RHS2000

Intan 128ch Stimulation/Recording Controller

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Features

- USB interface to Intan Technologies 16-channel or 32-channel stimulation/recording headstages (up to 4 total) using RHS2116 stimulation/amplifier chips.
- Free, open-source, multi-platform C++/Qt GUI software.
- Up to 128 stimulation/amplifier channels supported with sampling rates of 20, 25, or 30 kS/s.
- Any channel can independently source and sink currents from 10 nA to 2.55 mA over a ±7V compliance range.
- Biphasic and triphasic current pulses generated with timing resolution as fine as 33 μs.
- Independent or coordinated stimulation sequences on all channels triggered by digital inputs or keypresses.
- Analog output ports can generate custom voltage pulses or reconstruct waveforms from selected amplifier channels in real time.
- Digital output ports can generate custom TTL pulses or act as low latency threshold-based spike detectors.
- All-digital interface cables with independent ground isolation support robust, noise-free signaling over long distances; cables may be daisy-chained.
- Hardware or software-selectable referencing.
- Amplifier bandwidth settings reconfigurable through software; bandwidth may be changed on the fly.
- Software and hardware support *in situ* measurement of electrode impedances at user-selected frequencies.
- Stereo "line out" jack for real-time audio monitoring of any two selected amplifier signals.
- Digital (TTL) input lines supporting 2.0V to 5.5V logic levels synchronized to all amplifier channels.
- Analog input ports with ±10V range and 16-bit ADCs for recording auxiliary signals synchronized to all amplifier channels.
- Triggered episodic recording allows digital input to start and stop data acquisition to timestamped data files.

Description

The Intan RHS Stimulation/Recording System is a modular family of components that allows users to record biopotential signals from up to 128 low-noise amplifier channels and generate independent or coordinated constant-current stimulation pulses on any or all channels. The system is based on the RHS2000 series of digital electrophysiology stimulator/amplifier chips from Intan Technologies.

The **Intan Stimulation/Recording Controller** connects to a host computer via a standard USB cable. Small **RHS stim/record headstages** connect to the Controller via thin, flexible, all-digital cables that may be daisy-chained to form robust connections up to six meters in length. An **open-source, multi-platform GUI** controls the operation of the headstages, configures stimulation parameters, and streams data to the screen and to disk in real time at **user-selected sampling rates of 20, 25, or 30 kS/s**.

Each stim/record headstage includes one or two Intan RHS2116 stimulator/amplifier chips for a total of 16 or 32 channels. The chips have **software-reconfigurable bandwidths** which can be changed on the fly through the GUI. Any set of channels on the headstage can generate

constant-current stimulation pulses from 10 nA to 2.55 mA in magnitude, triggered by digital inputs to the Controller or keypresses on the host computer. The system also supports **electrode impedance measurement at arbitrary frequencies**.

The Stimulation/Recording Controller contains a variety of general-purpose digital and analog I/O ports including analog outputs which can produce custom voltage pulses or reconstruct waveforms from any amplifier channels with < 0.2 ms latency. Two of these analog signals are connected to a stereo "line out" jack for **audio monitoring of signals**. The controller also includes **general-purpose analog inputs and digital inputs** that are sampled in synchrony with the amplifiers. The GUI software supports viewing signals from all these channels and streaming the data to disk in binary format. Open-source code is provided for importing the data files into MATLAB.

Contents

Stimulation/Recording Controller Hardware

Figure 1A. Intan Stimulation/Recording Controller front panel.

The front panel of the Intan RHS Stimulation/Recording Controller provides connection points for Intan RHS headstages as well as auxiliary digital and analog inputs. From left to right:

- **Intan RHS headstage ports:** These ports, labeled A-D, provide connection points for stim/record headstages via 16-wire digital Stim SPI (serial peripheral interface) cables. Each cable can stream data from up to two 16-channel RHS2116 chips. Each headstage port is electrically isolated from the controller and from earth ground. Indicator lights provide information on the status of each port: green and yellow LEDs show that proper voltage supplies are being provided for each headstage. Red LEDs are activated when the software recognizes a headstage plugged into a port.
- **Digital inputs:** Two BNC sockets are provided for recording digital signals in synchrony with the headstage signals. The digital inputs accept TTL-level signals. Any voltage between 0V and +0.8V is read as a digital "low". Any voltage between +2.0V and +5.5V is read as a digital "high". Voltages delivered to these sockets should not exceed the range of 0V to +5.5V. These signals may be used to record discrete events associated with an experiment or to trigger a recording. These ports have an input impedance of 1.0 MΩ.
- **Analog inputs:** Two BNC sockets are provided for recording general-purpose analog signals. Signals are digitized with 16-bit ADCs over a range of -10.24V to +10.24V. Voltages delivered to these sockets should not exceed this range. These ports have an input impedance of 1.0 MΩ.
- **Status indicators:** Status indicator A is illuminated when the data acquisition is active. Status indicator B is controlled by DIGITAL IN 1; status indicator C is controlled by DIGITAL IN 2. These LEDs can be used to monitor the status of digital signals that are recorded in synchrony with the RHS headstages.
- **Power indicator:** This red LED is illuminated when the Intan Stimulation/Recording Controller is powered.

Figure 1B. Intan Stimulation/Recording Controller rear panel.

The rear panel of the Intan Stimulation/Recording Controller provides auxiliary output lines as well as other ports and switches. From left to right:

- **Analog outputs:** Two BNC sockets are provided for monitoring waveforms from RHS headstages or generating custom voltage pulses. The headstages communicate with the controller using purely digital signals, but 16-bit DACs are used to reconstruct analog signals with desired scaling factors. The control software allows users to route selected signals to any analog output ports, or to generate custom voltage pulses triggered by digital inputs or keypresses. These ports have a -10.24V to +10.24V voltage range.
- **Audio line out jack:** This standard 3.5-mm stereo phone jack allows users to connect an audio amplifier to the controller and listen to the signals routed to the two analog output ports. ANALOG OUT 1 is connected to the left channel; ANALOG OUT 2 is connected to the right channel. This port cannot drive speakers directly; an audio amplifier should be used, and the volume should be adjusted carefully to ensure that excessive levels are not delivered to speakers.
- **High-speed port:** This connector is reserved for future use.

- **I/O expansion port:** This connector is used to add an Intan I/O Expander. This board is described in the next section. It provides six additional analog inputs and outputs and 14 additional digital inputs and outputs for more complex experiments. Signals on this port are digital and serially encoded, and are not easily accessed without the I/O Expander.
- **CONFIG switches:** Configuration switches 1-3 are reserved for future use. Switch 4 (CONFIG4) is used to select the voltage level of the digital output ports (see next item). With CONFIG4 in the down position, 3.3V digital signals are generated. With CONFIG4 in the up position, 5.0V digital signals are generated.
- **Digital outputs:** Two BNC sockets produce either 3.3V or 5.0V digital signals (see previous item) that can be used to implement low-latency threshold comparators that operate on the signals routed to the analog outputs, or to generate custom pulses.
- **USB port:** A USB 2.0 port provides a high-speed connection to a host computer running the control software.
- **Sample clock out:** This port generates a digital pulse train at the amplifier sampling rate when the headstages are active. The voltage level of this signal is set by the CONFIG4 switch.
- **Mark out:** This port generates a digital pulse marking the onset and offset of data acquisition. The voltage level of this signal is set by the CONFIG4 switch.
- **I/O GND:** This binding post is connected to the controller system ground used by all analog and digital inputs and outputs. This is the preferred ground to use for Faraday cage and other shielding connections.
- **Chassis GND:** This binding post is connected to the controller chassis and to the grounding conductor of the AC power socket. Either Chassis GND or I/O GND can be connected to **Faraday cage shielding**. It is recommended that any conductive shield used in biopotential recording experiments is tied to one of these terminals for improved rejection of 50/60 Hz interference.
- **Power switch and fuse holder:** The unit uses two standard 1A 250V 5x20mm slow blow fuses that can be replaced by opening the fuse holder to the right of the power switch. The power cord must be removed to access the fuses.
- **AC power socket:** The controller is powered by 90-260V AC power, and is compatible with international voltage levels. A US-style power cord is supplied with the controller. International customers must use an adapter to accommodate non-US power sockets. The center grounding conductor must be connected to earth ground to avoid electric shock hazards.

Mounting

The Intan Stimulation/Recording Controller can be rack mounted on a standard 19” instrument rack using provided hardware, or it can be used on a bench top by folding out the feet on the bottom of the case:

Intan I/O Expander

Intan Technologies offers an optional I/O Expander (sold separately) that provides an additional six analog inputs and outputs and an additional 14 digital inputs and outputs. This unit is shown below:

Front Panel

The front panel of the Intan I/O Expander provides auxiliary digital and analog inputs, and analog outputs. From left to right:

- **Analog outputs:** Two analog outputs for monitoring signals from RHS headstages or generating custom voltage pulses. (Four more analog outputs are provided on the rear panel.) These ports have a -10.24V to +10.24V voltage range.
- **Digital inputs:** Six BNC sockets are provided for recording digital signals in synchrony with the headstage signals. (Eight more digital inputs are provided on the rear panel.)
- **Analog inputs:** Six BNC sockets are provided for recording analog signals. Signals are digitized with 16-bit ADCs over a range of -10.24V to +10.24V.
- **Power indicator:** This red LED is illuminated when the Intan I/O Expander is powered. The I/O Expander receives low-voltage DC power over an interface cable from the controller.

Rear Panel

The rear panel of the Intan I/O Expander provides auxiliary input and output ports. From left to right:

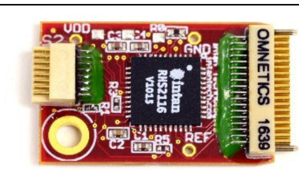
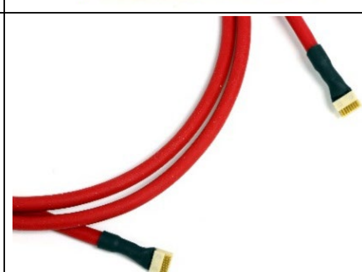
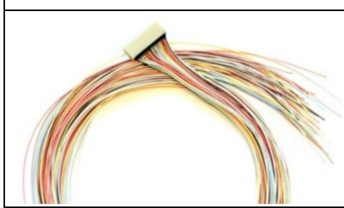
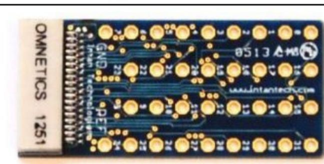
- **Interface port:** This connector is used to interface with the main controller unit.
- **Analog outputs:** Four analog outputs for monitoring signals from RHS headstages or generating custom voltage pulses. (Two more analog outputs are provided on the front panel.) These ports have a -10.24V to +10.24V voltage range.
- **Digital outputs:** Six BNC sockets produce either 3.3V or 5.0V digital signals that can be used to implement low-latency threshold comparators that operate on the signals routed to the analog outputs, or to generate custom digital pulses. The CONFIG4 switch on the main Intan controller selects the voltage level used by these ports.
- **Digital inputs 9-16:** Eight additional digital inputs are provided on screw terminal blocks. System ground connections are also provided on the ends of the terminal block.
- **Digital outputs 9-16:** Eight additional digital outputs are provided on screw terminal blocks. System ground connections are also provided on the ends of the terminal block. The CONFIG4 switch on the main Intan controller selects the voltage level used by these ports.

RHS Family Summary

The following table shows hardware components in the RHS family. The minimum required components for a functional electrophysiology recording system are: an **Intan RHS Stimulation/Recording Controller**, a **Stim SPI interface cable**, and an **RHS stim/record headstage**. Prices of all items are listed on the Intan Technologies website. These items are described in detail in the following pages.

Intan 128ch Stimulation/Recording Controller #M4200 — Includes USB cable and US-style power cord

Intan I/O Expander #E6500 — Includes interface cable

	**RHS 16-channel stim/record headstage** with 18-pin electrode connector #M4016		**RHS 32-channel stim/record headstage** with 36-pin electrode connector #M4032
	**RHS Stim SPI cable adapter board** for custom interface development #M4430		**RHS 3-ft (0.9 m) or 6-ft (1.8 m) Stim SPI interface cable** #M4563 or #M4566 (formerly part numbers #M3203, #M3206)
	**1-pin wire adapter** #B7600 **36-pin wire adapter** #C3420		**36-pin electrode adapter board** #C3410 **18-pin electrode adapter board** #C3418

RHS Stim/Record Headstages

The Intan Stimulation/Recording Controller communicates with the RHS headstages offered by Intan Technologies. A variety of **RHS stim/record headstages** are available for different applications. Each stim/record headstage contains: one or two RHS2116 amplifier chips, a 16-pin Omnetics polarized nano connector that mates with a **Stim SPI interface cable**, and a connector to mate with stimulation/recording electrodes.

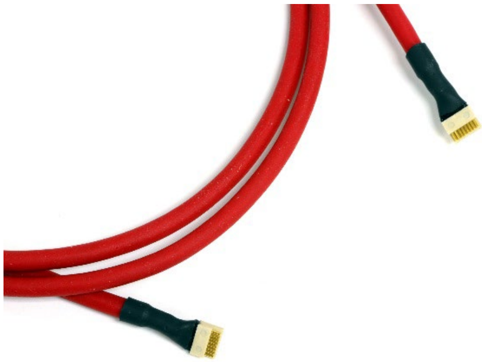


Figure 2. RHS Stim SPI interface cable used to connect stim/record headstages to the Stimulation/Recording Controller.

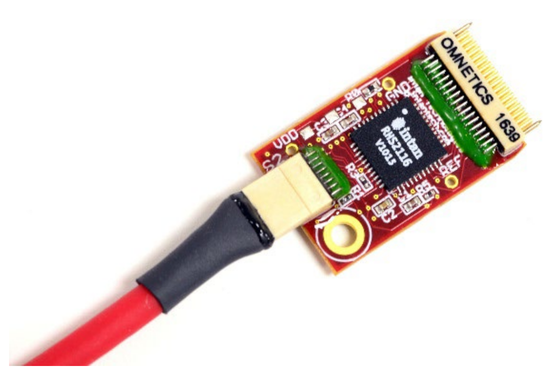


Figure 3. RHS 32-channel stim/record headstage plugged into a Stim SPI interface cable.

Figure 2 shows a Stim SPI (Serial Peripheral Interface) cable used to connect stim/record headstages to the Stimulation/ Recording Controller. The 16-conductor cable is 3.4 mm in diameter and weighs 11.9 grams/meter. Multiple interface cables may be daisy-chained to create cables of varying lengths up to a maximum recommended length of 6.4 meters (21 feet). (The **RHS Stim SPI Cable/Connector Specification** is available on the Intan Technologies website and provides details on this connection.) Figure 3 shows an RHS 32-channel stim/record headstage plugged in to a Stim SPI interface cable.

Figures 4 and 5 show detailed views of 16- and 32-channel stim/record headstages with relevant components labeled.

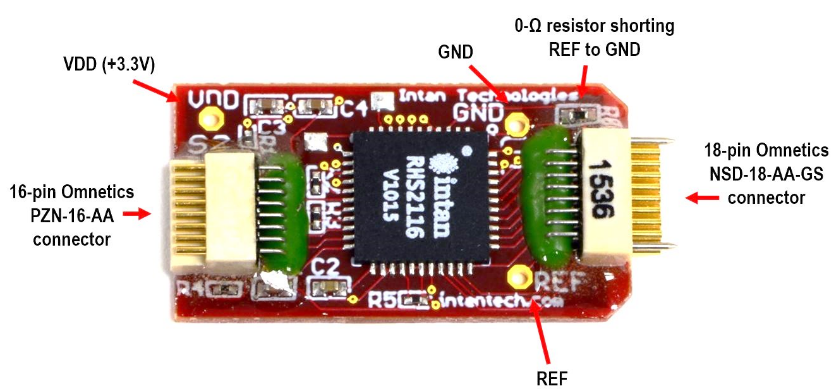


Figure 4. 16-channel stim/record headstage with connection ports labeled. The 0-Ω resistor may be removed to disconnect the reference electrode (REF) from ground (GND).

The board measures 24 mm x 13 mm and weighs 0.99 g.

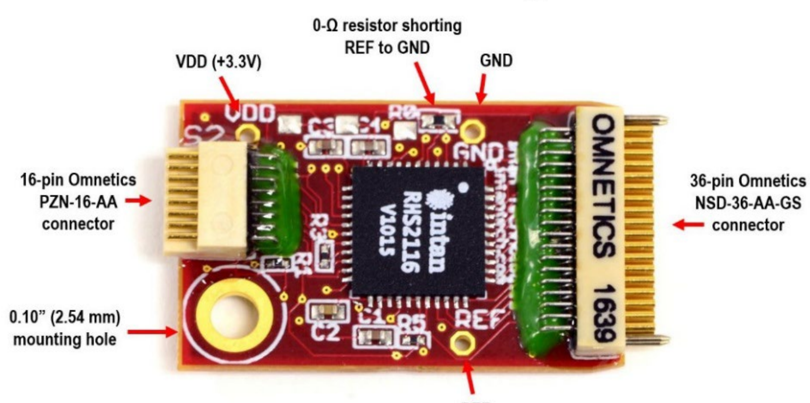


Figure 5. 32-channel stim/record headstage with connection ports labeled. The 0-Ω resistor may be removed to disconnect the reference electrode (REF) from ground (GND).

A 0.10" (2.54 mm) mounting hole is provided for optional mechanical attachment.

The board measures 24 mm x 15 mm and weighs 1.35 g.

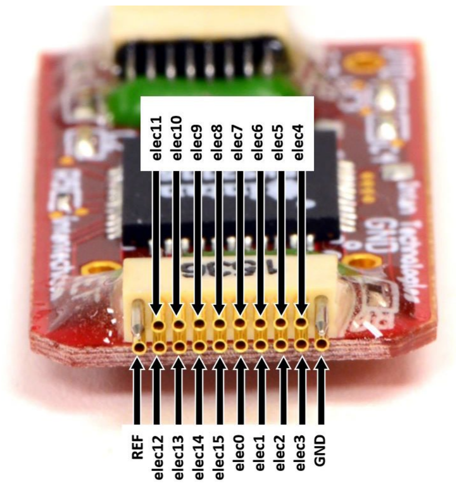


Figure 6. Electrode connector pin diagram for 16-channel stim/record headstage.

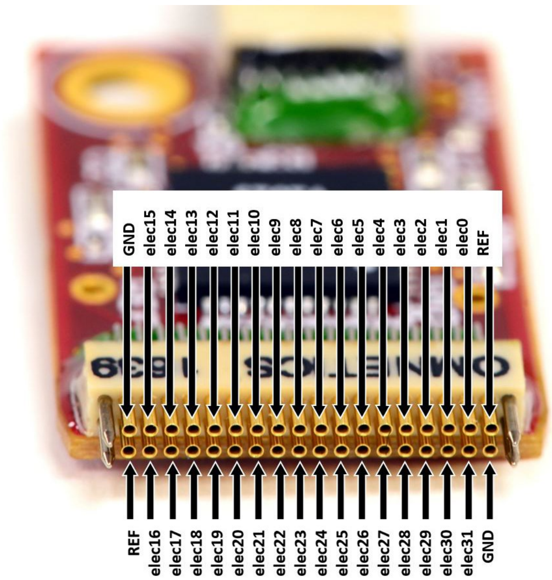


Figure 7. Electrode connector pin diagram for 32-channel stim/record headstage.

The two REF pins are connected on the board, so only one pin needs to be connected to the reference electrode. The GND pins are also connected on the board.

Figures 6 and 7 show pin diagrams for the electrode connectors on the 16- and 32-channel stim/record headstages. Pins elec0-elec15 or elec0-elec31 should be connected to stimulation/recording electrodes. The REF pin should be connected to a low-impedance reference electrode (typically a de-insulated electrode or a platinum or Ag/AgCl wire). If the 0-Ω resistor shorting REF and GND has been removed then the GND pin should be connected to tissue ground (typically a skull screw or a low-impedance electrode located away from active muscles). Stimulation currents return through the GND connection.

These pin arrangements are compatible with connectors used in a number of commercially-available electrode arrays, including the NeuroNexus electrodes, multi-channel arrays from MicroProbes, probes from Atlas Neuroengineering, Cambridge NeuroTech, Plexon, and the Blackrock. The exact order of the amplifier channels may differ from the numbering on a particular electrode array, but amplifier channels may be renamed and reordered in the software GUI to match any configuration.

If electrodes with an appropriate mating connector are not available, Intan Technologies offers 18-pin and 36-pin **electrode adapter boards** for the 16- and 32-channel stim/record headstages, respectively (see Figure 8 on following page). All electrode connections, as well as the REF and GND lines, are routed to solder holes spaced 0.10” (2.54 mm) horizontally. Wires may be soldered into these holes, or a standard 16-pin DIP (dual in-line package) socket (included) may be soldered onto this board to connect 16 of the amplifier channels to a NeuroNexus A, OA, or D16 acute electrode connector.

Intan Technologies also offers 18- and 36-pin wire adapters which mate with the 16- and 32-channel stim/record headstages (see Figure 9 on following page). This brings out all pins in the electrode connector directly to #34-AWG multi-colored wires.

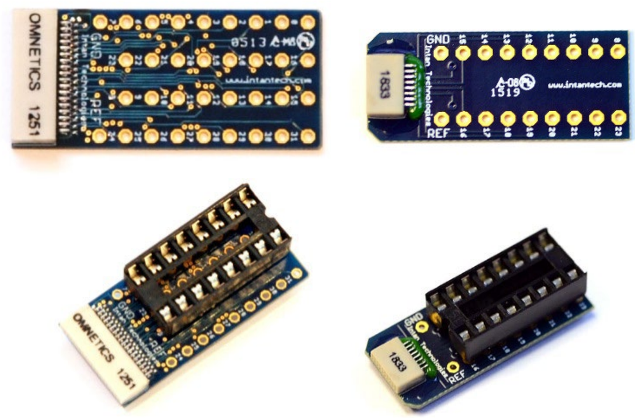


Figure 8. 36-pin electrode adapter board (upper left); with 16-pin DIP socket (lower left). 18-pin electrode adapter board (upper right); with 16-pin DIP socket (lower right).

Figure 9. 36-pin wire adapter for 32-channel stim/record headstage (left). 18-pin wire adapter for 16-channel headstage (right).

Using Stim/Record Headstages with Commutators

Intan Technologies provides simple hardware that allows signals from standard RHS Stim SPI interface cables to be adapted to commutators or other user-specific connectors with ease. An application note available from the Downloads page of the Intan website describes how to use the **Stim SPI cable adapter board** (part #M4430) to accomplish this.

Figures 10 and 11 below show the Stim SPI cable adapter board connected to an RHS Stim SPI interface cable. The adapter board contains no active circuitry; it simply breaks out all 12 signals from an SPI interface cable to easily accessible gold-plated holes with a 0.1" pitch. Wires or other connectors may be soldered to these holes, and then connected to commutators or other user-specific connectors.

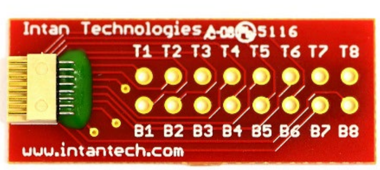


Figure 10. Stim SPI cable adapter board

Figure 11. Stim SPI cable adapter board plugged into RHS Stim SPI interface cable.

Data Acquisition Software

The Intan Stimulation/Recording System uses the free, open-source **RHX data acquisition software** developed by Intan Technologies. This software is available for Windows, Mac, and Linux. Easy-to-use installers and a complete user manual are available at:

https://www.intantech.com/RHX_software.html

Related RHS Documentation

The following supporting datasheets may be found at **https://www.intantech.com/downloads.html**:

- **RHS2116 Digital Electrophysiology Stimulator/ Amplifier Chip**
- **RHS USB/FPGA Interface: RhythmStim USB-7310**
- **RHS Stim SPI Cable/Connector Specification**

Application Notes:

- **Application Note: Noise Reduction Techniques**
- **Application Note: Data File Formats**
- **Application Note: Adapting Stim SPI Cables to a Commutator**

Contact Information

This datasheet is meant to acquaint engineers and scientists with the Intan Stimulation/Recording Controller developed at Intan Technologies. We value feedback from potential end users. We can discuss your specific needs and suggest a solution tailored to your applications.

For more information, contact Intan Technologies.

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