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Highlights of the DATAshuttle Express

Maximum Speed

100 k samples per second

Resolution

13 Bits

All DATAshuttle Express Feature

*16 Differential analog inputs (eight in each terminal drawer)
· 12 voltage input ranges · Accepts a wide range of signals
and sensors · Plug-in signal conditioning for each individual
channel · Test switches for each analog input channel · High
noise rejection at low sample rates · Software linearization
for RTDs and Thermocouples · 12 digital inputs (six in each
terminal drawer) with provision for digital isolation modules ·
12 digital outputs (six in each terminal drawer) with provision for
digital isolation modules · Two analog outputs (one in each
terminal drawer) · Two counter/timers (one in each terminal
drawer) · One trigger input · Parallel pass-through port for
multiple DATAshuttles or printer on same port · Everything in
one enclosure. No wires connecting termination boxes or
multiplexers · Factory guaranteed accuracy for two years
from date of purchase · Rugged · CE approved*

Chapter 1: Introduction & Installation

Thank you for selecting the DATAshuttle Express for your project!

Our primary objective is to provide you with data acquisition systems that are easy to install, operate, and maintain. We also strive to furnish the performance you need at the lowest overall cost. The benefits for you are increased productivity, data you can count on, and, of course, meeting your budget.

We manufacture the DATAshuttle Express as an enhancement product that readily plugs into the parallel port of a Microsoft/Intel Personal Computer, whether it is a portable or desktop machine.

The DATAshuttle Express is ideal for test and measurement and quality control in industrial environments. Its inputs and interconnections are rugged, and RFI emissions are low. With its parallel port interface, built-in screw terminations, and compact size, the DATAshuttle is also completely portable, providing for a quick and easy set-up in both in-house labs and remote test sites. It can handle a large number of channels of data in a single, compact, portable enclosure.

Using the DATAshuttle Express together with our graphical interface application software (such as WorkBench PC™ for Windows or QuickLog for Windows), you can easily and very quickly implement a broad spectrum of research and commercial tasks, in a wide variety of settings. You can, for example,

- **Display, and log data** to disk for later analysis,
- **Measure an extremely wide range of sensor and signal types**, including advanced easy-to-use signal conditioning,
- **Scale inputs and perform complex math** to get real-time results,
- **Monitor and control processes**,
- **Set alarm limits** on any input,
- **Control devices at preset levels** (fans, pumps, heaters, etc.),
- **Control devices from digital inputs** (from switches or TTL signals), and
- **Gather data unattended.**

DEVELOPMENT SYSTEM People who decide, on the other hand, to write their own software (rather than using an off-the-shelf application) can employ the Analog Connection Windows Development System™ (ACWDS) to access all the features of the DATAshuttle Express from within a program written in C, C++, or Visual Basic.

EXPANDABILITY All DATAshuttle Express have 16 differential analog input channels, 12 digital inputs, 12 digital outputs, two analog outputs, and two counter/timers. You can add one DATAshuttle at a time to your computer, for as many as 15 units with a total of 240 analog inputs, 180 digital inputs, 180 digital outputs, 30 analog outputs, and 30 counter/timers.

The DATAdock accessory (model BP-DS-EXP) provides a convenient way to interconnect four DATAshuttle Express in a compact package. The DATAdock plugs into any AC power from 90 to 264 Volts, 47 to 63 Hz, and it has a convenient carrying handle.

POWER The DATAshuttle Express comes with a power adapter that accepts 90 to 264 VAC. A DC adapter is available that accepts 9 to 36 VDC.

RANGES/ UNITS OF MEASURE The 12 input ranges of the DATAshuttle Express span from ± 2.5 milliVolts through ± 10 Volts DC, making it capable of accepting data from almost any sensor. The terminal drawers provide signal conditioning for the measurement of current, voltage, resistance, frequency, temperatures (thermocouples, RTDs, thermistors or semiconductor sensors), weight, vibration, sound, strain, pressure, force, displacement, torque, acceleration, and humidity. (See page 2–9 for a complete description of sensor types.)

The DATAshuttle together with our software, such as WorkBench PC for Windows or QuickLog for Windows, make it easy to specify engineering units (degrees, Volts, milliamperes, etc.) for measurements, as well as which ranges to use. You can measure temperature, for example, by selecting from among 11 different thermocouple types, or from a wide variety of Platinum resistance temperature devices (RTDs). With the application software, the process simply consists of selecting the type of sensing device from a menu - the driver itself automatically handles cold junction compensation and linearization.

DATA PRESENTATION The combination of Strawberry Tree hardware and application software enables both the display of data on the screen, and the logging of data to disk for later analysis.

The system is capable of showing data on the monitor in a variety of formats. On-screen meters can provide accurate display of any

parameter on any channel. Chart displays can indicate trends for comparison of actual measurements on several channels, or for setting data points or alarms.

SIGNAL CONDITIONING A wide range of sensors can be directly connected to the termination drawers. Complete signal conditioning and sensor excitation is built in.

NOISE REJECTION The *DATAshuttle Express* incorporates noise filtering. When the sample rate is less than the maximum, samples may be still taken near the maximum rate and averaged by the on-board digital signal processor (DSP) using the “average” selection of the resolution. This reduces the already low noise of the *DATAshuttle Express* by 10 times or more.

Some terminal drawers provide anti-aliasing filters to remove high frequency signals that can interfere and invalidate data. The cut-off frequency is selected in software.

UPDATES The software that runs the DSP in the *DATAshuttle Express* is stored in nonvolatile RAM. It is updated automatically when a program is run. This allows the *DATAshuttle Express* to be updated with new features so it won't become obsolete.

Features and Configurations

The *DATAshuttle Express* makes measurements with 13-bit resolution, twice as good as standard 12-bit data acquisition products. This allows the bipolar voltage ranges (+/-10 Volts, +/-5 Volts, etc.) to be used for unipolar inputs (0 to 10 Volts, 0 to 5 Volts, etc.) while maintaining full 12-bit resolution.

ANALOG INPUT CHANNELS The *DATAshuttle Express* has 16 differential analog inputs, eight in each terminal drawer.

RANGES There are 12 voltage ranges and 10 current ranges, all selected individually for each channel. Some terminal drawers lack current ranges.

DATA ACQUISITION SPEED The data acquisition rate for the *DATAshuttle Express* is 100,000 samples per second, divided by the number of channels in use. Ranges below ± 25 mV have a maximum sample rate of 50,000 samples per second.

NOISE REJECTION The on-board DSP can improve noise rejection by averaging as the sample rate is reduced from 100,000 samples/second to 390 samples/second. Power line rejection can be selected at sample rates at or below 60 Hz (or 50 Hz).

SENSORS The DATAshuttle supports a wide range of sensors. Refer to the chapter on terminal drawers for details. Sensor excitation voltages or currents and signal conditioning are built in to each drawer.

ACCURACY The specified accuracy is guaranteed for a period of two years from the date of purchase. Calibration constants are stored in nonvolatile memory.

INPUT PROTECTION Analog inputs are protected from damage for inputs of ± 35 V when powered, ± 20 V when unpowered.

ANALOG OUTPUT CHANNELS The DATAshuttle Express has two analog outputs, one in each terminal drawer. Each output has one current (4-20 mA) and six voltage ranges, software selectable.

DIGITAL I/O There are 12 digital inputs and 12 digital outputs, six in each terminal drawer.

ISOLATION The digital I/O lines on all terminal drawers may be galvanically isolated to protect the DATAshuttle using plug-in modules. The output modules allow switching up to 120 VAC at 3 Amps. Each module occupies one digital input and one digital output line.

The TD-ISO drawer accepts analog isolation modules for analog inputs or outputs. This higher drawer, which requires the DATAshuttle Express for isolation (model DS-EXP-ISO) for operation, can handle up to 250 VAC on analog inputs, analog outputs or digital I/Os.

COUNTER/TIMER There are two counter/timers, one in each terminal drawer, for pulse counting, frequency measurement, and precise timing.

SELF-CALIBRATION The DATAshuttle recalibrates its analog inputs and outputs on command to keep them at the factory-fresh accuracy.

SELF-TEST Each time the DATAshuttle is powered on it performs a complete self test. The power indicator light turns red and flashes an error code if there is a problem.

RUGGED The DATAshuttle has been tested to operate with 5 G vibration and 30 G shock.

FOR MORE INFORMATION For more information about the capabilities of your DATAshuttle Express, please see the "Product Specifications" in Chapter 4.

For instructions on controlling the unit with our interface software (such as WorkBench PC for Windows or QuickLog for Windows), refer to that particular software manual.

To learn more about data acquisition and process control in general, and how to use the Strawberry Tree systems together to accomplish everyday tasks, consult our *Applications Reference* in Chapter 3 of this manual.

And, last but not least, if you're creating your own program to address the unit for a custom purpose, please review the tools and utilities provided in the optional Analog Connection Windows Development System. Note that the DATAshuttle Express only works in Windows; it is not supported by a DOS driver.

SYSTEM REQUIREMENTS Before installing the DATAshuttle Express, make sure the computer system fulfills these minimum requirements:

Hardware –

- **Microsoft/Intel 386-DS PC or higher**, with at least 4 MB of system RAM,
- **3.5" floppy disk drive and a hard drive.**

Software Environment –

- **Windows 3.1 or 95** (Windows NT will be supported soon),
- **Application software** (WorkBench PC for Windows, QuickLog for Windows, the Analog Connection Windows Development System, or other compatible proprietary software; please see your software manual for directions for using it with the DATAshuttle Express).

PACKAGE CONTENTS Your DATAshuttle Express package should include:

- One DATAshuttle Express
- Terminal drawers you ordered
- One power adapter with IEC universal power connector
- Two locking screws for the power connector
- One parallel cable (DB-25 M-F)
- This binder, including the following manuals: DATAshuttle Express and QuickLog for Windows)
- One set of QuickLog for Windows Disk (two disks)
- One Quickstart card.

DATAshuttle Express Models and Accessories

You may adapt your DATAshuttle Express to almost any job by selecting from the terminal drawers that provide different signal conditioning for sensors. See Chapter 2 for more information.

In addition to the standard DATAshuttle Express, there is a DATAshuttle Express for isolation (model DS-EXP-ISO) which accepts terminal drawers that are 3.2 inches (8.2 cm) high, rather than the standard 2.2 inches (5.6 cm). This DATAshuttle Express is 3.8 inches (9.8 cm) in overall height, while the standard DATAshuttle Express is 2.8 inches (7.2 cm) high. The TD-ISO drawer requires the DATAshuttle Express for isolation. It will not fit into the standard DATAshuttle Express.

For applications with large numbers of channels, up to four standard DATAshuttle Express may be installed in one DATAdock (model BP-DS-EXP). It is a compact portable way to have large numbers of channels without losing any of the accuracy and convenience of the DATAshuttle Express.

The DATAshuttle Express is shipped with an AC power adapter that accepts 90 to 264 VAC, 47 to 63 Hz. The PWR/DC-DSE replaces the AC power adapter when using a DC power source. It accepts 9 to 36 VDC.

Installing Your DATAshuttle Express

Getting your DATAshuttle Express up and running is a straightforward process; you only need to:

- ***Connect the DATAshuttle Express to the parallel port of a computer,***
- ***Connect power to the DATAshuttle Express, and***
- ***Apply power to the DATAshuttle Express and computer at the same time.***

Guidelines for loading the software, and for starting up, depend on the application program you are going to use (such as our WorkBench PC for Windows, QuickLog for Windows, or a package from a third party).

The program you are going to use with the DATAshuttle Express might even be unique and proprietary, a product of your organization. The Analog Connection Windows Development System (ACWDS) is a powerful set of utilities making it possible for software engineers to design and develop their own programs to exploit the many features of the DATAshuttle Express.

In any event, please refer to the software provider's installation manual, or user guide, for specific information on how to load and run the particular program.

Troubleshooting – If you have any difficulty getting your unit to work, refer to the “Troubleshooting” section in Chapter 4.

Physical Installation

Installation very simply consists of plugging the DATAshuttle's DB-25 cable into the parallel port outside your computer. The DATAshuttle Express may not be used in combination with any of our other data acquisition products.

SINGLE UNIT INSTALLATION *To Install a DATAshuttle Express—*

1. **Turn the computer off.** It is a good idea not to plug anything into the computer's parallel port without first turning its power switch to the "off" position.
2. **Connect the parallel input connector** on the back of the DATAshuttle Express to the parallel port on your computer with the provided DB-25 cable. The parallel port on the PC has 25 pins and is often labelled "Printer" or "LPT." Computers may have up to four parallel ports; the DATAshuttle Express may be connected to any one of these. There are two 25-pin D-sub connectors on the back of the DATAshuttle Express; use the male connector.
3. **Connect the provided AC Adapter** to the power input just above the two D-sub connectors. Plug the AC Adapter into a power line that is between 110 and 240 VAC, 50 to 60 Hz.

OR

Connect the optional DC Adapter to the power input just above the two D-sub connectors. Connect the remaining cable on the adapter to a DC source, such as a battery, that is between 9 and 36 VDC. The DC adapter will consume up to 25 W from the DC source so be sure the source can maintain 9 V when supplying 25 W (2.8 A at 9 V). The cable may be plugged directly into a cigarette lighter in a car, or you may cut off the cigarette lighter adapter and connect to the DC power source using a connector you provide.

4. **Install one or two terminal drawers** by pulling one of the ribbon cables out of the DATAshuttle Express and plugging it into the connector on the back edge of the drawer. Engage the edges of the drawer in the guides in the DATAshuttle Express, and slide the drawer in until the front panel is flush with the unit. Fasten the drawer securely into place with the thumb screw. See Chapter 2 for more information about installing drawers.

5. **Connect the sensors needed for your application:** Slide out a drawer and connect the sensors to the screw terminals. Slide the drawer back in. You may wish to refer to the *Applications Reference* manual and Chapter 3 of this manual for examples of particular applications.
6. **Lock the power connector** using the optional locking screws. If you want the power connector attached more securely, simply screw them into the two white plastic projections on either side of the power connector on the back of the DATAshuttle Express. When the screws are in place, the power connector may be easily slid into place. To remove it, use a flat screwdriver to gently pry loose the plastic tabs.
7. **Apply power** to the DATAshuttle Express and computer at the same time.



CAUTION Disconnect any high voltage power to terminals for safety before removing, installing, or making connections to the terminal drawers.

**MULTIPLE UNIT
INSTALLATION**

To install more than one DATAshuttle Express— Follow the steps above to install the first DATAshuttle Express. Then for every additional unit you wish to install, simply connect the parallel input port of that DATAshuttle Express to the passthrough port of the previously installed DATAshuttle Express, using the additional DB-25 cables.

You may also use the DATAdock to interconnect units without cables.

To Install Multiple Units in the DATAdock –

1. **Slide each unit into the DATAdock.** Be sure to press them firmly into place so that the parallel port and power connectors are fully engaged.
2. **Twist the thumb screws into the sides** of the DATAshuttle Express until they clamp securely to the notches in the DATAdock.
3. **Connect the parallel connector on the right** of the back of the DATAdock to the computer's parallel port using one of the provided DB-25 cables. If you have another DATAdock, connect a DB-25 cable from the remaining parallel connector on the first unit to the right parallel connector on the second unit.
4. **Connect a power cord to the back of the DATAdock.** Plug the power cord into a power line that is between 110 and 240 VAC, 50 to 60 Hz.

Using either of the above methods, you may connect up to 15 DATAshuttles to one computer. Please note, however, that only one DATAshuttle Express may be powered from the same power adapter. Therefore, each unit requires its own adapter, unless the DATAdock is used.



CAUTION You must connect all your DATAshuttle Express to one parallel port to use them in synchronous mode. In synchronous mode the first DATAshuttle Express sends a clock signal through the parallel cable to all the others to synchronize their data acquisition. The synchronizing signal cannot be sent from one parallel port to the next. The application software should indicate whether it uses synchronous mode or not: WorkBench PC for Windows does; synchronous mode is optional in QuickLog for Windows.



CAUTION Do not install regular DATAshuttles and DATAshuttle Express on the same parallel port. They use different data protocols and will not work together.



CAUTION It is not necessary, nor advisable, to open the DATAshuttle Express, except for sliding out terminal drawers. There is no need to make internal adjustments when setting up your application, and it may be difficult to reassemble the unit correctly should you choose to do so.

A Note on Board Numbers— When you are using multiple units in your installation, each unit needs to have an identity, or “board number,” for the software to recognize it as “individual.”

When the software is loaded, it conducts a search for all installed hardware, scanning for any DATAshuttle Expresss connected to the parallel ports. The DATAshuttle Express connected at LPT1 nearest to the computer is assigned the first available board number. Additional DATAshuttle Express on LPT1 are assigned sequentially higher board numbers. This process is repeated on LPT2, LPT3, and LPT4 until all units have received a board number. The first unit has channels 1-16.

PRINTER INSTALLATION *If you wish to use a printer on the same parallel port as a DATAshuttle Express* – Connect the printer cable to the passthrough port of the last DATAshuttle Express in the series. When using the DATAdock, connect the printer to the remaining port on the last DATAdock.

NEXT STEPS *Installing the Software* – For information on loading and configuring WorkBench PC for Windows, QuickLog for Windows, or other software please refer to the user guide for that software package.

Chapter 2: Terminal Drawers

Terminal drawers serve as a convenient interface between the real world and the DATAshuttle Express internal circuitry, providing screw terminals or BNC connectors for connections to sensor wires.

There are several drawer types available; each is designed to meet different signal conditioning needs. Up to two drawers may be installed in a single DATAshuttle Express.

TYPES OF DRAWERS There are eight types of terminal drawer:

- **General Purpose** - TD-GP
- **General Purpose with BNC connectors** - TD-GP/BNC
- **General Purpose with anti-aliasing filter and BNC connectors** - TD-GP/AAF
- **Low Cost** - TD-GP/LC
- **Thermocouple** - TD-TC
- **Piezoelectric** - TD-PE
- **Piezoelectric with anti-aliasing filter** - TD-PE/AAF
- **Analog Isolation** - TD-ISO

The features and benefits of the different types of terminal drawer are discussed in the corresponding sections of this chapter.

Physical Installation

To Install a Terminal Drawer –

1. **Make sure that the DATAshuttle Express is properly installed** per the instructions in Chapter 1.
2. **Locate one of the ribbon cables inside of the DATAshuttle Express.**
The cable is located inside the slot into which the terminal drawers slide. Pull the cable straight out until approximately one inch (2.5 cm) is exposed. NOTE: It may be necessary to remove a blank front panel to gain access to the inside of the DATAshuttle Express.
3. **Plug the cable into the connector** on the back edge of the drawer. The connector is keyed to prevent improper connections.
4. **Connect the sensors needed for your application** to the screw terminals or BNC connectors on the terminal drawer. Connect low level signals like thermocouples first (lower channel numbers) to avoid crosstalk. Note that it is possible to have connections to both BNCs and screw terminals in the same drawer. Refer to the *Applications Reference* section in Chapter 3 of this manual for examples of particular types of applications.
5. **Engage the edges of the drawer in the guides** on the DATAshuttle Express unit, and slide the drawer in until its front panel is flush with the unit. Wires connected to the screw terminals should exit through the slot in the top of the drawer front.
6. **Fasten the drawer securely into place** with the thumb screw. The thumb screw must be held perpendicular to the drawer front in order to engage.



CAUTION It is not necessary, nor advisable, to open the DATAshuttle Express, except for sliding out terminal drawers. There is no need to make internal adjustments when setting up your application, and it may be difficult to reassemble the unit correctly should you choose to do so.



CAUTION The TD-ISO terminal drawer may only be installed in a DATAshuttle Express for isolation (model DS-EXP-ISO). It does not fit into a standard DATAshuttle Express.



CAUTION Disconnect high voltage power going to terminals for safety before removing, installing, or making connections to the terminal drawers.



CAUTION Do not connect devices that will draw excessive power from the power terminals on the drawer. Although all power terminals have overcurrent protection, the temperature could rise too high in certain situations. (*See the Specifications section in Chapter 4 for more details.*)

To remove a drawer, pull out the connector. If it is a new unit, the connection may be tight; use a screwdriver on the edge of the connector (where there is a small notch) to loosen it.

Types of Terminal Drawers

As was stated in the introduction, there are eight types of terminal drawer, each providing for different signal conditioning needs.

TD-GP The most flexible drawer available, the TD-GP can measure most types of analog inputs, including voltage, current, resistance, temperature (thermocouples, RTDs, thermistors, and semiconductor sensors), or strain gauges. Each channel may be configured for a different sensor.

For current measurements, there are switches for each channel that can individually connect a current shunt resistor. Plug-in signal conditioning resistors may also be installed separately in each channel to provide accurate measurement of 2- or 4-wire resistance, 2-, 3-, or 4-wire RTDs, standard or linear thermistors, and quarter-, half-, or full-bridge strain gauges. The TD-GP also features cold junction compensation for thermocouple applications. (*NOTE: For accurate thermocouple measurements, the TD-TC drawer, featuring an aluminum isothermal block, is recommended.*)

A separate switch for each channel, labelled “Floating/Gnd Ref,” provides a ground reference for an input when needed. All inputs must have a ground reference so they don’t exceed the common mode input range of the DATAshuttle. This switch provides that reference in case it is not provided by the input signal. If in doubt, set the switch to “Gnd Ref.” The ground reference is provided through a 348 k Ω resistor to avoid ground loops. The resistance

value may be changed by plugging in a different value resistor for R5. In addition, the switch may be used to provide shunt calibration of strain gauges by placing a high resistance across one leg of the strain gauge bridge to simulate a load on the strain gauges.

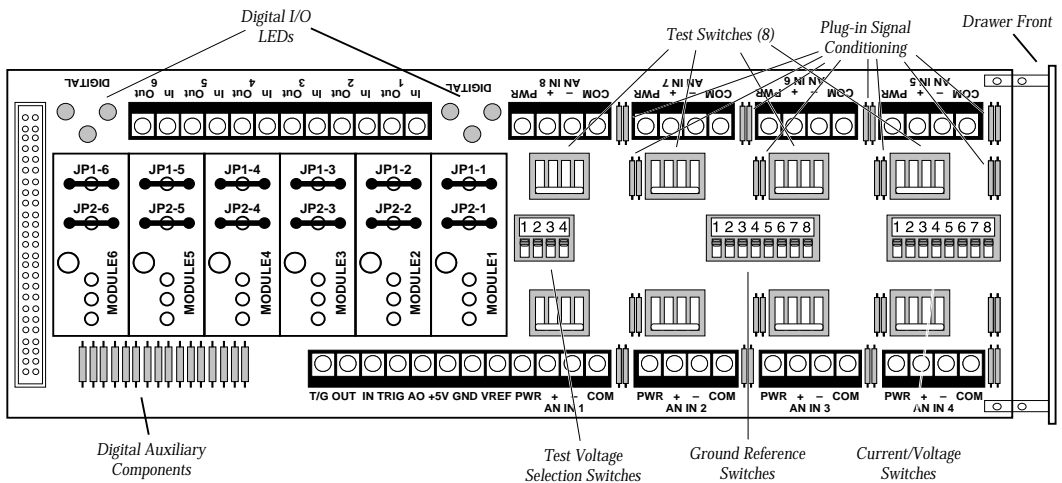
Each channel on the TD-GP has a Test switch. The external signal and on-board signal conditioning are disconnected, and an internal DC voltage is connected to test the operation of the DATAshuttle Express, the computer, and the software, making the DATAshuttle Express easy to configure. A separate switch selects the test voltage that is applied.

The TD-GP has screw terminals for eight analog inputs, one analog output, six digital inputs, six digital outputs, one counter/timer, a trigger input, one precision sensor excitation voltage, +5 V, digital ground, and analog ground. Up to six digital isolation modules may be installed. Cut jumpers JP1 and JP2 before installing a module. The sensor excitation or power may be switched to 10 V or 2.5 V.

CAUTION The maximum voltage on a digital input or output when using isolation modules is 125 V AC or DC. For CE requirements, the maximum is 60 V AC rms. Without isolation modules, the digital input must be between 0 and +5 V. The digital output must be between 0 and +30 V.



Figure 1. Illustration of the TD-GP and TD-GP/BNC Terminal Drawers –



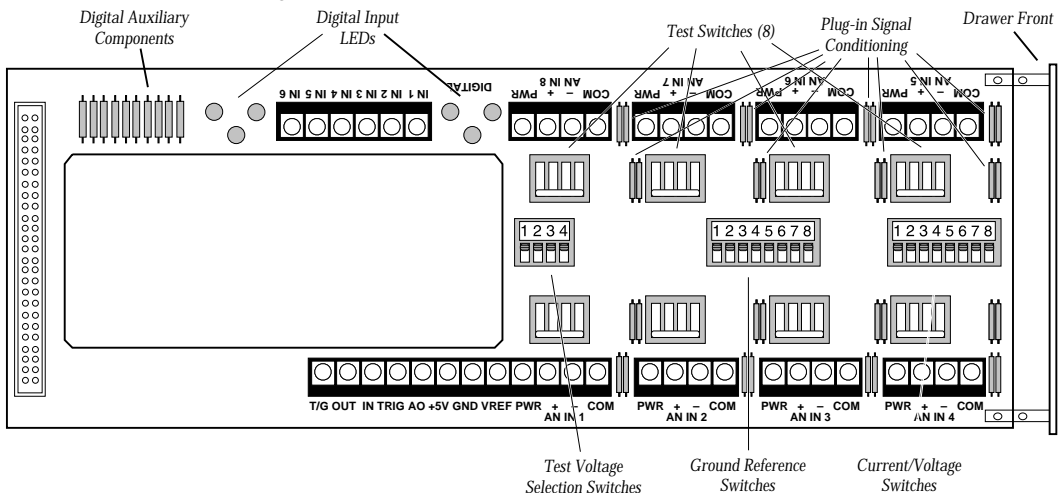
TD-GP/BNC The TD-GP/BNC is virtually the same as the TD-GP except it has eight BNC connectors to connect analog inputs without opening the drawer. The center of the BNC connector is connected to the “+” terminal. The barrel of the BNC connector is connected to the “-” terminal, and can be floating, or ground-referenced, as described in the TD-GP section above. The BNC connectors can be reconnected to any input or output on the drawer, adding great flexibility.

TD-GP/AAF The TD-GP/AAF is the same as the TD-GP/BNC with the following exceptions. A five-pole Butterworth filter may be selected on any or all of the eight analog inputs with a software selection. It may be used to remove high frequencies to prevent aliasing errors. The filter cut-off frequency is selected with a software selection to any frequency between 12 Hz and 40 KHz. It may be set with a precision of about 1%. All channels have the same cut-off frequency. The filter may be deselected on any channel to improve the accuracy of slow low-level signals like thermocouples. To minimize noise and offset, three sets of gain may ranges may be chosen:

- **Low** gives a maximum input of ± 100 mV
- **Medium** gives a maximum input of ± 1 V
- **High** gives a maximum input of ± 10 V.

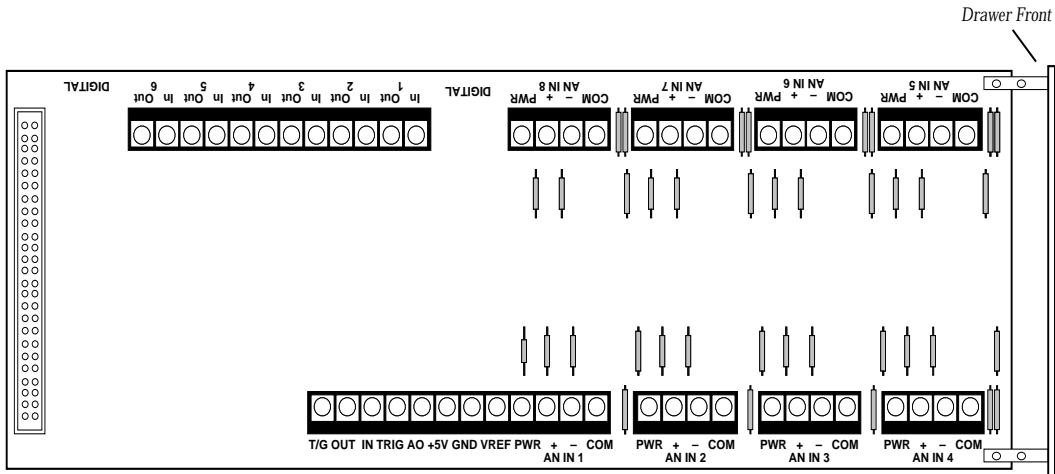
The sets of gain ranges may be different for the first four channels and the last four channels. There are no additional switches, terminals or adjustments needed for the filters. There are no digital outputs or provision for isolated digital input modules. Like the TD-GP/BNC, the front panel has BNC connectors for all eight analog inputs.

Figure 1a. Illustration of the TD-GP/AAF Terminal Drawer –



TD-GP/LC The TD-GP/LC is a low-cost drawer that has no switches, no signal conditioning and no sockets for isolated digital modules. It is best suited for non-isolated analog voltage input, non-isolated analog outputs and non-isolated digital input/output. It also has counter/timer support and VREF fixed at 10.0 Volts.

Figure 2. Illustration of the TD-GP/LC Terminal Drawer –



TD-TC The TD-TC drawer is designed to provide the most precise and accurate measurement of thermocouples. All of the analog input screw terminals are mounted on an aluminum block. This block keeps all the terminals at the same temperature, providing highly accurate cold junction compensation. The TD-TC is not limited to thermocouples, however. It can also measure voltage, current, resistance, or temperature (RTDs, thermistors, and semiconductor sensors) analog inputs.

Each channel may be configured for a different sensor. To measure current, a shunt resistor must be installed across the input terminals. Plug-in signal conditioning resistors may be installed separately in each channel to provide measurement of 2-wire resistance, 2-wire RTDs, and standard thermistors. For precise 4-wire resistance or 3- and 4-wire RTD measurements or for strain gauges, use the TD-GP, TD-GP/BNC, or TD-GP/AAF.

A separate switch for each channel labelled "Floating/Gnd Ref" provides a ground reference for an input when needed. The ground reference is provided through a 348 k Ω resistor to avoid

ground loops or damage when it is switched by mistake. The resistance may be changed by plugging in a different value resistor.

Open sensor detection is provided to give a full scale positive indication when a thermocouple or other input is broken or disconnected. The 22 MΩ resistance can be unplugged on any channel if it is not desired.

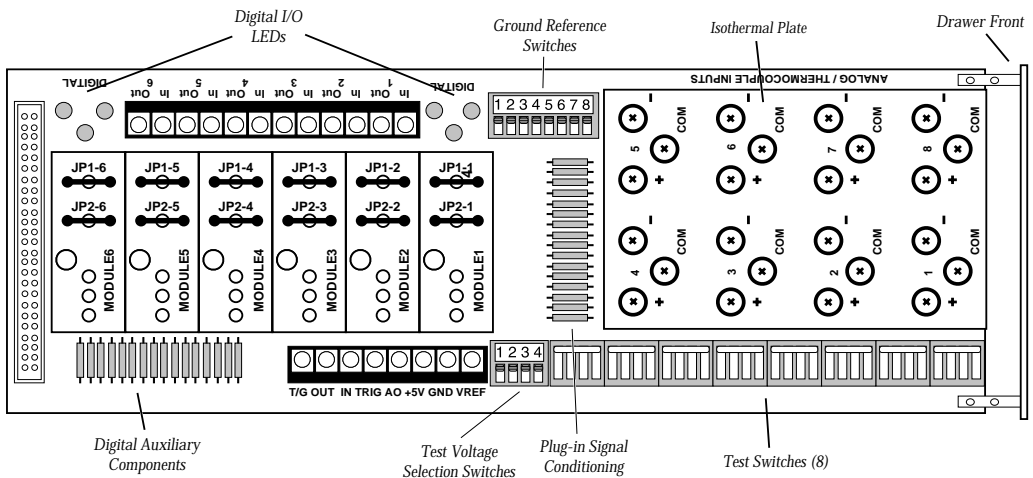
Each channel has a Test switch. The external signal and on-board signal conditioning are disconnected and an internal DC voltage is connected to test the operation of the DATashuttle Express, the computer, and the software, making the DATashuttle easy to configure. A separate switch selects the test voltage that is applied.

The TD-TC has screw terminals for eight analog inputs, one analog output, six digital inputs, six digital outputs, one counter/timer, a trigger input, one precision sensor excitation voltage, +5 V, digital ground and analog ground. Up to six digital isolation modules may be installed. Cut jumpers JP1 and JP2 before installing a module. The sensor excitation or power may be switched to 10 V or 2.5 V.



CAUTION The maximum voltage on a digital input or output when using isolation modules is 125 V AC or DC. For CE requirements, the maximum is 60 V AC rms. Without isolation modules, the digital input must be between 0 and +5 V. The digital output must be between 0 and +30 V.

Figure 3. Illustration of the TD-TC Terminal Drawer –



TD-PE The TD-PE drawer is designed to interface to piezoelectric sensors that are used to measure acceleration and vibration. The TD-PE can also measure audio inputs, voltage, and temperature from thermocouples. A 4 mA current source and capacitive coupling are provided for each channel for accelerometers. The current source has a compliance of 23 V, so that this drawer can measure accelerometer inputs up to 20 V peak to peak.

Chapter 3 shows how to connect these signals. There are three plug-in signal conditioning resistors. The input impedance and time constant of the capacitive coupling are set by R3. It is 1 M Ω as provided. R5 provides a connection between the "AN IN-" terminal and ground. The current source may be changed to other values between 0 and 10 mA by changing plug-in resistor R10 as follows:

Current	R10
10 mA	6.8 Ohms
4 mA	18 Ohms
2 mA	33 Ohms
1 mA	68 Ohms
500 μ A	130 Ohms
100 μ A	680 Ohms
10 μ A	6,800 Ohms
1 μ A	68,000 Ohms
zero	omit

Each channel has an "AC Coupled/DC Coupled" switch and a "DC+" screw terminal in addition to the "AN IN +" terminal. The AC Coupled/DC Coupled switch is only used to test an accelerometer by checking its bias voltage. Normally this switch should be set to AC Coupled. Use the "DC+" screw terminal for other inputs, such as voltage or temperature (thermocouples). Each channel may be configured for a different sensor. (*NOTE: For accurate thermocouple measurements, the TD-TC drawer, featuring an aluminum isothermal block, is recommended.*)

Each channel has a Test switch. The external signal and on-board signal conditioning is disconnected and an internal DC voltage is connected to test the operation of the DATAshuttle Express, the computer, and the software. A separate switch selects the test voltage that is applied. Unique to the TD-PE is a switch on the Test Voltage Selection Switches block that turns the 24 V power supply for the current source on and off. It reduces power dissi-

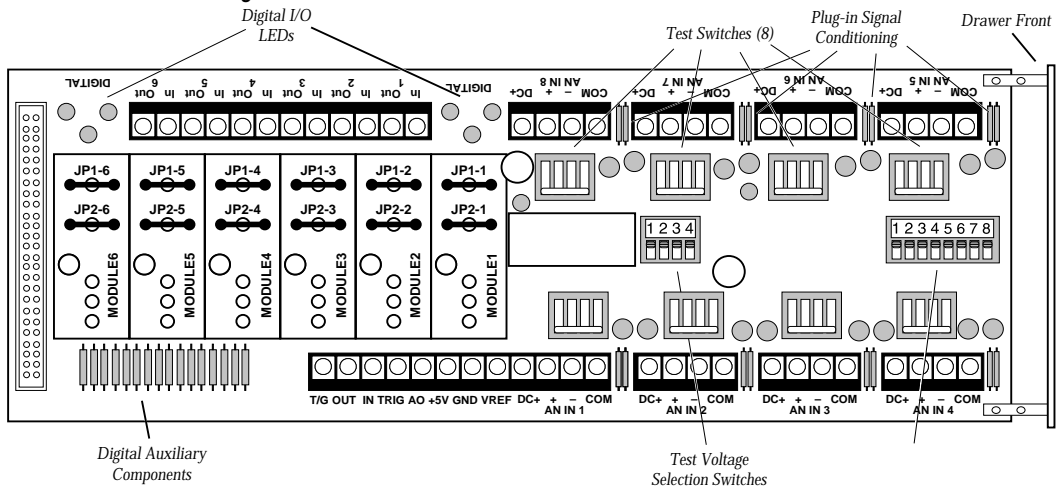
pation by 1.1 Watt (when the current sources are 4 mA) and may reduce the noise on analog inputs slightly when the 24 V power supply is turned off. This turns off all the current sources that are used by accelerometers.

The TD-PE has screw terminals for eight analog inputs, one analog output, six digital inputs, six digital outputs, one counter/timer, a trigger input, one precision sensor excitation voltage, +5 V, digital ground, and analog ground. Up to six digital isolation modules may be installed. Cut jumpers JP1 and JP2 before installing a module. The sensor excitation or power may be switched to 10 V or 2.5 V.



CAUTION The maximum voltage on a digital input or output when using isolation modules is 125 V AC or DC. For CE requirements, the maximum is 60 V AC rms. Without isolation modules, the digital input must be between 0 and +5 V. The digital output must be between 0 and +30 V.

Figure 4. Illustration of the TD-PE Terminal Drawer –

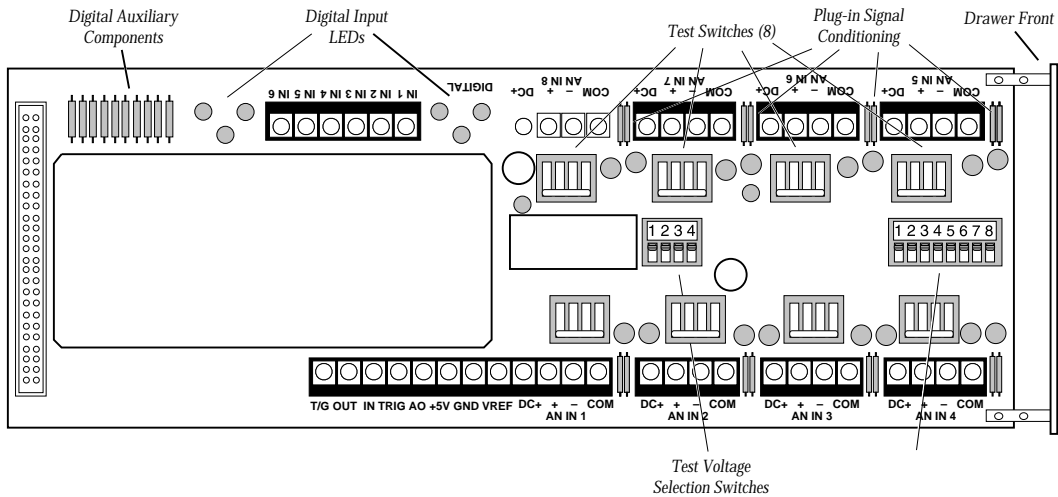


TD-PE/AAF The TD-PE/AAF is the same as the TD-PE with the following exceptions. A five-pole Butterworth filter may be selected on any or all of the eight analog inputs with a software selection. It may be used to remove high frequencies to prevent aliasing errors. The filter cut-off frequency is selected with a software selection to any frequency between 12 Hz and 40 KHz. It may be set with a precision of about 1%. All channels have the same cut-off frequency. The filter may be deselected on any channel to improve the accuracy of slow low-level signals like thermocouples. To minimize noise and offset, three sets of gain may ranges may be chosen:

- **Low** gives a maximum input of ± 100 mV
- **Medium** gives a maximum input of ± 1 V
- **High** gives a maximum input of ± 10 V.

The sets of gain ranges may be different for the first four channels and the last four channels. There are no additional switches, terminals or adjustments needed for the filters. There are no digital outputs or provision for isolated digital input modules.

Figure 4a. Illustration of the TD-PE Terminal Drawer –



TD-ISO The TD-ISO drawer is designed to accept industry standard 5B analog isolation modules. These modules provide complete galvanic isolation and signal conditioning separately for each channel for measuring voltage, current, thermocouples, RTDs, and strain gauges. The drawer is one inch (2.5 cm) higher than the standard drawer and only fits in the DATAshuttle Express for isolation (model DS-EXP-ISO).

Current input isolation modules come with a separate shunt resistor. It may be installed in the sockets labelled R3, but due to limited space, it is necessary to solder short wires to lengthen the pins on the shunt resistor.

The TD-ISO can also measure nonisolated analog inputs that are voltage or current by installing jumpers connecting Pins 5 to 19 and 6 to 18 (see Figure 5), and by cutting jumper JP3 at each analog isolation module. JP3 may be left uncut to connect “AN IN-” to ground.



CAUTION Be careful not to connect high voltages when these jumpers are in place, or the DATashuttle will be damaged. The maximum voltage on any input when using 5B isolation modules is 150 V AC or DC. For CE requirements, the maximum is 60 VDC or 30 VAC rms.

Each channel has a Test switch. The external signal and on-board signal conditioning is disconnected and an internal DC voltage is connected to test the operation of the DATashuttle, the computer, and the software, making the DATashuttle easy to configure. A separate switch selects the test voltage that is applied, 2.5 or 10.0 V.

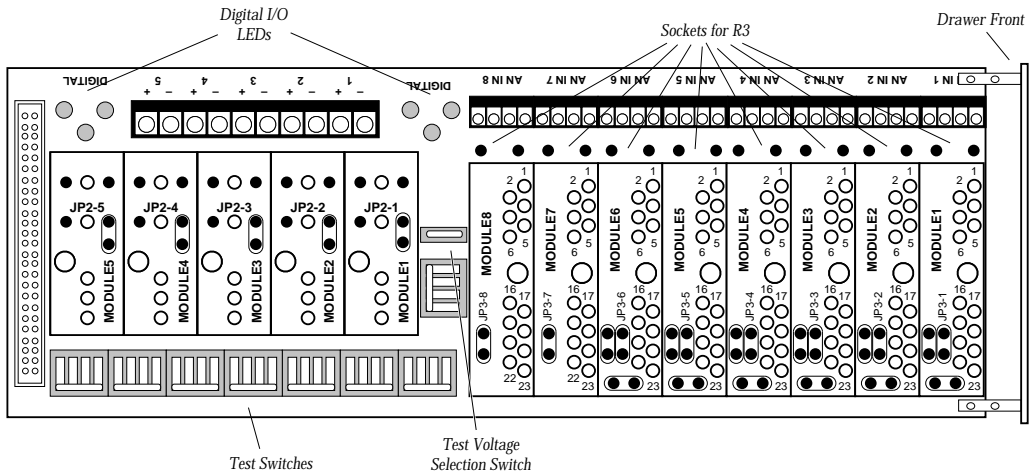
The TD-ISO has screw terminals for eight analog inputs, five digital inputs, and five digital outputs. Up to five digital isolation modules may be installed. Each digital isolation module occupies one input and one output. One analog output isolation module may be installed in place of an analog input module.

Non-isolated digital inputs or outputs may be connected to the TD-ISO if jumper JP2 is installed at each digital module. The digital input is connected to the digital output, so only one may be used at a time. The terminal labelled “-” connects to the input or output; the “+” terminal is not connected. Because the input and output are connected, the open connector output may not have more than 5 V on it.



CAUTION Be careful not to connect more than 5 V or less than 0 V when JP2 is in place, or the DATashuttle will be damaged.

Figure 5. Illustration of the TD-ISO Terminal Drawer –



Selecting the Right Terminal Drawer

AVAILABLE CHANNELS The following charts show the number of channels available for each type of measurement, or output, on each type of terminal drawer.

For Various Types of Measurement –

<i>Measurement</i>	<i>TD-GP</i>	<i>TD-GP /BNC</i>	<i>TD-GP /AAF</i>	<i>TD-GP /LC</i>	<i>TD-TC</i>	<i>TD-PE</i>	<i>TD-PE/ AAF</i>	<i>TD-ISO</i>
Voltage	8	8	8	8	8	8	8	8
Isolated Voltage	–	–	–	–	–	–	–	8
Current	8	8	8	8 ⁴	8 ⁴	8 ⁴	8 ⁴	8 ⁴
4-20 mA Signal	8	8	8	8 ⁴	8 ⁴	8 ⁴	8 ⁴	8 ⁴
Isolated Current	–	–	–	–	–	–	–	8 ⁴
Isolated 4-20 mA Signal	–	–	–	–	–	–	–	8 ⁴
Resistance	8	8	8	–	8 ⁵	–	–	–
Thermocouple	8 ³	8 ³	8 ³	–	8	8 ³	8 ³	–
Isolated Thermocouple	–	–	–	–	–	–	–	8
RTD	8	8	8	–	8 ⁶	–	–	–
Isolated RTD	–	–	–	–	–	–	–	8
Temperature (thermistor)	8	8	8	–	8 ⁷	–	–	–
Temperature (DC Voltage)	8	8	8	–	8	–	–	8 ⁹
Temperature (DC Current)	8	8	8	8 ⁴	8 ⁴	8 ⁴	8 ⁴	8 ^{4,9}
Humidity (DC Voltage)	8	8	8	8	8	8	8	8
Strain ¹	8	8	8	–	–	–	–	–
Isol. Strain Gauge Input ¹	–	–	–	–	–	–	–	8
Pressure ¹	8	8	8	–	–	–	–	–
Pressure (DC Voltage)	8	8	8	8	8	8	8	8
Force ¹	8	8	8	–	–	–	–	–
Weight ¹	8	8	8	–	–	–	–	–
Displacement ¹	8	8	8	–	–	–	–	–
Torque ¹	8	8	8	–	–	–	–	–
Acceleration ¹	8	8	8	–	–	–	–	–
Acceleration ²	–	–	–	–	–	8	8	–
Acceleration (DC Voltage)	8	8	8	8	8	8	8	8
Vibration ¹	8	8	8	–	–	–	–	–

Measurement	TD-GP	TD-GP /BNC	TD-GP /AAF	TD-GP /LC	TD-TC	TD-PE	TD-PE/ AAF	TD-ISO
Vibration ²	–	–	–	–	–	8	8	–
Sound	8	8	8	8	8	8	8	–
Frequency (DC Voltage)	8	8	8	8	8	8	8	8
Frequency (AC Signal)	1	1	1	1	1	1	1	–
Pulse Counting	1	1	1	1	1	1	1	–
Digital Input	6	6	6	6	6	6	6	5
Contact Closure	6	6	6	–	6	6	6	5 ⁸
TTL Level	6	6	6	6	6	6	6	5 ⁸
Isolated DC On/Off Sense	6	6	–	–	6	6	–	5
Isolated AC On/Off Sense	6	6	–	–	6	6	–	5

For Various Types of Output –

Output	TD-GP	TD-GP /BNC	TD-GP /AAF	TD-GP /LC	TD-TC	TD-PE	TD-PE/ AAF	TD-ISO
Digital Output	6	6	–	6	6	6	–	5
On/Off Control	6	6	–	6	6	6	–	5
Open Collector Switch	6	6	–	6	6	6	–	5 ⁸
Isolated DC Switch	6	6	–	–	6	6	–	5
Isolated AC Switch	6	6	–	–	6	6	–	5
Analog Voltage	1	1	1	1	1	1	1	–
Analog 4-20 mA Signal	1	1	1	1	1	1	1	–
Isolated Current	–	–	–	–	–	–	–	1 ¹⁰
Isolated 4-20 mA Signal	–	–	–	–	–	–	–	1 ¹⁰
Proportional Control	1	1	1	1	1	1	1	1 ¹⁰

1. Using resistance strain gauge technology.
2. Using piezoelectric sensor technology.
3. Accurate to about $\pm 5^\circ \text{C}$ due to lack of isothermal junction.
4. Requires the installation of a sense resistor.
5. Two-wire resistance measurement only. TD-GP, TD-GP/BNC, and TD-GP/AAF drawers can perform 2-, 3-, and 4-wire resistance measurements.
6. Accepts 2-wire RTDs only. TD-GP, TD-GP/BNC, and TD-GP/AAF drawers accept 2-, 3-, and 4-wire RTDs. The TD-ISO drawer accepts 2- and 3-wire RTDs.
7. Standard 2-terminal thermistors only. TD-GP, TD-GP/BNC, & TD-GP/AAF drawers accept linear thermistors also.
8. Selected in each channel by the installation of a jumper. Do not connect high voltages to the digital terminals when the jumper is installed.
9. Requires an external power source.
10. Reduces number of analog inputs by one.

Screw Terminals

The following charts show the different types of channels available on the various terminal drawers.

ANALOG TERMINALS *Functions of the Analog Terminals –*

Terminal Name	Function
AN IN +	Positive analog input terminal
AN IN -	Negative analog input terminal
PWR	Power for signal conditioning
COM	Power common for signal conditioning
EXC +	Power for signal conditioning on TD-ISO
EXC -	Power common for signal conditioning on TD-ISO only
DC +	Positive input for other than piezoelectric sensor on TE-PE only

DIGITAL TERMINALS *Functions of the Digital Terminals –*

Terminal Name	Function
IN	Digital input
OUT	Digital output
+	Positive digital I/O on TD-ISO
-	Negative digital I/O on TD-ISO

CT TERMINALS *Functions of the CT (Counter Timer) Terminals –*

Terminal Name	Function
IN	Input of the counter/timer
T/G	Trigger/Gate input that starts or enables the counter/timer
OUT	Not used

OTHER TERMINALS *Functions of the Other Terminals –*

Terminal Name	Function
Trigger	Digital trigger input that starts data acq.
AO	Analog output
+5 V	+5 V power
GND	Ground for digital signals
VREF	Precision power output for signal conditioning

TERMINAL AVAILABILITY *Terminals Available for Each Drawer Type –*

Terminal Name	TD-GP	TD-GP /BNC	TD-GP /AAF	TD-GP /LC	TD-TC	TD-PE	TD-PE/ AAF	TD-ISO
AN IN +	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AN IN -	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
PWR	Yes	Yes	Yes	Yes	–	–	–	–
COM	Yes	Yes	Yes	Yes	Yes	Yes	Yes	–
EXC +	–	–	–	–	–	–	–	Yes
EXC -	–	–	–	–	–	–	–	Yes
DC +	–	–	–	–	–	Yes	Yes	–
IN	Yes*	Yes*	Yes*	Yes	Yes*	Yes*	Yes*	–
OUT	Yes*	Yes*	–	Yes	Yes*	Yes*	–	–
+	–	–	–	–	–	–	–	Yes
-	–	–	–	–	–	–	–	Yes
T/G	Yes	Yes	Yes	Yes	Yes	Yes	Yes	–
OUT	Yes	Yes	Yes	Yes	Yes	Yes	Yes	–
IN	Yes	Yes	Yes	Yes	Yes	Yes	Yes	–
Trigger	Yes	Yes	Yes	Yes	Yes	Yes	Yes	–
AO	Yes	Yes	Yes	Yes	Yes	Yes	Yes	–
+5 V	Yes	Yes	Yes	Yes	Yes	Yes	Yes	–
GND	Yes	Yes	Yes	Yes	Yes	Yes	Yes	–
VREF	Yes	Yes	Yes	Yes	Yes	Yes	Yes	–

* When a digital isolation module is installed, the IN and OUT terminals become either two IN terminals for an input module or two OUT terminals for an output module. For DC modules the OUT terminal is “+” and the IN is “-”.

Analog Inputs

The analog input section of the terminal drawer has several features that make connecting sensors and testing the setup easy.

PLUG-IN SIGNAL CONDITIONING Each channel of the terminal drawers has plug-in signal conditioning. Some have more than others. Chapter 3 gives examples of how to use the plug-in signal conditioning for many different sensors. You can obtain precision parts from us, or from your parts distributor, or you can plug in standard size components, such as 1/4 Watt and 1/8 Watt resistors.

To Install Your Own Components - Bend the leads to a spacing of 0.4 inches (10 mm), and trim the vertical part of the leads to a length of 0.2 inches (5 mm). Then push them gently into the socket holes. Often, the resistor value needed is 0 Ohms. In that case, install a jumper wire (use AWG22-size wire) by cutting and bending it in the same way. NOTE: When the terminal drawer is new, you may need to use a needle nose pliers to gently push the component into the socket.

SENSOR EXCITATION An excitation voltage of 2.5 or 10.0 V is built into the terminal drawers. The TD-PE drawer also has a current output for sensor excitation.

FLOAT/GND REF SWITCH There is a group of eight switches on the terminal drawers with the label "FLOAT" on one side and "GND REF" on the other side. These switches, numbered 1 to 8, are the FLOAT/GND REF switches for the individual analog input channels.

As shipped from the factory, this switch puts a 348 K Ω resistor (R5) between the "AN IN -" input and "COM" when it is in the GND REF position. This is for signals that are floating; i.e., not referenced to ground. When using a non-isolated input, the signal must be referenced to ground either by an external connector or by switching to the GND REF position. The voltage from ground must not be more than the common mode range of ± 10 V.

When a signal is referenced to ground by an external connection, the switch should be put in the FLOAT position.

When you aren't sure if there is an external ground connection, or if a signal is intermittently connected to ground, such as a thermocouple on a corroded surface, put the switch in the GND REF position. The 348 K Ω resistor causes a negligible error in most cases.

When connecting strain gauges, the switch is used to provide shunt calibration. See Chapter 3.

The TD-ISO drawer does not have this switch. A ground reference is not required for an isolated signal. The TD-PE and TD-PE/AAF do not have this switch either, but they do have the resistor R5, which connects the “AN IN-” terminal to ground. Removing R5 is the same as setting the switch to “FLOAT.”

VOLTAGE/CURRENT SWITCH This switch is found only on the TD-GP, TD-GP/BNC, and TD-GP/AAF drawers. It inserts a 25 Ω 1/4 W resistor across the “+” and “-” input terminals to sense current. A current should enter at the “+” terminal and exit at the “-” terminal. Refer to Chapter 3 for more information.



CAUTION Do not allow more than 100 mA of current to flow through the resistor when switched to current. The resistor will overheat and can be permanently damaged.

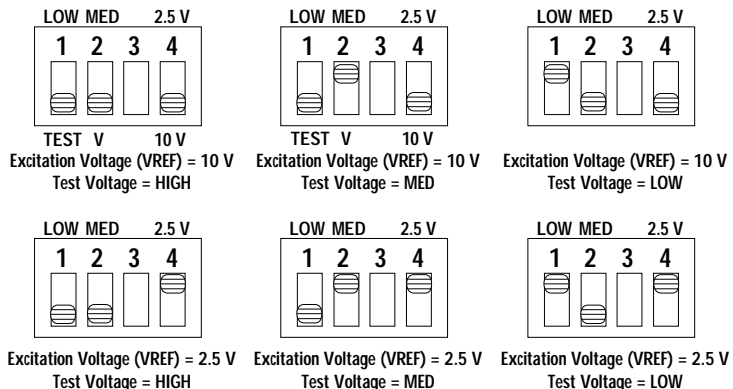
VREF & TEST SWITCHES The test switch for each analog input channel disconnects the inputs and signal conditioning (except for the Voltage/Current switch) and applies a DC test signal to check out the DATAshuttle, computer, and software.

A separate switch selects the DC test signal to be applied. There are three switches:

- **SW1** applies 0 V or a low level signal (LOW).
- **SW2** applies a medium level signal VREF/1000 (MED). The SW1 switch must be off when the SW2 switch is on. If both of these switches are off, a high level VREF is applied.
- **SW4** selects the value of VREF (HIGH). It can be 10.0 V or 2.5 V.

The actual voltage or current applied is as follows. The value is approximate and may differ somewhat from these values.

Settings for VREF & Test Switches –



VREF & Test Voltage Values –

Measurement	VREF	HIGH	MED	LOW
Voltage	10.0	10 V	10 mV	0 V
	2.5	2.5 V	2.5 mV	0 V
Current	10.0	0.1 mA	5 μ A	0 μ A
	2.5	25 μ A	1.25 μ A	0 μ A
E t/c	10.0	–	174° C	25° C
	2.5	–	65° C	25° C
J t/c	10.0	–	209° C	25° C
	2.5	–	72° C	25° C
K t/c	10.0	–	271° C	25° C
	2.5	–	74° C	25° C
N t/c	10.0	–	337° C	25° C
	2.5	–	113° C	25° C
T t/c	10.0	–	232° C	25° C
	2.5	–	83° C	25° C
B t/c	10.0	–	1491° C	25° C
	2.5	–	710° C	25° C
R t/c	10.0	–	972° C	25° C
	2.5	–	325° C	25° C
S t/c	10.0	–	1048° C	25° C
	2.5	–	335° C	25° C
C t/c	10.0	–	586° C	25° C
	2.5	–	186° C	25° C
D t/c	10.0	–	606° C	25° C
	2.5	–	208° C	25° C
G t/c	10.0	–	787° C	25° C
	2.5	–	340° C	25° C
Pt 100 RTD, RS = 100 k	10.0	–	0° C	-273° C
Pt 100 RTD, RS = 100 k	2.5	–	-185° C	-273° C
Pt 100 RTD, RS = 50 k	10.0	–	-125° C	-273° C
Pt 100 RTD, RS = 50 k	2.5	–	–	-273° C

Analog Output

Except for the TD-ISO, the analog output signal appears at the “AO” terminal. The output level is set in software. It may be a voltage or a 4-20 mA current.

The TD-ISO performs analog output when an analog output module is installed in one of the analog isolation sockets. The output appears at the “AN IN +” and “AN IN -” terminals.

Digital Input/Output

There are six digital input terminals and six separate digital output terminals on all terminal drawers except on the TD-ISO, which has only five of each and the TD-GP/AAF and TD-PE/AAF, which have no digital outputs. Each input and output channel shares a common plug-in pull-up resistor, R20, and an LED that shows the state of the channel (the LED is lit when the channel is in a TTL low state).

A diode, D20, connects the output to the input. Both input and output can be used independently by removing diode D20 from the Digital Auxiliary Component area for any channel. This change prevents the output from operating the LED.



CAUTION

Because the digital lines share an LED, the digital output should not be set to low if the interacting digital input is in use, unless diode D20 is removed.

When not using isolation modules, the inputs are TTL levels (low is < 0.8 V, high is > 2.0 V). The minimum input is 0 V; the maximum is 5 V. The output is an open collector. It can sink up to 24 mA of current and go as high as 30 V (5 V on the TD-ISO).

Exceeding these levels will damage the *DATAshuttle*. On the TD-ISO there are no plug-in auxiliary components. Inputs and outputs are completely independent when using isolation modules.

DIGITAL ISOLATION MODULES

Isolated digital modules may be installed on the terminal drawers, but you must first remove jumpers JP1 and JP2 to do so, except on the TD-ISO. The jumpers may be simply cut at each end with a small diagonal cutter and removed. This isolates the screw terminals from the *DATAshuttle*.

Each digital isolation module occupies the space and the screw terminals for an input and output channel, leaving a maximum of six channels available for digital isolation. Both input and output modules may be used in your installation; the terminals labeled IN and OUT become either two input or two output terminals on each channel accordingly.

You must leave diode D20 installed when using isolation modules. See Chapter 3 for more details.



CAUTION You must remove the jumpers JP1 and JP2 when using isolated digital modules (except on the TD-ISO). High voltages that are often applied to the isolated modules will cause severe damage to the DATAshuttle if the jumpers are not removed.

Counter/Timer

The counter/timer has three screw terminals labeled T/G, OUT, and IN above the label “----CT----” on the drawer. The inputs are TTL level (low is < 0.8 V, high is > 2.0 V): they must not go below 0 or above 5 V. The Output is not used.

To Count Pulses or Frequency – Connect the signal to the IN terminal. A pulse is counted each time the input transitions from high to low. When the T/G input is high or unconnected, it starts the counter/timer operating; when it is low, the C/T stops counting.

There is a pull-up resistor on each of the terminals. These may be changed by plugging in the desired value. Refer to Chapter 3 for details about connecting signals to the terminals.

<i>Terminal</i>	<i>Pull-Up Resistor</i>
<i>T/G</i>	<i>R21</i>
<i>IN</i>	<i>R22</i>
<i>OUT</i>	<i>R24</i>

The TD-ISO drawer does not have these terminals.

Trigger Input

The trigger input is a digital signal that signals the DATAshuttle Express to start data acquisition. The input is a TTL level (low is < 0.8 V, high is > 2.0 V): it must not go below 0 or above 5 V. There is a user-changeable plug-in, pull-up resistor, R23. Refer to Chapter 3 for details about connecting signals to the terminal. For information on the use of the trigger input refer to the software documentation.

The TD-ISO drawer does not have this terminal.

Power Terminals

Power is provided on two terminals: +5 V and VREF. +5 V is intended to provide power primarily for digital circuits, such as pull-up resistors. All the pull-up resistors for the digital inputs, outputs, counter/timer terminals, and trigger terminal are pulled up to this voltage.

Circuits that draw power from this source should be grounded to the GND terminal rather than COM to avoid degrading the VREF excitation. A self-resetting fuse protects from over-current on the +5 V terminal. Although the fuse trips at 1.5 A, no more than 1 A should be drawn.

VREF is the sensor excitation intended primarily for providing power for signal conditioning of analog inputs. It is very precise and stable. This power source is connected, through R4, to the PWR pin on the TD-GP, TD-GP/BNC, and TD-GP/AAF drawers. Circuits that draw power from this source should be grounded to one of the COM terminals to have the most accurate stable voltage.

VREF can be 2.50 V or 10.00 V, depending upon the setting of the VREF switch. Changing VREF changes the TEST signal level (see the “Analog Inputs” section of this chapter). VREF is short circuit protected.



CAUTION

The maximum current you should draw from VREF is 230 mA on each terminal drawer. The maximum current you should draw from +5 V is 1 Amp.

The maximum power that should be dissipated inside the DATAshuttle Express using these power terminals or signal conditioning is 7 W. Dissipating more power inside than this may raise the internal temperature too high if the ambient temperature is more than 40° C. This power limit may be reached with any combination of current from +5 V and VREF. NOTE: These limits do not include power dissipated outside the DATAshuttle Express; when dissipated outside, you may dissipate 12 W.

Further information about the accuracy, stability, and current capability of the power sources can be found in the Specifications section in Chapter 4.

The TD-ISO drawer does not have these terminals.

Chapter 3: Applications Reference

As mentioned in Chapter 1, our primary objective is to provide you with data acquisition systems that are easy to install, operate, and maintain. We also strive to furnish the performance you need at the lowest overall cost. The benefits for you are increased productivity, data you can count on, and, of course, meeting your budget.

Part of meeting that objective is expressed in this chapter. Because the DATAshuttle Express is a general purpose tool for data acquisition applications, we provide you with information for your specific application. This chapter gives you a detailed description of how to best use the features embodied in the DATAshuttle Express.

Data acquisition may be divided into two distinct types: ANALOG and DIGITAL. An example of analog data acquisition is measuring (and perhaps, logging to disk) temperature. A digital data acquisition example is to observe the on/off state of a heater, or a limit switch. Further, data acquisition usually refers to measurement (input signal) and control (signal output). Also, most applications have a combination of inputs and outputs, in analog and/or digital formats.

This chapter covers most common, and some not-so-common, applications of the features of the DATAshuttle Express. If your need is not covered here, please call our technical support department.

We begin with a few general sensor connections, followed by several more specific analog and digital applications.

Almost any type of sensor may be connected to the DATAshuttle Express. See Chapter 2 to select the best terminal drawer for your application. For each type of sensor, this chapter gives a detailed description of the connections and software setup. Sensors not covered are usually connected in similar fashion to the ones discussed here.

CONNECTION TYPES Examples of the following are shown in this chapter.

Analog Input –

- Voltage Input Figure 7

- Analog Input for the TD-PE Figure 8
 - Voltage Divider Figure 9
 - Current Figure 10
 - 4-20 mA input Figure 11
 - Isolated current Figure 12
 - Isolated 4-20 mA input Figure 13
 - Resistance Figure 14
 - Thermocouple Figure 15
 - Isolated thermocouple Figure 16
 - RTD Figure 17
 - Isolated RTD Figure 18
 - Thermistor Figures 19, 20
 - IC temperature sensors Figure 21
 - Strain gauges Figure 22
 - Isolated strain gauges Figure 23
 - Pressure sensor Figure 24
 - Piezoelectric sensor (accelerometer) Figure 25
 - Audio Figure 26
 - Filter Figure 27
- Analog Output –**
- Voltage Figure 28
 - 4-20 mA output Figure 28
- Digital Input –**
- Low voltage digital input Figure 29
 - Contact closure sense Figure 30
 - Pulse counting and frequency measurement Figure 31
 - Isolated digital on/off sense Figure 32
- Digital Output –**
- Low voltage digital output Figure 33
 - Open collector switch Figure 34
 - Isolated digital switch Figure 35

Sensor Connections

Before you begin setting up your application, it is important that you have an understanding of several general topics regarding sensor connections, including the difference between grounded and floating analog inputs; power output and sensor excitation; signal conditioning; and shielding. Please review this section for an overview of these topics.

GROUND REFERENCE VS. FLOATING All inputs (except isolated ones on TD-ISO) need a ground reference. If an external ground reference is not provided by the signal source, it may be provided by the FLOAT/GND REF switch. The - input is connected to ground through resistor (R5) by switching the FLOAT/GND REF switch to GND REF. When the input voltage already has a ground reference, switch to FLOAT, so that current won't flow between the two ground points, which can create a voltage drop in the wire (a ground loop), and affect the reading. If you are uncertain, you can usually put the switch in the GND REF position without causing errors. The TD-TC, TD-PE, and TD-PE/AAF do not have this switch. Removing R5 is the same as switching to FLOAT.

POWER OUTPUT & SENSOR EXCITATION Many sensors, such as RTDs, thermistors, strain gauges, and pressure sensors, need a stable power source, because the output is proportional to the power applied. For this reason, a stable excitation voltage (Vref) is built into the terminal drawer. See Chapter 2 for more information on Vref and terminal drawers.

Alternatively, you can use the +5 V terminal on the drawer to supply power for your sensors. This source, however, is noisy and not precise, so it does not always make for a very good sensor excitation voltage. This terminal is best used for powering digital circuits, such as relays and LEDs, which sometimes require large amounts of current.

SIGNAL CONDITIONING For some sensors, it is necessary to install signal conditioning components; e.g., resistors or capacitors. These can be easily plugged into sockets provided for this purpose on the terminal drawer. The rest of this chapter is devoted to examples showing what values to use. Below each diagram the values are listed. You can just install them without using the diagram. Refer to Chapter 2 for more information on the differences between drawers.

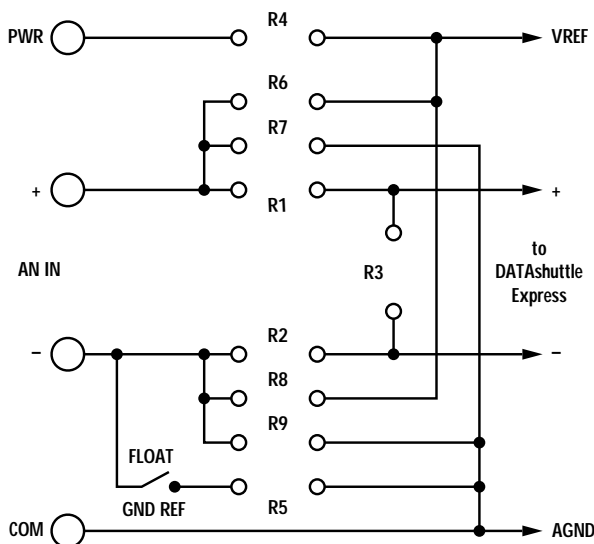
SHIELDING Noise is often a problem with long sensor wires. At high sample rates or low signal levels, noise can be a problem even with short wires. We recommend that, for best performance and accuracy,

you use shielded wires between the sensor and the DATAshuttle. The shield should be connected to the GND terminal, not COM, for the lowest noise.

Analog Input Examples

The analog input examples in this section show the signal conditioning schematically as it exists on the TD-GP, TD-GP/BNC, and TD-GP/AAF terminal drawers. See Figure 6 below.

Figure 6. Analog Input Channel Schematic –



The connections are similar for all of the terminal drawers, except the TD-PE and TD-ISO. Just ignore the components if a drawer does not have them. If the components are needed (their values are specified and not zero), that drawer cannot handle the example. Refer to Chapter 2 “Selecting the Right Terminal Drawer,” for a table showing what each drawer can do.

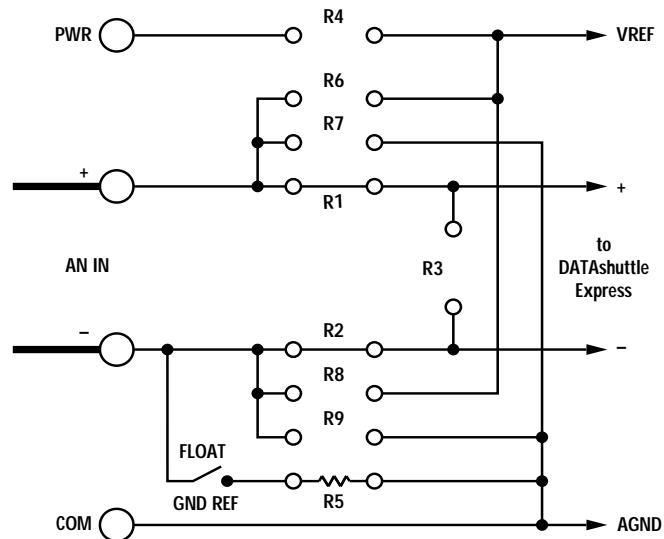
You can obtain precision parts from us or your distributor, or you can plug in standard size components, such as 1/4 W and 1/8 W resistors. If you select your own components, bend the leads to a spacing of 0.4 in (10 mm) and trim the vertical part of the leads to a length of 0.2 in (5 mm). Then push them gently into the holes. Often the resistor value needed is zero Ohms. In that case, install a jumper wire by cutting and bending it in the same way.

Use AWG22-size wire. Refer to Chapter 2 for more information on Plug-in Signal Conditioning and the switches on the terminal drawers.

Don't worry if the schematic diagrams don't make sense to you. Just make connections to the screw terminals as shown and install the components listed below the diagram. The locations are labelled at the sockets on the terminal drawers.

VOLTAGE INPUT Figure 7 shows how to connect a voltage to the terminal drawers. The drawers are supplied with the components as shown, so it is ready to go for voltage inputs. Switch the Float/Gnd Ref switch to Gnd Ref if the sensor does not supply a ground reference for that channel (each channel needs a ground reference).

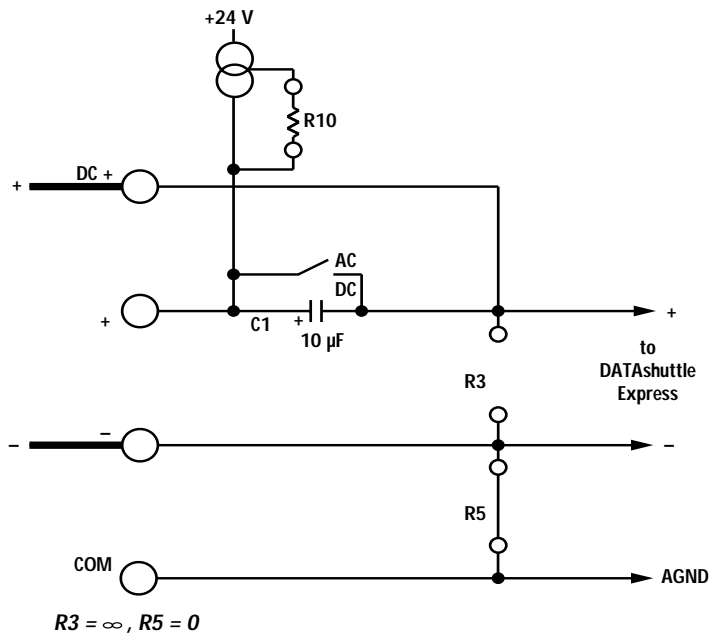
Figure 7. Voltage Input –



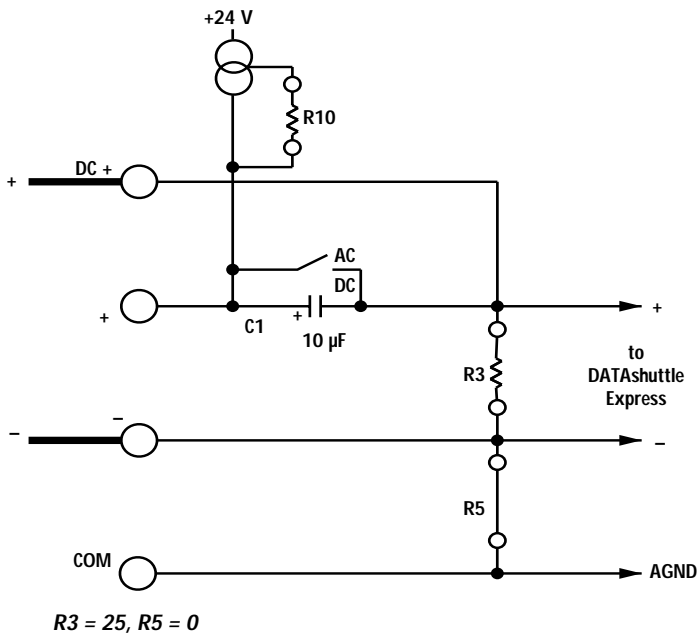
$R1 = 0, R2 = 0, R5 = 348\text{ k}$
FLOAT/GND REF in either position, as required.

ANALOG INPUT FOR THE TD-PE Voltage, current and thermocouple inputs to the TD-PE should be connected between the “AN IN-” and “DC+” terminals as shown in Figures 8a, 8b and 8c. These diagrams are similar to the equivalent diagrams for the other drawers. R3 is omitted, except when it is used to measure current, and the value of R10 does not matter as long as the AC/DC switch is set to AC. When R10 is omitted the current source at the “AN IN+” terminal is zero. Install R5 when a ground reference connection is needed; leave it out when a fully floating input is desired. In Figure 8b, current flows into the “DC+” terminal and out the “-” terminal.

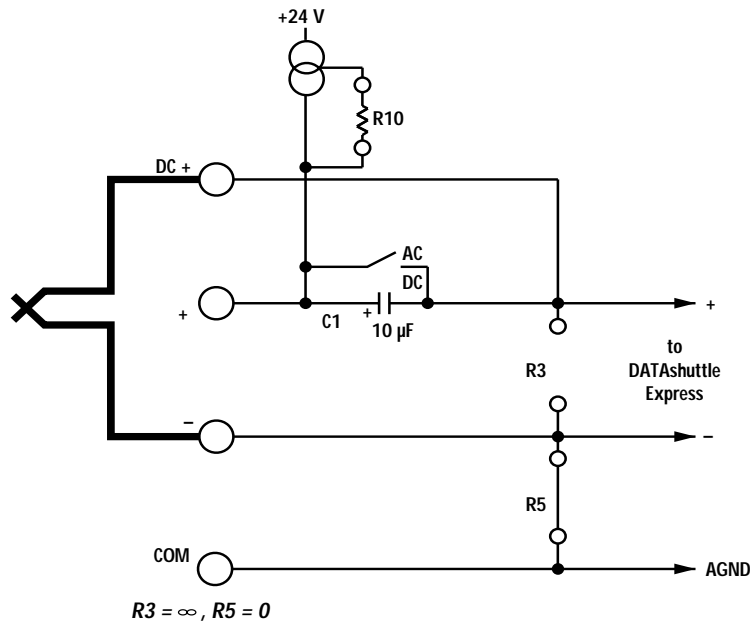
Figure 8. Analog Input for the TD-PE –



a. Voltage Input for TD-PE Drawer



b. Current Input for TD-PE Drawer



c. Thermocouple Input for TD-PE Drawer

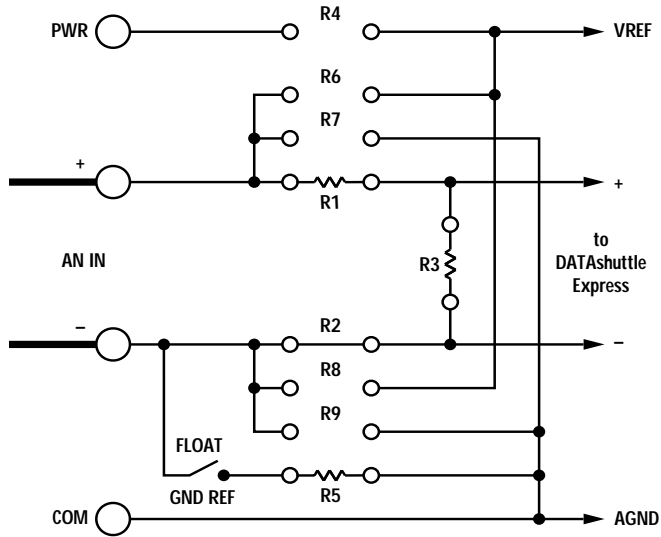
VOLTAGE DIVIDER Figure 9 shows how to reduce a 50 V input to 5 V. Be very careful of high voltages!

R1 was selected to keep the power dissipation below its maximum of 1/4 W. R3 is well below the input resistance of the DATAshuttle. The accuracy depends on the tolerance and temperature drift of R1 and R3.

CURRENT Figure 10 shows how to measure currents from microAmps to 100 mA. For the TD-GP, TD-GP/BNC, and TD-GP/AAF drawers, just switch the Voltage/Current switch to Current. For other drawers install a 25 Ohms resistor at R3, or connect a 25 Ohms resistor between the “-” and “+” terminals. To measure larger currents use a smaller resistor. Be careful that the resistor does not overheat. For currents larger than one Amp, install the resistor between the terminals, not at R3. The terminal drawer cannot handle currents greater than 1 A.

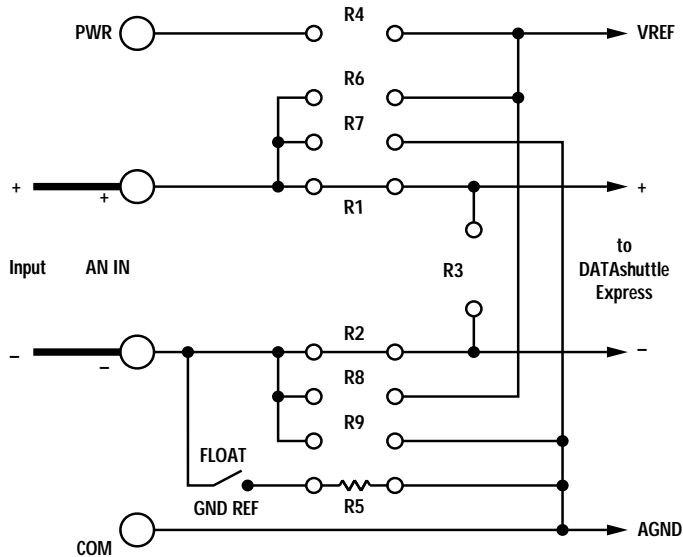
Figure 8b shows current input on a TD-PE.

Figure 9. Voltage Divider Configuration –



$R1 = 90\text{ k}$, $R2 = 0$, $R3 = 10\text{ k}$, $R5 = 348\text{ k}$
 FLOAT/GND REF in either position, as required.

Figure 10. Current Measurement Configuration –



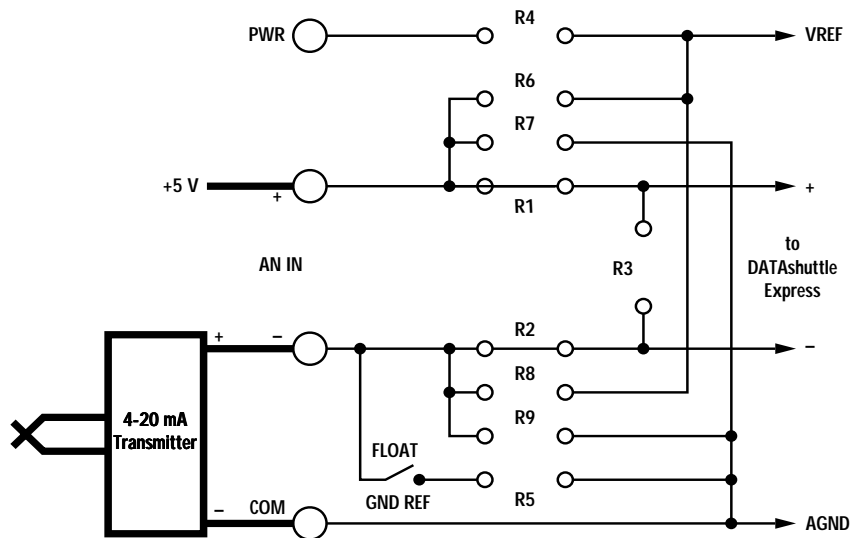
$R1 = 0$, $R2 = 0$, $R5 = 348\text{ k}$
 VOLT/CURR switch set for current.
 FLOAT/GND REF in either position, as required.

4-20 mA INPUT In industrial applications, many signals are transmitted by 4-20 mA transmitters. These signals require only two wires for power and signal, and they are quite immune to noise.

There are several ways that 4-20 mA transmitters may need to be connected. A common way that works for most terminal drawers is shown in Figure 11a. You need to connect a wire from the +5 V terminal to the AN IN+ terminal. In all the 4-20 mA examples for the TD-GP, TD-GP/BNC, and TD-GP/AAF drawers, switch the Voltage/Current switch to Current. For other drawers, install a 25 Ohms resistor at R3, or connect a 25 Ohms resistor between the “+” and “-” terminals. The current loop is completed through the +5 V supply.

Most 4-20 mA transmitters need more than 5 V to operate, however. Figure 11b provides 10 V. Many 4-20 mA transmitters need more than 10 V to operate, or they provide their own power. Connect them as in Figure 11c.

Figure 11. 4-20 mA Input Configurations –

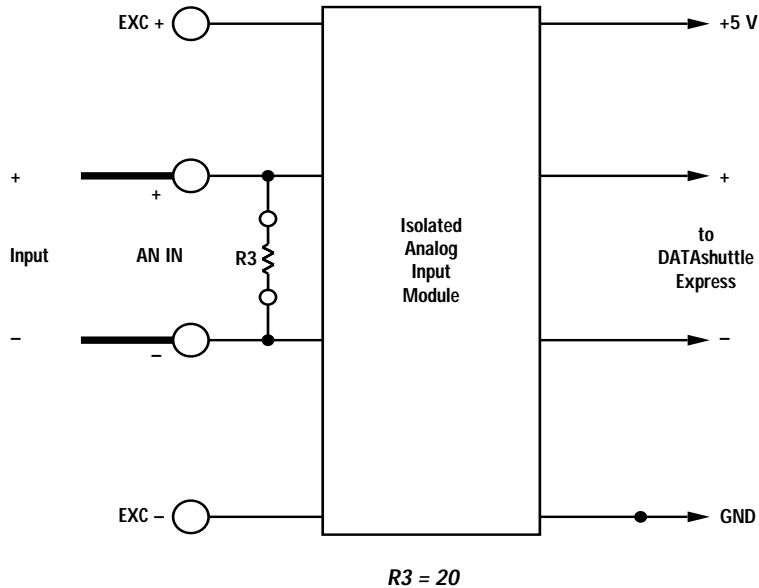


R1 = 0, R2 = 0, R5 = 348 k
 VOLT/CURR switch set for current

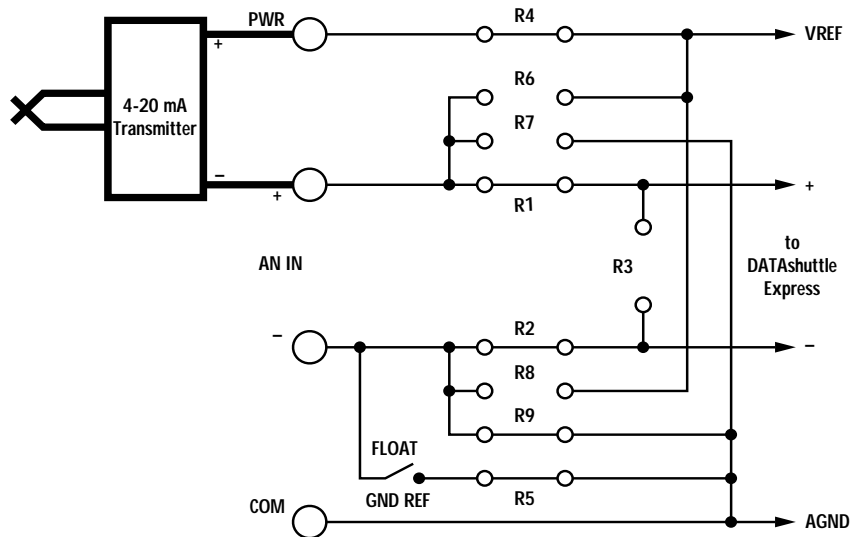
a. With +5 V Power Supply

ISOLATED CURRENT The TD-ISO provides fully isolated current measurement when the 5B32 modules are used. The connections are as shown in Figure 12. The accuracy of the current measurement depends upon the accuracy of R3. Overall accuracy is 0.2% if the resistor accuracy is 0.1%.

Figure 12. Isolated Current Configuration –

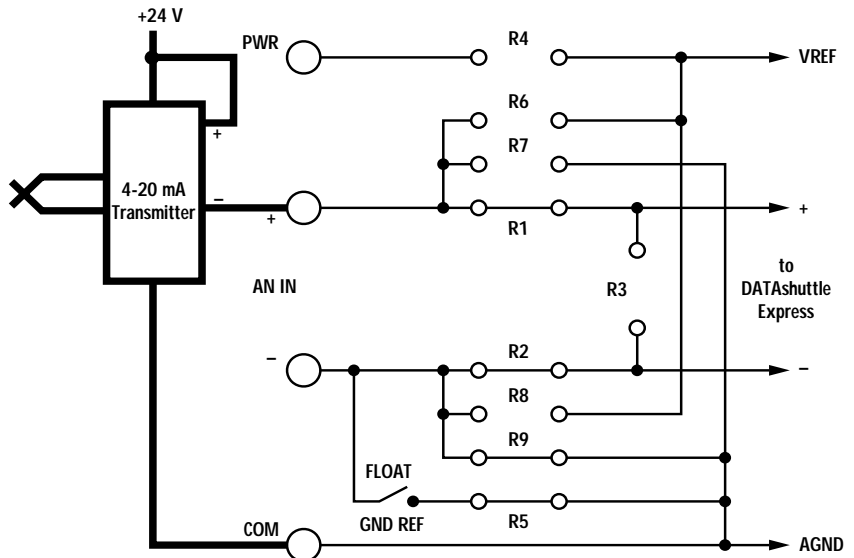


ISOLATED 4-20 mA INPUT The TD-ISO used with the 5B32 modules provides complete galvanic isolation from the DATAshuttle Express. Figure 13a shows a 4-20 mA transmitter connected one way. Figure 13b shows another. Since the input is isolated, both configurations work equally well. The loop must be powered by an external power supply (V_{supply}).



$R1 = 0, R2 = 0, R4 = 0, R5 = 0$ or $R9 = 0, VREF = 10\text{ V}$
VOLT/CURR switch set for current

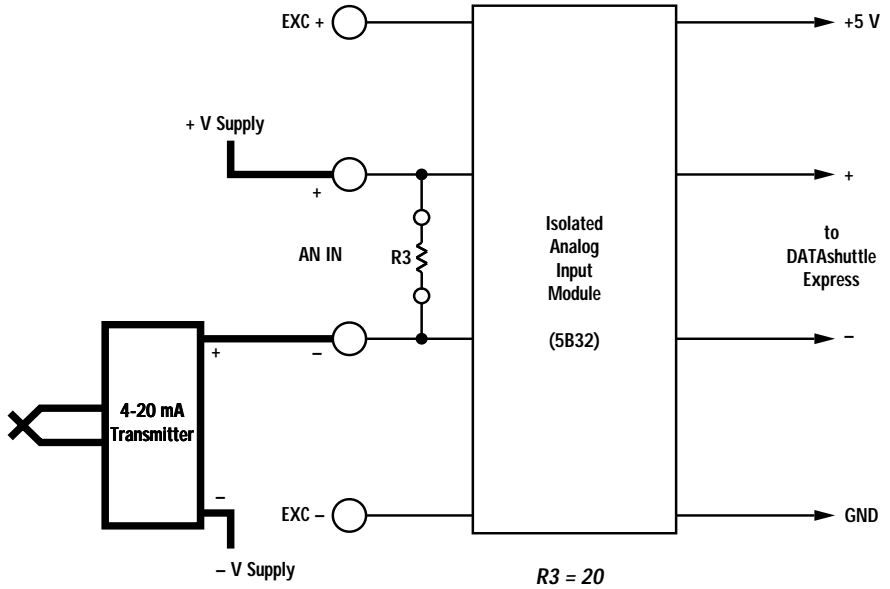
b. With +10 V Power Supply



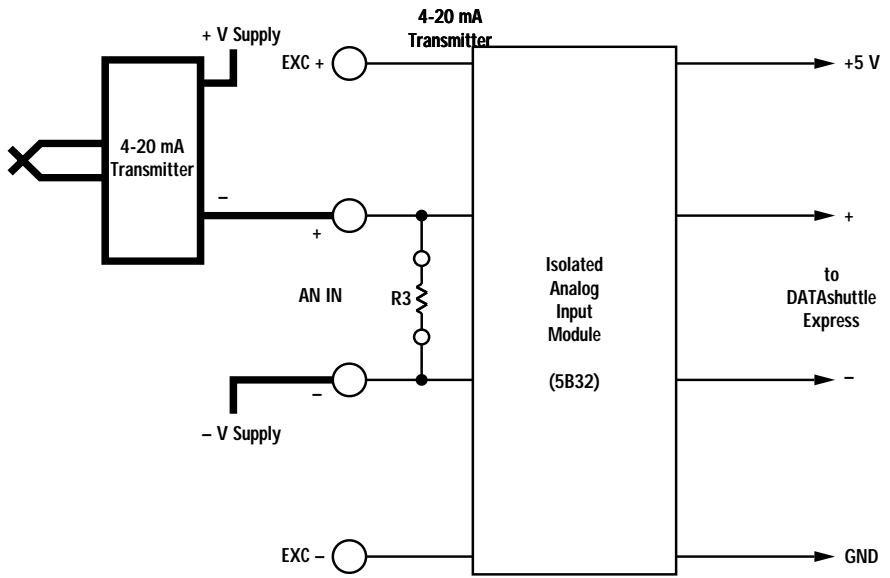
$R1 = 0, R2 = 0, R5 = 0$ or $R9 = 0$
VOLT/CURR switch set for current

c. With > 10 V Power Supply

Figure 13. Isolated 4-20 mA Input Configurations –



a. One Method



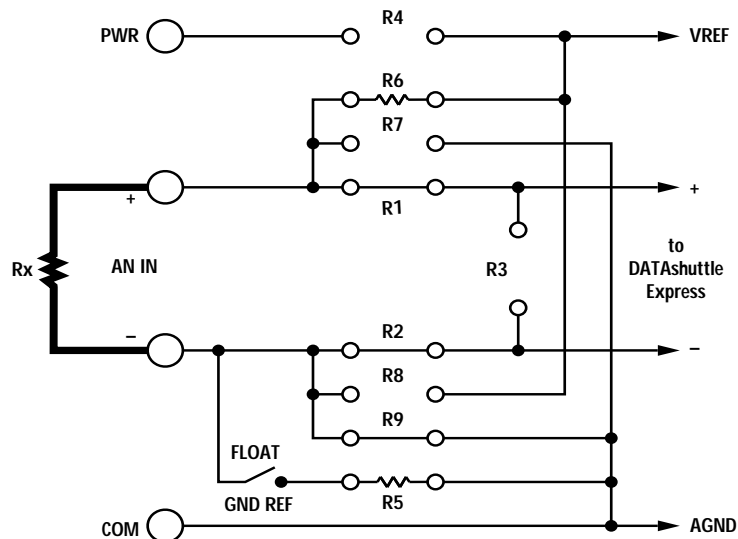
b. Another Method

RESISTANCE Most of the terminal drawers can measure resistance as in Figure 14a. The unknown resistance, R_x , is calculated in software as $R_x = V * R_6 / (V_{ref} - V)$, where V is the measured voltage and V_{ref} is the voltage on the V_{ref} terminal. Some software cannot perform this calculation. Figure 14a can measure resistance from 1 Ohm to 20,000 Ohms with an accuracy of at least 1%.

Figure 14a cannot measure low value resistors well because the resistance of the copper traces in the drawer itself are included in the resistance measurement. Figure 14b solves this with a 4-terminal resistance measurement. This, however, can only be done on the TD-GP, TD-GP/BNC and TD-GP/AAF drawers. The resistance is calculated as $R_x = V * R_4 / (V_{ref} - V)$. Figure 14b can measure resistance from 0.005 Ohms to 20,000 Ohms with at least 1% accuracy.

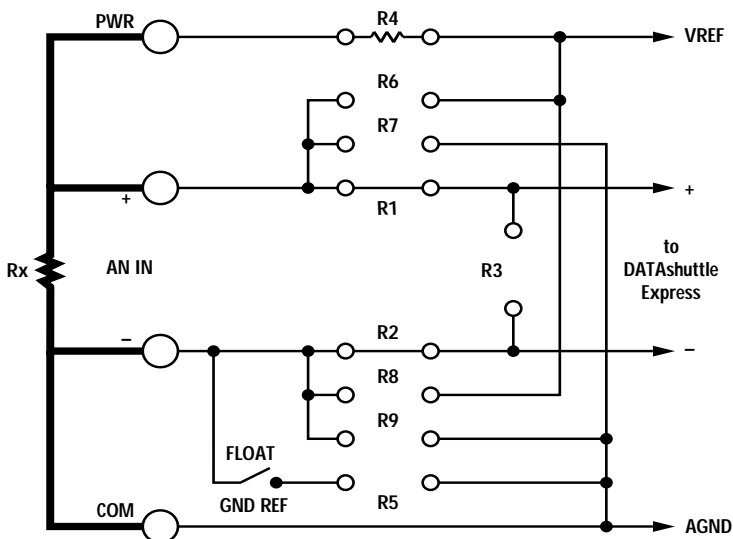
Figure 14a and 14b cannot measure high value resistors because the resistance at the input of the DATAshuttle must be low. Figure 14c can measure resistance from 200 Ohms to 20,000,000 Ohms with an accuracy of at least 1%. This can only be done on the TD-GP, TD-GP/BNC, and TD-GP/AAF drawers. The resistance is calculated as $R_x = R_3 * (V_{ref} - V) / V$, where V is the measured voltage.

Figure 14. Resistance Configurations –



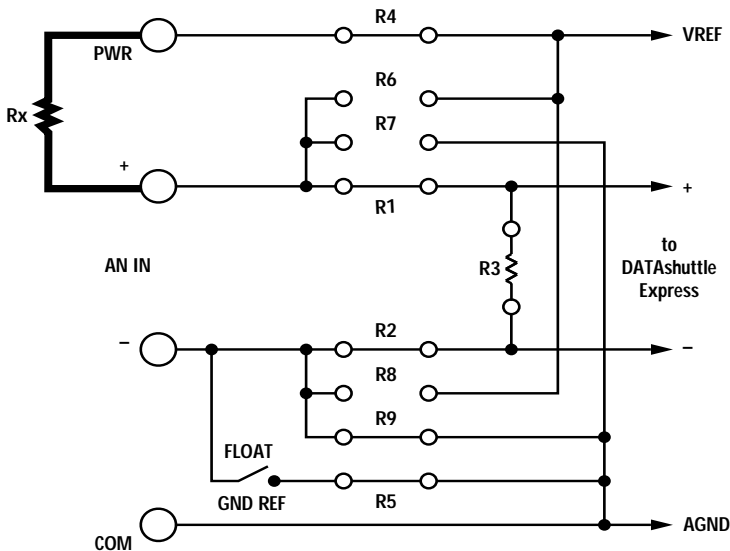
$R_1 = 0, R_2 = 0, R_5 = 0$ or $R_9 = 0, R_6 = 2K$
 FLOAT/GND REF set to GND REF if R5 is used.

a. For Most Termination Drawers



$R1 = 0, R2 = 0, R4 = 350$

b. For TD-GP, TD-GP/BNC, and TD-GP/AAF



$R1 = 0, R2 = 0, R3 = 2k, R5 = 0$ or $R9 = 0$
 FLOAT/GND REF set to GND REF if R5 is used.

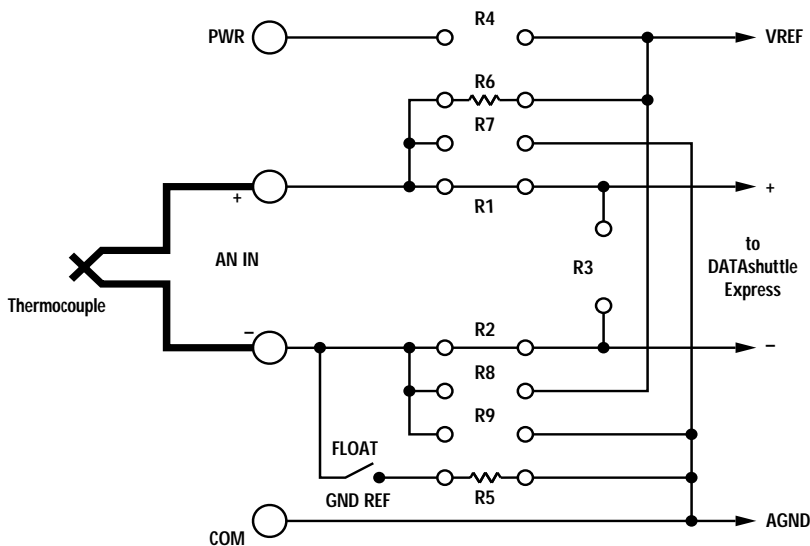
c. For High Value Resistors with TD-GP, TD-GP/BNC, and TD-GP/AAF

THERMOCOUPLES Thermocouples are the most widely used temperature sensor. They are rugged and available in a wide variety of types and configurations. Some types can be used in temperatures over 1000° C. Generally, thermocouples are not as accurate as thermistors or RTDs, and the low level output is susceptible to noise. Thermocouples have a voltage proportional to the temperature difference between the sensing point and the screw terminals. They require compensation using a “cold junction” sensor at the screw terminals, to measure absolute temperature. They are nonlinear and require linearization, but this is handled automatically by the driver software by selecting the thermocouple type in a menu.

Be sure to select a thermocouple that can handle the temperature range you plan to measure. Check Chapter 4, “Specifications,” for the usable ranges for each thermocouple type. R6 provides open thermocouple detection. See Figure 15. If the thermocouple is damaged or disconnected, a full scale positive reading results. Figure 8c shows the thermocouple connections on a TD-PE drawer.

Most of the terminal drawers have cold junction compensation and can be used for thermocouple measurement. For applications requiring highly accurate cold junction compensation, however, you should use the TD-TC as it has an isothermal plate. The TD-ISO gives accurate thermocouple readings when used with isolation modules (next example). The other drawers can have errors of many degrees that change unpredictably as temperature gradients come and go around the screw terminals.

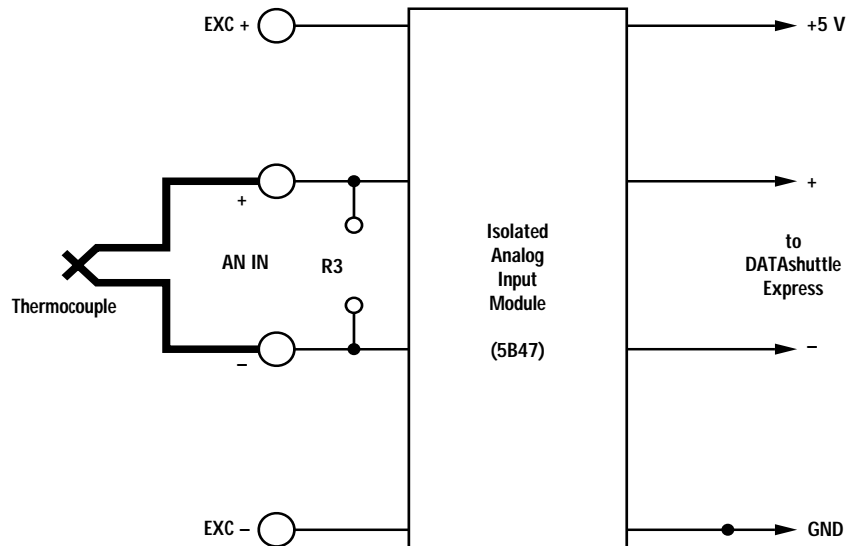
Figure 15. Thermocouple Configuration –



$R1 = 0, R2 = 0, R6 = 22\text{ M}, R5 = 348\text{ k}$
 FLOAT/GND REF in either position, as required.

ISOLATED THERMOCOUPLES When using the TD-ISO drawer with the 5B47 modules, as in Figure 16, the thermocouple is completely isolated from the DATAshuttle Express. These modules provide thermocouple linearization (don't use the 5B37 module; it doesn't provide linearization), and the TD-ISO provides cold junction compensation. Open thermocouple detection is provided so that, if the thermocouple is damaged or disconnected, a full scale positive reading results.

Figure 16. Isolated Thermocouple Configuration –



RTDS RTDs are very accurate temperature sensors that can be used over a wide range, from -200 to 850°C . They are more expensive than thermocouples, and they have low level outputs that are susceptible to noise. Although RTDs are not linear, the driver software performs linearization when you select the correct RTD in a menu.



CAUTION Be sure to set V_{REF} to 10 V when using RTDs, or there will be large errors. V_{REF} is used as excitation voltage.

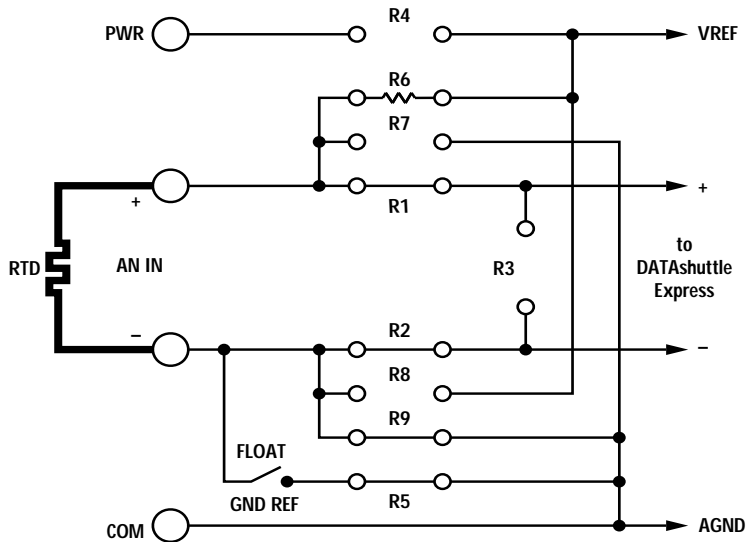
Figure 17a shows a 2-wire RTD connection that can be done using the TD-GP, TD-GP/BNC, TD-GP/AAF or TD-TC drawers. R_6 is the “set resistor”, R_s , which must be precise (0.1% is recommended). For a Platinum 100 Ohms RTD, R_s is either 50,000 Ohms or 100,000 Ohms. This configuration suffers from large errors with long wires, because the resistance of the lead wires is included in the RTD resistance.

Figure 17b eliminates most of the lead wire error with a 3-wire configuration. This is the most common configuration, but it can only be done with the TD-GP, TD-GP/BNC, and TD-GP/AAF drawers. Both R_6 and R_8 are the set resistor, R_s , which should be 0.1%. The TD-TC drawer can handle 3-wire RTDs by using R_5 instead of R_8 . The end of R_5 must be connected to the end of R_6 (toward the back of the drawer). Leave the R_5 socket pin toward the back empty. This requires soldering.

Figure 17c shows an even more precise 4-wire RTD configuration. The lead wire errors are completely eliminated. Typically, 4-wire RTDs are only used in laboratories where high accuracy is more important than cost. R4 is the set resistor, R_s, which should be 0.1% or better.

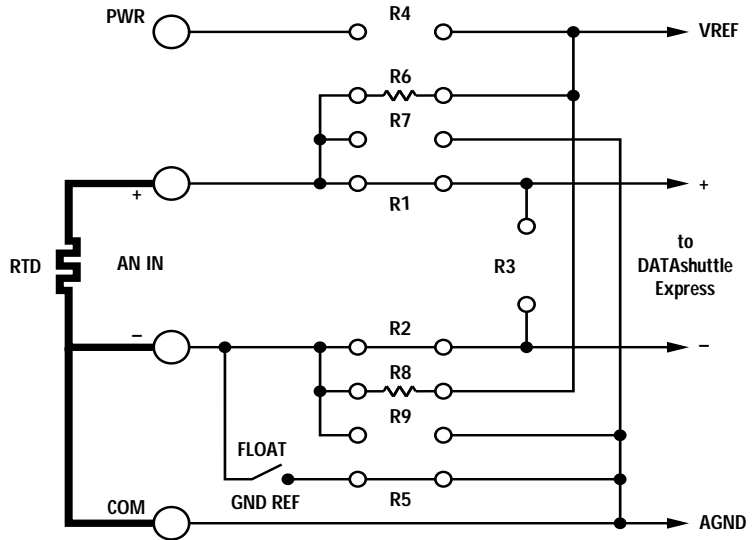
ISOLATED RTDS When using the TD-ISO drawer with the 5B34 modules, the RTD is completely isolated from the DATAshuttle. Excitation is provided for 2-wire (Figure 18a) or 3-wire RTDs (Figure 18b).

Figure 17. RTD Configurations –



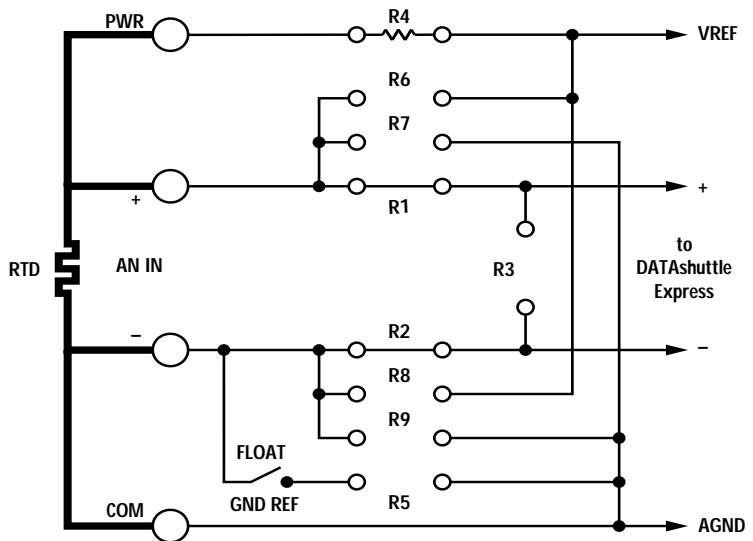
R1 = 0, R2 = 0, R5 = 0 or R9 = 0, R6 = R_s
 FLOAT/GND REF set to GND REF if R5 is used.

a. 2-Wire RTD



$R1 = 0, R2 = 0, R6 = R_s, R8 = R_s$

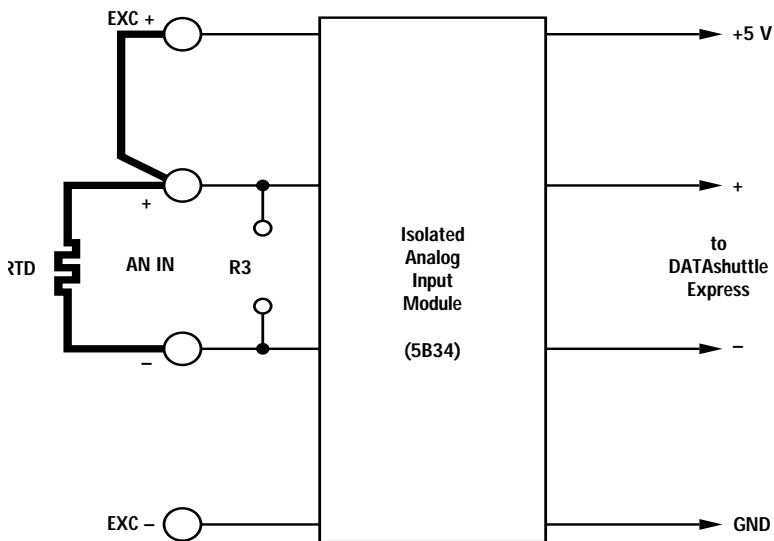
b. 3-Wire RTD



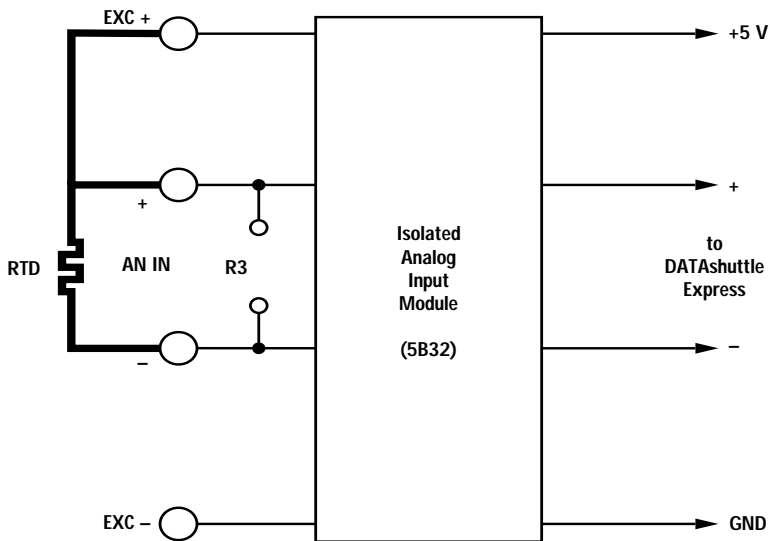
$R1 = 0, R2 = 0, R4 = R_s$

c. 4-Wire RTD

Figure 18. Isolated RTD Configurations –



a. 2-Wire Isolated RTD



b. 3-Wire Isolated RTD

THERMISTORS Thermistors can provide high accuracy temperature measurements over a modest temperature range, as much as -80° to 150° C, but they are highly nonlinear. They are less expensive than RTDs, and have a larger output, so they are more immune to noise. Figure 19 shows the connections for a standard thermistor. The TD-GP, TD-GP/BNC, TD-GP/AAF and TD-TC drawers can all handle this configuration. The example uses a model 44004 or 44033 thermistor made by Yellow Springs Instruments, Yellow Springs, OH 45387 USA, phone 513-767-7241. R6 should be a precise resistor. The highly nonlinear thermistor requires a complex calculation to linearize it. Some software is not able to do the calculation.

The temperature in degrees Kelvin is calculated from:

$$\text{Temperature(K)} = 1/(A + B * \ln(R) + C * (\ln(R))^3)$$

where A, B, and C are constants found from three known sets of data: R1, T1; R2, T2; and R3, T3. These data sets may be taken from a published table of resistance versus temperature for the thermistor. R1 and T1 should be near the low end of the temperature range, R2 and T2 near the middle, and R3 and T3 near the top. They can be calculated as follows:

$$A = \frac{T2 * T3 * X2 * X3 * (X3^2 - X2^2) + T1 * T3 * X1 * X3 * (X1^2 - X3^2) + T1 * T2 * X1 * X2 * (X2^2 - X1^2)}{Y}$$

$$B = \frac{T1 * T3 * (X3^3 - X1^3) + T1 * T2 * (X1^3 - X2^3) + T2 * T3 * (X2^3 - X3^3)}{Y}$$

$$C = \frac{T1 * T2 * (X2 - X1) + T2 * T3 * (X3 - X2) + T1 * T3 * (X1 - X3)}{Y}$$

where

$$Y = T1 * T2 * T3 * (X2 * X3^3 + X1^3 * X3 + X1 * X2^3 - X1^3 * X2 - X1 * X3^3 - X3 * X2^3)$$

$$X1 = \ln(R1)$$

$$X2 = \ln(R2)$$

$$X3 = \ln(R3)$$

For the thermistor in this example:

$$A = 0.001468012$$

$$B = 0.000238293$$

$$C = 1.0105E-07$$

when calculated for a wide temperature range ($T_1 = -70$, $T_2 = 25$, $T_3 = 140$).

To calculate the temperature you must first calculate the resistance from the measured voltage: $R = V * R_6 / (V_{ref} - V)$, where V is the measured voltage and V_{ref} is the voltage on the Vref or PWR terminal. If V_{ref} is 10 V the resulting equation that needs to be solved by the software in the example is:

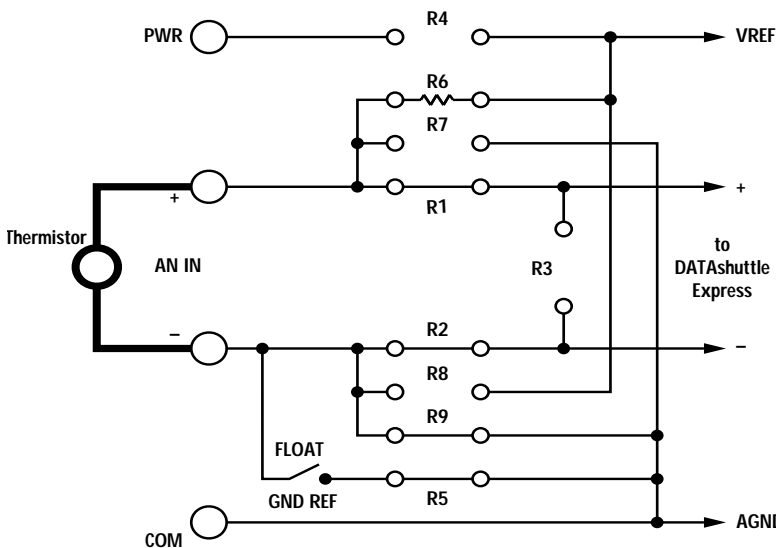
$$T = 1 / (A + B * \ln(R) + C * (\ln(R))^3)$$

where $R = V * R_6 / (V_{ref} - V)$ or

$$T = 1 / (0.001468012 + 0.000238293 * \ln(V * 20000 / (10 - V)) + 1.0105E-07 * (\ln(V * 20000 / (10 - V)))^3)$$

This is a complex equation to evaluate and may be somewhat slow if there are many channels of thermistors.

Figure 19. Standard Thermistor Configuration –



$R_1 = 0$, $R_2 = 0$, $R_5 = 0$ or $R_9 = 0$, $R_6 = 20\text{ k}$
 FLOAT/GND REF set to GND REF if R_5 is used.

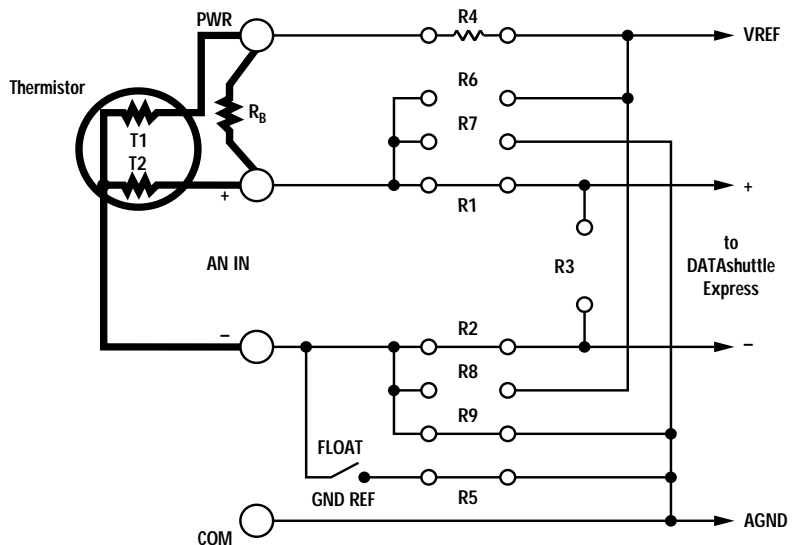
LINEAR THERMISTOR NETWORK The problem of linearizing the thermistor in software is solved by using a linear thermistor network shown in Figure 20. The example uses a model 44018 thermistor from Yellow Springs Instruments, Yellow Springs, OH 45387 USA, phone 513-767-7241. Only the TD-GP, TD-GP/BNC, and TD-GP/AAF terminal drawers can handle this configuration. Two precise resistors are required, RA and RB. R4 is RA. These resistors can be changed to get linear-

ity over different ranges with high accuracy. In this example, accuracy of ± 0.6 degrees is achieved in the range 0 to 100 degrees C. R_B is connected between the PWR and AN IN + terminals. For the modest complexity of the connections, determining the temperature requires a simple scale and offset, which can be done by most software:

$$T = (V - 0.86507 * VREF) / (0.0053483 * VREF) \text{ or}$$

$$\text{when } VREF = 10, T = V * 18.6975 - 161.747$$

Figure 20. Linear Thermistor Configuration –



$R1 = 0, R2 = 0, R4 = R_A = 3200, R5 = 0 \text{ or } R9 = 0, R_B = 6250$
 FLOAT/GND REF set to GND REF if R5 is used.

IC TEMPERATURE SENSORS

Temperature can be measured cheaply and easily using sensors that are semiconductor integrated circuits. The output is linear and high level, so it is rather immune to noise. There are two basic types: voltage output and current output. Figures 21a and b show two types of voltage output device. Only the TD-GP, TD-GP/BNC, and TD-GP/AAF terminal drawers can be configured as in Figure 21a; however, the sensor can be powered from the +5V terminal instead of the PWR terminal on the TD-TC drawer, except for the AD22100. The output of the LM34 is 700 mV at 70 degrees F, and changes 10 mV per degree F. The LM35 is 250 mV at 25 degrees C, and changes 10 mV per degree C. The output of the AD22100 is:

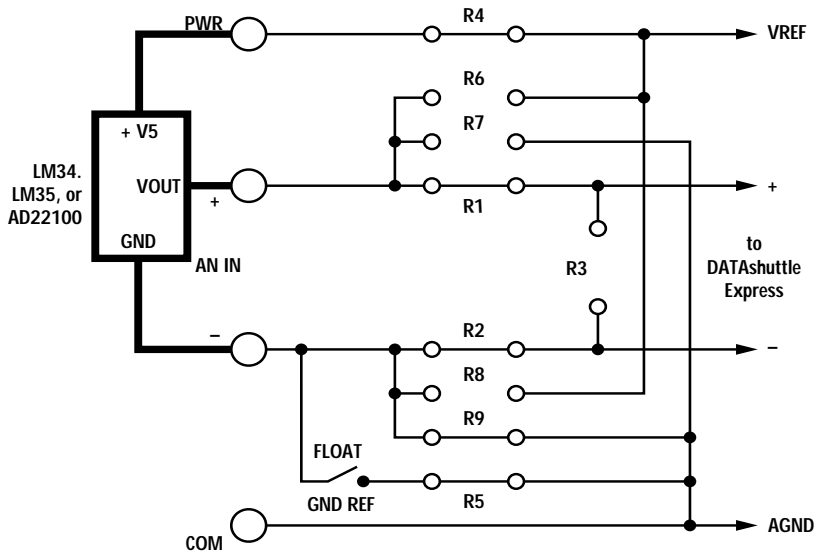
$$V = Vref / 5 * (1.375 + 0.025 * T)$$

where T is the temperature of the sensor and Vref is the voltage at the Vref terminal.

The TD-GP, TD-GP/BNC, TD-GP/LC, TD-GP/AAF and TD-TC drawers can be configured as in Figure 21b.

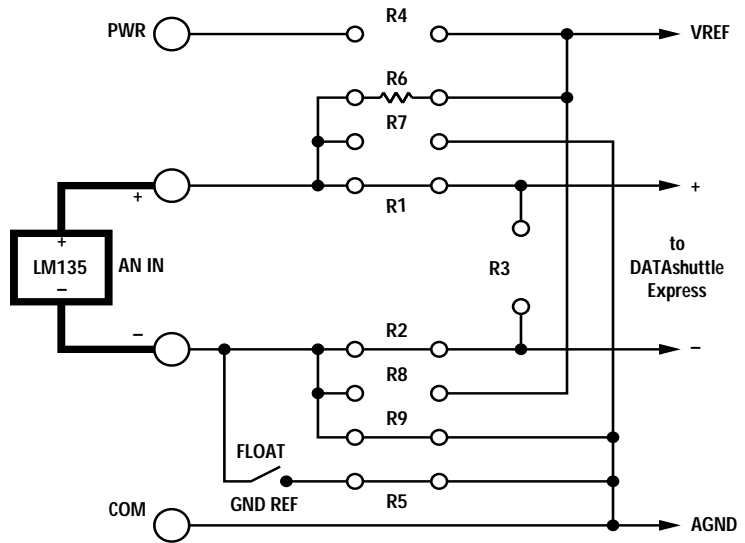
Figure 21c shows a current output device. The AD590 is the most popular semiconductor temperature sensor. Since it transmits a current, its accuracy is not affected by the resistance of the lead wires. Only the TD-GP, TD-GP/BNC, and TD-GP/AAF terminal drawers can be configured as in Figure 21c; however, the sensor can be powered from the +5 V terminal instead of the PWR terminal on the TD-TC, TD-PE, and TD-PE/AAF terminal drawers. The AD590 output changes 1 uA per degree C, and is 298 uA at 25° C (298 degrees K). The 1,000 Ohms resistor, R3, Figure 21a, converts this to 0.298 V at 25° C with a change of one mV per degree.

Figure 21. Temperature Configurations –



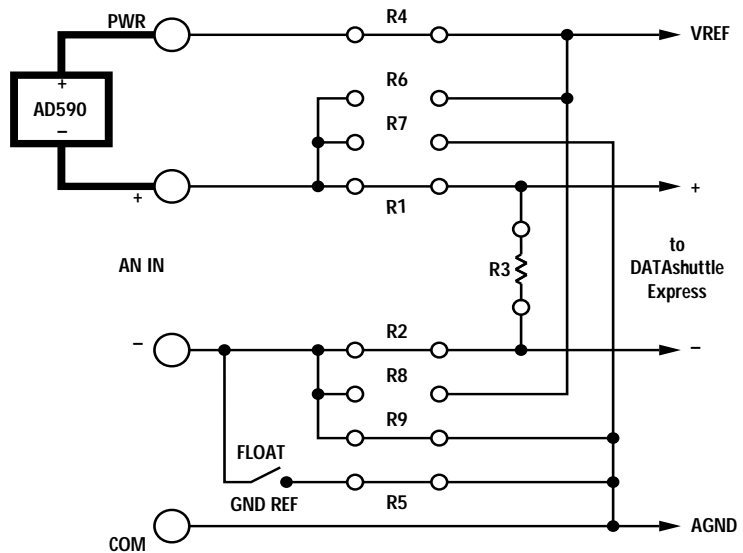
R1 = 0, R2 = 0, R4 = 0, R5 = 0 or R9 = 0
 FLOAT/GND REF set to GND REF if R5 is used.

a. With LM34, LM35, or AD22100



$R1 = 0, R2 = 0, R5 = 0$ or $R9 = 0, R6 = 10\text{ k}$
 FLOAT/GND REF set to GND REF if R5 is used.

b. With LM135



$R1 = 0, R2 = 0, R3 = 1\text{ k}, R4 = 0, R5 = 0$ or $R9 = 0$
 FLOAT/GND REF set to GND REF if R5 is used.

c. With AD590

STRAIN GAUGES Strain gauges change resistance when they are stretched or compressed. When they are bonded to materials they sense the stretching, or strain in materials. Because the change is usually less than one percent of the total resistance, they are almost always used in a bridge configuration. Strain gauges are used in quarter bridges as in Figure 22a, half bridges as in Figure 22b, and full bridges as in Figure 22c. Three-wire gauges may be used in a quarter bridge as in Figure 22d.

The most common strain gauges are 350 Ohms. 120 Ohm and 1000 Ohm strain gauges are also common. In quarter and half bridges, the bridge must be completed by precision resistors that match the resistance of the strain gauge. V_{ref} is typically 10 V to give the maximum output voltage. When strain gauges are mounted on material that is a poor heat conductor, you may want to set V_{ref} to 2.5 V to reduce the heat generation. In all these configurations, long lead wires can add significant errors, since the measurement is basically resistance. Use large-size wires to minimize this effect, or use a three-wire gauge as shown in Figure 22d. This puts one lead wire in series with R_4 and the other in series with the strain gauge, balancing the bridge.

The FLOAT/GND REF switch has a different function for strain gauges. It is used to calibrate the bridge by shunting a 348,000 Ohm resistor across one leg. This causes the bridge to be unbalanced by 0.1% when using 350 Ohm gauges. Only the TD-GP, TD-GP/BNC, and TD-GP/AAF termination drawers can be configured for strain gauges. They can handle gauges from 120 Ohms to over 10,000 Ohms. V_{ref} can power only two channels of 120 Ohm strain gauges if it is set to 10 V (or five channels if using quarter- or half-bridges and R_6 and R_7 are 1,200 Ohms). It is limited to 230 mA in each drawer. All other combinations of strain gauges and V_{ref} can be handled for all eight channels.

MICROSTRAIN CALCULATION The DATAshuttle measures the voltage output from the bridge. When there are two active gauges (half- or full-bridge with two active gauges), the change in output voltage from the bridge, V_{IN} , is:

$$\Delta V_{IN} = V_{REF} * 1/2 * \Delta R / R_G \quad (1)$$

where ΔV_{IN} is the change in voltage measured by the DATAshuttle, V_{REF} is the power applied to the bridge, R_G is the nominal strain gauge resistance, and ΔR is the change in strain gauge resistance. This equation is valid when all the gauges and dummy resistors in the bridge are equal.

When there are four active gauges, the equation is:

$$\Delta V_{IN} = VREF * \Delta R / R_G \quad (2)$$

The strain can be calculated by substituting for ΔR :

$$\Delta R = R_G F_G \varepsilon \quad (3)$$

where F_G is the gage factor of the strain gauge and ε is the strain. Multiply by 1,000,000 for microstrain. This becomes for two active gauges:

$$\varepsilon = (2 / F_G) (\Delta V_{IN} / VREF) \quad (4)$$

The equation for a quarter-bridge or where there is one active gauge in the bridge is:

$$\Delta V_{IN} = VREF \frac{\Delta R / R_G}{4 + 2 (\Delta R / R_G)} \quad (5)$$

When the strain is small (less than about 1000 microstrain), this equation becomes:

$$\Delta V_{IN} = VREF (\Delta R / 4R_G) \quad (6)$$

By substituting for ΔR this becomes

$$\varepsilon = (4 / F_G) (\Delta V_{IN} / VREF) \quad (7)$$

These equations can be used to calculate strain in most data acquisition software. To measure ΔV_{IN} you must subtract the initial input voltage. The *DATASHuttle* is designed so that the active strain gauges or dummy resistors may be placed in any arm of the bridge. There is no balance circuitry on any part of the bridge. This allows you to change the shunt calibration from simulating tensile strain to simulating compressive strain. This can be done by using R8 and R9 instead of R6 and R7. Because the *DATASHuttle* measures positive and negative voltages equally well, in many cases, it doesn't matter in which direction the shunt calibration goes.

The amount of simulated strain during shunt calibration can be calculated using Equation 3 converted to this form:

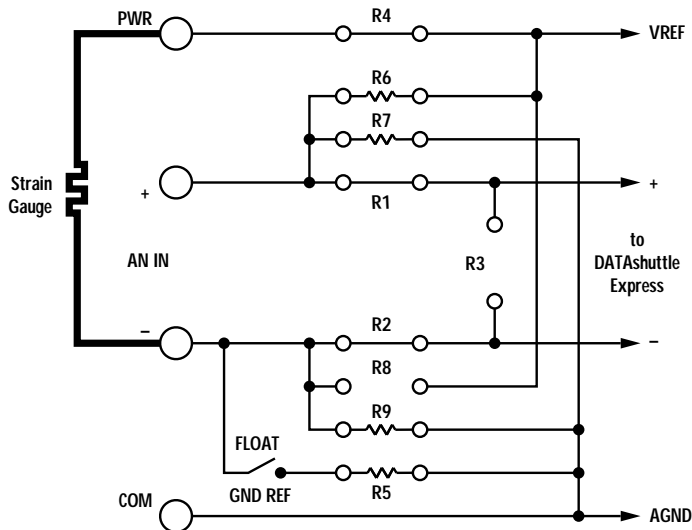
$$\varepsilon = \Delta R / (R_G F_G) \quad (8)$$

where ΔR is the apparent change in the resistor when R5 is placed in parallel with it:

$$\Delta R = R_G - (R_G * R5) / (R_G + R5) \quad (9)$$

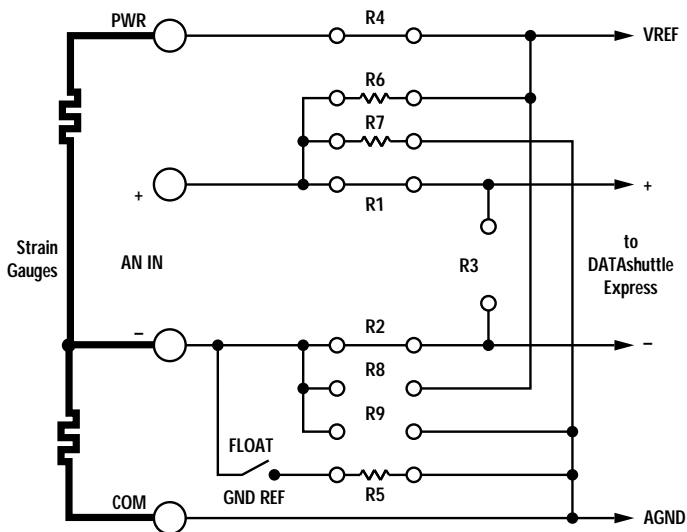
where it is assumed the strain gauge or dummy resistor being shunted has the value R_G . Resistor R5 is a 1% tolerance 348 k Ohms resistor. For more accurate shunt calibration, or for different values, you may install your own precision resistor.

Figure 22. Strain Gauge Configurations –



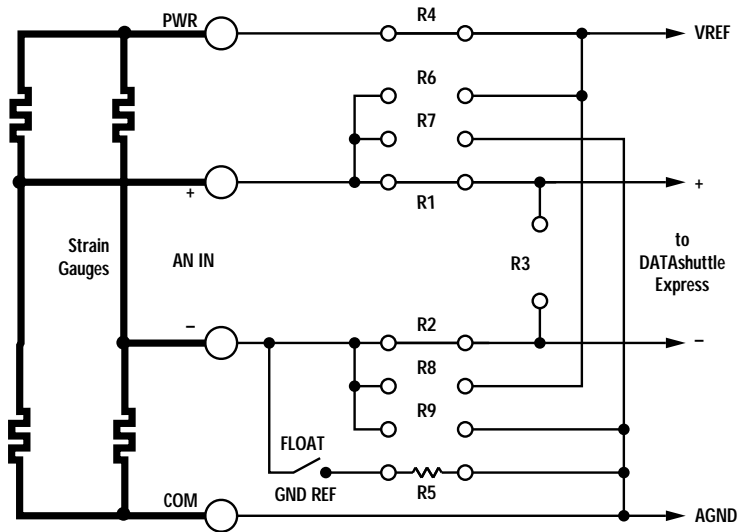
$R1 = 0, R2 = 0, R4 = 0, R5 = 348\text{ k}, R6 = 350, R7 = 350, R9 = 350$

a. Quarter-Bridge Strain Gauge



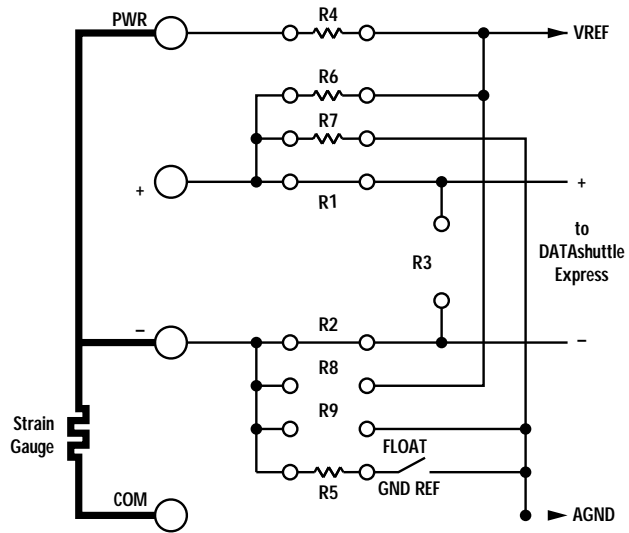
$R1 = 0, R2 = 0, R4 = 0, R5 = 348\text{ k}, R6 = 350, R7 = 350$

b. Half-Bridge Strain Gauge



$R1 = 0, R2 = 0, R4 = 0, R5 = 348\text{ k}$

c. Full-Bridge Strain Gauge



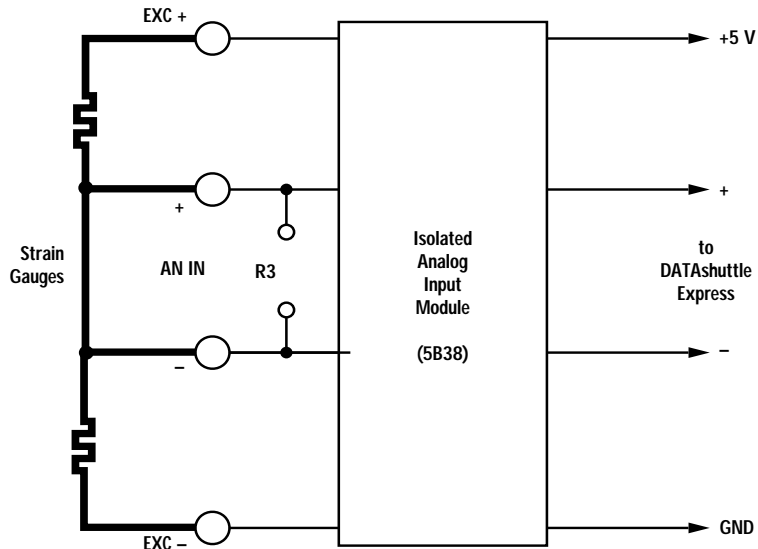
$R4 = R6 = R7 = 350, R5 = 348\text{ k}, R1 = R2 = 0$

d. 3-Wire Quarter-Bridge Strain Gauge

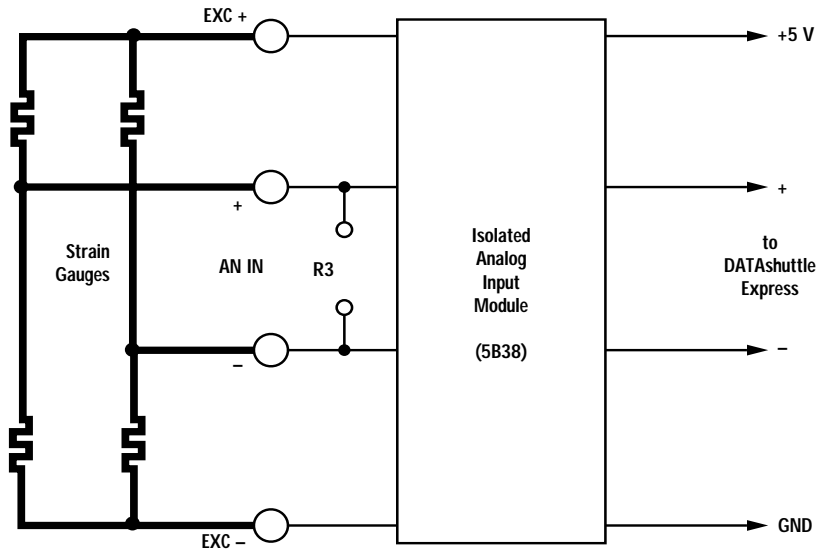
OTHER STRAIN GAUGE-BASED SENSORS Strain gauges are commonly used in many other sensors. Many pressure, torque, displacement, and force sensors use strain gauges. A load cell is a common example of a sensor that uses strain gauges to measure weight or force. Sometimes the signal is amplified and can be read as a voltage, and sometimes you connect directly to the strain gauges. In the latter case, the configuration of the terminal drawers is the same as shown here for strain gauges.

ISOLATED STRAIN GAUGE When using the TD-ISO drawer with the 5B38 modules, the strain gauges are completely isolated from the DATAshuttle. See Figures 23a and b. 10 V excitation is provided that can drive 350 Ohm and higher gauges. Only half and full bridges can be accommodated. You must use different modules for half and full bridges. There is no provision for shunt calibration.

Figure 23. Isolated Strain Gauge Configurations –



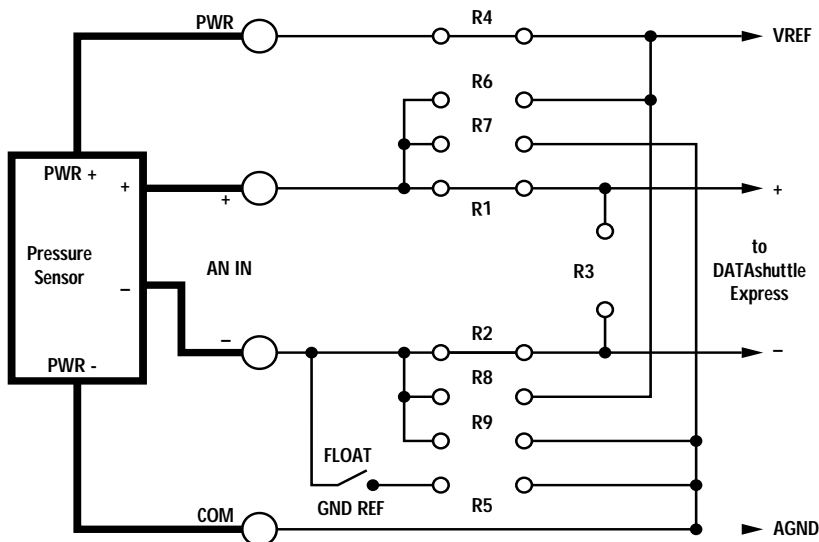
a. Half-Bridge Isolated Strain Gauge



b. Full-Bridge Isolated Strain Gauge

PRESSURE SENSOR There are several kinds of pressure sensors. Many use strain gauges. When there is no signal conditioning and amplification after the strain gauges, connect them as full bridge strain gauges, as shown in the section on strain gauges. When any kind of pressure sensor is followed by signal conditioning and amplification, the output is usually a voltage. Sometimes these sensors have 4-20 mA current outputs. Refer to the description of 4-20 mA input connections for that type. Figure 24 shows how to connect a pressure sensor that has an amplified voltage output. Although most voltage output pressure sensors are connected like this, there are variations. Some have three output wires, with the power negative and signal negative using a common wire. For those make R5 or R9 zero Ohms.

Figure 24. Pressure Sensor Configuration –



$$R1 = 0, R2 = 0, R4 = 0$$

PIEZOELECTRIC SENSORS Piezoelectric sensors are used to measure acceleration, vibration, and sound. They have unique signal conditioning requirements that cannot be met by the TD-GP, TD-GP/BNC, TD-GP/AAF, or TD-TC terminal drawers. The TD-PE and TD-PE/AAF drawer were designed specifically for this type of sensor. In addition, they can handle voltage and some other sensor inputs, as described throughout this chapter.

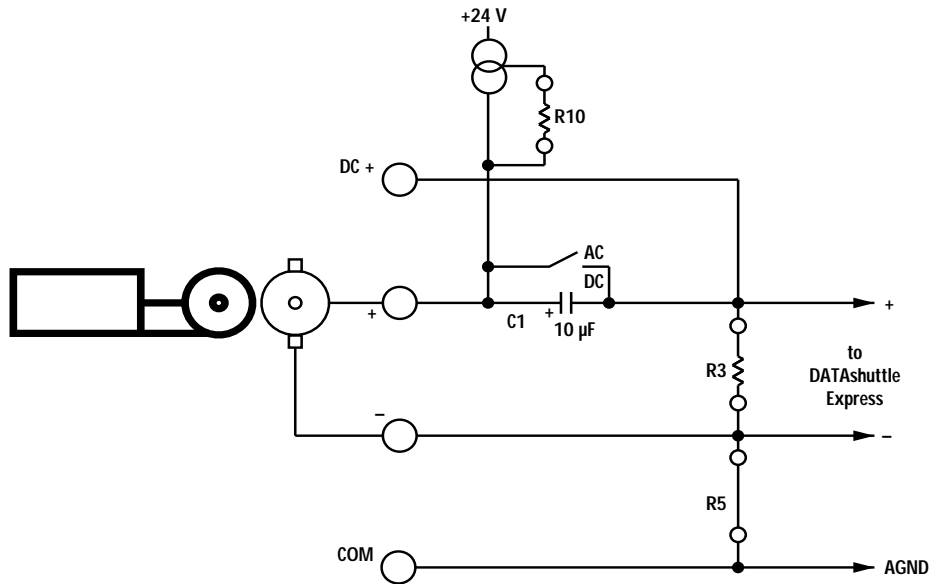
Change R3 to set the lower frequency limit. Normally, this should be left as 1 MOhm. Set R10 to adjust the current source (see Chapter 2 for values to use) when using accelerometers that need a current for power. The AC/DC switch is normally set to AC. Switch to DC to measure the DC voltage on an accelerometer (this indicates whether or not it is working).

To be able to handle DC voltages and piezoelectric sensors on the same drawer, sensors are connected to different screw terminals, as shown in Figure 25. Piezoelectric sensors are connected to the “AN IN +” and “AN IN -” terminals. Voltage and other inputs are connected to the “DC+” and “AN IN -” terminals. Note that the “DC+” terminal is not like the PWR terminal on other drawers.

Install R5 if the sensor has no ground reference; this is normally the case. When connecting to the BNC connectors on the front of the TD-PE and TD-PE/AAF, you may wish to leave the jumper for R5

installed so as to connect the outer conductor of the cable directly to ground. In many cases, you will have less noise if R5 is large, 348 kOhms for example, because the differential inputs of the DATAshuttle are excellent at rejecting noise.

Figure 25. Piezoelectric Sensor Configuration –

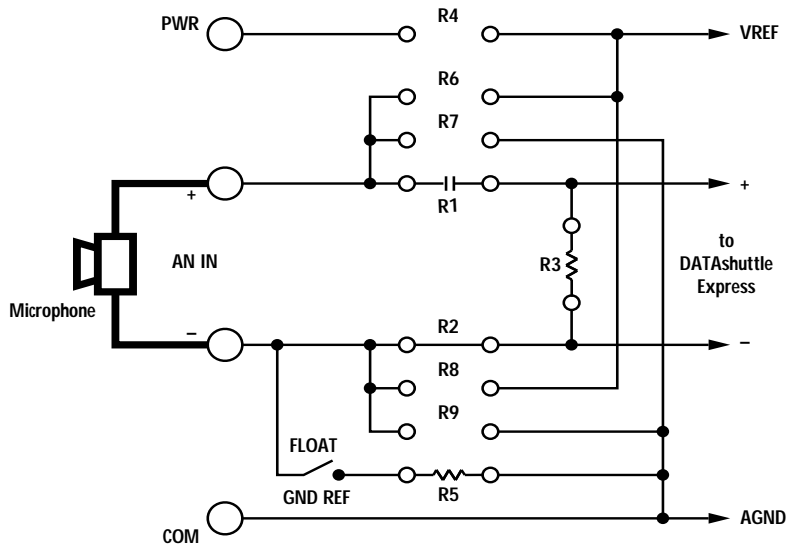


$$R3 = 1 M, R5 = 0, R10 = 17.8$$

AUDIO Audio inputs may come from microphones or amplified signals. Microphones use several sensor types, including piezoelectric crystals. Piezoelectric or crystal microphones are not normally connected as piezoelectric sensors shown above, however. Almost all microphones, including piezoelectric types are connected as shown in Figure 26a. The capacitor at R1 and resistor R3 have been chosen to pass frequencies above 10 HZ.

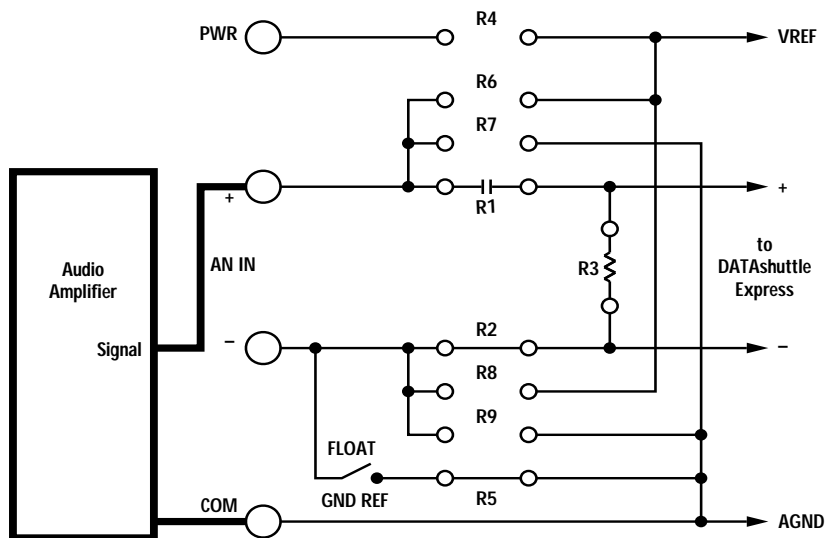
Figure 26b shows the connections for amplified signals. Usually the signal low and power ground are common. If they are separate, use the connections of Figure 26c. Be careful in connecting an amplifier to the COM terminal. It connects to ground in the DATAshuttle, and ultimately to the ground wire in the computer power connector. If the amplifier ground is not at the same potential, large currents could flow and damage the terminal drawer. Figure 26d shows the connections on the TD-PE and TD-PE/AAF. Leave the AC/DC switch set to AC. Remove R10 to shut off the current source. R3 was reduced to reduce the input time constant.

Figure 26. Audio Signal Configurations –



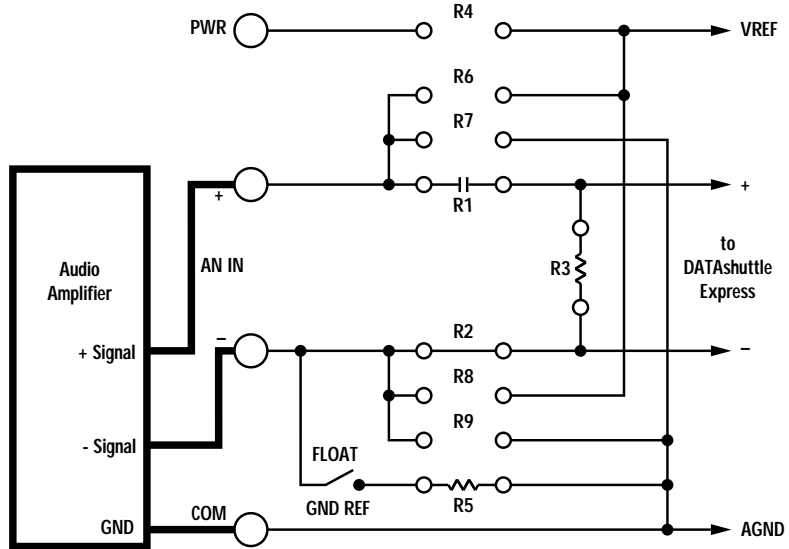
$R1 = 0.002 \mu F$, $R2 = 0$, $R3 = 1 M$, $R5 = 348 k$
 FLOAT/GND REF in GND REF position.

a. Low Level Audio Signals



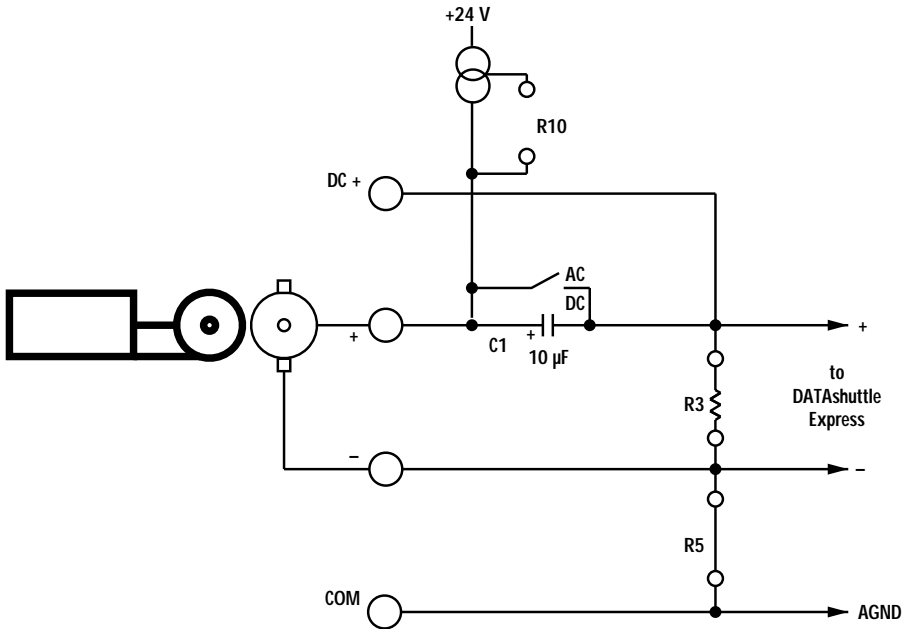
$R1 = 0.002 \mu F$, $R2 = 0$, $R3 = 1 M$, $R5 = 0$
 FLOAT/GND REF in GND REF Position.

b. Amplified Audio Signal, Ground-Referenced



$R1 = 0.002 \mu F$, $R2 = 0$, $R3 = 1 M$, $R5 = 348 k$
 FLOAT/GND REF in either position, as required.

c. Amplified Audio Signal, Floating



$R3 = 100 k$, $R5 = 0$

d. Audio Input for TD-PE Drawer

FILTERS It is frequently necessary to reject high frequency signals by using a low pass filter. High frequencies can add noise to the signal being measured. Or worse, signals with high frequencies near or above the sampling frequency can cause a form of distortion called aliasing, in which high frequencies are converted to much lower frequencies indistinguishable from the desired signal. Once aliasing occurs, little can be done to remove it. This being the case, it is important to remove the high frequencies before they get to the analog-to-digital converter. In many cases, this can be done with a simple one-pole low pass filter, shown in Figure 27. This can be applied to most of the examples in this chapter.

If the high frequency noise is large, you can sample faster than the highest frequency (perhaps 3 times as fast), or you can use a filter with a sharper cutoff, a multipole filter.

MULTIPOLE FILTERS A multipole filter is provided on the TD-GP/AAF and TD-PE/AAF drawers. When using these multipole filter drawers, there are two simple selections that are made in the application software: 1) set the filter to “on” for each channel, and 2) set the cut-off frequency (one setting for all channels). There are no switches or adjustments to be made on the drawer. The cut-off frequency input signals are attenuated 3 dB, which means their amplitude is reduced by 30%. Input signals above the cut-off frequency are heavily attenuated. You should set the sample rate three to six times the cut-off frequency. This ensures the sample rate is at least two times the highest frequency, avoiding aliasing.

Make sure there are no input signals 100 times the cut-off frequency. Due to the nature of the filter, at this exact frequency there is no rejection of input signals. If there may be frequencies in the input that are this high, use the one-pole filter described below to remove them. Set the one-pole filter cut-off frequency slightly higher than the cut-off frequency selected in the application software.

SIMPLE LOW PASS FILTERS Figure 27a shows a one-pole low pass filter on the TD-GP or TD-GP/BNC drawer. Resistor R1 and capacitor R3 are the active components. The cut-off frequency at which signals are attenuated 3 dB (30%) is calculated as follows:

$$f = 1 / (2\pi R1 C3) \quad \text{for } f = 1,000 \text{ Hz}$$

$$R1 = 1,600 \text{ Ohms}$$

$$C3 = 0.1 \mu\text{F}$$

where C3 is the capacitor in the R3 location. Higher frequencies are attenuated more, at the rate of 20 dB per decade increase in frequency.

Figure 27a can be applied to most of the examples shown in this chapter (using the TD-GP, TD-GP/BNC, and TD-GP/AAF drawers). Any example with R1=0 and R3 not used can have this filter installed to improve the high frequency performance.

Figure 27b shows a one-pole low pass filter on the TD-PE and TD-PE/AAF drawer. Resistor R5 and capacitor C3 are the active components. The equation for the components is similar to that for figure 27a:

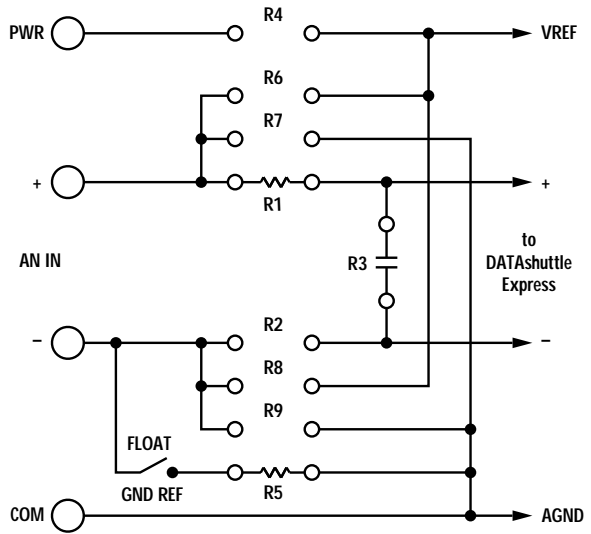
$$f = 1 / (2\pi R5 C3) \quad \text{for } f = 1,000 \text{ Hz}$$
$$R1 = 1,600 \text{ Ohms}$$
$$C3 = 0.1 \mu\text{F}$$

In figure 27b, solder C3 across R3 before plugging R3 into the drawer. Note that R5 must be much smaller than R3. The practical upper limit for R5 is about 2000 Ohms. Above that value, the DATAshuttle may exhibit an apparent offset and crosstalk between channels.

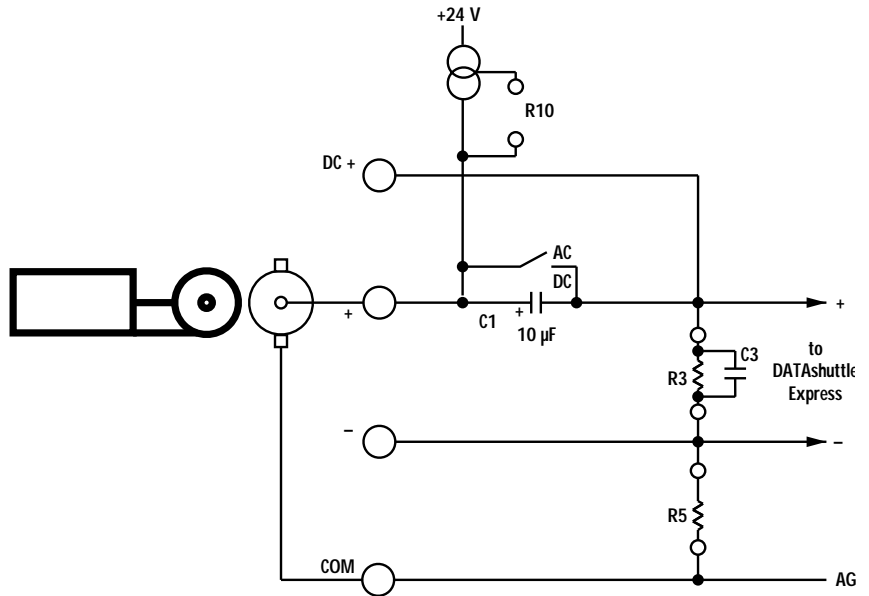
Figure 27b can be applied to all of the TD-PE and TD-PE/AAF examples shown in the chapter except Figure 8b. Be sure to change the connection of the negative input wire from the "-" terminal to the "COM" terminal.

SIMPLE HIGH PASS FILTERS A high pass filter can also be installed in the DATAshuttle Express. It rejects low frequencies. Figure 26a shows a high pass filter for the TD-GP, TD-GP/BNC, and TD-GP/AAF drawers. Figure 26d shows a high pass filter for the TD-PE drawer.

Figure 27. One-Pole Low Pass Filter –



a. TD-GP or TD-GP/BNC



b. TD-PE

Analog Output Examples

VOLTAGE For voltage outputs, simply connect the AO terminal to the positive and one of the COM terminals to the negative terminals of the device being driven as shown in Figure 28a. It is also acceptable to connect to the GND terminal, instead of COM. When using digital signals, the GND terminal may be noisier than COM, however. Make sure that the negative terminal of the device is at the same potential as the power ground to which the computer is connected. The COM and GND terminals connect to the DATAshuttle and computer power ground.

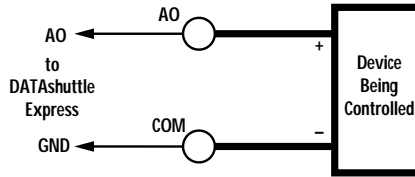
4-20 mA OUTPUT Almost all current loops are 4-20 mA. The DATAshuttle Express can only handle this type. 4-20 mA current devices have the advantage of running the power and signal over the same pair of wires. Also, current signals are much less susceptible to noise pickup than voltage signals. Select the 4-20 mA output range in the software. The AO terminal “sinks” the 20 mA current to ground, meaning the current flows into the AO terminal and to ground. For this reason, if you have a series of devices connected in the current loop, the DATAshuttle Express must be the last one, the one that connects to the negative side of the supply.

The connection of these devices depends upon whether the power is supplied from the DATAshuttle Express terminal drawer or from an external source. Figure 28b shows the power being supplied by the drawer. Often 10 V is not enough to power a current loop, however.

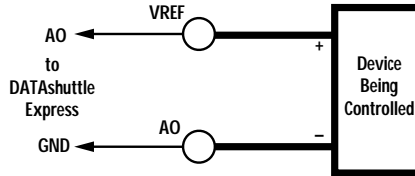
Figure 28c uses an external supply to overcome this limitation. The TD-GP, TD-GP/BNC, TD-GP/AAF, TD-GP/LC, TD-TC, TD-PE, and TD-PE/AAF drawers can all be connected this way.

The TD-ISO terminal drawer does not have a terminal for analog output. The analog output is connected to the analog isolation module simply by plugging the module into the analog isolation module socket. The analog input terminal is converted to an analog output. Any one socket may be used for analog output. When the output is current, insert the terminals in series with the load as shown in 28d.

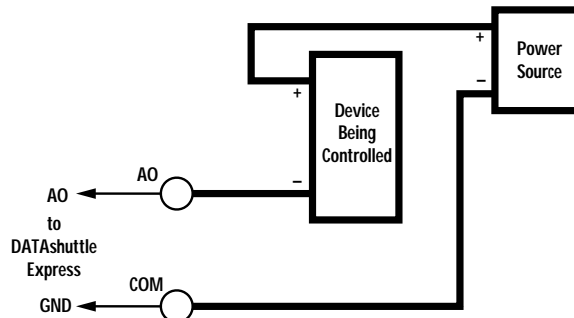
Figure 28. Analog Output Configurations –



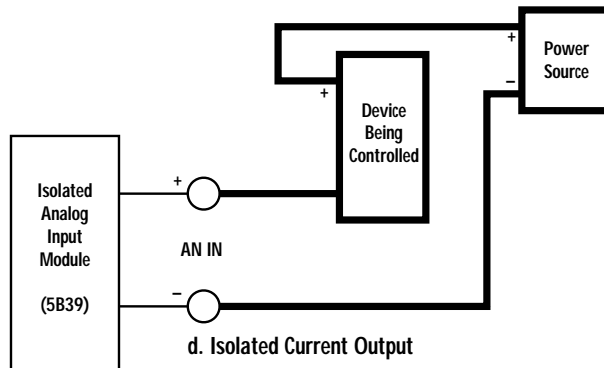
a. Voltage Output



b. Current Output, Internal Power



c. Current Output, External Power



d. Isolated Current Output

Digital I/O Examples

The digital input and output lines are independent, and may be used separately. They share an LED (Light Emitting Diode) that shines red to indicate when either the input or output is low. Diode D20 connects the output to the input. If you want to use them separately, you must remove this diode from the socket. You will then need an external pull-up resistor for the output, and the LED will not indicate the state of that output.

When using digital isolation modules, you must remove jumpers JP1 and JP2 and leave the diode in place. With the diode in place, be sure that the digital output is not in use while the digital input is in use. If the output goes low, it pulls the input low.

The counter/timer and trigger lines are discussed in this section because they are digital inputs and outputs. They have different components on the terminal drawer, however. There is no provision for digital isolation modules on these lines, and there is no need to install or remove jumpers to use them. The TD-ISO terminal drawer does not have counter/timer or trigger lines.

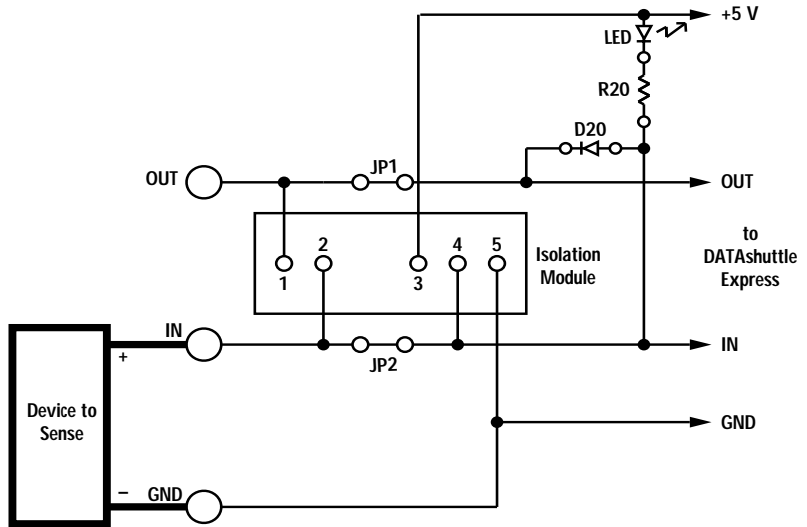
All the terminal drawers except the TD-ISO may be used for both low voltage and isolated connections, as shown below. The TD-ISO may be used as shown for isolated connections.

INPUT EXAMPLES Digital inputs detect the state of an on/off device. The first, non-isolated examples, are only for 0-5 V signals. The digital input detects whether the input is “high” (over 2.0 V) or “low” (under 0.8 V). Figure 29 shows the connections to sense a 5 V digital input.

Figure 30 shows the connections to sense a contact closure. The pull-up resistor, R20, assures that the input is high when the switch is open.

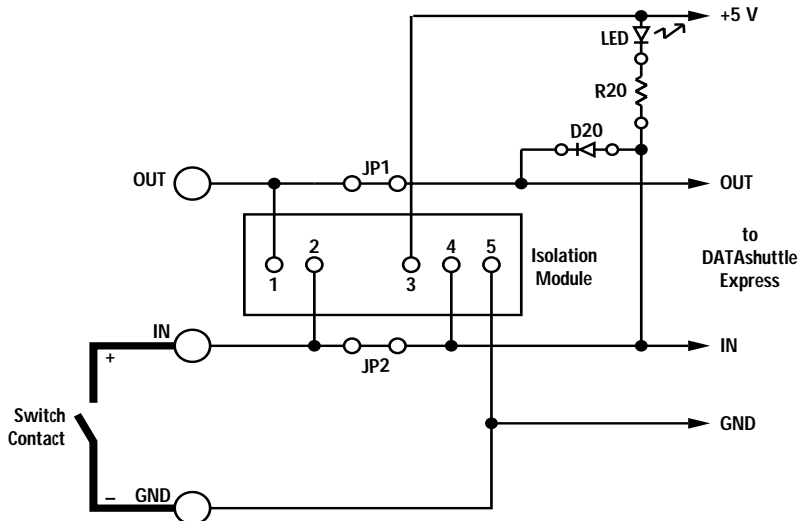
Figure 31 shows the connections to the counter/timer or trigger input. The connections are identical to Figure 29, except that there are no jumpers to install. These inputs cannot accept the high voltage isolated modules. The resistor R is R21 for C/T T/G, R22 for C/T IN, or R23 for the TRIG terminal.

Figure 29. Low Voltage Digital Input Configuration –



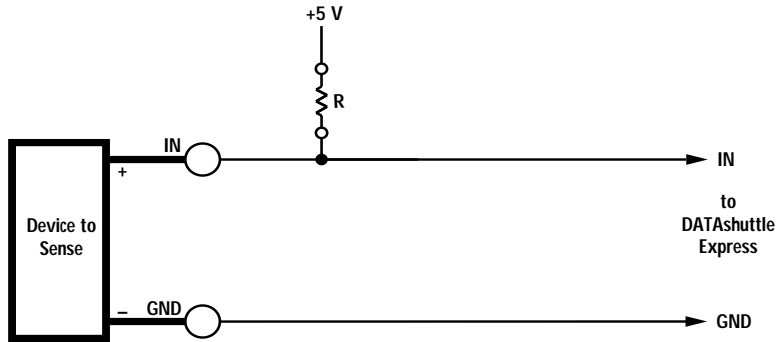
JP2 short, R20 = 1,000.

Figure 30. Contact Closure Sense Configuration –



JP2 short, R20 = 1,000.

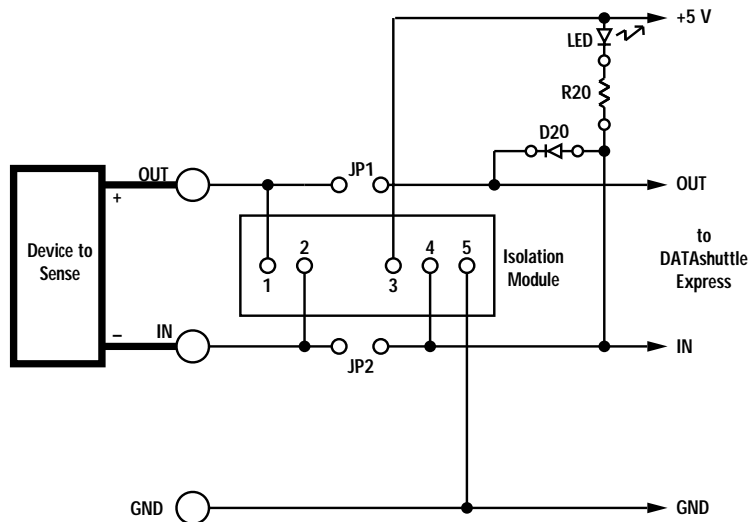
Figure 31. Counter/Timer or Trigger Input Configuration –



HIGH VOLTAGE SENSING

To sense voltages over 5 V, and to protect the sensitive digital inputs from damage, use the isolated modules shown in Figure 32. You must remove jumpers JP1 and JP2 to install isolated modules except on the TD-ISO. The modules send a low level to the DATAshuttle Express when the input senses a high level. The example shows connections to sense DC power (IDC5 module), but the connections are the same for AC power (IAC5 module), except that there is no polarity. Ignore the “+” and “-” signs when sensing AC power. Be sure to leave D20 in place.

Figure 32. Isolated Digital On/Off Sense Configuration –



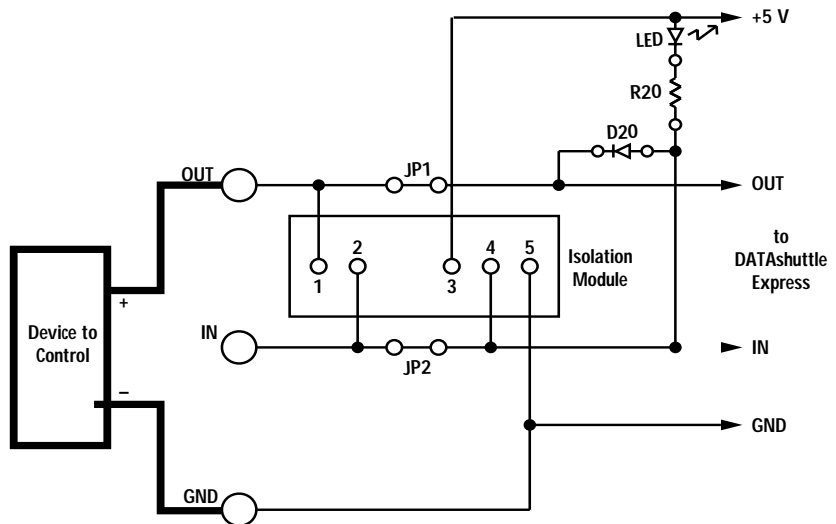
JP1 open; JP2 open; D20 installed; R2 = 1,000.



CAUTION Sensing high voltages without an isolation module presents a risk of shock and injury and will damage the DATAshuttle Express. Always use isolation modules for high voltage inputs or outputs. Be sure to remove jumpers JP1 and JP2 before using the isolation modules, or the DATAshuttle Express will be damaged.

OUTPUT EXAMPLES Digital outputs turn something on or off. The first, non-isolated examples, are only for voltages up to 30 V. The digital output is “open collector”, which means it operates like a switch. It can be closed (shorted to ground) or open (not conducting). It differs from a switch in that current can only flow into the digital output when it is closed. It will be damaged if you try to force current to flow out of the terminal. When software sets the output high, the open collector is open, or off. When software sets the output low, the open collector is closed, or on. Figure 33 shows the connections for a low voltage digital output. Pull-up resistor R20 and diode D20 force the output voltage “high” when the open collector output is off (the output is set high in software).

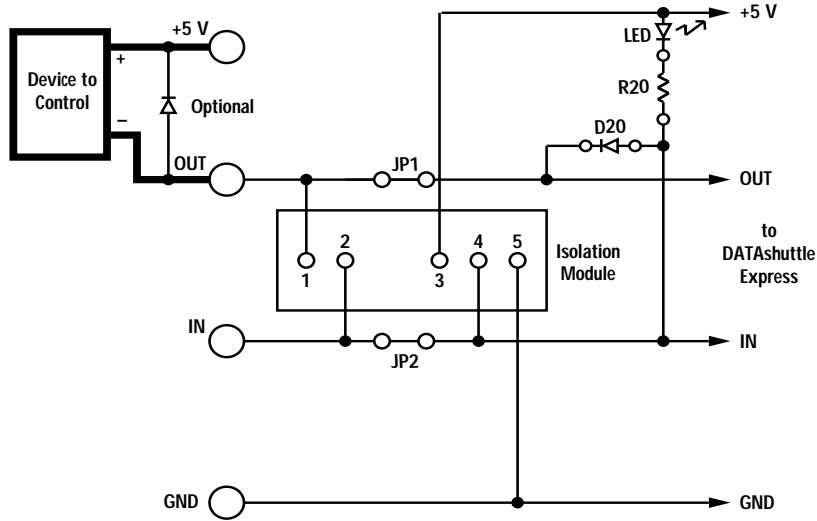
Figure 33. Low Voltage Digital Output Configuration –



JP1 short; D20 installed; R20 = 1,000.

Figure 34 shows the advantage of the open collector output. It can drive moderate currents, up to 24 mA, to operate devices such as lights and relays. It can operate devices that require up to 30 V. You may connect the positive side of the device being controlled to any positive voltage up to 30 V, instead of using the internal +5 V. R20 and D20 are not required except to operate the LED. If the load is inductive (i.e., relay coil or solenoid valve), use a commutating diode, as shown. A 1N4003 will work.

Figure 34. Open Collector Switch Configuration –

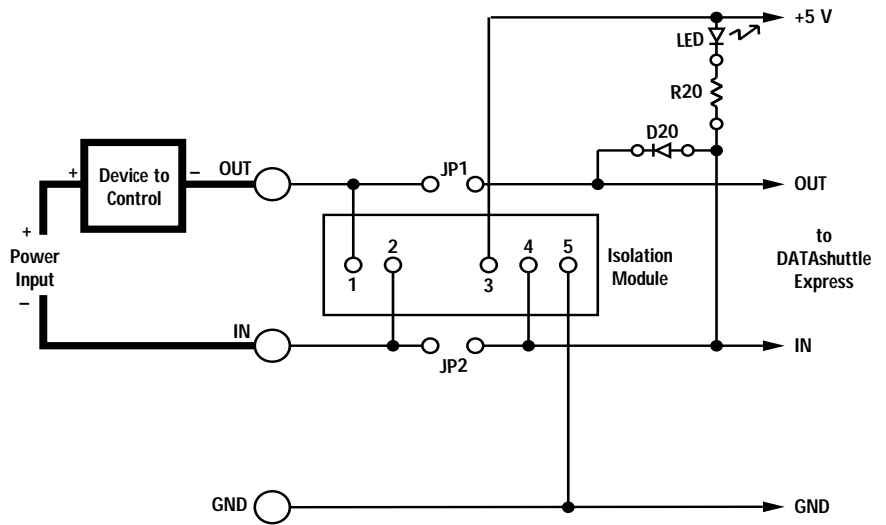


JP1 short, D20 installed, R20 = 1,000, 1N4003 optional commutating diode.

To operate voltages higher than 30 V, and to protect the sensitive digital outputs from damage, use the isolated modules as shown in Figure 35. These are solid state relays that can drive up to 3 A at 120 V or 240 V. The example shows DC power (ODC5 module), but the connections are the same for AC power, except that there is no polarity (OAC5 module). You may ignore the “+” and “-” signs in the example when using AC power.



CAUTION Sensing and/or controlling high voltages without an isolation module presents a risk of shock and injury and will damage the DATAshuttle Express. Always use isolation modules for high voltage inputs or outputs. Be sure to remove jumpers JP1 and JP2 before using the isolation modules, except on the TD-ISO, or the DATAshuttle Express will be damaged.

Figure 35. Isolated Digital Switch Configuration –

JP1 open, JP2 open, D20 installed, R20 = 1,000.

Chapter 4: Technical Notes

Although operations in this chapter are seldom necessary during everyday data acquisition, they are included here for advanced users of the DATAshuttle Express. They are:

- **Block diagram** (of the DATAshuttle Express showing on-unit processing);
- **Pinout diagram** of the terminal drawer cable;
- **Tips for connecting to other devices directly;**
- Instructions for **changing the test voltages and VREF** for different applications;
- **Recalibration;**
- **Troubleshooting:** some possible problems and solutions after installing and during operation of your unit;
- **Specifications of the DATAshuttle Express** and terminal drawers.

Figure 36. Block Diagram of DATAshuttle Express –

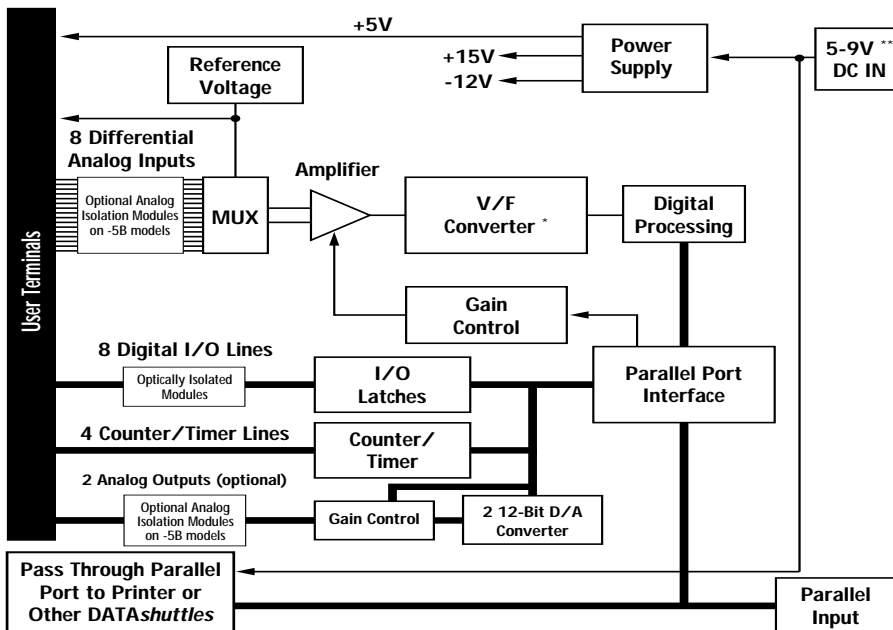
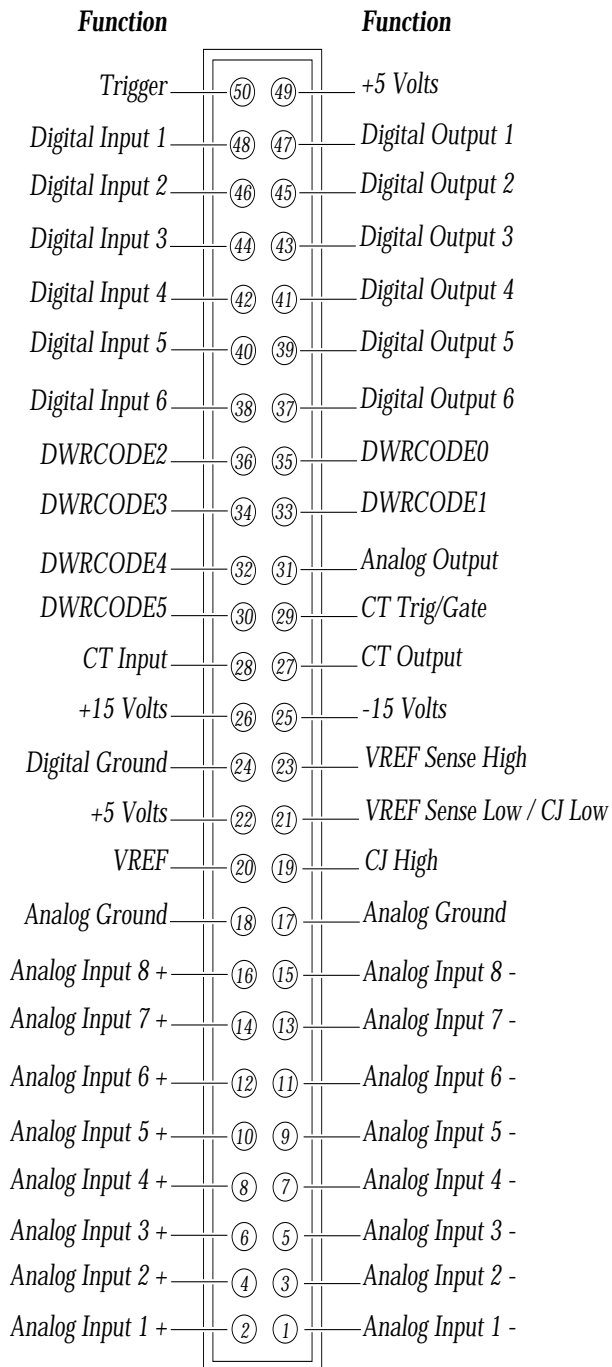


Figure 37. Pinouts of the Terminal Drawer Cable –



Connecting to Other Devices

Instead of using the terminal drawers, you may wish to connect your DATAshuttle Express to external digital or analog isolation devices, or you may connect directly to some other devices. You may do so by connecting the analog or digital signals directly from the ribbon cable in the DATAshuttle Express.

RIBBON CABLE SIGNALS It is important to note, however, that the signals differ from what is available at the screw terminals of the terminal drawer. The differences are as follows:

- *Analog inputs AI1 to AI8 are voltage only. There is no sensor signal conditioning.*
- *The analog output is unchanged.*
- *Digital inputs DI1 to DI6 lack a pull-up resistor. It is not required, but adding one improves noise immunity.*
- *Digital outputs DO1 to DO6 lack a pull-up resistor. Since they are open collector, the outputs will appear to remain low until they are connected to a load. The load must be connected between the output and a positive voltage less than 30 V. You may add a pull-up resistor to +5 V to drive standard digital logic.*
- *CT Trig/Gate, CT Input, and Trigger lack pull-up resistors. They are the same as the digital inputs above.*
- *DGND is the ground for digital signals.*
- *AGND is the ground for analog signals.*
- *+5 V is unchanged. It is protected from short circuits by a self-resetting fuse inside the DATAshuttle Express.*
- *+15 V and -15 V. These are not available at the terminals of the terminal drawers. It is not recommended to use them because they are designed to power only the DATAshuttle Express. You may draw up to 50 mA from these supplies if you do not exceed the total power dissipation specification for the DATAshuttle Express, but be careful not to inject noise into the DATAshuttle. This could reduce the accuracy or increase the noise on the analog inputs or outputs.*
- *DWRCODE0 to DWRCODE5. These tell the DATAshuttle Express about the capabilities of the installed terminal drawer. Connect all of them to ground to get the full capability of the DATAshuttle.*

To Use the Sensor Excitation Voltage Output - VREF must be connected to VREF Sense High, and VREF Sense Low must be connected to AGND, to have the reference voltage output work. Directly connecting these pins results in a 2.5 V output. You may get a 10 V output by connecting a 500 Ohm resistor between VREF Sense High and VREF Sense Low and a 1,500 Ohm resistor between Sense High and VREF. Also connect VREF Sense Low to AGND. The voltage output depends upon the ratio of these resistors, so you may replace the 1,500 Ohm resistor with a potentiometer to get a variable reference voltage. NOTE: The accuracy and stability of these resistors determine the accuracy of VREF.

For Thermocouple Applications - If you want to measure thermocouples directly, you must install a cold junction sensor to replace the one on the terminal drawers. It is an LM335 installed between VREF Sense Low and CJ High. Contact the factory for details.

Changing the Test Voltages and VREF

You may change the test voltages on the drawers that are connected to the analog inputs by the TEST switch. It may be desirable to have one of the voltages be near full scale of a range you use frequently, or to have the LO setting select a voltage other than zero. You may also change the value of VREF to any value between 2.50 and 10.00 V.

The test voltages are created from VREF using voltage dividers. We recommend leaving R10 at 100,000 Ohms. Change R11 and R12 to change the value of the MED and LO selections; they form a simple voltage divider with R11. R13 and R14 are required to be in series with the test voltage because the TEST switch is “make before break,” which means that the analog inputs are briefly connected to the TEST voltage when operating the switch.

VREF may be changed by changing R15 from its value of 1,500 Ohms. We don't recommend changing R16. As the value of R15 is decreased, VREF is decreased from its initial 10.00 V. When R15 is zero VREF is 2.50 V. In order to maintain the high stability of VREF, you should use a resistor that has a temperature drift of 25 parts per million or less. Be sure to set VREF to 10.00 V when using RTDs. The DATAshuttle relies on VREF being 10.00 V for RTD signal conditioning.

Recalibration

The factory calibration of the DATAshuttle Express can be adjusted using the QuickLog for Windows software and precise voltage sources.



CAUTION This should not be attempted unless you have the proper equipment. All changes to factory calibration will be permanent.

During operation, you can perform autocalibration periodically (every few minutes) to maintain the accuracy of analog inputs. Periodic calibration does not make permanent changes. The procedure described in this section changes the factory calibration that is the reference for autocalibration. The factory calibration adjusts the on-board references with numbers stored permanently in an EEPROM on the DATAshuttle Express.

To Recalibrate –

You should use a voltage source that is 5 to 10 times the accuracy of the DATAshuttle Express (as listed in the Specifications section of this chapter). Follow these steps:

- 1. Install and run QuickLog for Windows.**
- 2. Select “Change Calibration” from the Calibrate menu.** You can see the calibration numbers that will be changed. Be sure to record them for future reference. The original factory calibration numbers are printed on the back of the DATAshuttle.
- 3. Click on the Recalibrate button.** You may select one of the voltage ranges to calibrate: 2.5 V, 250 mV, 25 mV or 2.5 mV.
- 4. Apply a voltage about 90% of full-scale positive.** It must be precise to 0.01%. Type in the exact voltage applied.
- 5. Click the button to update the calibration number.** You may need to do this several times until it does not change.
- 6. Click OK to see what the new number is.**
- 7. Repeat steps 3 through 6** with each of the remaining ranges.

For more information, click the Help button in QuickLog.

Troubleshooting: Installation

If you experience difficulty in getting your DATAshuttle Express up and running, please check to see that the installation is according to the descriptions in Chapter 1.

If the software reports a unit failure, or that it cannot find a DATAshuttle Express, then try these remedies:

1. **Make sure the cable is securely connected** from the DATAshuttle Express input connector to the parallel port on the computer.
2. **Make sure the DATAshuttle Express is connected to a power source.** A light on the unit indicates that power is present.
3. **Check that the DATAshuttle Express passed its self test.** Each time the DATAshuttle is powered on it performs a self test. If the test passes, the power light is green. If the test fails, the power light turns red and flashes an error code. Any red flashing error code, or lack of a steady green light, indicates that the DATAshuttle Express is malfunctioning. Try turning the power off and on. If the unit does not recover, contact the factory or your distributor for repair information.
4. **Verify that the software is up to date** (a version compatible with the unit you are using). Contact us, or your software provider.
5. **Disconnect additional DATAshuttle Express** and printers in your setup to see if the DATAshuttle will work alone.
6. **Connect the DATAshuttle Express to another parallel port** to see if the port is functioning properly.
7. **Remove any additional data acquisition cards** from the computer. The DATAshuttle must work alone, or with other DATAshuttle Express only.
8. **If possible, install the DATAshuttle Express with another computer** to verify its correct operation.
9. **Remove other terminate and stay resident (TSR)** programs from your system's AUTOEXEC.BAT file, temporarily. Also REM out any AUTOEXEC.BAT and CONFIG.SYS lines that relate to a PCMCIA port, such as device drivers, as these have been known to cause conflicts.

- 10. Make sure that you plug the DATAshuttle Express in and that power is connected** before starting your computer. Some laptops deactivate the parallel port at the start-up if nothing is attached to it.
- 11. Make sure that the Print Manager is not active in the Windows environment** when attempting to start the DATAshuttle Express. Some computers automatically load the Print Manager at startup, and it can interfere with the data acquisition software's ability to communicate with the hardware. Printing is possible by connecting the printer to the DATAshuttle passthrough parallel port, but not while the data acquisition software is running.
- 12. Run the application DTEST.EXE to test the DATAshuttle and parallel port.** It is a DOS application so you must be in DOS to run it.
- 13. Check that a printer works on the parallel port** without the DATAshuttle connected.
- 14. Use the TEST switches on each channel on each drawer to apply a known voltage to the DATAshuttle.** Check that the software reads it correctly.

(Please call our Technical Support line before returning a DATAshuttle Express – we hope to assist you with your problem via telephone.)

Troubleshooting: Operation

HINTS It's essential to have exactly one ground reference per channel. This single connection to ground makes sure you don't exceed the common mode range of the input.

(More than one connection per channel can lead to ground loops, causing errors or erratic readings. Switching the Gnd Ref switch provides a single ground. Your sensor might also provide another ground. If you're not sure that your sensor is grounded, try switching the Gnd Ref switch off and on to see which works best. R5 must be installed.)

Remember that if speed is not critical, selecting the "low noise mode" in software always provides the best accuracy and resolution with your data acquisition unit.

OPERATING Qs AND As Here are mini “case studies” of difficulties, along with some easy solutions:

Problem: *My unit reads analog inputs wrong.*

Action: Make sure the calibration numbers in the non-volatile memory are non-zero (click the EDITCAL button in WorkBench PC for Windows or select Change Calibration in QuickLog for Windows to check this). If the figures are correct, try switching the TEST switch on each channel to see if that voltage is read correctly.

Problem: *My unit reads the thermocouple as a very negative or positive temperature.*

Action: Verify the connections are secure. Opens read as positive very high temperature on the TD-TC. They may read positive or negative on other drawers.

Problem: *My readings are noisy.*

Action: Try using the average or low noise modes (see your software help menu for more information).

Problem: *My digital inputs are “high” with nothing connected to them.*

Action: This is normal. The digital inputs are pulled up to a high. You can pull them low by shorting them to ground.

Problem: *My 5V terminal reads only 4.8 V.*

Action: This is normal. Tolerance is 4.7 to 5.25 V. It may be lower when you connect additional loads in either drawer.

Problem: *My analog output accuracy is poor.*

Action: Perform calibration on the analog outputs. Note, however, that calibration sends full scale outputs, so it may be necessary to remove any instruments connected to the outputs.

BEFORE CALLING CUSTOMER SUPPORT *Check the following key areas to validate whether or not the DATAshuttle Express is operational:*

- 1. Make sure the Power Adapter is not damaged.** To do this, detach the adapter from the DATAshuttle Express, while leaving it plugged in to the wall outlet. Then measure the voltage between the two lower pins on the connector. The voltage should measure 5 V. If this is not the case, it is likely that the Power Adapter needs to be replaced.

2. **Check the power on the DATAshuttle Express.** After plugging the Power Adapter back into the DATAshuttle Express, check to make sure the LED is functioning. If the LED is not lighting up, then there is likely a problem with the power section of the unit. Contact technical support for further assistance.
3. **Check the DATAshuttle Express' internal power supply.** To do this, it is necessary to measure two voltages on one of the drawers: +5V and Vref. Connect the negative terminal of your voltmeter to the GND terminal.

If you have been installing resistors or capacitors on the analog input auxiliary section, then you should remove them and re-check the +5V and Vref voltages. If, after removal, these voltages return to normal, it is likely that there is a short-to-ground on the terminal drawer. Check the resistor/capacitor installations for such a short and reinstall the drawer.

If removal does not fix the voltages, then there is a problem with the DATAshuttle Express internal power supply. Contact technical support for further assistance.

IF YOU NEED CUSTOMER SUPPORT *To help us serve you better, please have the following information ready:*

1. Have the part numbers of your DATAshuttle Express and terminal drawers ready.
2. Have the type and version number of the software you're using.
3. Have your computer's type, model, and the version of the operating system.
4. Try to start the QuickLog for Windows software and select Hardware in the Help menu. Click the print button to print out the screen, or write down the data.

Product Specifications

ANALOG INPUT ACCURACY These specifications include all error factors and are reported as an overall percent of range or in degrees C. These are worst case numbers. Typically, accuracy is two to four times better. The accuracy is presented in a straightforward way, as it is with voltmeters, that makes it easy to determine the suitability for an application. The specifications are not directly comparable to many other data acquisition products for this reason.

VOLTAGE RANGES AND ACCURACY-

Range	Accuracy (%)		Resolution (μ V)	Noise (μ V)		
	at 25° C:	0 - 50°:		13-bits	Ave. 256	Low Noise
± 10 V	0.13	0.3	2,400	4,000	400	400
± 5 V	0.11	0.25	1,200	2,000	200	200
± 2.5 V	0.11	0.25	600	1,000	100	100
± 1 V	0.13	0.3	240	300	30	30
± 500 mV	0.11	0.25	120	200	15	15
± 250 mV	0.11	0.25	60	150	8	8
± 100 mV	0.13	0.3	24	100	4	4
± 50 mV	0.11	0.25	12	80	3	3
± 25 mV	0.11	0.25	6	70	2	2
± 10 mV	0.23	0.4	2.4	60	2	1
± 5 mV	0.35	0.5	1.2	60	2	1
± 2.5 mV	0.65	0.8	0.6	60	2	1

CURRENT RANGES AND ACCURACY-

Range	Accuracy (%) 0 - 50° C:	Resolution (μ A)	Noise (μ A)		
			13-bits	Ave. 256	Low Noise
± 100 mA	1.3	24	40	4	4
± 40 mA	1.3	10	12	1.2	1.2
± 20 mA	1.3	5	8	0.6	0.6
± 10 mA	1.3	2.4	6	0.3	0.3
± 4 mA	1.3	1.0	4	0.16	0.16
± 2 mA	1.3	0.5	3.2	0.12	0.12

Range	Accuracy (%) 0 - 50° C:	Resolution (μ A)	Noise (μ A)		
			13-bits	Ave. 256	Low Noise
± 1 mA	1.3	0.24	2.8	0.08	0.08
± 0.4 mA	1.4	0.10	2.4	0.08	0.04
± 0.2 mA	1.5	0.05	2.4	0.08	0.04
± 0.1 mA	1.8	0.024	2.4	0.08	0.04

General Conditions: Accuracy is \pm percent of full scale (where, for example, 10 V is full scale on the ± 10 V range) and includes off-set, gain, linearity, calibration, resolution, and drift errors over the rated ambient temperature. Source impedance is 1,000 Ohms or less. Accuracy applies after performing the software autocalibration. Included in the accuracy specified above is:

- Linearity error: 0.03%
- Offset error: 0.02%
- Temperature drift from 0 to 50° C ambient: 0.15% (0.006%/degree C)
- Current shunt resistor: 1%

Noise is the typical rms (root-mean-square) noise at the specified "resolution" setting. At "13-bits" the noise is shown for any single reading up to the maximum sample rate. The "Ave. 256" column averages 256 readings. This noise level was achieved at a sample rate of 390 samples per second. The "Low Noise" resolution selection averages for one power line cycle in order to reject power line frequencies.

Resolution is the smallest change that can be detected. It is limited by the analog-to-digital-converter.

THERMOCOUPLE ACCURACY –

Accuracy is shown in bold for the most-used operating conditions.

Range	Ambient (°C.)	Temperature Being Measured (°C.)							
		-200	-100	25	300	600	1200	1700	2200
E t/c, 25 mV	25	1.7	1.2	1.0	0.9	–	–	–	–
	0-50	4.5	3.4	3.0	2.8	–	–	–	–
J t/c, 25 mV	25	1.8	1.2	1.1	1.1	–	–	–	–
	0-50	4.6	3.3	3.0	2.9	–	–	–	–
K t/c, 25 mV	25	2.4	1.5	1.2	1.2	1.2	–	–	–
	0-50	6.0	4.0	3.4	3.4	3.5	–	–	–
T t/c, 25 mV	25	2.3	1.5	1.2	1.0	–	–	–	–
	0-50	6.1	4.4	3.6	3.3	–	–	–	–
C t/c, 25 mV	25	–	–	2.5	2.1	1.9	2.2	–	–
	0-50	–	–	6.8	5.8	5.5	6.0	–	–
D t/c, 25 mV	25	–	–	3.3	2.1	1.9	2.0	–	–
	0-50	–	–	9.2	6.4	6.1	6.2	–	–
G t/c, 25 mV	25	–	–	14.3	2.8	2.1	1.9	–	–
	0-50	–	–	33.6	8.0	6.3	5.8	–	–
R t/c, 25 mV	25	–	–	5.1	3.3	3.1	2.5	2.7	–
	0-50	–	–	13.0	9.0	8.4	7.2	7.5	–
S t/c, 25 mV	25	–	–	5.1	3.6	3.3	2.8	3.1	–
	0-50	–	–	12.7	9.3	8.7	7.6	8.1	–
B t/c, 25 mV	25	–	–	–	9.7	5.1	3.3	2.8	–
	0-50	–	–	–	23.6	13.4	9.4	8.3	–
N t/c, 25 mV	25	3.3	1.9	1.5	1.3	1.3	–	–	–
	0-50	8.1	4.8	4.1	3.7	3.5	–	–	–
E t/c, 50 mV	25	2.8	1.8	1.4	1.3	1.2	–	–	–
	0-50	6.9	4.7	4.0	3.6	3.5	–	–	–
J t/c, 50 mV	25	3.1	1.9	1.6	1.6	1.5	–	–	–
	0-50	7.4	4.8	4.1	4.1	3.9	–	–	–
K t/c, 50 mV	25	4.2	2.4	1.9	1.9	1.8	2.1	–	–
	0-50	10.1	6.0	4.9	4.9	4.8	5.3	–	–
T t/c, 50 mV	25	4.0	2.5	1.8	1.5	–	–	–	–
	0-50	9.9	6.6	5.1	4.3	–	–	–	–
C t/c, 50 mV	25	–	–	4.5	3.6	3.3	3.8	4.5	6.1
	0-50	–	–	11.2	9.2	8.6	9.6	11.2	14.7

Range	Ambient (°C.)	Temperature Being Measured (°C.)							
		-200	-100	25	300	600	1200	1700	2200
D t/c, 50 mV	25	–	–	6.1	3.6	3.3	3.4	3.8	5.1
	0-50	–	–	15.3	9.8	9.2	9.5	10.2	13.2
G t/c, 50 mV	25	–	–	28.1	5.1	3.6	3.2	3.4	4.5
	0-50	–	–	64.2	13.1	9.7	8.8	9.4	11.7
R t/c, 50 mV	25	–	–	9.7	6.1	5.6	4.5	4.8	–
	0-50	–	–	23.2	15.1	14.0	11.6	12.2	–
S t/c, 50 mV	25	–	–	9.7	6.7	6.1	5.1	5.6	–
	0-50	–	–	22.9	16.1	14.8	12.7	13.7	–
B t/c, 50 mV	25	–	–	–	18.9	9.7	6.1	5.1	–
	0-50	–	–	–	44.1	23.6	15.5	13.4	–
N t/c, 50 mV	25	6.1	3.2	2.5	2.1	2.0	2.0	–	–
	0-50	14.2	7.8	6.3	5.4	5.1	5.2	–	–

Thermocouple Conditions: Accuracy is ±degrees C and includes off-set, gain, linearization, calibration, resolution, drift, and cold junction compensation errors over the rated ambient temperature. Source impedance is 1,000 Ohms or less. Accuracy applies after performing the software autocalibration. Ambient is the temperature of the DATashuttle Express and terminal drawer. Temperature being measured is the temperature on the thermocouple.

An additional and very important error is the temperature difference between the cold junction sensor and the screw terminals on the drawer. On the TD-TC there is an aluminum isothermal plate that maintains all the terminals at the same temperature as the cold junction sensor, which is imbedded in the isothermal plate. Temperature differences in the local ambient are reduced by a factor of 15 when AWG 22 or smaller thermocouple wire is used. All of the other drawers lack the isothermal plate, so local temperature differences are seen directly as errors in the temperature readings. This error can be several degrees C, which is larger than all the other errors combined for many thermocouple types, and it changes unpredictably. Because of this error it is impossible to calibrate any drawers other than the TD-TC to the specifications shown here. To summarize: Without the isothermal plate on the TD-TC, there is often several degrees of error in the thermocouple reading. This error changes unpredictably.

Accuracy better than specified can be achieved with a two point calibration in the region of interest. Calibrate with a software offset and gain at the top and bottom of the temperature range being used. After this calibration, the accuracy is limited by the repeatability. In many applications the absolute accuracy is less important than repeatability.

Repeatability is the ability of the *DATAshuttle Express* to measure the same temperature each time, despite noise and drift. Repeatability does not include the calibration to a NIST traceable reference.

Repeatability on the *DATAshuttle Express* can be determined from the noise and drift specifications in the voltage accuracy section. Thermocouple measurements consist of two readings, one on the 25 or 50 mV range to read the thermocouple, and one on the 5 V range to read the cold junction sensor. The cold junction sensor changes 10 mV per degree C. Noise is approximately equal to the resolution when using averaging or the low noise mode. For an example of the repeatability that can be achieved, the J thermocouple has an accuracy of $\pm 1.1^{\circ}\text{C}$ at 25°C when measured on the 25 mV range. It has a repeatability of $\pm 0.2^{\circ}\text{C}$ under the same conditions. The accuracy of the J thermocouple is $\pm 3^{\circ}\text{C}$ when the *DATAshuttle Express* temperature changes between 0 and 50°C . The repeatability is $\pm 0.8^{\circ}\text{C}$ under the same conditions.

THERMOCOUPLE RESOLUTION AND USABLE RANGE –

Range	Temperature Being Measured (°C.)								Usable Range (°C)
	-200	-100	25	300	600	1200	1700	2200	
E t/c, 50 mV	0.5	0.3	0.2	0.2	0.2	–	–	–	-270 to 670
J t/c, 50 mV	0.6	0.3	0.2	0.2	0.2	–	–	–	-210 to 770
K t/c, 50 mV	0.8	0.4	0.3	0.3	0.3	0.3	–	–	-270 to 1260
T t/c, 50 mV	0.8	0.4	0.3	0.2	–	–	–	–	-270 to 400
C t/c, 50 mV	–	–	0.9	0.7	0.6	0.7	0.9	1.2	0 to 2320
D t/c, 50 mV	–	–	1.2	0.7	0.6	0.6	0.7	1.0	-18 to 2315
G t/c, 50 mV	–	–	6.0	1.0	0.7	0.6	0.6	0.9	-18 to 2315
R t/c, 50 mV	–	–	2.0	1.2	1.1	0.9	0.9	–	-50 to 1768
S t/c, 50 mV	–	–	2.0	1.3	1.2	1.0	1.1	–	-50 to 1768
B t/c, 50 mV	–	–	–	4.0	2.0	1.2	1.0	–	100 to 1820
N t/c, 50 mV	1.2	0.6	0.4	0.3	0.3	0.3	–	–	-270 to 1300
E t/c, 25 mV	0.2	0.1	0.1	0.1	–	–	–	–	-270 to 360
J t/c, 25 mV	0.3	0.2	0.1	0.1	–	–	–	–	-210 to 480
K t/c, 25 mV	0.4	0.2	0.2	0.2	–	–	–	–	-270 to 626
T t/c, 25 mV	0.4	0.2	0.1	0.1	–	–	–	–	-270 to 400
C t/c, 25 mV	–	–	0.4	0.3	0.3	0.4	–	–	0 to 1374
D t/c, 25 mV	–	–	0.6	0.3	0.3	0.3	–	–	-18 to 1340
G t/c, 25 mV	–	–	3.0	0.5	0.3	0.3	–	–	-18 to 1505
R t/c, 25 mV	–	–	1.0	0.6	0.6	0.4	0.5	–	-50 to 1768
S t/c, 25 mV	–	–	1.0	0.7	0.6	0.5	0.6	–	-50 to 1768
B t/c, 25 mV	–	–	–	2.0	1.0	0.6	0.5	–	100 to 1820
N t/c, 25 mV	0.6	0.3	0.2	0.2	0.2	–	–	–	-270 to 729

Thermocouple Conditions – Resolution is in degrees C. Noise is approximately equal to the resolution when measured using the Average 256 selection or the low noise selection. The usable range of each thermocouple is determined by the range for which the National Institute of Standards and Technology (NIST) or others who have published reference tables, and the voltage that can be measured on the corresponding range of the DATAshuttle. For B type thermocouples, an NIST table exists for temperatures down to 0° C, but there is almost no change in voltage with temperature below 100° C so it is not usable.

Thermocouples on the TD-TC drawer have built-in open detection that gives a full-scale reading when a thermocouple is disconnected or broken.

RTD ACCURACY –

Range	Accuracy (%) at		Resolution	Usable Range
	25° C	0-50° C		
50 Ω RTD, R _s =20K, α=.00385	0.6	1.3	0.1	-200 to 266
50 Ω RTD, R _s =50K, α=.00385	1.4	3.0	0.3	-200 to 850
100 Ω RTD, R _s =50K, α=.00385	0.7	1.6	0.2	-200 to 408
100 Ω RTD, R _s =100K, α=.00385	1.4	3.0	0.3	-200 to 850
200 Ω RTD, R _s =100K, α=.00385	0.7	1.6	0.2	-200 to 408
200 Ω RTD, R _s =200K, α=.00385	1.4	3.0	0.3	-200 to 850
500 Ω RTD, R _s =200K, α=.00385	0.6	1.3	0.1	-200 to 266
500 Ω RTD, R _s =500K, α=.00385	1.4	3.0	0.3	-200 to 850
1000 Ω RTD, R _s =500K, α=.00385	0.7	1.6	0.2	-200 to 408
1000 Ω RTD, R _s =1M, α=.00385	1.4	3.0	0.3	-200 to 850
50 Ω RTD, R _s =20K, α=.00392	0.6	1.3	0.1	-200 to 266
50 Ω RTD, R _s =50K, α=.00392	1.4	3.0	0.3	-200 to 850
100 Ω RTD, R _s =50K, α=.00392	0.7	1.6	0.2	-200 to 408
100 Ω RTD, R _s =100K, α=.00392	1.4	3.0	0.3	-200 to 850
200 Ω RTD, R _s =100K, α=.00392	0.7	1.6	0.2	-200 to 408
200 Ω RTD, R _s =200K, α=.00392	1.4	3.0	0.3	-200 to 850
500 Ω RTD, R _s =200K, α=.00392	0.6	1.3	0.1	-200 to 266
500 Ω RTD, R _s =500K, α=.00392	1.4	3.0	0.3	-200 to 850
1000 Ω RTD, R _s =500K, α=.00392	0.7	1.6	0.2	-200 to 408
1000 Ω RTD, R _s =1M, α=.00392	1.4	3.0	0.3	-200 to 850

RTD Conditions – Accuracy is ± degrees C and includes offset, gain, linearization, calibration, resolution, and drift errors over the rated ambient temperature. Accuracy is shown at a measured temperature of 25° C. It is slightly better at higher temperatures and slightly worse at lower temperatures. Accuracy applies after performing the software autocalibration. Ambient is the temperature of the DATAshuttle and terminal drawer. Temperature being measured is the temperature on the RTD. RTDs are powered from VREF which must be set to 10 V.

Resolution is in degrees C. Noise is approximately equal to the resolution when measured using the Average 256 selection or the low noise selection. The usable range of each RTD is determined

by the range for which there is a published reference table, and the voltage that can be measured on the corresponding range of the DATAshuttle Express.

- MAXIMUM SAMPLE RATE** Divide these rates by the number of channels being used:
- 100,000 samples per second on 25 mV and 1 mA ranges and above.
 - 50,000 samples per second on 2.5 mV, 5 mV, 10 mV, 100 uA, 200 uA, and 400 uA ranges. These low ranges are primarily for use with averaging where the noise is low.

See the section below, “Buffers, Triggers, and Sample Rates” for more about sample rates.

RESOLUTION The resolution of the analog inputs is as follows:

- 13-bits
- Average 8
- Average 32
- Average 256
- Low Noise: 50 or 60 Hz

The resolution of the converter is fixed at 13 bits. The other resolution selections use averaging to reduce noise in the analog input. “Average 8” averages 8 readings, “Average 32” averages 32 readings, and “Average 256” averages 256 readings. The maximum sample rate is reduced accordingly. “Low Noise” averages for one power line cycle to minimize interference from power lines. When using Low Noise, each channel has a maximum sample rate of 50 Hz or 60 Hz. Select the frequency that matches the power line frequency in your area.

Pseudo-simultaneous sampling is achieved when 13-bit resolution is selected. When sampling multiple channels they are all sampled rapidly in succession, at the maximum sample rate, then there is a pause until the next sample interval. This means that all the channels are sampled within 10 μ S to 20 μ S times the number of channels in use, regardless of the selected sample rate.

INPUT IMPEDANCE *Resistance* – greater than 1,000 M Ω

Bias Current – less than 1 nanoamperes

BANDWIDTH *Capacitance* – less than 200 picofarads

50 KHz with an amplitude error no more than 1%.

900 KHz with an amplitude error no more than 3 dB.

MAXIMUM INPUT SIGNAL The maximum analog input that can be measured is -10 to +10 V.
The maximum analog input without damage is:

- -35 to +35 V, continuous, powered.
- -20 to 20 V, continuous, unpowered

The maximum analog input on the TD-ISO Drawer is 150 V AC or DC maximum with isolation modules. For CE the maximum rating is 60 VDC or 30 V rms.

COMMON MODE INPUTS The maximum common mode input that can be measured is -10 to +10 V.

The maximum common mode input without damage is -35 to 35 V, powered

COMMON MODE REJECTION RATIO *CMRR* –

<i>Range</i>	<i>1 V</i>	<i>100 mV</i>	<i>10 mV</i>
<i>DC</i>	<i>84 dB min.</i>	<i>90 dB min.</i>	<i>92 dB min.</i>
<i>AC (50 kHz)</i>	<i>32 dB</i>	<i>62 dB</i>	<i>–</i>

CMRR is measured with a source resistance of no more than 1,000 Ω. AC CMRR is the typical value on the worst channel. It is not tested on each unit. AC CMRR decreases in proportion to the frequency. At 5 kHz it is 10 times (20 dB) smaller than at 50 kHz.

CROSSTALK *On a Single Unit* –

<i>Between Channels</i>	<i>Same Drawer</i>	<i>Opposite Drawer</i>
<i>DC</i>	<i>same as CMRR</i>	<i>same as CMRR</i>
<i>AC (50 kHz)</i>	<i>-57 dB</i>	<i>-69 dB</i>

Crosstalk is the voltage on the measured channel divided by the voltage on the forced channel. It is measured with all inputs within their operating range, source impedance no more than 1,000 Ω. AC crosstalk is measured on the 100 mV range. It typically improves in proportion to the range. For example, crosstalk on the 50 mV range is 63 dB on the same drawer and 75 dB on the opposite drawer. AC cross talk is the typical value between the worst channels. It is not tested on each unit. This includes crosstalk from one channel to the next one sampled, except on the ranges below 25 mV. AC cross talk decreases in proportion to the frequency. At 5 kHz it is 10 times (20 dB) smaller than at 50 kHz.

From Digital Inputs to Analog Inputs–

5 V Range	50 mV Range
8 mV	600 μ V

Value is for the worst channel. Digital input rise time is 10 nS.
Analog input source impedance is 1,000 Ω .

From Digital Outputs to Analog Inputs - none.

From Analog Outputs to Analog Inputs - none.

**PIEZOELECTRIC
INPUTS ON THE TD-PE**

Current Source – 4 mA with a 23 V compliance.

Current Accuracy – $\pm 20\%$.

The current is selectable on each channel from 0 to 10 mA by changing R10:

Current	R10
10 mA	6.8 Ω
4 mA	18 Ω
2 mA	33 Ω
1 mA	68 Ω
500 μ A	130 Ω
100 μ A	680 Ω
10 μ A	6,800 Ω
1 μ A	68,000 Ω
zero	omit

DC Decoupling Capacitor (C1) – 10 μ F.

Load Resistance (R3) – 1 M Ω , user selectable separately on each channel.

Noise – Less than 500 μ V rms measured on a piezoelectric transducer.

**FILTER INPUTS ON
TD-GP/AAF &
TD-PE/AAF**

Each analog input has a five-pole Butterworth, anti-aliasing filter.

There are 8 channels, individually selectable on each channel.

Cut-off Frequency – 12 to 40 Hz (all channels are the same).

Passband Gain – 0 dB, ± 0.2 dB ($\pm 2.5\%$).

Attenuation – 30 dB per octave or 100 dB per decade.

Phase Match – better than 2 degrees between any channels.

Stopband Rejection – 80 dB typical.

Input Ranges – same as DATAshuttle Express.

Input Offset –

- 1 mV maximum (1 V range)
- 0.1 mV maximum (0.1 V range)
- 5 mV maximum (10 V range).

Noise –

- 100 μ V rms maximum (0.1 V range)
- 1 mV rms maximum (1 V range)
- 5 mV rms maximum (10 V range).

Input Current –

Input Impedance – > 100 MOhms.

Common Mode Input Rejection – 80 dB typical, 60 dB minimum at 25 kHz.

Common Mode Input Voltage – ± 10 V.

Input Protection – ± 30 V (unpowered), ± 45 V (powered).

ANALOG OUTPUTS The DATAshuttle Express has two analog outputs, one on each termination drawer.

Maximum Output Speed – 100,000 outputs per second

ANALOG OUTPUT ACCURACY, 0-50° C –

Range	Accuracy (%)
0-5 V	0.5
0-10 V	0.5
± 5 V	0.5
± 2.5 V	0.5
0-2 V	0.5
± 1 V	0.5
4-20 mA	1.5

Accuracy is \pm percent of full scale and includes offset, gain, linearity, calibration, resolution, and drift errors over the rated ambient temperature. Accuracy applies after performing the software calibration.

Voltage Compliance – Current output is +5 V to +15 V. Do not exceed 15 V on the output.

Output Impedance – Voltage output is <2 Ohms.

Response Time – 1 mS for a 10 V change.

Overshoot – None on high ranges, 0.5 V on the 0-2 V and ± 1 V ranges.

DIGITAL I/O 12 digital inputs, six on each termination drawer.

12 digital outputs, six on each termination drawer.

Maximum Speed – 100,000 samples per second.

Inputs have Schmitt triggers to make the transitions clean. Outputs are open collector with pull-up resistors on the drawers.

Maximum Voltage –

Without Isolation Modules:

- Open collector digital output: 0 to +30 V, except TD-ISO: 5 V
- Digital inputs: 0 to 5 V.

With Isolation Modules:

- 125 Volts AC or DC
- TD-ISO drawer: 150 Volts AC or DC, for CE the maximum rating is 60 VDC or 30 VAC rms.

Maximum Current –

Without Isolation Modules:

- Open collector digital output: 40 mA sink current
- Digital inputs: less than 400 μ A low, less than 20 μ A high (one LS-TTL input)

COUNTER/TIMERS Two counter/timers, one on each termination drawer.

Maximum Pulse Input Rate – 2 MHz

Maximum Sample Rate – 100,000 samples per second

Input Voltage and Current – same as digital inputs above

POWER OUTPUT **VREF Specifications** –

- Switched on the drawers to either 10 V or 2.5 V
- Maximum current: 230 mA (each drawer)
- Short circuit current: 330 mA (each drawer)

- Accuracy: $\pm 0.6\%$ at zero current
 - TD-GP/LC only: $\pm 2\%$ accuracy
- Load regulation: less than 40 mV change from zero to maximum current, measured at any terminal on any drawer
- Drift with temperature: less than 0.005% per degree C
- Drift with time: 0.0025% per 1000 hours
- Noise: less than 5 mV rms

NOTE: The voltage applied by the TEST switches on the drawers is derived from VREF but does not meet these accuracy specifications.

+5 V Specifications –

- Maximum current: 1.0 A total on both drawers.
- Short circuit current: 1.5 A
- Accuracy: $\pm 5\%$ with load currents below 100 mA.
- When using more than 500 mA of current be sure the total power consumption (below) is not exceeded. The voltage drops to about 4.8 V at 500 mA and 4.5 V at 1 A.

BUFFERS, TRIGGERS & SAMPLE RATES

Inputs can be captured in a burst up to and somewhat beyond the size of the buffer at the full 100,000 samples per second speed of the DATAshuttle Express. This speed must be divided by the number of channels in use. Data can be captured *continuously* at a rate determined by the speed of the parallel port and the PC. An ECP port can transfer data up to approximately 60,000 samples per second. An EPP or a standard parallel port (SPP) can transfer data up to approximately 15,000 samples per second. The burst speed can occur simultaneously on multiple DATAshuttles, while the parallel port speed must be divided by the total number of channels in use on all DATAshuttles. The achievable continuous rate into an application depends upon the software, how it is configured, and the speed of the PC. The speeds listed above apply to a Pentium PC running WorkBench PC for Windows.

Digital input sample rates are the same as analog inputs, except that all 12 channels are sampled simultaneously in one sample. Analog and digital outputs can update at the 100,000 samples per second rate from the internal buffer. When each point is sent from the application software, the rate is determined by the parallel port speed, the software, and the computer.

When using more than one DATAshuttle in synchronous (interrupt) mode, all units begin sampling at the same time. The first channel on each DATAshuttle is sampled at the same time. This is true for continuous or triggered acquisition.

Analog Input Buffer Size – 32,000 samples in burst mode. 8,000 samples when running in continuous mode or doing other types of I/O at the same time.

Digital Input Buffer Size – 8,000 samples

Analog Output Buffer Size – 8,000 samples

Digital Output Buffer Size – 8,000 samples

Triggers – Bursts of samples may be started upon making a selection in the software, or they may be triggered by an event. The event may be a digital, high/low, signal using the Trigger line on the DATAshuttle, or it may be an analog signal using one of the analog inputs. Pretriggering may be specified, providing for the capture of data points before the trigger signal.

Pseudosimultaneous Sample and Hold – When not using one of the averaging modes (when using 13-bit resolution) all analog inputs are sampled rapidly in succession at the maximum sample rate. This is repeated at the sample frequency specified in the application software. Sampling all the inputs nearly simultaneously is called pseudosimultaneous sample and hold.

The time between samples on adjacent channels is between 10 and 20 μS . At maximum speed, the time between samples is 10 μS . As the sample rate is lowered, the time between samples is increased in one microsecond increments. The time between samples can be as much as 20 μS . For slower sample rates, time is inserted between the last channel and the first channel, keeping the time between channels to no less than 10 μS and no more than 20 μS . This means that all the channels are sampled within 10 to 20 microseconds times the number of channels in use, regardless of the selected sample rate.

PARALLEL CABLE The maximum length is 50 feet (15 meters). All DATAshuttle Express must be on the same parallel port.

AC POWER ADAPTER An AC Power Adapter is included with each DATAshuttle Express.

Input – 90 VAC to 264 VAC, 47 to 63 Hz, 25 W maximum.

The power supply automatically adjusts to the voltage applied.

Ground of DATAshuttle connects to third wire ground input on adapter.

Size – 6 x 3 x 1.5 inches (15 x 8 x 4 cm) approximate.

Temperature – 0 to 50° C (32 to 122° F), operating. -20 to 70° C (-4 to 158° F), storage.

Cables –

- From Adapter to DATAshuttle: 24 inches (60 cm) approximate
- Cable from Power Source: accepts standard power cable with IEC connector.

DC POWER ADAPTER A DC Power Adapter is available as an option.

Input – 9 VDC to 36 VDC, 25 W maximum.

The power supply automatically adjusts to the voltage applied.

Isolation from Power Source – 500 V.

Size – 6 x 3 x 1.5 inches (15 x 8 x 4 cm) approximate.

Temperature – -20 to 50° C (-4 to 122° F), operating. -20 to 70° C (-4 to 158° F), storage.

Cable Lengths –

- From Adapter to DATAshuttle: 24 inches (60 cm)
- Cable from Power Source: 6 feet (2 meters) long, with cigarette adapter.

POWER DISSIPATION The power dissipation in a DATAshuttle Express with two TD-GP drawers is 8.0 W.

Maximum power dissipation:

- Including customer loads: 20 Watts
- Inside DATAshuttle enclosure at 50° C ambient: 15 W

The maximum load of 230 mA on VREF on each drawer amounts to 4.6 W plus an additional 2.1 W dissipated internally in the DATAshuttle. The additional 2.1 W must be included in the total internal power dissipation. Power drawn from the +5 V supply does not add any significant internal power. Total power may exceed 15 W (up to 20 W) as long as some of it is dissipated outside the DATAshuttle Express case, and the total dissipated inside the case is 15 W or less. The full 20 W may be dissipated inside the DATAshuttle Express case when the ambient temperature is below 40° C.

TEMPERATURE *Operating Temperature* – 32 to 122° F or 0 to 50° C.

Storage Temperature – -4 to 158° F or -20 to 70° C.

Humidity – 0 to 95%, noncondensing.

SHOCK & VIBRATION *Maximum Vibration* – 5 G, per IEC68-2-6 at 5G from 10 Hz to 500 Hz, operating.

Maximum Shock – 30 G, per IEC68-2-27 at 30 G from 11 mS, operating. Survives drop of 20 inches (0.5 meters) onto concrete floor.

SIZE & WEIGHT *PHYSICAL DIMENSIONS* –

Product	Size (Height x Width x Depth)	Weight
<i>DATAshuttle Express (DS-EXP)</i>	<i>2.8 x 8.7 x 10.75 in (7.2 x 22.0 x 27.4 cm)</i>	<i>2 lbs, 9 oz (1.2 kg)</i>
<i>DATAshuttle Express for Isolation (DS-EXP-ISO)</i>	<i>3.8 x 8.7 x 10.75 in (9.8 x 22.0 x 27.4 cm)</i>	<i>2 lbs, 12 oz (1.2 kg)</i>
<i>TD-GP Drawer</i>	<i>2.2 x 3.3 x 9.2 in (5.6 x 8.4 x 23.4 cm)</i>	<i>5.7 oz (9 g)</i>
<i>TD-GP/BNC Drawer</i>	<i>2.2 x 3.3 x 9.2 in (5.6 x 8.4 x 23.4 cm)</i>	<i>8.0 oz (230 g)</i>
<i>TD-GP/LC Drawer</i>	<i>2.2 x 3.3 x 9.2 in (5.6 x 8.4 x 23.4 cm)</i>	<i>4.5 oz (130 g)</i>
<i>TD-PE Drawer</i>	<i>2.2 x 3.3 x 9.2 in (5.6 x 8.4 x 23.4 cm)</i>	<i>8.9 oz (255 g)</i>
<i>TD-TC Drawer</i>	<i>2.2 x 3.3 x 9.2 in (5.6 x 8.4 x 23.4 cm)</i>	<i>11.5 oz (330 g)</i>
<i>TD-ISO Drawer</i>	<i>3.2 x 3.3 x 9.2 in (8.2 x 8.4 x 23.4 cm)</i>	<i>4.3 oz (125 g)</i>
<i>5B Isolation Module</i>	<i>1.25 x 0.6 x 1.7 in (3.2 x 1.5 x 4.3 cm)</i>	<i>2.6 oz (75 g)</i>
<i>Digital Isolation Module</i>	<i>2.25 x 0.6 x 2.25 in (5.7 x 1.5 x 5.7 cm)</i>	<i>1.3 oz (38 g)</i>

* Drawer length does not include 0.5 in (1.3 cm) BNC connector on some models.

Meets CE requirements for emissions, susceptibility to radio frequency and static discharge, and safety. Input accuracy specifications are degraded slightly by high radio frequency fields.

Termination drawers are not approved for more than 60 VDC (30 V rms) on any screw terminal for CE.