intan TECHNOLOGIES, LLC

RHD2000

SPI Interface Cable/Connector Specification

28 February 2013; updated 25 March 2015

Features

- Self-aligning standard Omnetics PZN-12 polarized nano connectors; no guide pins required
- Twisted pairs in cable facilitate the use of LVDS (low-voltage differential signaling) communication for low-noise operation and high signal integrity over long distances
- 12-conductor cable contains two power wires and five LVDS pairs: one cable can support two RHD2000-series chips if command signals are shared
- Small connector size: 4.5 mm × 4.3 mm × 2.0 mm
- Cable design permits daisy-chaining for easy adjustment of cable length
- Available in two cable thicknesses: standard (2.9 mm diameter) and ultra thin (1.8 mm diameter)

Applications

- RHD2000-based electrophysiology signal acquisition systems
- Starting point for the development of custom connectors to RHD2000 chips

Cable Description

To support the evaluation system for the RHD2000 digital electrophysiology chips, Intan Technologies has developed a standard interface cable and connector scheme to transmit digital low-voltage differential signaling (LVDS) data and power over distances of several meters. These cables allow RHD2000-based electrophysiology amplifier boards or headstages to be located some distance from the USB/FPGA interface board that controls the chips and streams data from them into a host computer. The design of this cable is quite simple, and can serve as an example for more sophisticated variations of wired interfaces to RHD2000 chips.

The cable described here supports the serial peripheral interface (SPI) communication scheme used by RHD2000 chips to receive commands and transmit digitized signals from biopotential amplifiers. The 4-wire SPI interface uses a chip select ($\overline{CS}$) signal and a serial clock (SCLK) signal to sequence 16-bit data words. The MOSI (master out, slave in) signal transmits commands from the SPI master to the RHD2000 chip. A MISO (master in, slave out) signal is used by each RHD2000 chip to send data back to its controller. (See the RHD2000 series datasheet for more details on this communication protocol.)

Each RHD2000 SPI cable contains 12 conductors: two thicker wires for power and ground, and ten thinner wires arranged in five twisted pairs for five LVDS digital signals. The five LVDS signal paths in the cable allow for two MISO lines so that two RHD2000 chips may send data over one cable provided they both receive the same commands from the single MOSI line. This allows for the construction of a 128-channel recording headstage (i.e., two RHD2164 chips) using only one cable. The use of terminated, twisted-pair data wires and LVDS signaling eliminates the need for any conductive shielding on the cables.

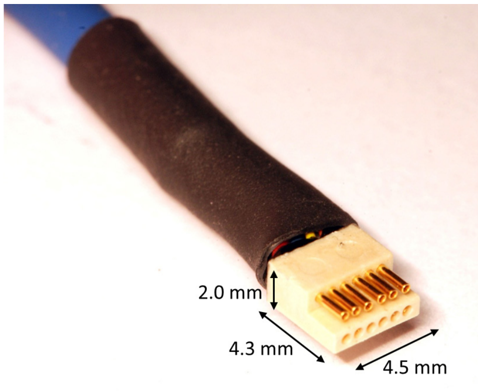

Figure 1. Dimensions of a RHD2000 SPI connector from Intan Technologies. The connector on each end is a self-aligning 12-pin Omnetics PZN-12 polarized nano connector.

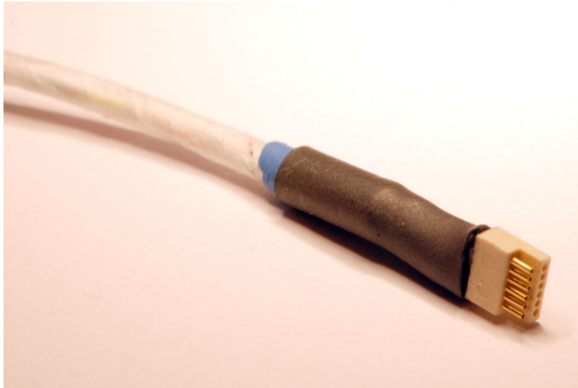

Figure 2. Standard cable with blue TPE jacket removed. This reduces the cable diameter to 2.0 mm and increases flexibility somewhat.

The cables use self-aligning 12-pin Omnetics PZN-12 polarized nano connectors at each end. Figure 1 above shows the end of a cable with connector dimensions indicated.

Intan Technologies supplies RHD2000 SPI cables in fixed lengths. Standard SPI cables with a 2.9-mm diameter are available in 3-foot (0.9-meter) and 6-foot (1.8-meter) lengths. Ultra thin SPI cables with a 1.8-mm diameter are available in 3-foot (0.9-meter) and 6-foot (1.8-meter) lengths.

Standard SPI Cables

Standard RHD2000 SPI cables have a diameter of 2.9 mm and a mass of 8.20 g/m. Each connector and associated protective sheathing adds roughly 0.12 g. The power wires in a standard cable are 32 AWG wire (with a conductor diameter of 202 µm) and have a DC resistance of 0.564 Ω/m. The LVDS signal wires use 36 AWG wire (with a conductor diameter of 127 µm) and have a DC resistance of 1.39 Ω/m. At typical SPI data frequencies in the MHz range, resistance will increase due to the skin effect.

The cable diameter of 2.9 mm includes a flexible blue thermoplastic elastomer (TPE) jacket that may optionally be removed by carefully cutting through this material and peeling it away (see Figure 2). Removing the blue TPE jacket reduces diameter of the cable to 2.0 mm and increases its flexibility somewhat. This reduces the mass of the cable to 4.92 g/m. The wire bundle is wrapped in white paper tape. If this tape begins to unravel, it can be bound by periodic segments of standard 3/16” diameter heat-shrink tubing (e.g., Digi-Key part number RNF316K-ND). The tubing should be cut into short segments and slid onto the cable where heat can be applied to shrink it into place where desired.

Ultra Thin SPI Cables

Ultra Thin RHD2000 SPI cables have a diameter of 1.8 mm and a mass of 4.07 g/m – about half the weight of the standard SPI cable, and only 39% of the cross-sectional area. The cable is covered with a thin silicone rubber jacket that provides extremely high flexibility.

The power wires in an ultra thin cable are 34 AWG wire (with a conductor diameter of 160 µm) and have a DC resistance equal to 0.564 Ω/m. The LVDS signal wires use 40 AWG wire (with a conductor diameter of 80 µm) and have a DC resistance of 1.39 Ω/m. At typical SPI data frequencies in the MHz range, resistance will increase by as much as 65% due to the skin effect.

The violet silicone rubber jacket may optionally be removed by carefully cutting through this material and peeling it away. Removing the jacket reduces diameter of the cable to 1.2 mm and increases its flexibility somewhat. This reduces the mass of the cable to 2.21 g/m. The wire bundle is wrapped in white PTFE (Teflon) tape.

The twisted-pair data lines in both standard and ultra thin SPI cables have characteristic impedances (Z_0) close to the 100-Ω standard used in LVDS termination to minimize signal reflections. Detailed physical and electrical characteristics of both the standard and ultra thin RHD2000 SPI cables are listed on the following page.

Physical and Electrical Characteristics

PARAMETER	VALUE (STANDARD CABLE)	VALUE (ULTRA THIN CABLE)	UNITS	COMMENTS
Cable diameter	2.9 2.0	1.8 1.2	mm mm	Including outer jacket With outer jacket removed
Cable cross-sectional area (related to cable flexibility)	6.6 3.1	2.5 1.1	mm^2 mm^2	Including outer jacket With outer jacket removed
Cable mass	8.20 2.50 4.92 1.50	4.07 1.24 2.21 0.67	g/m g/ft g/m g/ft	Including outer jacket With outer jacket removed
Outer jacket material	blue 0.013" thermoplastic elastomer (TPE)	violet 0.013" silicone rubber		
Inner wrap material	0.001" paper tape	0.002" PTFE (Teflon) tape		
Wire insulation material	0.006"/0.005" PVC	0.002" PFA		
Wire gauge and conductor diameter: power wires	32 202	34 160	AWG µm	2 power wires per cable
Wire gauge and conductor diameter: data wires	36 127	40 80	AWG µm	10 data wires are grouped in 5 twisted pairs for LVDS signals
Number of Intan RHD2000 chips supported per cable	2	2		Two chips supported, provided they receive identical command sequences
Power wire DC resistance	0.564 0.172	1.12 0.341	Ω/m Ω/ft	
Data wire DC resistance	1.39 0.423	4.59 1.40	Ω/m Ω/ft	Resistance at typical SPI data frequencies will be up to 65% higher due to skin effect
Data wire twisted pair inductance (L')	810 247	699 213	nH/m nH/ft	
Data wire twisted pair capacitance (C')	55.8 17.0	41.0 12.5	pF/m pF/ft	
Data wire twisted pair characteristic impedance (Z_0)	120	130	Ω	$Z_0 = \sqrt{L'/C'}$ Close to 100-Ω LVDS standard
Data wire twisted pair propagation speed (v)	0.149 0.488 0.50	0.187 0.613 0.62	m/ns ft/ns c	$v = 1/\sqrt{L'C'}$ c = speed of light
Connector type	Omnetics PZN-12 polarized nano			See www.omnetics.com
Connector size	4.5 × 4.3 × 2.0		mm^3	
Connector mass	0.074		g	Approximately 0.120 g including protective sheathing and epoxy used in cables

Cable Wiring and Pin Locations

RHD2000 SPI cables mate with any Omnetics PZN-12 connector (see **www.omnetics.com**). For printed circuit board (PCB) applications, the most convenient connector to use is the PZN-12-AA (Omnetics part number A79623-001), shown in Figure 3 below. Figure 4 shows the recommended PCB footprint for surface-mount attachment.

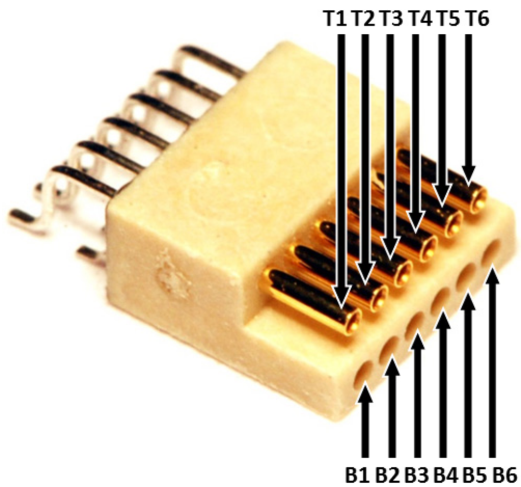

Figure 3. Omnetics PZN-12-AA 12-pin polarized nano connector (part number A79623-001) with Intan Technologies pin numbers (**T** = top, **B** = bottom).

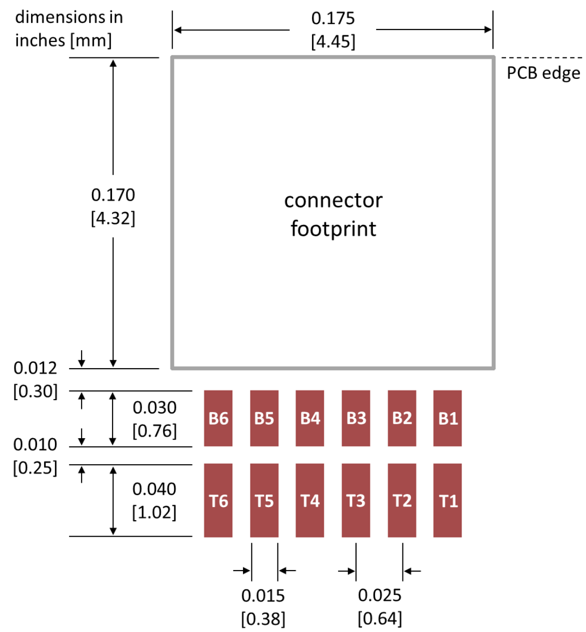

Figure 4. Printed circuit board (PCB) footprint for Omnetics PZN-12-AA connector.

Table 1 lists the pin locations for each signal in the SPI cable. Note that the pin locations are different for the connections on the SPI master side (i.e., the data acquisition controller, such as a microcontroller or FPGA) and the SPI slave side (i.e., the amplifier board containing the RHD2000 chip): the "top" and "bottom" pins are inverted.

Table 1. Pin locations of SPI signals and power wires

Signal	PZN-12-AA pin number (SPI master side: CPU or FPGA)	PZN-12-AA pin number (SPI slave side: RHD2000 chip)
$\overline{CS}$+	B1	T1
$\overline{CS}$–	T1	B1
SCLK+	B2	T2
SCLK–	T2	B2
MOSI+	B3	T3
MOSI–	T3	B3
MISO1+	B4	T4
MISO1–	T4	B4
MISO2+	B5	T5
MISO2–	T5	B5
Power (+3.2V – +3.6V)	B6	T6
Ground	T6	B6

As Table 1 illustrates, LVDS signal pairs and the two power lines are paired vertically on each connector and within the cable. Each SPI cable is wired in a manner that permits multiple cables to be daisy chained (i.e., connected in series) to form a longer cable. Figure 5 below shows the nature of the connections. (The twisted geometry of each signal pair is omitted in this diagram to aid clarity.)

Figure 5. Cross-sectional schematic of cable showing connector wiring.

Conceptually, all signals are passed straight through the cable from one connector to an inverted connector on the other end. This allows signals to pass straight through daisy-chained cables when the polarized nano connectors are mated as shown in the diagram and photo below:

Figure 6. Illustration of daisy chaining multiple cables together.

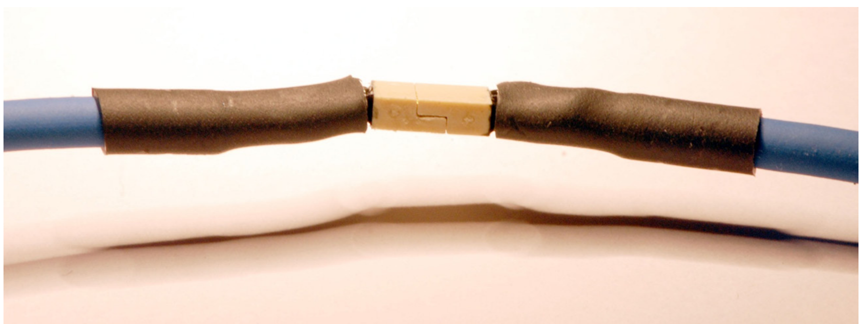

Figure 7. Photograph of two cables daisy chained together.

While this wiring scheme allows multiple cables to be connected serially, it is important to recognize that it also renders any color coding of wires in the cable ambiguous. In the diagram below, we show a red wire and a blue wire. Let's assume that one of these wires carries the +3.3V power signal and the other wire is ground. For a general cable, we cannot say that the red wire is power and the blue wire is ground, because if the cable is flipped and connected in the opposite direction the roles of these two wires reverse (see Figure 8 below). This is an important fact to remember if custom cables are developed based on this wiring scheme.

Figure 8. Schematic of cable in two possible orientations.

When creating long cables, it is important to consider the voltage drop along the power lines. The RHD2000 datasheet gives supply current estimates for the chip in various configurations; these should be multiplied by the series resistance of both the power line **and** the ground line in the cable to calculate voltage drop. Since the RHD2000 can operate at full specifications over a supply voltage range of 3.2V to 3.6V, it may be desirable to supply a regulated voltage near 3.6V to allow for several hundred millivolts of loss across the power line resistance in long cables. (The RHD2000 Evaluation System USB interface board provides a 3.5V supply to its SPI ports.)

The series resistance of the LVDS signal wires is less critical. As long as the total series resistance of **both** wires in a twisted pair is significantly less than the 100 Ω termination resistance, long cables will have little effect on LVDS signal integrity.

Development Products

Intan Technologies supplies RHD2000 SPI cables in fixed lengths. Figure 9 shows the 6-foot (1.8-meter) interface cable in both standard and ultra thin versions; 3-foot (0.9-meter) cables of both types are also available.

An SPI cable adapter circuit board is also available (see Figure 10). This simple circuit board brings out the signals from all twelve conductors (labeled T1-T6 and B1-B6) to 0.1"-pitch solder holes. This may be used to interface RHD2000 SPI cables to prototype devices without using Omnetics PZN-12-AA connectors. This board may be used to connect SPI signals to a commutator, as described in the **RHD2000 Application Note: Adapting SPI Cables to a Commutator**, available from the Downloads page on the Intan Technologies website.

The **RHD2000 dual headstage adapter** allows two amplifier boards to share a single SPI interface cable, using both MISO lines. Information on this product is available at the Intan Technologies website.

Figure 9. 6.0-foot (1.8-meter) RHD2000 SPI interface cable: standard cable (left, blue) and ultra thin cable (right, violet)

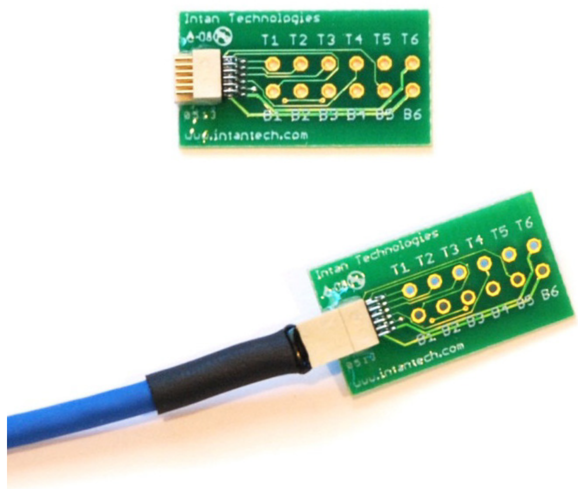

Figure 10. RHD2000 SPI cable adapter circuit board available from Intan Technologies.

Related Documentation

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

- **RHD2000 Dual Headstage Adapter Datasheet**
- **RHD2000 Application Note: Adapting SPI Cables to a Commutator**
- **RHD2000 Series Digital Electrophysiology Interface Chips**
- **RHD2000 Series Amplifier Evaluation System**
- **RHD2000 USB Evaluation System Catalog**