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ADA-AMP

INSTRUMENTATION AMPLIFIER

USER'S MANUAL

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FEATURES OF THE ADA-AMP INSTRUMENTATION AMPLIFIER

Interactive Microware's ADA-AMP (tm) instrumentation amplifier is a versatile signal conditioning accessory. ADA-AMP facilitates interfacing scientific instruments to IMI's ADALAB(tm) data acquisition/control interface for the APPLE II computer. ADA-AMP can amplify voltage input signals as low as ±5ØØ microvolts and can attenuate signals as high as ±1Ø volts. ADA-AMP's modular design allows you to equip the basic amplifier with the operational features necessary for your specific application, including programmable gain/attenuation and 8- to 16-channel differential multiplexers or 16- to 32-channel single-ended multiplexers. ADA-AMP provides a cost-effective approach to signal conditioning since it can be upgraded (at the factory) to include options not specified at the time of initial purchase. Key specifications and available options for ADA-AMP are described below.

ADA-AMP Specifications

* Allows IMI's ADALAB interface card to read full-scale voltages ranging from ±5ØØ microvolts to ±1Ø volts.

* High-quality instrumentation amplifier allows switch-selectable gains of Ø.1, 1, 1Ø and 1ØØ.

* Additional amplification is provided by an operational amplifier with variable gain from 1 to 1Ø. Thus, the overall gain is continuously adjustable from Ø.1 to 1ØØØ.

* Differential inputs offer high common mode rejection (7Ø-1ØØ dB) and high input impedance (8 megohms).

* A low-pass filter smoothes high frequency noise. The normal time constant is 1 millisecond.

* Includes 16-pin DIP sockets for input and output; both sockets are identical to ADALAB's analog cable.

* Pin terminal connections for D/A, A/D+, A/D- and ground are also provided, similar to IMI's Self-Test Adapter terminals.

* Mounted in plastic box 4-1/4" W x 7-1/2" L x 3-3/4" H.

* Optional programmable attenuation by a factor of 2, 4, 8, 16, 32, 64, 128, 256, 512 or 1Ø24, selected by ADALAB's digital output bits 4 through 7. This allows your programs to select high gain for small input voltages and low gain for large input voltages.

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* Optional solid-state multiplexer selects one of eight differential inputs or one of 16 single-ended inputs, under control of bits Ø through 3 of ADALAB's digital output. The multiplexer option includes convenient screw-terminal connections for all input signals.

* Optional expander card adds an additional eight differential inputs or 16 single-ended inputs.

ADA-AMP Options*

The basic ADA-AMP Instrumentation Amplifier includes switch selectable gains of Ø.1, 1.Ø, 1Ø and 1ØØ plus operational amplifier with variable gain from 1 to 1Ø, permitting overall gain from Ø.1 to 1ØØØ.

Option 1 : Software Programmable Gain/Attenuation Module.

Option 2A: 8-Channel Differential Multiplexer Module.

Option 2B: 16-Channel Single-Ended Multiplexer Module (Note: only one of Options 2A or 2B may be selected, although you may change from Option 2A to Options 2B, or from Option 2B to Option 2A in the field by making one modification to the printed circuit board and ordering the alternate integrated circuit from IMI for $25.)

Option 3A: 8-Channel Differential Input Expander (total of 16 channels).

Option 3B: 16-Channel Single-Ended Expander (total of 32 channels).

Option 4 : Solid-State Temperature Sensor for Cold Junction Compensation of Thermocouples, Ø to 2ØØ uV/degree C, with 6-foot cable, factory installed on input channel Ø.

Option 5 : 9-Volt Battery Power Supply for remote signal amplification. This is recommended when signal wires are longer than 5 feet. Batteries included. Operating voltage is limited to ±6 Volts. This option is not recommended when the multiplexer or programmable gain options are used, because the digital output cable would also need to be extended in this case.

Option 6 : 12" Cable (16-conductor) with DIP headers on each end for connecting ADA-AMP to ADA-MUX (1 required) or for chaining ADA-MUX modules (2 required).

*Options listed may be installed retroactively at the factory for a modest additional charge.

MAKING CONNECTIONS TO ADA-AMP

As you read this section, you should identify the various parts in the diagram on the last page of this manual or on the ADA-AMP interface module.

The ANALOG OUT socket on ADA-AMP is connected to ADALAB via the 16-conductor ANALOG cable, which carries power to ADA-AMP and also routes analog voltages to the A/D and D/A converters on ADALAB. If the multiplexer and/or programmable attenuator options have been installed on your ADA-AMP, you will also need to connect ADALAB's OUTPUT cable to the DIGITAL OUT socket on ADA-AMP. If you are using ADA-AMP with an ADA-MUX multiplexer, connect ADALAB's OUTPUT cable to the HEADER socket on ADA-MUX and also connect a short (12") cable between one of the two ANALOG sockets on ADA-MUX to the ANALOG IN socket on ADA-AMP. When making these cable connections, be sure to connect pin 1 on the socket (bevelled corner marked white) to pin 1 of the cable (marked white).

On the left side of the ANALOG IN socket, you will note two columns of four terminals labelled D (for D/A), H (for High, or A/D+), L (for LOW, or A/D-) and G (for Ground). The left-hand column of terminals is used only for the multiplexer options. As shipped, two jumpers are installed on the right-hand column to connect H to D and L to G, just like the Self-Test Adapter. This configuration is useful for testing purposes; you may output a voltage on ADALAB's D/A converter and read the amplified voltage on the A/D converter. On the right side of the ANALOG IN socket is a 1Ø Kohm potentiometer (DA GAIN), which is used as a voltage divider to attenuate the D/A output voltage. If you wish to adjust the D/A gain, you should output the full-scale D/A voltage (set D%=2Ø47: &AOØ), attach your voltmeter to pins D and G and turn the DA GAIN pot to yield the desired input voltage to the amplifier.

There are several ways to connect external voltage signals to ADA-AMP. Before connecting external signals you <u>must</u> remove the two jumpers connecting D to H and L to G. Then, you may connect your input voltage directly to the H and L terminals. Alternatively, you may insert a #22 wire in one side of a jumper and connect the other side of the jumper to a terminal pin. Another way to connect signals to ADA-AMP is via the ANALOG IN socket, which has the same pinout as ADALAB's ANALOG socket:

```
Pins 1 - 9 = Digital Ground
Pin 1Ø     = A/D+ (high)
Pin 11     = Analog Ground
Pin 12     = A/D- (low)
Pin 13     = D/A+ (high)
Pin 14     = -12 Volts
Pin 15     = +12 Volts
Pin 16     = Digital Ground
```

You may solder wires or components to the 16-pin DIP header, which is plugged into the ANALOG IN socket. (Additional headers are available from IMI).

If the 8-channel multiplexer option has been installed on your ADA-AMP, connections will be made to the screw-terminal barrier strip, where you will find the high (H) and low (L) inputs side-by-side for each channel numbered from Ø to 7. The terminal labelled DA carries the D/A output voltage, and the terminal labelled AG is analog ground. (For the 16-channel single-ended multiplexer, the low (L) terminals are used for channels Ø to 7 and the high (H) terminals are used for channels 8 to 15; all signals share a common ground which must be connected to the rightmost screw terminal labelled AG.) If you have purchased the multiplexer expander card, the remaining inputs are on the terminal strip on the piggyback board.

IMPORTANT: When using the multiplexer, BE SURE to remove the jumper connecting D to H before connecting any inputs to the screw terminals. For the differential multiplexer, turn the jumpers 9Ø degrees on both terminals H and L; this connects the multiplexer outputs to the amplifier. For the single-ended multiplexer, turn only the jumper on terminal H by 9Ø degrees and connect a jumper between terminals L and G (not turned 9Ø degrees).

CAUTION: DO NOT apply a voltage to ADA-AMP which exceeds ±12 volts; otherwise, permanent damage may result and the 9Ø-day warranty is voided. The output voltage from ADA-AMP saturates at about ±1Ø volts. Although ADALAB can only read voltages up to ±4 volts, it will not be harmed by voltages less than ±12 volts.

CALIBRATION ADJUSTMENTS OF ADA-AMP

You should always allow at least 15 minutes warmup time for the ADALAB interface card and ADA-AMP before calibrating the amplifier. First, select the primary gain of the instrumentation amplifier by turning on only one of the four GAIN switches marked 0.1, 1, 10 or 100. The gain selection switches are ON when the button is down on the side marked 0.1, 1, 10 or 100. For slide switch models, the switch is ON when the knob is closest to the number labels.

The following adjustment procedure requires a voltmeter with an input impedance of at least 1 megohm or an oscilloscope. If you do not have access to either of these, you should not change the IZ zero pot or the AZ zero pot; these pots have been pre-adjusted at the factory. Instead, you should calibrate the amplifier as described in the section entitled "CALIBRATING ADA-AMP WITHOUT A VOLTMETER".

Remove any inputs to terminals H or L (sockets, jumpers or wires) and install a jumper from H to L. Attach a voltmeter between the ground (G) terminal and the test pin marked IA near the center of the ADA-AMP interface card. Adjust the instrumentation amplifier zero pot (marked IZ) until the voltmeter reading is zero. If the programmable attenuator option is installed, next attach the voltmeter to the test pin marked AA and adjust the attenuation amplifier zero pot (marked AZ) for a zero reading on the voltmeter. Finally, attach the voltmeter to the test pin marked OA and adjust the output amplifier zero pot (marked OZ) for a zero reading.

Now, remove the jumper between H and L and apply the desired full-scale input voltage to the ADA-AMP input terminals labelled H and L. Adjust the output amplifier gain pot (marked OG) to give a voltage at test point OA that is somewhat less than the range selected by the jumpers on ADALAB (±0.5, 1, 2 or 4 Volts). An easy way to apply a voltage for calibration purposes is to use ADALAB's D/A voltage output by connecting jumpers from D to H and from L to G on ADA-AMP's input terminals. For example, to output the full-scale D/A voltage, type D%=2047: &AO0. Of course, QUICKI/O must first be initialized by RUNning QUICKSAMPLE or by BRUNning QUICKI/O. When the amplifier is set for high gain, it is necessary to adjust the D/A gain pot so that after amplification, the output voltage remains within the voltage range of ADALAB's A/D INPUT.

PROGRAMMING ADA-AMP

In its simplest configuration, without the multiplexer and programmable attenuator options, no special programming is needed. You simply attach your external voltage signal to ADA-AMP and read the amplified voltage via ADALAB's ANALOG cable in the normal way, using the &AI0 command in QUICKI/O.

The multiplexer is controlled by the least significant four bits of ADALAB's digital OUTPUT. Channels 0 to 15 are selected by setting the appropriate binary pattern in the low bits. For example, to select channel 2, you would set D%=2 and issue the &PO0 command. (If you have purchased the 32-channel single-ended expander version, digital OUTPUT bit 7 selects either channels 0 to 15 (bit 7 off) or channels 16 to 31 (bit 7 on); also, only attenuation values 0 through 7 are available.)

The programmable attenuator is controlled by the most significant four bits of ADALAB's digital OUTPUT. Attenuation factors from 2 to 1024 are calculated by multiplying 16 times a number from 0 to 9 and adding the channel number. In other words, the series of values 0, 16, 32, 48, 64, 80, 96, 112, 128, 144 will yield attenuation factors of 2, 4, 8, 16, 32, 64, 128, 256, 512, and 1024, respectively. For example, D%=16+1: &PO0 will read channel 1 with an attenuation factor of 4. Notice that as the digital OUTPUT value increases, the attenuation increases, whereas the effective gain decreases. The minimum attenuation factor is 2; therefore, the gain range of the output amplifier has been increased to allow gains from 1 to 20. Thus, the overall gain range is the same as that of ADA-AMP without the programmable gain option.

Here is a sample program that will enable you to read any channel with any desired attenuation factor. The input voltage is assumed to come from the D/A converter (jumper D to H and L to G).

```
 1 HIMEM:36095: D%=0: PRINT CHR$(4)"BRUN QUICKI/O"
 2 POKE 36273,0  (disable parallel handshake)
 3 POKE 36259,1  (enable analog handshake)
 4 INPUT "ADALAB VOLTAGE RANGE (0.5, 1, 2 OR 4) ?";FS
 5 INPUT "D/A OUTPUT (-2047:2047) ?";D%: &AO0
10 INPUT "CHANNEL # (0:15) ?";CH
20 INPUT "ATTENUATION FACTOR (0:9) ?";GN
30 D%=CH+GN*16: &PO0
40 &AI0  (throw away first reading)
50 &AI0: PRINT "READING ="D%;TAB(20)"VOLTAGE = "D%/2047*FS
60 GOTO 5
```

Note that the first reading after changing the channel or gain must be discarded because the amplifier output is inaccurate for a short time while it adjusts to the new input voltage. If your ADA-AMP does not have the multiplexer or programmable attenuator option, you should omit lines 10 or 20, respectively, and modify line 30 if necessary. To repeatedly read and print the voltage until any key is pressed, insert this line:

```
55 IF PEEK(-16384) < 128 GOTO 50
```

CALIBRATING ADA-AMP WITHOUT A VOLTMETER

If you don't have a reliable voltmeter, you should leave the IZ zero pot and the AZ zero pot in their factory-adjusted positions. However, it is easy to adjust the overall gain and offset of ADA-AMP by using ADALAB as your voltmeter and voltage source. The sample program listed under "PROGRAMMING ADA-AMP" will be used for this purpose. First, select the gain (0.1, 1, 10 or 100) of the instrumentation amplifier as described in the section called "CALIBRATION ADJUSTMENTS OF ADA-AMP." Then, RUN the sample program (including line 55, which will continuously update the readings on the screen). Enter 0 as the value for D/A OUTPUT and adjust the OZ zero pot to give a zero reading on the screen. Press the space key to continue on. Next, enter 2 as the D/A OUTPUT and turn the DA gain pot in the direction that increases the reading on the screen. Turn this pot until the reading no longer increases; this means that the D/A output voltage is now unattenuated by the DA gain pot. We can now calculate the actual voltage of the D/A, based on the voltage range of the D/A jumper on the ADALAB card. (We will assume that the A/D jumpers on ADALAB are set for the same range as the D/A jumper). For example, if the D/A jumper is set for the ±1 volt range, then the output voltage will be 1 Volt if we enter 2047 as the value of D/A OUTPUT. The final calibration step involves adjusting the OG gain pot on ADA-AMP to give an appropriate reading for a known D/A output voltage. For instance, to obtain an overall gain of 100, enter 20 as the D/A OUTPUT value and adjust the OG gain pot to yield a reading of 2000 (or 20 * 100) on the screen. This completes the calibration procedure.

If you wish to adjust the gain of the amplifier to a very high value, it is desirable to attenuate the D/A gain so that a finer gradation of D/A values may be applied to the amplifier. In order to adjust the DA gain pot, select a D/A OUTPUT value that produces an A/D reading of 2000 (as close as possible) on the screen. Then, turn the DA gain pot to reduce the reading to the desired attenuated level. For example, to divide the D/A voltage by 10, you should turn the DA gain pot until the reading on the screen is reduced from 2000 to 200 (or 2000/10).

HINTS ON REDUCING NOISE AND LOW PASS FILTERING

Unfortunately, when external signals are amplified, the noise is amplified along with the signal. Noise can cause big problems when very large gains are used. Here are some suggestions for minimizing noise:

1. Keep the signal cables from your instrument to ADA-AMP as short as possible. Cables pick up induced noise from their surroundings.

2. Avoid use of ribbon cables to carry analog signals. Twist the two signal wires around each other so that any induced noise will be the same for both wires; the instrumentation amplifier rejects noise which is equal on both the high and low signals.

3. Use a shielded two-conductor cable to carry signals from your instrument to ADA-AMP. The outer shield should be connected either to the signal ground of your instrument or to the ground terminal on ADA-AMP (the shield should be connected to one end or the other, but not to both ends).

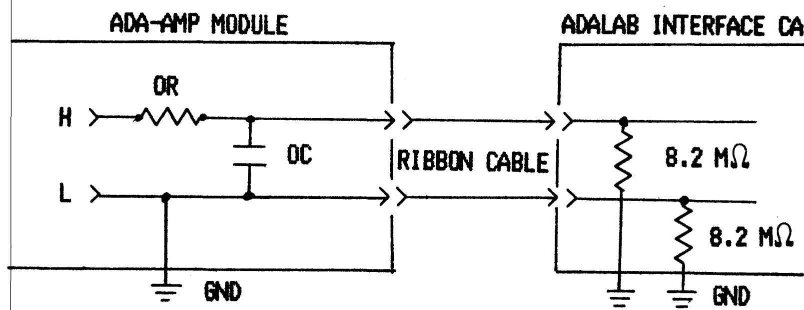
4. If your istrument has a 3-prong AC line cord, connect a wire from the chassis of your instrument to the case of the APPLE computer's power supply. This equalizes the ground potential. Another way to accomplish this is to plug your APPLE computer into the same electrical outlet that is used for your instrument.

5. The input resistance (impedance) of ADA-AMP is very high (8.2 megohm). High input resistance makes signal wires act as antennas that can readily pick up noise. If the output resistance of your instrument is lower than 1ØK ohms (as is the case for most instruments), it is desirable to decrease the input resistance of ADA-AMP. You can do this by replacing the input resistors to ground from both the H and L terminals of ADA-AMP (these are currently 8.2 megohm resistors with gray, red and green stripes, located between the GAIN switches and the AD521 chip). The appropriate value for input resistance depends entirely upon the output impedance (drive capability) of your external equipment; if the applied voltage decreases significantly when grounded through the input resistor, then you should increase the input resistance.

   A quick way to check the effect of reducing the input resistance is to connect a resistor between the H terminal of ADA-AMP and the G terminal and also from the L terminal to the G terminal. Normally, the input resistance should be at least 1Ø K ohms; some instruments may be damaged if the input resistance is too low or if their signal leads are shorted together.

6. The ADA-AMP board includes a provision for adding a low pass

filter for its output voltage. A low pass filter can reduce noise very effectively, at the expense of lengthening the response time. For example, a 20K ohm resistor in series with a 0.5 uF capacitor to ground will yield a time constant of 10 milliseconds (20E3*0.5E-6). Since ADALAB has an input resistance of 8.2 megohms to ground, the voltage reading will be attenuated by a factor of 20E3/8.2E6=2.44E-3. Of course, larger resistors will result in longer time constants and greater attenuation. A low pass filter looks like this:

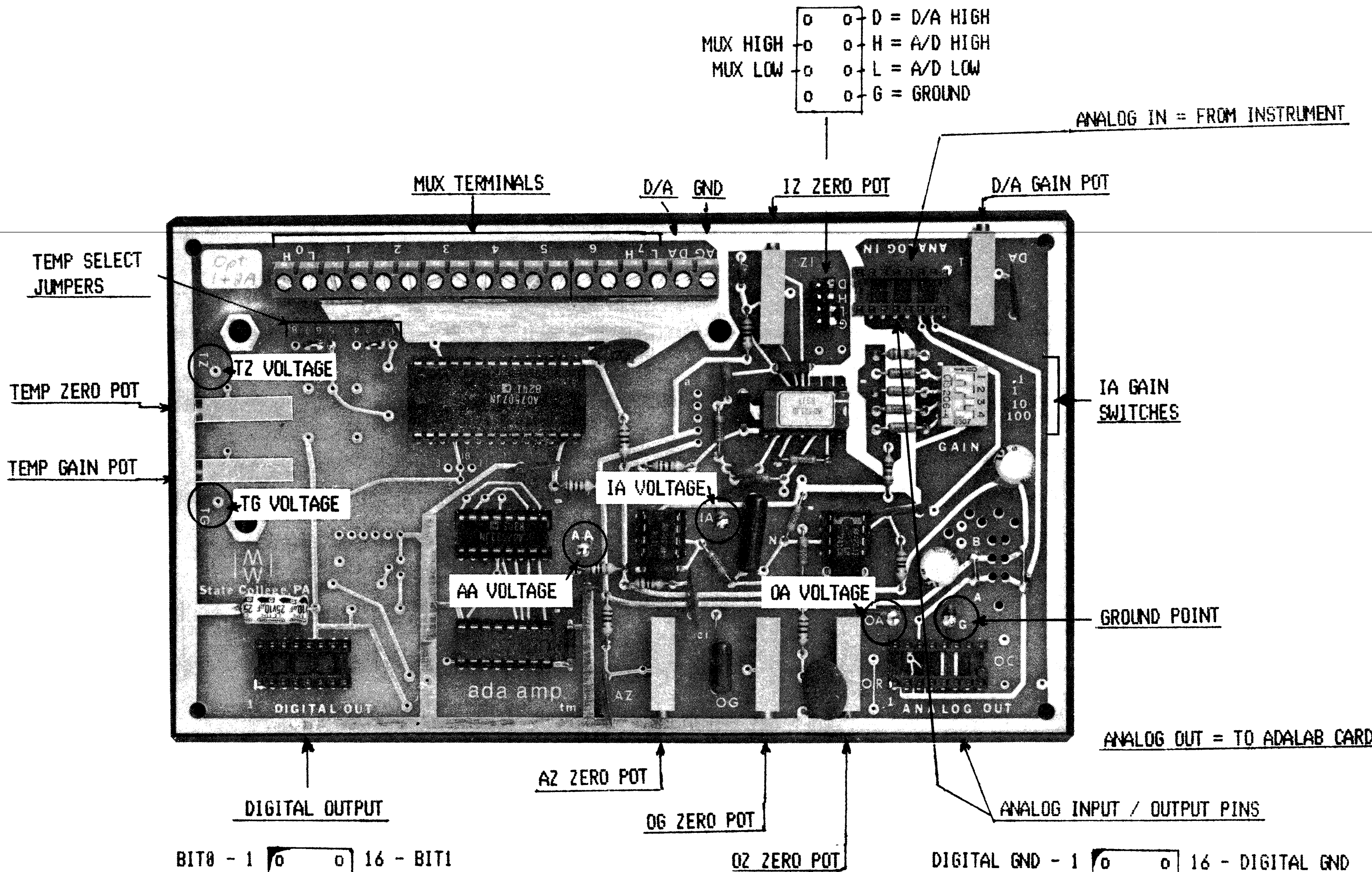


Resistor OR should be installed between the pads marked OR to the left of the ANALOG OUT socket (cut the existing trace or replace the 47 ohm resistor if present). Install capacitor OC between the pads marked OC on the other side of the ANALOG OUT socket.

7. Another approach to smoothing noisy signals is to average multiple readings. This is a practical solution when speed of response is less important than accuracy.

THE SOLID STATE TEMPERATURE SENSOR OPTION

If the solid-state temperature sensor (Option 4) has been installed on your ADA-AMP, there will be two groups of four terminal pins labelled 1 to 4 and 5 to 8. Jumpers on pins 2 to 3 and 6 to 7 will disconnect the temperature sensor from multiplexer channel Ø. To connect the temperature sensor to channel Ø, install jumpers from 1 to 2, 3 to 4, 5 to 6, and 7 to 8. See the addendum called "Notes on the Use of Solid State Temperature Sensors" and the TEMPSENSE Manual for details on calibration and use.



BIT0 - 1	o	o	16 - BIT1
BIT2 - 2	o	o	15 - BIT3
BIT4 - 3	o	o	14 - BIT5
BIT6 - 4	o	o	13 - BIT7
GND - 5	o	o	12 - +5V
GND - 6	o	o	11 - +5V
GND - 7	o	o	10 - CA1
GND - 8	o	o	9 - CA2

DIGITAL GND - 1	o	o	16 - DIGITAL GND
DIGITAL GND - 2	o	o	15 - +12V
DIGITAL GND - 3	o	o	14 - -12V
DIGITAL GND - 4	o	o	13 - D/A OUT
DIGITAL GND - 5	o	o	12 - A/D LOW INPUT
DIGITAL GND - 6	o	o	11 - ANALOG GND
DIGITAL GND - 7	o	o	10 - A/D HIGH INPUT
DIGITAL GND - 8	o	o	9 - DIGITAL GND

THE ADA-AMP BOARD WITH OPTIONS 1 AND 2A.