to an RA16PA with the use of an adapter. Analog signal are buffered inside the headstage and digitized on the preamplifier/ neurodigitizer for transfer to a base station processor, such as the RZ2 or RZ5D.

By default, ground and reference are separate on all ZIF-Clip® headstages yielding a referential configuration. Reference and ground may be tied together on the headstage adapter or microwire array for single-ended configurations.

The ZIF-Clip® headstage (Patent No. 7540752) features an innovative, hinged headstage design that ensures quick, easy headstage connection with almost no insertion force applied to the subject. ZIF-Clip® headstage contacts seat inside the probe array and snap in place, firmly locking the headstage and probe with very little applied pressure. These self-aligning headstages provide long lasting low insertion performance for a variety of channel number and electrode configurations. An aluminum finish provides increased durability.

Part Numbers:

ZC16 - 16-channel Aluminum ZIF-Clip® headstage

ZC32 - 32-channel Aluminum ZIF-Clip® headstage

ZC64 - 64-channel Aluminum ZIF-Clip® headstage

ZC96 - 96-channel Aluminum ZIF-Clip® headstage

ZC128 - 128-channel Aluminum ZIF-Clip® headstage

ZIF-Clip® Passive Headstages

ZIF-Clip® passive headstages contain no active electronics. They provide passive cabling in 16, 32, 64, 96, 128 channel ZIF-Clip® form factors.

Part Numbers:

ZC16-P - 16 channel ZIF-Clip® passive headstage

ZC32-P - 32 channel ZIF-Clip® passive headstage

ZC64-P - 64 channel ZIF-Clip® passive headstage

ZC96-P - 96 channel ZIF-Clip® passive headstage

ZC128-P - 128 Channel ZIF-Clip® passive headstage

ZIF-Clip® LED Headstages

ZIF-Clip® LED headstages have built-in red and green LEDs on each side. The LEDs provide an ample amount of light for tracking test subjects and are available for 16, 32 and 64-channel ZIF-Clip® standard headstages.

> ✏️ **Note**
>
> ZIF-Clip® headstage LEDs cannot be added to existing non-LED headstages.

Part Numbers:

ZC16-LED - 16-channel ZIF-Clip® headstage with LEDs

ZC32-LED - 32-channel ZIF-Clip® headstage with LEDs
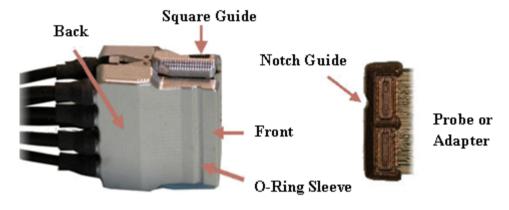
ZC64-LED - 64-channel ZIF-Clip® headstage with LEDs

Adapter and Probe Connection
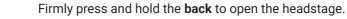
> ⚠️ **Warning**
>
> The headstage has sensitive electronics. Always ground yourself before handling.

ZIF-Clip® headstages are designed to automatically position the high density connectors on the headstage and probe (or adapter).

Standard ZIF-Clip® Headstage

Connect probes and adapters to the headstage as described below.

Firmly press and hold the **back** to open the headstage.

Align the **notch guide** of connector to the **black square guide** of the fully opened headstage then move headstage into position.

Press the **front** of the headstage together as shown to lock the connector in place. You should hear an audible click when the locking mechanism is engaged.

> ⚠️ **Warning**
>
> The ZIF-Clip® headstage must be held in the fully open position while being slid into position. The headstage should only be closed when fully engaged. Sliding the headstage into position while applying pressure to the tip will **permanently damage** the ZIF-Clip® headstage and micro connectors.

ZIF-Clip® Headstage O-Rings

All ZIF-Clip® headstages are shipped with two o-rings for additional connection security. Gently slip the o-ring onto the headstage sleeve and then roll the o-ring towards the back of the headstage. Connect the probe or adapter to the headstage as described above. Once the connection is secure, roll the o-ring forward until it settles into the sleeve on the front of the headstage.

O-Ring Use and Positioning

ZIF-Clip® Headstages to Amplifier Connection

One or more MiniDB26 connectors are used to connect the ZIF-Clip® standard headstage to a PZ5 or Subject Interface depending on the number of channels in the headstage. Each MiniDB26 connector carries 16 channels and is labeled with a bank letter that corresponds to its matching bank on the preamplifier. For example the MiniDB26 connector labeled "Bank A" should connect to bank A on the PZ5 or Subject Interface bank 1 and will carry channels 1-16. Subsequently, "Bank B" corresponds to the next 16 channels of the headstage, etc. See PZ5 NeuroDigitizer or SIM Subject Interface for more information.

Headstages to PZ5 Connection

Headstage Voltage Range
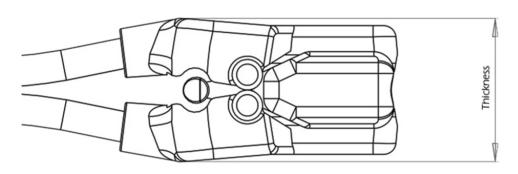
When using a TDT preamplifier the voltage input range of the preamplifier (PZ5, Subject Interface, RA16PA) is typically lower than the headstage and must be considered the effective range of the system. Also keep in mind that the output range of the headstage varies depending on the power supply provided by the preamplifier. PZ5 and Subject Interface supply ±2.5 V. PZ2 and RA16PA preamplifiers supply ±1.5 V. Third party preamplifiers may vary. TDT recommends using preamplifiers which deliver ±2.5 V or less. The table below lists the input voltage ranges for the ZIF-Clip® standard headstage for either ±1.5 V or ±2.5 V power sources.
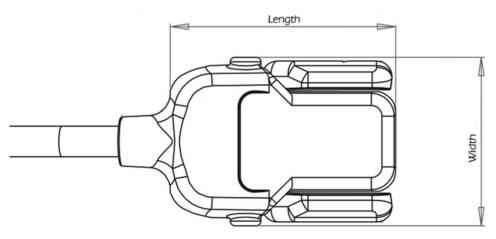
Power Source	Headstage Input Range
±1.5 V	±1.48 V
±2.5 V	±2.49 V

ZIF-Clip® ZC Headstages Technical Specifications

Input referred noise	3 uVrms bandwidth 300-3000 Hz
	6 uVrms bandwidth 30-8000 Hz
Headstage Gain	Unity (1x)
Frequency Response	DC - 25 kHz
Input Impedance	1e14 ohms

Dimensions

Headstage	Length Open	Length Closed	Width	Thickness Open	Thickness Closed	Mass
ZC16/ZC32*	14.401 mm	14.300 mm	10.500 mm	10.255 mm	10.051 mm	2.6 g
ZC64	16.461 mm	16.400 mm	15.500 mm	10.328 mm	10.051 mm	4.8 g
ZC96	17.452 mm	17.400 mm	19.000 mm	10.015 mm	10.051 mm	6.5 g
ZC128	17.948 mm	17.900 mm	25.500 mm	10.212 mm	10.051 mm	9.9 g

* Form factor for both the ZC16 and ZC32 is the same.

> 🔥 **Important**
>
> When using multiple headstages, ensure that a single ground is used for all headstages. This will avoid unnecessary noise contamination in recordings. See the Headstage Connection Guide for more information.

ZIF-Clip® Headstage Pinouts

If you are interested in using a third party electrode see ZIF-Clip® Headstage Adapters. If there is no adapter offered for the desired electrode, the following diagrams show the headstage pinouts (channel connections to the amplifier) and board dimensions for connectors to match ZIF-Clip® headstages. A black square guide is used to align the headstage to ZIF-Clip® compatible connectors and can be used in the diagrams below to orient "left" and "right" sides of the headstage shell.

16- and 32-Channel Headstage Pinouts
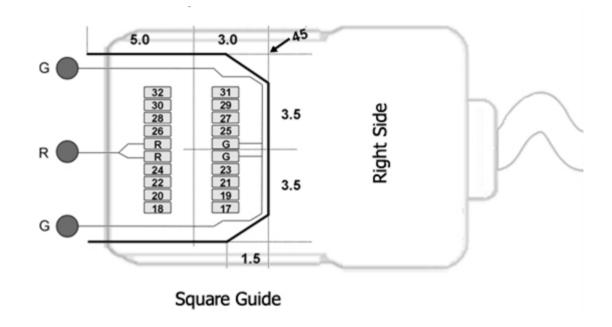
Images are not to scale. Pinouts are looking through the headstage shell (or into a matching board connector). All board dimensions are in millimeters and are identical for both sides, board thickness is 0.75 mm, and connectors are centered as shown.

G Common/Ground Connection

R Reference Connection

Square Guide

> **✎ Note**
>
> The 16-channel ZIF-Clip® headstage does not have any pins connected on the right side of the headstage; the Hirose connector is there for mechanical support. See Hirose specification for recommended footprint.
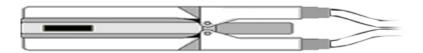
Hirose Connectors:
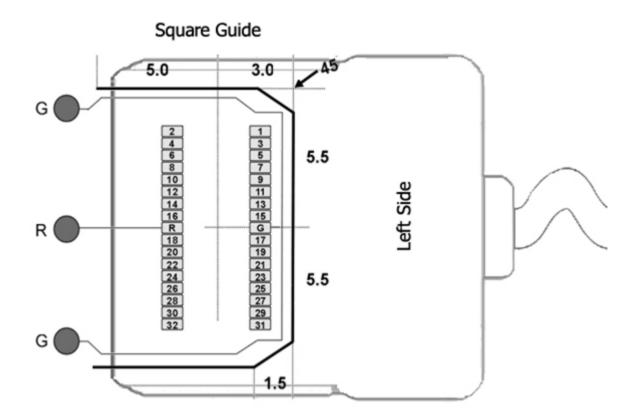
ZC16 - DF30FC-20DS-0.4V x 1

ZC32 - DF30FC-20DS-0.4V x 2
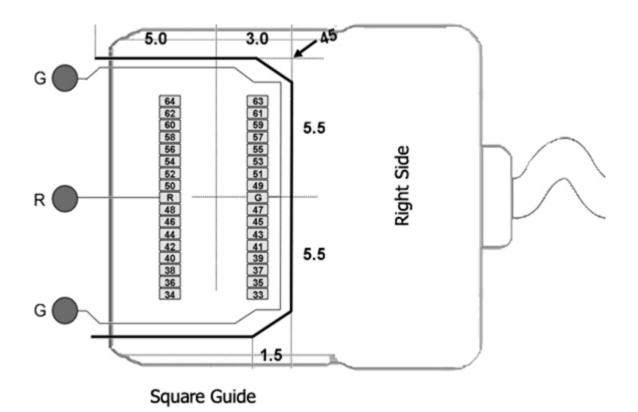
64-Channel Headstage Pinouts

Images are not to scale. Pinouts are looking through the headstage shell (or into a matching board connector). All board dimensions are in millimeters and are identical for both sides, board thickness is 0.75 mm, and connectors are centered as shown.

G Common/Ground Connection

R Reference Connection

Square Guide

See Hirose specification for recommended footprint.
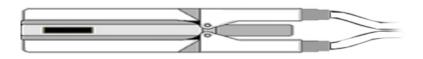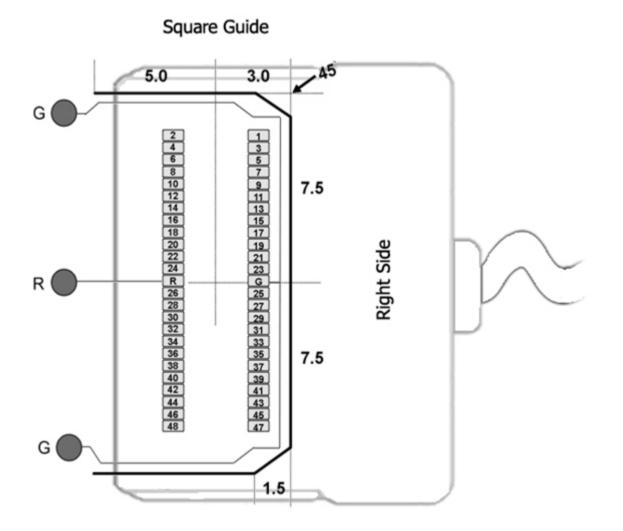
Hirose Connectors:

ZC64 - DF30FC-34DS-0.4V x 2
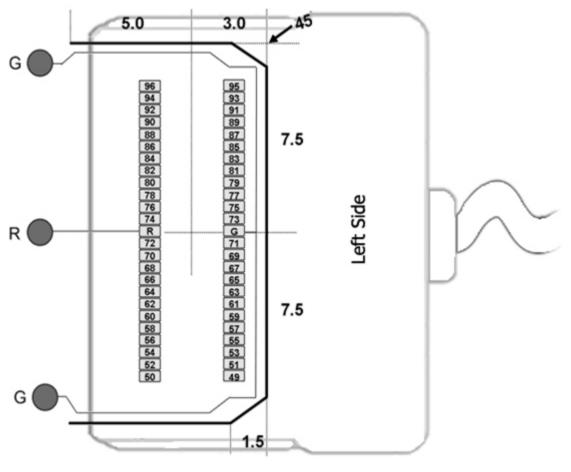
96-Channel Headstage Pinouts

Images are not to scale. Pinouts are looking through the headstage shell (or into a matching board connector). All board dimensions are in millimeters and are identical for both sides, board thickness is 0.75 mm, and connectors are centered as shown.

Square Guide

G Common/Ground Connection

R Reference Connection

Square Guide

See Hirose specification for recommended footprint.
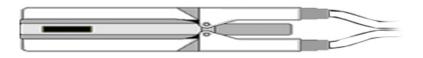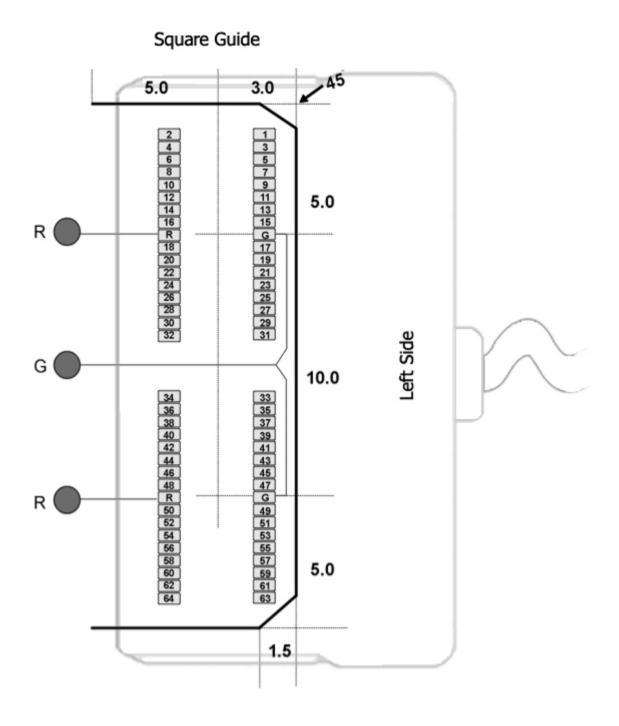
Hirose Connectors:

ZC96 - DF30FC-50DS-0.4V x 2

128-Channel Headstage Pinouts

Images are not to scale. Pinouts are looking through the headstage shell (or into a matching board connector). All board dimensions are in millimeters and are identical for both sides, board thickness is 0.75 mm, and connectors are centered as shown.

G Common/Ground Connection

R Reference Connection

See Hirose specification for recommended footprint.

Hirose Connectors:

ZC128 - DF30FC-34DS-0.4V x 4

ZIF-Clip® ZD Digital Headstages

ZIF-Clip® ZD Overview

ZD ZIF-Clip® digital headstages use Intan RHD2000 amplifier chips to digitize physiological recordings directly inside the headstage. Digitized signals are routed to a PZ5 or Subject Interface (SIM) with a digital input board for transfer to an RZ base station. A single PZ5/SIM digital input board can support up to 128 channels via a direct connection to any of the ZD headstage form factors (32, 64, 96, or 128 channels). The headstage cable is detachable for easy, low-cost replacement.

The ZIF-Clip® headstage (Patent No. 7540752) features an innovative, hinged headstage design that ensures quick, easy headstage connection with almost no insertion force applied to the subject. ZIF-Clip® headstage contacts seat inside the probe array and snap in place, firmly locking the headstage and probe with very little applied pressure. These self-aligning headstages provide long lasting low insertion performance for a variety of channel number and electrode configurations. An aluminum finish provides increased durability.

These headstages are recommended for use with probe that have an impedance in the range of 20 Kohm to 2 Mohm. By default, ground and reference are separate on all ZIF-Clip®

headstages yielding a referential configuration. Reference and ground may be tied together on the headstage adapter or microwire array for single-ended configurations.

Part Numbers:
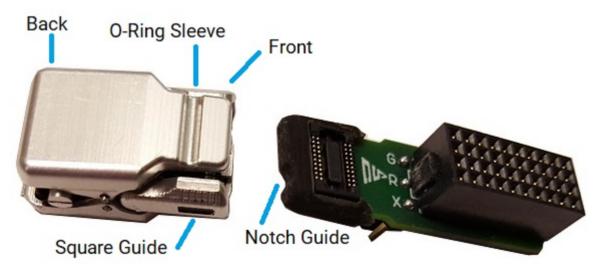
ZD32 - 32-channel Digital ZIF-Clip® headstage

ZD64 - 64-channel Digital ZIF-Clip® headstage

ZD96 - 96-channel Digital ZIF-Clip® headstage

ZD128 - 128-channel Digital ZIF-Clip® headstage

ZD-CBL - digital headstage cable

Adapter and Probe Connection

> ⚠️ **Warning**
>
> The headstage has sensitive electronics. Always ground yourself before handling.
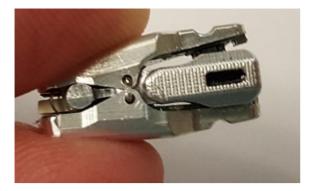
ZIF-Clip® headstages are designed to automatically position the high density connectors on the headstage and probe (or adapter).

ZIF-Clip® Connection (ZD32 headstage and ZCA-NN32 adapter)

Connect probes and adapters to the headstage as described below.

Firmly press and hold the **back** to open the headstage.

Align the **notch guide** of connector to the **black square guide** of the fully opened headstage then move headstage into position.

Press the **front** of the headstage together as shown to lock the connector in place. You should hear an audible click when the locking mechanism is engaged.

> ⚠️ **Warning**
>
> The ZIF-Clip® headstage must be held in the fully open position while being slid into position. The headstage should only be closed when fully engaged. Sliding the headstage into position while applying pressure to the tip will **permanently damage** the ZIF-Clip® headstage and micro connectors.

ZIF-Clip® Headstage O-Rings

All ZIF-Clip® headstages are shipped with two o-rings for additional connection security. Gently slip the o-ring onto the headstage sleeve and then roll the o-ring towards the back of the headstage. Connect the probe or adapter to the headstage as described above. Once the connection is secure, roll the o-ring forward until it settles into the sleeve on the front of the headstage.

O-Ring Use and Positioning

ZIF-Clip® Digital Headstages PZ5/SIM Connection

The ZD ZIF-Clip® digital headstage uses a single detachable SPI Interface Cable that transmits all channels to a digital input board, housed in a PZ5 or SIM. The PZ5/SIM will automatically detect the number of channels in the headstage. If more than one headstage is used, all channels will be concatenated together, starting with connector "-A-", to create the output signal to the RZ base station. The total channel count of all connected headstages cannot exceed the maximum channel count for the PZ5/SIM. See PZ5 NeuroDigitizer or SIM Subject Interface for more information.

ZD Headstage
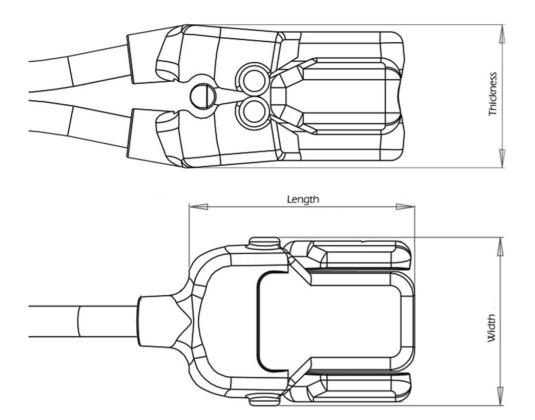
ZIF-Clip® ZD Digital Headstage to Preamplifier Connection Diagram

ZIF-Clip® Digital Headstage Technical Specifications

Input referred noise	2.4 uVrms typical. Varies slightly (<15%) with amplifier bandwidth
Input Impedance	1300 Mohm @ 10 Hz
	13 Mohm @ 1 kHz
	TDT recommends using less than 2 Mohm electrodes
A/D	Up to 128 channels, 16-bit successive-approximation
A/D Sample Rate	Up to 24414.0625 Hz
Maximum Voltage In	±5 mV
Frequency Response	3 dB: 0.1 Hz - 10 kHz
Anti-Aliasing Filter	3rd order low-pass (-18 dB per octave)
Distortion (typical)	<0.8%

Dimensions

Headstage	Length Open	Length Closed	Width	Thickness Open	Thickness Closed	Mass
ZD32	16.107 mm	16.050 mm	10.500 mm	8.137 mm	7.400 mm	1.2 g
ZD64	16.446 mm	16.497 mm	15.500 mm	12.760 mm	10.400 mm	2.0 g
ZD96	17.469 mm	17.562 mm	19.000 mm	12.577 mm	10.499 mm	

> 🔥 **Important**
>
> When using multiple headstages, ensure that a single ground is used for all headstages. This will avoid unnecessary noise contamination in recordings. See the Headstage Connection Guide for more information.

ZIF-Clip® Headstage Pinouts

If you are interested in using a third party electrode see ZIF-Clip® Headstage Adapters. If there is no adapter offered for the desired electrode, the following diagrams show the headstage pinouts (channel connections to the amplifier) and board dimensions for connectors to match ZIF-Clip® headstages. A black square guide is used to align the headstage to ZIF-Clip® compatible connectors and can be used in the diagrams below to orient "left" and "right" sides of the headstage shell.

For Synapse users, use the Channel Mapper gizmo to reorder the channels according to the pinouts below. Choose TDT > HEADSTAGE > then the ZDn that matches your headstage.

16- and 32-Channel Headstage Pinouts
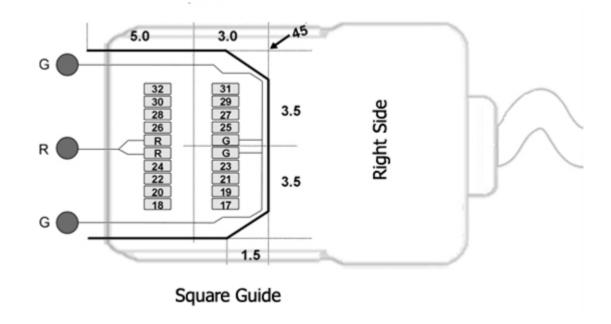
Images are not to scale. Pinouts are looking through the headstage shell (or into a matching board connector). All board dimensions are in millimeters and are identical for both sides, board thickness is 0.75 mm, and connectors are centered as shown.
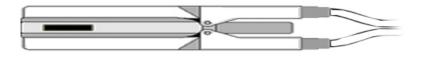

G Common/Ground Connection

R Reference Connection

Square Guide
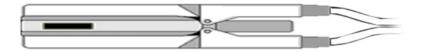
Hirose Connectors:
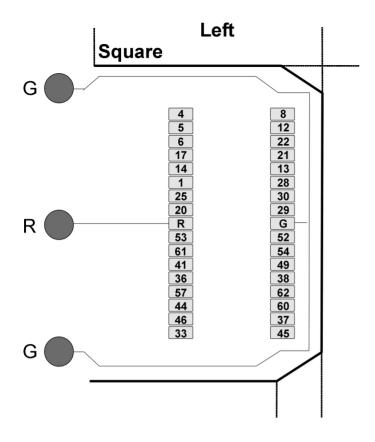
ZD16 - DF30FC-20DS-0.4V x 1
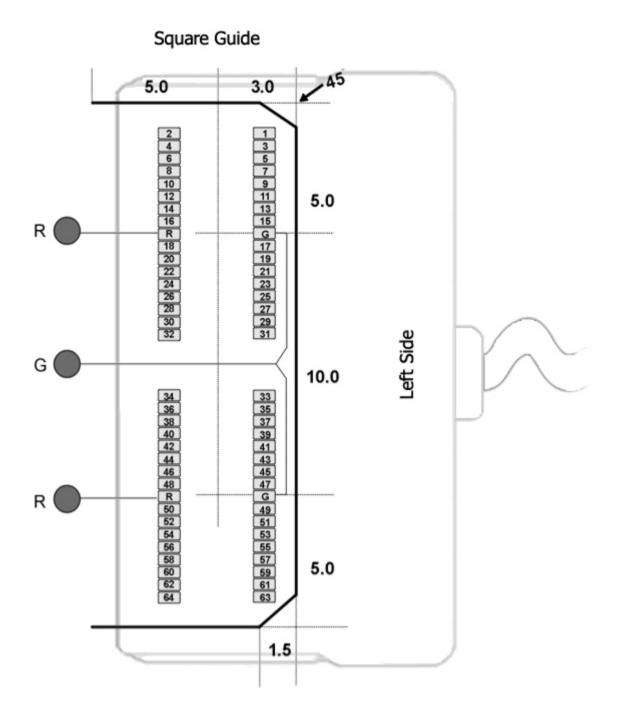
ZD32 - DF30FC-20DS-0.4V x 2
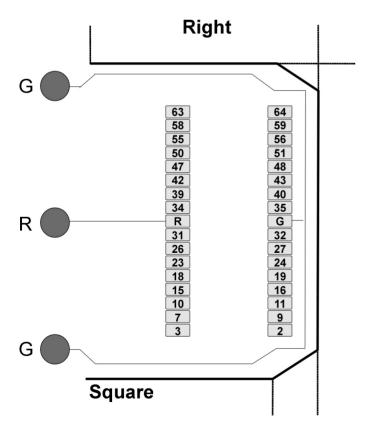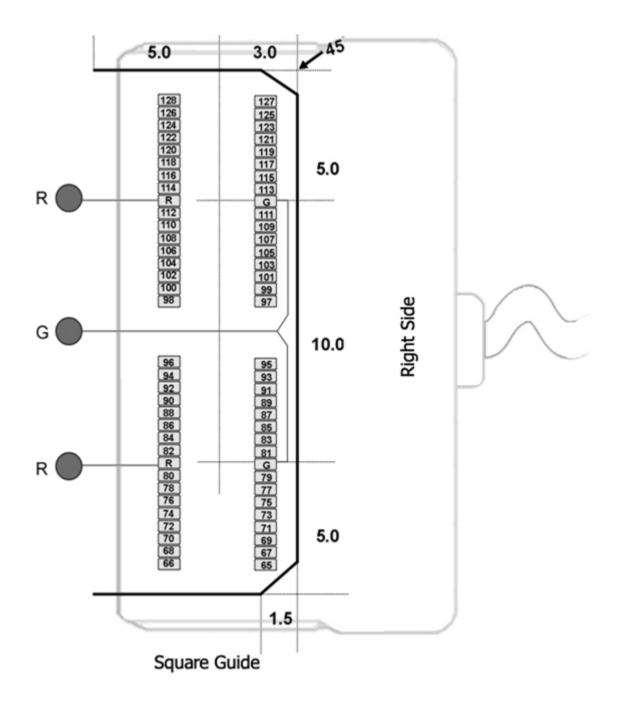
64-Channel Headstage Pinouts

Images are not to scale. Pinouts are looking through the headstage shell (or into a matching board connector). All board dimensions are in millimeters and are identical for both sides, board thickness is 0.75 mm, and connectors are centered as shown.

Left

Square

G

4		8
5		12
6		22
17		21
14		13
1		28
25		30
20		29
R		G
53		52
61		54
41		49
36		38
57		62
44		60
46		37
33		45

R

G

G Common/Ground Connection

R Reference Connection

Right

G

63		64
58		59
55		56
50		51
47		48
42		43
39		40
34		35
R		G
31		32
26		27
23		24
18		19
15		16
10		11
7		9
3		2

R

G

Square

See Hirose specification for recommended footprint.
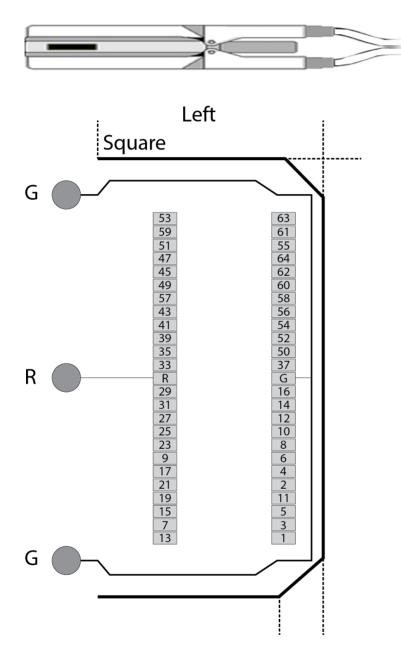
Hirose Connectors:

ZD64 - DF30FC-34DS-0.4V x 2
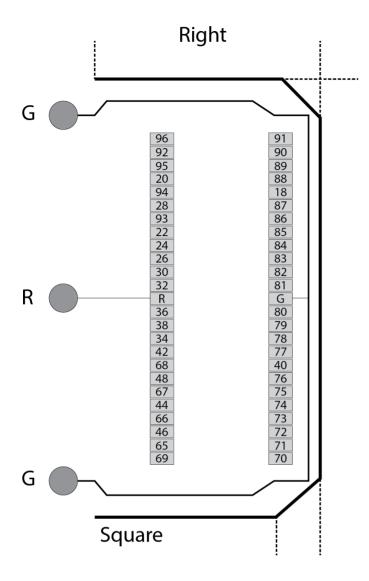
96-Channel Headstage Pinouts

Images are not to scale. Pinouts are looking through the headstage shell (or into a matching board connector). All board dimensions are in millimeters and are identical for both sides, board thickness is 0.75 mm, and connectors are centered as shown.

G Common/Ground Connection

R Reference Connection

Right

G

96	91
92	90
95	89
20	88
94	18
28	87
93	86
22	85
24	84
26	83
30	82
32	81
R	G
36	80
38	79
34	78
42	77
68	40
48	76
67	75
44	74
66	73
46	72
65	71
69	70

R

G

Square

See Hirose specification for recommended footprint.

Hirose Connectors:

ZD96 - DF30FC-50DS-0.4V x 2

128-Channel Headstage Pinouts

Images are not to scale. Pinouts are looking through the headstage shell (or into a matching board connector). All board dimensions are in millimeters and are identical for both sides, board thickness is 0.75 mm, and connectors are centered as shown.

Square Guide

G Common/Ground Connection

R Reference Connection

See Hirose specification for recommended footprint.

Hirose Connectors:

ZD128 - DF30FC-34DS-0.4V x 4

ZIF-Clip® Headstage Holders

The ZIF-Clip® headstage holders securely hold your analog or digital ZIF-Clip® headstages during electrode insertion and can be used with most micromanipulators. The headstage holders, including the stabilizing rod, are approximately 4.5" in length. The stabilizing rod is 3" in length and has a 3/32" diameter. An aluminum lock pin ensures the ZIF-Clip® does not open during insertion.

Each holder is designed for use with the corresponding ZIF-Clip® or Digital ZIF-Clip® headstage.

Part Numbers:

Z-ROD32 - 16 or 32-channel analog ZIF-Clip® headstage holder (for ZC32)

Z-ROD64 - 64-channel analog ZIF-Clip® headstage holder (for ZC64 and ZD64)

Z-ROD96 - 96-channel analog ZIF-Clip® headstage holder (for ZC96 and ZD96)

Z-ROD128 - 128-channel analog ZIF-Clip® headstage holder (for ZC128)

ZCD-ROD32 - 32-channel digital ZIF-Clip® headstage holder (for ZCD32 and ZD32)

ZCD-ROD64 - 64-channel digital ZIF-Clip® headstage holder (for ZCD64)

ZCD-ROD96 - 96-channel digital ZIF-Clip® headstage holder (for ZCD96)
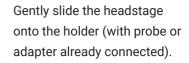
Using the Holder with ZIF-Clip® Headstages
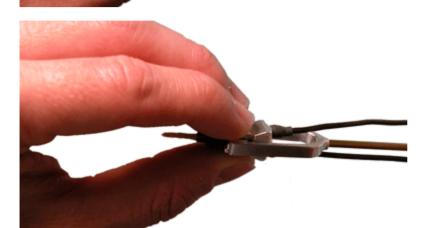
Each holder is sized to fit a particular headstage and with the exception of the ZCD-ROD32 (see below), they all can be fitted to the headstage in the same way.

First, connect the probe or adapter to your ZIF-Clip® headstage **before** putting the headstage in the holder (the square guide provided to ensure the probe or adapter is connected with the correct polarity is hidden from view when the headstage is in the holder). See ZIF-Clip® Headstage Adapters for more information.

Next, gently slide the ZIF-Clip® headstage onto the holder until it is completely secure as shown in the images below.
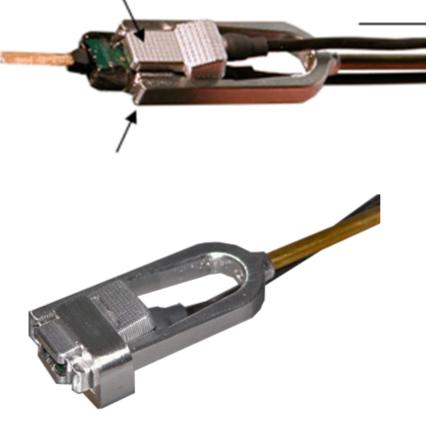
Finally, secure the lock pin to the headstage holder.

Gently slide the headstage onto the holder (with probe or adapter already connected).
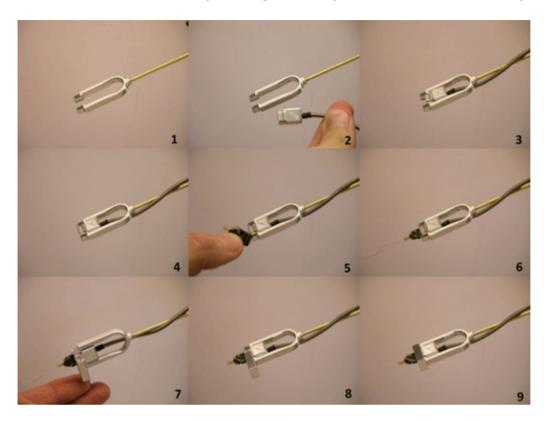
Position the headstage holder between the cables of the ZIF-Clip® headstage. The headstage should be completely secured in the holder.

To remove, grip the top and bottom of the headstage and gently slide the holder away.

The U-shaped lock pin secures the connection and prevents the ZIF-Clip® from opening and releasing the probe.

Using the ZCD-ROD32

The ZCD-ROD32 has a unique design that requires a different insertion procedure.
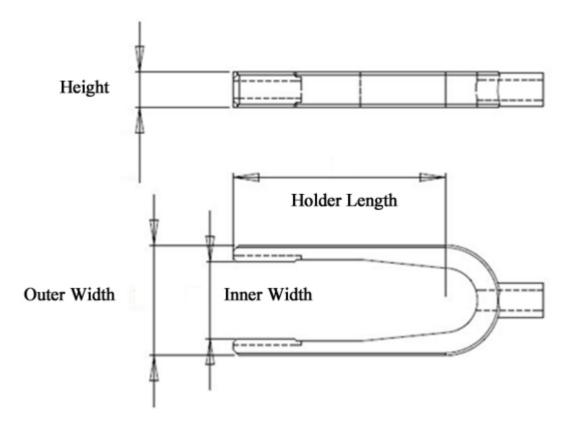
To use the headstage holder:

1. Set the ZCD32 headstage inside the base (or U) of the holder and slide it forward until it is stopped by the interior flange (Image 1-4).

2. After the clip is in place, insert the probe (Image 5-6) and then slide the provided lock pin over the ZCD32 (Image 7-9).

The lock pin prevents the clip from opening and releasing the probe, and also from sliding backward during insertion.

The lock pin has small ridges that should be aligned with the grooves on the face of the clip. If you have trouble connecting the lock pin, make sure that the clip has been pushed in completely and that the ridges and grooves are properly aligned (Image 7).

Holder Dimensions

Z-ROD Dimensions (for analog and digital headstages)

Form Factor	16/32-channel ZC16 / ZC32	64-channel ZC64 / ZD64	96-channel ZC96 / ZD96	128-channel ZC128
Height	4.10 mm (9.62 mm with lock pin)			
Inner Width	9 mm	14 mm	17.50 mm	24 mm
Outer Width	13 mm (16 mm with lock pin)	18 mm	21.50 mm	28 mm
Holder Length	25 mm	28 mm	28 mm	28 mm
Rod Length	76.2 mm			
Rod Diameter	2.29 mm			

ZCD-ROD Dimensions (for digital headstages)

Form Factor	32-channel ZCD32 / ZD32	64-channel ZCD64	96-channel ZCD96
Height	5.5 mm (11.50 mm with lock pin)	4.10 mm (15.30 mm with lock pin)	4.10 mm
Inner Width	11.10 mm	14.39 mm	17.50 mm
Outer Width	18.50 mm (18.50 mm with lock pin)	17.79 mm (21.5 mm with lock pin)	21.50 mm
Holder Length	31.50 mm	25.36 mm	25.36 mm
Rod Length	76.2 mm		
Rod Diameter	2.29 mm		

Omnetics Analog Headstages

LP32CH-Z - 32 Channel Chronic Headstage

The 32 channel chronic headstage is recommended for extracellular neurophysiology using silicon electrodes, metal microelectrodes or microwire arrays with input impedance from 20 kOhm to 5 MOhm. The headstage uses a female Omnetics connector to mate with chronic electrodes.

The LP32CH-Z uses an Omnetics 36 socket female dual row nano connector (0.025" or 0.64 mm) with 4 guide posts. The LP32CH-ZNF uses non-ferrous materials, including a non-ferrous female Omnetics connector with the same size and pinout as the LF32CH. It can be used for recording single-unit electrophysiology during fMRI neuroimaging.

Part Numbers:

LP32CH-Z - 32-Channel Chronic Low Profile Headstage for PZ PreAmps

LP32CH-ZNF - 32-Channel Non-Ferrous, Chronic Low Profile Headstage for PZ Preamps

> ⚠️ **Warning**
>
> The headstage has sensitive electronics. Always ground yourself before handling.

Headstage Voltage Range

When using a TDT preamplifier the voltage input range of the preamplifier (PZ5, Subject Interface, RA16PA) is typically lower than the headstage and must be considered the effective range of the system. Also keep in mind that the output range of the headstage varies depending on the power supply provided by the preamplifier. PZ5 and Subject Interface supply ±2.5 V. PZ2 and RA16PA preamplifiers supply ±1.5 V. Third party preamplifiers may vary. TDT recommends using preamplifiers which deliver ±2.5 V or less. The table below lists the input voltage ranges for the LP32CH-Z headstage for either ±1.5 V or ±2.5 V power sources.

Power Source	Headstage Input Range
±1.5 V	±1.48 V
±2.5 V	±2.49 V

Technical Specifications

Input referred noise	3 uVrms bandwidth 300-3000 Hz
	6 uVrms bandwidth 30-8000 Hz
Headstage Gain	Unity (1x)
Frequency Response	DC - 25 kHz
Input Impedance	1e14 ohms
Connector	Omnetics 36 socket female dual row nano connector (0.025" or 0.64 mm) with 4 guide posts

Pinout

The numbers on the pinout diagram above show the channel connections to the amplifier. By default, the headstage inputs are single ended, with Reference and Ground tied together by a jumper. To make the inputs referential, cut the jumper pictured below.

LP32CH:
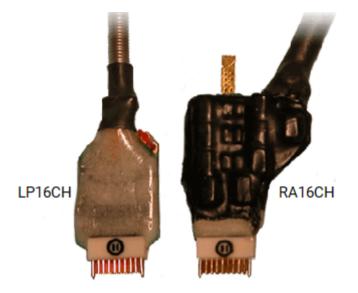
> 🔥 **Important**
>
> When using multiple headstages, ensure that a single ground is used for all headstages. This will avoid unnecessary noise contamination in recordings. See the Headstage Connection Guide for more information.

RA16CH/LP16CH/LP16CH-ZNF - 16 Channel Chronic Headstage

The 16 channel chronic headstages are recommended for extracellular neurophysiology using silicon electrodes, metal microelectrodes or microwire arrays with input impedance from 20 kOhm to 5 MOhm. They come in three configurations: standard profile, low profile, and non-ferrous low profile.

The RA16CH and LP16CH (low profile) use a female Omnetics 18 socket female dual row nano connector (0.025" or 0.64 mm) with 2 guide posts that is compatible with NeuroNexus chronic electrodes and a wide variety of connectors. Users can also request a matching male Omnetics connector (OMCON_ML_HB) from TDT for custom built electrode arrays. The low profile LP16CH provides a smaller footprint than the RA16CH for better clearance in tight applications.

The LP16CH-ZNF uses non-ferrous materials, including a non-ferrous Omnetics connector with the same size and pinout as the RA16CH and LP16CH headstages. It can be used for recording single-unit electrophysiology during fMRI neuroimaging.

Part Numbers:

LP16CH - 16-Channel Chronic Low Profile Headstage for Medusa PreAmps

LP16CH-Z - 16-Channel Chronic Low Profile Headstage for PZ PreAmps

LP16CH-ZNF - 16-Channel Non-Ferrous, Chronic Low Profile Headstage for PZ Preamps

RA16CH - 16-Channel Chronic Headstage for Medusa PreAmps

RA16CH-Z - 16-Channel Chronic Headstage for PZ PreAmps

> ⚠ **Warning**
>
> The headstage has sensitive electronics. Always ground yourself before handling.

Headstage Voltage Range

When using a TDT preamplifier the voltage input range of the preamplifier (PZ5, Subject Interface, RA16PA) is typically lower than the headstage and must be considered the effective range of the system. Also keep in mind that the output range of the headstage varies depending on the power supply provided by the preamplifier. PZ5 and Subject Interface supply ±2.5 V. PZ2 and RA16PA preamplifiers supply ±1.5 V. Third party preamplifiers may vary. TDT recommends using preamplifiers which deliver ±2.5 V or less. The table below lists the input voltage ranges for the 16-channel chronic headstage for either ±1.5 V or ±2.5 V power sources.

Power Source	LP16CH Input Range	RA16CH Input Range
±1.5 V	±1.48 V	±0.9 V
±2.5 V	±2.49 V	±1.9 V

Technical Specifications

Input referred noise	3 uVrms bandwidth 300-3000 Hz 6 uVrms bandwidth 30-8000 Hz
Headstage Gain	Unity (1x)
Frequency Response	DC - 25 kHz
Input Impedance	1e14 ohms
Connector	Omnetics 18 socket female dual row nano connector (0.025" or 0.64 mm) with 2 guide posts
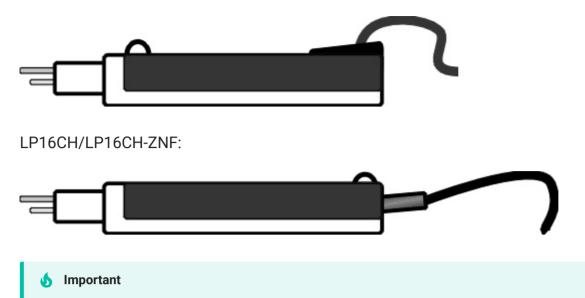
Pinout

Looking into headstage

The numbers on the pinout diagram above show the channel connections to the amplifier. By default, the headstage inputs are single ended, with Reference and Ground tied together by a jumper. To make the inputs referential, cut the jumper pictured below.

RA16CH:

LP16CH/LP16CH-ZNF:

> 🔥 **Important**
>
> When using multiple headstages, ensure that a single ground is used for all headstages. This will avoid unnecessary noise contamination in recordings. See the Headstage Connection Guide for more information.

Omnetics Digital Headstages

Omnetics OD Overview

OD Omnetics digital headstages use Intan RHD2000 amplifier chips to digitize physiological recordings directly inside the headstage. Digitized signals are routed to a PZ5 or Subject Interface (SIM) with a digital input board for transfer to an RZ base station. A single PZ5/SIM digital input board can support up to 128 channels via a direct connection to any of the OD headstage form factors. The headstage cable is detachable for easy, low-cost replacement.

These headstages are recommended for use with probe that have an impedance in the range of 20 Kohm to 2 Mohm. By default, ground and reference are connected by a blue jumper wire on the headstage for single-ended configuration. This wire may be cut for a referential configuration.
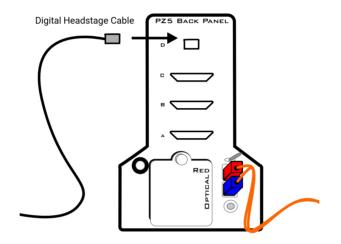
Part Numbers:

OD32 - 32-channel Digital Omnetics headstage

ZD-CBL - digital headstage cable

Omnetics Digital Headstages PZ5/ Subject Interface Connection

The OD Omnetics digital headstage uses a single detachable SPI Interface Cable that transmits all channels to a digital input board, housed in a PZ5 or Subject Interface. The PZ5/ SIM will automatically detect the number of channels in the headstage. If more than one headstage is used, all channels will be concatenated together, starting with the earliest digital bank ordered from bottom "-A-" to top, to create the output signal to the RZ base station. The total channel count of all connected headstages cannot exceed the maximum channel count for the PZ5 / SIM.

Omnetics OD Digital Headstage to Preamplifier Connection Diagram

Omnetics Digital Headstage Technical Specifications

Input referred noise	2.4 uVrms typical. Varies slightly (<15%) with amplifier bandwidth
Input Impedance	1300 Mohm @ 10 Hz
	13 Mohm @ 1 kHz
	TDT recommends using less than 2 Mohm electrodes
A/D	Up to 32 channels, 16-bit successive-approximation
A/D Sample Rate	Up to 24414.0625 Hz
Maximum Voltage In	±5 mV
Frequency Response	3 dB: 0.1 Hz - 10 kHz
Anti-Aliasing Filter	3rd order low-pass (-18 dB per octave)
Distortion (typical)	<0.8%
Mass	0.93 g with resin

> 🔥 **Important**
>
> When using multiple headstages, ensure that a single ground is used for all headstages. This will avoid unnecessary noise contamination in recordings. See the Headstage Connection Guide for more information.

Omnetics Headstage Pinout

P=Guide Pins **R**=Reference **G**=Ground

The numbers on the pinout diagram show the channel connections to the amplifier. By default, the headstage inputs are single ended, with Reference and Ground tied together by a jumper. To make the inputs referential, cut the jumper wire.

ECoG Headstages

CB16-PMT - 16 Channel ECoG Headstage

The 16 Channel ECoG headstages are recommended for 13 gauge tunneling needle/inline tail probes with impedance ranging from 20 kOhm to 5 Mohm. The headstage includes a Touch Proof connector for optional reference input and a locking bar for secure connection of probe to headstage.

The CB16-PMT is available as a passive or active headstage.

CB16-PMT Connector - Open / Closed, View from Bottom

Part Numbers:

CB16-PMT - 16 Channel Active Headstage for PZ PreAmps

CB16P-PMT - 16 Channel Passive Headstage for PZ PreAmps

> ⚠️ **Warning**
>
> The headstage has sensitive electronics. Always ground yourself before handling.

Headstage Voltage Range

When using a TDT preamplifier the voltage input range of the preamplifier (PZ5, Subject Interface, RA16PA) is typically lower than the headstage and must be considered the effective range of the system. Also keep in mind that the output range of the headstage varies depending on the power supply provided by the preamplifier. PZ5 and Subject Interface supply ±2.5 V. PZ2 and RA16PA preamplifiers supply ±1.5 V. Third party preamplifiers may vary. TDT recommends using preamplifiers which deliver ±2.5 V or less. The table below lists the input voltage ranges for the 16-channel ECoG headstages for either ±1.5 V or ±2.5 V power sources.

Power Source	Headstage Input Range
±1.5 V	-1.5 V to +1.4 V
±2.5 V	-2.5 V to +2.4 V

Technical Specifications

Input referred noise	3 uVrms bandwidth 300-3000 Hz
	6 uVrms bandwidth 30-8000 Hz
Headstage Gain	Unity (1x)
Input Impedance	1e13 ohms

Pinout

The numbers on the pinout diagram above show the channel connections to the amplifier.

A three position switch is used to connect either REFa, REFb, or GND to the REF line on the DB26 connector.

The headstage does not provide access to ground and instead relies on the use of the external ground on the PZ5 / Subject Interface.

Acute (Non-ZIF) Headstages

NN32AC - 32 Channel Acute Headstage

The 32 Channel Acute headstage is recommended for extracellular neurophysiology using silicon electrodes, metal microelectrodes or microwire arrays with input impedance from 20 kOhm to 5 Mohm. The headstage features a 40-pin connector designed for use with the NeuroNexus Acute 32-channel probe. The headstage connects to a PZ series preamplifier via two mini 26-pin connectors or to two RA16PA preamplifiers via two 25-pin connectors. For either headstage, Connector A carries the signals for channels 1-16, power and ground. This connector must be connected whether you are acquiring data from one of these channels or not.

Part Numbers:

NN32AC - 32-Channel Acute Headstage for Medusa PreAmps

NN32AC-Z - 32-Channel Acute Headstage for PZ PreAmps

> ⚠️ **Warning**
>
> The headstage has sensitive electronics. Always ground yourself before handling.

Headstage Voltage Range

When using a TDT preamplifier the voltage input range of the preamplifier (PZ5, Subject Interface, RA16PA) is typically lower than the headstage and must be considered the effective range of the system. Also keep in mind that the output range of the headstage varies depending on the power supply provided by the preamplifier. PZ5 and Subject Interface supply ±2.5 V. PZ2 and RA16PA preamplifiers supply ±1.5 V. Third party preamplifiers may vary. TDT recommends using preamplifiers which deliver ±2.5 V or less. The table below lists the input voltage ranges for the NN32AC and NN32AC-Z headstages for either ±1.5 V or ±2.5 V power sources.

Power Source	Headstage Input Range
±1.5 V	±0.9 V
±2.5 V	±1.9 V

Jumper Configuration

The following table describes the jumper configurations and associated requirements.

Jumper Connections	Operation	Requirements
G R X (Ref) [G, R boxed together]	Shorts headstage Ground and Reference inputs together, yielding single-ended amplification of signals relative to ground.	Connect common Ground/ Reference wire to the headstage or electrode
G R X (Ref) [R, X boxed together]	Shorts headstage Reference input to the pin labeled X (a low impedance site on the probe) yielding referential amplification of signals relative to the voltage of the X (Ref) site.	Connect Ground wire to the headstage or electrode
G R X (Ref)	Headstage Ground and Reference separated and X (Ref) pin is not used, yielding referential amplification of signals relative to the voltage of the Reference	Connect both a Ground wire and a Reference wire to the headstage or electrode

Technical Specifications

Input referred noise	3 uVrms bandwidth 300-3000 Hz 6 uVrms bandwidth 30-8000 Hz
Headstage Gain	Unity (1x)
Frequency Response	DC - 25 kHz
Input Impedance	1e14 ohms

Pinout

> 🔥 **Important**
>
> When using the NN32AC with the NeuroNexus Acute 32-channel probe, keep in mind that there are several versions of the probe and the NN32AC was designed to correspond to the NeuroNexus rev 3 probe. Check the NeuroNexus Website for pin diagrams. For Synapse users, use the Channel Mapper gizmo to reorder the channels according to the pinouts below.

Pinouts are looking into the connector and reflect the preamplifier channels

The surfaced connections on the back of the headstage include female connectors to simplify connections to external devices and jumper locations to short G, R and Ref refers to the built-in reference site on the NeuroNexus probe). The ground channel (G) should either be tied to an external ground or to the reference (R) for a single ended input.

> 🔥 **Important**
>
> When using multiple headstages, ensure that a single ground is used for all headstages. This will avoid unnecessary noise contamination in recordings. See the Headstage Connection Guide for more information.

NN64AC 64-Channel Acute Headstage

The 16 Channel acute The 64 Channel Acute headstage is recommended for extracellular neurophysiology using silicon electrodes, metal microelectrodes or microwire arrays with input impedance from 20 kOhm to 5 Mohm.

The headstage features two 40-pin connectors designed for use with NeuroNexus Acute 64-channel probes. The headstage connects to a PZ series preamplifier via four mini 26-pin connectors or with System 3 Medusa preamplifiers (such as four RA16PAs) via four DB25 connectors. In either case, each connector carries the signals for 16 channels, power and

ground. Therefore, each connector can be connected independently. The connector labeled Bank-1 carries channels 1-16, Bank-2 carries 17-32, etc.

Part Numbers:

NN64AC - 64-Channel Acute Headstage for Medusa PreAmps

NN64AC-Z - 64-Channel Acute Headstage for PZ PreAmps

> ⚠️ **Warning**
>
> The headstage has sensitive electronics. Always ground yourself before handling.

Headstage Voltage Range

When using a TDT preamplifier the voltage input range of the preamplifier (PZ5, Subject Interface, RA16PA) is typically lower than the headstage and must be considered the effective range of the system. Also keep in mind that the output range of the headstage varies depending on the power supply provided by the preamplifier. PZ5 and Subject Interface supply ±2.5 V. PZ2 and RA16PA preamplifiers supply ±1.5 V. Third party preamplifiers may vary. TDT recommends using preamplifiers which deliver ±2.5 V or less. The table below lists the input voltage ranges for the NN64AC-Z headstage for either ±1.5 V or ±2.5 V power sources.

Power Source	Headstage Input Range
±1.5 V	±0.9 V
±2.5 V	±1.9 V

Jumper Configuration

The following table describes the jumper configurations and associated requirements.

Jumper Connections	Operation	Requirements
G **R** X (Ref)	Shorts headstage Ground and Reference inputs together, yielding single-ended amplification of signals relative to ground.	Connect common Ground/ Reference wire to the headstage or electrode
G **R** **X** (Ref)	Shorts headstage Reference input to the pin labeled X (a low impedance site on the probe) yielding referential amplification of signals relative to the voltage of the X (Ref) site.	Connect Ground wire to the headstage or electrode
G R X (Ref)	Headstage Ground and Reference separated and X (Ref) pin is not used, yielding referential amplification of signals relative to the voltage of the Reference	Connect both a Ground wire and a Reference wire to the headstage or electrode

Technical Specifications

Input referred noise	3 uVrms bandwidth 300-3000 Hz 6 uVrms bandwidth 30-8000 Hz
Headstage Gain	Unity (1x)
Frequency Response	DC - 25 kHz
Input Impedance	1e14 ohms

Pinout

> 🔥 **Important**
>
> When using the NN64AC with the NeuroNexus Acute 64-channel probe, keep in mind that there are several versions of the probe. Check the NeuroNexus Website for pin diagrams. For Synapse users, use the Channel Mapper gizmo to reorder the channels according to the pinouts below.

Pinouts are looking into the connector and reflect the preamplifier channels

The numbers in the diagram above show the channel connections to the amplifier. The headstage also features jumper locations to short G, R and Ref refers to the built-in reference site on the NeuroNexus probe). The ground channel (G) should either be tied to an external ground or to the reference (R) for a single ended input.

> 🔥 **Important**
>
> When using multiple headstages, ensure that a single ground is used for all headstages. This will avoid unnecessary noise contamination in recordings. See the Headstage Connection Guide for more information.

RA16AC - 16 Channel Acute Headstage

The 16 Channel acute headstages is recommended for extracellular neurophysiology using silicon electrodes, metal microelectrodes or microwire arrays with recommended input impedance from 20 kOhm to 5 Mohm unless otherwise noted.

The 16 channel acute headstage has an 18-pin DIP connector that can be used with standard high impedance metal electrodes. The pinout of the RA16AC matches the wiring of NeuroNexus electrodes to allow for direct connection to the headstage. TDT recommends connecting electrodes to an 18-pin socket and then connecting the socket to the headstage to protect the headstage from unnecessary wear and tear. The RA16AC4 provides 4x gain and is used with electrodes with a recommended impedance range of 20 kOhm to 300 kOhm.

The headstage connects to a System 3 Medusa preamplifier (such as the RA16PA) via a DB25 connector or to a PZ series preamplifier via a mini 26-pin connector.

Part Numbers:

RA16AC - 16-Channel Acute Headstage for Medusa PreAmps, with unity (1x) gain

RA16AC4 - 16-Channel Acute Headstage for Medusa PreAmps, with 4x gain

RA16AC-Z - 16-Channel Acute Headstage for PZ PreAmps, with unity (1x) gain

> ⚠️ **Warning**
>
> The headstage has sensitive electronics. Always ground yourself before handling.

Headstage Voltage Range

When using a TDT preamplifier the voltage input range of the preamplifier (PZ5, Subject Interface, RA16PA) is typically lower than the headstage and must be considered the effective range of the system. Also keep in mind that the output range of the headstage varies depending on the power supply provided by the preamplifier. PZ5 and Subject Interface supply ±2.5 V. PZ2 and RA16PA preamplifiers supply ±1.5 V. Third party preamplifiers may vary. TDT recommends using preamplifiers which deliver ±2.5 V or less. The table below lists the input voltage ranges for the RA16AC and RA16AC4 headstages for either ±1.5 V or ±2.5 V power sources.

Power Source	RA16AC Input Range	RA16AC4 Input Range
±1.5 V	±0.9 V	±0.37 V
±2.5 V	±1.9 V	±0.62 V

Technical Specifications

Input referred noise	3 uVrms bandwidth 300-3000 Hz
	6 uVrms bandwidth 30-8000 Hz
Headstage Gain	RA16AC-Z - Unity (1x)
	RA16AC - Unity (1x)
	RA16AC4 - 4x
Frequency Response	DC - 25 kHz
Input Impedance	1e14 ohms

Pinout

Pinouts are looking into the connector and reflect the preamplifier channels

The electrode connector accepts 0.5 mm diameter male pins. For pinouts for the preamplifier connector, see the RA16PA pinout.

> 🔥 **Important**
>
> When using multiple headstages, ensure that a single ground is used for all headstages. This will avoid unnecessary noise contamination in recordings. See the Headstage Connection Guide for more information.

RA4AC - 4 Channel Acute Headstage

The 4 Channel Acute headstages are recommended for extracellular neurophysiology using silicon electrodes, metal microelectrodes, or microwire arrays with input impedance from 20 kOhm to 5 MOhm.

The RA4AC1 and RA4AC4 headstages have a low-profile 6-pin connector. The RA4AC1 provides unity gain (1x). The RA4AC4 provides 4x gain and is used with electrodes with a recommended impedance range of 20 kOhm to 300 kOhm. The 25-pin connector connects to the RA4PA 4-channel Medusa preamplifier.

Part Numbers:

RA4AC1 - 4-Channel Acute Headstage for Medusa PreAmps, with unity (1x) gain

RA4AC4 - 4-Channel Acute Headstage for Medusa PreAmps, with 4x gain

> ⚠️ **Warning**
>
> The headstage has sensitive electronics. Always ground yourself before handling.

Headstage Voltage Range

When using a TDT preamplifier the voltage input range of the preamplifier (PZ5, Subject Interface, RA16PA) is typically lower than the headstage and must be considered the effective range of the system. Also keep in mind that the output range of the headstage varies depending on the power supply provided by the preamplifier. PZ5 and Subject Interface supply ±2.5 V. PZ2 and RA16PA preamplifiers supply ±1.5 V. Third party preamplifiers may vary. TDT recommends using preamplifiers which deliver ±2.5 V or less. The table below lists the input voltage ranges for the RA4AC and RA4AC4 headstages for either ±1.5 V or ±2.5 V power sources.

Power Source	RA4AC Input Range	RA4AC4 Input Range
±1.5 V	±0.9 V	±0.37 V
±2.5 V	±1.9 V	±0.62 V

Technical Specifications

Input referred noise	3 uVrms bandwidth 300-3000 Hz
	6 uVrms bandwidth 30-8000 Hz
Headstage Gain	RA16AC1 - Unity (1x)
	RA4AC4 - 4x
Frequency Response	DC - 25 kHz
Input Impedance	1e14 ohms

Pinout

Channel 1 marked with a dot on probe head

Pinouts are looking into the connector and reflect the preamplifier channels

The electrode connector accepts 0.76 mm diameter male pins. For pinouts for the preamplifier connector, see the RA16PA pinout.

> 🔥 **Important**
>
> When using multiple headstages, ensure that a single ground is used for all headstages. This will avoid unnecessary noise contamination in recordings. See the Headstage Connection Guide for more information.

The RA4AC1/RA4AC4 also comes with a 6-pin male connector with flying leads. When connecting to the headstage, note that the silver dots marking channel 1 line up.

The colors of the lead wires correspond to the headstage channels as follows:

Color	Channel
Black	1
Red	2
Orange	3
Yellow	4
Blue	Reference
Green	Ground

Low Impedance Headstages

RA4LI - Four Channel Headstage

The RA4LI headstage is designed for low impedance electrodes with input impedance between <1 kOhm and 20 kOhm. Electrode connectors are standard 1.5 mm safety connectors making it easy to connect to standard needle and surface electrodes for recording evoked potentials and EEG's. The headstage connects directly to the RA4PA Medusa preamplifier's 25-pin connector. A built-in impedance checker can be used to test each channel and the reference. Additional 20x gain on the headstage improves signal-to-noise of low voltage signals.

Impedance Checking with the Low-Impedance Headstage

The impedance checker on the RA4LI provides a simple check of the channel impedance relative to ground. To check the impedance level, press the button next to the channel indicator. The highest-level light indicates the maximum impedance between the channel and the ground. If all impedance lights are illuminated it is likely that one of the channels is not properly connected. The (-) impedance button checks the impedance between the reference (black connector) and the ground (green connector).

Headstage Voltage Range

When using a TDT preamplifier the voltage input range of the preamplifier (PZ5, Subject Interface, RA16PA) is typically lower than the headstage and must be considered the effective range of the system. Also keep in mind that the output range of the headstage varies depending on the power supply provided by the preamplifier. PZ5 and Subject Interface supply ±2.5 V. PZ2 and RA16PA preamplifiers supply ±1.5 V. Third party preamplifiers may vary. TDT recommends using preamplifiers which deliver ±2.5 V or less. The table below lists the input voltage ranges for the RA4LI headstage for either ±1.5 V or ±2.5 V power sources.
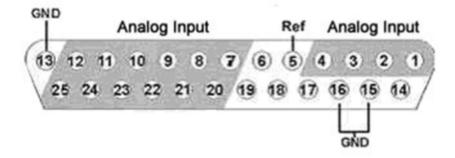
Power Source	Headstage Input Range
±1.5 V	±33 mV
±2.5 V	±80 mV

RA4LI Technical Specifications

Input referred noise	0.1 uVrms bandwidth 300-3000 Hz
	0.3 uVrms bandwidth 2-8000 Hz
Headstage Gain	20x
Highpass Filter	2.2 Hz
Lowpass Filter	7.5 kHz
Input Impedance	1e6 ohms

RA16LI - 16 Channel Headstage

The sixteen channel low impedance headstage (RA16LI) is a high quality, low- impedance headstage designed for recording high channel count EEG's.

The RA16LI headstage is designed for low impedance electrodes and electrode caps with input impedance between <1 kOhm and 20 kOhm. Either headstage unit connects to the Medusa preamplifier's 25-pin connector. The simple interface to the RA16PA preamplifier makes it easy to connect your electrodes to our system.

An adapter is also available to connect a low impedance headstage to a PZ preamplifier. See Preamplifier Adapters for more information. A built-in impedance checker can be used to test each channel and the reference. Additional 20x gain on the headstage improves signal-to-noise of low voltage signals.

Impedance Checking with the Low-Impedance Headstage

The impedance checker on the RA16LI provides a simple check of the channel impedance relative to ground. To check the impedance level, press the button next to the channel indicator. The highest-level light indicates the maximum impedance between the channel and the ground. If all impedance lights are illuminated it is likely that one of the channels is not properly connected. The (-) impedance button checks the impedance between the reference and the ground.

Headstage Voltage Range

When using a TDT preamplifier the voltage input range of the preamplifier (PZ5, Subject Interface, RA16PA) is typically lower than the headstage and must be considered the effective range of the system. Also keep in mind that the output range of the headstage varies depending on the power supply provided by the preamplifier. PZ5 and Subject Interface supply ±2.5 V. PZ2 and RA16PA preamplifiers supply ±1.5 V. Third party preamplifiers may vary. TDT recommends using preamplifiers which deliver ±2.5 V or less. The table below lists the input voltage ranges for the RA16LI headstage for either ±1.5 V or ±2.5 V power sources.

Power Source	Headstage Input Range
±1.5 V	±33 mV
±2.5 V	±80 mV

RA16LI Technical Specifications

Input referred noise	0.1 uVrms bandwidth 300-3000 Hz
	0.3 uVrms bandwidth 2-8000 Hz
Headstage Gain	20x
Highpass Filter	2.2 Hz
Lowpass Filter	7.5 kHz
Input Impedance	1e6 ohms

Electrode Connector Pinout

The electrode connector is a 25-pin connector. Information on the pin inputs is provided below.

> ✏️ **Note**
>
> Pins 6, 14, 17, 18 and 19 are not connected.

Pin	Name	Description		Pin	Name	Description
1	A1	Analog Input Channels		14	NA	Not Used
2	A2			15	GND	Ground
3	A3			16	GND	
4	A4			17	NA	Not Used
5	Ref	Reference		18	NA	Headstage Detect
6	NA	Not Used		19	NA	
7	A5	Analog Input Channels		20	A6	Analog Input Channels
8	A7			21	A8	
9	A9			22	A10	
10	A11			23	A12	
11	A13			24	A14	
12	A15			25	A16	
13	GND	Ground				

RA16LI-D - 16 Channel Headstage with Differential

The RA16LI-D headstage is designed for fully differential recordings from low impedance electrodes and electrode caps with input impedance between <1 kOhm and 20 kOhm. It connects to the Medusa preamplifier's 25-pin connector. The simple interface to the RA16PA preamplifiers makes it easy to connect your electrodes to our system. An adapter is also available to connect a low impedance headstage to a PZ preamplifier. See DBF-MiniDBM Low Impedance Headstage to PZ Preamplifier (16-channels) for more information.

The differential inputs allow for improved common mode rejection on all channels. Because of the increased complexity of the circuitry, the RA16LI-D does not have impedance checking. The headstage connector is a DB44. The pin out diagram is shown below.
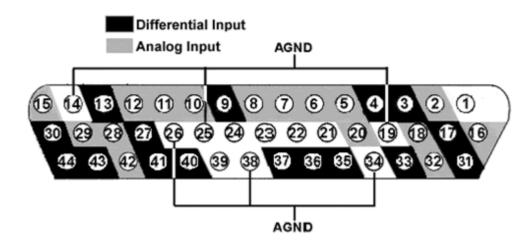
Headstage Voltage Range

When using a TDT preamplifier the voltage input range of the preamplifier is typically lower than the headstage and must be considered the effective range of the system. Check the specifications of your amplifier for voltage range.

RA16LI-D Technical Specifications

Input referred noise	0.1 uVrms bandwidth 300-3000 Hz
	0.3 uVrms bandwidth 2-8000 Hz
Headstage Gain	20x
Highpass Filter	2.2 Hz
Lowpass Filter	7.5 kHz
Input Impedance	1e6 ohms

Pinout Diagram

> **Note**
>
> Pins 1, 21-24 and 39 are not connected.

Pin	Name	Description	Pin	Name	Description
1	NA	Not Used	23	NA	Not Used
2	A2	Analog Input	24	NA	
3	D3	Differential Input	25	GND	Ground
4	D5		26	GND	
5	A5	Analog Input	27	D12	Differential Input
6	A7		28	A14	Analog Input
7	A8		29	A15	
8	A9		30	D16	Differential Input
9	D9	Differential Input	31	D1	
10	A10	Analog Input	32	A3	Analog Input
11	A11		33	D4	Differential Input
12	A12		34	GND	Ground
13	D13	Differential Input	35	D6	Differential Input
14	GND	Ground	36	D7	
15	A16	Analog Input	37	D8	
16	A1		38	GND	Ground
17	D2	Differential Input	39	NA	Not Used
18	A4	Analog Input	40	D10	Differential Input
19	GND	Ground	41	D11	
20	A6	Analog Input	42	A13	Analog Input
21	NA	Not Used	43	D14	Differential Input
22	NA		44	D15	

MZ60 MicroElectrode Array Interface

MZ60 Overview
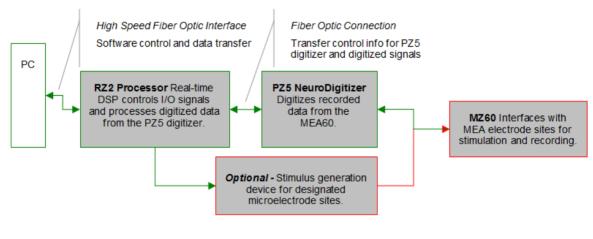
The MZ60 Microelectrode Array (MEA) Interface is used with our RZ2 BioAmp Processor and the PZ5 NeuroDigitizer (or SIM Subject Interface) as part of a complete solution for high spatio-temporal resolution tissue slice and cell culture recordings.

The interface supports simultaneous stimulation and extracellular in-vitro recording on up to 60 channels. Headstage buffering on the MZ60 provides high signal-to-noise ratio, sensitivity, and stability for long experimental durations.

The MZ60 is compatible with a large selection of MEA plates and both inverted and upright microscopes.

The MEA System

A typical system consists of an RZ2 processor, a PZ5 digitizer and the MZ60 MEA interface. An optional stimulus generation device may also be used and controlled by the RZ2 processor as part of an integrated solution. The diagram below illustrates the function of the components in the system.

MEA System Diagram

The MZ60 acquires analog input signals from cell lines or tissue slices via an MEA plate and sends those signals to the PZ5 digitizer. All channels are digitized on the PZ5 at up to ~50 kHz sampling rate per channel. Digitized data is streamed to the RZ2 multiprocessor DSPs on a fiber optic connection and processed data is transferred to the PC for data storage. A single RZ2 and PZ5 system is capable of interfacing with up to two MZ60's.

Stimulation can be delivered to any of the MZ60's electrode sites while the RZ2 processor simultaneously records from non-stimulus channels and may be provided by the RZ2 processor or an optional stimulus device.

The MEA Interface

The MZ60 is compatible with the standard 49 x 49 mm arrays from NMI or Ayanda Biosystems and can accommodate a wide selection of readily available arrays. The arrays are placed on an aluminum plate and spring loaded connections are secured over the contact pads when the top is lowered and locked using the twist lock mechanism.

A voltage-follower headstage provides a high input impedance and low output impedance with unity-gain. The dynamic range of the MZ60 and PZ5 is 500 mV with a signal resolution of 3 uVolt or less at ~25 kHz sampling rate.

The MZ60 channels are organized in four individual 16-channel banks that correspond to banks of channels on the PZ5 digitizer. Each bank transmits 15 analog signals recorded from the MEA to the PZ5 digitizer (the sixteenth channel of each bank is connected to ground and is not used). If any channel is designated for stimulation, it is grounded internally on the PZ5.

Headstage Voltage Range

When using a TDT preamplifier the voltage input range of the preamplifier (PZ5, Subject Interface, RA16PA) is typically lower than the headstage and must be considered the effective range of the system. Also keep in mind that the output range of the headstage varies depending on the power supply provided by the preamplifier. PZ5 and Subject Interface supply ±2.5 V. PZ2 and RA16PA preamplifiers supply ±1.5 V. Third party preamplifiers may vary. TDT recommends using preamplifiers which deliver ±2.5 V or less. The table below lists the input voltage ranges for the MZ60 headstage for either ±1.5 V or ±2.5 V power sources.

Power Source	Headstage Input Range
±1.5 V	±0.9 V
±2.5 V	±1.9 V

Hardware Set-up

To insert the MEA into the MZ60:

1. Twist the knob on the front edge of the MZ60 counterclockwise to release the hinged top.

2. Lift the top and position the MEA on the aluminum plate.

3. Lower the top and twist the knob clockwise to secure the MEA inside the interface housing.
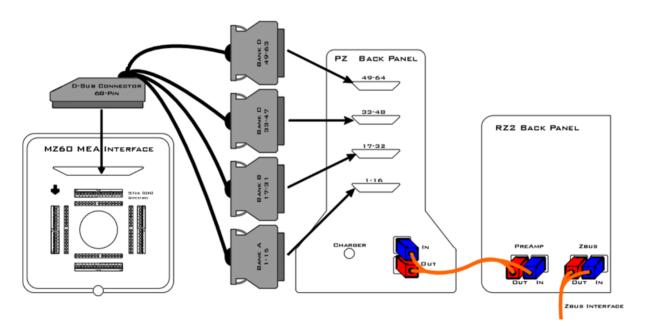
> 🔥 **Important**
>
> The securing knob on the MEA turns on a screw that allows for pressure adjustment between the MEA plate and the MZ60 interface contact pins. The pressure should be set to achieve only light contact between the spring loaded contact pins and the MEA plate (enough pressure to visually depress the spring contacts). Excessive pressure may cause damage to the device or MEA plate.

Refer to the vendor's specifications of the chosen MEA plate regarding the MEA pinouts and technical specifications of the electrodes.

To connect the system hardware:

1. Ensure that the TDT drivers, PC interface, and device chassis are installed, setup, and configured according to the System 3 Installation Guide provided with your system.

2. Connect the MZ60 Interface to the PZ5 digitizer via the MZ60 interface cable provided. Attach the 68-pin D-Sub connector on the interface cable to the corresponding connector on the MZ60.

3. Attach each of the labeled Mini-DB26 connectors to the corresponding channel bank connector on the PZ5 digitizer.

4. Connect the PZ5 digitizer to the RZ2 processor using the provided fiber optic cable. The fiber optic wires are keyed and color coded to reduce connection errors.

5. Power on the RZ2 processor and PZ5 digitizer.

6. If using the system with other devices, such as a third party stimulus device or preamplifiers, see the documentation for those devices for hardware connection information.

Setup of the MEA System
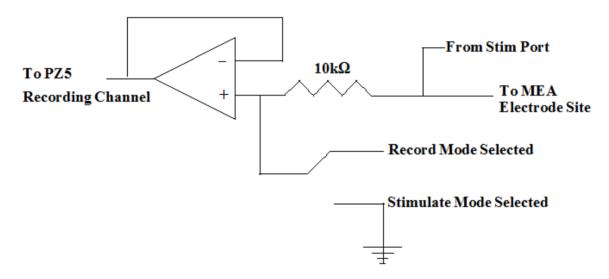
MEA Interface Features

Analog Input and Output

The MZ60 supports MEAs containing up to 60 electrode sites. Any of these analog channels may be configured for recording or stimulus presentation using top panel stimulus switches.

Stimulus Switches

A DIP-style switch for each of the 60 analog input channels controls whether the channel is in Stimulate mode (ON) or Record mode (OFF).

MZ60 Single Channel Circuit Diagram

Each of the sixty channels can be configured in one of two states:

Record   Channels in record mode are connected to a PZ5 digitizer input channel when the corresponding DIP-switch is in the **OFF** position.

Stimulate   Channels in stimulate mode allow current to pass through the electrode to ground when the corresponding DIP-switch is in the **ON** position. Stimulating channels are not connected to the PZ5 and will not saturate the input to the PZ5 digitizer nor are they connected to the REF line on the MZ60. A common ground pin is available on the MEA Interface.

> ⚠️ **Warning**
>
> Channels designated for recording are still connected to the corresponding stim port located on the MZ60. To avoid damage to the MZ60 headstage, DO NOT attempt to present stimulus signals to channels configured for record mode.

MZ60 Interface Cable Connector

An interface cable is provided to connect the MZ60 to the PZ5 digitizer. The cable features four mini-DB26 connectors which connect to four banks on the back of the PZ5.

Common Ground Pin

A single ground pin is attached to the MZ60 and serves as the common ground for both stimulating and recording channels on the MZ60. The PZ5 digitizer ground and reference pins for each bank are tied to this pin internally when the PZ5 and MZ60 are connected.

Some MEA plates have an internal reference pin integrated into dish. Please review the MEA dish manufacturer specifications for proper grounding.

Troubleshooting

This section is provided to address common issues that may be encountered when using the MZ60 MEA Interface. If you need assistance beyond the scope of this guide, contact tech support at +1.386.462.9622 or support@tdt.com.

General Tips

When recording signals make sure that the PZ5 digitizer is not connected to the charger as this will induce mains interference in your recordings.

Make sure there are no power strips or AC power sources anywhere near the MZ60 setup. Power strips will induce mains interference into your recordings. Also minimize electrical interference from other electrical devices (50-60 Hz and their harmonics). We recommend that the MZ60 and PZ5 are approximately 1 meter from computers, oscilloscopes, RZ and RX devices and other electronic equipment.

Make sure there is no liquid on the MEA plate contacts. Clean the contacts gently with isopropyl alcohol to assure a clean connection.

Make sure the MZ60 knob is oriented in the correct position. If the MZ60 top is not tight enough, open the MZ60 and ensure that the MEA plate is seated correctly in the MZ60 housing. As you close the MZ60 top ensure that all of the gold pins are touching the MEA electrode dish contacts.

Make sure that all of the spring-loaded contact pins are not stuck in a compressed position. If a pin becomes stuck, use a pair of forceps or small pliers to gently pull the pin out.

MZ60 Noise Floor is Too High

If 50-60 Hz hum (caused by mains voltage sources) is prevalent in your recordings, make sure that the common ground wire is making contact with the liquid in the MEA.

Noisy Single Electrode Channels

Large noise signals may be a sign of a bad electrode contact or pin. To test the electrode contact, rotate the MEA plate and see if the noise follows the MZ60 channel or the electrode.
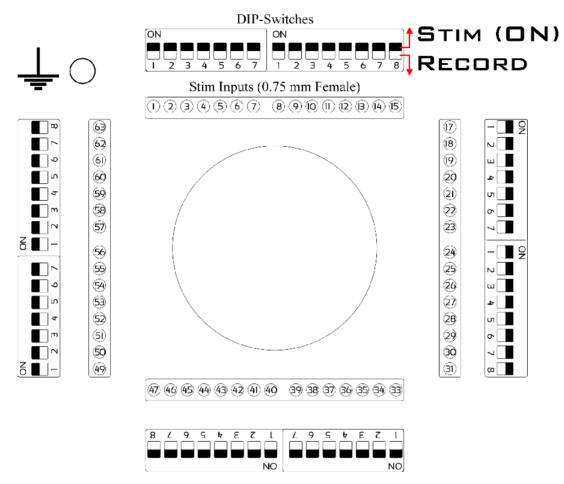
If the electrode contact is affected you may remedy the problem by cleaning the MEA contact sites with a cotton swab and some pure alcohol (100%). If the problem persists after cleaning the MEA electrode contacts, the contacts are damaged beyond repair and the MEA plate must then be replaced.

MZ60 Technical Specifications

Stimulus Input Channels	Up to 60 (0.75 mm female input pin)
Analog Input Channels	Up to 60
Input Impedance	1e14 Ohms
Gain	Unity (1x)
Compatible MEAs	Standard MEA Arrays 49 x 49 mm

MEA Connector Pinouts
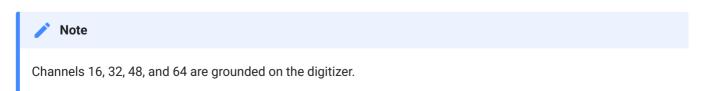
MZ60 MEA Interface

Stimulate/Record Switching Banks

A DIP-switch bank is located on each of the four sides of the MZ60 and toggles between stimulate or record modes for 15 electrode sites. Stimulating inputs accept 0.75 mm male pins.

Pinouts are shown looking into the connector and reflect the digitizer channels assuming the MZ60 is used with a PZ5-64 or PZA Subject Interface in Local, None, or Shared reference mode. For higher channel count channel numbers may be offset depending on the MZ60-PZ5 connections.

> ✏️ **Note**
>
> Channels 16, 32, 48, and 64 are grounded on the digitizer.

Headstage Connection Guide

Overview

Ground and Reference placement is important in all headstage configurations. They determine the operation of the headstage and can, if incorrectly wired, produce undesired results.

> 🔥 **Important**
>
> High channel count recordings (implemented either with PZ or multiple Medusa preamplifiers) may be implemented using multiple headstages. When using multiple headstages, ground pins on all headstages should be connected together to form a single common ground. This ensures that all headstage ground pins are at the same potential and eliminates additive noise from varying potentials across the subject's brain.

This section serves as a guide to headstage connection and will illustrate single and multiple headstage configurations. A common error example is provided for the final illustration.
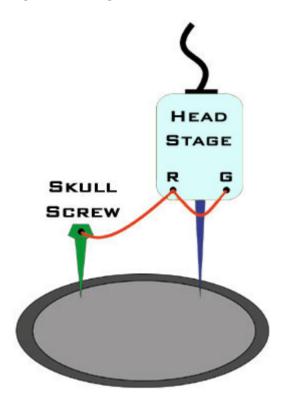
Headstage Operation

Headstage operations can be categorized into three forms listed below. It is important that multiple headstage configurations use a common node for all grounds regardless of the operation of the headstage.
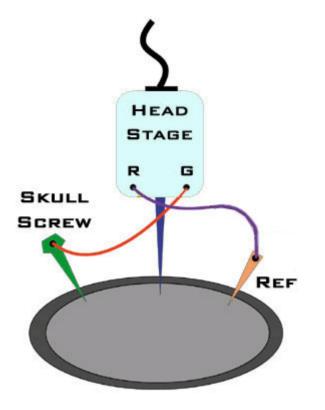
Operation	Description
Single-Ended	Ground and reference pins are tied together and the probe(s) reference all channels to ground.
Referential	Ground and reference pins are separate and the probes may use shared or multiple references.
Hybrid	A mixture of single-ended or referential operations when multiple headstages are used.

Single Headstage Configurations

Single Headstage with a Shared Ground and Reference

When using a single headstage with a shared ground and reference, the ground and reference pins of the headstage should be tied together. A ground is used and attached to a skull screw. All recordings will reference this connection. This configuration is referred to as "Single-Ended".
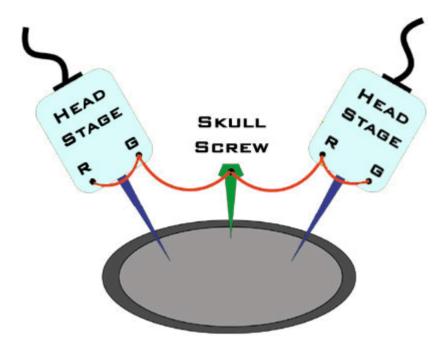
Single Headstage with a Separate Ground and Reference

When using a single electrode with a separate ground and reference, it is important that the headstage itself is not single-ended, that is, its ground and reference pins are NOT tied together. This will allow the headstage to reference each channel to ground as well as an additional chosen site on the subject. This configuration is referred to as "Referential".

Multiple Headstage Configurations

> ✏️ **Note**
>
> All headstages must use the same Ground wire. But not all headstages need to use the same Reference wire.
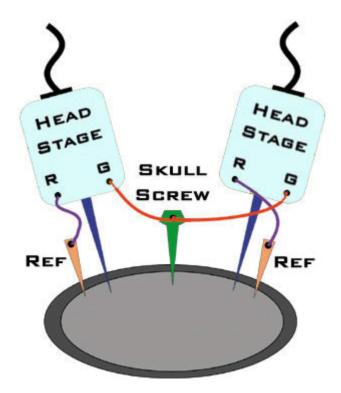
Multiple Headstages with a Shared Ground or Reference
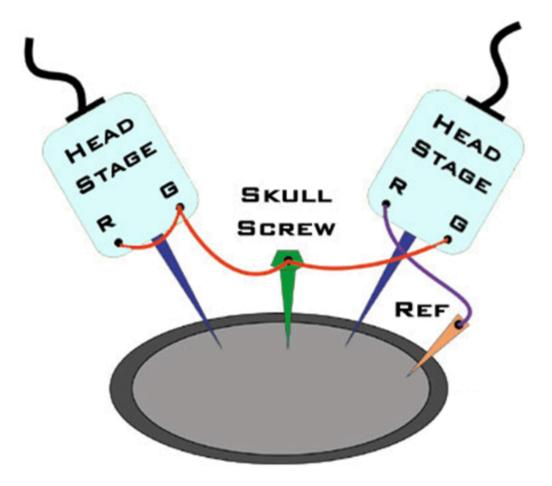
When using multiple headstages with a shared ground or reference, the ground and reference pins of each headstage should be tied together. A ground is used and attached to a skull screw. This ground is used by all headstages and ensures the headstages are referencing the same potential. This is a multiple single-ended configuration.

Multiple Headstages with a Single Ground and Multiple References

This configuration uses multiple referential headstages each with their own separate references. Notice that all the headstages' ground pin are tied together. This is a multiple referential configuration.

Multiple Headstages with a Shared Ground and different Ground/Reference configurations
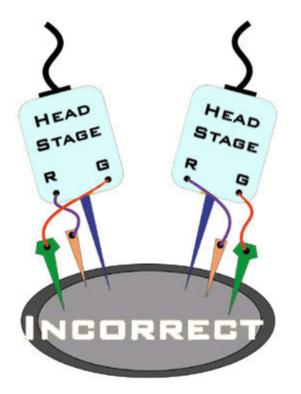
When using multiple electrodes with a shared ground and separate reference, all headstages' grounds are connected to the skull screw. A reference wire is present and connected to the desired headstage. This ensures all headstages have the same ground potential and provides a reference for the desired headstage. This is a hybrid configuration and uses a mixture of single-ended and referential headstages.

A Common Error to Avoid
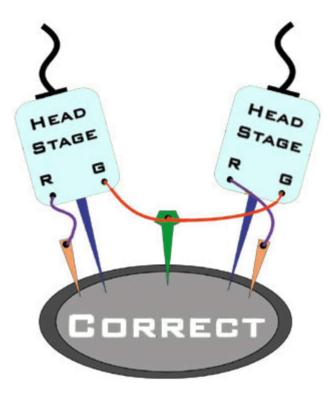
When using multiple headstages a common error is to connect separate grounds for each headstage. This allows additional noise to corrupt signals increasing the number of artifacts present. To avoid this, ensure that all headstage ground pins are wired as a single ground.

Incorrect Configuration

Both headstages are connected to a unique node for ground. This will introduce additional noise artifacts into the recordings.

Correct Configuration

These headstages are correctly sharing a single node for ground. All headstages will be able to reference the same ground and will eliminate unnecessary noise artifacts from the recordings.

20. Headstage Adapters

ZIF-Clip® Headstage Adapters

ZIF-Clip® headstage adapters are available for use with a variety of electrode styles. When using adapters, keep in mind that standard operation (referential vs single-ended) may vary for acute and chronic preparations. Carefully note and understand the use of the ground (G) and reference (R) connections provided on each adapter.
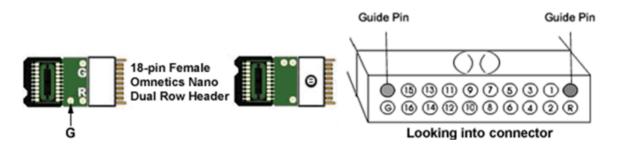
Standard operation for ZIF-Clip® headstages is referential. Headstage adapters can be configured for single-ended operation by tying ground (G) and reference (R) connections together on the adapter (if available). Refer to the electrode manufacturer's documentation for information on single-ended or referential configurations.

> ✏️ **Note**
>
> When using these adapters with NeuroNexus, Gray Matter, or CyberKinetics probes, keep in mind that there may be updates to pin configurations. Check the suppliers' website for pin diagrams. Also see the Channel Mapper gizmo in Synapse for a description and examples on how to re-order channel numbers.

### ZCA-OMN16 ZIF-Clip® Headstage to Chronic Probe (16 Channels)

The ZCA-OMN16 adapter connects a 16-channel chronic Omnetics based probe to a 16-channel ZIF-Clip® headstage. Ground and reference pins may be tied together for single-ended operation with a jumper wire between the G and R pads. Otherwise the adapter operates in referential mode.
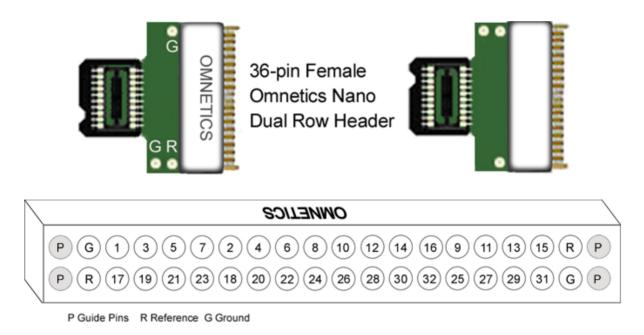
*Pinouts are looking into the connector and reflect the preamplifier channels*

ZCA-OMN32 ZIF-Clip® Headstage to Chronic Probe (32 Channels)

The ZCA-OMN32 adapter connects a 32-channel chronic Omnetics based probe to a 32-channel ZIF-Clip® headstage.

Ground and reference pins may be tied together for single-ended operation with a jumper wire between the G and R pads. Otherwise the adapter operates in referential mode.

P Guide Pins   R Reference G Ground
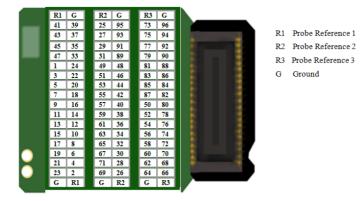
Pinouts are looking into the connector and reflect the preamplifier channels

ZCA-OMN96 ZIF-Clip® Headstage to 96-Channel Omnetics Probe
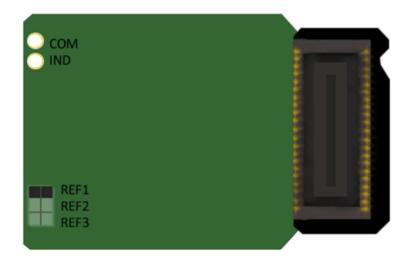
The ZCA-OMN96 adapter connects a 96-channel chronic Omnetics connector to a 96-channel ZIF-Clip® headstage. For single-ended operation, tie COM (ground) and IND (indifferent reference) together. IND is the global headstage reference.

> 🔥 **Important**
>
> The pinouts below are for the ZC96 analog headstages only. If you are using a ZD96 digital headstage, please refer to the ZD96 Headstage section of this manual for the pinout.

R1	G	R2	G	R3	G
41	39	25	95	73	96
43	37	27	93	75	94
45	35	29	91	77	92
47	33	31	89	79	90
1	24	49	48	81	88
3	22	51	46	83	86
5	20	53	44	85	84
7	18	55	42	87	82
9	16	57	40	50	80
11	14	59	38	52	78
13	12	61	36	54	76
15	10	63	34	56	74
17	8	65	32	58	72
19	6	67	30	60	70
21	4	71	28	62	68
23	2	69	26	64	66
G	R1	G	R2	G	R3

R1   Probe Reference 1
R2   Probe Reference 2
R3   Probe Reference 3
G   Ground

Pinouts are looking into the connector and reflect the preamplifier channels

Use jumper to choose which reference (R1, R2, R3) to use for all channels. Only one reference may be selected.
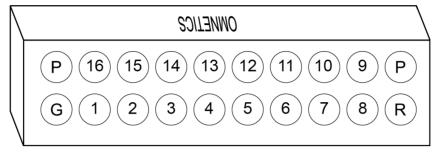
ZCA-FLEX-OMNX2 ZIF-Clip® Headstage to Chronic Probe (2 x 16 Channels)

The ZCA-FLEX-OMNX2 adapter connects two 16-channel chronic Omnetics based probe to a 32-channel ZIF-Clip® headstage with flex cable.
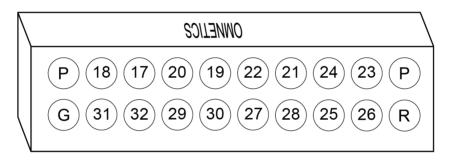
ZCA-FLEX-OMNX2 (Side A on top, Side B on bottom)

The standard cable length is two inches. The reference pins on each connector are shared on the PCB. The ground pins are also shared. The ground and reference are independent and can only be shorted on the probe or by choosing the 'None' reference option on the PZ5/SIM amplifier if using an analog ZIF-Clip® headstage.

Side A pinouts are looking into the connector and reflect the preamplifier channels

Side B pinouts are looking into the connector and reflect the preamplifier channels
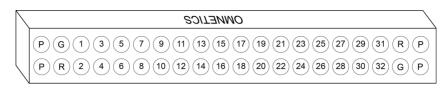
ZCA32-FLEX-OMN ZIF-Clip® Headstage to Chronic Probe (32 Channels)

The ZCA32-FLEX-OMN adapter connects a 32-channel chronic Omnetics based probe to a 32-channel ZIF-Clip® headstage with flex cable.

ZCA32-FLEX-OMN (Side A shown)
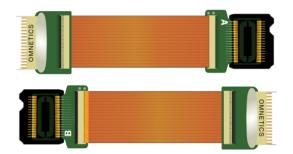
The standard cable length is two inches. A jumper location on the PCB can be used to short ground and reference together for single-ended operation. Otherwise the adapter operates in referential mode.

Pinouts are looking into the connector and reflect the preamplifier channels

ZCA64-FLEX-OMN ZIF-Clip® Headstage to Chronic Probe (2 x 32 Channels)

The ZCA64-FLEX-OMN adapter connects two 32-channel chronic Omnetics based probe to a 64-channel ZIF-Clip® headstage with flex cable.

ZCA64-FLEX-OMN (Side A on top, Side B on bottom)

The standard cable length is two inches. The reference pins on each connector are shared on the PCB. A jumper location on the PCB can be used to short ground and reference together for single-ended operation. Otherwise the adapter operates in referential mode.

> 🔥 **Important**
>
> The pinout below is for the ZC64 analog headstages only. If you are using a ZD64 digital headstage, please refer to the ZD64 Headstage section of this manual for the pinout.

Side A pinouts are looking into the connector and reflect the preamplifier channels

Side B pinouts are looking into the connector and reflect the preamplifier channels
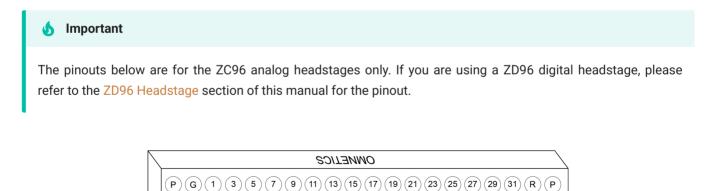
ZCA96-FLEX-OMN ZIF-Clip® Headstage to Chronic Probe (3 x 32 Channels)

The ZCA96-FLEX-OMN adapter connects three 32-channel chronic Omnetics based probe to a 96-channel ZIF-Clip® headstage with flex cable.

ZCA96-FLEX-OMN (Side A on top, Side B on bottom)

The standard cable length is two inches. The reference pins on each connector are shared on the PCB. A jumper location on the PCB can be used to short ground and reference together for single-ended operation. Otherwise the adapter operates in referential mode.

> 🔥 **Important**
>
> The pinouts below are for the ZC96 analog headstages only. If you are using a ZD96 digital headstage, please refer to the ZD96 Headstage section of this manual for the pinout.

Side A 1-32 pinout looking into the connector, reflects the preamplifier channels
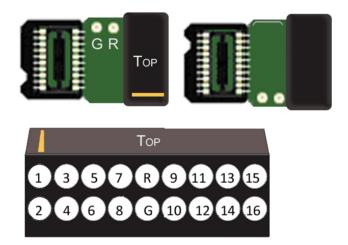
Side A 33-64 pinout looking into the connector, reflects the preamplifier channels

Side B 65-96 pinout looking into the connector, reflects the preamplifier channels

ZCA-MIL16 ZIF-Clip® Headstage to Mill-Max connector (16 Channels)

The ZCA-MIL16 adapter connects a 18-channel Mill-Max based probe to a 16-channel ZIF-Clip® headstage. By default, the inputs are single ended, with Reference (R) and Ground (G) tied together. To make the inputs referential, sever the jumper trace on the board between R and G (shown below).

Pinouts are looking into the connector and reflect the preamplifier channels

Mill-Max Connector Specifications:
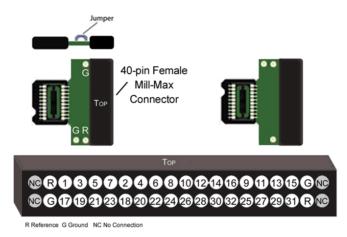
Pitch	0.050" (1.27 mm)
Row Spacing:	0.050" (1.27 mm)

ZCA-MIL32 ZIF-Clip® Headstage to Mill-Max connector (32 Channels)

The ZCA-MIL32 adapter connects a 32-channel Mill-Max based probe to a 32-channel ZIF-Clip® headstage. By default, the inputs are single ended, with Reference (R) and Ground (G) tied together. To make the inputs referential, cut the jumper between R and G (shown below).

Pinouts are looking into the connector and reflect the preamplifier channels

Mill-Max Connector Specifications:

Pitch	0.050" (1.27 mm)
Row Spacing:	0.050" (1.27 mm)

ZCA-DIP16 ZIF-Clip® Headstage to Acute Probe (16 Channels)
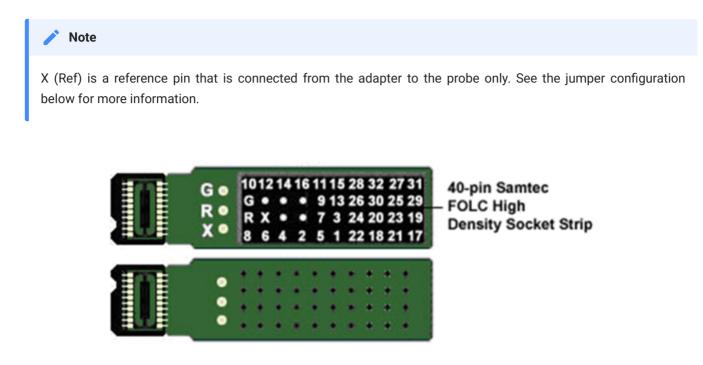
The ZCA-DIP16 adapter allows the user to connect a 16-channel acute probe (such as NeuroNexus) to a 16-channel ZIF-Clip® headstage. Ground and reference pins are located on the DIP connector and may be tied together for single-ended operation.


Pinouts are looking into the connector and reflect the preamplifier channels

ZCA-NN32 ZIF-Clip® Headstage to 32 Channel Acute Probe)

The ZCA-NN32 adapter connects a 32-channel acute NeuroNexus probe to a 32-channel ZIF-Clip® headstage.

> ✏️ **Note**
>
> X (Ref) is a reference pin that is connected from the adapter to the probe only. See the jumper configuration below for more information.

Pinouts are looking into the connector and reflect the preamplifier channels.

ZCA-NN64 ZIF-Clip® Headstage to 64 Channel Acute Probe)

The ZCA-NN64 adapter connects a 64-channel acute NeuroNexus probe to a 64-channel ZIF-Clip® headstage.

> ✏️ **Note**
>
> X (Ref) is a reference pin that is connected from the adapter to the probe only. See the jumper configuration below for more information.

Jumper Configuration
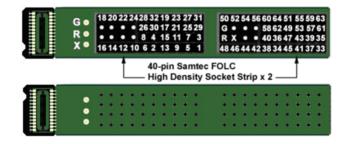
The following table describes the jumper configurations for both the ZCA-NN32 and ZCA-NN64.

Jumper Connections	Operation
G R X (Ref)	Shorts headstage Ground and Reference inputs together, yielding single-ended amplification of signals relative to ground.
G R X (Ref)	Shorts headstage Reference input to the pin labeled X (a low impedance site on the probe) yielding referential amplification of signals relative to the voltage of the X (Ref) site.
G R X (Ref)	Headstage Ground and Reference separated and X (Ref) pin is not used, yielding referential amplification of signals relative to the voltage of the Reference

Pinout

> 🔥 **Important**
>
> The pinout below is for the ZC64 analog headstages only. If you are using a ZD64 digital headstage, please refer to the ZD64 Headstage section of this manual for the pinout.
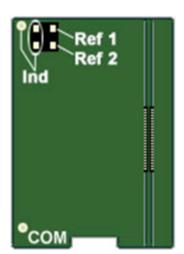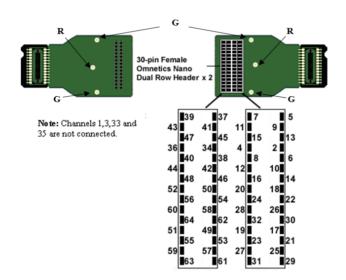

Pinouts are looking into the connector and reflect the preamplifier channels.

## ZCA-CK96A ZIF-Clip® Headstage to 96-Channel Chronic Probe

The ZCA-CK96A adapter connects a 96-channel chronic CyberKinetics CerePort connector to a 96-channel ZIF-Clip® headstage. For single-ended operation, tie the ground and reference pins (shown in diagram) together.

ZCA-CK96A Connection Diagram.

A four-pin header located on the backside of the adapter is provided for access to two probe reference pins. These pins are separate references and are connected internally to the adapter.

Connecting a jumper between the headstage reference pins (Ind) and either of the probe reference pins (Ref1 or Ref2) connects the headstage reference to the desired probe reference (see table below for more information).

Jumper Configuration
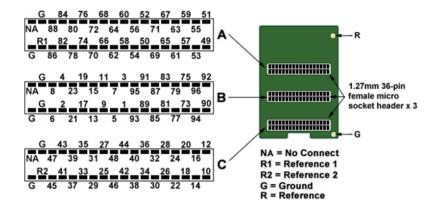
The following table describes the jumper configurations for the ZCA-CK96A.

Jumper Connections	Operation
Ind Ref₁ Ind Ref₂	Headstage Ground and Reference separated and Ref1, Ref2 pins are not used, yielding referential amplification of signals relative to the voltage of the Reference (Ind). An external connection for the headstage reference (Ind) must be used for referential amplification.
[Ind Ref₁] Ind Ref₂	Shorts headstage Reference input (Ind) to the pin labeled Ref1 (a low impedance site on the probe) yielding referential amplification of signals relative to the voltage of the Ref1 site.
Ind Ref₁ [Ind Ref₂]	Shorts headstage Reference input (Ind) to the pin labeled Ref2 (a low impedance site on the probe) yielding referential amplification of signals relative to the voltage of the Ref2 site.

Pinouts

> 🔥 **Important**
>
> The pinouts below are for the ZC96 analog headstages only. If you are using a ZD96 digital headstage, please refer to the ZD96 Headstage section of this manual for the pinout.

Pinouts are looking into the connector and reflect the preamplifier channels

# ZCA-GM60 ZIF-Clip® Headstage to 60-Channel Chronic Probe
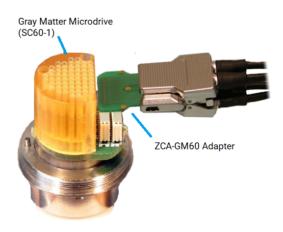
The ZCA-GM60 adapter connects a 60-channel chronic Gray Matter microdrive (SC60-1) to a 64-channel ZIF-Clip® headstage. Ground and reference pins are located on the adapter for access to single-ended and referential modes of operation. See the diagram below for connection details.

> 🔥 **Important**
>
> The pinout below is for the ZC64 analog headstages only. If you are using a ZD64 digital headstage, please refer to the ZD64 Headstage section of this manual for the pinout.

Pinouts are looking into the connector and reflect the preamplifier channels.

ZCA-GM60 Connection Diagram
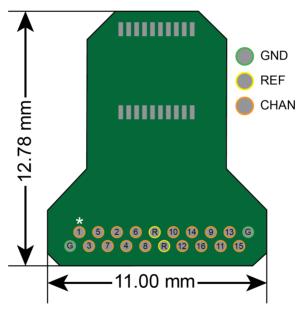
ZCA-EIB16 ZIF-Clip® Headstage to Electrode Interface Board (16 Channels)

The ZCA-EIB16 adapter allows the user to connect 16 channels of electrode wire to a 16-channel ZIF-Clip® headstage plus ground and reference.

Wires can be soldered to holes or connected using EIB pins, such as the small EIB tapered pins available from NeuraLynx.
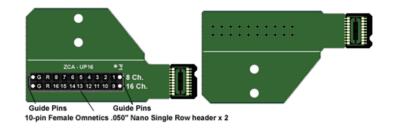
To guard against noise pickup, the lengths of any additional wires should be minimized and the wires should be bundled together to avoid creating open loops that can pick up inductive interference.

Specifications	
Hole diameter	0.3 mm
Row Spacing	0.69 mm from center to center

ZCA-EIB16 Pinout and Dimensions Diagram

ZCA-EIB32 ZIF-Clip® Headstage to Electrode Interface Board (32 Channels)

The ZCA-EIB32 adapter allows the user to connect 32 channels of electrode wire to a 32-channel ZIF-Clip® headstage plus ground and reference.

Wires can be soldered to holes or connected using EIB pins, such as the small EIB tapered pins available from NeuraLynx.

To guard against noise pickup, the lengths of any additional wires should be minimized and the wires should be bundled together to avoid creating open loops that can pick up inductive interference.

Specifications	
Hole diameter:	0.3 mm
Row Spacing	0.69 mm from center to center

ZCA-EIB32 Pinout and Dimensions Diagram

# ZCA-UP16 16-Channel Plextrode U-Probe to ZIF-Clip® headstage
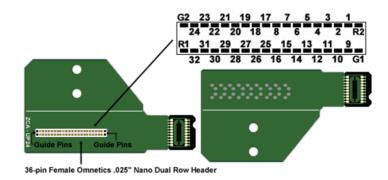
The ZCA-UP16 adapter connects an 8 or 16-channel acute Plextrode U-Probe connector to a 16-channel ZIF-Clip® headstage. The adapter includes mounting holes for attachment to a micromanipulator. Configuration for single-ended or referential operation is provided on the electrode. Refer to the Plextrode documentation for jumper configurations.

Pinouts are looking into the connector and reflect the preamplifier channels

ZCA-UP24 24-Channel Plextrode U-Probe to ZIF-Clip® headstage
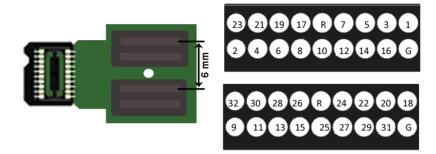
The ZCA-UP24 adapter connects a 24-channel acute Plextrode U-Probe connector to a 32-channel ZIF-Clip® headstage. The adapter includes mounting holes for attachment to a micromanipulator. Configuration for single-ended or referential operation is provided on the electrode. Refer to the Plextrode documentation for jumper configurations.

Pinouts are looking into the connector and reflect the preamplifier channels

ZCA-VD8 ZIF-Clip® Headstage to Versa Drive connector (32 Channels)

The ZCA-VD8 adapter connects a Versa Drive (Versa-8 Optical) via two Mill-Max connectors to a 32-channel ZIF-Clip® headstage.

Pinouts are looking through the connector and reflect the preamplifier channels

Mill-Max Connector Specifications:

Pitch	0.050" (1.27 mm)
Row Spacing:	0.050" (1.27 mm)

Connector to Connector Specification:

Pitch	0.236" (6 mm), Pin 1 to Pin 18
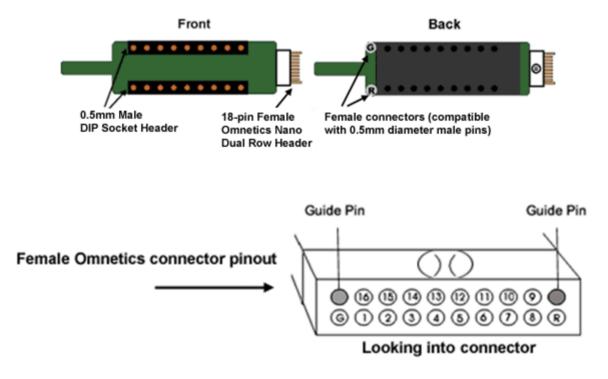
Probe Adapters

Adapters Overview

Each TDT headstage is designed for use with a particular style of probe. Probe adapters allow each headstage to be used with a wider variety of probes. When using adapters, keep in mind that standard operation (referential vs single ended) varies for acute and chronic preparations and headstages are designed accordingly. When adapting across preparations, carefully note and understand the use of the ground (G) and reference (R) connections provided on each adapter.

AC-CH Acute Headstage to Chronic Probe (16 Channels)

The AC-CH adapter allows the user to connect a 16-channel chronic probe to an acute TDT headstage (RA16AC/RA16AC4). Standard operation for chronic preparations is single ended with ground and reference shorted together in the chronic headstage. However, the acute headstage is designed for referential operation. Short G and R together on the adapter for single-ended operation.
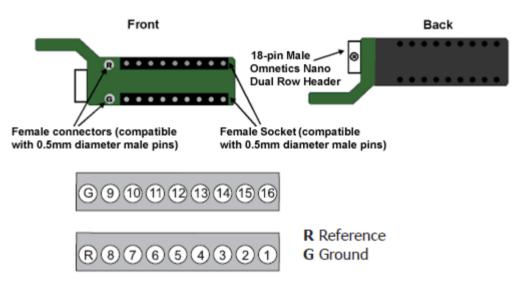

Pinouts are looking into the connector and reflect the preamplifier channels.

TDT probe adapters are designed for specific TDT headstage to probe connections. If you are using a third party headstage, please contact TDT support for assistance.

CH-AC Chronic Headstage to Acute Probe (16 Channels)

The CH-AC adapter connects a 16-channel acute probe to a TDT chronic headstage (RA16CH). Reference and ground are tied together by default on the chronic headstage so in general only one pin connection is necessary. A jumper is provided on the RA16CH for referential operation. See RA16CH/LP16CH/LP16CH-ZNF - 16 Channel Chronic Headstage for more information.
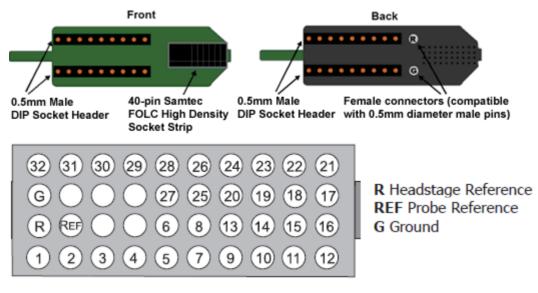
*Pinouts are looking into the connector and reflect the preamplifier channels.*

TDT probe adapters are designed for specific TDT headstage to probe connections. If you are using a third party headstage, please contact TDT support for assistance.

ACx2-NN 16 Channel Acute Headstage to 32 Channel Acute Probe

The ACx2-NN adapter connects a 32-channel acute NeuroNexus probe to two 16-channel acute TDT headstages (RA16AC/RA16AC4). Standard operation with the NeuroNexus probe is referential. If you wish to use the Reference pad on the probe, do not tie G and R together.

Pinouts are looking into the connector and reflect the preamplifier channels.
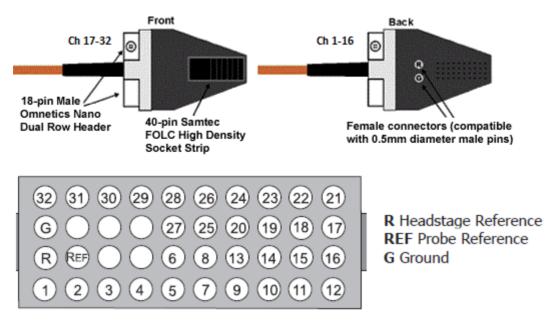
TDT probe adapters are designed for specific TDT headstage to probe connections. If you are using a third party headstage, please contact TDT support for assistance.

> 🔥 **Important**
>
> When using these adapters with NeuroNexus probes, keep in mind that there are several versions of each of the probes. TDTs ACx2-NN is designed for use with Rev 2 of the 32-channel NeuroNexus acute probe. Also see the Channel Mapper gizmo in Synapse for a description and examples on how to re-order channel numbers.

CHx2-NN 16 Channel Chronic Headstage to 32 Channel Acute Probe

The CHx2-NN adapter connects a 32-channel acute NeuroNexus probe to two 16-channel chronic TDT headstages (RA16CH). Connect the first RA16CH headstage (channels 1-16) to the front of the adapter. Connect the second RA16CH (channels 17-32) to the back of the adapter. This adapter also features a holding rod for connection to a micromanipulator. As with the CH-AC adapter, reference and ground are tied together by default on the chronic headstage so in general only one pin connection is necessary. If you wish to use the Reference pad on the probe, do not tie G and R together and cut the jumper on each headstage to make the inputs referential. See RA16CH/LP16CH/LP16CH-ZNF - 16 Channel Chronic Headstage for more information.

Pinouts are looking into the connector and reflect the preamplifier channels.

TDT probe adapters are designed for specific TDT headstage to probe connections. If you are using a third party headstage, please contact TDT support for assistance.

> 🔥 **Important**
>
> When using these adapters with NeuroNexus probes, keep in mind that there are several versions of each of the probes. TDTs CHx2-NN is designed for use with Rev 2 of the 32-channel NeuroNexus acute probe. Check the NeuroNexus website for pin diagrams. Also see the Channel Mapper gizmo in Synapse for a description and examples on how to re-order channel numbers.
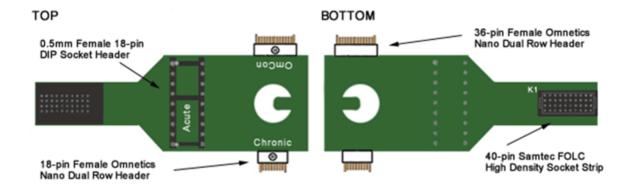
nanoZ-OMN/DIP nanoZ™ to Omnetics and DIP Based Probes

The nanoZ-OMN/DIP adapter allows the user to connect an Omnetics or DIP based probe to a nanoZ™ impedance tester. Connectors are labeled on the circuit board for easy identification.

The K1 connector on the bottom of the adapter is used to connect the nanoZ™ to one of the following:

- The **Chronic** connector is a dual row 18-pin Omnetics nano connector that is used with a 16-channel chronic probe.

- The **OmCon** connector is a dual row 36-pin Omnetics nano connector that is used with a 32-channel chronic probe.

- The **Acute** connector is a 0.5 mm female 18-pin DIP socket that is used with a 16-channel DIP-based probe, such as a 16-channel acute Neuronexus probe.
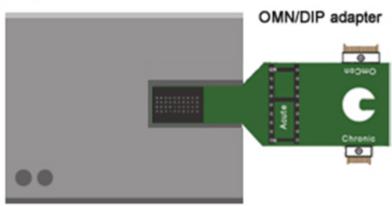
> 🔥 **Important**
>
> The corresponding channels from each probe connection are tied together, so that channel 1 of the Chronic connector, the OmCon connector, and the Acute connector are all tied to channel 1 of the nanoZ connector. See pinouts below for more detail.
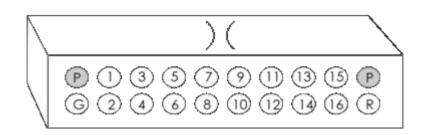

Connecting the Adapter to the nanoZ™

After configuring the nanoZ™ impedance tester as directed in the nanoZ™ User Manual, connect the adapter to the Samtec connector closest to the center, ensuring it is firmly seated. The adapter should cover both nanoZ™ Samtec connectors (as shown below).
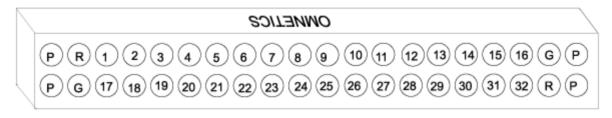
Chronic Pinout

18-pin female Omnetics nano dual row header (pinout looking into the connector)
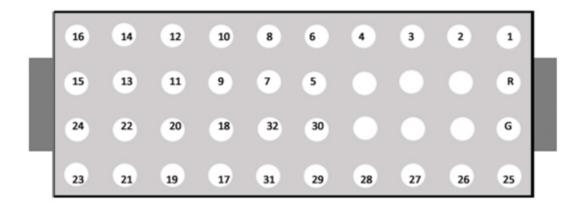
OmCon Pinout

36-pin female Omnetics nano dual row header (pinout looking into the connector)

Acute Pinout

0.5 mm female 18-pin DIP socket header (pinout looking into the connector)

K1 Pinout

40-pin Samtec FOLC high density socket strip (pinout looking into the connector)

nanoZ-ZCA32/ZCA64 nanoZ™ to ZIF-Clip® Probes

The nanoZ-ZCA32 and nanoZ-ZCA64 adapters allow the user to connect a nanoZ™ impedance tester to a 32- or 64-channel ZIF-Clip® probe.

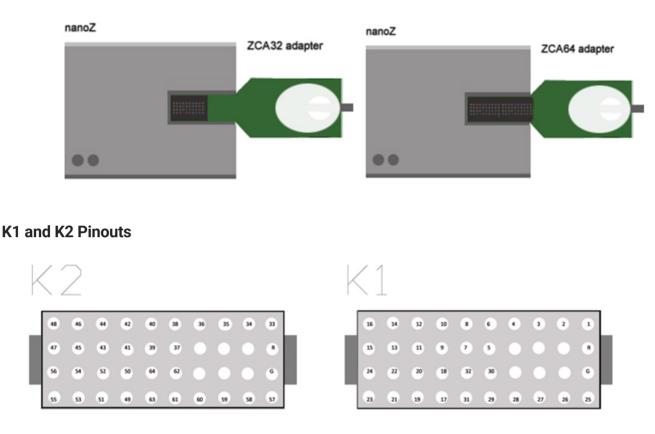The nanoZ-ZCA32 K1 connector is used to connect the nanoZ™ to a 32-channel chronic probe.

The nanoZ-ZCA64 K1 and K2 connectors are used to connect the nanoZ™ to a 64-channel chronic probe.

See ZIF-Clip® Analog Headstages for more information on ZIF-Clip® connectors.

Connecting the Adapter to the nanoZ™

After configuring the nanoZ™ impedance tester as directed in the nanoZ™ User Manual, connect the adapter so that both nanoZ™ Samtec connectors (as shown below). Ensure that it is firmly seated. The nanoZ-ZCA32 should connect to the Samtec connector closest to the center of the nanoZ™.

K1 and K2 Pinouts

40-pin Samtec FOLC high density socket strips (pinouts looking into the connector)

Splitters

S-BOX_PZ5 - Amplifier Input Splitter

The S-BOX_PZ5 is a 32-channel passive signal splitter for use with the PZ5 Amplifier or PZA (Subject Interface) Amplifier. The splitter provides a simple and effective means of routing low impedance biological signals to both a TDT acquisition system and a parallel recording system.

Two DB26 connectors provide direct connection to a PZ5 amplifier and a single DB37 provides a parallel output connection. Bank letters as well as channel number ranges are labeled on all the DB26 connectors (i.e. Bank A Channels 1-16).

> 🔥 **Important**
>
> The S-BOX_PZ5 is NOT FDA approved and is intended for use with the PZ5 Amplifier.

The S-BOX_PZ5 uses standard 1.5 mm safety connectors for electrode input. Front panel numbering of these inputs corresponds to TDT amplifier channels.
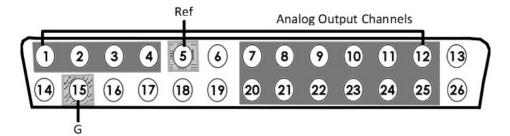
DB37 Pinout

Pin	Name	Description	Pin	Name	Description
1	A1	Analog input channels	20	A2	Analog input channels
2	A3		21	A4	
3	A5		22	A6	
4	A7		23	A8	
5	A9		24	A10	
6	A11		25	A12	
7	A13		26	A14	
8	A15		27	A16	
9	A17		28	A18	
10	A19		29	A20	
11	A21		30	A22	
12	A23		31	A24	
13	A25		32	A26	
14	A27		33	A28	
15	A29		34	A30	
16	A31		35	A32	
17	NA	Not Used	36	NA	Not Used
18	NA		37	REF	Reference
19	GND	Ground			

> ✏️ **Note**
>
> No connections should be made to pins 17, 18, and 36.

DB26 Pinout

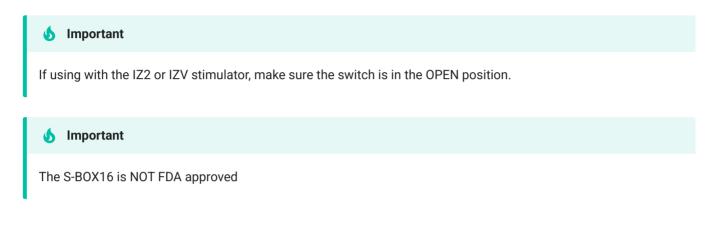| Pin	Name	Description	Pin	Name	Description
1	A1	Analog Input Channels	14	NA	Not Used
2	A2		15	GND	Ground
3	A3		16	GND	Ground
4	A4		17	NA	Not Used
5	Ref	Reference	18	HSD	Headstage Detect
6	HSD	Headstage Detect	19	HSD	
7	A5	Analog Input Channels	20	A6	Analog Input Channels
8	A7		21	A8	
9	A9		22	A10	
10	A11		23	A12	
11	A13		24	A14	
12	A15		25	A16	
13	NA	Not Used	26	NA	Not Used

S-BOX16 - 16 Channel Input Splitter

The S-BOX16 is a 16-channel passive signal splitter for use with the PZ5 Amplifier or PZA (Subject Interface) Amplifier. It has a physical switch to optionally short ground and reference together.

The S-BOX16 uses standard 1.5 mm safety connectors for input from electrodes. Front panel numbering of these inputs corresponds to TDT amplifier channels.

It has the same pinout as the S-BOX_PZ5.

> 🔥 **Important**
>
> If using with the IZ2 or IZV stimulator, make sure the switch is in the OPEN position.

> 🔥 **Important**
>
> The S-BOX16 is NOT FDA approved

S-BOX64 - 64 Channel Input Splitter

The SBOX64 is a 64-channel passive signal splitter for use with the PZ5 Amplifier or PZA (Subject Interface) Amplifier. It has a physical switch to optionally short ground and reference together.

The S-BOX64 uses standard 1.5 mm safety connectors for input from electrodes. Front panel numbering of these inputs corresponds to TDT amplifier channels.

Each DB26 has the same pinout as the S-BOX_PZ5.

- Bank A Ch 1-16

- Bank B Ch 17-32

- Bank C Ch 33-48

- Bank D Ch 49-64

All GND pins on Banks A-D are shared, and all Ref pins are shared.

Front and back pinout of S-BOX64

> 🔥 **Important**
>
> If using with the IZ2 or IZV stimulator, make sure the switch is in the OPEN position.

> 🔥 **Important**
>
> The S-BOX64 is NOT FDA approved

Connectors

LI-CONN - Low Impedance Connectors

A set of multi-channel low impedance connectors (LI-CONN) for the RA16LI is available for users who do not require a direct connection between the electrodes and the headstage. The LI-CONN uses standard 1.5 mm safety connectors to ensure proper connection between electrodes and the preamplifier.
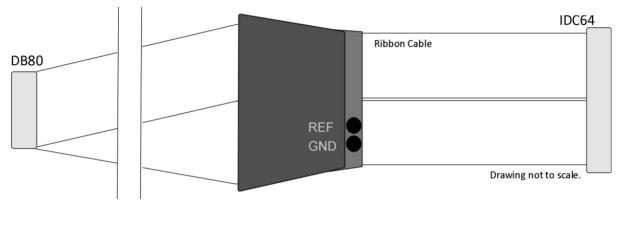
LI-CONN-Z - Low Impedance Connector for PZ PreAmps

The PZ5/PZ3/SIM are designed to record from low impedance electrodes and electrode caps with input impedance less than 20 kOhm. Signals are input via multiple DB26 connectors on the PZ back panel. A break out box or connector(s) is required for electrode connection.

The **LI-CONN-Z** features standard 1.5 mm safety connectors and provides easy connections between electrodes and the amplifier.
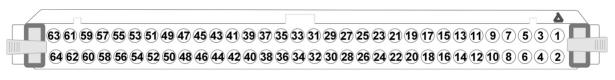
DB80-I64 PZ5M to I Cable Adapter (64 Channel)

The DB80-I64 adapter connects a standard I connection to a single PZ5M DB80 input connector. Ground and reference are available via standard 1.5 mm touch proof inputs on the polymer bracket. The light-weight bracket reduces tangling near the subject.

DB80-I64 Cable Adapter

The male I connector is keyed to ensure correct connection and includes locking latches to prevent disconnection. The standard length of ribbon cable, from end to end, is 3.6 meters.

Connector Pinout

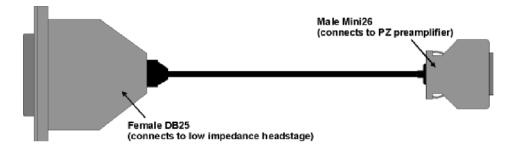*Pinouts are looking into the connector and reflect the preamplifier channels*

The connector is marked to indicate channel 1.

Preamplifier Adapters

Each TDT headstage is designed for use with either a Legacy or Z-Series preamplifier. Preamplifier adapters allow TDT headstages to be used with a variety of preamplifiers by converting the type of preamplifier connector.
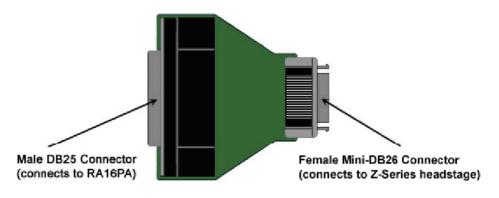
DBF-MiniDBM Low Impedance Headstage to PZ Preamplifier (16-channels)

This adapter connects a low impedance headstage (RA4LI or RA16LI) to a PZ preamplifier.
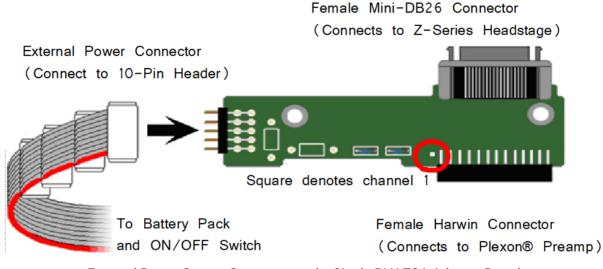

MiniDBF-DBM Z-Series Headstage Female Mini-DB26 to Male DB25 Cable Adapter

This adapter converts a Z-Series headstage Mini-D connector to a DB25 connector for use with a Medusa RA16PA preamplifier.

PLX-ZCA Z-Series Headstage to Plexon Preamplifier

This adapter connects a Z-Series headstage to a Plexon preamplifier. Each PLX- ZCA adapter board connects 16-channels. Multiple adapter boards can be stacked for a higher channel count and are fastened together using two screws on either side of the adapter board. An external power source is provided to power the headstage.

External Power Source Connector and a Single PLX-ZCA Adapter Board

External Power Source

In order to power TDT headstages when using this adapter, an external power source is required. Each external power source includes four connectors and can power up to four PLX-ZCA adapter boards. The external power source uses two 1.5 V D batteries and is enabled through a simple ON/OFF switch.

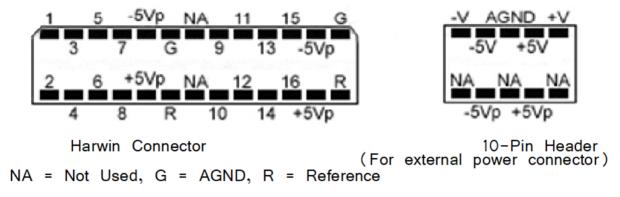**To power the PLX-ZCA adapter:**

1. Align the red colored stripe to the Harwin connector side of the adapter (as shown in the diagram above).

2. Connect an external power connector to the 10-pin header located on the adapter.

3. Ensure that the batteries are correctly inserted in the battery pack then move the switch to the ON position.

> ✏️ **Note**
>
> To power multiple PLX-ZCA adapters, simply connect each 10-pin header to one of the available external power connectors.
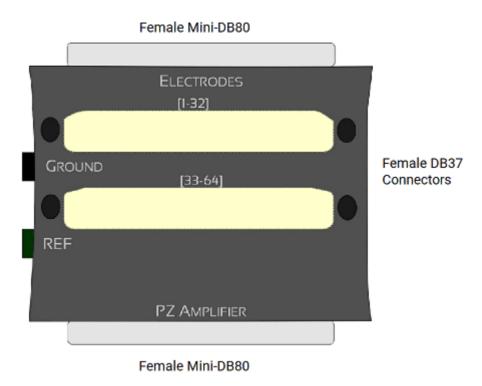
Plexon Header Pinout

Pinouts are looking into the connector and reflect the preamplifier channels

SB64 64-Channel Stimulator Buffer

This adapter provides multiple ways of connecting up to 64-channels. Two mini- DB80 connectors, one for direct connection to a PZ5M NeuroDigitizer/Amplifier and one for connection to up to 64 electrode channels. Two DB37 connectors provide an additional passive input or output connection. Each DB37 is tied to the corresponding 32 electrode channels and is buffered from the active electronics associated with the PZ amplifier connection. They can be used to connect stimulation to the corresponding electrodes, pass electrode signals to a parallel recording system, or serve as an alternative input connection from a breakout box (such as a a Xltek EMU128FS).

The SB64 uses standard 1.5 mm safety connectors for Ground and Reference (REF) connections. Front panel numbering of the DB37 connectors corresponds to TDT amplifier channels. Use caution to avoid miswiring.

Female Mini-DB80

ELECTRODES
[1-32]

GROUND

[33-64]

Female DB37
Connectors

REF

PZ AMPLIFIER

Female Mini-DB80

The DB37s connect to stimulator, parallel recording system, or an alternative breakout box.

The Female Mini-DB80 connects to the PZ5M via a Male to Male Ribbon Cable.

> ⚠ **Caution**
>
> The maximum allowed stim voltage through the SB64 is ±15 V

Pinout Diagrams

(1-32) DB37 Connector

19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20

Pin	Name	Description		Pin	Name	Description
1	A1	Analog input channels		20	A2	Analog input channels
2	A3			21	A4	
3	A5			22	A6	
4	A7			23	A8	
5	A9			24	A10	
6	A11			25	A12	
7	A13			26	A14	
8	A15			27	A16	
9	A17			28	A18	
10	A19			29	A20	
11	A21			30	A22	
12	A23			31	A24	
13	A25			32	A26	
14	A27			33	A28	
15	A29			34	A30	
16	A31			35	A32	
17	NA	Not Used		36	NA	Not Used
18	NA			37	REF	Reference
19	GND	Ground				

> ✏️ **Note**
>
> No connections should be made to pins 17, 18, and 36.

(33-64) DB37 Connector

Increment above channel numbers by 32.

Electrodes Mini-DB80

The pinout for this connector duplicates the map of the PZ5M Input Connectors and is dependent on the PZ5M reference mode.