TMX32 User's Manual

Real Time Devices, Inc.

"Accessing the Analog World"®

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TMX32

User's Manual

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INTRODUCTION

The TMX32 analog input expansion board with thermocouple compensation economically expands the input capability of any channel on your A/D converter board to 32 single-ended or 16 differential channels. The TMX32 is especially well suited for applications where a thermocouple sensor is monitored with other sensor types. When you have several thermocouples, we recommended that you use the TS16 temperature sensor and input expansion board for the thermocouple measurements.

The TMX32 external interface board features:

- 32 single-ended or 16 differential analog input channels,
- 100 kHz throughput,
- On-board temperature sensor cold junction compensation for thermocouples through software,
- Shunt terminals for current measurement,
- Jumper-selectable gains of 1, 10, 100 or 1000 (1, 2, 4 & 8 optional), or software programmable gain,
- Circuit pads to install resistors and capacitors for input signal conditioning,
- ±35V overvoltage protection, ±10V common mode input voltage,
- Connector for external +12 volt power,
- Miniature screw terminal blocks for easy input signal connection,
- Extra I/O connector for daisy chaining (cascade up to 16 boards).

The following paragraphs briefly describe the major function of the board. A more detailed discussion of the board is included in Chapter 3, *Board Operation*. The board setup is described in Chapter 1, *Board Settings*.

Multiplexing

Two on-board multiplexers receive up to 32 single-ended or 16 differential analog input channels and route them to the selected channel on the A/D converter board. The A/D converter channel to which these inputs are fed is selected using jumpers on the TMX32. Channel selection is made using five digital control lines connected from the A/D converter board to the TMX32. The input voltage range of the TMX32 channels is the same as the range of A/D converter board. Jumper-selectable gains of 1, 10, 100, and 1000 are available on the TMX32, or the gain can be programmed through software using two digital control lines connected from the A/D board. The gains available on the TMX32, when coupled with the gains on the A/D board, yield a very flexible signal amplification capability.

On-board circuit pads are provided so that you can construct several different types of conditioning circuitry on each input signal.

Thermocouple Compensation

The TMX32 has an on-board sensor for cold junction temperature sensing and amplification which makes the board ideal for thermocouple measurement. The temperature sensor’s voltage output can be routed through channel 8 or 16 on the A/D board where it is available to correct thermocouple measurements through software. This manual provides information and general formulas for thermocouple measurement and compensation.

MX32 Compatibility

The TMX32 also replaces the earlier MX32 analog input expansion board. For those ordering an MX32, Appendix C explains the changes made to configure the board as an MX32 equivalent.

What Comes With Your Board

You receive the following items in your TMX32 package:

- TMX32 analog input expansion board
- User’s manual

If any item is missing or damaged, please call Real Time Devices’ Customer Service Department at (814) 234-8087. If you require service outside the U.S., contact your local distributor.

In addition to the items included in your TMX32 package, Real Time Devices offers a full line of board accessories. Key accessories for the TMX32 include the XT50 twisted pair cable, TB50 terminal board and XB50 prototype/terminal board which can be connected to the daisy chain connector for prototype development and easy signal access.

Using This Manual

This manual is intended to help you get your new board running quickly, while also providing enough detail about the board and its functions so that you can enjoy maximum use of its features even in the most complex applications. We assume that you already have an understanding of data acquisition principles and that you can provide the software necessary to control the TMX32 board.

When You Need Help

This manual provides enough information to properly use your board’s features. If you have any problems installing or using this board, contact our Technical Support Department, (814) 234-8087, during regular business hours, eastern standard time or eastern daylight time, or send a FAX requesting assistance to (814) 234-5218. When sending a FAX request, please include your company’s name and address, your name, your telephone number, and a brief description of the problem.

CHAPTER 1

BOARD SETTINGS

The TMX32 has jumper and switch settings you can change if necessary for your application. The factory settings are listed in the table and shown on the board layout in the beginning of this chapter. Should you need to change these settings, use these easy-to-follow instructions.

Factory-Configured Switch and Jumper Settings

Table 1-1 (on the next page) lists the factory settings of the user-configurable switch and jumpers on the TMX32 board. Figure 1-1 shows the board layout and the locations of the factory-set jumpers. The following paragraphs explain how to change the factory settings.

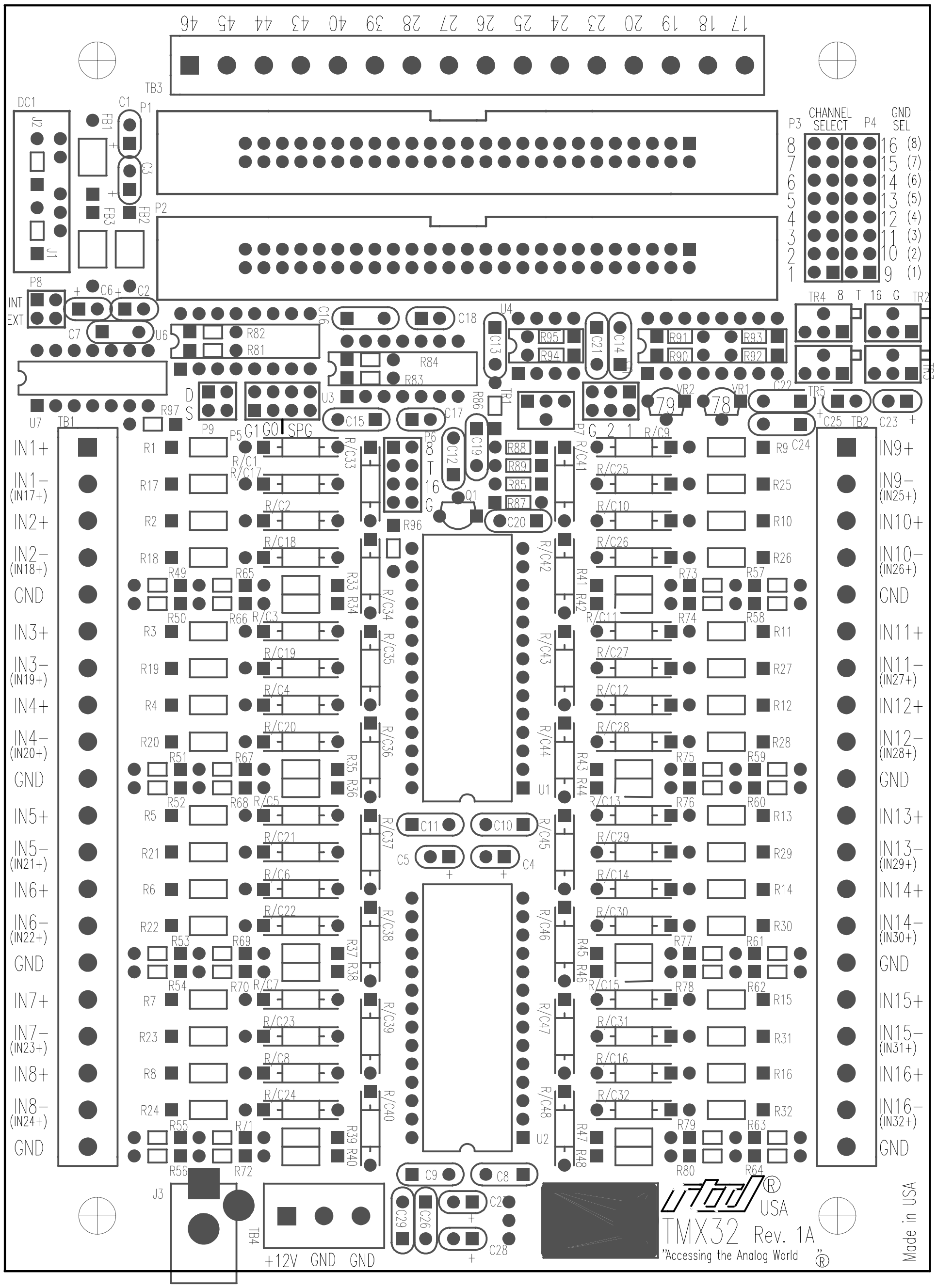


Fig. 1-1 — Board Layout Showing Factory-Configured Settings

Table 1-1 Factory Settings		
Jumper/ Switch	Function Controlled	Factory Setting
P3, P4	Select the channel that the TMX32 is connected to on the A/D converter board. One or two jumpers must be installed, as explained later in this chapter.	P3 = Channel 1; P4 = Channel 1 GND
P5	Sets the TMX32 board gain (this gain is multiplied by the gain setting of the A/D converter board to determine the overall channel gain)	Jumpers installed on G0 and G1 (gain = 1)
P6	Feeds the temperature sensor's voltage output into channel 8 or 16 on the A/D board to enable cold junction compensation through software	Jumpers installed on DIS (disabled)
P7	Selects the TMX32 amplifier offset adjustment source	G
P8	Connects the TMX32 power to the internal power (supplied from A/D board) or external power (supplied by user)	Connected to internal power
P9	Sets the analog input signal type for S (single-ended) or D (differential)	Single-ended

P3 and P4 — A/D Converter Board Channel Select (Factory Setting: Channel 1/GND)

The TMX32 expands a single channel on your A/D converter board to either 32 single-ended or 16 differential analog input channels. P3 and P4 are used to select which analog input channel on your A/D converter board you connect to the TMX32. These connectors accommodate A/D converter boards with up to 16 channels.

For 1-8 Input Channels (single-ended or differential on A/D board): When you connect the TMX32 to an A/D converter board with eight or fewer analog input channels, P3 is used to set the desired input channel, and P4 is used to set the corresponding ground for that channel. For example, if you place the jumper across the pins for channel 1 on P3 as shown in Figure 1-2, you should place the P4 jumper across the channel 1 ground pins (labeled “9 (1)” on the board), as shown. You must install both jumpers — the selected channel jumper and the corresponding ground jumper — regardless of whether you are operating in the single-ended or differential mode.

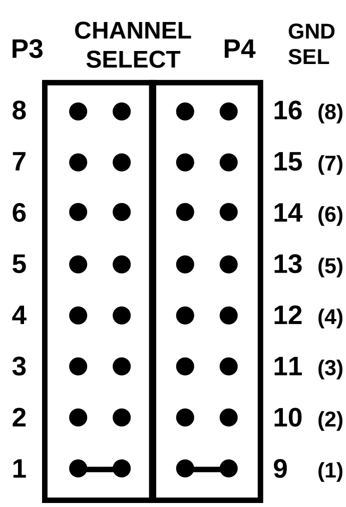


Fig. 1-2 — Channel Select Jumpers, 8-Channel A/D Boards

For 16 Input Channels (single-ended on A/D board): When you connect the TMX32 to an A/D converter board with 16 input channels, only one jumper is installed on P3 and P4. Figure 1-3 shows you how to configure the TMX32 for channel 1, and Figure 1-4 shows you how to configure the TMX32 for channel 9 when used with a 16-channel A/D converter board. Note that the leftmost row of pins on P3 carries the analog input signal for chan-

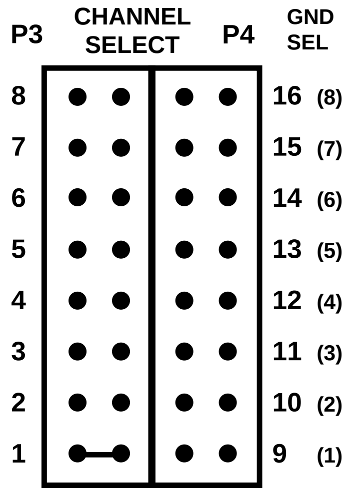


Fig. 1-3 — Connecting Channel 1 to a 16-Channel A/D Board

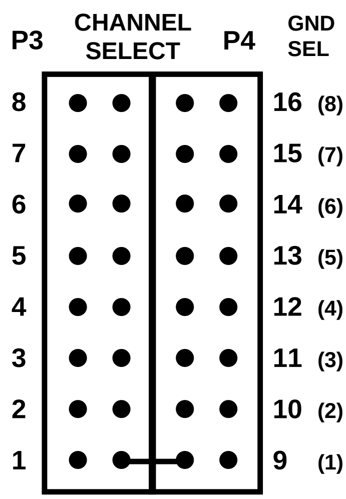


Fig. 1-4 — Connecting Channel 9 to a 16-Channel A/D Board

nels 1 through 8, the rightmost row of pins on P3 provides the common signal for all 16 channels, and the leftmost row of pins on P4 carries the analog input signal for channels 9 through 16. The rightmost row of pins on P4 is connected to ground and is not used when connecting to a 16-channel A/D converter board.

P5 — Gain Select (Factory Setting: G0 and G1 Installed (Gain = 1))

P5, shown in Figure 1-5, lets you select one of four gain settings: 1, 10, 100, or 1000, or set the gain through software. The two pins, G0 and G1, are used to set the gain for all TMX32 channels to one of the four values above. The table below shows you how to install the jumpers to achieve the desired gain (ON = jumper installed; OFF = jumper removed).

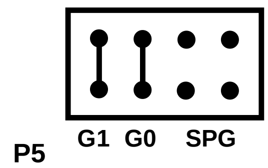


Fig. 1-5 — Gain Select Jumpers, P5

Gain	G0	G1	D5	D6
x1	ON	ON	0	0
x10	OFF	ON	1	0
x100	ON	OFF	0	1
x1000	OFF	OFF	1	1

The two pins, labeled SPG, are used to allow control of the gain setting through software. For software programmable gain, install the jumpers across both pairs of SPG pins. When the jumpers are installed across these pins, bits 5 and 6 of the digital control word written to the TMX32 from the A/D converter board are used to program the gain.

Note that the gain set on the TMX32 board is multiplied by the gain setting of your A/D converter board to determine the overall channel gain.

P6 — Temperature Sensor Voltage Output Select (Factory Setting: Disabled)

P6, shown in Figure 1-6, lets you select to which channel on the A/D board the temperature sensor's voltage is routed. When both jumpers are installed across the left pins as shown in Figure 1-6a, the temperature sensor's voltage is fed nowhere (disabled). When a jumper is installed across pins 8 and T, as shown in Figure 1-6b, the voltage is fed into channel 8 on the A/D board. When a jumper is installed across pins T and 16, as shown in Figure 1-6c, the voltage is fed into channel 16 on the A/D board. When the A/D board is being operated in the DIFFERENTIAL mode, then two jumpers must be installed: one across 8 and T, and one across 16 and G. Chapter 3 provides more information about the temperature sensing circuit.

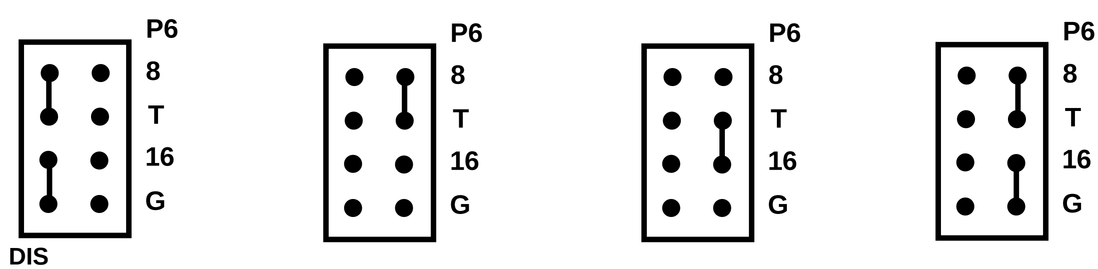


Fig. 1-6a: Disabled (Factory Setting)

Fig. 1-6b: Temperature Sensor to Channel 8 A/D

Fig. 1-6c: Temperature Sensor to Channel 16 A/D

Fig. 1-6a: Temperature Sensor to Channel 8 A/D, A/D DIFFERENTIAL Mode

Fig. 1-6 — Temperature Sensor Voltage Output Select Jumpers, P6

P7 — Offset Adjustment Source Select (Factory Setting: G (TMX32 TR1 Offset Adjust))

P7, shown in Figure 1-7, lets you select the offset adjustment source for the TMX32 amplifier. When the jumper is placed across the pins labeled G, the offset is controlled only by trim pots on the TMX32 board. When the jumper is placed across 1 or 2, the offset adjustment source is the voltage output of DAC1 (labeled 1) or DAC2 (labeled 2) on the A/D board, as well as by the trim pots. Chapter 3 explains how the offset adjustment is used for measurements.

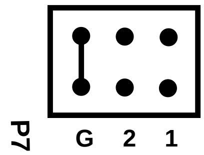


Fig. 1-7 — Offset Adjustment Source Select Jumper, P7

P8 — Power Source Select (Factory Setting: Internal)

P8 lets you select the power source for the TMX32. When the jumper is placed across the INT pins, power is supplied from the +5 volt pin on the A/D board. This will be satisfactory for most applications. If several TMX32 boards or other front-end boards such as relay boards are to be connected to the same A/D board or if you suspect that the internal +5 volt supply is causing noisy readings, it is recommended that you power the TMX32 from an external +12 volt supply connected to TB4. An internal +5 volt regulator converts the external +12 volts to the proper voltage for the board. When external power is used, move the jumper on P8 to EXT.

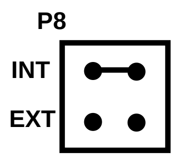


Fig. 1-8 — Power source select, P8

P9 — Single-Ended/Differential Analog Inputs (Factory Setting: Single-Ended)

P9 shown in Figure 1-9, configures the analog input channels for single-ended or differential operation.

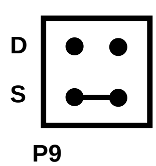


Fig. 1-9 — Analog Input Signal Type Jumper, P9

CHAPTER 2

BOARD CONNECTIONS

This chapter tells you step-by-step how to connect the TMX32 to your A/D converter board and to your external signal sources.

Connecting to the A/D Converter Board

Connecting to a 50-pin A/D Converter Board

Figure 2-1 shows the TMX32's P1 I/O connector pinout, with all of the pins used by the TMX32 board labeled. The TMX32 is pin-for-pin compatible with Real Time Devices' 50-pin I/O connector DAS boards. These include DataMaster™ boards, AIC boards, Precision Integrating boards, and dataModules®. The unlabeled pins on the TMX32 carry the same signal found at the I/O connector of the DAS board or module you are using.

If you want to access other signals on your A/D converter board, such as digital I/O or timer/counters, you can connect to the 16 signals available on TB3 at the top of the TMX32 board, shown in Figure 2-2. This terminal strip is labeled with the pin numbers brought out to it from P1. To find the signals available on these pins, refer to the A/D converter board's pinout in the board manual.

To further expand your input channel capability by adding more TMX32 boards, you can use the daisy chain connector on the TMX32 board, P2. The signals at this connector are identical to the pinout of your 50-pin A/D converter board. You can connect to another TMX32 board, or to a TB50 or XB50 breakout board to easily access all of the digital I/O and timer/counter signals. Our technical staff is available to help you select the accessories you need for your application.

> **WARNING!** If you connect more than one TMX32 board to an A/D converter board, be sure that you select a different A/D converter board channel for each TMX32 board used (header connectors P3 and P4 on the TMX32). If you connect more than one TMX32 to the same channel, damage to the boards and data acquisition system can result!

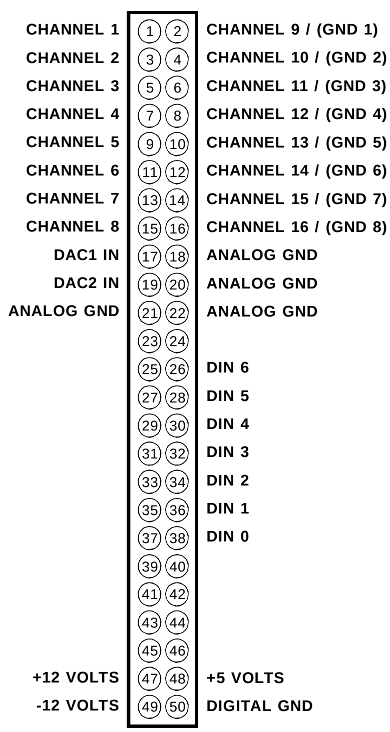


Fig. 2-1 — P1 I/O Connector Pin Assignments

Connecting to the Signal Sources

Figure 2-2 shows TB1 and TB2, where the analog input signal sources are connected. These 20-terminal miniature screw terminal strips let you easily connect and disconnect analog inputs to the board. Four additional analog ground terminals are provided on each strip for your convenience when connecting signal sources.

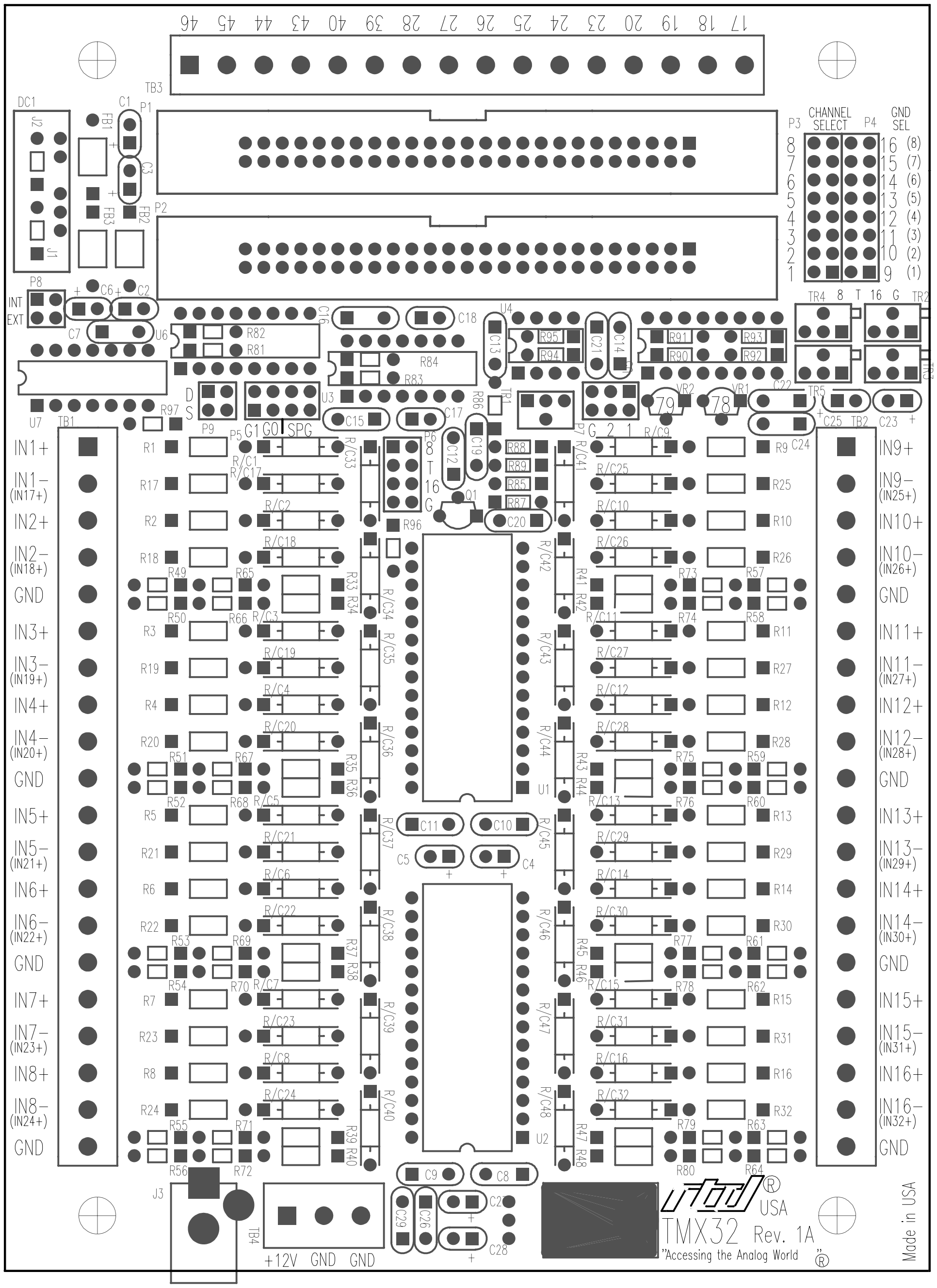


Fig. 2-2 — Board Layout, TB1, TB2, and TB3

Connecting Single-Ended Analog Inputs

In the single-ended mode, up to 32 signal sources can be connected to the TMX32. Connect the high side of the signal source to the selected IN+ terminal and connect the low side to one of the GND terminals. Note that channels 17 through 32 are labeled in parentheses on the board. Figure 2-3 shows you how to make these connections.

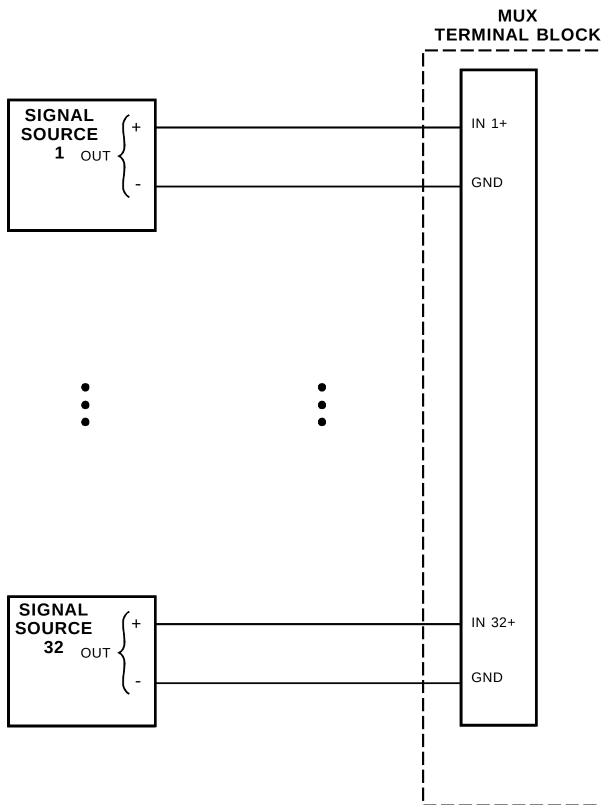


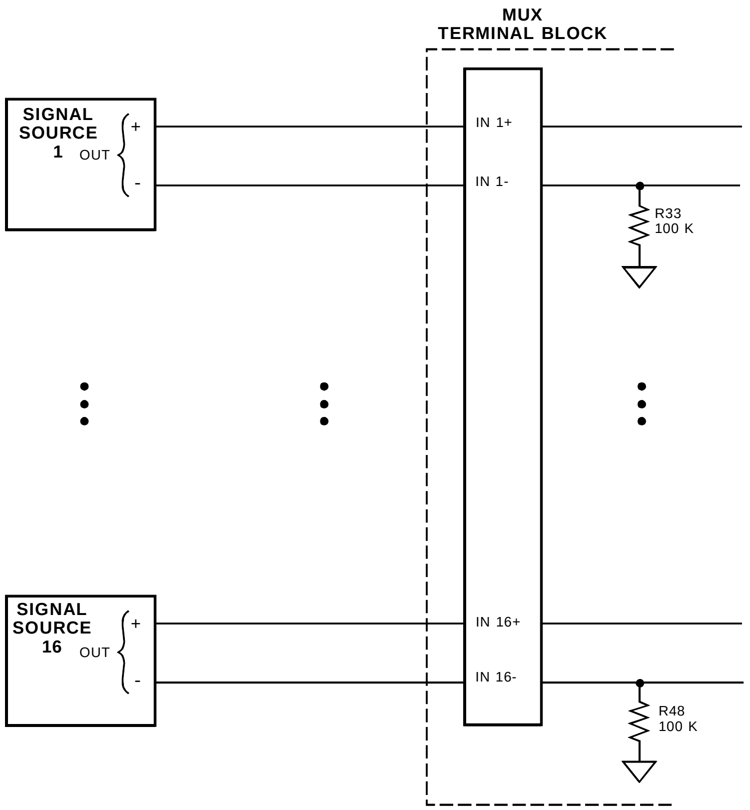
Fig. 2-3 — Single-Ended Input Connections

Connecting Differential Analog Inputs

In the differential mode, up to 16 signal sources can be connected to the TMX32. When operating in the differential mode, twisted pair cable is recommended to reduce the effects of magnetic coupling at the inputs. Your signal source may or may not have a separate ground reference. Figure 2-4 shows how to connect the input if you do not have a ground reference from the signal source, and Figure 2-5 shows you how to make the connections with a ground reference from the signal source.

If your signal source DOES NOT HAVE a ground reference signal:

- Refer to Figure 2-4 and install a 100 kilohm resistor in the appropriate resistor location on the board, as shown in the table below. Next, connect the high side of the analog input to the selected analog input channel, IN1+ through IN16+, and connect the low side of the input to the corresponding IN- pin, as shown in Figure 2-4.



Channel	Ra
1	R33
2	R34
3	R35
4	R36
5	R37
6	R38
7	R39
8	R40
9	R41
10	R42
11	R43
12	R44
13	R45
14	R46
15	R47
16	R48

Fig. 2-4 — Differential Input Connections Without Ground Reference

If your signal source HAS a ground reference signal:

- Refer to Figure 2-5 and connect the high side of the analog input to the selected analog input channel, IN1+ through IN16+, and connect the low side of the input to the corresponding IN- pin. Then, connect the ground from the signal source to one of the GND terminals. When a signal source has a reference ground, no resistors are necessary.

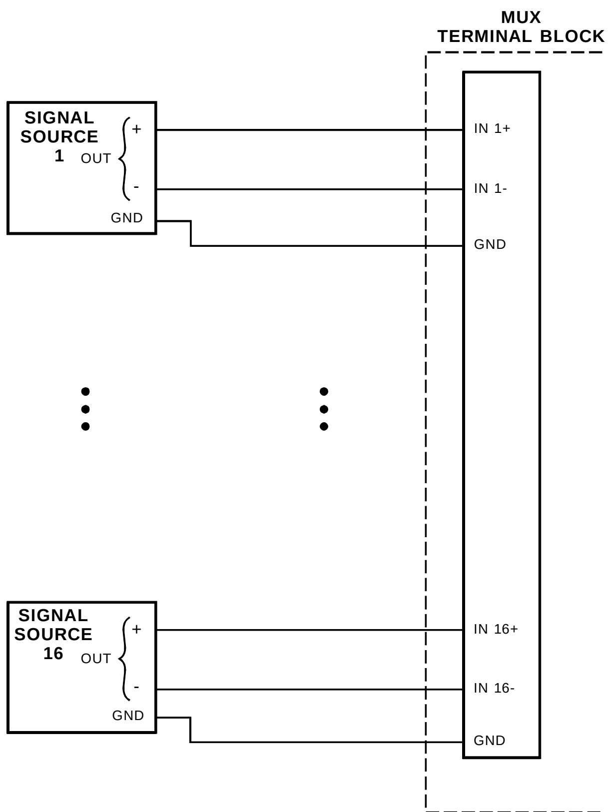


Fig. 2-5 — Differential Input Connections With Ground Reference

CHAPTER 3

BOARD OPERATION

This chapter describes the features of the TMX32, how to install resistors and capacitors for some types of input signal conditioning, and board operation.

The TMX32 multiplexes up to 32 single-ended (16 differential) analog input channels into a single input channel on your A/D converter board. The board also has temperature sensing circuitry for thermocouple measurements, jumper selectable or software selectable gain, and channel-by-channel offset adjustment. Figure 3-1 shows the functional block diagram of the board.

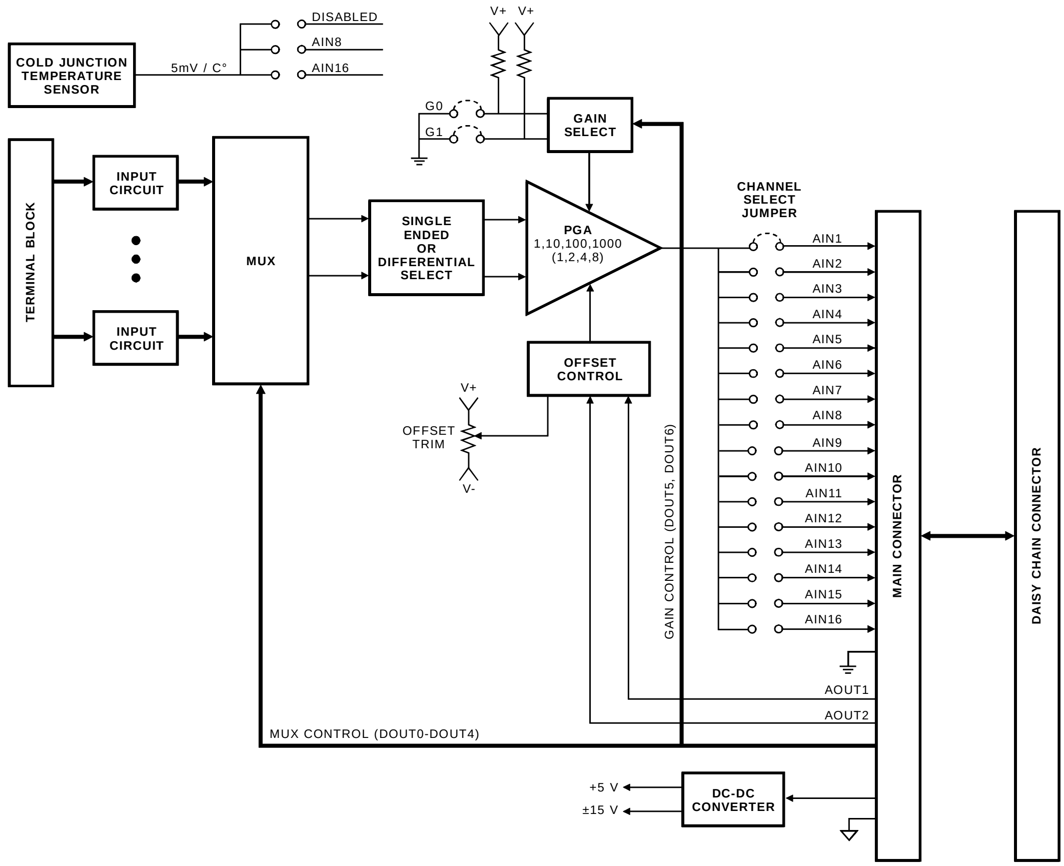


Fig. 3-1 — TMX32 Block Diagram

Multiplexing Circuitry

The TMX32 uses two 16-input analog multiplexers to provide a single output which is fed to the selected input channel on an A/D converter board. Each multiplexer has ±35 Vdc overvoltage protection to protect it against accidental signal overloads.

Input Voltage Range

The input voltage range of the TMX32 is determined by the range of the A/D converter board. If the A/D board is set for a ±5 volt range, then all of the TMX32 board inputs must fall within the range of ±5 volts before being sent to the A/D board.

Gain

You can set a jumper-selectable gains of 1, 10, 100, or 1000, or you can configure the TMX32 to program the gain through software for applications where the input voltage varies widely because of different sensor types on different channels. Chapter 1 describes how to set the gain jumpers for either gain configuration. Digital lines DIN5 and DIN6 control the gain setting when in the software selectable mode. These lines are programmed through the A/D converter board, and must be set up on that board as digital output lines, and as mode 0 if your A/D board has an 8255 PPI chip. The A/D converter board's manual tells you how to set up the PPI. The following table shows the states of these lines for each gain setting.

Programmable Gain Digital Lines		
Gain	**DIN6**	**DIN5**
1	0	0
10	0	1
100	1	0
1000	1	1

Offset Voltage Adjustment

Trimpots TR5 (x1), TR4 (x10), TR3 (x100) and TR2 (x1000) are provided on the TMX32 to adjust the offset voltage for each gain. These offsets have been calibrated at the factory and should not need to be changed.

To compensate for sensors with an inherent offset that you want to eliminate, You can use a D/A output from your A/D converter board to provide the offset voltage adjustment. The output from the A/D converter board 's DAC1 or DAC2 can be used simply by placing the jumper on the TMX32's P7 header across the pins labeled 1 (DAC1) or 2 (DAC2). When a jumper is installed in either of these locations, then whatever voltage is fed out the corresponding DAC output from the A/D converter board becomes the offset voltage. In this way, you can change the offset on a channel-by-channel and gain-by-gain basis. For example, if a sensor has an inherent offset of +2 volts but changes only in millivolts around the +2 volt value, you can send a value of -2 volts out the DAC to center the millivolt readings around zero and allow you to use gain to amplify the signal.

Note that offsets which may be insignificant at low gains could become a factor when you further increase the gain through the A/D converter board. For example, a gain of 10 on the TMX32 coupled with a gain of 16 on your converter board provides a total gain of 160, large enough to substantially affect readings should the offset not be zeroed. To adjust the offset when the P7 jumper is installed across the G pins, short the inputs to channel 1 together, and, observing the channel 1 output, adjust the appropriate trimpot until a value equal to 0 volts is read.

Also note that when you are using the TMX32 in a system that is set for a high gain (100 or more), the analog inputs may carry a significant amount of noise. To help lower the noise levels, you can reduce the gain or use some of the techniques described in the noise reduction discussion in this chapter.

Digital Control Lines

Five digital control lines, DIN0 through DIN4 (or DOUT0 through DOUT4 when looking at the signals output from the A/D converter board), let you select which TMX32 channel is active. These lines are programmed from the A/D converter board and must be set up as outputs on that board. The TMX32 **cannot** be controlled by analog lines! If your board has an 8255 PPI chip, then you must set up the lines that you use for TMX32 channel (and gain) selection as mode 0 outputs. The A/D converter board manual tells you how to set up the PPI.

Table 3-1 shows the 5-bit digital data and their corresponding channel selections. Note that when operating in the differential mode, only the first 16 entries are valid. In the differential mode, the MSB of the 5-bit data must always be 0.

Table 3-1 Analog Input Channel Select, DIN0-DIN4

Input Channel	DIN Line Setting 5 4 3 2 1	Input Channel	DIN Line Setting 5 4 3 2 1
1	0 0 0 0 0	17	1 0 0 0 0
2	0 0 0 0 1	18	1 0 0 0 1
3	0 0 0 1 0	19	1 0 0 1 0
4	0 0 0 1 1	20	1 0 0 1 1
5	0 0 1 0 0	21	1 0 1 0 0
6	0 0 1 0 1	22	1 0 1 0 1
7	0 0 1 1 0	23	1 0 1 1 0
8	0 0 1 1 1	24	1 0 1 1 1
9	0 1 0 0 0	25	1 1 0 0 0
10	0 1 0 0 1	26	1 1 0 0 1
11	0 1 0 1 0	27	1 1 0 1 0
12	0 1 0 1 1	28	1 1 0 1 1
13	0 1 1 0 0	29	1 1 1 0 0
14	0 1 1 0 1	30	1 1 1 0 1
15	0 1 1 1 0	31	1 1 1 1 0
16	0 1 1 1 1	32	1 1 1 1 1

Channels 17-32 in single-ended mode only

Temperature Sensing Circuity for Thermocouple Cold Junction Compensation

The TMX32 has an on-board temperature sensor which provides an output voltage representing the board's ambient temperature that can be routed to channel 8 or 16 on the A/D converter board for use in cold junction compensation and linearization through software of thermocouple measurements. Up to two cold junction compensation channels are supported by the TMX32, regardless of how many TMX32 boards are daisy chained. If you require more channels for thermocouples, it is recommended that you use a TS16 Thermocouple Sensor Board which accepts up to 16 J or K type thermocouples and can be used in a system with the TMX32.

To then estimate the temperature when the thermocouple output voltage is known, the following polynomial can be used:

$$T = a_0 + a_1V + a_2V^2 + ... + a_nV^n$$

Where T = temperature in °C, V = the thermocouple output voltage in millivolts, and a_n = the constants from the table below:

	Copper-Constantan Type T	Chromel-Constantan Type E	Iron-Constantan Type J	Chromel-Alumel Type K	Platinum-Pt (10% Rh) Type S
a_0	0.100860910	0.104967248	-0.048868252	0.226584602	0.927763167
a_1	25727.94369	17189.45282	19873.14503	24152.10900	169526.5150
a_2	-767345.8295	-282639.0850	-218614.5353	67233.42488	-31568363.94
a_3	78025595.81	12695339.5	11569199.78	2210340.682	8990730663
a_4	-9247486589	-448703084.6	-264917531.4	-860963914.9	-1.63565×10^{12}
a_5	6.97688×10^{11}	1.10866×10^{10}	2018441314	4.83506×10^{10}	1.88027×10^{14}
a_6	-2.66192×10^{13}	-1.76807×10^{11}		-1.18452×10^{12}	-1.37241×10^{16}
a_7	3.94078×10^{14}	1.71842×10^{12}		1.38690×10^{13}	6.17501×10^{17}
a_8		-9.19278×10^{13}		-6.33708×10^{13}	-1.56105×10^{19}
a_9		2.06132×10^{13}		-6.33708×10^{13}	1.69535×10^{20}

To convert the output (cold junction) voltage measured by the TMX32's temperature sensor to the cold junction temperature in degrees Centigrade, use the following formula:

Cold Junction Voltage / 10mV = Cold Junction Temperature (°C)

After finding the thermocouple temperature and the cold junction temperature in degrees Centigrade, add the thermocouple temperature to the cold junction temperature to determine the true temperature being measured.

Table 3-2 on the next page shows the ideal output voltages for some common thermocouples at selected temperatures.

Table 3-2 Output Voltage vs. Temperature (in mV) for Common Thermocouples					
Temperature (¡C)	Copper-Constantan (Type T)	Chromel-Constantan (Type E)	Iron-Constantan (Type J)	Chromel-Alumel (Type K)	Platinum-Pt (10% Rh) Type S)
-260	-6.232	-9.797			
-240	-6.105	-9.604			
-220	-5.889	-9.274			
-200	-5.603	-8.824	-7.890	-5.891	
-180	-5.261	-8.273	-7.402	-5.550	
-160	-4.865	-7.631	-6.821	-5.141	
-140	-4.419	-6.907	-6.159	-4.669	
-120	-3.923	-6.107	-5.426	-4.138	
-100	-3.378	-5.237	-4.632	-3.553	
-80	-2.788	-4.301	-3.785	-2.920	
-60	-2.152	-3.306	-2.892	-2.243	
-40	-1.475	-2.254	-1.960	-1.527	
-20	-0.757	-1.151	-0.995	-0.777	
0	0.000	0.000	0.000	0.000	0.000
20	0.789	1.192	1.019	0.798	0.111
40	1.611	2.419	2.058	1.611	0.232
60	2.467	3.683	3.115	2.436	0.363
80	3.357	4.983	4.186	3.266	0.501
100	4.277	6.317	5.268	4.095	0.647
120	5.227	7.683	6.359	4.919	0.800
140	6.204	9.078	7.457	5.733	0.959
160	7.207	10.501	8.560	6.539	1.124
180	8.235	11.949	9.667	7.338	1.294
200	9.286	13.419	10.777	8.137	1.468
250	12.011	17.178	13.553	10.151	1.923
300	14.860	21.033	16.325	12.207	2.400
350	17.816	24.961	19.089	14.292	2.896
400	20.869	28.943	21.846	16.395	3.407
450		32.960	24.607	18.513	3.933
500		36.999	27.388	20.640	4.471
600		45.085	33.096	24.902	5.582
700		53.110	39.130	28.128	6.741
800		61.022		33.277	7.949
900				37.325	9.203
1000				41.269	10.503
1100				45.108	11.846
1200				48.282	13.224
1300				52.398	14.624
1400					16.035
1500					17.445
1600					18.842
1700					20.215

Reducing the Noise on Your Analog Inputs

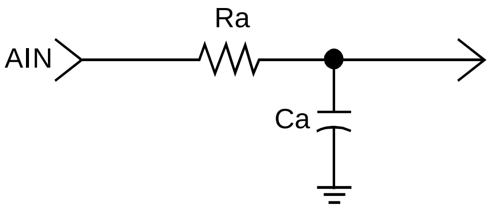
Because the TMX32 board is used externally and can be positioned almost anywhere in your data acquisition environment, it is susceptible to noise coupling. Therefore, you may want to use some noise reduction techniques to ensure accurate conversion results. Note that for very low voltage measurements, it is recommended that you place the TMX32 as close to the sensor as possible.

Input Signal Conditioning

The TMX32 has a series of resistor and capacitor pads on the printed circuit board for each analog input. You can install custom conditioning circuitry, such as low-pass filters, attenuators, current shunts, and other circuitry, in these pads. This section shows you how to develop these circuits and the formulas for calculating resistance and capacitance values.

• Low-Pass Filter, Single-Ended Inputs

A low-pass filter on your single-ended inputs can reduce noise by filtering out harmonics and other undesirable frequency components. Figure 3-2 shows you how to build this circuit. The table included in Figure 3-2 shows you where to install the components Ra and Ca on the board for each channel.



Formula: Frequency = 1/[2pRaCa]

Example: Ra = 10KW
Ca = 1000 pF

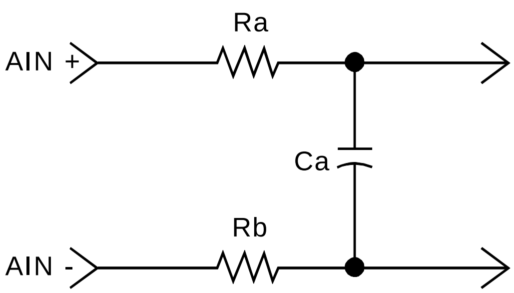
Frequency = 1/2p[(10 x 10^{3}) x (1000 x 10^{-12})]
Frequency = 15.915 kHz

Channel	Ra	Ca	Channel	Ra	Ca
1	R1	R\C1	17	R17	R\C17
2	R2	R\C2	18	R18	R\C18
3	R3	R\C3	19	R19	R\C19
4	R4	R\C4	20	R20	R\C20
5	R5	R\C5	21	R21	R\C21
6	R6	R\C6	22	R22	R\C22
7	R7	R\C7	23	R23	R\C23
8	R8	R\C8	24	R24	R\C24
9	R9	R\C9	25	R25	R\C25
10	R10	R\C10	26	R26	R\C26
11	R11	R\C11	27	R27	R\C27
12	R12	R\C12	28	R28	R\C28
13	R13	R\C13	29	R29	R\C29
14	R14	R\C14	30	R30	R\C30
15	R15	R\C15	31	R31	R\C31
16	R16	R\C16	32	R32	R\C32

Fig. 3-2 — Single-Ended Low-Pass Filtering

• Low-Pass Filter, Differential Inputs

A low-pass filter on your differential inputs can reduce noise by filtering out harmonics and other undesirable frequency components. Figure 3-3 shows you how to build this circuit. The table included in Figure 3-3 shows you where to install the components Ra, Rb, and Ca on the board for each channel.



Formula: Frequency = 1/[2p(Ra+Rb)Ca]

Example: Ra = 10KW
Rb = 10KW
Ca = 1000 pF

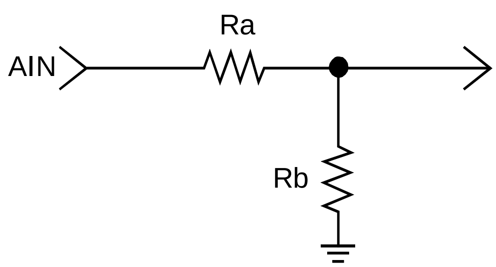
Frequency = 1/2p[(10 x 10^{3} + 10 x 10^{3}) x (1000 x 10^{-12})]
Frequency = 7.958 kHz

Channel	Ra	Rb	Ca
1	R1	R17	R\C33
2	R2	R18	R\C34
3	R3	R19	R\C35
4	R4	R20	R\C36
5	R5	R21	R\C37
6	R6	R22	R\C38
7	R7	R23	R\C39
8	R8	R24	R\C40
9	R9	R25	R\C41
10	R10	R26	R\C42
11	R11	R27	R\C43
12	R12	R28	R\C44
13	R13	R29	R\C45
14	R14	R30	R\C46
15	R15	R31	R\C47
16	R16	R32	R\C48

Fig. 3-3 — Differential Low-Pass Filtering

• Attenuator, Single-Ended Inputs

An attenuator or voltage divider can be used to reduce the voltage level of the incoming signal so that it falls within the analog input voltage range of your A/D converter board. Figure 3-4 shows you how to build this circuit. The table included in Figure 3-4 shows you where to install the components Ra and Rb on the board for each channel.



Formula: Vout = Vin[Rb/Ra+Rb]

Example: Ra = 10KW
Rb = 20KW
Vin = 3V

Vout = $3[(20 \times 10^3)/(10 \times 10^3) + (20 \times 10^3)]$
Vout = 2V

Channel	Ra	Rb	Channel	Ra	Rb
1	R1	R\C1	17	R17	R\C17
2	R2	R\C2	18	R18	R\C18
3	R3	R\C3	19	R19	R\C19
4	R4	R\C4	20	R20	R\C20
5	R5	R\C5	21	R21	R\C21
6	R6	R\C6	22	R22	R\C22
7	R7	R\C7	23	R23	R\C23
8	R8	R\C8	24	R24	R\C24
9	R9	R\C9	25	R25	R\C25
10	R10	R\C10	26	R26	R\C26
11	R11	R\C11	27	R27	R\C27
12	R12	R\C12	28	R28	R\C28
13	R13	R\C13	29	R29	R\C29
14	R14	R\C14	30	R30	R\C30
15	R15	R\C15	31	R31	R\C31
16	R16	R\C16	32	R32	R\C32

Fig. 3-4 — Single-Ended Attenuator

• Current Shunt, Differential Inputs

When your signal source provides an input current instead of a voltage, a current shunt is used to convert the input current into a voltage. Figure 3-5 shows you how to build this circuit. The table included in Figure 3-5 shows you where to install Ra on the board for each channel.

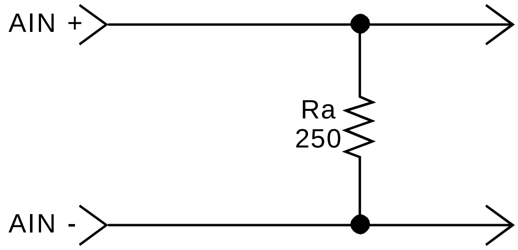
• Grounding the Negative Input, Differential Inputs

When your signal source does not have a separate ground reference, you must ground the IN- input through a 10 kilohm resistor. Figure 3-6 shows you how to build this circuit. The table included in Figure 3-6 shows you where to install Ra on the board for each channel.

Other Noise Reduction Techniques

Some more tips on noise reduction:

- When connecting to an A/D converter board with differential capability, set the board up for differential operation on your TMX32 channel even if you are using the TMX32 in the single-ended mode.
- Install filters.
- Average the readings you take in software.



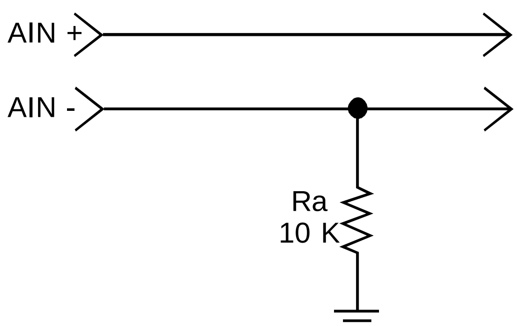
Channel	Ra
1	R\C33
2	R\C34
3	R\C35
4	R\C36
5	R\C37
6	R\C38
7	R\C39
8	R\C40
9	R\C41
10	R\C42
11	R\C43
12	R\C44
13	R\C45
14	R\C46
15	R\C47
16	R\C48

Formula: Vout = [Input Current x 250W]

Example: Input Current = 13 mA

Vout = $(13 \times 10^{-3}) \times 250$
Vout = 3.25V

Fig. 3-5 — Differential Current Shunt



Channel	Ra
1	R33
2	R34
3	R35
4	R36
5	R37
6	R38
7	R39
8	R40
9	R41
10	R42
11	R43
12	R44
13	R45
14	R46
15	R47
16	R48

Fig. 3-6 — Differential IN- Grounding

APPENDIX A

TMX32 SPECIFICATIONS

TMX32 Characteristics Typical @ 25° C

Multiplexer HI506

Number of channels	32 single-ended, 16 differential
Input impedance	10 MW
Gains, software -selectable	1, 10, 100, 1000
Gain error (gain < 1000)	0.05%, typ, 0.25% max
Gain error (gain = 1000)	0.1%, typ, 1.0% max
Overvoltage protection	±35 Vdc
Common mode input voltage	±10 volts
Analog output range	±10 volts, max
Non-linearity	0.012%, max

Temperature Sensor

Temperature range	-55 to +125°C
Accuracy over temperature	±2°C
Temperature coefficient	10mV/°C
Output at 25°C	250 mV

Current/Power Requirements

+5 volts	70 mA
Power consumption	350 mW

Connectors

Two 50-pin shrouded headers with ejector tabs

Size

6.875"L x 5.0"W (175mm x 127mm)

APPENDIX B

TMX32 50-PIN I/O CONNECTOR PINOUT

TMX32 Pinout:

CHANNEL 1	1	2	CHANNEL 9 / (GND 1)
CHANNEL 2	3	4	CHANNEL 10 / (GND 2)
CHANNEL 3	5	6	CHANNEL 11 / (GND 3)
CHANNEL 4	7	8	CHANNEL 12 / (GND 4)
CHANNEL 5	9	10	CHANNEL 13 / (GND 5)
CHANNEL 6	11	12	CHANNEL 14 / (GND 6)
CHANNEL 7	13	14	CHANNEL 15 / (GND 7)
CHANNEL 8	15	16	CHANNEL 16 / (GND 8)
DAC1 IN	17	18	ANALOG GND
DAC2 IN	19	20	ANALOG GND
ANALOG GND	21	22	ANALOG GND
	23	24	
	25	26	DIN 6
	27	28	DIN 5
	29	30	DIN 4
	31	32	DIN 3
	33	34	DIN 2
	35	36	DIN 1
	37	38	DIN 0
	39	40	
	41	42	
	43	44	
	45	46	
+12 VOLTS	47	48	+5 VOLTS
-12 VOLTS	49	50	DIGITAL GND

APPENDIX C

MX32 CONFIGURATION

The TMX32 is a direct replacement of the MX32 analog input expansion board. For those ordering an MX32 board, the TMX32 is sent with the following modifications.

Gain Amplifier

The gain amplifier is changed from a 1, 10, 100, or 1000 amplifier to a 1, 2, 4, and 8 gain amplifier. The settings for the gains and corresponding jumpers on P5, G0 and G1, are shown in the table below.

Gain	G0	G1
x1	ON	ON
x2	OFF	ON
x4	ON	OFF
x8	OFF	OFF

When the jumpers on P5 are placed across the SPG pins, the gains can be programmed on DIN5 and DIN6 as shown in the table below.

Programmable Gain Digital Lines		
Gain	**DIN6**	**DIN5**
1	0	0
2	0	1
4	1	0
8	1	1

Offset Voltage Circuitry

The offset voltage circuitry, using the on-board trimpot TR1 or the output of DAC1 or DAC2 as described in this manual, is active on the MX32 configured board.

APPENDIX D

WARRANTY

LIMITED WARRANTY

Real Time Devices, Inc. warrants the hardware and software products it manufactures and produces to be free from defects in materials and workmanship for one year following the date of shipment from REAL TIME DEVICES. This warranty is limited to the original purchaser of product and is not transferable.

During the one year warranty period, REAL TIME DEVICES will repair or replace, at its option, any defective products or parts at no additional charge, provided that the product is returned, shipping prepaid, to REAL TIME DEVICES. All replaced parts and products become the property of REAL TIME DEVICES. **Before returning any product for repair, customers are required to contact the factory for an RMA number.**

THIS LIMITED WARRANTY DOES NOT EXTEND TO ANY PRODUCTS WHICH HAVE BEEN DAMAGED AS A RESULT OF ACCIDENT, MISUSE, ABUSE (such as: use of incorrect input voltages, improper or insufficient ventilation, failure to follow the operating instructions that are provided by REAL TIME DEVICES, "acts of God" or other contingencies beyond the control of REAL TIME DEVICES), OR AS A RESULT OF SERVICE OR MODIFICATION BY ANYONE OTHER THAN REAL TIME DEVICES. EXCEPT AS EXPRESSLY SET FORTH ABOVE, NO OTHER WARRANTIES ARE EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, ANY IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, AND REAL TIME DEVICES EXPRESSLY DISCLAIMS ALL WARRANTIES NOT STATED HEREIN. ALL IMPLIED WARRANTIES, INCLUDING IMPLIED WARRANTIES FOR MECHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, ARE LIMITED TO THE DURATION OF THIS WARRANTY. IN THE EVENT THE PRODUCT IS NOT FREE FROM DEFECTS AS WARRANTED ABOVE, THE PURCHASER'S SOLE REMEDY SHALL BE REPAIR OR REPLACEMENT AS PROVIDED ABOVE. UNDER NO CIRCUMSTANCES WILL REAL TIME DEVICES BE LIABLE TO THE PURCHASER OR ANY USER FOR ANY DAMAGES, INCLUDING ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES, EXPENSES, LOST PROFITS, LOST SAVINGS, OR OTHER DAMAGES ARISING OUT OF THE USE OR INABILITY TO USE THE PRODUCT.

SOME STATES DO NOT ALLOW THE EXCLUSION OR LIMITATION OF INCIDENTAL OR CONSEQUENTIAL DAMAGES FOR CONSUMER PRODUCTS, AND SOME STATES DO NOT ALLOW LIMITATIONS ON HOW LONG AN IMPLIED WARRANTY LASTS, SO THE ABOVE LIMITATIONS OR EXCLUSIONS MAY NOT APPLY TO YOU.

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