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Instruction Manual

Model 8020-59

Vibrating Wire to Analog Converter

(Doc Rev K, 05/01/19

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EQUATIONS

1. INTRODUCTION

The Model 8020-59 Vibrating Wire (VW) to Analog Converter is a low-cost module that provides a simple way to connect Geokon's vibrating wire transducers to data acquisition systems that are not capable of reading frequency signals nor able to generate the proper signals required to excite VW transducers. The converter can operate with single transducers, as a stand-alone device, or with multiple transducers in conjunction with the Geokon Model 8032 Multiplexer. The converter is powered using either a 12V or a 24V supply.

The 8020-59 interface is capable of outputting a 0-5V or 4-20mA signal that is directly proportional to "digits", a vibrating wire sensor's native units. These outputs are easily converted to digits via several simple formulas (see Section 4.3). The analog outputs are automatically scaled to minimum and maximum parameters (defaults are 0 and 25,000) and sloped to provide their complete 0-5V or 4-20mA range for each individual transducer. These analog outputs offer 20-bit resolution (one part in 1,048,576) with an accuracy of better than 0.1% of full-scale span (0-5V output) throughout the operating temperature range (-20 ºC min, +80 ºC max). In a similar fashion, the temperature reading from the transducer's thermistor is available with 10-bit resolution (one part in 1024). When configured for single-channel operation, the 8020-59 updates the reading approximately once every second.

Pin Number	Signal Name	Signal Description
1	GND	Analog Signal Ground
2	V OUT	Conversion Voltage Output, 0 to 5 Volts
3	+24V	24 Volt Power In
4	+24V GND	Ground for 24V Power
5	I-RET	Return for Conversion Current Output
6	+12V	12 Volt Power Supply In **OR** +12V Output, if powered by 24V
7	GND	Ground for 12 Volt Power
8	TH+	Thermistor Positive Lead
9	TH-	Thermistor Negative Lead
10	C+	Vibrating Wire Positive Lead
11	C-	Vibrating Wire Negative Lead
12	VALID	Valid Output: 5V indicates conversion complete 0V indicates conversion not done
13	ENABLE	Enable Input: Single Channel Mode: 0V = VW output (digits) 5V = Temperature output (˚C) 16/32-Channel Mode: 0V = Conversion Disabled 5V = Conversion Enabled
14	CLOCK	Clock Input: Single Channel Mode: 0V = 8020-59 ON 5V = 8020-59 OFF 16-Channel Mode: 0 → 5V transition = increment channel and select VW Analog or Temperature Analog 32-Channel Mode: 0 → 5V transition = increment channel
15	I-OUT	VW and Thermistor Conversion Current Output

Table 1 - Connector Pinout and Signal Description

2. INSTALLING AND CONFIGURING THE 8020-59 SOFTWARE APPLICATION

A free setup and configuration application is available for download on Geokon's website, providing a user-friendly way to set up the 8020-59 VW to Analog Converter. Follow the steps below to install the software:

1) After downloading the installer from the Geokon website, right-click on the zip file, "8020-59_setup.zip", and select "Extract All…" from the resulting popup menu (see Figure 1).

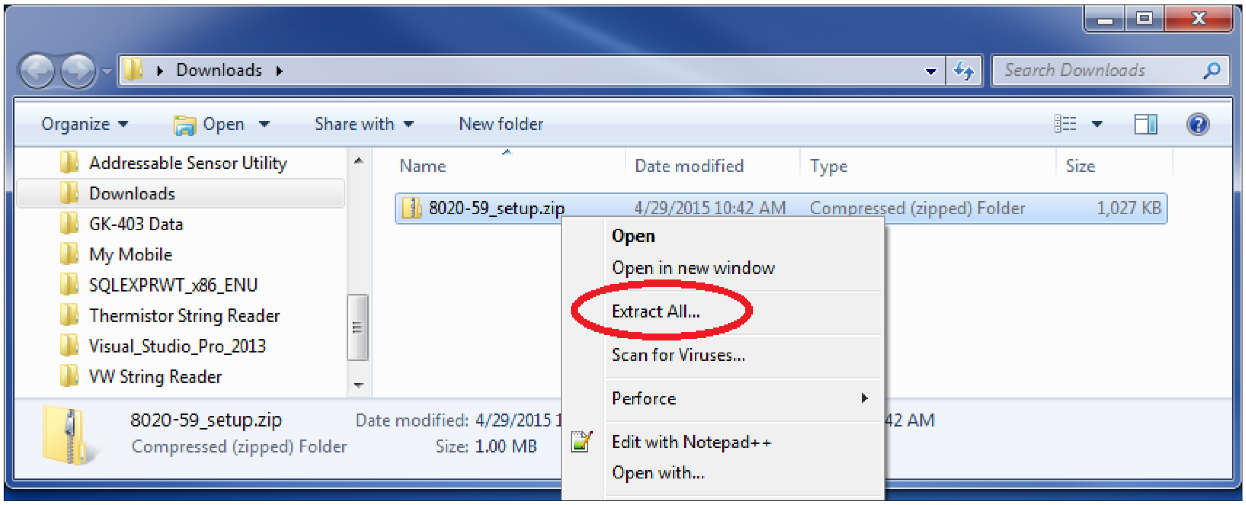


Figure 1 - Extracting the 8020-59 Installer

2) Another dialog will be displayed showing the editable default destination folder for the extracted contents (see Figure 2). When satisfied with the destination folder, click on the Extract button to extract the contents of the zipped installer (see Figure 2).

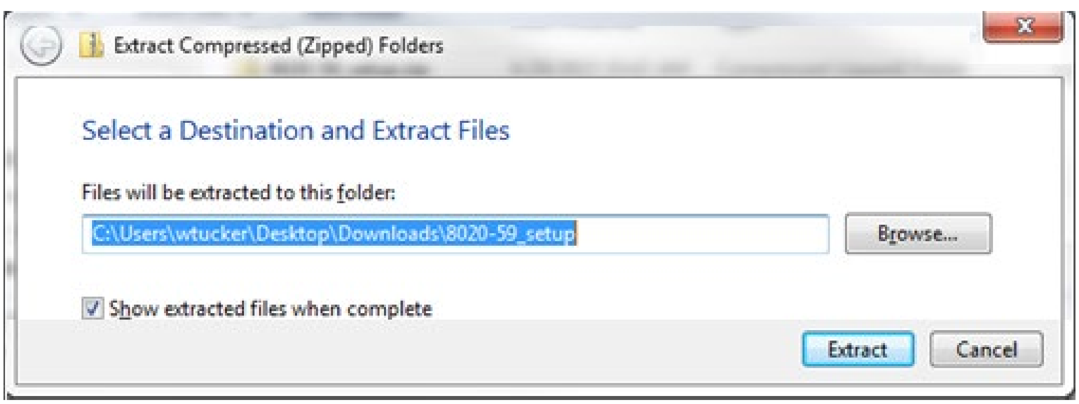


Figure 2 - Select Destination Folder

3) Figure 3 on the following page shows the extracted installer in the destination folder. Double click on the file, "setup.exe", to start the install process.

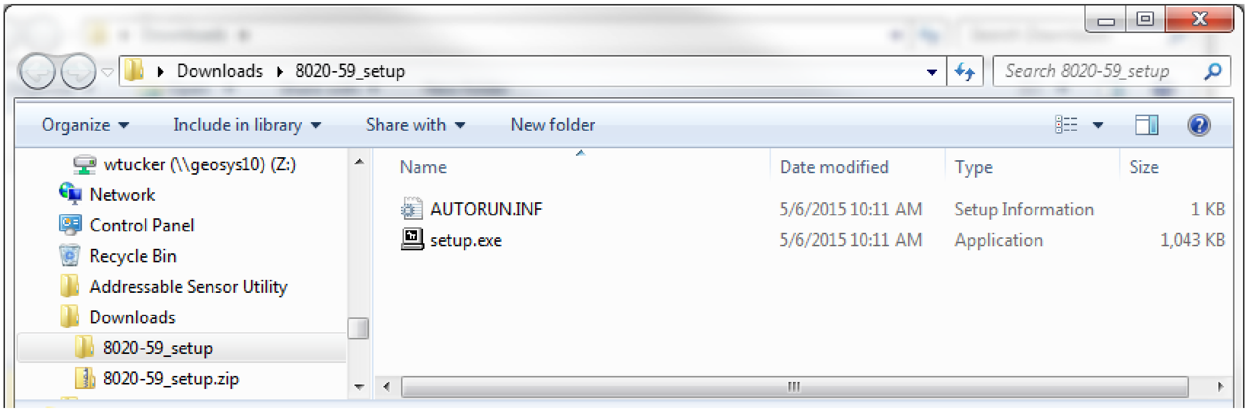


Figure 3 - Extracted 8020-59 Installer

4) After a few moments, the dialog shown in Figure 4 will be displayed.

Figure 4 - Install Wizard, Start Screen

5) After clicking on the “Next >” button, the dialog shown in Figure 5 is displayed.

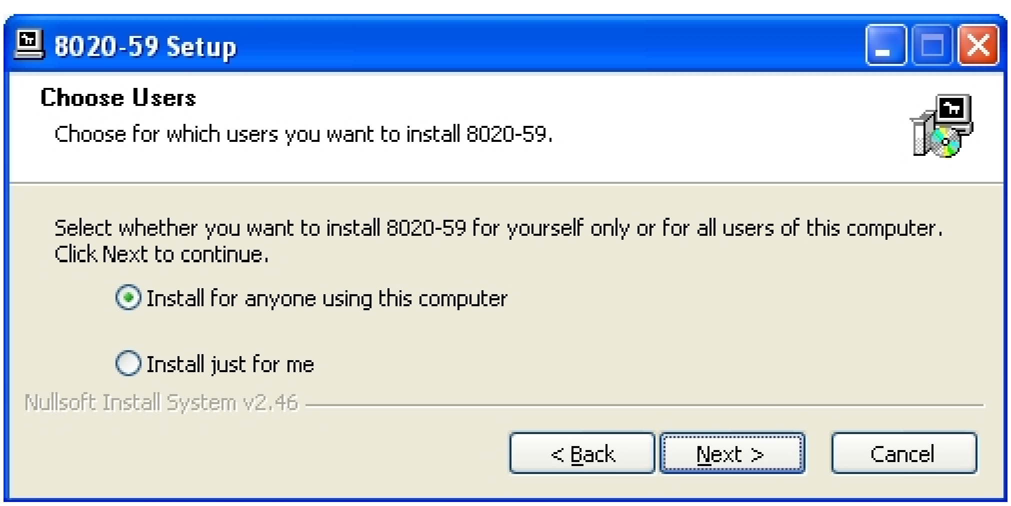


Figure 5 - Install Wizard, Choose Users

6) Choose whether to install the 8020-59 Software Application for all users or just for the current user (see Figure 5). **NOTE:** Without administrative privileges on the PC, the only option allowed will be "Install just for me". After making a selection, click "Next >"; this will bring up the dialog shown in Figure 6.

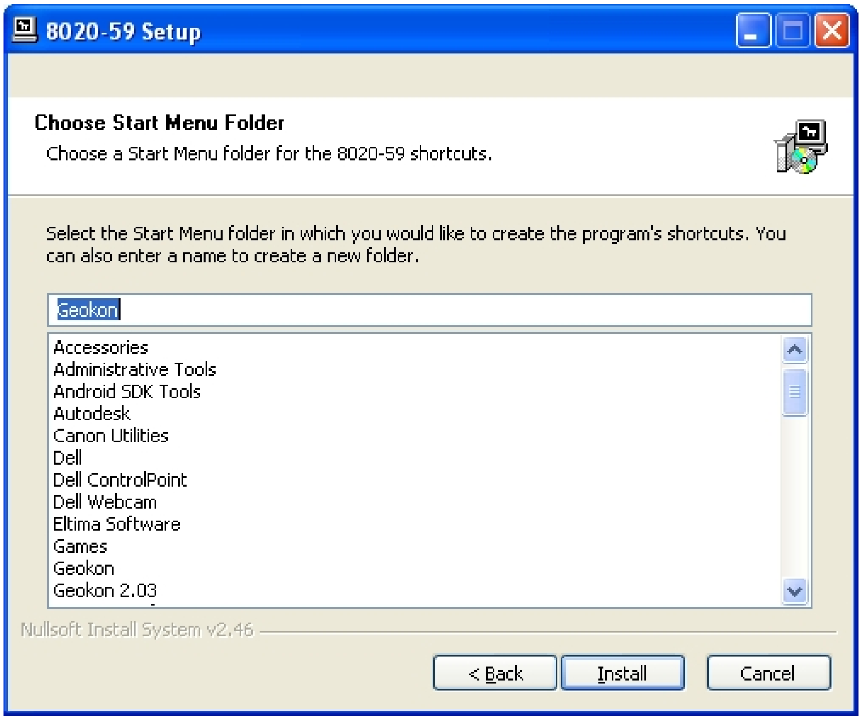


Figure 6 - Install Wizard, Choose Start Menu Folder

7) The dialog shown in Figure 6 allows the installer to choose where the "shortcut" to launch the application will be located – the default is the "Geokon" folder. A "shortcut" will also be located on the desktop. Clicking on "Install" begins the process of copying files and causes the dialog box shown in Figure 7 to be displayed:

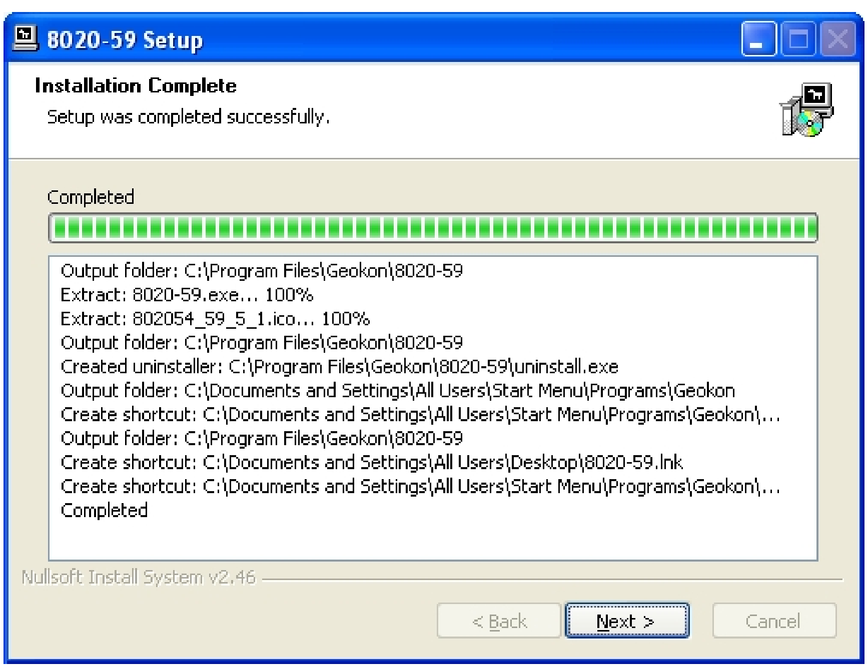


Figure 7 - Install Wizard, Installation Complete

8) The installation process is now complete. Clicking “Next >” allows the opportunity to launch the 8020-59 application when finished by checking the box next to “Launch 8020-59 Application” (see Figure 8). Click on “Finish” (see below) to close the install wizard.

Figure 8 - Install Wizard, Launch 8020-59 Application

2.1 Configuring the COM Port

After launching the 8020-59 Software Application, the first thing that must be done is to configure the COM Port. Click on the “Com Setup” (or press the “Alt” and the “c” key at the same time) to select a COM port for communication with the 8020-59 VW to Analog Converter (See Figure 9).

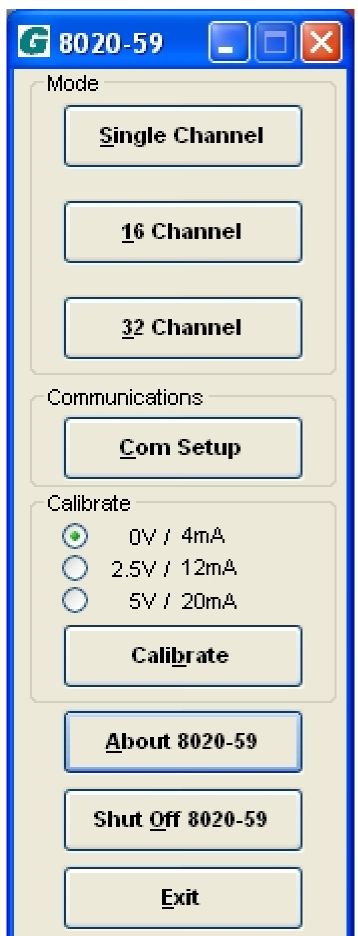


Figure 9 - 8020-59 Software Application, Startup Dialog

Select a COM port that corresponds to an available RS-232 communication port, whether it is built-in (such as COM1) or an external one via a USB to Serial Converter (see Figure 10). Some newer PCs are so fast that a small delay between characters is needed to give the 8020-59 time to process the characters. The "Inter-character Delay" is specified in milliseconds.

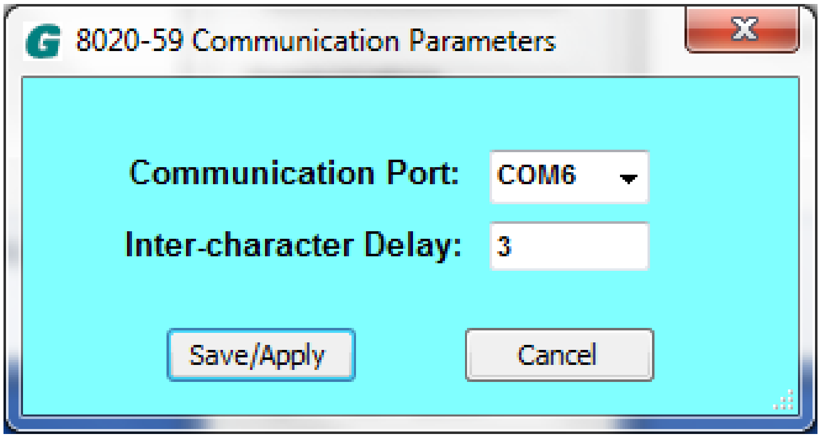


Figure 10 - Communications Parameters Dialog

3. QUICK START (SINGLE CHANNEL)

To properly set up and use the 8020-59 VW to Analog Converter, a field "Zero Reading" will need to be taken. This is required so that the 0-5V and 4-20mA outputs are scaled correctly for the transducer being monitored. This section will allow the user to quickly set up and obtain valid readings from the 8020-59 Converter:

Equipment Required:

Personal Computer (PC) with RS-232 COM port
8020-59 Software Application
RS-232 Cable (supplied)
VW Transducer
VW Transducer Calibration Report

1) Install the 8020-59 software on the PC that will be used to interface to the 8020-59 unit (see Section 2).

2) Connect the 8020-59 to the computer's serial port (typically COM1). If using an external USB to Serial converter, drivers for this device will need to be installed before this step (see Section 2.1).

3) Connect +12VDC to connector pin six **OR** +24VDC to connector pin three (see Table 1 in Section 1).

4) Connect the power supply return (or Ground) to connector pin seven **OR**, if using a 24V supply, connector pin four, 24V GND (see Table 1).

5) Connect the un-pressurized VW transducer to the 8020-59 (see Table 1):
   RED wire to connector pin 10 (C+).
   BLACK wire to connector pin 11 (C-).
   WHITE wire to connector pin 8 (TH+).
   GREEN wire to connector pin 7 (TH-)
   SHIELD wire to connector pin 1 (GND).

6) Start the 8020-59 program.

7) Click the "Single Channel" button (or press the "Alt" and "s" keys) from the program's Startup Dialog (see Section 2.1).

8) The Single Channel Configuration screen should now be displayed (see Figure 11 on the following page). This screen is used to define the parameters that the 8020-59 uses to read the attached transducer.

Figure 11 - Single Channel Configuration Screen

9) Ensure that the Transducer Model drop-down control is correctly set to the proper VW model and that the "Use Defaults" checkbox is checked.

10) Click "Activate/Monitor" (or press the "Alt" and "m" keys). The "Upload Confirmation" dialog will be displayed with the prompt: "Do you want to upload the current settings to the 8020-59?". Click the "Yes" button. The Single Channel Monitor screen should now appear (see Figure 12), and after several seconds should update with a reading.

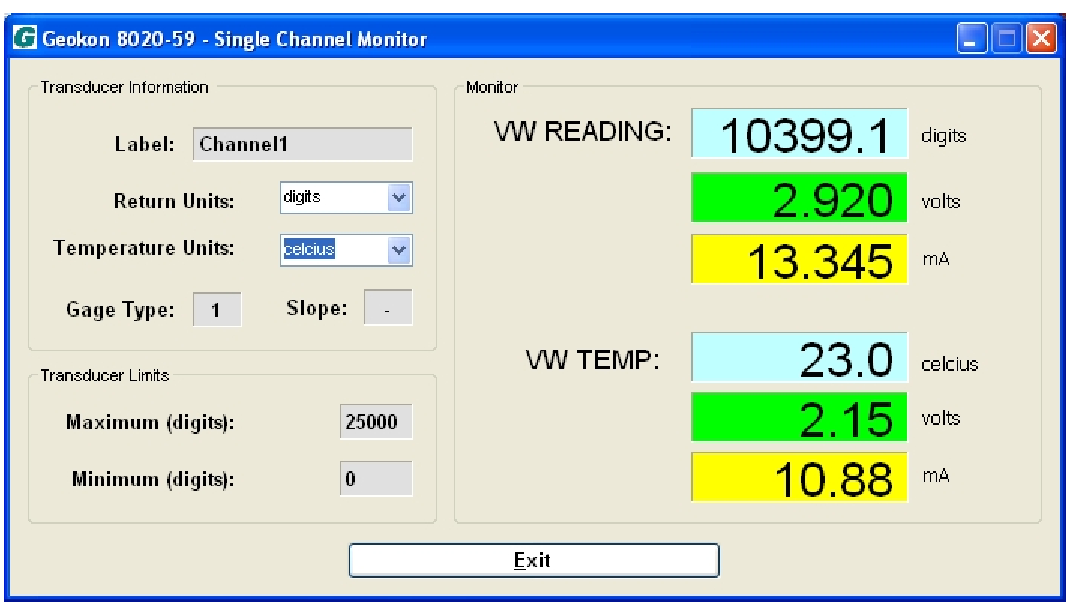


Figure 12 - Single Channel Monitor

11) Note the digits that are displayed. Record the VW reading, barometric pressure, and temperature. This is what is known as the “initial zero” reading. The “initial zero” reading will be used in future calculations. For example, the VW zero reading will be the $\mathbf{R_0}$ value in the pressure calculations equation: $\mathbf{P = (R_1 – R_0) \times GF}$, where $\mathbf{R_1}$ equals the “Current Reading” and **GF** is the Gauge Factor obtained from the calibration report for the sensor being measured. See Appendix D for further information on Data Reduction.

12) Click “Exit” (or press the “Alt” and “e” keys) to return to the Setup Screen.

After setup is complete, the PC is disconnected from the 8020-59 and the sensor is in a pressurized state, the “Current Reading” (R_1) “Digits” will need to be calculated from the value read from the analog voltage (V OUT, in volts) or current (I-OUT, in milliamperes) output. See Section 4.3 for more information on how to convert from an analog voltage or current value into digits. Once a “Digits” value has been obtained, translation into other engineering units is accomplished by multiplying the “Digits” value by the Gauge Factor for the particular sensor read.

4. SINGLE AND MULTI-CHANNEL OPERATION

In addition to working as a stand-alone device to interface a single transducer to a Data Acquisition System (DAS), multiple channels may be configured in similar fashion to the Single Channel. The 8020-59 works in conjunction with the 8032 Multiplexer and the user's Data Acquisition System to select either 1 of 16 or 1 of 32 transducers.

The 8020-59 was developed with multiplexing in mind and uses the same control signals as the Geokon model 8032 Vibrating Wire Multiplexer (for control signal timing requirements, refer to the model 8032 Multiplexer Instruction Manual). With a simple control program executing on the host DAS, it can work with 16 vibrating wire transducers (with thermistors), or 32 transducers (without thermistors). All setup parameters for each channel are stored in internal EEPROM memory, requiring no backup battery and can be retained for years.

The 8020-59 is powered from either a 12V or 24V supply (nominal) and draws approximately 70mA when taking readings. When it is "shut-off", or between scans when multiplexing, the total current consumption of the 8020-59 is less than 10μA (12V) or 16.5mA (24V).

The 8020-59 setup and configuration utility runs on a PC operating under the Windows operating system and communicates to the 8020-59 via the 8020-59's RS-232 port. A "Command Line" interface is provided in the 8020-59 internal firmware, with a command set that allows all functions to be easily set up and calibrated.

4.1 Theory of Operation

The 8020-59 provides excitation for a VW transducer using a swept frequency pluck that is optimized for the selected gauge type. The period of the resulting VW signal is measured using a 25 MHz clock. This measurement is performed 512 times, resulting in an average period being stored in internal memory. The microprocessor then converts the average period into digits and scales the output accordingly, for the specific transducer being read. This information is then sent to a 20-bit D/A converter, which outputs a voltage (0-5V) that is directly proportional to the average digits. Post-processing circuitry converts this voltage to a non-isolated 4-20mA current signal. In addition, the 20-bit D/A is put through a self-calibration routine at the start of each measurement cycle to minimize errors due to temperature and power supply variations. The resulting 0-5V and 4-20mA signals are brought to the output connector for connection to the input(s) of the host DAS.

4.2 Operating Modes

The 8020-59 has three modes of operation: single channel mode, 16-Channel mode, and 32-Channel mode. Each operation mode is detailed in the subsections below.

4.2.1 Single Channel Mode

In this mode (Figure 13), the 8020-59 will maintain continuous excitation of the VW transducer and provide a continuous 0-5V and 4-20mA output to the host DAS, updated approximately every second.

By controlling the ENABLE input to the 8020-59, the 8020-59 voltage and current outputs (VOUT and IOUT) will either be proportional to the transducer's digits (ENABLE=0V – or disconnected) or the transducer's temperature in degrees Centigrade (ENABLE=5V).

By controlling the CLOCK input to the 8020-59, the 8020-59 will either be ON (CLOCK=0V − or disconnected) or OFF (CLOCK=5V).

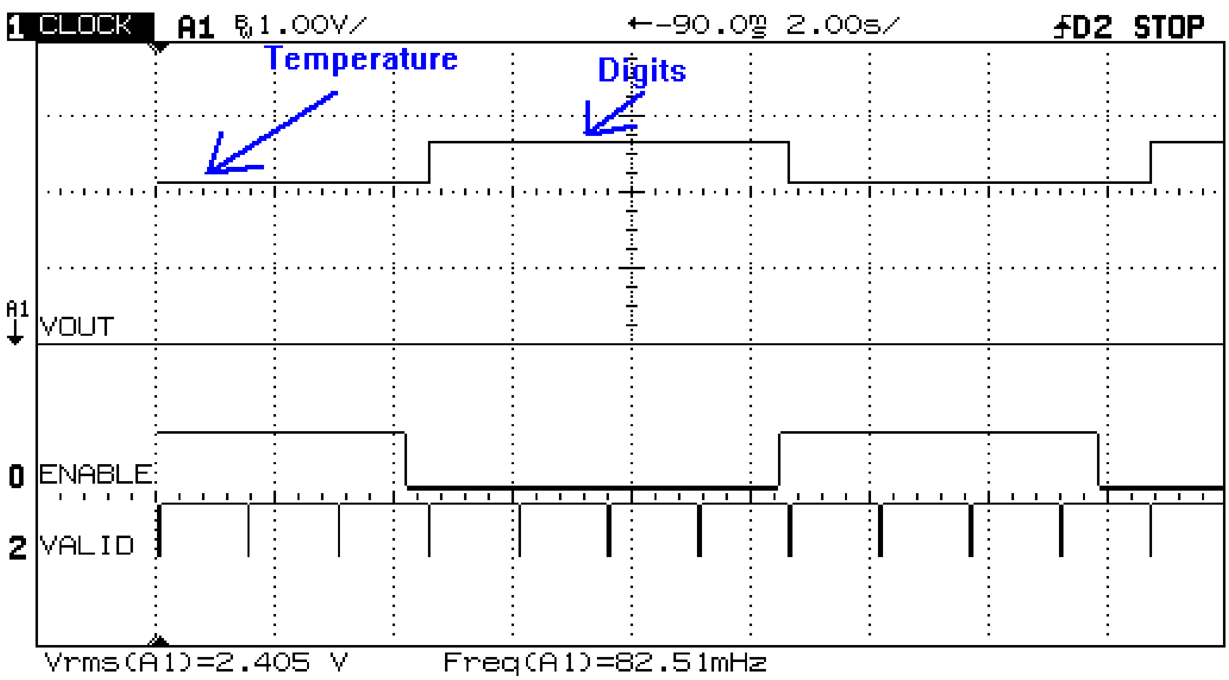


Figure 13 - Control Signal Sequence: Single Channel Mode

4.2.2 16-Channel Multiplexed Mode

In this mode (Figure 14), the 8020-59 will excite and provide output only when told to do so from the host DAS. As soon as the 8020-59 is powered, if ENABLE and CLOCK are low (0V), the 8020-59 will go to "sleep" and will wait for commands from the host DAS, drawing less than 10µA from the +12V system power supply (16.5mA if using a +24V system power supply).

When a reading is to be taken, the host system first brings ENABLE high (5V) to enable the 8020-59 and then CLOCK high (5V) to activate channel 1 of 16 (for control signal timing requirements, refer to the model 8032 Multiplexer Instruction Manual). The 8020-59 will "wake up" and read the transducer connected to channel one of the multiplexer. When the reading is ready (approximately one to two seconds later), the 8020-59 will bring the VALID output high (5V), indicating to the host DAS that the voltage and current outputs (proportional to the digits) are at VOUT and IOUT and are ready to be acquired.

Once the reading is acquired, the host system brings CLOCK low (0V) and then high (5V) again to read the temperature of the transducer. When this reading is ready (<100ms later), the VALID output will again go high (5V), indicating that the voltage and current outputs (now proportional to temperature) are at VOUT and IOUT and are ready to be acquired. When the host DAS again brings CLOCK low (0V) and then HIGH (5V), the 8020-59 and multiplexer increment to channel 2 of 16 and this reading sequence starts over again. This reading sequence may be used for up to 16 transducers.

When the final transducer has been read, the host DAS brings CLOCK and ENABLE both low (0V) to reset the system. The 8020-59 will go back to sleep until it is time for the next reading. Using this feature, up to 16 Vibrating Wire transducers with thermistors may be multiplexed into a single DAS.

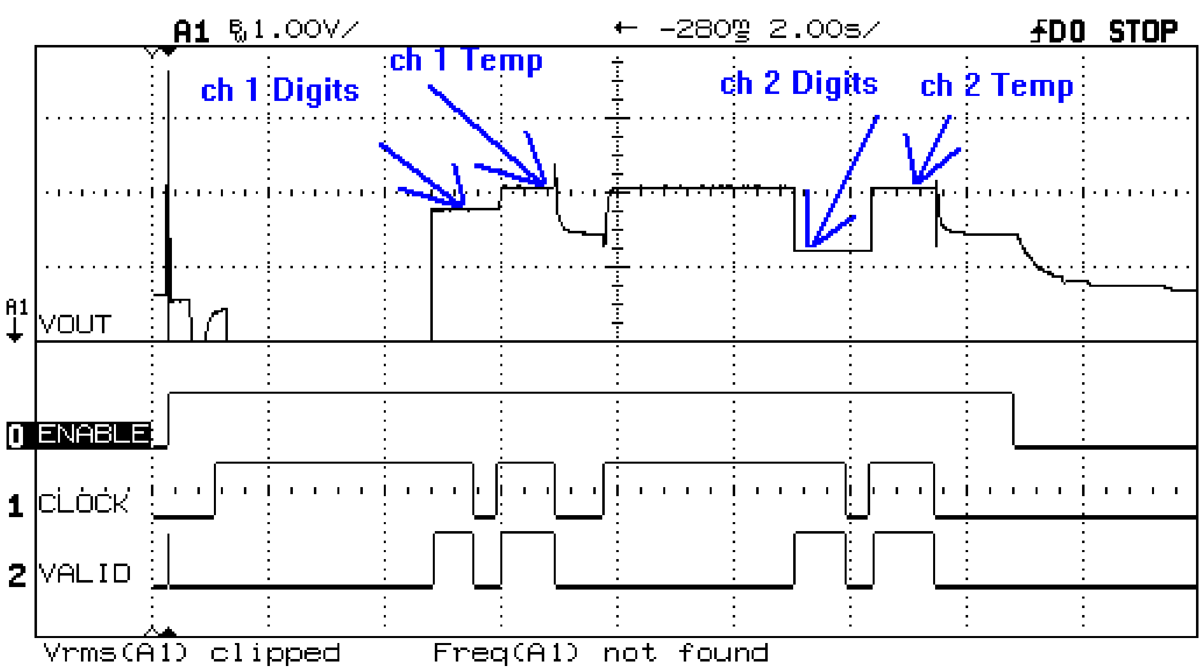


Figure 14 - Control Signal Sequence: 16-Channel Mode (Channels One and Two Only)

4.2.3 32-Channel Multiplexed Mode

In this mode (Figure 15), the 8020-59 will also excite and provide output only when told to do so from the host DAS. As soon as the 8020-59 is powered, if ENABLE and CLOCK are low (0V), the 8020-59 will go to "sleep" and will wait for commands from the host DAS, drawing less than 10μA from the +12V system power supply (16.5mA if using a +24V system power supply).

When a reading is to be taken, the host system first brings ENABLE high (5V) to enable the 8020-59 and then CLOCK high (5V) to activate channel 1 of 32 (for control signal timing requirements, refer to the model 8032 Multiplexer Instruction Manual). The 8020-59 will "wake up" and read the transducer connected to channel one of the multiplexer. When the reading is ready (approximately one to two seconds later (typ)), the 8020-59 will bring the VALID output high (5V), indicating to the host DAS that the voltage and current outputs (proportional to the digits of transducer number one) are at VOUT and IOUT and are ready to be acquired.

Once the reading is acquired, the host system brings CLOCK low (0V), and then high (5V) again to increment the 8020-59 and multiplexer to the next transducer. When this reading is ready (approximately one to two seconds later), the VALID output will again go high (5V), indicating that the voltage and current outputs (proportional to the digits of transducer number two) are at VOUT and IOUT and are ready to be acquired. This reading sequence may be used for up to 32 transducers.

When the final transducer has been read, the host DAS brings CLOCK and ENABLE both low (0V) to reset the system. The 8020-59 will go back to sleep until it is time for the next reading. Using this feature, up to 32 Vibrating Wire transducers may be multiplexed into a single DAS.

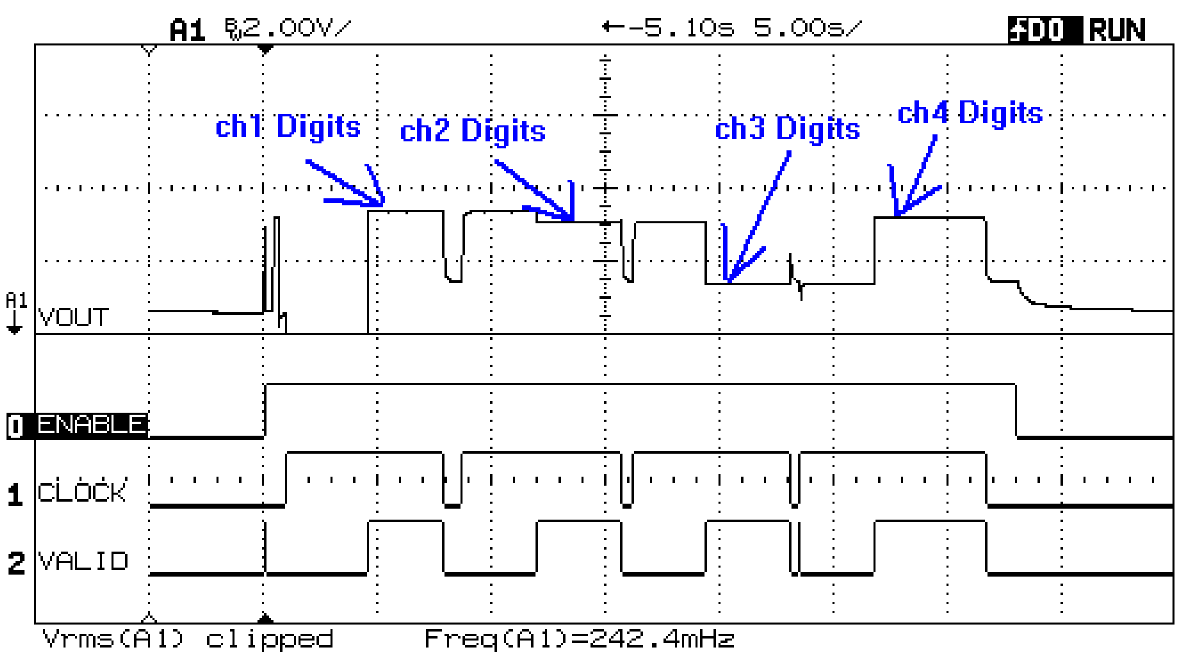


Figure 15 - Control Signal Sequence: 32-Channel Mode (Channels One through Four Only)

4.3 Conversion to "Digits"

A useful frequency related unit that is directly proportional to pressure is the "digit". These units are related to vibrating wire frequency as:

$$\text{Digits} = [\text{Frequency (Hz)}]^2 \times 0.001$$

Equation 1 - Vibrating Wire Frequency to Digits Conversion

The 8020-59 provides analog outputs that are directly proportional to digits.

Referring to the sample calibration in Figure 36 of Appendix E, a value in digits can be derived from the voltage and current outputs as described below.

For the following "positive slope" transducers: 4000, 4100, 4150, 4200, 4210, 4300, 4350, 4360, 4400, 4420, 4425, 4450, 4650 and 4700; use Equation 2 for Analog Voltage Output (assumes Vout is in volts (V)), or Equation 3 for Analog Current (4-20mA) Output (assumes Iout is in milliamperes (mA).

$$\text{Digits} = (\text{Vout} * (\text{Digits Span}/5\text{V})) + \text{Minimum Limit}$$

Equation 2 - Analog Voltage Output

$$\text{Digits} = ((\text{Iout} - 4\text{mA}) * (\text{Digits Span}/16\text{mA})) + \text{Minimum Limit}$$

Equation 3 - Analog Current Output

For the following "negative slope" transducers: 4500, 4600, 4675, 4800 and 4900; use Equation 4 for Analog Voltage Output (assumes Vout is in Volts (V)), or Equation 5 for Analog Current (4-20mA) Output (assumes Iout is in milliamperes (mA)).

$$\text{Digits} = \text{Maximum Limit} - (\text{Vout} * (\text{Digits Span}/5\text{V}))$$

Equation 4 - Analog Voltage Output

$$\text{Digits} = \text{Maximum Limit} - ((\text{Iout} - 4\text{mA}) * (\text{Digits Span}/16\text{mA}))$$

Equation 5 - Analog Current Output

Where:

Minimum Limit = Minimum limit parameter set in the channel specific setup screen of the 8020-59 configuration utility (default is zero)

Maximum Limit = maximum limit parameter set in the channel specific setup screen of the 8020-59 configuration utility (default is 25,000)

Digits Span = Maximum Limit - Minimum Limit

Example:
(Assumes the use of default values and transducer type of 4500S-100):

Minimum Limit = 0 digits
Maximum Limit = 25,000 digits
Digits Span = 25,000 – 0 = 25,000 digits
Vout = 3.250V

Digits = Maximum Limit – (Vout * (Digits Span/5V))
Digits = 25,000 – (3.25V * (5000 digits/V))
Digits = 25,000 – 16,250
Digits = 8750

4.4 Connection to a Voltage Input DAS

The 8020-59 outputs a voltage (V OUT, 0-5V) that is proportional to the digits of the transducer being read (ENABLE = 0V (or disconnected) in Single Channel Mode, after the first of two CLOCKS in 16-Channel Mode, or after each CLOCK in 32-Channel Mode). The 8020-59 offers a digits to voltage output with 20-bit resolution (one part in 1,048,576) of the span of the transducer (default span is 25,000 digits). This output voltage can be input directly to any Data Acquisition System capable of reading a 0-5V analog voltage.

The 8020-59 also outputs a voltage proportional to the temperature (also on V OUT) of the transducer being read (ENABLE = 5V in Single Channel Mode or after the second of two CLOCKS in 16-Channel Mode). The 8020-59 offers a temperature voltage output with 10-bit resolution (one part in 1024) over a 100º C span (-20º C to +80º C). See Section 4.6 for specific calculations.

4.5 Connection to a Current Input DAS

The 8020-59 sources a current (I-OUT, 4-20mA) that is proportional to the digits of the transducer being read (ENABLE = 0V (or disconnected) in Single Channel Mode, after the first of two CLOCKS in 16-Channel Mode, or after each CLOCK in 32-Channel Mode). The 8020-59 offers a digits current output with 20-bit resolution (one part in 1,048,576) of the span of the transducer (default span is 25,000 digits). This output current can be input directly to any Data Acquisition System capable of reading a non-isolated 4-20mA analog current.

The 8020-59 also outputs a current proportional to the temperature (also on I-OUT) of the transducer being read (ENABLE = 5V in Single Channel Mode or after the second of two CLOCKS in 16-Channel Mode). The 8020-59 offers a temperature current output with 10-bit resolution (one part in 1024) over a 100º C span (-20º C to +80º C). See Section 4.6 for specific calculations.

See Appendix C for the various voltage and current measurement options.

4.6 Temperature Measurement

The 8020-59 can read the thermistor that is part of a VW sensor. The 8020-59 outputs this reading as a voltage (0-5V) and current (4-20mA) that are proportional to temperature whenever ENABLE is high (5V), in Single Channel Mode, or while the second clock pulse is high, in 16-Channel mode. See Figure 14 for 16-Channel mode control signal timing.

Temperature is derived from the voltage output by Equation 6.
Note: Assumes Vout is in volts (V). Minimum Temperature = -20 °C, Degree Span = 100°.

$$°C = \text{Minimum Temperature} + (\text{Vout} * (\text{Degree Span} / 5V)) = -20° + (20 * \text{Vout})$$

Equation 6 - Temperature Derived from Voltage Output

Temperature is derived from the current output by Equation 7.
Note: Assumes Iout is in milliamperes (mA).

$$° C = \text{Minimum Temperature} + ((\text{Iout} - 4mA) * (\text{Degree Span} / 16mA)) = -20° + (6.25 * (\text{Iout} - 4mA))$$

Equation 7 - Temperature Derived from Current Output

5. COMMUNICATIONS

The 8020-59 offers a standard 9-pin RS-232 Serial Port for connection to most desktop and laptop computers (an optional USB to Serial interface adapter is available).

If using a terminal emulator program such HyperTerminal, Putty, etc., for command line set up (see Section 5.1) of the 8020-59, configure the program's communication parameters as follows:

Port:	Serial port that 8020-59 is connected to (i.e., COM1, COM2)
Bits per Second:	9600
Data bits:	8
Parity:	None
Stop bits:	1
Flow Control:	None

5.1 Command Line Interface

When connected to a computer using a terminal emulator program such as HyperTerminal, typing <Enter> returns the title screen:

```
           Geokon, Inc
 8020-59 VW to Analog Interface
       Rev 4.0.2  12/05/2011
         Type ? for Help
*
```

Typing ? <Return> returns the Help Screen:

```
*?
COMMAND                DESCRIPTION
C1                     Single VW and Thermistor
C2                     16 VW's and 16 Thermistors
C3                     32 VW's

D#                     Display Channel # Parameters
D0                     Display ALL Channel Parameters (C2 & C3 only)

E#                     Enable channel # (C2 and C3 only)
E0                     Enable ALL Channels (C2 and C3 only)

ME                     Enable output monitor
MD                     Disable output monitor

U#,ddddd,+/-,g         Store Upper digits,channel #,digits (25000
Max.),slope,gauge type
L#,ddddd               Store Lower digits,channel #,digits (160 Min.)

RD                     Ready Disabled
RE                     Ready Enabled

N#                     Disable channel # (C2 & C3 only)
N0                     Disable ALL Channels (C2 and C3 only)
```

```
X4                  Calibrate 4mA
X12                 Calibrate 12mA
X20                 Calibrate 20mA

S                   Display 8020-59 Status
R                   Display Firmware Revision

Z                   Shutdown and Sleep
<Esc>               Exit and Start Taking Readings (C1 only)
*
```

Commands C1, C2 and C3 configure the 8020-59 for single channel, 16-Channel multiplexing or 32-Channel multiplexing, respectively.

Note: The default value for the lower limit is zero, so for cases where this is acceptable, there is no need to explicitly set the lower limit.

Typing “D” and the channel # <Enter> displays the limits and slope for that channel. Typing “D0” <ENTER> displays the limits and slope for all channels.

Typing “E” and the channel # <Enter> ENABLES that channel (16 and 32-Channel mode only) when multiplexing. Typing “E0” <ENTER> enables all channels.

Commands ME and MD enable and disable the readings monitor.

To set the maximum digits, slope and gauge type for each transducer, type “U” and the channel # (comma) maximum digits (comma) slope (+/-) (comma) gauge type <Enter>
Example: *U1,10590,-,1 <Enter>

To set the minimum digits type “L” and the channel # (comma) minimum digits <Enter>
Example: *L1,9990 <Enter>

Command RD disabled the VALID line from activating when a non-successful vibrating wire sensor conversion takes place. A high level on the VALID line would then indicate that a successful conversion took place.

Command RE enables the VALID line to go “Ready” (high) after each CLOCK pulse while the ENABLE line is high. The VALID output then indicates that the CLOCK and ENABLE sequencing was proper but does not reflect the success of the vibrating wire sensor conversion. The default state for the 8020-59 is READY ENABLED.

Typing “N” and the channel # <Enter> DISABLES that channel (16 and 32-Channel mode only) when multiplexing. Typing “N0” <ENTER> disables all channels.

Typing “X4” <Enter> will allow calibration of the 4mA set point.

Typing “X12” <Enter> will allow calibration of the 12mA set point.

Typing “X20” <Enter> will allow calibration of the 20mA set point.

Typing "S" <Enter> displays the 8020-59 status:

```
*S
Monitor Enabled
Configuration 2:      16 VW's and 16 Thermistors
1,5000,1000,+,Enabled
2,25000,160,+,Disabled
3,25000,160,+,Disabled
4,25000,160,+,Disabled
5,25000,160,+,Disabled
6,25000,160,+,Disabled
7,25000,160,+,Disabled
8,25000,160,+,Disabled
9,25000,160,+,Disabled
10,25000,160,+,Disabled
11,25000,160,+,Disabled
12,25000,160,+,Disabled
13,25000,160,+,Disabled
14,25000,160,+,Disabled
15,25000,160,+,Disabled
16,25000,160,+,Disabled
```

Typing "R" <Enter> will return the firmware revision.

Typing "Z" <Enter> will put the 8020-59 into low power sleep mode (off), drawing less than 10µA from the 12V power source (less than 16.5mA from the 24V power source).

Finally, pressing the <Esc> key (in C1 single channel mode only) will start the readings screen with the 8020-59 outputting 0-5V and 4-20mA:

```
1,11665.75,22.8,-,1,#
1,11665.95,22.7,-,1,#
1,11666.50,22.8,-,1,#
1,11666.60,22.8,-,1,#
1,11667.05,22.8,-,1,#
1,11666.55,22.9,-,1,#
1,11666.10,22.8,-,1,#
1,11665.65,22.8,-,1,#
1,11666.30,22.9,-,1,#
1,11666.50,22.8,-,1,#
1,11666.65,22.8,-,1,#
1,11666.35,22.8,-,1,#
1,11665.85,22.8,-,1,#
1,11666.10,22.8,-,1,#
1,11666.60,22.8,-,1,#
```

Where;
Comma delimited field one is the channel number, followed by the reading in digits, then the transducer temperature in deg. C, the slope, and finally the gauge type. The pound sign (#) signifies the end of the data string.

6. 8020-59 WINDOWS APPLICATION

The commands described in the Command Line Interface Section 5.1 of this manual are included in a simple Windows program designed to set up, control and monitor the 8020-59. This software is provided as a convenient way to set and store the various parameters associated with each transducer, and to monitor the digits and temperature output of each transducer. All settings such as communications parameters, channel enable, individual transducer type, upper limits (digits), lower limits (digits), and transducer model are set using a simple and intuitive user interface.

6.1 Software Installation

Included with the Model 8020-59 VW to Analog Converter is a CD-ROM containing the 8020-59 application. For more details about installing and configuring the application, please see Section 2.

6.2 Starting the 8020-59 Application

To start the 8020-59 application, select Start/Programs/8020_59/8020_59. This brings up the Startup dialog (see Figure 9).

From the Startup dialog, the major functions (Mode, Communications, and Calibration) of the 8020-59 can be accessed. Click **Com Setup** to select the Com Port that the 8020-59 is connected to (see Section 2.1 and Figure 10).

After the communication port that the 8020-59 is attached to is selected, click **Save/Apply** to return to the Startup dialog. The communication port selected will be saved to a configuration file and will not need to be set again unless the communication port changes.

6.3 Communications Timeout Error

If communications to the 8020-59 are interrupted for any reason, after approximately 15 seconds an error message will be displayed with a descriptive error status message in **bold** font (see Figure 16).

Figure 16 - Communication Timeout Warning Message

NOTE: In Single Channel Mode, the ENABLE line may indeed be active although the PC should still be able to communicate with 8020-59 VW to Analog Converter.

6.4 Single Channel Configuration

If the 8020-59 is to be used with only one transducer, the 8020-59 Mode should be set to Single Channel. Click "**Single Channel**" (or press the "Alt" and "s" keys) to display the Single Channel Configuration window (see Figure 11).

From this window, all of the transducer information may be entered. The transducer limits, transducer type, and slope are stored in non-volatile EEPROM internal to the 8020-59. All other information is stored to a configuration file on the host computer's hard drive and loaded automatically when this screen is displayed. Configurations may also be saved by using the **"Save Info"** button and opened later by using the **"Open Info"** button. Opened configurations must be sent to the 8020-59 by using the **"Update Info"** button to take effect.

From the **Transducer Model** drop-down list box, select the model of the transducer being used. This selection determines the transducer type/slope and these parameters will be set with no further interaction from the user. Enter the transducer's limits (in digits) in the text boxes labeled, **Maximum (digits)** and **Minimum (digits)**. If desired, enter a **Label** for the transducer.

NOTE: Minimum and maximum values can be obtained from the transducer's calibration report by taking the lowest average reading for the minimum value and the highest average reading for the maximum value. Another option is to click on "Use Defaults" checkbox in the Limits section of the setup dialog. As of firmware revision 4.0.0, the default minimum and maximum values are 0 and 25,000, respectively. With its 20-bit Digital to Analog Converter, the 8020-59 has more than enough resolution to allow the entire voltage or current range to be divided by 25,000. This can make setup easier than previous firmware revisions.

When complete, click '**Update Info**' to store this information to the 8020-59. (**Note:** to determine the information settings of the currently connected 8020-59, click "**Retrieve Info**")

Clicking "**Activate/Monitor**" (or press the "Alt" and "m" keys) starts the 8020-59 transducer excitation and reading output functions and displays the Single Channel Monitor screen (see Figure 12). This screen displays the transducer information along with the reading in digits or microstrain (µE), the calculated reading voltage, the calculated reading current, the temperature of the transducer, and the calculated voltage and current that is representative of the temperature. The screen updates approximately every three to five seconds, providing an almost real-time display of the transducer output.

NOTE: In Single Channel Configuration, the user selects whether the actual voltage and current outputs represent the VW reading or the VW temperature by toggling the ENABLE control line (5V=VW temperature, 0V=VW reading). When left unconnected, the physical voltage and current outputs default to the VW reading.

If monitoring of the 8020-59 outputs is not of interest, then click **Activate/Exit** from the Configuration Window to begin the transducer excitation and reading and return to the Main Menu.

6.5 16-Channel Configuration

The 8020-59 can be used in conjunction with the Geokon model 8032 Multiplexer to configure and monitor up to 16 vibrating wire transducers with thermistors. For wiring details of this configuration, see Appendix C. The 8020-59 Mode should be set to 16-Channel. Clicking "**16-Channel**" (or press the "Alt" and "1" keys) from the Startup dialog displays the 16-Channel Configuration window:

Figure 17 - 16-Channel Configuration Screen

From this window, all of the transducer information for each of the 16-Channels may be entered. The transducer type, slope, and limits are stored in non-volatile EEPROM internal to the 8020-59. All other information is stored to a configuration file on the host computer's hard drive and loaded automatically when this screen is displayed. Configurations may also be saved by clicking the **"Save Info"** button and may be recalled later by clicking the **"Open Info"** button.

From the **Channel Selection** section of the 16-Channel Configuration screen (see Figure 17), select the transducer channel to be configured by clicking on the up arrow (▲) or down (▼) arrow. Alternately, a number from one to 16 can be entered directly. Check "**Enable"** if the channel is to be read, otherwise uncheck "**Enable"**. The circle in the upper right corner indicates if the channel is currently enabled or not. Green is enabled, and red is disabled.

In the **Transducer Information** section, select the model of the transducer being used from the "**Transducer Model"** drop-down list box. This selection determines the transducer type/slope and these parameters will be set with no further interaction from the user. If desired, enter a "**Label"** for the transducer.

In the **Transducer Limits** section, the current minimum and maximum settings for the channels stored in the 8020-59's on-board EEPROM are in the gray fields on the right. New values in the configuration are in the white fields on the left. Enter the transducer's limits (in digits) from the transducer's calibration report at **"Maximum (digits)**" and **"Minimum (digits)**"**.** Alternately, clicking on the "Use Defaults" checkbox will set the minimum and maximum limits to 0 and 25,000, respectively.

When complete, click "**Update Info"** to store this information to the 8020-59. To update all of the channels with the current configuration click **"Update All Info"**. To retrieve the info from the 8020-59's EEPROM for the current configuration, click **"Retrieve Info"** for the current channel and **"Retrieve All Info"** for all channels. The **"Copy"** button may be used to copy the current channels settings, and the **"Paste"** button may be used to write the current copied settings into the currently selected channel. If the **"Increment Channel Selection Before Paste"** checkbox is checked, the "**Paste"** button may be clicked repeatedly to rapidly set the parameters of all channels to the same values. The "**Label"** textbox will automatically populate with channel appropriate text.

Clicking "**Activate/Monitor**" puts the 8020-59 into low power Standby (Sleep) mode, waiting for the proper control signals on the ENABLE and CLOCK inputs (refer to Section 4.2.2,16-Channel Multiplexed Mode and Figure 22 in Appendix A.2, for signal timing details) and displays the Monitor screen (see Figure 18).

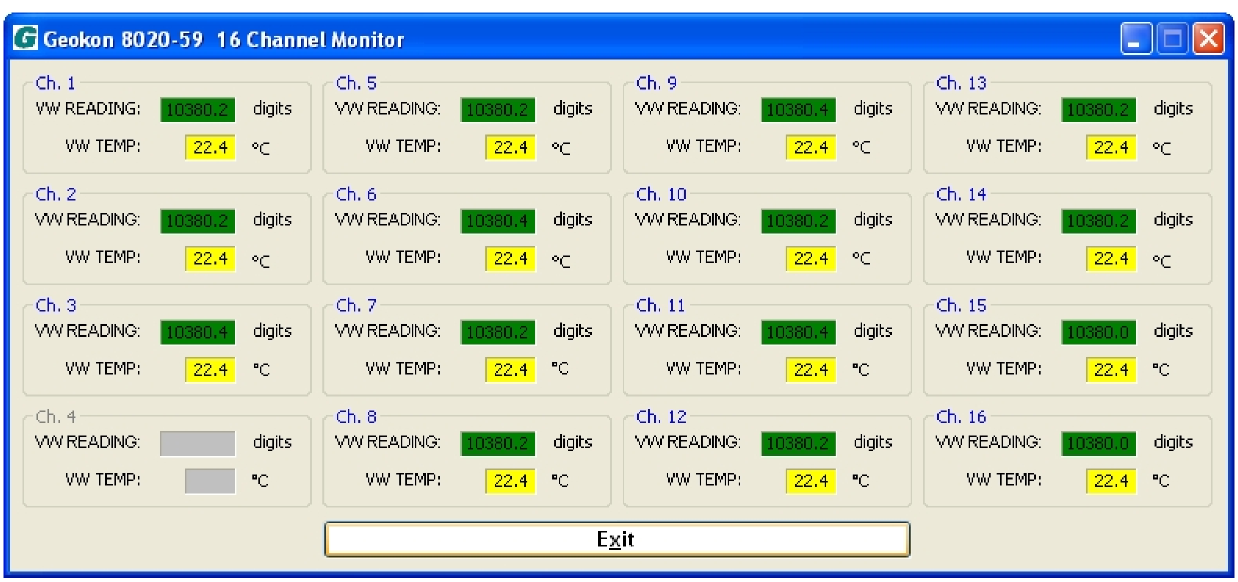


Figure 18 - 16-Channel Monitor Screen

The 16-Channel Monitor Screen (see Figure 18) displays the readings and temperatures of any enabled transducers. Any under-range or over-range conditions are highlighted in red and the channels that are currently being read is highlighted in green and yellow. (**Note:** Any channels that are disabled will be "grayed-out". Any channels that are enabled but do not have a transducer connected will display 99999 and be highlighted in red). Hovering the mouse in the lower-left corner of any channel's frame (border) displays the tooltip: "Double-click to expand". Double-clicking where indicated activates the reading screen (Figure 19) for that channel:

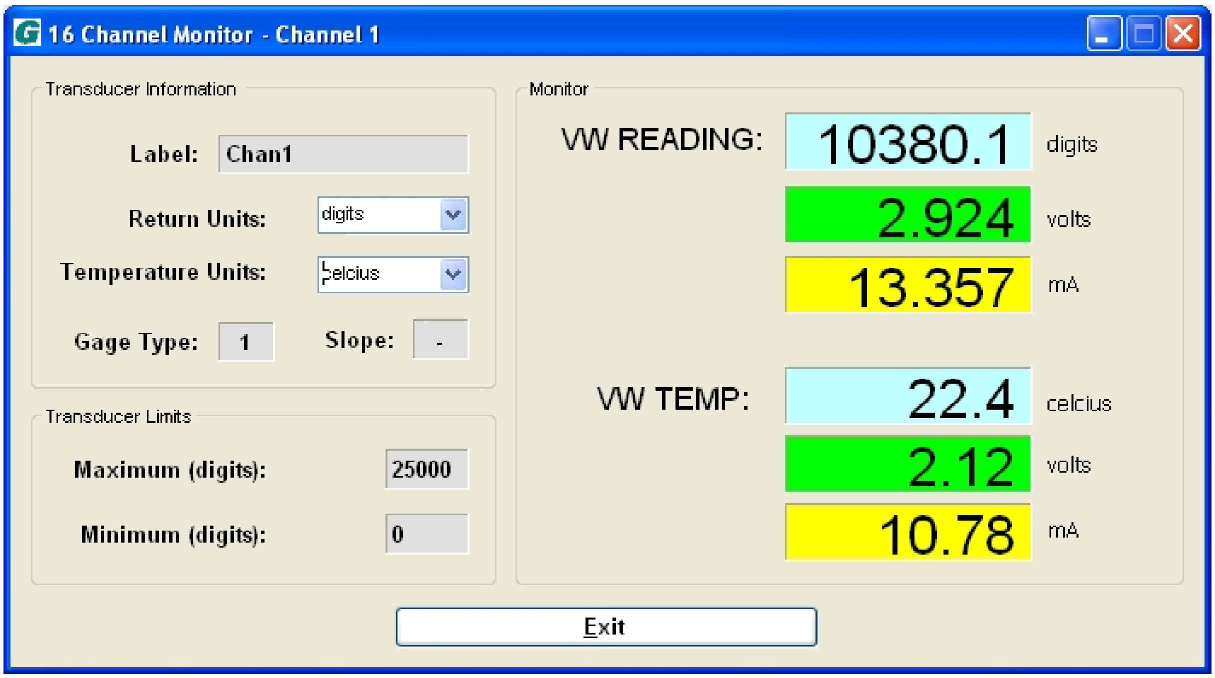


Figure 19 - Channel One Monitor

This screen displays the transducer information along with the reading in digits or microstrain (µE), the calculated reading voltage, the calculated reading current, the temperature of the transducer, and the calculated voltage and current that is representative of the temperature. The screen updates based on ENABLE and CLOCK timing from the Data Acquisition System.

If monitoring the 8020-59 outputs is not of interest, then click **Activate/Exit** from the **C**onfiguration Window to put the 8020-59 into low power Standby (Sleep) mode, waiting for the proper control input signals (refer to Section 4.2.2, for signal timing details).

6.6 32-Channel Configuration

32-Channel Configuration and Monitor modes work identically to their 16-Channel counterparts with the only difference being that there are no temperature measurements (see Figure 20).

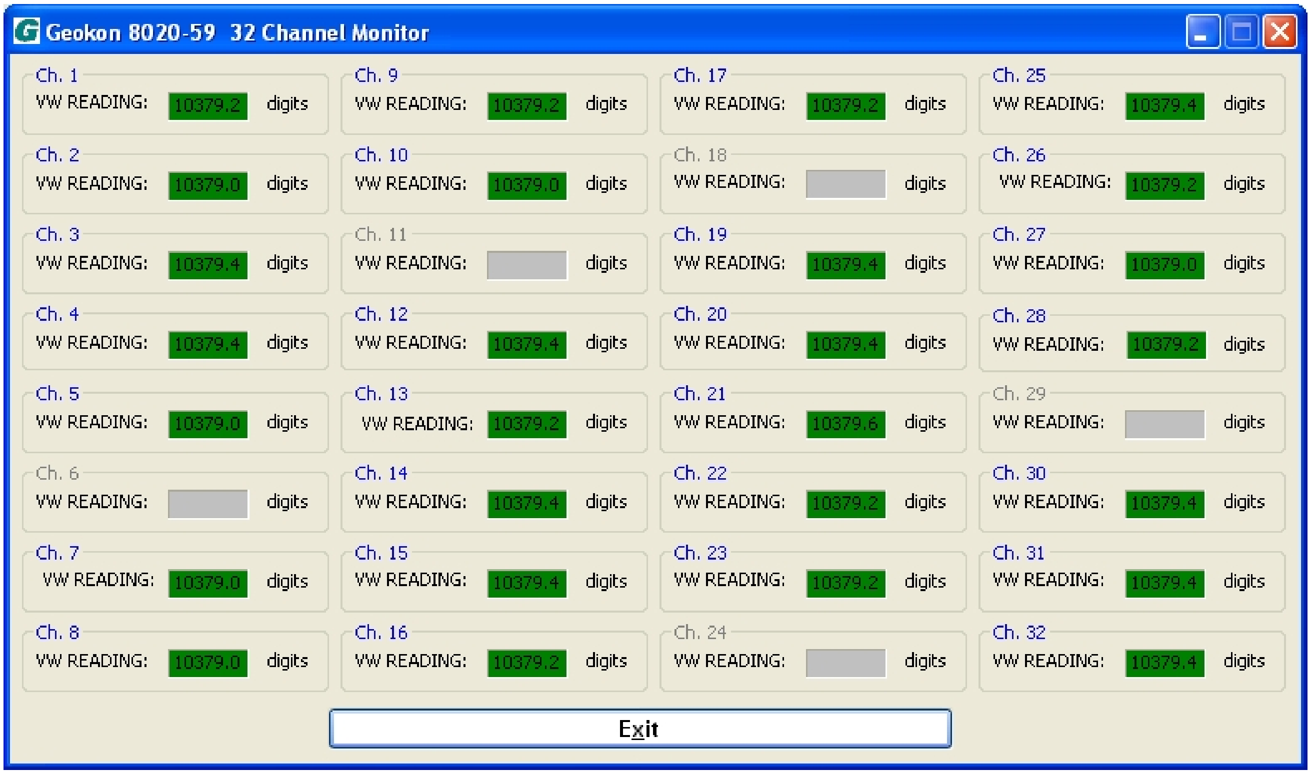


Figure 20 - 32-Channel Monitor Screen

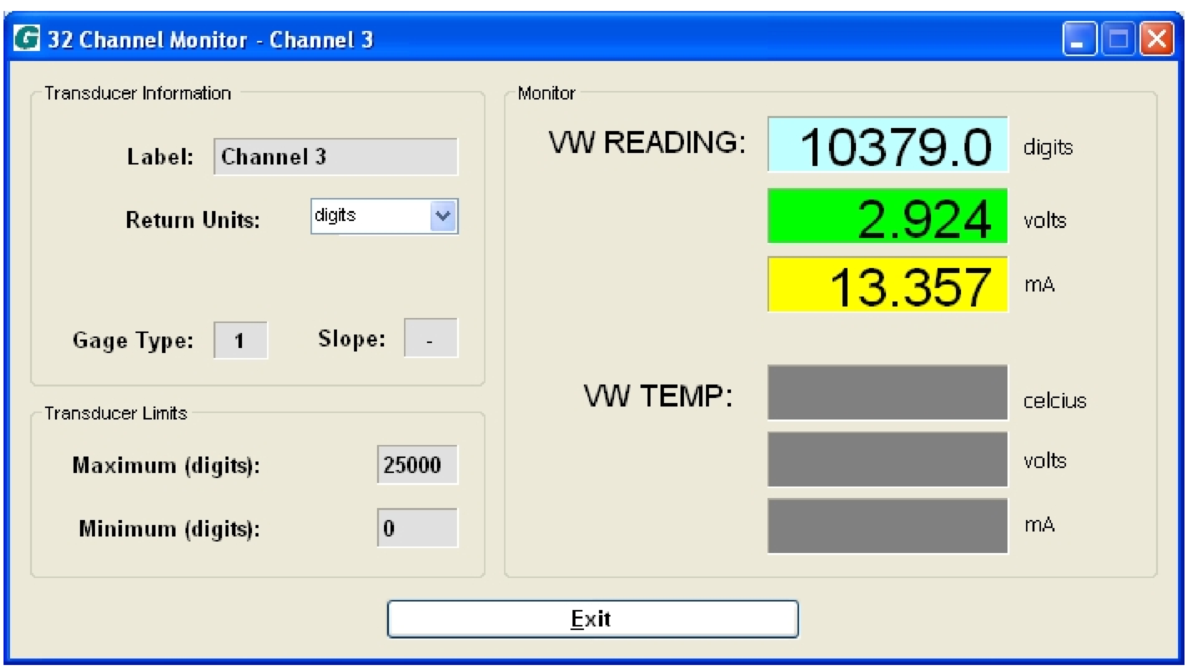


Figure 21 - Channel Three Monitor

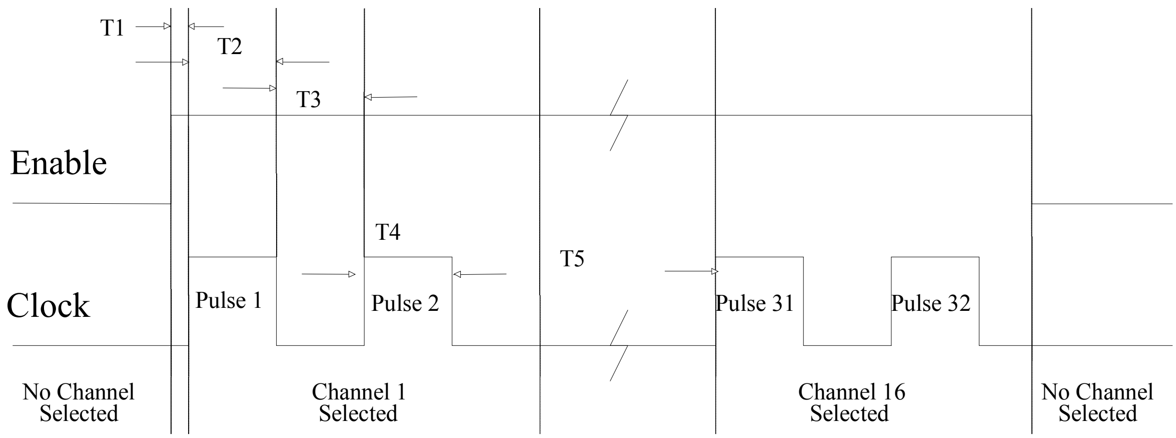
APPENDIX A. SPECIFICATIONS

A.1 8020-59 Specifications

Physical:	
Dimensions (L x W x H):	111.13 mm, 108.36 mm x 36.53 mm 4.375" x 4.266" x 1.438"
Weight:	0.456 lbs.
Operating Temperature:	-20 to +80 degrees Celsius
Power Requirements:	
+12V Input Voltage Range:	9 to 15 VDC (12V nominal)
+24V Input Voltage Range:	18 to 30 VDC (24V nominal)
Operating Current:	90mA (max) at 12V @ 25 ºC 75mA (max) at 24V @ 25 ºC
Sleep Current:	10uA (max) at 12V @ 25 ºC 16.5mA (max) at 24V @ 25 °C
VW Frequency Range:	400 – 5000 Hz
Internally Generated Fsweep (pluck):	
Gauge Type 0:	Frequency (start): 400 Hz Frequency (end): 5000 Hz Sweep Duration: 200 mSec Sweep Shape: Linear
Gauge Type 1:	Frequency (start): 1400 Hz Frequency (end): 3500 Hz Sweep Duration: 50 mSec Sweep Shape: Linear
Gauge Type 2:	Frequency (start): 2800 Hz Frequency (end): 4500 Hz Sweep Duration: 60 mSec Sweep Shape: Linear
Gauge Type 3:	Frequency (start): 400 Hz Frequency (end): 1200 Hz Sweep Duration: 300 mSec Sweep Shape: Linear
Gauge Type 4:	Frequency (start): 1200 Hz Frequency (end): 2800 Hz Sweep Duration: 120 mSec Sweep Shape: Linear
Gauge Type 5:	Frequency (start): 2500 Hz Frequency (end): 6000 Hz Sweep Duration: 50 mSec Sweep Shape: Linear
Gauge Type 6:	Frequency (start): 800 Hz Frequency (end): 1600 Hz Sweep Duration: 50 mSec Sweep Shape: Linear
Accuracy:	
Vibrating Wire (0-5V output):	≤ ± 0.1% of Full Scale over temperature
Vibrating Wire (4-20mA output):	≤ ± 0.5% of Full Scale over temperature
Temperature:	≤ ± 0.5% of Full Scale over temperature
Voltage Output Resolution (20 bit):	4.77 uV
Current Output Resolution (20 bit):	0.015 uA

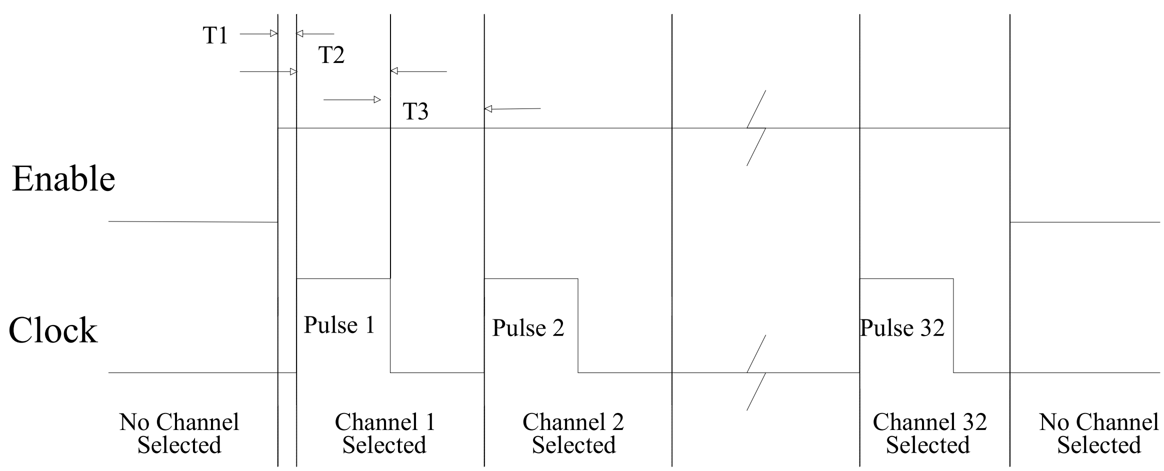
Digital Control Input – ENABLE:	
(Single Channel) 5V CMOS levels:	0V = VW OUT 5V = °C OUT
(Multiplexed) 5V CMOS levels:	0V = SLEEP 5V = READ
Digital Control Input – CLOCK:	
(Single Channel) 5V CMOS levels:	0V = ON 5V = OFF
(Multiplexed) 0-5V transition:	Channel increment
Digital Control Output – VALID:	
5V CMOS levels:	0V = READING NOT READY 5V = READING READY
Thermistor Excitation Voltage:	2.5 VDC

A.2 Multiplexer Timing Specifications



Timing: T1,T5 = 250 µsec(min.)
T2, T4 = indefinate
T3 = 250 µsec(min.)

Figure 22 - 16-Channel Multiplexer Timing Requirements



Timing: T1,T3 = 250 µsec(min.)
T2 = indefinate

Figure 23 - 32-Channel Multiplexer Timing Requirements

APPENDIX B. THERMISTOR TEMPERATURE DERIVATION

B.1 Standard Thermistor

Thermistor Type: YSI 44005, Dale #1C3001-B3, Alpha #13A3001-B3

Resistance to Temperature Equation:

$$T = \frac{1}{A + B(LnR) + C(LnR)^3} - 273.15\ °C$$

Equation 8 - Convert Thermistor Resistance to Temperature

Where: T = Temperature in °C.

LnR = Natural Log of Thermistor Resistance

A = 1.4051×10^{-3} (coefficients calculated over the −50 to +150° C. span)

B = 2.369×10^{-4}

C = 1.019×10^{-7}

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	+30	525.4	+70	153.2	+110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.1	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	+1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342.2	83	107.9	123
77.66K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-34	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	292.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	5692	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965.0	53	250.9	93	83.6	133
41.56K	-26	4939	14	929.6	54	243.4	94	81.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	**3000**	**25**	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149
								55.6	150

Table 2 - Standard Thermistor Resistance versus Temperature

B.2 High Temperature Thermistor

Resistance to Temperature Equation for *US Sensor 103JL1A*:

$$T=\frac{1}{A+B(LnR)+C(LnR)^3+D(LnR)^5}-273.15\ °C$$

Equation 9 - High Temperature Resistance to Temperature

Where;

T = Temperature in °C.

LnR = Natural Log of Thermistor Resistance.

$A = 1.127670 \times 10^{-3}$

$B = 2.344442 \times 10^{-4}$

$C = 8.476921 \times 10^{-8}$

$D = 1.175122 \times 10^{-11}$

Note: Coefficients optimized for a curve "J" Thermistor over the temperature range of 0°C to +250°C.

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
32,650	0	7,402	32	2,157	64	763.5	96	316.6	128	148.4	160	76.5	192	42.8	224
31,029	1	7,098	33	2,083	65	741.2	97	308.7	129	145.1	161	75.0	193	42.1	225
29,498	2	6,808	34	2,011	66	719.6	98	301.0	130	142.0	162	73.6	194	41.4	226
28,052	3	6,531	35	1,942	67	698.7	99	293.5	131	138.9	163	72.2	195	40.7	227
26,685	4	6,267	36	1,876	68	678.6	100	286.3	132	135.9	164	70.8	196	40.0	228
25,392	5	6,015	37	1,813	69	659.1	101	279.2	133	133.0	165	69.5	197	39.3	229
24,170	6	5,775	38	1,752	70	640.3	102	272.4	134	130.1	166	68.2	198	38.7	230
23,013	7	5,545	39	1,693	71	622.2	103	265.8	135	127.3	167	66.9	199	38.0	231
21,918	8	5,326	40	1,637	72	604.6	104	259.3	136	124.6	168	65.7	200	37.4	232
20,882	9	5,117	41	1,582	73	587.6	105	253.1	137	122.0	169	64.4	201	36.8	233
19,901	10	4,917	42	1,530	74	571.2	106	247.0	138	119.4	170	63.3	202	36.2	234
18,971	11	4,725	43	1,480	75	555.3	107	241.1	139	116.9	171	62.1	203	35.6	235
18,090	12	4,543	44	1,432	76	539.9	108	235.3	140	114.5	172	61.0	204	35.1	236
17,255	13	4,368	45	1,385	77	525.0	109	229.7	141	112.1	173	59.9	205	34.5	237
16,463	14	4,201	46	1,340	78	510.6	110	224.3	142	109.8	174	58.8	206	33.9	238
15,712	15	4,041	47	1,297	79	496.7	111	219.0	143	107.5	175	57.7	207	33.4	239
14,999	16	3,888	48	1,255	80	483.2	112	213.9	144	105.3	176	56.7	208	32.9	240
14,323	17	3,742	49	1,215	81	470.1	113	208.9	145	103.2	177	55.7	209	32.3	241
13,681	18	3,602	50	1,177	82	457.5	114	204.1	146	101.1	178	54.7	210	31.8	242
13,072	19	3,468	51	1,140	83	445.3	115	199.4	147	99.0	179	53.7	211	31.3	243
12,493	20	3,340	52	1,104	84	433.4	116	194.8	148	97.0	180	52.7	212	30.8	244
11,942	21	3,217	53	1,070	85	421.9	117	190.3	149	95.1	181	51.8	213	30.4	245
11,419	22	3,099	54	1,037	86	410.8	118	186.1	150	93.2	182	50.9	214	29.9	246
10,922	23	2,986	55	1,005	87	400.0	119	181.9	151	91.3	183	50.0	215	29.4	247
10,450	24	2,878	56	973.8	88	389.6	120	177.7	152	89.5	184	49.1	216	29.0	248
10,000	**25**	2,774	57	944.1	89	379.4	121	173.7	153	87.7	185	48.3	217	28.5	249
9,572	26	2,675	58	915.5	90	369.6	122	169.8	154	86.0	186	47.4	218	28.1	250
9,165	27	2,579	59	887.8	91	360.1	123	166.0	155	84.3	187	46.6	219		
8,777	28	2,488	60	861.2	92	350.9	124	162.3	156	82.7	188	45.8	220		
8,408	29	2,400	61	835.4	93	341.9	125	158.6	157	81.1	189	45.0	221		
8,057	30	2,316	62	810.6	94	333.2	126	155.1	158	79.5	190	44.3	222		
7,722	31	2,235	63	786.6	95	324.8	127	151.7	159	78.0	191	43.5	223		

Table 3 - Thermistor Resistance Versus Temperature for HT Models

APPENDIX C. WIRING CONFIGURATIONS

C.1 Voltage Output – Single Channel Mode (Digital I/O DAS)

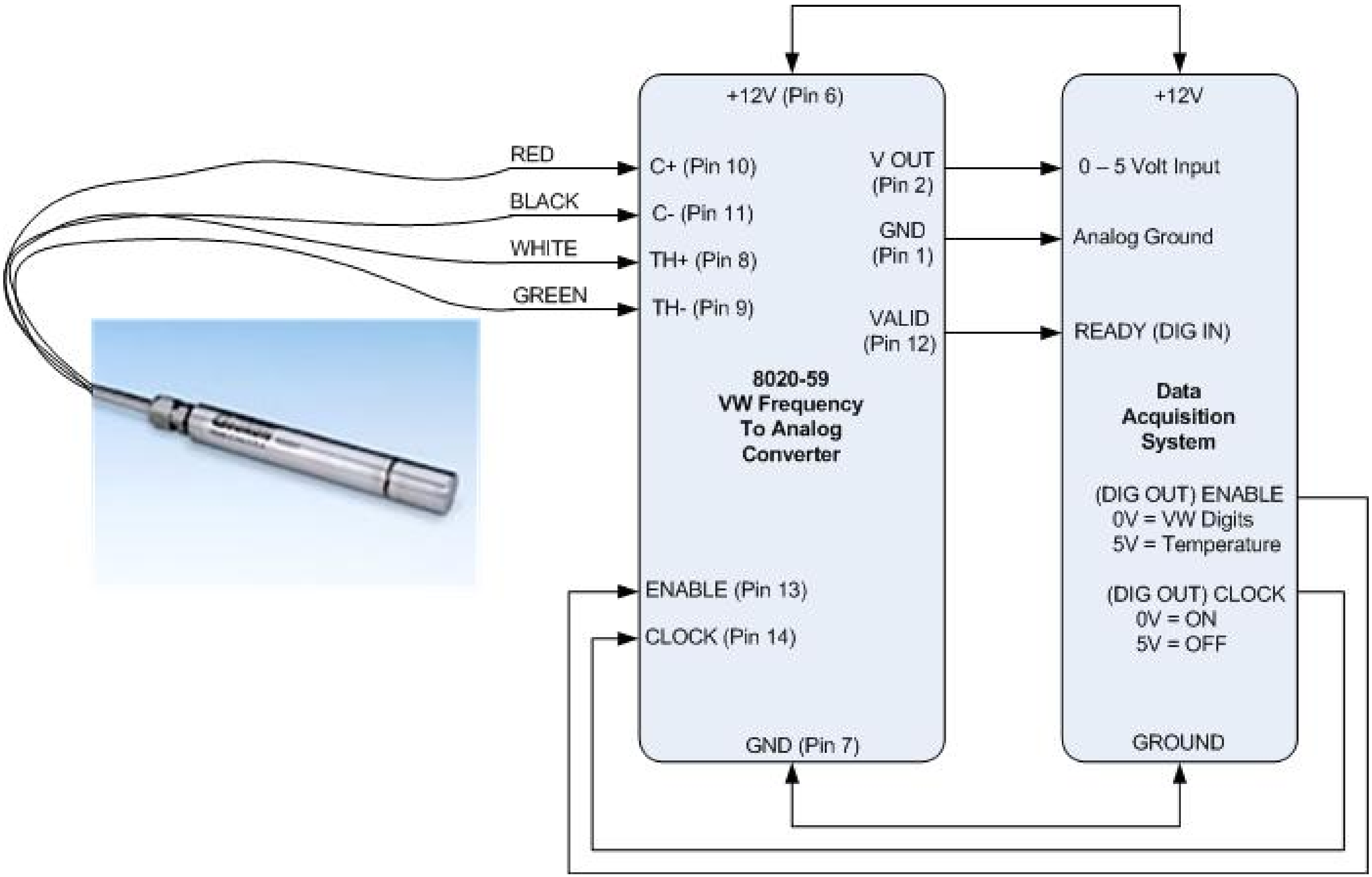


Figure 24 - Connection Example for One Channel 8020-59 with Voltage Output to Digital I/O DAS

C.2 Voltage Output – 16-Channel Mode (Digital I/O DAS)

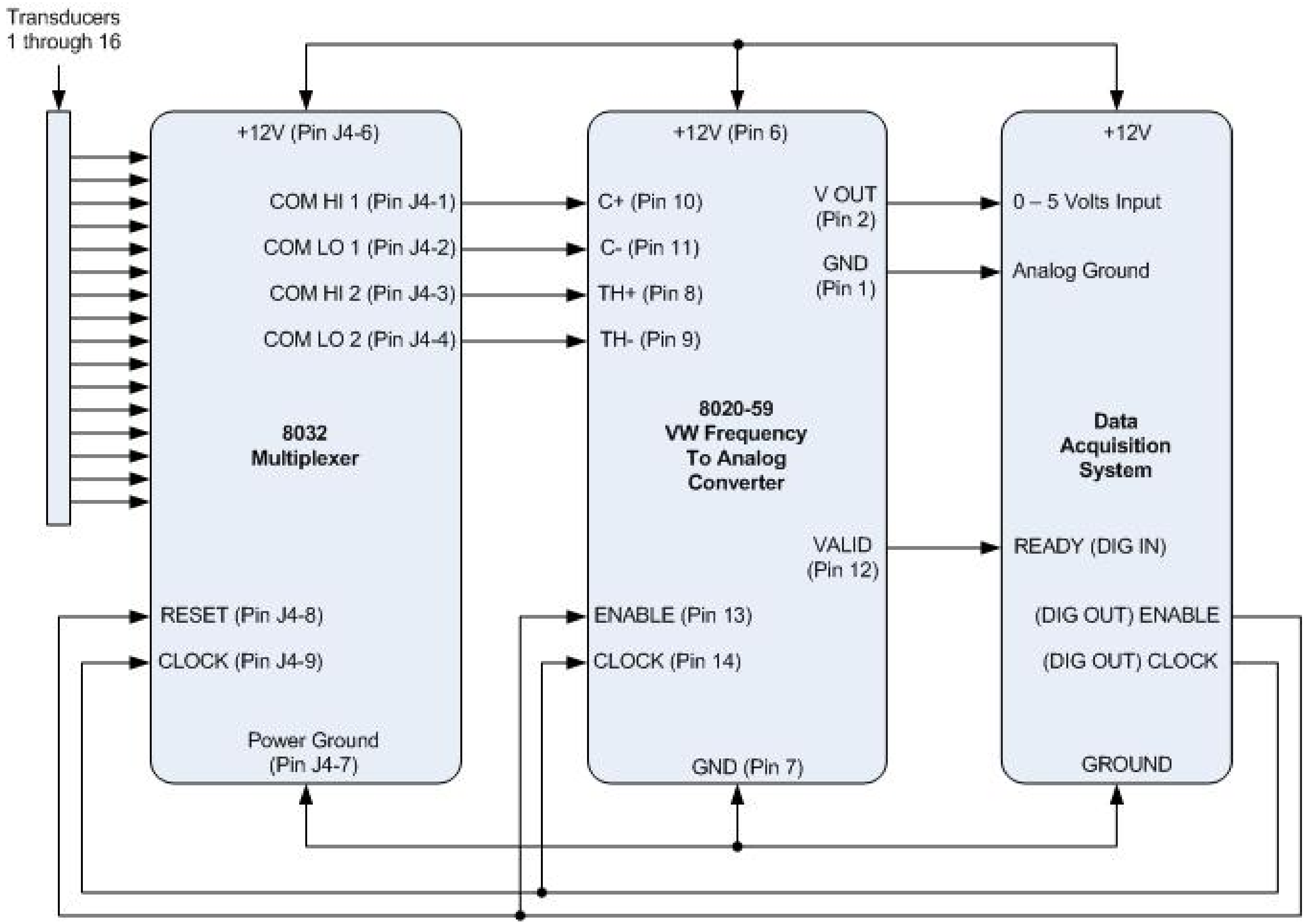


Figure 25 - Connection Example for 16-Channel Multiplexer, 8020-59 with Voltage Output and Digital I/O DAS

C.3 Voltage Output – 32-Channel Mode (Digital I/O DAS)

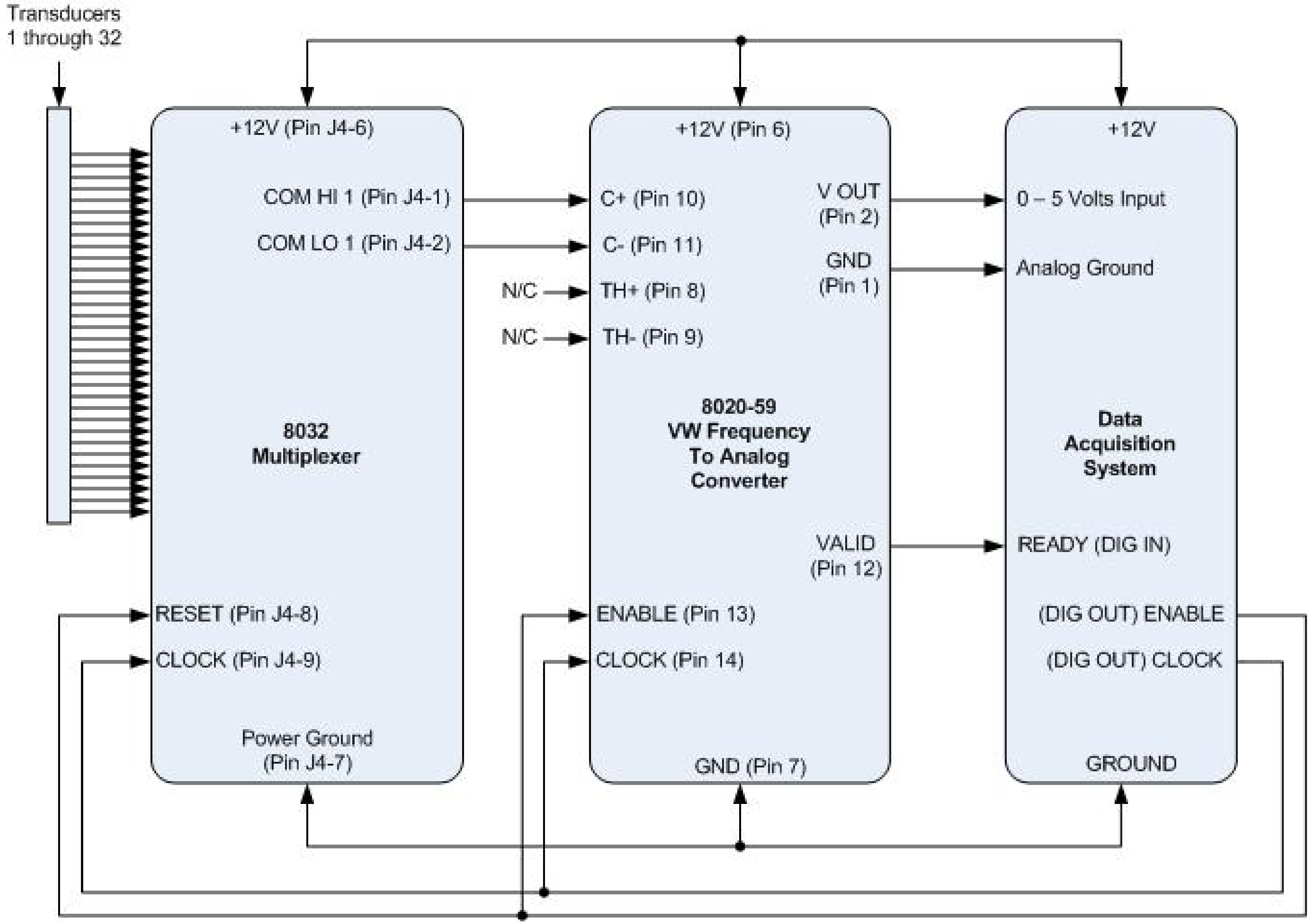


Figure 26 - Connection Example for 32-Channel Multiplexer, 8020-59 with Voltage Output and Digital I/O DAS

C.4 Current Output – Single Channel Mode (Digital I/O DAS)

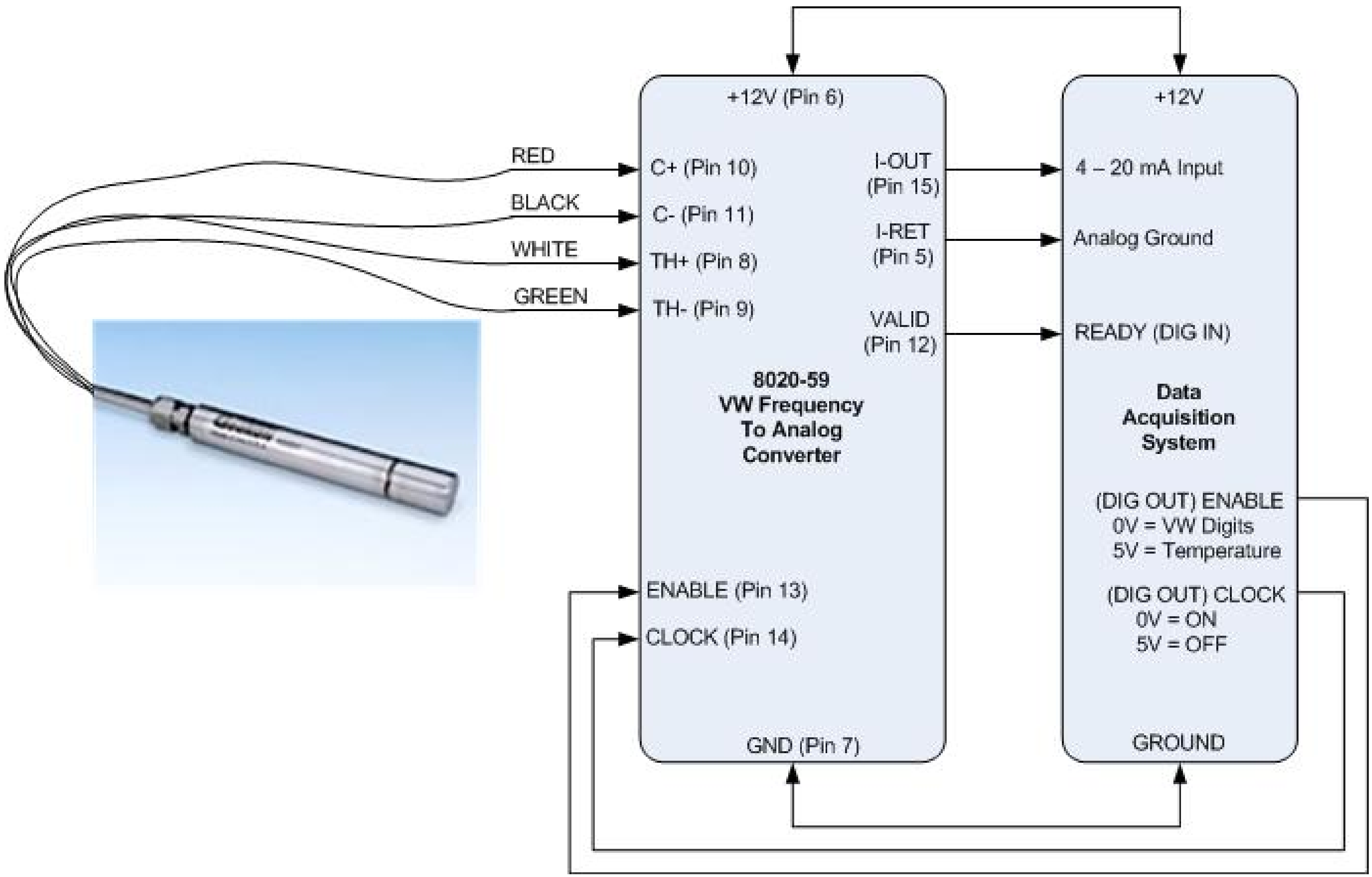


Figure 27 - Connection Example for One Channel 8020-59 with Current Output to Digital I/O DAS

C.5 Current Output – 16-Channel Mode (Digital I/O DAS):

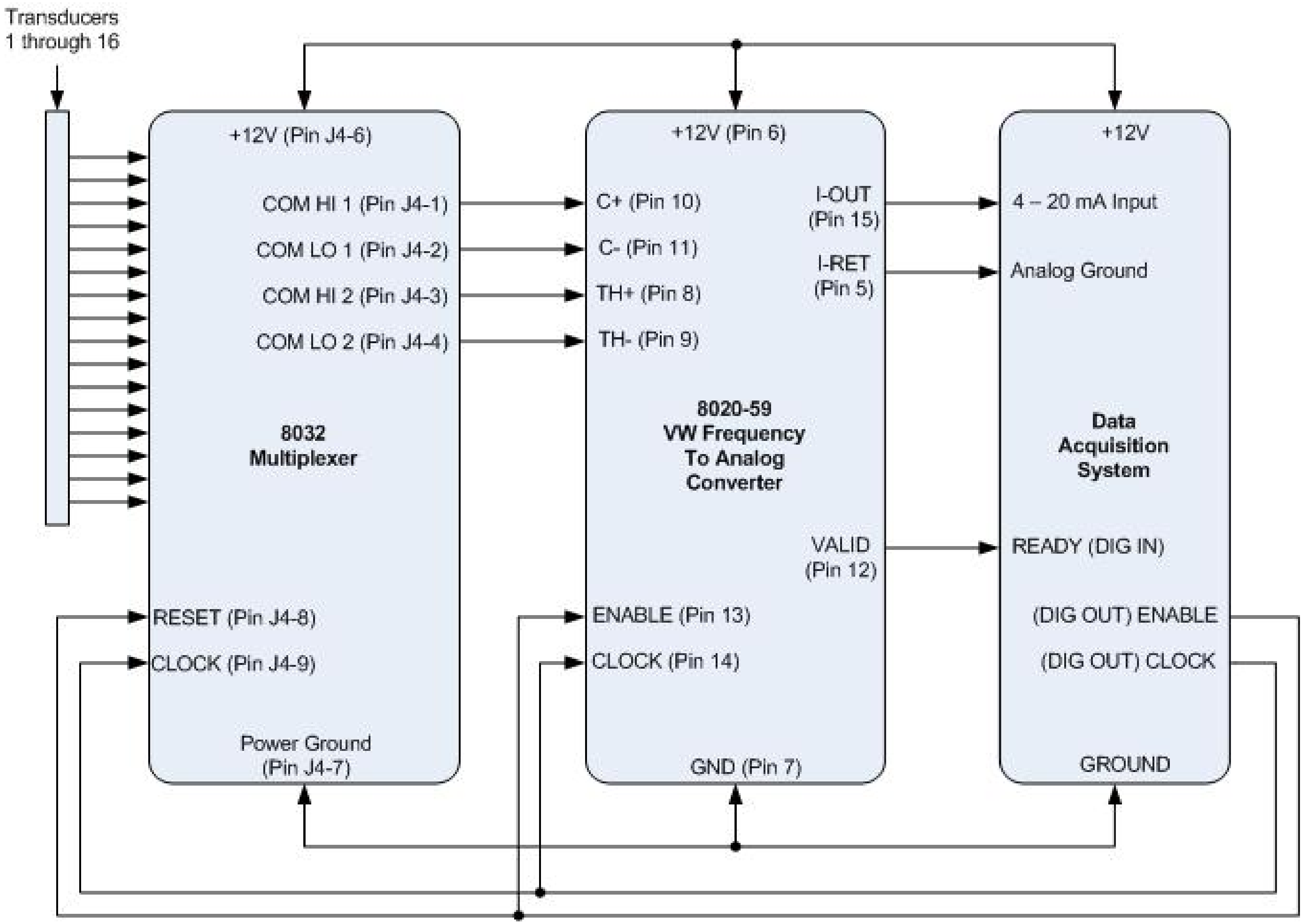


Figure 28 - Connection Example for 16-Channel Multiplexer, 8020-59 with Current Output and Digital I/O DAS

C.6 Current Output – 32-Channel Mode (Digital DAS)

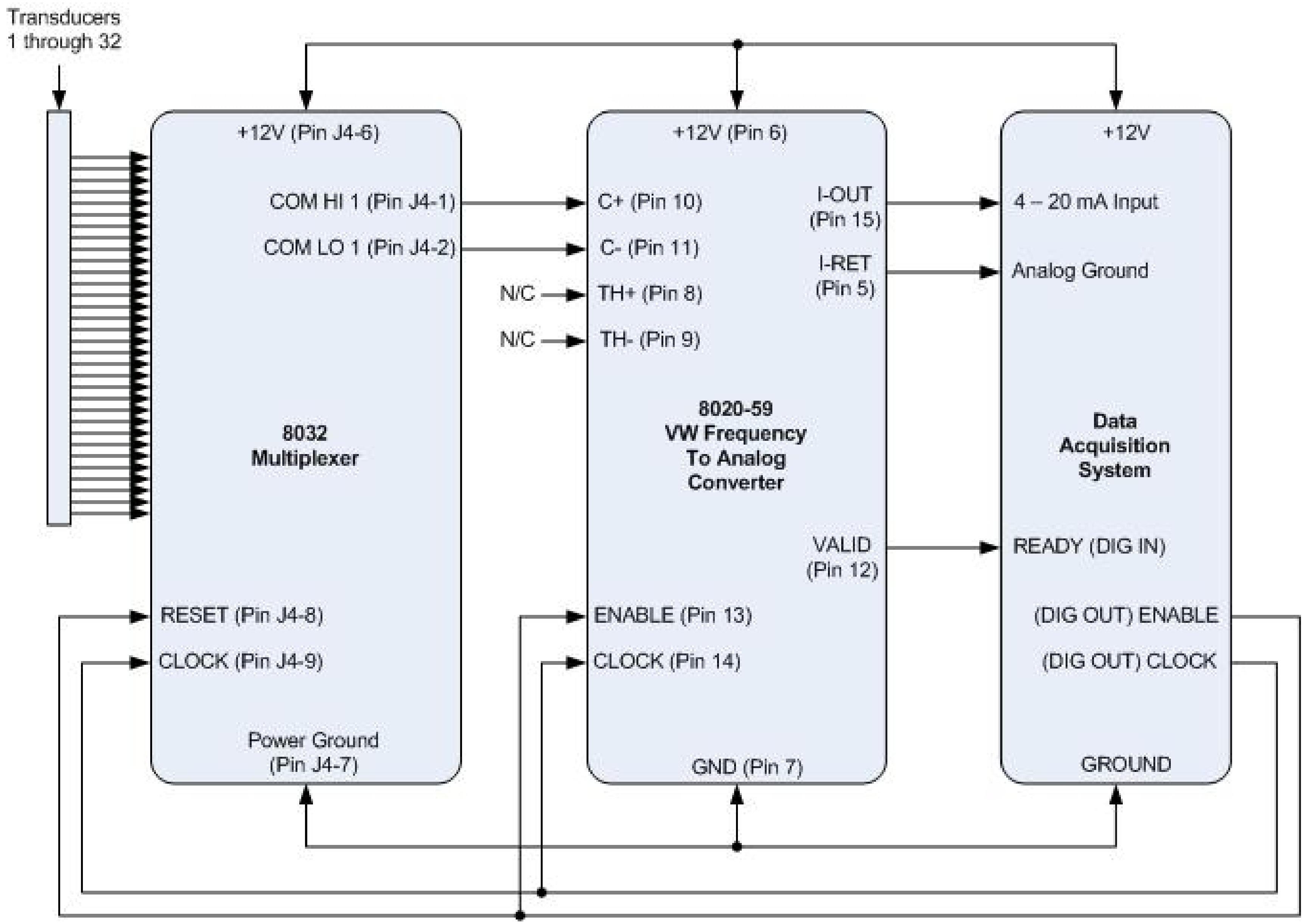
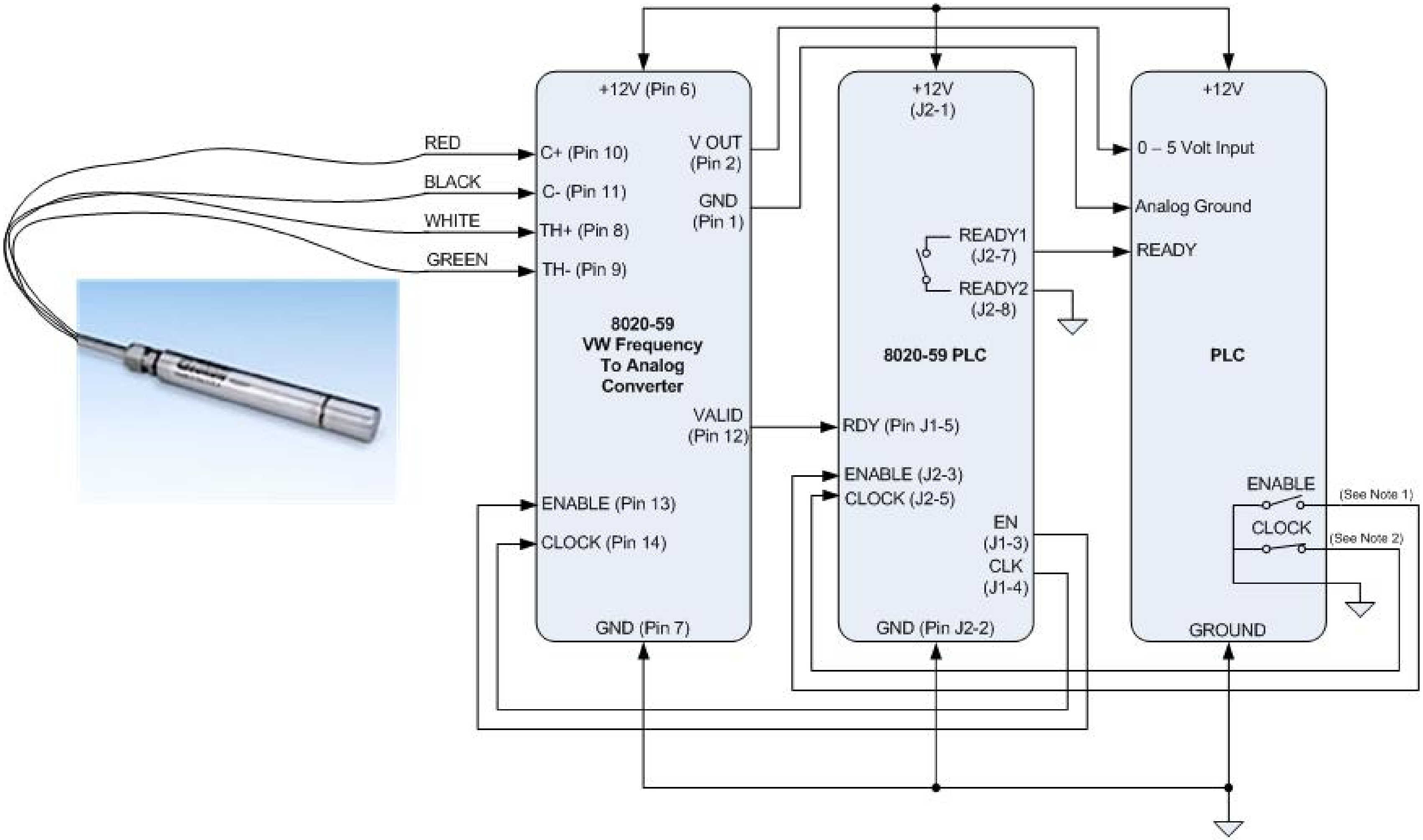


Figure 29 - Connection Example for 32-Channel Multiplexer, 8020-59 with Current Output and Digital I/O DAS

C.7 Voltage Output – Single Channel Mode (PLC DAS)



NOTE 1:
As depicted, when the PLC ENABLE relay is closed (energized), the 8020-59's output (V OUT) will be proportion to the measured temperature, otherwise the output will be proportional to the transducer reading in digits.

NOTE 2:
As depicted, when the PLC CLOCK relay contact is opened (energized), the 8020-59 will be ON, (enabled).

Figure 30 - Connection Example for One Channel. 8020-59 with Voltage Output, 8020-59 PLC and PLC DAS

C.8 Voltage Output – 16-Channel Mode (PLC DAS)

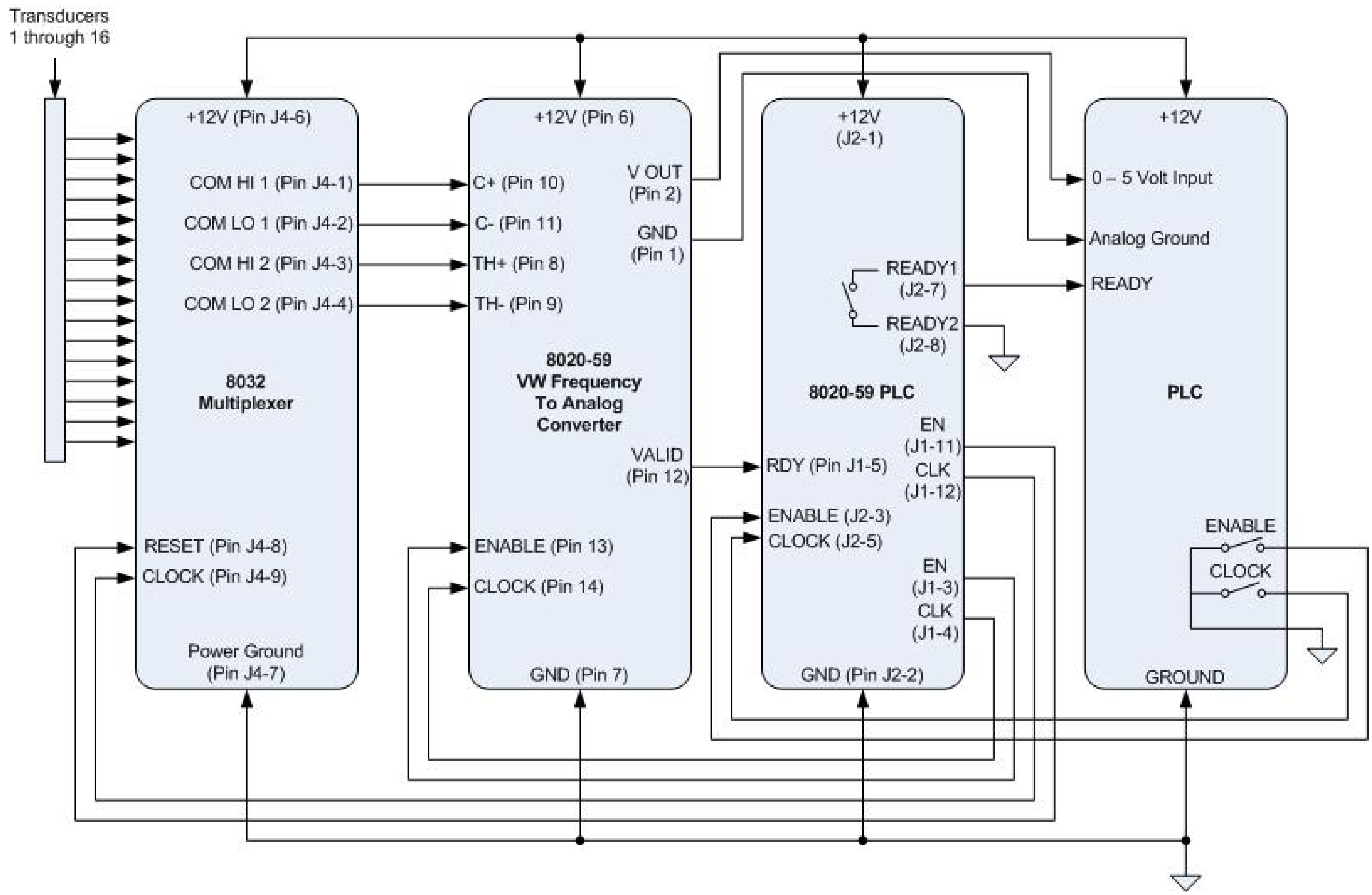


Figure 31 - Connection Example for 16-Channel Multiplexer, 8020-59 w/ Voltage Output, 8020-59 PLC and PLC DAS

C.9 Voltage Output – 32-Channel Mode (PLC DAS)

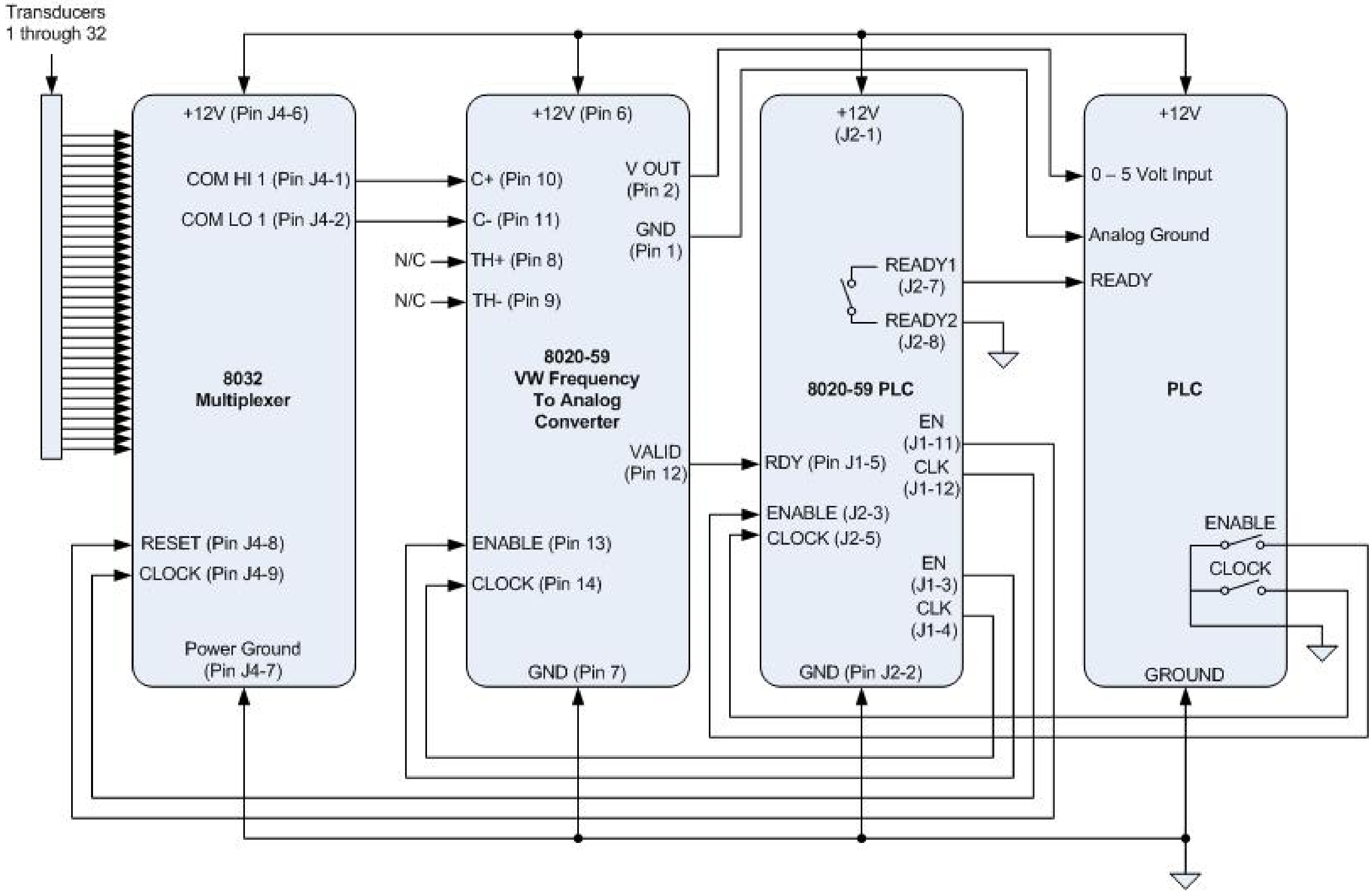


Figure 32 - Connection Example for 32-Channel Multiplexer, 8020-59 w/ Voltage Output, 8020-59 PLC and PLC DAS

C.10 Current Output – Single Channel Mode (PLC DAS)

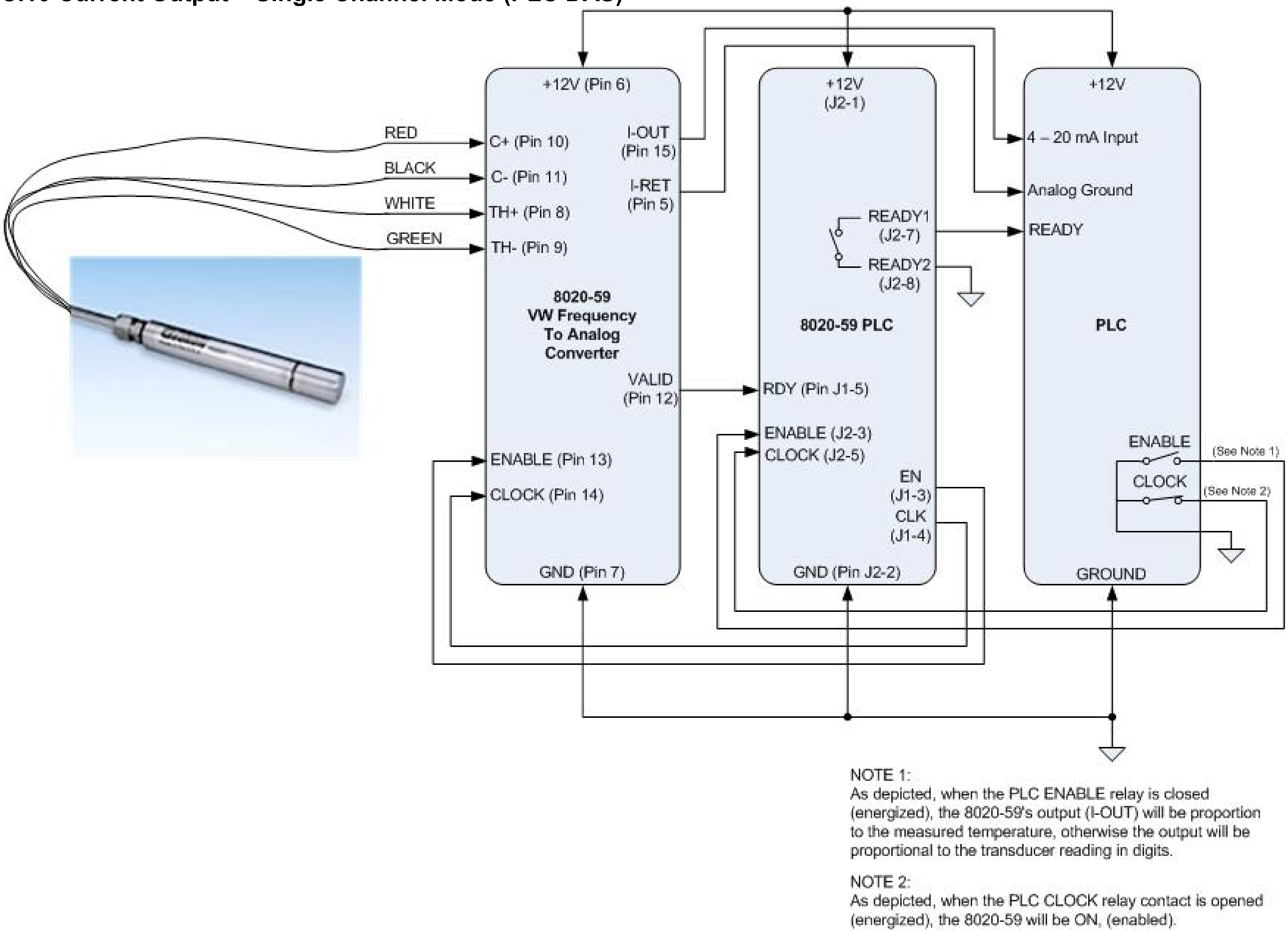


Figure 33 - Connection Example for One Channel 8020-59 with Current Output, 8020-59 PLC and PLC DAS

C.11 Current Output – 16-Channel Mode (PLC DAS)

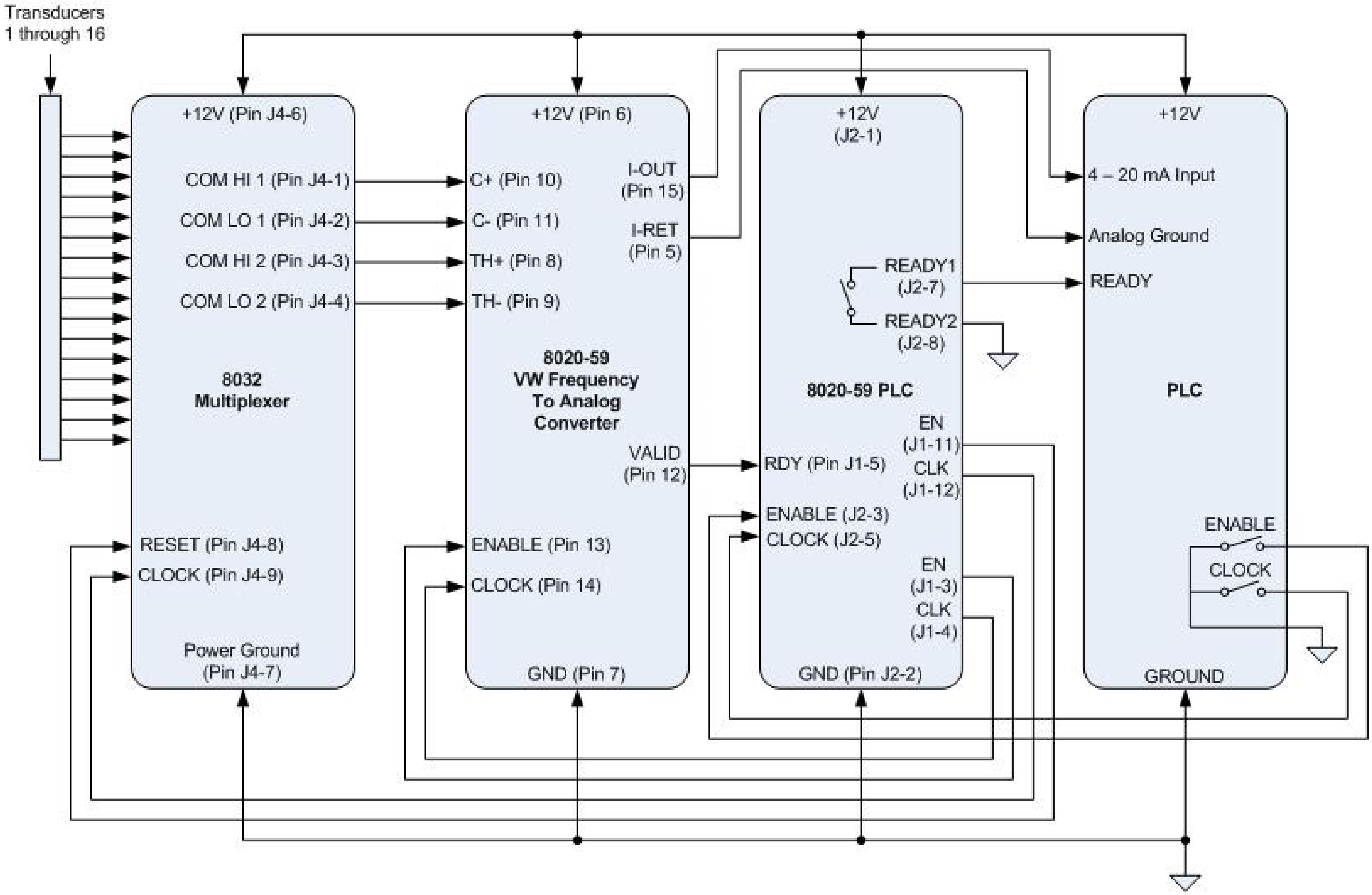


Figure 34 - Connection Example for 16-Channel Multiplexer, 8020-59 w/Current Output, 8020-59 PLC and PLC DAS

C.12 Current Output – 32-Channel Mode (PLC DAS)

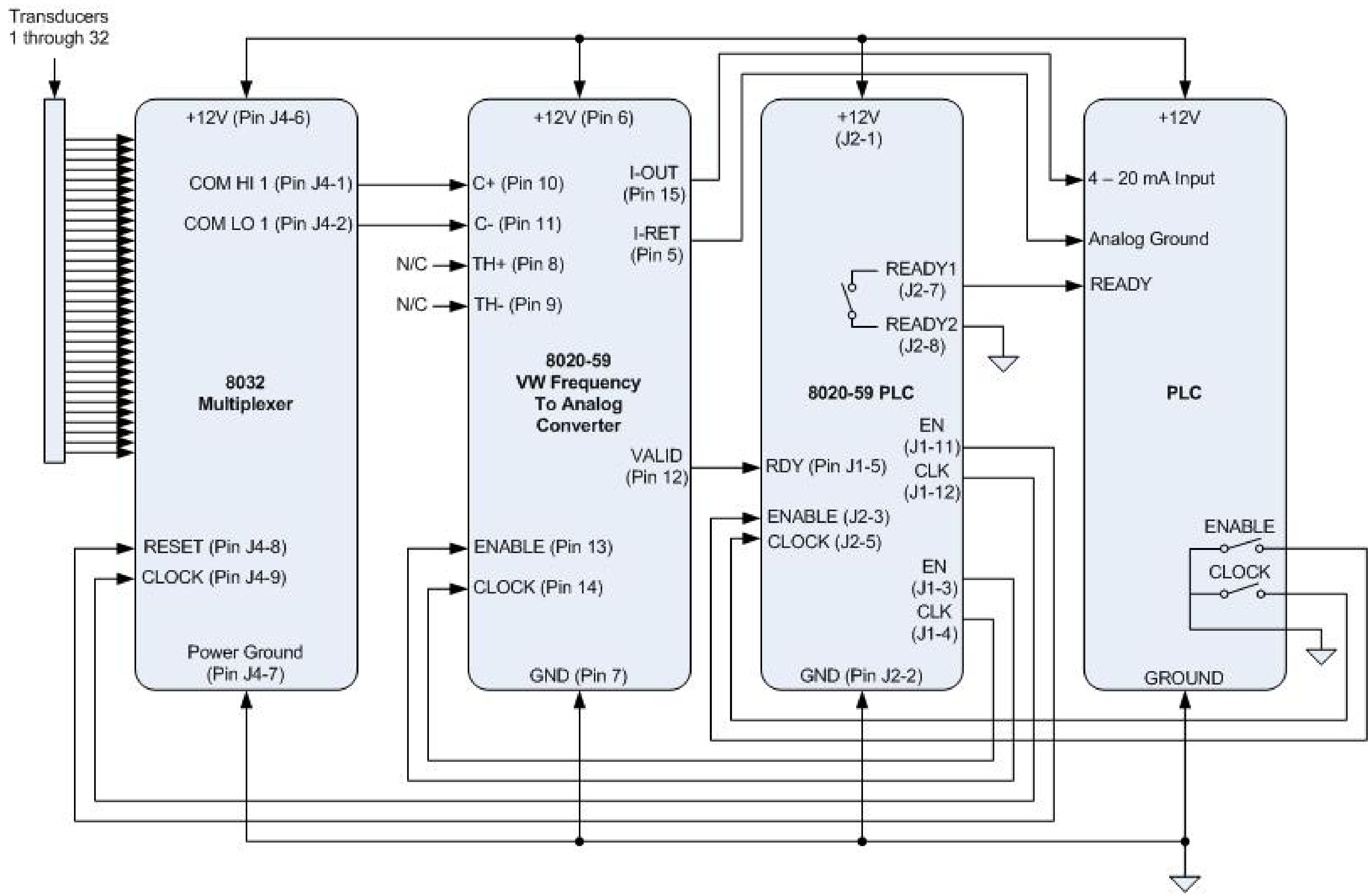


Figure 35 - Connection Example for 32-Channel Multiplexer, 8020-59 w/Current Output, 8020-59 PLC and PLC DAS

APPENDIX D. DATA REDUCTION

D.1 Pressure Calculation

The digits that are calculated from the voltage and current outputs are based on the equation:

$$\text{Digits} = \left(\frac{1}{\text{Period}}\right)^2 \text{ x } 10^{-3}$$

Or

$$\text{Digits} = \frac{\text{Hz}^2}{1000}$$

Equation 10 - Digits Calculation

For example, a piezometer reading 8000 digits corresponds to a period of 354 μs and a frequency of 2828 Hz. Note that in the above equation, the period is in seconds.

Digits are directly proportional to the applied pressure.

$$\text{Pressure} =$$

$$(\text{Current Reading - Initial Zero Reading}) \times \text{Linear Calibration Factor}$$

Or

$$P = (R_1 - R_0) \times G$$

Equation 11 - Convert Digits to Pressure

Since the linearity of most sensors is within 0.2% FS the errors associated with non-linearity are of minor consequence. However, for those situations requiring the highest accuracy it may be desirable to use a second order polynomial to get a better fit of the data points. The use of a second order polynomial is explained in Appendix F.

The calibration report included with each transducer shows the data from which the linear gauge factor and the second order polynomial coefficients are derived. Columns on the right show the size of the error incurred by assuming a linear coefficient and the improvement that can be expected by going to a second order polynomial. In many cases, the difference is minor. The calibration reports give the pressure in certain engineering units. These can be converted to other engineering units using the multiplication factors shown in Table 4 below.

From → To ↓	psi	"H_2O	'H_2O	mm H_20	m H_20	"HG	mm HG	atm	mbar	bar	kPa	MPa
psi	1	.036127	.43275	.0014223	1.4223	.49116	.019337	14.696	.014503	14.5039	.14503	145.03
"H_2O	27.730	1	12	.039372	39.372	13.596	.53525	406.78	.40147	401.47	4.0147	4016.1
'H_2O	2.3108	.08333	1	.003281	3.281	1.133	.044604	33.8983	.033456	33.4558	.3346	334.6
mm H_20	704.32	25.399	304.788	1	1000	345.32	13.595	10332	10.197	10197	101.97	101970
m H_20	.70432	.025399	.304788	.001	1	.34532	.013595	10.332	.010197	10.197	.10197	101.97
"HG	2.036	.073552	.882624	.0028959	2.8959	1	.03937	29.920	.029529	29.529	.2953	295.3
mm HG	51.706	1.8683	22.4196	.073558	73.558	25.4	1	760	.75008	750.08	7.5008	7500.8
atm	.06805	.0024583	.0294996	.0000968	.0968	.03342	.0013158	1	.0009869	.98692	.009869	9.869
mbar	68.947	2.4908	29.8896	.098068	98.068	33.863	1.3332	1013.2	1	1000	10	10000
bar	.068947	.0024908	.0298896	.0000981	.098068	.033863	.001333	1.0132	.001	1	.01	10
kPa	6.8947	.24908	2.98896	.0098068	9.8068	3.3863	.13332	101.320	.1	100	1	1000
MPa	.006895	.000249	.002988	.00000981	.009807	.003386	.000133	.101320	.0001	.1	.001	1

Table 4 - Engineering Units Multiplication Factors

Note: Due to changes in specific gravity with temperature, the factors for mercury and water in Table 4 are approximations.

D.2 Temperature Correction

Careful selection of materials is made in constructing the vibrating wire piezometer to minimize thermal effects; however, most units still have a slight temperature coefficient. Consult the supplied calibration report to obtain the coefficient for a given piezometer.

Since piezometers are normally installed in a tranquil and constant temperature environment, corrections are not normally required. If however, that is not the case for a selected installation, corrections can be made using the internal thermistor for temperature measurement.

Temperature correction equation is as follows:

$$\text{Temperature Correction} =$$

$$(\text{Current Temperature - Initial Zero Temperature}) \times \text{Thermal Factor}$$

Or

$$P_T = (T_1 - T_0) \text{ x } K$$

Equation 12 - Temperature Correction

The calculated correction would then be **added** to the Pressure calculated using Equation 11. (If the engineering units were converted, remember to apply the same conversion to the calculated temperature correction!) For example, assume the initial temperature was 22° C, the current temperature is 15° C, and the thermal coefficient is −.01879 PSI per °C rise. The temperature correction is 0.13 PSI. Adding this to the calculated pressure in the beginning of this appendix results in a temperature corrected pressure of 19.98 PSI.

D.3 Barometric Correction (required only on non-vented transducers)

Since the standard piezometer is hermetically sealed and unvented, it responds to changes in atmospheric pressure. That being the case, corrections may be necessary, particularly for the sensitive, low-pressure models. For example, a barometric pressure change from 29 to 31 inches of mercury would result in ≈1 PSI of error (or ≈2.3 feet if monitoring water level in a well!). Thus, it is advisable to read and record the barometric pressure every time the piezometer is read. A separate pressure transducer (piezometer), kept out of the water, may be used for this purpose.

Barometric correction equation is as follows;

$$\text{Barometric Correction} =$$

$$(\text{Current Barometer - Initial Zero Barometer}) \times \text{Conversion Factor}$$

Or

$$P_B = (S_1 - S_0) \text{ x } F$$

Equation 13 - Barometric Correction

Since barometric pressure is usually recorded in inches of mercury, a Conversion Factor is necessary to convert to PSI. The Conversion Factor for inches of mercury to PSI is .491. Table 4 lists other common Conversion Factors.

The calculated correction is usually **subtracted** from the Pressure calculated using Equation 11. If the engineering units were converted, remember to apply the same conversion to the calculated barometric correction!

The user should be cautioned that this correction scheme assumes ideal conditions. In reality, conditions are not always ideal. For example, if the well is sealed, barometric effects at the piezometer level may be minimal or attenuated from the actual changes at the surface. Thus, errors may result when applying a correction that is not required.

An alternative to making barometric correction is to use piezometers that are vented to the atmosphere.

Equation 14 describes the pressure calculation with temperature and barometric correction applied.

$$P_{corrected} = ((R_1 - R_0) \text{ x } G) + ((T_1 - T_0) \text{ x } K) - ((S_1 - S_0) \text{ x } F)$$

Equation 14 - Corrected Pressure Calculation

APPENDIX E. SAMPLE CALIBRATION REPORT

GEOKON

Vibrating Wire Pressure Transducer Calibration

Model Number: 4500S-100 Pressure Range: 100 psi

Serial Number: 48056 Mfg. Number: 8-3275

Customer: Temperature: 21.1 °C

Cust. I.D. #: n/a Barometric Pressure: 998.1 mbar

Job Number: 13053 Date: Nov. 7, 1998

Cal. Std. Control #(s): 183, 468 Technician:

Pressure (psi)	Reading 1st Cycle	Pressure (psi)	Reading 2nd Cycle	Average Pressure	Average Reading	Change	Linearity (%FS)	Polynomial Fit (%FS)
0	9136	0	9141	0	9139		0.18	-0.04
20	8453	20	8456	20	8455	684	0.03	0.08
40	7772	40	7774	40	7773	682	-0.19	-0.01
60	7085	60	7083	60	7084	689	-0.19	-0.01
80	6392	80	6390	80	6391	693	-0.08	-0.03
100	5694	100	5687	100	5691	701	0.25	0.03

Linear Gage Factor (G): 0.029021 (psi/digit) Regression Zero: 9145

Polynomial Gage Factors: A: -1.40E-07 B: -0.026943 C:* 257.8826

Thermal Factor (K): -0.004326 (psi/°C)

Calculated Pressures: **Linear,** $P = G(R_0 - R_1) + K(T_1 - T_0) - (S_1 - S_0)$**

Polynomial, $P = AR_1^2 + BR_1 + C + K(T_1 - T_0) - (S_1 - S_0)$**

***Barometric compensation is not required with vented transducers.*

Factory Zero Reading:

GK-401 Pos. B or $F(R_0)$: 9128 Temp(T_0): 21.8 °C Baro(S_0): 1001.4 mbar Date: Jan. 27, 1997

**The user is advised to establish zero conditions in the field by recording the reading at a known temperature and barometric pressure.*

Wiring Code: Red and Black: Gage White and Green: Thermistor Bare: Shield

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

Figure 36 - Vibrating Wire Pressure Transducer Calibration Report

APPENDIX F. IMPROVING THE ACCURACY OF CALCULATED PRESSURES

Most vibrating wire pressure transducers are sufficiently linear (± 0.2 % FS) that use of the linear calibration factor satisfies normal requirements. However, it should be noted that the accuracy of the calibration data, which is dictated by the accuracy of the calibration apparatus, is always ± 0.1 % FS.

This level of accuracy can be recaptured, even where the transducer is non-linear, by the use of a second order polynomial expression, which gives a better fit to the data then does a straight line.

The polynomial expression has the form:

$$\text{Pressure} = AR^2 + BR + C$$

Equation 15 - Second Order Polynomial Expression

Where;
R is the reading (digits)
A, B, and C, are coefficients

Figure 36 shows a calibration report of a transducer that has a comparatively high non-linearity. The figure under the "Linearity (%FS)" column is:

$$\frac{\text{Calculated Pressure-True Pressure}}{\text{Full Scale Pressure}} \times 100\% = \frac{G(R_1\text{-}R_0)\text{-}P}{\text{F.S.}} \times 100\%$$

Equation 16 - Linearity Calculation

For example when P= 40 psi, G (R_0 - R_1) gives a calculated pressure of 39.642 psi. The error is 0.357 psi or as much as 9.9 inches of water!

Whereas the polynomial expression gives a calculated pressure of $A(7773)^2 + B(7773) + C =$ 39.996 psi and the actual error is only 0.004 psi or 0.1 inch of water.

Note: If the polynomial equation is used, it is important that the value of C, in the polynomial equation, be taken in the field. The field value of C is calculated by inserting the initial zero reading into the polynomial equation with the pressure, P, set to zero. As of 8/2011, Geokon no longer includes the C coefficient on its calibration reports, ensuring that, to properly use the polynomial equation, users must calculate a C coefficient.

It should be noted that where *changes* of water levels are being monitored it makes little difference whether the linear coefficient or the polynomial expression is used.

APPENDIX G. BAROMETRIC CORRECTION (NON-VENTED TRANSDUCERS ONLY)

Since the standard piezometer is hermetically sealed and unvented, it responds to changes in atmospheric pressure. That being the case, corrections may be necessary, particularly for the sensitive, low-pressure models.
The digits for the range of the transducer, as shown on the calibration report, may vary considerably with changes in elevation (offset). It is a simple matter to compensate for this offset with the 8020-59.

Referring to the example calibration report (Appendix E, Figure 36), note that the average zero reading (0 psi) is 9139 digits (8020-59 maximum digits) and the average maximum reading (100 psi) is 5691 digits (8020-59 minimum digits). These readings were recorded at an atmospheric pressure of 1001.4 mbar, corresponding to the conditions and altitude at the Geokon factory. To compensate for elevation change, take a new zero reading at the site location. This new zero reading becomes the maximum digits entered into the 8020-59. Add the difference between the new zero reading and the original zero reading to the maximum reading shown on the calibration report. This becomes the new minimum digits entered into the 8020-59.

For example:

	0 psi Average Reading		100 psi Average Reading
Calibration Report:	9139		5691
Site Location:	**9950**	(+811 digits)	**6502**
	(new maximum digits)		(new minimum digits)