# Electrical Stimulation User Guide

Subject Interface (SI)



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# Overview

This guide describes the stimulation setup and protocol for TDT's Subject Interface (SI) IZV stimulation boards and provides many template Synapse experiments to get you started.

The goal of this document is to explain the various modes of stimulation that are offered by the Subject Interface IZV. These modes can be broadly categorized by either stimulation type (voltage-controlled or current-controlled) or by hardware method (individual banks, serial, parallel, repeated). We will briefly go into what each of these categories implies and highlight which are being used in the various template experiments that are expounded later. The results of any stimulation paradigm are restricted by inherit hardware limitations - we will outline what these limitations are before the template experiments to serve as a frame of reference for the user. Lastly, instructions for using the TDT switching headstage are also included.

# The Stimulator System

The stimulator system consists of an RZ real-time processor with a DSP that connects to a Subject Interface via fiber optic cable. The Subject Interface supports three different kinds of boards, PZA for analog recording, PZD for digital recording, and IZV for electrical stimulation. Each Subject Interface can have up to 8 boards. The IZV can deliver arbitrary electrical stimulation waveforms of up to 20 kHz bandwidth (depending on the RZ processor sampling rate) through a passive or switching headstage.

## IZV Circuit Detail

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.



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 removes excess voltage in between stim pulses.



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

## IZV Configuration

The banks of the IZV can be separated into isolated 'Sub Stimulators'. Each sub stimulator must be configured independently and has its own multi-channel input signal. For example, the first sub stimulator uses the gizmo input called "VoiceIn-A", the second sub stimulator uses "VoiceIn-B" gizmo input, and so on.

) Sub1	O Sub2	O Sub3	◯ Sub4
🗢 Configure 🕴	Compliance and S	afety	
Name ID:	VoiceIn-A		🗹 Auto
Output Type:	● Current ○	) Voltage	AC Coupled
Output Mode:	Normal	•	
Number of Boards:	1	<b>▲</b> ▼	
Current Doubling:	None	•	Voices per Board: 4
Range per Board:	16	-	Output Channel Range: 1-16
Chan-1	B1a	Ch	ans: 1-16

IZV Stimulator Configure Tab Options

The input signal format is a multi-channel signal where the odd channels contain the actual stim waveforms and the even channels contain the target stim channel. For an input that has 4 unique stim signals, it will be an 8-channel signal where channels 1, 3, 5, 7 are the stim signals and channels 2, 4, 6, 8 are the corresponding target stim channels. Information about the state of the channels between stimulation pulses (Channel Hold, Channel Release, Discharge, or Ground) is also encoded in the target stim channel signals. It is generally expected that this input signal comes from an Electrical Stim Driver gizmo so that it has the proper format. If you are trying to send arbitrary waveforms to the IZV, please contact TDT support for more information.

### Sub Stimulator Options

The sub stimulator options in the Configure tab are described below. For more information on how to apply these options to your application, see Stimulation Types.

Option	Description
Output Type	Select whether this sub amp is current-controlled or voltage-controlled. AC Mode adds a DC block to the output signal (an in-line 20 MOhm resistor and 22 uF capacitor in parallel).
Output Mode	The settings in this group determine how the input Voiceln signals are mapped to a particular hardware voice on a board of the sub stimulator. It handles this channel mapping for you, so the stim channels you give it from the Electrical Stim Driver gizmo make sense for how the headstage is physically connected.
	<ul> <li>Parallel assumes boards in this sub stimulator are wired in parallel, so you can get more than 4 unique voices per 16 channels or up to 4 higher current voices per 16 channels. Typically use an SI-MUX4 adapter for shorting 4 banks together, or the SI-MUX2 adapter for a 2 bank configuration. The Voiceln input to the sub stimulator must contain enough voices/channels.</li> <li>Serial assumes channel 16 on all sub stimulator boards is physically shorted together. Allows one channel of bipolar stimulation with a higher compliance range.</li> <li>Repeated repeats the same input voices on all boards of the sub stimulator.</li> </ul>
Number of Boards	Number of boards in sub stimulator.
Current Doubling	<ul> <li>None - all four hardware voices on each board are unique.</li> <li>By two - connect pairs of hardware voices together on each board to achieve 2x max current compliance.</li> <li>By four - connect all four hardware voices together on each board to achieve 4x max current compliance.</li> </ul>
Voices per Board	How many unique stim signals for each stimulator board.
Range per Board	How many channels are available to stim on each board.

The data table at the bottom of the Configure tab shows the mapping between the gizmo input voices and the physical hardware voices. The first column is the voice of the "Voiceln" for this sub stimulator. The middle column is the board number within the sub stimulator that it uses and the hardware voice on that board it uses (a, b, c, d). The last column is the range of channel numbers that the Voiceln stim channels should address.

For example, an input from an Electrical Stim Driver gizmo with two voices on it targeting banks 1 and 2 on a sub stimulator would read as:

Chan-1 | B1a, B2a | Chans: 1-32 Chan-2 | B1b, B2b | Chans: 1-32

## Safety

When Safety Mode is enabled in Synapse, the Subject Interface IZV must be armed by the user before any current can flow (see Runtime Interface below). The hardware ensures that maximum output current is not exceeded. The Subject Interface is battery powered and thus isolated from any mains power, when not charging. The safety configuration options for the IZV (Compliance and Safety) are below.

🔅 Configure 🖗 🤇	Compliance and Safety	
Safety Mode:	✓ Enabled	Remote Arming
Max Output Voltage:	0.5 volts $\vee$	
	Warning: Bipolar stimu	lation voltages can be up to four times greater.
Grounding:	Shared $\vee$	
Monitoring:	View Only $\checkmark$	ID: MonA
Impedance Checking:	C Enabled	Save to CSV
	Identifier: 🗹 Auto I	Name IZV10(1)p1

IZV Stimulator Compliance and Safety Tab Options

Option	Description
Safety Mode	If enabled, IZV checks total output current and will disarm if system is outside specs. The device requires arming before it will operate. To arm, run your experiment and make sure no stim presentation is sent to the device.
	The physical IZV card will light all LEDs red if it is not ready to be armed. It will light all LEDs green when it is ready to be armed. When armed, it will light the LEDs on the stimulation channels during stimulation.
Remote Arming	Enable this to force the user to arm the device via the Subject Interface touchscreen interface. Otherwise, the user can arm the device via a button in Synapse at run-time.
Max Output Voltage	Set the maximum allowed output voltage for this sub stimulator. Max is 15-18 V, depending on the current battery level. If Safety Mode is Enabled and any channel goes beyond 1 V of this maximum, a Fault occurs and disarms the device.
Grounding	<ul> <li>Isolated - each bank of 16 uses its own ground connection for return path.</li> <li>Shared - all banks in sub stimulator share the same ground return path (ground on first bank of sub stimulator).</li> <li>To Banana Jack - connect sub stimulator ground to the external banana jack on physical Subject Interface device.</li> <li>Caution: When using multiple sub stimulators make sure they aren't all sharing the Banana Jack connection or else they won't be isolated!</li> </ul>
Monitoring	Off - disable compliance voltage monitoring. View Only - visualize the compliance voltage for each voice in the Flow Plot at runtime but do not save it to disk. Store - visualize and save the compliance voltage for each voice.
Impedance Checking	Enable runtime impedance checking interface and optionally log each impedance check to a CSV text file.

## Runtime Interface

## Safety Mode

IZV10(1)			8	×
0	Not Ready			
IZV10(1)			8	×
0	Ready	Arm		
IZV10(1)			8	x
0	Armed	Disarm		

States of the IZV Runtime Interface

If **Safety Mode** is enabled on the Safety and Compliance Tab, then an LED will show the state of the compliance monitor. If Remote Arming is disabled, the Arm/Disarm button is shown and the device can be armed when ready.

#### **b** Important

The system can only Arm if the fiber is connected and a zero current command is sent to the IZV, so make sure the gizmo controlling stimulation is muted. In Safety Mode, you can ensure the stimulation is muted when you start the recording by setting Mute Control to **Default Muted** in the Electrical Stim Driver gizmo 'Misc and Saving' tab.

🧿 eStim1 🖉	Run-time Persistence I On
🗇 General 🖗 Stim Voices 🗐 Misc and Sa	aving
Misc Options Required Sample Rate: 25K ∨	
Run-time Options	
Run-time Window: Show ~	1
Manual Strobe Control: 🗹 Show	
Mute Control: Default Muted ~	/

### Impedance Check

If **Impedance Checking** is enabled, the IZV provides an interface for impedance checking on all channels.



IZV Impedance Check Runtime Interface

The display represents the stimulation channels divided into sub stimulators. Set the test stimulus frequency and amplitude, and define the high and low impedance threshold targets for visualization.

#### **Running the Check**



Run an impedance check on the currently selected sub stimulator. The test signal (sine wave of frequency defined by Freq (Hz) parameter and amplitude defined by Target (uA) parameter) is presented iteratively on each channel in the currently selected sub stimulator for ~500 ms and the impedance is measured using the IZV built in compliance monitor.



**Check All.** Run an impedance check for all IZV channels using the test signal as described above.



Stop Checking. Stops the impedance checking prematurely.

Double-click on any individual LED to run the impedance check on that channel only.

Results of impedance check are indicated by color: below low impedance target (green), above high impedance target (red), between low and high impedance targets (yellow). The actual impedance values (in KOhm) are displayed beneath each indicator.

Impedance results are optionally saved in a CSV text file located in the data block folder.

## Testing

Each IZV bank comes with an RB10 resistor block to verify the IZV output signal. The RB10 has a 10 kOhm resistor on each channel to ground.



**RB10** Resistor Block

Plug this directly into the Subject Interface IZV stim boards instead of a headstage and run an impedance check. The LEDs on the impedance check interface should indicate ~10 (kOhm) for each channel.

Each SW switching headstage comes with a ZCA32-RB10 or ZCA64-RB10 resistor block. If using a switching headstage, clip the switching headstage onto this resistor block and run the impedance check. The LEDs on the impedance check interface should indicate ~10 (kOhm) for each channel.



Zif-Clip® Resistor Block

# Stimulation Types

## Stimulation Types

The goal of this section is to explain different stimulation types (voltage mode vs current mode) and special hardware configurations (serial and parallel outputs). The IZV gizmo in Synapse has several modes (normal, repeated, serial, parallel) that will also be discussed where appropriate. These concepts apply to the Template Experiments. Please refer to The Stimulator System for further information regarding these elements.

### Voltage Mode

Voltage mode is used to stimulate across a load at a specified voltage. The current output of the Voice (the signal) being used for stimulation will vary, depending on the impedance of the targeted load, in order to meet the requested voltage output. The compliance voltage of any Voice of the IZV is  $\pm 15$  V.

#### 🖍 Note

Special methods such as bipolar stimulation (see Bipolar diagram below) or Serial Outputs can be used to increase the effective voltage across a load.

Below is a diagram that shows an expected measured output across a typical load resistance (> 3 k $\Omega$ ) for monopolar ("single-ended") and bipolar configurations.

Monopolar (electrode across load to ground), monophasic or biphasic





Bipolar (electrode across load to another electrode), monophasic or biphasic result



The voltage compliance max of any stim card is 15 V, but here we get 20 V. This is because each electrode generates a potential with respect to an "effective GND" in the middle. But we measure the potential difference between cathode and anode.

### **Current Mode**

Current mode is used to stimulate across a load at a specified current. The current output is limited by the voltage compliance of each Voice ( $\pm$  15 V), thus you may not be able to achieve maximum current outputs (> 5 mA) if the load impedance is high (>3 k $\Omega$ ) due to Ohm's Law: V = I\*R.

Below is a diagram that shows an expected measured output across a 20 k $\Omega$  load resistance for monopolar ("single-ended") and bipolar configurations.



The measured voltage across the load does not change between monopolar and bipolar configurations because the positive and negative currents flow in the same direction. This is as opposed to voltage mode where the measured voltage doubles in bipolar mode. No current flows across the Voltmeter ~V due to its large impedance.

Monopolar (electrode across load to ground), monophasic or biphasic





Bipolar (electrode across load to another electrode), monophasic or biphasic result



## Hardware Configurations

### Serial Outputs

Outputs can be serialized in either current mode or voltage mode to increase the effective voltage compliance across a load. The stim configuration must be bipolar and requires at least two banks. **Voltage sources in series add**, thus serialization can increase the voltage compliance across a load. Each stimulation Voice never exceeds the compliance limits of the IZV (±15 V) because the output waveform is generated with respect to an effective ground in the middle of the load.

When serializing, make note of how many voltage sources are being added together. The measured output voltage will be 2 \* requested voltage \* Nbanks. This math is explained in the diagrams below.

#### Note

The diagrams below pertain to a manual serial configuration (not using Serial Mode). The manual configuration, which is setup in several template experiments, makes use of IZV sub stimulators. The sub stimulators receive duplicated bipolar Voice inputs and do not require using channels 1 and 16 only (the stim channels and shorted channels can be any two numbers 1 - 16). It can also scale beyond two boards/banks. Serial Mode, which is a special option in Current Mode, uses a single bipolar Voice, is limited to two boards, and assumes channel 16 on any sub stimulator is shorted together.





Voltage sources in series add. In bipolar mode, the max effective voltage (in this monophasic case) across my load for any one source is: 15 V - (-15) V = 30 V. So for two sources: 30 V + 30 V = 60 V.

Notice that the compliance limits of the op amps are never exceeded for any phase.





Serial: 4 Banks | Current/ Voltage Mode | 4 Sub Stimulators (GND isolated, NOT 'serial mode')



Note: each voice has a 5 mA limit, so the max current is 120/R. If that current > 5 mA, use current doubling in Imode. In V mode, you will have to use 2 bipolar voices/ board and point them to the same channel.

### **Repeated Mode**

**Repeated Mode** is very useful for duplicating the same stimuli across several banks with only having to configure one eStim input. Repeated Mode is only available in Current Mode, but you can easily setup several sub stimulators in Voltage Mode with the same eStim signal as an input to get the same effect.



### **Parallel Outputs**

Outputs can be shorted in parallel to increase the amount of current delivered across a load. **Current sources in parallel add together**, so each voice that is targeted to a common node (electrode) will contribute as a current source, even in Voltage Mode.

There are other efficient ways in the IZV gizmo to increase current compliance, namely Current Doubling (By Two; By Four). Beyond this, channel outputs must be shorted together.

#### Sub Stimulators | Voltage/Current Mode



The SI-MUX4 adapter from TDT shorts four banks together, and the SI-MUX2 adapter shorts two banks together.

#### 🖻 Note

There is an important distinction between using Current Doubling and physically shorting output channels together. The requested current output in Current Doubling is **not** multiplied by two or four. Instead, this increases the max current compliance for any Voice from 5 mA to 10 mA or 20 mA. Physically shorting output channels does multiply the requested current \* Nsources.

#### 🔥 Tip

If you are physically shorting output channels, consider using Repeated Mode to easily output the same stimulus on each output channel in use.

**Parallel Mode** can be used to increase the number of stimulus voices on any given output set. The typical limit is four Voices per card/ bank. This is useful for merging many stimuli into a 16 channel headstage or electrode array. Parallel Mode in the IZV gizmo allows the user to address channels on each bank in a range of 1 - 16 instead of the typical 1 - 16, 17 - 32, etc.

Parallel Mode | Current Mode



# Understanding Hardware Limitations

Please take a moment to review the Subject Interface Technical Specifications.

Important specifications particular to this guide:

Stim Output Channels	16 per card
Stim Output Voices	4 per card
Stim Compliance	Up to ±15 V (load >3 kΩ) ±5 mA per voice (load <3 kΩ)

## Compliance vs Load Impedance

The Subject Interface IZV voltage compliance follows a curve that is load-dependent (figure to right). For impedance loads >3 k $\Omega$  the output compliance per card is ±15 V. At lower impedances, however, the output voltage compliance is reduced due to operation limits of the op amps in the IZV.

The user should note that the current compliance limit of  $\pm 5$  mA for loads <3 k $\Omega$  is strictly a consequence of



Ohm's law (V = IR). Impedance loads >3 k $\Omega$  would produce a voltage output larger than ±15 V at a 5 mA current. Since the output request in this case is current and not voltage (current mode vs voltage mode), the voltage compliance curve shown does not apply, as you will see later.

## **Output Impedance**

Below are two diagrams that demonstrate what is occurring at a hardware level when a stimulus is output in either Voltage Mode or Current Mode



As stated earlier, the absolute output voltage is limited by the impedance of the load resistor  $R_L$ . Thus, the measured output voltage  $V_o$  when in Voltage Mode may not meet the requested voltage  $V_s$ . The issue is further compounded because the measured voltage  $V_o$  is affected by the output impedance  $R_o$  of the IZV. The voltage drop  $V_o$ across  $R_L$  follows the scheme of a



voltage divider, since some voltage is lost across  $R_0$ . Thus, your measured voltage will always be less than your requested voltage  $V_s$  for **all** impedance loads <3 k $\Omega$  or >3 k $\Omega$ , even if your requested voltage is below the compliance limit (see Fractional Voltage graph for expected loss and the example Voltage Mode oscilloscope output below).

In Current Mode, the requested current  $I_s$  flows across both resistors equally. Thus, the measured  $V_o$  is not affected by  $R_o$  (see example Current Mode oscilloscope output below).

## Using <3 k $\Omega$ Resistance Loads

Below are oscilloscope images that show the measured voltage output across a 500  $\Omega$  resistor load (R<sub>L</sub>). The test was performed in Voltage Mode and Current Mode to compare the compliance limits for a targeted 10 V output. The voltage division for each graph is 5 V.



Voltage Mode: RL = 500  $\Omega$  load, Vs = 10 V requested

The measured voltage is slightly less than the compliance maximum of ~5 V for the 500  $\Omega$  load resistance due to  $R_{\rm o}.$ 



Current Mode: Ro = 500  $\Omega$  load, Is = 20 mA requested

Current Doubling: By Four was active to achieve {5 mA \* 4 Voices} current compliance maximum V = {I \* R}; 10 V = {20 mA \* 500  $\Omega$ } to mimic the 10 V request test from Voltage Mode The measured voltage is 10 V because we used Current Mode.

# Quick Start

## Requirements

This guide assumes you have already configured your Synapse rig with your Subject Interface hardware. See this tutorial for more information.

You can download any template experiment and import it into Synapse to begin using it. See this Lightning Video for a quick demonstration.

## Understanding Stim Info

This quick start guide uses the **Single Channel Across Four Boards (5 mA or ±15 V)** template experiment to show features of the IZV and Electrical Stim Driver gizmos and how to interpret what you see.





### Understanding Output Ranges

- <b>▶</b> IZV10(1)				
Use Sub Stimulators			🚺 eStim1 🖉 🛛 🦻	Run-time Persistence I On
🗢 Configure 🖗 (	Compliance and Safety		🗢 General 🦌 Stim Voices 📟 Misc	c and Savir
Name ID:	VoiceIn-A	Auto	Target Setup Device: IZV10	
Output Type:	<ul> <li>Current</li> <li>Voltage</li> </ul>	AC Coupled	Output Channels: 64 Stim Duration: Strobe Limited	2
Output Mode:	Normal		Voices Number of Voices: 1	N.
Number of Boards: Current Doubling:	4 •	Voices per Board: 1	C Single Ended Output Type: C Bipolar C Local Ground	
Range per Board:	16	Output Channel Range: 1-64	Output Control	
Chan-1	B1a, B2a, B3a, B4a	Chans: 1-64	Inter-pulse Action: Channel Hold Inter-stim Action: Channel Release	•

In Normal Mode, when using a single sub stimulator with multiple boards, the user must address channels within a range of {16 \* NBoards}. In the case of 4 boards, the output range is 64. Thus, to address channel 1 on board 1 - 4, the stimulus channel numbers would be '1', '17', '33', and '49', respectively.

Saving Stimulus Information

	eStim1 🖉	]		Persi	n-time istence ] On					1		D
ji i	General 🗲 S	tim Voices		Misc an	d Saving	I						
(	Voice-A	Voice-B C	V	<sub>oice-C</sub> c	Voice-	D						
	Type: Biphas	ic				Balanced	Ť	T1  Td   T2	2			
	Phase: Fixed			T1 Td			Amp L2	JL	L L	ı		
					1		L2					
				Т2	2: 50.0	)% ÷		← Dur -	÷			
				T2 L2		0% ÷ .0% ÷		← Dur −	÷			_
Ele	ectrical Stim Para Name	meters:			100	.0% 📩	Мах	← Dur −	•	ID	Show All	_
		1	•	L2		.0% 📩	Мах	Ерос	> -	ID eA/	1	
1	Name	Mode	-	L2 Value	: 100.	.0% ÷	Max 10000.0	Epoc on Stim	-		Auto ID	
1 2	Name PeriodA (ms)	Mode Constant	•	L2 Value 20.0	i: 100.	0% ×	Max 10000.0	Epoc on Stim on Stim	•	PeA/	Auto ID	
1 2 3	Name PeriodA (ms) CountA	Mode Constant Constant	•	L2 Value 20.0 5	: 100. Jit(%) 0.0 0.0	0% ×	Max 10000.0 100000 20000.0	Epoc on Stim on Stim on Stim	•	eA/	Auto ID	
1 2 3 4	Name PeriodA (ms) CountA AmpA (uA)	Mode Constant Constant Widget	• •	L2 Value 20.0 5 20.0	: 100. Jit(%) 0.0 0.0 0.0	.0% <u>⇒</u> Min 0.1 1 -20000.0	Max 10000.0 100000 20000.0 10000.0	Epoc on Stim on Stim on Stim on Stim	- - -	eA/ IntA mpA	Auto ID	
1 2 3 4 5	Name PeriodA (ms) CountA AmpA (uA) DurA (ms)	Mode Constant Constant Widget Constant	• • • •	L2 Value 20.0 5 20.0 10.00	: 100. jit(%) 0.0 0.0 0.0 0.0	.0% ÷ Min 0.1 1 -20000.0 0.01	Max 10000.0 100000 20000.0 10000.0	Epoc on Stim on Stim on Stim on Stim	- - -	eA/ IntA ImpA urA	Auto ID       Image: Point of the second	
1 2 3 4 5	Name PeriodA (ms) CountA AmpA (uA) DurA (ms) DelayA (ms)	Mode Constant Constant Widget Constant	• • • •	L2 Value 20.0 5 20.0 10.00 0.00	:: 100. Jit(%) 0.0 0.0 0.0 0.0 0.0 0.0	Min           0.1           1           -20000.0           0.01           0.00	Max 10000.0 20000.0 10000.0 10000.0	Epoc on Stim on Stim on Stim on Stim	- - -	≥eA/ IntA ImpA IurA IelA	Auto ID	

The user can save information (Period, Count, Amplitude, Duration, Delay, Channel) of any eStimDriver Voice by enabling the appropriate 'Epoc' storage options in the eStim parameter table (highlighted in blue box to right). This will store the values of select parameters on each stimulation request. The output will be timestamped with the onset and offset of your stimulation output (see runtime figure below).

Regarding the IZV10 Monitor Output

Flow Plot		# × IZV10(1) eStim1
▶ ॥ ≪	() » * # 0	🚽 Strobe 🦸
MonA	i i	° Voice-A
[1]		T1: 50.0% =
[2]		Td: 0.0%
[3]		T2: 50.0%
[4]		L2: 100.0% =
[5]		Monitor Feeds Show Constant
[6]		AmpA (uA) 100.0 : -20000 20000
[7]		ChanA 64 : 064
[8]		
[9]		
[10]		
[11]		-
[12]	·	-
[13]		-
[14]		-
[15]		-
[16]		
PeA/		
CntA AmpA	19 9885 19 9885 19 9885 19 9885 19 9885 5 5 5 5 5 5 100 100 100 100	
DurA DelA	10 10 10 10 10	
ChnA	ان والمحالي والمحالي 1 1 17 39 42 64	

Observe the 'MonA' output channels in the runtime figure below. Only 1, 5, 9, and 13 have active signals on them, despite having stimulated on channels 1, 17, 39, 42, 64. This is because the IZV10 monitor looks at the 4 Voice monitor streams per board and we are only using 1 Voice.

ChanA Stim Channel	MonA Monitor Channel	Bank	Voice
1 - 16	1	А	1
17 - 32	5	В	1
33 - 48	9	С	1
49 - 64	13	D	1

If there is more than one voice, then signals would appear on MonA sets 2 - 4, 6 - 8, 10 - 12, or 14 - 16 depending on my which Voice is active and which Channel is targeted.

# Template Experiments

Included with this guide are template experiments that help you set up and understand various IZV stimulation paradigms.

Choose an appropriate template based on your electrode impedance and desired current or voltage output. Use the tables below to guide you.

The templates are described in detail, and include a link to the Synapse experiment (\*.synexpz) that is used. Please be sure to have your IZV10 and other appropriate hardware detected in your rig (Menu  $\rightarrow$  Edit Rig  $\rightarrow$  Detect) so there are no issues when importing templates.

These templates all assume at least 4 stim banks are available.

## Picking a Template Based on Impedance and Desired Output

#### 🖍 Note

The settings of each recommended templates may need to be modified depending on the desired electrode configuration (monopolar (single-ended) or bipolar). If the recommended template needs the output mode (current-mode vs voltage-mode) switched, there will be an asterisk\*.

For options marked as 'Not Recommended', there may be workaround solutions. Please consult with TDT tech support for possible options.

### Current-controlled (Monopolar)

Choose the tab for your electrode impedance below to see the recommended templates.

### >3 kΩ

Desired Current	Output Voltage	20 kΩ load	Recommended Template
$0 \text{ mA} \rightarrow 5 \text{ mA}$	$0~V \rightarrow \pm 15~V$	$0 \text{ V} \rightarrow \pm 15 \text{ V}$	Stimulating on a Single Channel Across Four Boards
$5 \text{ mA} \rightarrow 10 \text{ mA}$	±15 V	±15 V	Not Recommended
$10 \text{ mA} \rightarrow 20 \text{ mA}$	±15 V	±15 V	Not Recommended
>20 mA	±15 V	±15 V	Not Recommended

### <3 kΩ

Desired Current	Output Voltage	500 Ω load	Recommended Template
$0 \text{ mA} \rightarrow 5 \text{ mA}$	$0 \text{ V} \rightarrow \pm 15 \text{ V}$	$0~V \rightarrow \pm 2.5~V$	Stimulating on a Single Channel Across Four Boards
5  mA  ightarrow 10  mA	$0~V \rightarrow \pm 15~V$	$\pm 2.5~V \rightarrow \pm 5~V$	Stimulating Up to 10 mA per Voice
$10 \text{ mA} \rightarrow 20 \text{ mA}$	$0~V \rightarrow \pm 15~V$	$\pm5~V\rightarrow\pm10~V$	Stimulating Up to 20 mA per Voice
>20 mA	$0~V \rightarrow \pm 15~V$	$\pm 10~V \rightarrow \pm 15~V$	Stimulating >20 mA Across a Monopolar Electrode

### Current-controlled (Bipolar)

### $>3 k\Omega (20 k\Omega example)$

Desired Current	Output Voltage	20 kΩ load	Recommended Template
$0 \text{ mA} \rightarrow 5 \text{ mA}$	$0 \text{ V} \rightarrow \pm 30 \text{ V}$	$0 \text{ V} \rightarrow \pm 30 \text{ V}$	Stimulating on a Single Channel Across Four Boards
5  mA  ightarrow 10  mA	$\pm 30~V \rightarrow \pm 120~V$	$\pm 100 \text{ V} \rightarrow \pm 120 \text{ V}$	Stimulating >5 mA with Impedance Loads >3 $k\Omega$
$10 \text{ mA} \rightarrow 20 \text{ mA}$	$\pm 60 \text{ V} \rightarrow \pm 120 \text{ V}$	±120 V	Stimulating >5 mA with Impedance Loads >3 $k\Omega$
>20 mA	±120 V	±120 V	Not Recommended

### $<3 k\Omega (500 \Omega \text{ example})$

Desired Current	Output Voltage	500 Ω load	Recommended Template
$0 \text{ mA} \rightarrow 5 \text{ mA}$	$0 \text{ V} \rightarrow \pm 15 \text{ V}$	$0~V \rightarrow \pm 2.5~V$	Stimulating on a Single Channel Across Four Boards
$5 \text{ mA} \rightarrow 10 \text{ mA}$	$0 \text{ V} \rightarrow \pm 30 \text{ V}$	$\pm 2.5~V \rightarrow \pm 5~V$	Stimulating Up to 10 mA per Voice
$10 \text{ mA} \rightarrow 20 \text{ mA}$	$0 \text{ V} \rightarrow \pm 30 \text{ V}$	$\pm5~V\rightarrow\pm10~V$	Stimulating >10 mA Across a Bipolar Electrode Pair
>20 mA	$0 \text{ V} \rightarrow \pm 30 \text{ V}$	$\pm 10~V \rightarrow \pm 30~V$	Stimulating >10 mA Across a Bipolar Electrode Pair

Recall that a bipolar configuration in current mode allows up to increase the effective voltage compliance because each phase is measured with respect to a GND in the center of the anode

and cathode. However, it will not double the measured voltage across the load impedance like in Voltage Mode. As you can see, the 500  $\Omega$  examples result in the same output ranges as monopolar for current below 20 mA because V = I\*R.

### Voltage-controlled (Monopolar or Bipolar)

#### >3 k $\Omega$ (20 k $\Omega$ example)

Desired Voltage	Output Voltage	20 kΩ load	Recommended Template
$0 \text{ V} \rightarrow 15 \text{ V}$	$0~V \rightarrow \pm 15~V$	$0~V \rightarrow \pm 15~V$	Stimulating on a Single Channel Across Four Boards*
$15~V \rightarrow 30~V$	$\pm 15~V \rightarrow \pm 30~V$	$\pm 15~V \rightarrow \pm 30~V$	Single Bipolar Output*
$30~V \rightarrow 60~V$	$\pm 30~V \rightarrow \pm 60~V$	$\pm 30~V \rightarrow \pm 60~V$	Stimulating Up to $\pm 60$ V in a Bipolar Configuration
>60 V	$\pm 60 \text{ V} \rightarrow \pm 120 \text{ V}$	$\pm 60 \text{ V} \rightarrow \pm 120 \text{ V}$	Stimulating Up to $\pm 120$ V in a Bipolar Configuration

#### $<3 k\Omega (500 \Omega \text{ example})$

Desired Voltage	Output Voltage	500 $\Omega$ load	Recommended Template
$0~V \rightarrow 15~V$	$0~V \rightarrow {\sim}{\pm}15~V$	$0 \; V \rightarrow {\sim} \pm 5 \; V$	Stimulating on a Single Channel Across Four Boards
$15~V \rightarrow 30~V$	$0~V \rightarrow {\sim} \pm 15~V$	~±5 V	Not Recommended
$30~V \rightarrow 60~V$	$0~V \rightarrow {\sim} \pm 15~V$	~±5 V	Not Recommended
>60 V	$0~V \rightarrow {\sim}{\pm}15~V$	~±5 V	Not Recommended

\* Change IZV10 'Output Type' to Voltage Mode

## Voltage or Current Mode



This template is covered in the Quick Start Example
Single Bipolar Output (5 mA or ±30 V)

## Single Bipolar Output (5 mA or ±30 V)

Experiment MonitorBipolarOutput Download Experiment

Objective Use a bipolar electrode configuration and monitor the voltage output across the load

Connections "SIMIO(1)"



When performing bipolar stimulation, the IZV10 monitor output ('MonA') will likely not provide a meaningful readout of the stimulation across your load. The user must subtract the two bipolar channels from one another to see the voltage across their load. This is done using the following gizmos: Selector, Unary Processor, Stream Data Storage.



In this example shows the output of a 250  $\mu$ A stimulation across a 20 k $\Omega$  load. The expected voltage is 5 V. 'Monr' is the output from the bipolar subtraction.

List of Channels and Parameters over a Specified Time Sequence

## List of Channels and Parameters over a Specified Time Sequence

#### Experiment OneChan4BanksParSeq Download Experiment

Objective Use the parameter sequencer to stimulate across a list of channels with a specified time interval. also be used to parametrically change the stimulation amplitude, duration, pulse count, etc.

Connections

"SIM10(1)"

"RZ2(1)"		"Pa	arSeq1 "		"eS	timl "		"IZV	10(1
#ROOT	>	Main	ParOut	(1:24)	StrobeIn	Stim	(1:2)	► VoiceIn-A	Mo
#Reset			StrobeOut		Par Input	StimSync			
#Enable			SeqActive			VoiceAct			
#iTime			CurIndex			Par Output			
#SwFire									

The Parameter Sequencer is a powerful gizmo that enables the user to sequentially change stimulation parameters and target channels in a well-defined timing and pattern. In this example, we are targeting random channels from all 4 banks (output range 1 - 64).

Flow Plot		# × IZV10(1) eStim1 ParSeq1
	< > » × I U	Control
MonA		📕 Stop
	1111	49%
[1]	WW/	_Strobing
[2]		Period (ms) 200.000 🗄 Jitter (%) 0.0
[3]		
[4]		Indexing
		File: Local
[5]	WWW WWW WWW	
[6]		57 30 58 45
[7]		59 25
[8]		60 48
[9]		61 10
	AANAN ANANA ANANA	62 18 63 29
[10]		▶ 64 <u>36</u>
[11]		
[12]		Parameters
[13]		File: Local Strenge Manual 23
	AAAAA AAAAA A	
[14]		▶ 29 29
[15]		<u>30</u> <u>30</u> <u>31</u> <u>31</u>
[16]		32 32
		33 33
ChA/		34 34 34 35 35
		35 35

### Note

You must either arm the IZV10 first or turn off safety mode before beginning your stimulation sequence. Thus, if you have both Start Seq at Run-Time and Safety Mode enabled on the Parameter Sequencer and IZV10, respectively, you will not be able to stim.

# Current Mode

### 5 Stimulating Up to 10 mA per Voice

## Stimulating Up to 10 mA per Voice

#### Experiment OneChan4BanksCurrentDoubling Download Experiment

Objective Use Current Doubling: By Two to stimulate up to 10 mA per voice on each board

Connections "SIM10(1)"

"RZ2(1)"					
#ROOT	"eSt	iml"		"IZV	10(1)"
#Reset	 StrobeIn	Stim	(1:2)	VoiceIn-A	MonOut-A
#Enable		StimSync			
#iTime		VoiceAct			
#SwFire		Par Output			

Setting the IZV10 to Current Doubling: By Two allows the user to stimulate up to 10 mA per voice. This setting decreases the max Voices per Board from 4 to 2. This is because, in order to achieve current doubling, two voices are directed to the same output channel.

→ IZV10(1)		
Use Sub Stimulators		
🗢 Configure 🖗 (	Compliance and Safety	
Name ID:	VoiceIn-A	Muto
Output Type:	• Current C Voltage	AC Coupled
Output Mode:	Normal	
Number of Boards:	4	
Current Doubling:	By Two	Voices per Board: 1 🚔
Range per Board:	16 *	Output Channel Range: 1-64
Chan-1	B1ab, B2ab, B3ab, B4ab	Chans: 1-64

In this example, we are sending 10 mA across a 500  $\Omega$  load to achieve a ± 5 V biphasic voltage output across channel 1 (channel 1, board 1).

Flow Plot	8 × IZV10(1) 8 ×
MonA X d S X X d S	ArmedDisarm
	eStim1 # Strobe
5e3 <sup>-</sup>	T1:       50.0% 当         Td:       0.0% 当         T2:       50.0% 当         L2:       100.0% ∃         Monitor Feeds       Show Constant
	AmpA (uA) 10000.0 20000 20000 20000 ChanA 1 : 0 4 64

### Stimulating Up to 20 mA per Voice

## Stimulating Up to 20 mA per Voice

Experiment OneChan4BanksCurrentQuadrupling Download Experiment

Objective Use Current Doubling: By Four to stimulate up to 20 mA per voice on each board

Connections "SIM10(1)"

"RZ2(1)"					
#ROOT	"eSt	iml "		"IZV	10(1)"
#Reset	 StrobeIn	Stim	(1:2)	► VoiceIn-A	MonOut-A
#Enable		StimSync			
#iTime		VoiceAct			
#SwFire		Par Output			

Setting the IZV10 to Current Doubling: By Four allows the user to stimulate up to 20 mA per voice. This setting decreases the max Voices per Board from 4 to1. This is because, in order to achieve current doubling, four Voices are directed to the same output channel. One can only perform single-ended stimulation with the Current Doubling: By Four option since Bipolar and Local Ground require two Voices per stim signal.

->> IZV10(1)	
Use Sub Stimulators	
🔹 Configure 🖗	Compliance and Safety
Name ID:	VoiceIn-A 🗹 Auto
Output Type:	Current C Voltage     AC Coupled
Output Mode:	Normal
Number of Boards:	4
Current Doubling:	By Four Voices per Board: 1
Range per Board:	16 Output Channel Range: 1-64
Chan-1	B1abcd, B2abcd, B3abcd, B4abcd Chans: 1-64

In this example, we are sending 20 mA across a 500  $\Omega$  load to achieve a ±10 V biphasic voltage output across channel 32 (channel 16, board 2).

e	Stim1			Pers	n-time istence On					<u>N</u>	
G	General 👂	Stim Voices		Misc an	ıd Saving						
						_					
(*	Voice-A	<ul> <li>Voice-B</li> </ul>	V	'oice-C C	Voice-	D					
-	Type: Bip	hasic		• •	Charge	Balanced		T1 Td T	2		
	Phase: Fix	od		- T1	L: 50.0	% ÷	Amp				
		cu		 To			4	5	'n		
		cu		та Та	j: 0.09	6 🔅		← Dur -	ך		
	,	cu			1: 0.09 2: 50.0	6	4	- Dur -	Ţ		
		Parameters:		T2	1: 0.09 2: 50.0	% ×	4	← Dur -	רָ		Show All
				T2	1: 0.09 2: 50.0	6 ÷ 1% ÷	4	Epoc	Ţ	ID	Show All Auto ID
Elec	trical Stim	Parameters:		T2 L2	1: 0.09 2: 50.0 2: 100.	6 ÷ 1% ÷		Ерос		ID PerA	1 1
Elec	trical Stim Name	Parameters:	•	T2 L2 Value	d: 0.09 2: 50.0 2: 100.	6 ± 1% ± 0% ± Min	L2 Max	Epoc None	• P		Auto ID
Elec 1 2	trical Stim Name PeriodA (n	Parameters: Mode is) Constant Constant	•	T2 L2 Value 20.0	1: 0.09 2: 50.0 2: 100. 2: 100. 100.	6 ± 9% ± 0% ± Min 0.1 1	▲ L2 Max 10000.0	Epoc None None	• P • (	PerA	Auto ID
Elec 1 2 3	trical Stim Name PeriodA (n CountA	Parameters: Mode is) Constant Constant ) Constant	•	T2 L2 Value 20.0 5	1: 0.09 2: 50.0 2: 100. 1: 100. 0.0 0.0 0.0	6 ± 9% ± 0% ± Min 0.1 1	▲ L2 Max 10000.0 1000000	Epoc None None None	• P • C • A	PerA CotA	Auto ID
Elec 1 2 3 4	trical Stim Name PeriodA (n CountA AmpA (uA	Parameters: Mode as) Constant Constant ) Constant Constant	•	T2 L2 20.0 5 20.0	1: 0.09 2: 50.0 2: 100. 2: 100. 0.0 0.0 0.0	6 ∞ % ∞ 0% ∞ 0% ∞ 0% ∞ 0.1 1 -20000.0 0.01	Max 10000.0 20000.0	Epoc None None None None	• P • C • A • C	PerA CntA AmpA	Auto ID

## 🖍 Note

The output channels on the IZV10 'MonA' store (below) show four stimuli trains on channels 5 - 8. This is because in Current

Doubling: By Four there are four Voices being played, but they target the same output channel (recall that current sources in parallel add). The range is 5 - 8 because the IZV10 monitor looks at 4 Voice monitor streams per board.

Recall from Quick Start: Understanding Stim Info that the target channel information is contained in the eS1r stream, or if you enable Epoc Storage for the Chan parameter in the eStimDriver parameter table (see eStim1 image below).

Flow Plot	ð×	IZV10(1) & ×
N W K ( ) ≫ X I O MonA		Armed Disarm
		eStim1
		Td: 0.0%
10e3 (7) 0 		ChanA 32 : 064

# Serial Outputs

Stimulating Up to ±60 V in a Bipolar Configuration

## Stimulating Up to ±60 V in a Bipolar Configuration

### Experiment SerialMode2Banks Download Experiment

Objective Use a manual serial configuration with Voltage Mode to stimulate beyond the ±15 V Voice voltag compliance up to ±60 V across a load.

Connections



Serializing an output is useful for increasing the compliance voltage across a load. The user can manually configure a serialized output (as opposed to using Serial Mode) using 2 or more boards. Recall from Serial Outputs that this is a bipolar configuration, and that specific channels are shorted together to achieve the hardware configuration.

The connection diagram is showing the serial output setup. A User Input gizmo (UIn1) is used to synchronize the output timing of two eStim waveforms. The eStim1 and eStim2 waveforms are inverses of one another and are sent to either sub stimulator 1 or sub stimulator 2 of the IZV10. The Selector Unary Processor Stream Storage Gizmo is to monitor the true bipolar output. The equation in the Unary Processor reduces to the serial output equation specified earlier once the subtraction of inverse signals is accounted for: {2 \* requested voltage \* Nbanks}.

Here is the output from a 15 V request using channels 1 and 16 in Voltage Mode. The output is +60 V across an open load.



### Note

The load is open to demonstrate max compliance. Recall that, in Voltage Mode, for a non-infinite load impedance there is some voltage loss vs the max compliance due to the output impedance of the stim.

Stimulating Up to ±120 V in a Bipolar Configuration

## Stimulating Up to ±120 V in a Bipolar Configuration

### Experiment SerialMode4BanksVMode Download Experiment

Objective Use a manual serial configuration with Voltage Mode to stimulate beyond the ±15 V Voice voltag compliance up to ±120 V across a load.

Connections "



The connection diagram is showing the serial output setup for four boards. The same paradigm that was used in a two-board serial configuration is applied here.

A User Input gizmo (UIn1) synchronizes the output timing of two eStim waveforms.

The eStim1 and eStim2 waveforms are inverses of one another and are sent to either sub stimulator 1, 3 or sub stimulator 2, 4 of the IZV10 to achieve the waveform setup outlined in the Serial Outputs diagram for 4 board serialization.

The Selector Unary Processor Stream Storage Gizmo is to monitor the true bipolar output. The equation in the Unary Processor reduces to the serial output equation specified earlier once the subtraction of inverse signals is accounted for: {2 \* requested voltage \* Nbanks}.



Here is the output from a 20 V request using channels 1 and 16 in Voltage Mode. The output is +120 V across an open load. This is because the compliance is still +15 V per Voice, so the 'requested voltage' here is 15 V and not 20 V.

🔥 Stimulating Beyond 5 mA with Impedance Loads Greater than 3 kΩ

## Stimulating Beyond 5 mA with Impedance Loads Greater than 3 k $\Omega$

#### Experiment SerialMode4BanksIMode Download Experiment

Connections



The setup is nearly identical to the Voltage Mode setup. The main difference is that the user can easily setup Current Doubling: By Two in order to increase the current compliance from 5 mA to 10 mA per Voice across the load. Recall from Current Mode that the current across the load is the requested current and not 2\*requested current, so the voltage compliance increased but the voltage output is still just V = I\*R.



In this output example, we are stimulating 5 mA across a 20 k $\Omega$  resistor to achieve an output voltage of 100 V. In a normal configuration, the max current we could send across a 20 k $\Omega$  load is 750  $\mu$ A {V = I\*R; 15 V = 750  $\mu$ A \* 20 k $\Omega$ }. However, because we serialized the boards together, the voltage compliance is increased to {2 \* Voice voltage compliance \* Nbanks}, so we can send the full Voice current limit of 5 mA across the load.

# Repeated Mode

### 🗴 Duplicating Stim Signals On Many Banks

## **Duplicating Stim Signals On Many Banks**



Repeated Mode is an easy way to send the same stimulus to identical target channels across multiple boards. In this mode, the 'Output Channel Range' is 1 - 16, even though more than one board is active in 'Number of Boards'. In Repeated Mode channels in higher board numbers are addressed as if they were on board 1. This is because the same Voice is repeated on every board in the sub stimulator.

In this example, we are repeating four different Voices on 4 boards. ChanA addresses the first Voice on boards 1 - 4, ChanB the second Voice, and so forth. The notation 'B1a', 'B2a', 'B3b', etc. refers to BoardN, Voice A - D. Chan-1 controls Voice A on boards 1 - 4, Chan-2 controls Voice B on boards 1 - 4, etc.



The LEDs on the SI-8 board indicate voltage activity during the stimulation trains. All four boards repeated the same LED activity because they had the same stimulation signals.

Flow Plot					8 ×	IZV10(1)	6
	()» × 🗗 🗸						
PeA/ CntA AmpA DurA PerB	99.9834 5 20 10 24.9856	99.9834 5 20 10 24.9856	10	99.9834 5 20 10 24.9856		Armed	Disarm
CntB AmpB DurB PerC CntC	10 50 10 99.9834 1	10 50 10 99.9834 1	10 50 10 99.9834 1	10 50 10 99.9834 1		eStim1	đ
AmpC DurC PerD CntD AmpD DurD	-10 10 99.9834 1 10 10	-10 10 99,9834 1 10 10	10 99.9834 1 10	-10 10 99.9834 1 10 10		<ul> <li>Voice-A ○ Voice-</li> <li>T1: 50.0% =</li> <li>Td: 0.0% =</li> </ul>	c
MonA		10		10		T2: 50.0% ÷	
[1] -						L2: 100.0% 🗄	Monitor Feeds 🗍 Show Consta
[3] [4]						ChanA 1 : ChanB 2 :	0 <u>16</u> 0 <u>16</u>
[5] [6]					~ <del>~~~~~~~</del>	ChanC 3 : ChanD 4 :	0 16 0 16
[7] [8]							
[9] - [9] -	{						
[11] · · [12] · ·							
[13] <sup>-</sup> [14] <sup>-</sup>							
[15]							

# Parallel Outputs and Parallel Mode

**5** Sending 16 Unique Signals to a 16 Channel Output

# Sending 16 Unique Signals to a 16 Channel Output





The connection is showing a Parallel Mode output of 16 unique Voices over four banks. Each eStim gizmo can output four Voices and four Channel Number signals. The eight signals from each eStim gizmo are then merged to create one multi-channel signal to inform the IZV10.

The 'Output Channel Range' is limited to 16 and each board range is 16 in Parallel Mode. This is because Parallel Mode assumes the outputs from each board are physically shorted together. Use the SI-MUX4 adapter for this (or the SI-MUX2 adapter for a 2 bank configuration). This makes a single output set. In this example, 16 unique voices can target 16 individual channels on an electrode array. Each channel in the parallel configuration is addressed within a range of 1 - 16 instead of 1 - 64 to make the configuration easier to understand. Channel '1' is the actual first channel for all boards in the sub stimulator, in this case, and so forth up to channel '16'. Please refer to the Parallel Outputs section for more details.

Stimulating Greater than 20 mA Across a Monopolar Electrode

# Stimulating Greater than 20 mA Across a Monopolar Electrode

Experiment	IMode_4Banks_SingleEnd	led_Parallel Download E	xperiment	
Objective	Use parallel outputs to acl electrode pair.	hieve high current output	across a single-	ended (monopolar)
Connections	"SIM10(1)"			
	"RZ2(1)"			
	#ROOT	"eStiml "		"IZV10(1)"
	#Reset	► StrobeIn Stim	(1:2)	VoiceIn-A MonOut-A
	#Enable	StimSync		
	#iTime	VoiceAct		
	#SwFire	Par Output		
->> IZV10(1	L)			
Use Sub Stimu	lators			
	I			
Name ID:		Y Auto		
Output Type:	Current Voltage	AC Coupled		
Output Mode:	Repeated 💌			
Number of Boa	ards: 4			
Current Doubli	ng: By Four 💌	Voices per Board: 1		
Range per Boa	rd: 16	Output Channel Range: 1-16		
Chan-1	B1abcd, B2abcd, B3abcd, B4	abcd Chans: 1-16		

Some experiments may require very large current outputs (>20 mA) which cannot be achieve through Normal output mode configurations. In this case, the user can short outputs of each board together to make a parallel current output. The easiest way to do this is to make use of Repeated Mode and Current Doubling. In this example, we are sending 7.5 mA from a Bipolar Voice repeated four times across a 500  $\Omega$  load. This provides a 30 mA current, since current sources in parallel add together.



The result is a 15 V output across our load. {7.5 mA \* 4 Voices = 30 mA; 15 V = 500 Ohms \* 30 mA}

Stimulating Greater than 10 mA Across a Bipolar Electrode Pair

## Stimulating Greater than 10 mA Across a Bipolar Electrode Pair

#### Experiment IMode\_4Banks\_Bipolar\_Parallel Download Experiment Objective Use parallel outputs to achieve high current output across a bipolar electrode pair. "SIM10(1)" Connections "RZ2(1)" "IZV10(1)" "Sell" #ROOT "eStiml " "UProcl" (1.4)(1.16)NonOut-A Main #Reset StroheIn Stim -> Input SigSelOut-1 Input #Enable StimSync SigSelOut-2 🔶 OpParB-1 🛛 Par Output #iTime VoiceAct #SwFire Par Output ->> IZV10(1) eStim1.Stim ₹ {1:4} VoiceIn-A Monitors MonOut-A [16] Stor Use Sub Stimulators Configure Compliance and Safety 4 Auto Name ID: VoiceIn-A • Current • Voltage Output Type: AC Coupled Output Mode: Repeated • ÷ Number of Boards: 4 • Current Doubling: By Two Voices per Board: 2 \* Output Channel Range: 1-16 Range per Board: 16 B1ab, B2ab, B3ab, B4ab Chans: 1-16 Chan-1 Chan-2 B1cd, B2cd, B3cd, B4cd Chans: 1-16

Some experiments may require a bipolar electrode configuration with currents beyond the Normal output mode limits for bipolar Voices (10 mA). In this case, the user can short outputs of each board together to make a parallel current output. The easiest way to do this is to make use of Repeated Mode and Current Doubling. In this example, we are sending 10 mA from a Bipolar Voice repeated four times across a 500  $\Omega$  load. The result is a ±20 V output, which is a 40 mA current. Recall that a bipolar configuration allows up to increase the effective voltage compliance because each phase is only 10 V with respect to GND.

Flow Plot Sel1 UProc1		IZV10(1) eStim1
	K 🗗 U	🚽 Strobe
Monr		Voice-A
		T1: 50.0% 📫 Td: 0.0% 👘
20-	пп	T2: 50.0%
		L2: 100.0%
		Monitor Feeds Show Constant AmpA (uA) 10000.0 :
[1] 0-		
-20-		

# Using a Switching Headstage

The TDT switching headstage lets you stimulate and record from the same electrodes. It has one ZIF clip® connection to the subject and connects to IZV and PZA boards on a Subject Interface. The switching headstage comes in one of the configurations below.

Part Number	Electrode Channels	Stim Channels*
ZC16_SW4	16 (1 bank)	4 (1 bank)
ZC32_SW4	32 (2 banks)	4 (1 bank)
ZC32_SW8	32 (2 banks)	8 (2 banks)
ZC64_SW4	64 (4 banks)	4 (1 bank)
ZC64_SW16	64 (4 banks)	16 (4 banks)

### olmportant 🔥

\* Recall that each stimulator bank provides up to 4 independent stim channels (voices) on any given sample. These can be switched to any of the electrode channels. With the SI-MUX4 adapter from TDT you can connect four banks of stimulation to a single 16 channel electrode. With four stim banks you can stimulate all 16 channels of a ZC16\_SW4 simultaneously. With the SI-MUX2 adapter and two stim banks you can stimulate up to 8 channels simultaneously.

### Caution

The switching headstage only supports up to ±15 V per channel and can NOT be used in Serial Output Mode.

# Software Configuration

## **IZV** Configuration

The IZV sends control signals to the switching headstage to tell each channel whether it is connected to the stimulator or the recording banks. To enable switching headstage control, simply check **Switching Headstage** in the IZV Configuration options.

->> IZV10(1)			
Use Sub Stimulators -			
Configure	Compliance and Safety		
Name ID:	VoiceIn-A	🗹 Auto	
Output Type:	Ourrent O Voltage	AC Coupled	
Switching Head Short Ref to Groun			
Output Mode:	Normal ~		
Number of Boards:	2		
Current Doubling:	None ~	Voices per Board:	4 ≑
Range per Board:	16	Output Channel Ra	ange: 1-32
Chan-1	B1a, B2a	Chans: 1-32	

IZV Configuration

If the electrode has a reference electrode, you may want to short reference to ground in the headstage to help with stimulation artifacts.

Important

All banks of the switching headstage *must* be assigned to one sub stimulator. The control signals are sent through the first stim DB26 connector on the switching headstage. The switching headstage channels can not be spread across multiple IZV sub stimulators.

## **Electrical Stim Driver Configuration**

By default, all channels on the switching headstage are in record mode. Recall from The Stimulator System that the input signal to the IZV gizmo includes both the voices *and* the channel numbers. The IZV will only send new commands to change the channel switches when a channel number input signal changes.

## of Important

All of the inter-pulse and inter-stim actions defined in the The Stimulator System, except for 'Channel Release', will keep the selected channel connected to the stimulator.

The switching time is 1 + N samples, where N is the number of stim banks. For example, an ZC32\_SW8 headstage with 2 stim banks takes 3 samples to switch its channels to a new configuration. Since the switching time is not instantaneous, the channel information has to come before the stimulation waveforms begin. To do this, set the **Padding** parameter in the Electrical Stim Driver gizmo to the correct value.

General 🥖 St	tim Voices 🛛 🔳	Misc and Sa	ving	
Target Setup				
Device:	IZV10	$\sim$		
Output Channels:	32	<b></b>		
Stim Duration:	Strobe Limited	I		
Voices				
Number of Voices:	1	*		
	Single Ended	I		
Output Type:	🔘 Bipolar			
	Cocal Ground	1		
Output Control		_		
Inter-pulse Action:	Channel Hold	✓ Padd	ing: 3 sam	ples 韋

Electrical Stim Driver gizmo configuration

## Note

If you are not using the Electrical Stim Driver to generate stimulus waveforms for the switching headstage then you must account for this delay in your custom gizmo.