

# AIM9

## LVDT/RVDT Module

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This documentation describes the features, installation, and operation of the AIM9 LVDT/RVDT Module in the Series 500 or System 570. This manual also contains important programming information and several example programs.

The AIM9 is a dual-channel module for making measurements with AC-driven transducers such as LVDT's, RVDT's, and variable-reluctance transducers. Typically, linear variable differential transformers (LVDT's) measure linear displacement, while rotary variable differential transformers (RVDT's) measure angular displacement. Throughout this manual, the term "transducer" implies an LVDT, RVDT, or other AC-driven, displacement-type sensor.

The AIM9's important features include the following:

- Dual channels, each with differential input.

- A quick-disconnect terminal block for each channel. Connections include excitation output, three shield/common terminals, signal A input, and signal B input.

- Selectable excitation frequencies of 1kHz, 2kHz, 5kHz, 10kHz, or 20kHz.

- Provision for driving the excitation circuitry of up to nine AIM9 modules from the master oscillator of one AIM9.

- Selectable low-pass filter with 2Hz, 20Hz, and 200Hz bandwidths. The filter is software-selectable through the IONAME FILT% parameter.

- Continuously variable on-board gain of X1 ( $\pm 10V$  full-scale input) to X20 ( $\pm 0.5V$  full-scale input).

- Offset adjustments for zeroing the output of the AIM9 gain amplifiers.

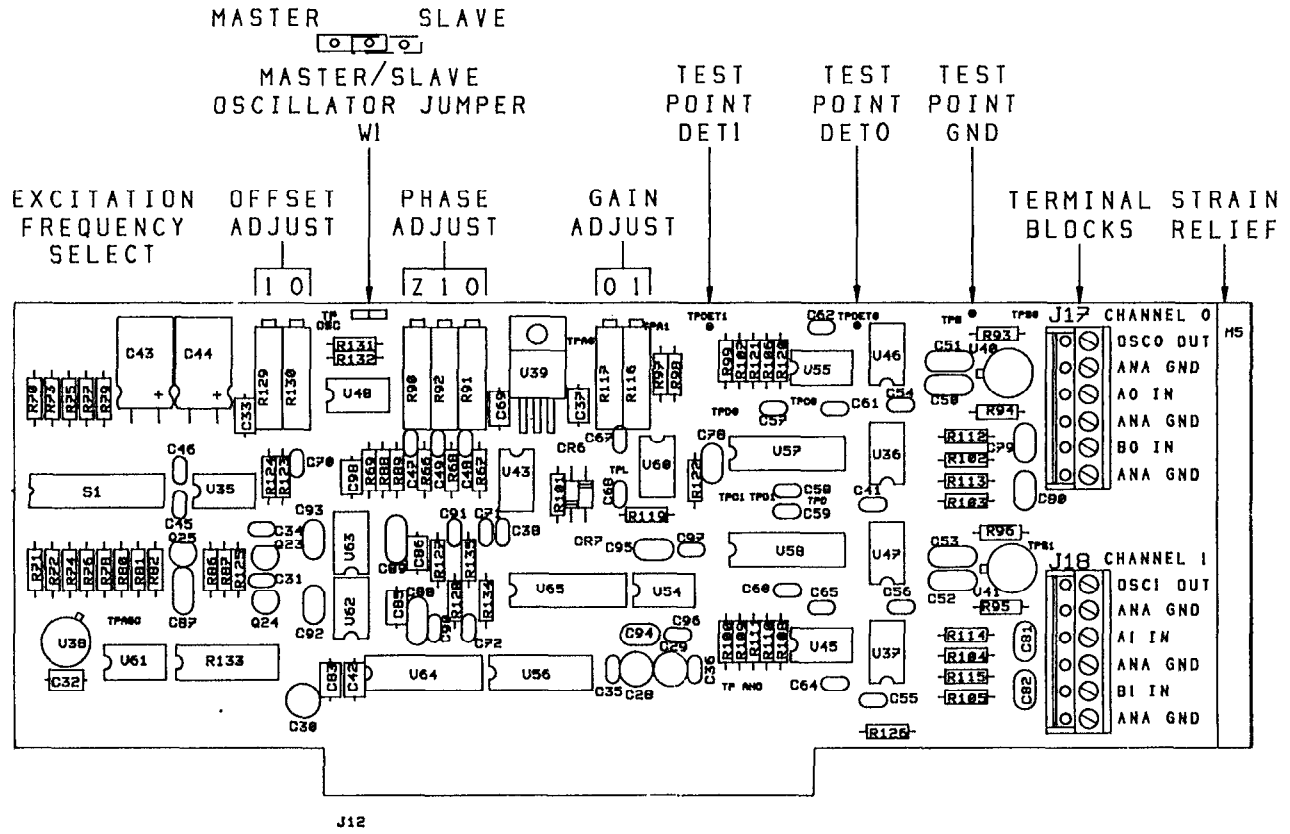
- Phase adjustment potentiometers to align the excitation and returning signals for each channel.

- Compatibility with Series 500 or System 570. The System 570 accepts one AIM9. The Series 500 can accept up to nine AIM9 modules.

The AIM9 is intended for transducers which require AC excitation and produce AC output signals. However, it is also compatible with some types of general-purpose DC-driven transducers which normally produce DC output levels. Examples are strain gages and potentiometric transducers

Figure 1 identifies the adjustment potentiometers, jumpers, switches, and important test points on the AIM9 module.

Figure 1. AIM9 Module



## Requirements for Using the AIM9

The AIM9 is hardware-compatible with Keithley's IBM-Version Series 500 and System 570 products. When used in the Series 500, the AIM9 requires a master analog input module AMM1 or AIM1 in slot 1. The AIM1 requires either an ADM1 or ADM2 A/D module in slot 2. The System 570 already contains the master analog input and A/D functions, and accepts one AIM9.

The AIM9 is programmed with Soft500 Version 4.0 or later. Soft500 runs under IBM PC Advanced BASIC (BASICA) included in IBM PC-DOS. IBM PC-DOS versions 3.1 and later are recommended for use with IBM PC, XT, and AT computers.

Compaq computers must run Soft500 under Compaq DOS 3.0 or later, with the matching BASICA version. Earlier versions of Compaq DOS and BASICA are not compatible with Soft500 V4.0 or later.

Soft500 is also compatible with many 100% IBM-compatible computers which run GW-BASIC under MS-DOS (Version 3.0 or later). Regardless of the brand or rev level of the DOS, you must use the GW-BASIC version which accompanies or is recommended for the DOS version. Mixing DOS and BASIC versions can cause problems.

The AIM9 module can also be programmed directly using BASICA's PEEK and POKE functions, or the corresponding memory read and write functions of other programming languages. This capability permits the AIM9 to be programmed outside the Soft500 environment.

## Installation

Install the AIM9 in any of the slots 2-10 of the Series 500 (slots 3-10 if the AIM1 is used). For maximum immunity to noise, install the AIM9 and any other analog input modules in the lowest-numbered available slots. The System 570 can accept one AIM9 module in its option slot. For either system, update the configuration table to show the location of the AIM9.

## User-Configured Features

The AIM9 module requires a number of settings and adjustments for best performance with a given transducer. The user-definable parameters and adjustments include frequency selection, phase correction, zero offset adjustment, and gain adjustment. A bank of DIP switches sets the excitation frequency. Potentiometers control the phase, offset, and gain adjustments.

**To get the maximum utility from the AIM9 and transducer, the two must be calibrated as a unit, and the calibration factor entered into the configuration table as part of an IONAME. Even if you do not elect to enter IONAME's in the configuration table, you must select an excitation frequency, adjust the phase potentiometers, and adjust offset.**

This manual provides programs and other information to help you derive a calibration factor for a chosen transducer. The calibration factor applies only to the transducer and AIM9 as a pair. You must repeat calibration if you change the AIM9 gain, phase adjustment, or excitation frequency. Since the transducer and AIM9 are calibrated as a pair, you must also recalibrate if you replace either the transducer or the AIM9.

Generally, an AIM9 set up involves the eight steps listed below. The list and the accompanying detailed instructions assume that the transducer is connected to channel 0. The instructions refer to various test points and adjustments. Be sure to select those test and adjustment points for channel 0. The corresponding controls for channel 1 are physically near those for channel 0 (see Figure 1).

1. Select a transducer which is suited to the application.
2. Perform the mechanical installation of the transducer on the test/calibration fixture.
3. Connect the transducer to the AIM9 channel 0 terminal block.
4. Select an excitation frequency.
5. Install the AIM9 in the data acquisition system and turn on the system. Turn the Channel 0 GAIN potentiometer fully CW (maximum gain position).
6. Monitor the detector test point DET0 with an oscilloscope. Adjust the Phase 0 and/or Phase Z potentiometers for the proper waveform.
7. Run a short Soft500 program to read the voltage output of the gain amplifier. Adjust the AIM9's offset potentiometer OS0 for an output of zero.
8. Adjust for a suitable gain with the channel 0 GAIN potentiometer.

The following paragraphs discuss these steps in greater detail.

### **Selecting and Connecting the Transducer to the AIM9**

You must select a suitable transducer for the experiment or measurement system. For more information on this topic, refer to manufacturers' catalogs and literature covering various types of transducers and applications.

An LVDT or RVDT generally has two secondary signal windings (A and B), a primary winding for excitation, and a movable core. The primary and secondary windings comprise a transformer. The amplitudes of voltages induced into windings A and B vary inversely with each other as the core is moved.

You can connect a transducer's signal windings to the AIM9 in a number of configurations. The series-opposing connection (Figure 2) allows linear measurement of the core position to either side of the center (null) position. At one extreme of the core's movement, the AIM9 output will be negative. At the other extreme, the AIM9 output will be positive. The terminals for "Winding A Ground" and "Winding B Ground" are not used for the series-opposing configuration.

TYPICAL LINEAR VARIABLE DIFFERENTIAL TRANSFORMER TRANSDUCER

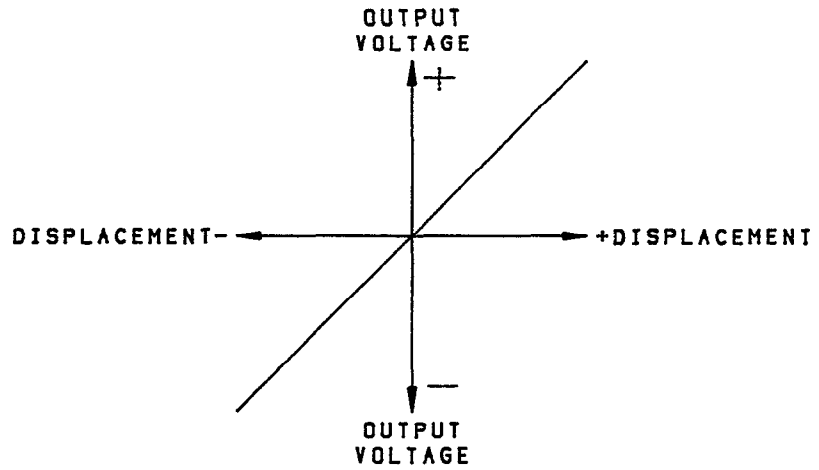
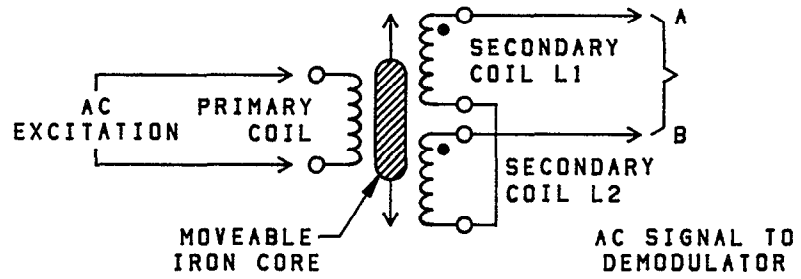


Figure 2A. LVDT Series-Opposing Connection to AIM9, with Corresponding Signal Variation

TYPICAL VARIABLE INDUCTANCE TRANSDUCER

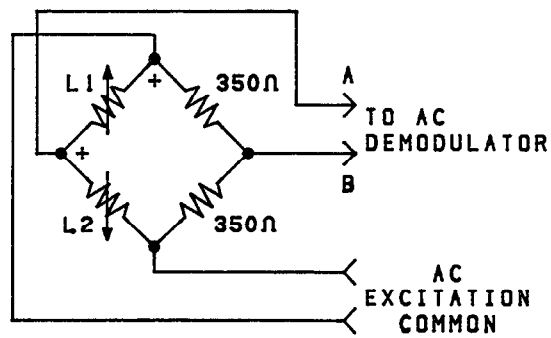
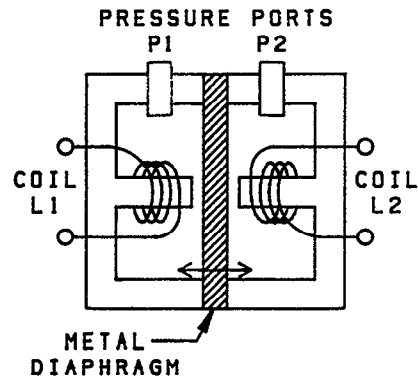


Figure 2B. LVDT Series-Opposing Connection to AIM9, with Corresponding Signal Variation

The AIM9 card has two quick-disconnect terminals, each with six screw terminals (see Figure 1). The screws make connections to each channel's oscillator (excitation) output, ground, and channel A and B inputs.

<b>Pin</b>	<b>Terminal Name</b>	<b>Transducer Connect</b>
1	Oscillator Out	Primary
2	Ground	Primary Ground
3	Signal A Input	Secondary Winding A
4	Ground	Winding A Ground
5	Signal B Input	Secondary Winding B
6	Ground	Winding B Ground

To connect wires to a terminal block, first loosen the screws several turns. Strip ¼" of insulation from a wire lead, insert the lead in the receptacle beneath the screw, and tighten the screw.

To make the task of connecting the leads easier, you can remove a terminal block by pulling it off the board in a perpendicular direction with a firm, even pressure. Do not pry the terminal blocks off with a screwdriver or other sharp tools or you may damage the circuit board. After you have connected the wires to the terminal block, reinstall the block on the AIM9.

### **Selecting the Excitation Frequency**

The AIM9 uses a Wein-bridge oscillator for AC excitation of both channels. The single oscillator feeds an adjustable phase shift network and buffer amplifier for each channel. The oscillator also feeds a third adjustable phase shift network which produces the "Phase Z" signal.

The Phase 0 and Phase 1 potentiometers adjust for any phase difference between the oscillator and signal returning from the transducer. The Phase Z potentiometer adjusts for proper phase relationship between the oscillator and detector.

The module design produces a non-adjustable excitation amplitude of 5V RMS nominal. Oscillator drive buffers boost the excitation drive current to 100mA.

Individual DIP switches on the AIM9 select oscillator frequencies of 1kHz, 2kHz, 5kHz, 10kHz, or 20kHz. Turn on only one frequency select switch at a time. Turning on more than one frequency select switch will produce a non-standard frequency. See Figure 1 for the location of the frequency switches.

The choice of excitation frequency depends on the application, type of transducer, and other factors. The transducer manufacturer may recommend a particular excitation frequency to minimize phase shift or other undesirable effects in the transducer. The phase controls for channel 0, 1, and Phase Z can compensate for constant phase shifts in the transducer.

Where the transducer measures simple displacements of an otherwise static element, there is no implicit advantage to using any given frequency. Unless the transducer manufacturer recommends a specific frequency, set the AIM9 for 5kHz.

Measuring the displacement of a vibrating element requires a careful evaluation of the vibration frequency, type of vibration, filter, and sampling rate. Generally, the excitation frequency should be at least ten times the vibration frequency of the element being monitored with the transducer.

### **Driving Multiple AIM9's From One Master Oscillator**

If you operate more than one AIM9 in a Series 500, you may need to drive all AIM9 excitation circuits from the oscillator of one AIM9. This will assure that the excitation delivered to all transducers is at precisely the same frequency.

The AIM9 has a single jumper for setting the oscillator in either master or slave mode (see Figure 1). With the jumper in the master position, the AIM9's oscillator drives its own excitation circuitry and a common daisy-chain line in the Series 500 bus. Placing the jumper in the slave position disconnects the AIM9's oscillator from the phase shift and buffer circuits, and connects this excitation circuitry to the daisy-chain line in the baseboard.

To operate several AIM9 modules from one oscillator, first refer to Figure 1. For the master AIM9, install the jumper block on the center and left-most pins of W1. To make an AIM9 a slave, install the jumper block on the center and right-most pins of W1. The daisy-chain line in the Series 500 baseboard bus automatically makes the proper connections between the master and slave AIM9's when these modules are plugged into the Series 500.

### **Adjusting the Phase 0, Phase 1, and Phase Z Potentiometers**

The phase adjustments permit the relative phases of the channel 0 and channel 1 return signals to be aligned with each other and Phase Z. The Phase 0 and Phase 1 potentiometers control the phase of the excitation for channel 0 and channel 1 relative to the oscillator. The Phase Z potentiometer controls the phase shift of a third oscillator signal used by the AIM9 demodulator (detector). The phase potentiometers give an adjustment range of approximately 170° at the 1kHz excitation frequency.

The need for phase adjustments becomes clearer if one considers a simple LVDT measurement. In practice, the AIM9 excites the transducer which returns AC waveforms to the AIM9 "A" and "B" inputs. The amplitudes of these waveforms vary inversely with each other depending on the displacement of the LVDT core.

As is often the case, the return waveforms may experience some phase shift relative to the oscillator, and to Phase Z which represents the oscillator waveform. For proper decoding of the signals returning from the transducer, the phase-sensitive AIM9 detector circuit requires that the transducer signals be properly aligned relative to Phase Z. The Phase 0 and Phase Z adjustments provide for this alignment.



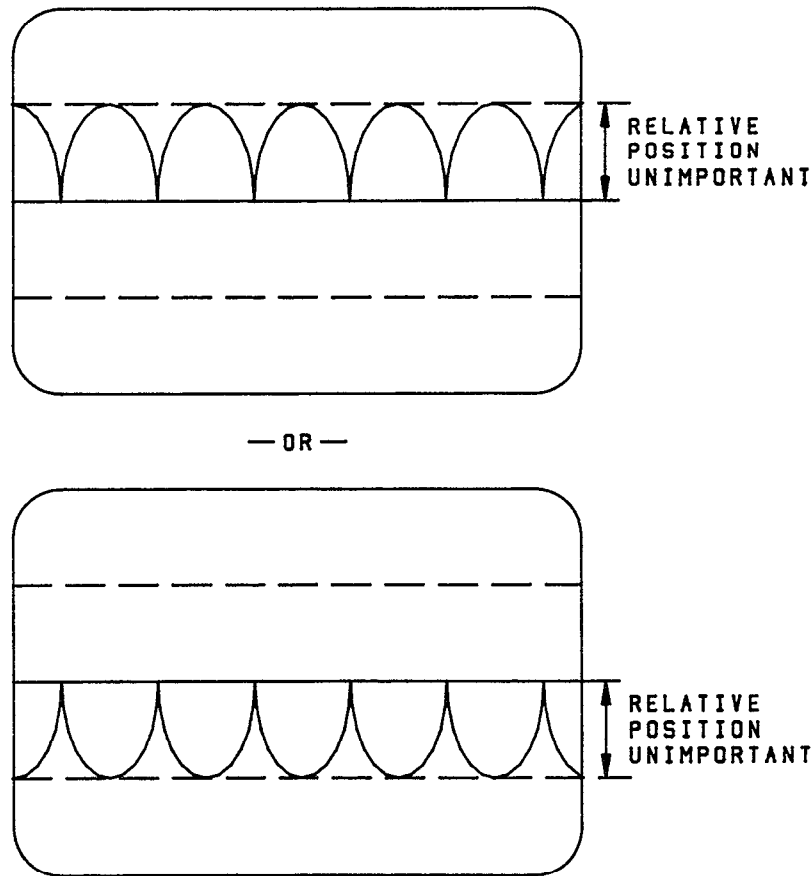
When two transducers are used, there may be a need to align the phase angles of the channel 0, channel 1, and Phase Z waveforms. The separate phase controls for each channel and Phase Z gives a broad range of adjustment between the channel 0 and channel 1 input signals and Phase Z.

You must use an oscilloscope to adjust the Phase 0, Phase 1, and Phase Z potentiometers. With the transducer connected to the AIM9, monitor the test point DET0 with the oscilloscope. The signal level at DET0 will be on the order of 50mV-150mV depending on the degree that the LVDT core is off-center electrically. If the output of a transducer is zero, the waveform will be a straight line or nearly so. If this is the case, move the transducer off electrical center to provide a workable waveform at DET0.

For channel 0, adjust the Phase Z and/or Phase 0 potentiometers to produce a waveform at DET0 resembling Figure 3. There will be an adjustment range for both potentiometers wherein either will correct an out-of-phase condition. Ultimately, you may turn one or the other potentiometer beyond the point where it has any effect, and it will no longer be possible to achieve alignment. Therefore, the adjustment may require some trial-and-error to find the best positions for each potentiometer. You may have to turn each potentiometer lock-to-lock to find its active range.

Once set, the phase potentiometers should require no further adjustment unless you change the excitation frequency or the orientation of the transducer.

For two-channel operation, first adjust Phase 0 and/or Phase Z for the proper waveform at test point DET0. Next, monitor test point DET1 and adjust Phase 1 for the proper waveform at test point DET1. You may have to readjust Phase 0 or Phase Z to find the potentiometer positions which mutually align the waveforms at DET0 and DET1.



**Figure 3. Waveform at Test Point DET0 or DET1 with Properly Adjusted Phase Controls**

### **Adjusting the Offset**

The offset adjustment sets the output of the AIM9 to 0V when the mechanical and electrical "zeros" of a transducer do not coincide. In such a case, the transducer may produce a net output signal even though it is positioned at mechanical zero. The AIM9 offset potentiometers OS0 and OS1 adjust the offset for channels 0 and 1, respectively. The easiest method of adjusting offset is to use a Soft500 program to read the offset directly.

**(Perform this step only after you have connected the transducer to the AIM9 and adjusted the phase controls.)**

To read the AIM9 offset with Soft500, first make sure the transducer is at mechanical zero. Turn the gain amplifier GAIN0 potentiometer fully CW for maximum gain. Load and run the following short program. Adjust the offset potentiometer for a reading of zero volts.

```

10 cls:VA=0
20 call init
30 call ioname("offset",8,0,12,1)
40 call anread("offset",va,1)
50 locate 1,1;print va;" millivolts      "
60 goto 40

```

The program assumes an AIM9 in slot 8, with the transducer connected to channel 0. A/D accuracy is 12, and global gain is 1. The IONAME is "offset". The program returns the reading "VA" in millivolts (EUF%=1).

As written, this program can accommodate a signal input of up to 10V. After you have made a coarse adjustment of offset, increase the sensitivity of the adjustment by increasing the global gain GA% parameter (last in IONAME) to 2, 5, or 10. Repeat the offset adjustment until no further improvement can be made.

The programs later in this manual all make an initial reading of offset and use the reading to correct subsequent measurements. This technique can be used to compensate for any residual offset.

### Selecting the Filter

The AIM9 includes a 5-pole, 30dB-per-octave low-pass filter with selectable cutoff frequencies of 2Hz, 20Hz, and 200Hz. The primary function of the AIM9 filter is to remove the excitation carrier from the transducer return signal.

The best filter setting for a given application depends on a number of factors. While the 2Hz filter may often give the best results, this is not always the case.

First, the selected filter frequency should be no greater than one tenth the excitation frequency. Practically speaking, the 200Hz filter should not be used with 1kHz excitation since the ratio is only 1:5. Any other combination of AIM9 filter and excitation frequency passes the 1:10 test.

Second, the filter frequency should be higher than the frequency of the signal being investigated. For displacement readings of a non-vibrating element, the 2Hz filter would generally be preferred. Measuring the displacement of an element which itself is vibrating requires a filter setting at least five times the fundamental vibration frequency. The maximum usable filter frequency depends on the vibration frequency, type of vibration, and A/D sampling rate. Avoid sampling at too low a rate for a particular filter setting, or aliasing may result.

The IONAME FILT% parameter programs the filter. This parameter is part of the expanded IONAME command structure of Soft500 Version 4.0. The values for FILT% are 0 for 2Hz, 1 for 20Hz, and 2 for 200Hz. The 20Hz filter is the default selection. The filter function affects both channels, and cannot be disabled. However, FILT% can specify a different filter frequency for each channel.

Consult the Soft500 IONAME documentation for information on specifying parameters. Note that beginning with Soft500 Version 4.0, you can specify IONAME's as part of the software and hardware configuration process.

### Setting the Gain

Each channel of the AIM9 module contains a gain buffer stage which amplifies the signal immediately before it is multiplexed to the Series 500 or System 570 bus. Each gain amplifier has a gain potentiometer which provides a continuous adjustment from  $\times 1$  to  $\times 20$ . These gains correspond to a full-scale voltage input range for the AIM9 of  $\pm 10V$  to  $\pm 0.5V$ .

The best setting of the gain potentiometer gives a full-scale output at AIM9 test point A0 (A1 for channel 1) that fits the A/D input range. The global gain GA% also influences the setting for the AIM9 gain adjustment. Global gain sets the maximum input signal that the master analog input module (AIM1 or AMM1) can handle.

As an example, the range of voltages from an LVDT might span  $\pm 150mV$ . By setting the gain potentiometer for progressively higher gains, the AIM9 gain amplifier could boost the voltage at test point A0 anywhere from  $\pm 150mV$  up to  $\pm 3V$  (see Figure 4).

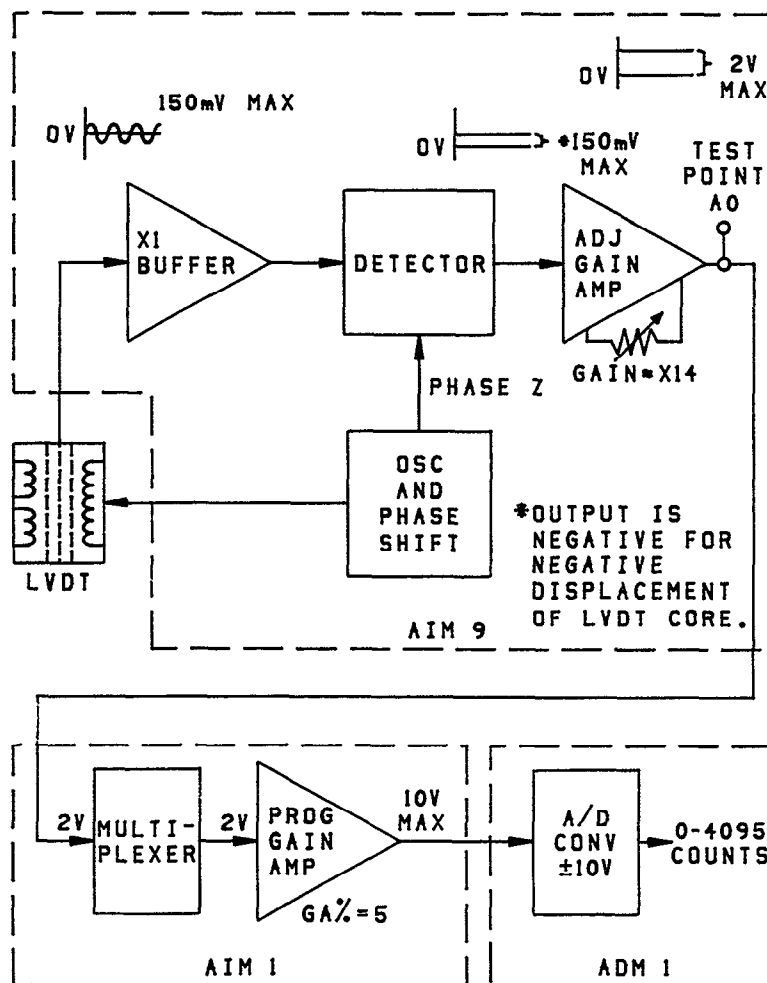


Figure 4. Effect of Gain, Global Gain, and A/D Range in the AIM9

With the factory-default A/D range, the maximum signal that the A/D converter can accept from the master analog input module (AIM1 or AMM1) is  $\pm 10V$ . A global gain (GA% of 5 would give the AMM1 or AIM1 an input sensitivity of  $\pm 2V$  for  $\pm 10V$  full-scale output. To match this input range, the signal at AIM9 test point A0 should not exceed  $\pm 2.0V$  with maximum transducer displacement. An AIM9 gain adjustment of approximately  $\times 14$  gives a  $\pm 2V$  signal at A0. If the GA% parameter were programmed to  $\times 10$ , the maximum voltage permissible from the AIM9 would be  $\pm 1V$ .

In practice, the AIM9 gain is adjusted for a desired output voltage at A0 without regard for the absolute gain factor which results. The test program included in the section on calibration factors will aid you in adjusting the gain potentiometer.

## Software Considerations

Beginning with Version 4.0, Soft500's IONAME command gives full control of all AIM9 operating parameters. The format of IONAME when programmed specifically for the AIM9 is as follows:

```
CALL IONAME'( ION$, SLOT%, CHAN%, ACC% [,GA%][,FILT%] )
```

The IONAME command specifies global gain GA% for a given slot and channel. The AIM1 or AMM1 programmable gain amplifier applies the global gain to the signal before the signal is digitized by the A/D converter module.

The FILT% parameter selects the 2Hz, 20Hz, or 200Hz filters. The values for FILT% are 0 for 2Hz, 1 for 20Hz, and 2 for 200Hz. The 20Hz filter is the default filter. If you do not program FILT% specifically, IONAME assumes the default value of 1. The filter function affects both channels, and can not be disabled. However, FILT% can specify different filter frequencies for different channels.

### Entering a Calibration Factor into the Configuration Table

Soft500 V4.0 and later versions can accept a transducer calibration factor as part of an IONAME. For an LVDT, this factor is usually expressed as:

millivolts signal / volt excitation / units of displacement

(150mV / V / 1 cm, for example)

For other Series 500 modules, entering an IONAME and calibration factor into the configuration table is not mandatory, although it does simplify the test programs and the unit conversion process.

For the AIM9, automatic conversion of voltages to measured units requires that you set up IONAME's in the configuration table. The IONAME for a channel must contain the calibration factor for the transducer connected to that channel. This practice enables you to use the Engineering Unit Flag 80 in ANREAD or ARGETVAL commands. EUF%=80 will return displacement readings directly in the measured units of the calibration factor.

## Calibrating an AIM9 and Transducer

Normally, LVDT and RVDT transducers do not include a precise calibration factor. Excitation amplitude, frequency and waveform, hardware gain, and other variables make only nominal calibration factors possible.

You can derive an accurate calibration factor for a transducer by using a displacement calibration standard (micrometer) and a few simple calibration procedures. The following example program calibrates an LVDT. Calibration of an RVDT would be similar, except that the calibration would be angular, rather than linear displacement.

Before you proceed with this program, connect the transducer to the AIM9's channel 0 terminals. Make sure the AIM9 is set to the excitation frequency suggested for the transducer. If a specific frequency is not suggested by the manufacturer, set the AIM9 for 5kHz.

The program assumes that the AIM9 is in slot 8, with transducer connected to channel 0. Twelve-bit A/D is specified. This program also produces an optimum setting for the GAIN0 potentiometer. This setting fits the full-scale displacement of the LVDT to the selected global gain and A/D range of the system. Before you run the program, turn the GAIN potentiometer for channel 0 fully CW to select maximum gain. This will aid in setting the offset.

```
10 KEY OFF
20 CLS:LOCATE 3,5:PRINT" PROGRAM WHICH GENERATES A CALIBRATION
   FACTOR FOR AN LVDT"
30 LOCATE 10,5:INPUT"What is the desired global gain (1, 2, 5, or 10)";GA%
40 LOCATE 12,5:INPUT"What is the calibrating displacement (number only)";D
50 LOCATE 14,5:INPUT"What are the units of measure (in, cm, mm, etc.)";U$
60 LOCATE 16,5:INPUT"What is the maximum displacement you anticipate (number
   only)";MAX
70 CLS
80 ' Adjust phase
90 CLS
100 LOCATE 1,1:PRINT"Connect the input of an oscilloscope to the test point DET0 on
   the"
110 LOCATE 2,1:PRINT"AIM9. Adjust the Phase 0 and/or Phase Z potentiometers to
   get a waveform"
120 LOCATE 3,1:PRINT"resembling an unfiltered full-wave rectified sine wave (manual
   Figure 3)."
```

```
130 LOCATE 7,10:PRINT "When adjustment is completed, press any key to continue.
140 IF INKEY$=""THEN 140
150 CLS
160 VOFL=0:VOFH=0:VCAL=0
170 ' Call INIT and set up IONAME's
180 CALL INIT
190 CALL IONAME("OFFSETL",8,0,12,1,1)
200 CALL IONAME("OFFSETH",8,0,12,10,1)
210 CALL IONAME("VOLTS",8,0,12,ga%,1)
220 LOCATE 3,1:PRINT "Move the LVDT to mechanical zero."
230 LOCATE 5,1:PRINT"LOW-GAIN Adjust: Adjust the channel 0 OFFSET pot for a
   reading of 0."
240 LOCATE 9,1:PRINT "After offset is 0, press any key to continue. . ."
250 CALL ANREAD("OFFSETL",VOFL,0)
260 LOCATE 7,1:PRINT "Offset = ";VOFL;" volts          "
```

```

270 R$=INKEY$:IF R$=""THEN 250
280 LOCATE 5,1:PRINT"HIGH-GAIN Adjust: Trim the channel 0 OFFSET pot for a
      reading of 0."
290 LOCATE 9,1:PRINT "After offset is 0, press any key to continue. . ."
300 CALL ANREAD("OFFSETH",VOFH,1)
310 LOCATE 7,1:PRINT "Offset = ";VOFH;" millivolts      "
320 R$=INKEY$:IF R$=""THEN 300
330 ' Read calibrating displacement
340 CLS
350 LOCATE 1,1:PRINT:PRINT "Move the LVDT core to";D;U$;" for calibration."
360 LOCATE 3,1:PRINT "Adjust the channel 0 GAIN pot until reading equals
      ";(10000/GA%)*(D/MAX)+VOFH;" millivolts"
370 LOCATE 8,1:PRINT "Press any key when adjustment is completed."
380 CALL ANREAD("VOLTS",VCAL,1)
390 LOCATE 5,1:PRINT "Calibration voltage = ";VCAL;" millivolts      "
400 R$=INKEY$:IF R$=""THEN 380
410 CLS
420 CF = (VCAL-VOFH)/5
430 PRINT "Cal Factor = ";CF;"mV signal / V excitation ";D;U$;
440 END

```

The program initially asks for the calibration displacement and for the maximum displacement that is expected. The calibration displacement is the precise distance you will move the LVDT core during calibration. The maximum displacement is the greatest distance that the LVDT core will move during actual measurements, and may not be known precisely at this time. If you don't have a good idea of the maximum displacement, estimate on the high side and continue the calibration.

Transducer manufacturers normally specify a "full-scale" displacement for an LVDT as part of a nominal calibration factor. Such a full-scale value represents the maximum permissible displacement for the transducer. Core movement beyond the suggested full-scale displacement may give inaccurate readings, and may damage some types of transducers. For the purposes of this program, neither the calibration displacement nor the maximum expected displacement should exceed the manufacturer's suggested full-scale displacement. The calibration displacement you apply must be less than or equal to the maximum displacement you expect.

This program provides for adjustment of the phase potentiometers. As instructed, monitor the test point DET0 with an oscilloscope and adjust the Phase 0 potentiometer, Phase Z potentiometer, or both, to achieve a waveform resembling Figure 3. If the waveform appears to be a straight or slightly wavy line, first try a more sensitive input range on the oscilloscope. The signal will probably be in the range of 50mV-150mV. You can also change the displacement of the LVDT to provide a higher amplitude signal for this adjustment. Any offset of the waveform is not relevant to this adjustment.

The program prompts for an offset adjustment in two stages: a low-gain adjustment at a gain of 1, and a high-gain trim at a gain of 10. Before you adjust offset, turn the gain potentiometer fully CW (maximum gain position). During offset adjustment, you may not be able to obtain a reading of precisely 0. More often, the best that can be done is a flashing polarity sign and a reading of a few millivolts or less.

The program includes an adjustment for AIM9 gain. Unlike the global gain (GA%) parameter, the AIM9's gain is not programmable or readable through software. This ad-

justment sets the level of the signal after it has been demodulated and filtered, and before it is routed to the master analog input module. With insufficient gain, the reading may suffer in resolution and accuracy. Excessive gain will cause the input signal to saturate the AIM9 gain amp or the AIM1/AMM1 programmable gain amp. If you encounter either condition, alter the GA% parameter, or adjust the AIM9 gain potentiometer accordingly.

The ideal setting for the GAIN0 potentiometer is one where the maximum expected displacement of the transducer produces an AIM9 output equal to the input range of the AIM1 or AMM1. The calibration program automatically calculates the gain setting which matches the transducer output to the analog input range. The calculation uses your estimate of maximum displacement, and assumes that the A/D range is the factory default  $\pm 10V$ .

This program produces a calibration factor expressed as millivolts of signal per volt excitation per units of displacement. The cal factor applies only to a transducer/AIM9 calibrated pair. Its cal factor may not agree with any calibration factor suggested by the transducer manufacturer. This is because the amplification applied by the AIM9 gain amplifier is included in the calibration factor.

The program uses the nominal excitation value of 5V RMS to calculate the cal factor. The long-term stability of the excitation is more important than its precise amplitude. As such, any slight difference between the actual excitation level and the presumed 5V RMS has no practical effect on the accuracy of the cal factor.

The calibration factor must be entered into the configuration table as part of an IONAME. The CONFIG.EXE program's CHANNEL SETUP asks for the calibration factor in millivolts per volt. The cal factor can be entered to three decimal places.

After receiving the cal factor, CHANNEL SETUP asks for full-scale units. Enter the measured units of linear displacement applied to the transducer during calibration, not the maximum expected displacement or the manufacturer's suggested full-scale. The full-scale units must be entered as an integer. Therefore, only whole units of displacement should be applied for calibration.

As an example, you may have calibrated an LVDT at 5cm of displacement. The calibration program might return a cal factor of 155.2138mV / volt / 5cm. Enter "155.214" as the calibration factor, and "5" for full-scale units. Subsequent readings of unknowns using EUF%=80 will be expressed as centimeters.

After you complete the calibration program and have entered the resulting cal factor into the calibration table, run a test program and make a few measurements. Judge whether your original estimate matches the actual maximum displacement of the LVDT core. If the estimate was too high, you can rerun the calibration program with a smaller maximum displacement value based on your measurements.

**NOTE:** The calibration factor derived with this program applies only to the transducer and AIM9 which have been calibrated as a pair. Calibration must be repeated if the gain, phase, or excitation frequency are changed. Calibration must also be repeated if the transducer or AIM9 are replaced.



## AIM9 Example Programs using a CAL Factor and IONAME in the Configuration Table

The following short programs demonstrate the simplicity of reading an LVDT directly in measuring units (centimeters, in this case) once you have entered the cal factor into the configuration table. For this example, the cal factor of a hypothetical LVDT was found to be  $60.6\text{mV} / \text{V} / 1\text{cm}$  and entered into the configuration table as part of an IONAME. The IONAME includes the following other parameters: ION\$="dist", SLOT%=8, CHANNEL%=0, ACC%=12, GA%=10, and FILT%=1.

These programs assume that the gain and phase adjustments have not been altered from those settings made during initial set up and calibration of the AIM9.

The first program uses ANREAD. It reads the residual imbalance of the LVDT at mechanical zero, and provides an opportunity to trim the offset potentiometer. The program saves the final offset and uses it to correct subsequent readings of displacement. Use of EUF%=80 in the ANREAD's of offset ("OF") and signal ("VA") yields readings in centimeters. The difference between VA and OF is the corrected displacement of the LVDT core.

```
20 CLS
30 CALL INIT
40 VA=0:OF=0
50 LOCATE 1,1:PRINT"Reading offset - Adjust offset potentiometer for a reading of 0"
60 LOCATE 6,1:PRINT"Press any key to continue. . ."
70 CALL ANREAD("dist",of,80)
80 LOCATE 3,1:PRINT"Equivalent Offset = ";OF;" cm          "
90 R$=INKEY$:IF R$=""THEN 70
100 CLS
110 LOCATE 1,1:PRINT"Reading displacement - press any key to exit"
120 CALL ANREAD("dist",va,80)
130 LOCATE 3,1:PRINT "Displacement = ";VA-OF;" cm          "
140 R$=INKEY$:IF R$=""THEN 120
150 END
```

The next program uses the ANIN command to read 20 values and write them to an array. It also demonstrates how to retrieve data values from the array directly in measuring units using ARGETVAL with EUF%=80. The IONAME information for "dist" from the previous example also applies to this program.

The program first uses an ANREAD to read the offset of the LVDT at mechanical zero. The offset reading is used to correct the subsequent measurements made with the ANIN command. The EUF%=80 in the ARGETVAL statement yields readings directly in centimeters.

```
20 CLS
30 CALL INIT
40 KEY OFF:VA=0:OF=0:STAT=0
50 LOCATE 1,1:PRINT"Reading offset - Adjust offset potentiometer for a reading of 0"
60 LOCATE 6,1:PRINT"Press any key to continue. . ."
70 CALL ANREAD("dist",of,80)
80 LOCATE 3,1:PRINT"Equivalent Offset = ";OF;" cm "
90 R$=INKEY$:IF R$=""THEN 70
```

```

100 CLS
110 LOCATE 1,1:PRINT"Apply displacement - press any key to take reading"
120 R$=INKEY$:IF R$=""THEN 120
130 CALL ANIN("ary%",20,"dist",1,"done")
140 CALL INTON(100,"mil")
150 CALL STATUS("done",stat%)
160 IF STAT% < > 0 THEN 150
170 CALL INTOFF
180 CLS
190 LOCATE 1,1:PRINT "Sample ----- cm "
200 FOR T=1 TO 20
210 CALL ARGETVAL("ary%",t,"dist",va,80)
220 PRINT T,VA-OFF
230 NEXT T
240 END

```

### Calibration Directly Within a SOFT500 Program (No IONAME in the Configuration Table)

Another method is available for reading a transducer displacement directly in measurement units. It does not require that an IONAME or calibration factor be entered into the configuration table. Instead, calibration is done within the program. This type of program does not use Engineering Unit Flags, but relies on multiplying the voltage reading times a conversion factor to yield displacement.

You must apply a calibrating displacement to the transducer each time you run the program. The following example program uses a 3cm distance to calibrate an LVDT. The program assigns a variable "CON" to the calibration factor it generates. CON equals the 3cm calibration displacement divided by the number of millivolts generated at this displacement. CON is valid as a calibration factor until the program is terminated, or unless some other number is assigned to CON.

The IONAME commands have been set up for an LVDT connected to channel 0 of an AIM9 in slot 8. A/D ACC%=12, and FILT%=1 (20Hz). A gain GA% of 10 is used for offset adjustments, and a GA% of 2 is used for LVDT measurements.

The program assumes that you have already used an oscilloscope to set the phase adjustments. It also assumes that the GAIN0 control has been set to give a suitable full-scale output from the AIM9. To fine-tune this program and cal procedure to specific applications, you may need to alter the IONAME GA% parameters, the AIM9 gain, or the calibration distance.

```

20 CLS:KEY OFF
30 CALL INIT
40 CALL IONAME("offset",8,0,12,10,1)
50 CALL IONAME("calib",8,0,12,2,1)
60 VA=0:OF=0:CON=0:CAL=0
70 LOCATE 1,1:PRINT"Adjust Offset for 0 then press any key to continue"
80 CALL ANREAD("offset",of,1)
90 LOCATE 3,1:PRINT"Offset = ";OF;" millivolts          "
100 R$=INKEY$:IF R$=""THEN 80
110 CLS
120 LOCATE 1,1:PRINT"Calculating conversion factor. Apply 3cm displacement and
press any key."

```

```

130 CALL ANREAD("calib",cal,1)
140 R$=INKEY$:IF R$=""THEN 130
150 CON=3/CAL
160 CLS
170 LOCATE 1,1:PRINT"Reading displacement. Move LVDT core to desired position."
180 CALL ANREAD("calib",va,1)
190 LOCATE 3,1:PRINT (VA-OF)*CON;" cm          "
200 LOCATE 8,1:PRINT"Press spacebar to exit"
210 R$=INKEY$:IF R$=" " THEN END
220 GOTO 180
230 END

```

## Service and Calibration Information

The AIM9 module does not contain any user-serviceable components or calibration screws. Therefore, normal troubleshooting consists of simple signal checking and substitution of a known good module for a suspected module.

A module which malfunctions should be returned to Keithley for service or replacement. If you have access to a repair facility which is skilled in repair of multilayer boards, you may elect to have repairs done locally, rather than by Keithley. If so, note the following:

**NOTE:** The AIM9 module uses a multi-layer circuit board. Repair of multi-layer boards requires special care. Keithley recommends that you return the AIM9 to the factory for repair.

All components on the AIM9 are soldered in position. As a rule, you cannot replace a component soldered to a multi-layer board and guarantee the integrity of connections made through the internal board layers. Many of the traces on the AIM9 board are narrow and can be damaged by excessive heat during desoldering. A module so damaged by the user may not be repairable by Keithley. Damage through improper repair may void the warranty.

## Troubleshooting the AIM9

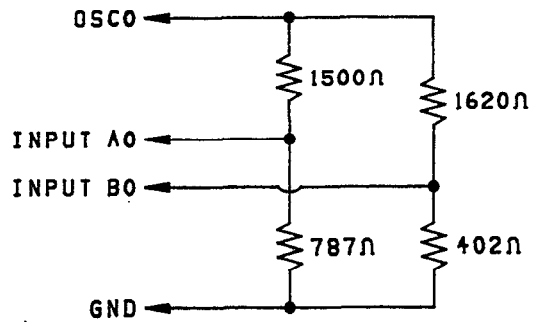
The following checks will show whether a problem exists with the AIM9 module. As a first step in troubleshooting a malfunctioning AIM9/transducer system, make sure the transducer is in good condition. An ohm meter can be used to check for continuity of the windings in an RVDT or LVDT. Other types of AC-driven transducers may not be checkable with an ohmmeter.

The AIM9 contains 16 test points. Only a few of the test points are monitored during normal set up and operation. The most-used points include DET0 and DET 1, A0 and A1, and GND. The remaining test points provide information about the operation of the various AIM9 circuits for the purpose of troubleshooting. Check these points sequentially, starting at the first stages of the AIM9, according to Table 1 and Figure 5.

Before you perform these tests, you must make a transducer simulator and connect it to the A0 and B0 inputs of the AIM9 channel 0. The simulator consists of four resistors,

connected as shown in Figure 5. Connect this simulator to the AIM9 quick-disconnect terminal block.

If all signals on the AIM9 check out correctly, the problem may lie with the transducer or elsewhere in the data acquisition system.



**Figure 5. Transducer Simulator for AIM9 Troubleshooting**

**Table 1. AIM9 Test Points, Signals, and Functions for Channel 0 (CHANNEL 1)**

Test Point	Waveform	Function
GND	0V (straight line)	Tie point to analog ground.
OSC	Sine wave with period =100 $\mu$ sec (f = 10kHz). 14.14V AC p-p.	Output of Wein Bridge oscillator. First check all frequency switches for proper operation. Then select 10kHz excitation.
AGC	0V (straight line)	Automatic Gain Control for Wein Bridge.
S0, (S1)	Sine wave with period =100 $\mu$ sec 14.14V AC p-p.	Phase-shifted and buffered output of oscillator. Turn Phase 0 (Phase 1) pot and check for phase shift.
DET0, (DET1)	Full-wave rectified, unfiltered AC. Adjust Phase 0 (Phase 1) or Phase Z if necessary proper waveform - see Figure 3. Period=100 $\mu$ sec.	Output of subtractor stage.
C0, (C1) D0, (D1)	Slightly disjointed sine-wave 3.75V AC p-p Period =100 $\mu$ sec.	Output of detector stage. Slight adjustment of Phase 0 or Phase Z will break the waveforms.
L	Square wave with rounded corners 1V p-p. Period = 100 $\mu$ sec.	Input of 1-bit A/D
D	Square wave 3.5V p-p Period =100 $\mu$ sec.	Output of 1-bit A/D
A0, (A1) with no input.	DC. Remove transducer simulator from AIM9. Check that offset adjustment pot for (+) and (1) voltage range adjustment. Set to 0V.	Output of gain amplifier
A0, (A1) with input.	DC. Replace transducer simulator. Check range of GAIN pot. Output should be adjustable to approx. -11V DC.	Output of gain amplifier
AN0	DC, same as A0 (A1). See note below.	Output of AIM9 immediately before signal is transmitted to the system bus.

NOTE: To switch A0 or A1 to output AN0, run BASICA and enter:

DEF SEG=&HCFF0 : POKE CMDA,CH

SLOT#	CMDA ADDR
2	&H82
3	84
4	86
5	88
6	8A
7	8C
8	8E
9	90
10	92

Where:

CFF0 is the base address of the system interface card. If you set the interface to reside at another base address, use that address in place of CFF0.

CMDA is the slot-dependent address of the slot where the AIM9 resides. See the Series 500 baseboard documentation for a complete list. For System 570, CMDA for the option slot is &H8E.

CH is the channel number, either 0 or 1.

Examples:

With interface at &HAFF0, a command to switch channel 1 output to the test point ANO of an AIM9 in slot 8 would be:

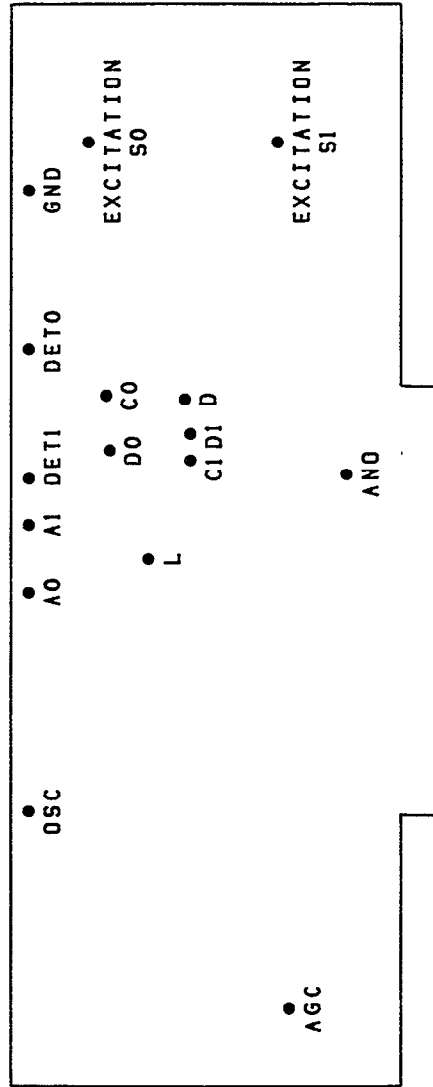
```
DEF SEG=&HAFF0 : POKE &H8E,1
```

With interface at CFF0, a command to switch channel 0 output to the test point ANO of an AIM9 in slot 5 would be:

```
DEF SEG=&HCFF0 : POKE &H88,0
```

**Table 2. Data for Peaks and Pokes to CMDA of AIM9 Slot**

<b>D3</b>	<b>D2</b>	<b>D1</b>	<b>D0</b>	<b>Data Selection</b>	<b>Function</b>
X	X	X	0	Channel 0	Channel
X	X	X	1	Channel 1	Select
0	0	X	X	Filter cutoff is 200Hz	
0	1	X	X	Filter cutoff is 20Hz	Filter
1	0	X	X	Filter cutoff is 2Hz	Frequency



**Figure 6. AIM9 Test Points**

## AIM9 Specifications

### Input Characteristics

Input Channels (local): 2 differential and balanced to ground

Gain: Adjustable per channel, 1 to 20

Input Dynamic Range:  $\pm 3.5\text{V}$  peak max without distortion

Input Protection:  $\pm 15\text{V}$  max (powered)  
 $\pm 10\text{V}$  max (unpowered)

Input Resistance:  $100\text{k}\Omega$  each input to common

Common Mode Rejection:  $60\text{dB}$  @  $60\text{Hz}$

Nonlinearity: 0.05% of full scale

Quadrature Balance Range: adjustable,  $\pm 90^\circ$

Phase Balance Range: adjustable,  $\pm 125\text{mV}$  @  $\times 1$  gain

Bandwidth: software selectable five pole filter ( $-3\text{dB}$ ), 2, 20 or  $200\text{Hz}$

Settling Time (to 0.01%):

2Hz	1000ms
20Hz	100ms
200Hz	20ms

Noise: (residual carrier with 10:1 or greater oscillator to filter ratio),  $1\text{mV}$  p-p

Temperature Coefficient:

Gain:  $200\text{ppm}/^\circ\text{C}$

Offset:  $100\text{ppm}/^\circ\text{C}$

### Excitation Characteristics:

Frequency: selectable per system, 1k, 2k, 5k, 10k or  $20\text{kHz}$  with master/slave synchronization for up to 10 modules

Frequency Accuracy:  $\pm 3\%$

Amplitude:  $5\text{V RMS}$   $\pm 10\%$

Third Harmonic Distortion: 1%

Amplitude Stability versus Load ( $100\Omega$  min): .01%

Temperature Coefficient: Frequency:  $+200\text{ppm}/^\circ\text{C}$   
Amplitude:  $40\text{ppm}/^\circ\text{C}$

Power Requirements:

+15Vdc 60mA (100mA)-No load (max loads)

-15Vdc 90mA (125mA)

+5Vdc 60mA



## AIM9 PARTS LIST

Part Number	Title	Remarks
500-480	Component Layout	
EA-135	Pen Nut	
6-32×3/32 PPH	6-32 × 3/32 Phil Pan Head	
C-237.01	Capacitor	C34
C-237.1	Capacitor	C6-C9, C14, C19, C20, C22-C24, C27, C33, C39, C46, C47-C49, C54, C57-C59
C-2371	Capacitor	C10, C11, C28, C36-C38, C40
C-314-10	Capacitor	C51, C55, C56
C-314-250	Capacitor	C1, C2
C-347-1000p	Capacitor	C12, C13, C16-C18, C31, C43
C-365-.1	Capacitor	C3-C5, C15, C50, C52, C53
C-64-47p	Capacitor	C21, C25, C26, C60, C61
C-238-.01	Capacitor	C45
C-347-8200p	Capacitor	C30, C41
C-389-.082	Capacitor	C29, C42
CS-521-5	Connector (6-pin)	J1, J2
CS-553	Connector (6-pin)	A0, A1, DET0, DET1, TPG, OSC, AGC, AN0
IC-227	Int. Circuit (TL061)	U6
IC-279	Ont. Circuit (TL062)	U19
IC-320	Int. Circuit (DG211)	U13
IC-342	Int. Circuit (LF411)	U3, U4, U7, U16, U22
IC-381	Int. Circuit (ADG200)	U21
IC-504	Int. Circuit (LF412)	U1, U10, U14, U23
IC-505	Int. Circuit (LM7905)	U2
IC-506	Int. Circuit (AM686)	U8
IC-507	Int. Circuit (LH0002)	U5, U17
IC-508	Int. Circuit (DG271)	U9, U15
IC-518	Int. Circuit (LTC1062)	U11, U12
IC-517	Int. Circuit (74LS175)	U20
R-263-100k	Resistor	R26, R27
R-176-10k	Resistor	R18-R21, R57-R60
R-263-93.1	Resistor	R66
R-76-10k	Resistor	R17, R25, R31, R56
R-76-1k	Resistor	R55
R-76-82	Resistor	R22, R34, R39, R61
R-76-75k	Resistor	R50
R-76-100k	Resistor	R23, R24
R-88-237k	Resistor	R8, R9
R-88-42k	Resistor	R52, R54
R-88-10.5k	Resistor	R32
R-88-100k	Resistor	R36, R38, R45, R63, R65
R-88-10k	Resistor	R15, R16
R-88-15.4k	Resistor	R4, R43
R-88-158k	Resistor	R1, R40
R-88-1k	Resistor	R35, R37, R62, R64
R-88-200k	Resistor	R33
R-88-20k	Resistor	R47
R-88-30.1k	Resistor	R48
R-88-30.9k	Resistor	R3, R42
R-88-43k	Resistor	R46
R-88-7.5k	Resistor	R5, R44
R-88-82.5k	Resistor	R49

### AIM9 PARTS LIST (CONT.)

Part Number	Title	Remarks
R-88-76.8k	Resistor	R2, R41
R-76-1M	Resistor	R53
R-88-3.32k	Resistor	R28-R30
RF-28	Rectifier	CR1, CR2
RP-89-10k	Potentiometer	R6, R7
RP-89-1M	Potentiometer	R10-R12
RP-89-200k	Potentiometer	R13, R14
SW-467	Switch	S1
TF-102-2	Resistor Network	R51
TG-166	Transistor (J270)	Q1
TG-84	Transistor (2N3906)	Q2, Q3
SO-83-1	Socket	
CC-38-2	Cable Clamp	
CS-339-3	Connector (3-pin-BERG)	
CS-476	Connector	W1
500-323	Clamp Assembly	
500-321	Clamp	
500-322	Strip Rubber	
	Scotch 3M #411 Tape	
500-322	Strip Rubber	
	Scotch 3M #411 Tape	
6-32×7/16 PPH	6-32 × 7/16 Phil Pan Head Screw	
500-486	Schematic	

AIM9 COMPONENT LAYOUT

