

IZ2 Stimulator



IZ2 Overview

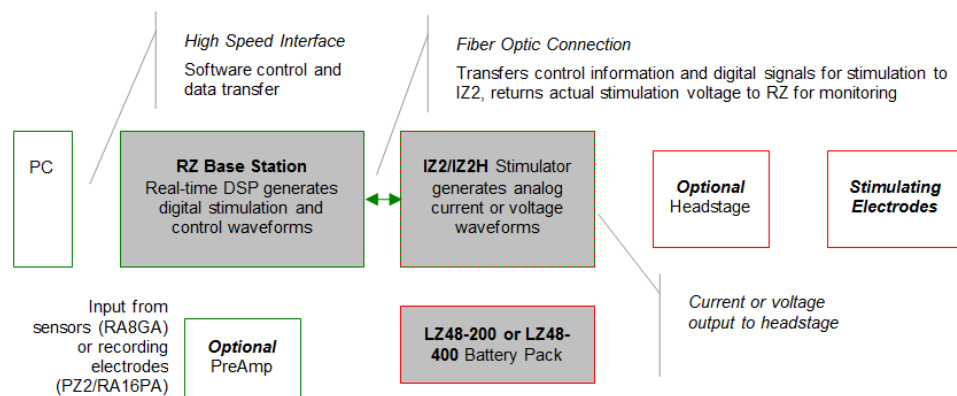
The IZ2 Stimulator converts digital waveforms into analog waveforms as part of a computer-controlled neural microstimulator system that delivers user-defined stimuli through multichannel electrodes. The IZ2 can output either a voltage-controlled waveform or a current-controlled waveform and provides feedback of the actual voltages delivered to the electrodes.

The IZ2H is a high current range version of the IZ2 and is available with sixteen stimulus channels.

The IZ2 Stimulator System

A typical system consists of a Stimulator (IZ2-32, IZ2-64, IZ2-128, or IZ2H-16); a Battery Pack (LZ48-200 or LZ48-400); and an RZ processor equipped with a specialized DSP (RZ-DSP-1) and additional fiber optic connector on the back panel.

The block diagram below illustrates the functionality of the system.



Multichannel IZ2/IZ2H 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 battery powered stimulator. On the stimulator, specialized circuitry for each electrode channel generates an analog voltage waveform.

In current mode, 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 on the IZ2/IZ2H read the output voltage for a chosen bank of channels and send that information back to the RZ for monitoring.

In Current mode, the IZ2 Stimulator System is capable of delivering up to 300 μA of current simultaneously across up to 128 stimulating electrodes (impedance up to 50 kOhm). The IZ2H Stimulator System is capable of delivering up to 3 mA of current simultaneously across up to 16 stimulating electrodes (impedance up to 5 kOhm).

In Voltage mode, both the IZ2 and IZ2H are capable of delivering up to $\pm 12\text{V}$ across each individual electrode.

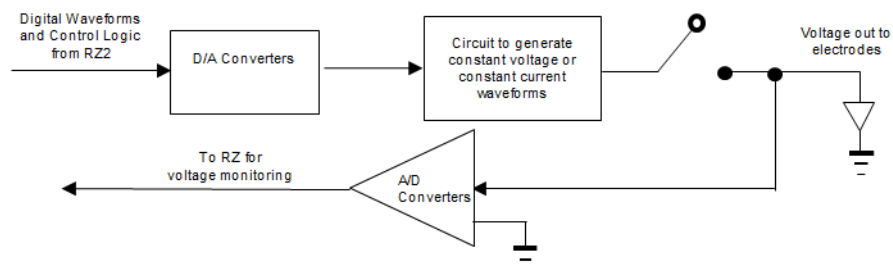
Special features for IZ2 serial numbers > 2000 and all IZ2H devices:

- Individual channels can be open circuited or shorted to ground.
- A 1 MOhm shunt resistor to ground can be applied to all channels. This is most useful for electrodes with very high impedance and that would normally produce large quiescent voltages when in Current mode.

The Stimulator

The IZ2 stimulator features 32, 64, or 128 channels that can deliver arbitrary waveforms of up to 80 kHz bandwidth and the IZ2H features 16 channels for high current range stimulation. Each channel uses PCM D/As to ensure sample delays of only 4 samples and square edges on pulse stimulation waveforms.

The stimulator uses a rechargeable Li-Poly battery from the LZ48 battery pack (VC) for logic control and D/A converter operation. Special circuitry on the stimulator draws on the LZ48 high voltage batteries (VA and VB) to convert low voltage waveforms from the D/A converters to constant voltage or constant current waveforms as shown in the diagram below.



Stimulator Diagram

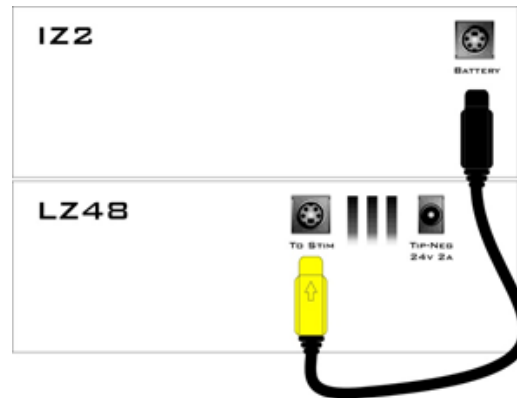
Stimulator Batteries

Power for stimulation is supplied by one of TDT's battery packs (LZ48-200 or LZ48-400). Both batteries produce the same output voltage/current characteristics. The LZ48-200 has a 200 Wh battery life and the LZ48-400 has a 400 Wh battery life. The number of channels needed for stimulation determines power requirements. The IZ2-128 and IZ2H-16 should only be used with the LZ48-400. The IZ2-32 and IZ2-64 can be used with either the LZ48-200 or LZ48-400. See "LZ48 Battery Reference" on page 7-16, for technical specifications and for more information.

Hardware Set-up

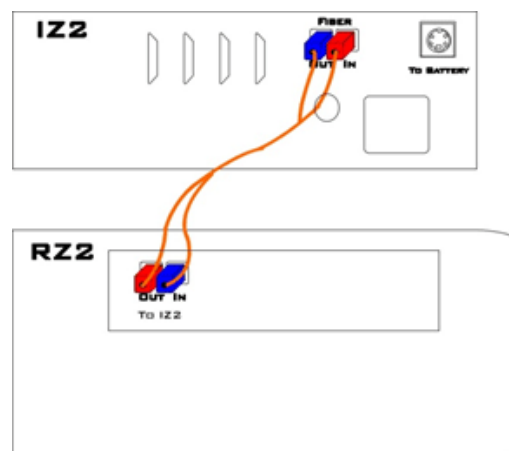
To connect the system hardware:

1. 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.
2. Connect the battery pack cable to the back panel of the stimulator via the connector labeled **Battery**, as shown in the diagram below.



WARNING!: Shorting the battery connection pins can cause damage to the device and injury to the user. Always use caution when handling or connecting the devices.

3. Connect the stimulator to the base station using the provided fiber optic cable.



4. Connect the fiber optic cable from the IZ2/IZ2H fiber optic port labeled Fiber to the fiber optic port labeled To IZ2 on the back side of the RZ. Be sure to note the difference in the two sides of the fiber optic cable connectors and ensure they are inserted with the correct side up.
5. 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 “IZ2 Stimulator Technical Specifications” on page 7-12, for pinouts.
6. Power on the base station, then power on the LZ48 using the power switch on the LZ48’s front panel. This will also power on the stimulator.

Note: Ensure that the LZ48 rechargeable batteries are fully charged before starting your protocol.

The hardware is ready for use.

If using the system with other devices, such as a switching headstage or preamplifiers, see the documentation for those devices for hardware connection information.

IZ2 Features

Analog Outputs (Stim Outputs)

The IZ2 is equipped with 32, 64, or 128 analog output channels, arranged in sixteen-channel banks that are powered down when no headstage is connected.

The IZ2H is equipped with 16 analog output channels, arranged in eight-channel banks that are powered down when no headstage is connected.

Stim Lights

The Stim Lights are located on the front plate of the IZ2/IZ2H 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.

Status Light

This LED provides connection and output mode information.

| Light Pattern | Description |
|----------------------------------|--|
| Solid Red | IZ2/IZ2H is not properly connected to RZ base station or cannot sync. |
| Solid Green | IZ2/IZ2H is properly connected to RZ and is operating in current mode. |
| Solid Green, Slowly Flashing Red | IZ2/IZ2H is properly connected to RZ and is operating in voltage mode. |

Fiber Optic Port (Fiber)

The fiber optic input port (labeled Fiber) provides an isolated connection to the RZ base station. One end of the fiber optic cable connects to the IZ2/IZ2H fiber optic

input port (labeled Fiber) and the other end connects to the fiber optic input port (labeled To IZ2) on the back panel of the RZ base station. See “Hardware Set-up” on page 7-5.

Battery Input (Back Panel)

The stimulator uses either the LZ48-200 or the LZ48-400 battery pack for stimulation and to power the logic circuitry. The battery pack should be connected via the Battery connection on the back panel using the battery pack cable provided. See “Hardware Set-up” on page 7-5.

Power Switch (Front Panel)

The Power switch turns the power on or off. The status lights on the front panel will be illuminated when the IZ2/IZ2H is on.

External Ground (Back Panel)

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 banana jack below the fiber optics on the back panel provides a connection to analog ground. This connection was added with IZ2-32 serial number 3011, IZ2-64 serial number 3001, IZ2-128 serial number 3003, and IZ2-16H serial number 2017.

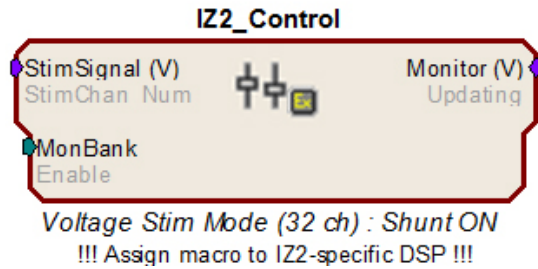
A cable kit is also provided to ensure cables used with the external ground are suitable for this use. Each kit includes: one male banana plug to male banana plug pass through and one male banana plug to alligator clip pass through. These cables also include ferrite beads to remove any potential RF noise that might travel through the cable. For best results position the ferrite bead close to the source of the RF noise.

An IZ2 Battery Interconnect cable with a ferrite bead is also included for use when using the external ground. For best results position the ferrite bead close to the LZ48.

Software Control

Operation of the stimulator system is controlled via an RPvdsEx circuit that runs on the connected RZ base station. TDT recommends using the **IZ2_Control** macro (pictured below) in your control circuit. This macro simplifies control of stimulator signal outputs and bank monitoring.

Note: The label on the additional fiber optic port on the back of the RZ processor will indicate which DSP is used to control the IZ2/IZ2H. The **IZ2_Control macro** must be assigned to this special DSP.



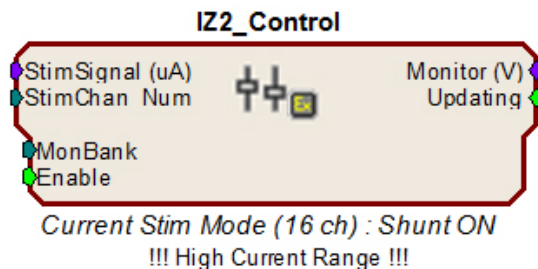
| Macro Settings | Description |
|--------------------|--|
| StimSignal: | Multi-channel floating point input stream of stimulus waveforms. |
| MonBank: | Select which bank of eight channels to update on the monitor output (integer, 0-15). |
| Monitor: | Multi-channel floating point monitor output. |

Note: *StimChan_Num, Enable and Updating* are for *SH16-Z* use only.

Selecting Voltage or Current Mode

The **IZ2_Control** macro should be included in all circuits. The Stimulation Mode setting on the Setup tab of the macro properties dialog box determines whether the IZ2 is configured to output in voltage mode or in current mode.

The macro can also be used to select high current range when using the IZ2H-16.



Important Circuit Design Considerations

Sampling Rate

The IZ2 can control 128 channels at up to 50 kHz, 64 channels at up to 100 kHz, and 32 channels at a maximum 200 kHz. The IZ2/IZ2H sampling rate is the same as the sampling rate of the circuit running on the RZ device, so the maximum sampling rate of the IZ2/IZ2H is also limited to the maximum sampling rate of the type of RZ device controlling it.

Note: When sampling at 200 kHz, the channel stim lights and output monitoring are not available and stimulation is limited to the first five channels of each bank of channels.

Signal Resolution

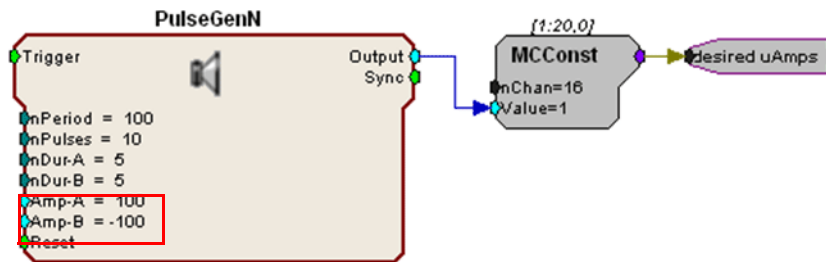
Signal resolution is dependent on the sampling rate used. PCM D/A converters allow users to generate precise pulsed signals, including square waves with durations of only 1 sample. When using the maximum sampling rate of 195.3125 kHz, the sample period is 5.12 microseconds. The IZ2/IZ2H has an effective bandwidth of 80 kHz for continuous (non-pulsed) waveforms.

Designing the Stimulus Signal

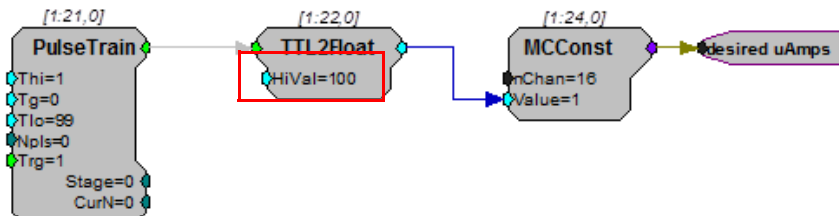
The IZ2/IZ2H Stimulator system offers flexible stimulus delivery capable of generating complex patterns of pulses or arbitrary waveforms. This allows you to make use of the full range of the waveform and pulse generators in the RPvdsEx component library, including the **PulseGenN** macro.

Desired Signal Range

Consider the output range of the system when adding and configuring waveform components. The default configuration of the stimulator can deliver stimuli in the range of $\pm 300 \mu\text{A}$ (at 50kOhm) or $\pm 12\text{V}$ and the IZ2H-16 can deliver up to $\pm 3\text{mA}$ (at 5kOhm) or $\pm 12\text{V}$. Be sure to set component amplitude parameters with the output range of your device in mind. In the figure below, the amplitude of a biphasic pulse is defined in the **Amp-A** and **Amp-B** parameters.



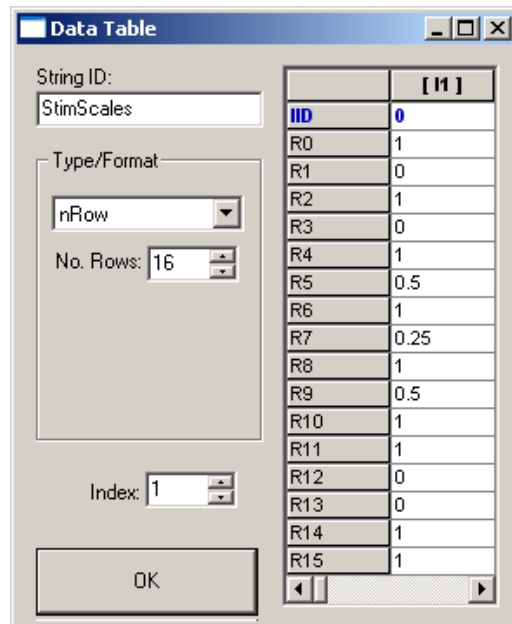
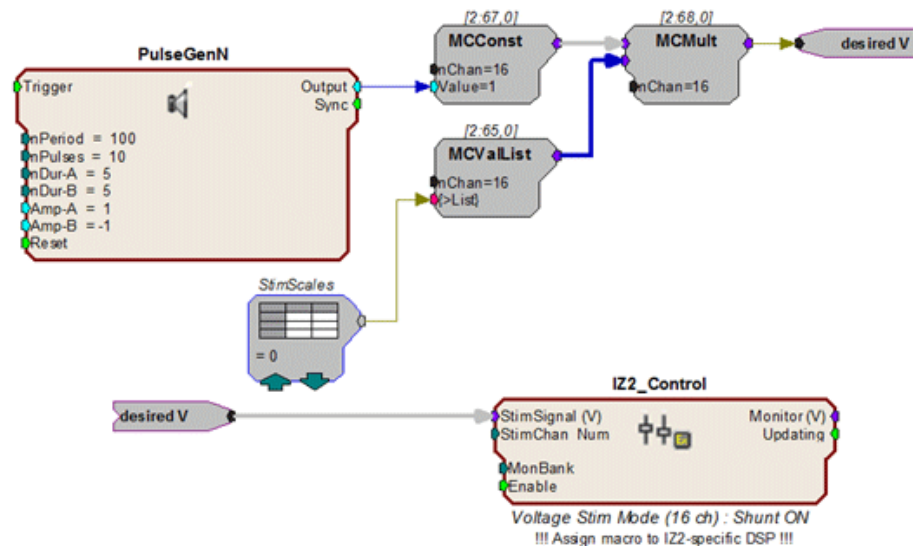
When using components that output a logical (TTL) signal, such as a **PulseTrain**, the output range can be defined when the output is converted to the desired data type. In the figure below, the **PulseTrain** component sends out a TTL signal with a fixed duration. A **TTL2Float** component is then used to convert the signal to a user specified value between 0 and 300 (or 0 and 3000 for the IZ2H). This floating point value indicates the desired stimulator output in microAmps. The **desired uAmps** hop is a multi-channel floating point signal that can be fed directly to the **IZ2_Control** macro's **StimSignal** input or further manipulated as in the next example.



Setting Multiple Channels for Stimulation

This example generates a 16-channel signal for voltage stimulation. The base stimulation is a $\pm 1\text{V}$ bipolar pulse generated by the **PulseGenN** macro. The **StimScales** data table holds the scale factors that will be applied to each channel's

stimulus. The output (**desired V**) can be connected directly to the **StimSignal** port of the **IZ2_Control** macro. The **IZ2_Control** macro is configured for Voltage Stim Mode.



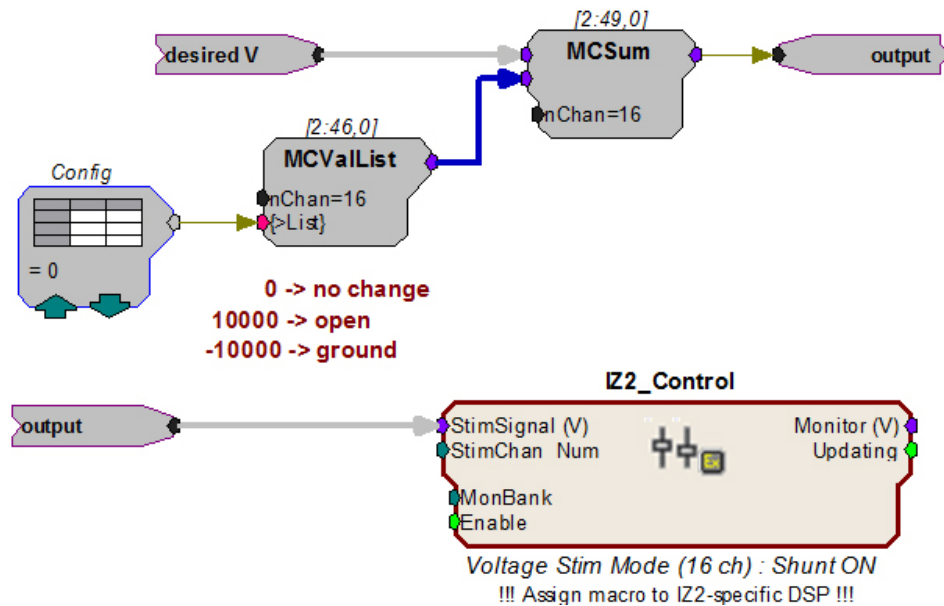
Double-clicking the StimScales DataTable component prompts the Data Table dialog which allows you to adjust individual scale factors for each channel.

Note: To turn off a particular channel, set its scale factor to 0.

IZ2 Serial Number > 2000 or any IZ2H

Set the signal value less than the lowest allowed value (e.g. constant -10000) on any channel to short that channel to ground. Set the signal value greater than the highest allowed value (e.g. constant 10000) on any channel to open circuit that channel. Use the macro settings to enable the 1MOhm shunt resistors on all channels.

Grounding or opening the channels can be achieved by using a second MCVallList that is added to the stim signals, as in the example below.



Summing a large constant value with the signal will switch that channel into Open or Short mode. The values in the Config DataTable must be large enough to clip the target channel. A value of +10000 is sufficient to open a channel; a value of -10000 is sufficient to short a channel. A value of 0 in the Config data table will have no effect on the output signal.

Monitoring the Stimulation

Eight PCM A/D converters on the IZ2/IZ2H 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: There is a single pole 16kHz lowpass filter on these inputs. The filter can affect impedance checking beyond 10 kHz.

Note: The onboard A/D converters provide the feedback clip at +/-20V, which is higher than any possible output signal in either voltage or current mode.

Important note for IZ2H users: To monitor the first 8 channels on the IZ2H, set MonBank to 0. To monitor the upper 8 channels on the IZ2H, set MonBank to 2.

Circuit Design Using the MCEstim Component

Using the IZ2_Control macro simplifies circuit design for the IZ2 Stimulator System. If you would like to change the output mode (voltage or current) in real-time, you can use the RPvdsEx MCEstim component to control the IZ2.



| Macro Settings | Description |
|-----------------|--|
| Input: | Multi-channel floating point input stream of stimulus waveforms. |
| Output: | Multi-channel floating point monitor output. |
| nChan: | Number of stimulus channels to send to IZ2/IZ2H. |
| VMode: | Configures the IZ2/IZ2H to run in Voltage Mode (1) or Current Mode (0). |
| MonBank: | Select which bank of eight channels to actively monitor (integer, 0-15). |
| OpBits: | Set to 48 to enable the shunt resistors (For IZ2 serial numbers > 2000 or any IZ2H only). This is also used for SH16-Z control. However if using an SH16-Z the IZ2_Control macro must be used. |

IZ2 Stimulator Technical Specifications

Includes specifications for the IZ2-32, IZ2-64, IZ2-128 and IZ2H-16.

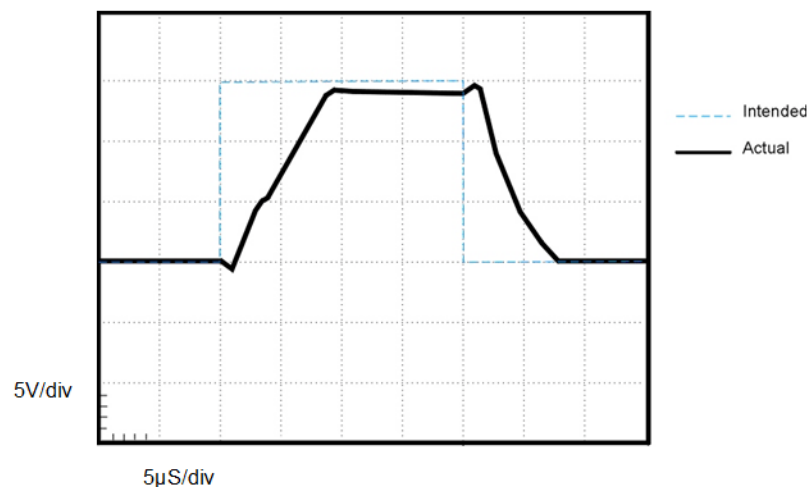
| | |
|---------------------------------|---|
| Stimulus Output Channels | 16 (IZ2H-16), 32 (IZ2-32), 64 (IZ2-64) or 128 (IZ2-128) PCM DACs |
| Sampling rate | IZ2H-16: Up to 195.3125 kHz [^] IZ2-32: Up to 195.3125 kHz [^] IZ2-64: Up to 97.65625 kHz [^] IZ2-128: Up to 48.828125 kHz [^] |
| Stimulus Output Voltage | +/- 12 V with LZ48 |
| Stimulus Output Current | IZ2: +/- 300 μ A up to 50 kOhm load with LZ48 IZ2H: +/- 3 mA up to 5 kOhm load with LZ48 |

| | |
|----------------------------------|---|
| Offset Current | < 100 nA on active channels and < 3 nA on open channels |
| ADC Filter | Single pole 16kHz |
| Power Control/Stimulation | LZ48 Rechargeable Battery with Li-Poly batteries |
| Battery Life | <p>LZ48-200 ~ 6-8 hours to charge LZ48-400 ~ 12-14 hours to charge</p> <p>Battery life between charges:</p> <p>LZ48-200 w/ IZ2: 32 ch ~ 20 hrs 64 ch ~ 10 hrs</p> <p>LZ48-400 w/ IZ2H: 8 ch ~ 12 hrs 16ch ~ 6 hrs</p> <p>LZ48-400 w/ IZ2: 32 ch ~ 30 hrs 64 ch ~ 20 hrs 128 ch ~ 10 hrs</p> <p>Note: The LZ48-200 is not recommended for use with the IZ2-128 or the IZ2H-16</p> |

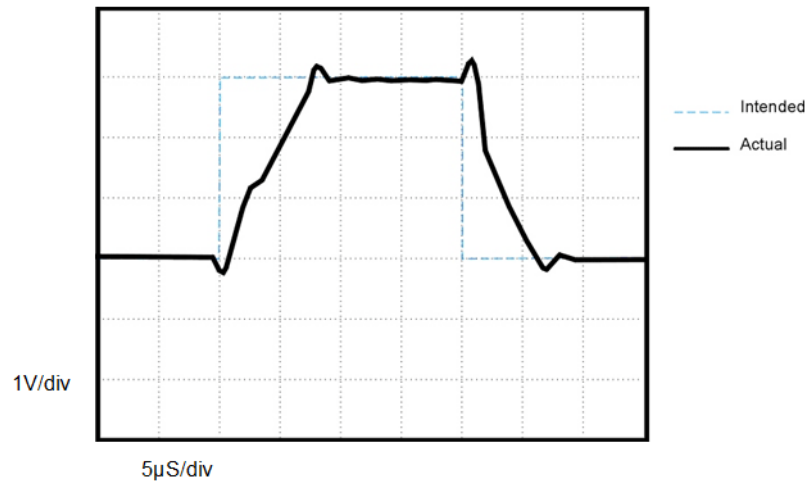
^Note: the sampling rate is also limited by the RZ processor used for stimulator control. When sampling at 195.3125 kHz, recording is limited to the first five channels on each bank of channels.

Slew Rate for the IZ2H-16

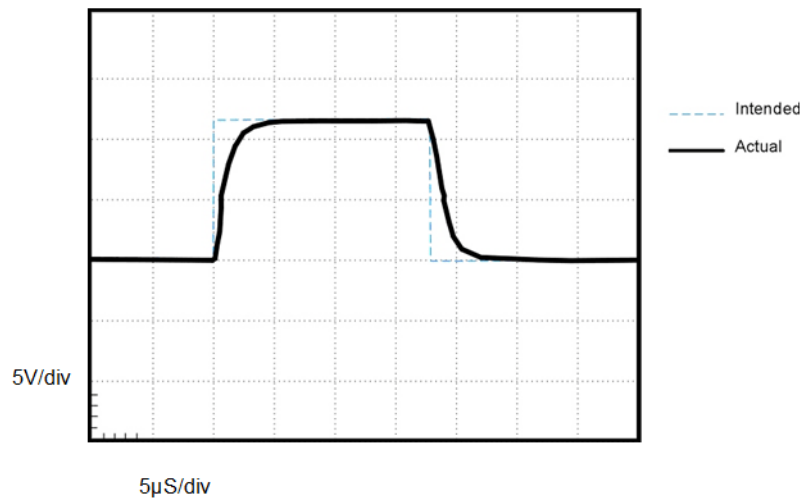
The slew rate is a measure of how quickly the output voltage of the device can change. The plots below show the effect of the slew rate on a square wave produced by the IZ2H at different loads and levels.



**5k load, 3 mA stim, 50 kHz sampling rate. Slew rate: ~ 1.6 V/us
Devices SN < 2018: ~0.21V/us**



1k load, 3mA stim, 50kHz sampling rate. Slew rate: $\sim 0.38\text{V}/\mu\text{s}$



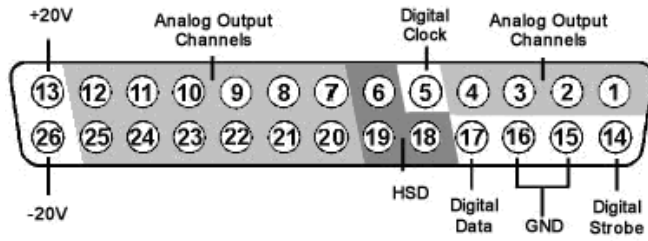
5k load, 12V stim, 50kHz sampling rate. Slew rate: $\sim 2.0\text{V}/\mu\text{s}$
 Devices SN < 2018: $\sim 0.16\text{V}/\mu\text{s}$

Note: Changes to the device improved the slew for IZH-16s, SN 2018 and greater.

Mini-DB26 Connector Pinouts for the IZ2

Stim Output Connector

The Stim Output connector provides access to the analog output channels. These channels are used primarily for stimulus output.



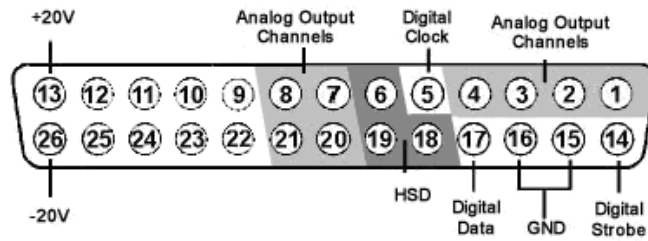
| Pin | Name | Description | Pin | Name | Description |
|-----|------|------------------------|-----|------|------------------------|
| 1 | A1 | Analog Output Channels | 14 | | Digital Strobe |
| 2 | A2 | | 15 | GND | Ground |
| 3 | A3 | | 16 | GND | Ground |
| 4 | A4 | | 17 | | Digital Data |
| 5 | | 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: TDT technical support (386-462-9622 or support@tdt.com) before attempting to make any custom connections to pins 6, 18, or 19.

Mini-DB26 Connector Pinouts for the IZ2H

Stim Output Connector

The Stim Output connector provides access to the analog output channels. These channels are used primarily for stimulus output.



| 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 | | Not Connected | 22 | | Not Connected |
| 10 | | | | | |
| 11 | | | | | |
| 12 | | | | | |
| 13 | V+ | | +20 V | 26 | |

Note: TDT technical support (386-462-9622 or support@tdt.com) before attempting to make any custom connections to pins 6, 18, or 19.

LZ48 Battery Reference



The LZ48 has several batteries to power both the stimulation and the IZ2 stimulator logic circuitry. A 24 Volt battery charger with 2.7A of current capacity is included with the stimulator and can be connected via the connector on the LZ48's back panel. The charger tip is center negative. If it is necessary to replace the charger, ensure that the power supply has the correct polarity.

| Issue | LZ48-200 | LZ48-400 |
|--------------|----------|----------|
| Battery life | 200 Wh | 400 Wh |
| Rechargeable | Yes | Yes |

| | | |
|---|--------------------------|--------------------------|
| Compliance voltage | +/- 15V | +/- 15V |
| Maximum impedance for a 300 microAmp current | 50 kOhms | 50 kOhms |
| Ambient temperature | Normal room temperatures | Normal room temperatures |

LZ48 Status LEDs

V_A: Positive Battery Pole

V_B: Negative Battery Pole

V_C: Logic Battery Level

Eight LEDs indicate the voltage level of the currently displayed battery. When the battery is fully charged, all eight LEDs will be lit green. When the battery voltage is low, only one green LED will be lit. If the voltage is allowed to drop further, the last LED will flash red. TDT recommends charging the battery before this flashing low-voltage indicator comes on. While charging, the Status LEDs will flash.

| Status | Description |
|------------------|-----------------------------------|
| 8 Green | Fully Charged |
| 1 Green, 7 Unlit | Low Voltage |
| 1 Flashing Red | Low Voltage - Charge Immediately! |
| 8 Green Flashing | Charging in Progress |

LZ48 Battery Pack

The LZ48 Battery Pack uses multiple Lithium Polymer (LiPoly) batteries.



WARNING! Just as with all batteries, shorting the LZ48 Battery Pack can cause damage to the device and injury to the user. Always use caution when handling or connecting the devices.

Important! Used LiPoly batteries must be recycled.

The LZ48 Battery pack should be stored at normal room temperatures. Temperature extremes can affect the operation of the batteries. Battery packs stored for longer than two months should be tested prior to use.

