

AOM2

High-Resolution Analog Output Module

The AOM2 High-Resolution Analog Output Module is available in two versions. The AOM2/1 has one channel, while the AOM2/2 has two channels of analog output. Each channel has a separate D/A converter. Unipolar and bipolar ranges are switch-selected independently for each channel.

The converters provide true 16-bit resolution with a maximum nonlinearity of $\pm 0.0015\%$ and low temperature coefficients. The AOM2 module also supports the system strobe feature, which allows any number of output channels to be updated simultaneously.

Signal connections are made directly to screw terminals located on the module itself.

The AOM2 module may be placed in any slot in the baseboard. To install the module, first turn off power and remove the top cover. Insert the module into the desired slot with the component side facing the power supply. Place the AOM2 as far away from the power supply as possible.

CAUTION: Always turn off the power when installing or removing modules. To avoid the possibility of EMI radiation, never operate the system with the top cover removed.

User-Configured Components

Each channel of the high resolution AOM2 module has a range selection switch, optional filter capacitor location, and screw terminal for signal connection. In addition, channel 0 or channel 1 may be connected to the AN OUT baseboard path. See Table 1 and Figure 1 for a summary of user-configured components on AOM2.

The range-selection switch sets, S101 and S102 (AOM2/2 only), can be set for two output ranges; $\pm 10\text{V}$ and 0 to $+10\text{V}$. Optional filter capacitors help preserve the converter's 16-bit accuracy through the reduction of noise.

Screw Terminals for both converters are located on a single bank, with a common terminal for ground connection.

Jumpers select whether channels 0 or 1 are connected to the analog output signal path, and allow shorting of the output resistor for each channel.

Table 1. Summary of User-Configured Component on the AOM2

Name	Designation	Function
Capacitor 108	C108	Optional noise filter channel 0
Capacitor 105	C105*	Optional noise filter channel 1
Jumper 101	W101	Select AN OUT signal (channel 0 or channel 1)
Jumper 103	W103	Short channel 0 output resistor
Jumper 102	W102*	Short channel 1 output resistor
Screw Terminals	J146	Output connection for channels 0 and 1
Switch Set 102	S102	Analog output range channel 0
Switch Set 101	S101*	Analog output range channel 1

*AOM2/2 only.

Connections

Connecting terminals for the AOM2 module are marked on the module board. Typical connections are shown in Figure 2. The use of shielded cable is recommended to minimize the possibility of EMI radiation. Connect the shield to module ground, but leave the other end disconnected. Do not use the shield as a signal-carrying lead.

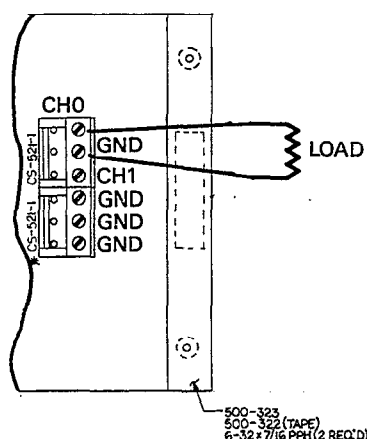


Figure 2. Typical AOM2 Connections (Channel 0 shown)

Range Switches

Each D/A converter on the AOM2 module has a switch set that controls the output range. Each of these switch sets has two DIP switches that must be set to configure the output for the desired range. Table 2 summarizes the positions for the DIP switches on each set (these positions apply to both sets). Note that the module must be recalibrated if the range is changed; see the Service section of this manual for details.

Table 2. DIP Switch settings for Switch Sets S101 and S102

Output Range	1	2
-10 to +10V*	Open	Closed
0 to +10V	Closed	Open

*Factory default settings

Note: Switch settings are the same for both switch sets.

Preserving 16-Bit Accuracy

With a 16-bit D/A converter, the value of a single voltage step is extremely small: 0.0001525V when the 0 to +10V range is used. Electrical noise or temperature drift can easily obscure such a small voltage change, reducing accuracy dramatically. The following sections suggest measures to maintain the accuracy of the converter.

Noise

Signal changes at the microvolt level are extremely difficult to transmit over wires even a few inches long. Therefore, good signal connection practices should always be observed. The length of connecting wires should be minimized, and these wires should never run alongside AC power lines. In addition, shielded cable should always be used, with the shielding connected to the ground terminal of the module.

If noise remains a problem, output filters for each channel can be installed on the module itself.

C108 provides filtering for channel 0, while C105 is for channel 1. The required capacitor value for a given bandwidth can be calculated as follows:

$$C = \frac{1}{2\pi Rf}$$

Where C is in farads, f is in hertz and R is in ohms. Note that large capacitor values, while providing greater noise rejection, will reduce output bandwidth accordingly. For example, assume that the bandwidth is to be restricted to 30Hz. The required capacitor value is (with a channel output resistance of 1k Ω):

$$C = \frac{1}{6283(30)}$$
$$C = 5\mu F$$

Note: Do not install filter capacitors with output resistors jumpered.

Analog Output

A direct connection between the output of channel 0 or channel 1 and the AIM1 is made through the baseboard connector's AN OUT signal path. An on-card Berg jumper

(W101) is provided, so the connection can be defeated if noise from this source is experienced. To connect channel 0 to the AN OUT path, place the W101 jumper on the middle two pins. To connect channel 1, place the jumper on the left two pins. Place the jumper on the right two pins to leave both channels disconnected.

Temperature Drift

D/A converters, like many electrical components, are sensitive to temperature change. The AOM2 converters are designed with extremely low temperature coefficients (low sensitivity to temperature changes); however, an attempt should be made to maintain the operating environment near room temperature.

The converter has been calibrated to be accurate when operating. Because the temperature of the device is higher when it is operating than when it is not in use, no critical operations should be performed until the system has been on for at least five minutes.

Output Loading

The source resistance of each output is $1k\Omega$ with the output jumper removed. With this configuration, a load resistance of $1M\Omega$ will result in a loading error of only 0.1%. This error may be compensated for by adjusting channel calibration as described in the servicing section of this manual. Note that with the resistor in the circuit, accuracy decreases as the load resistance is decreased.

CAUTION: Placing the jumper across the output resistor eliminates output overload protection. The module can be easily damaged with the jumper in place.

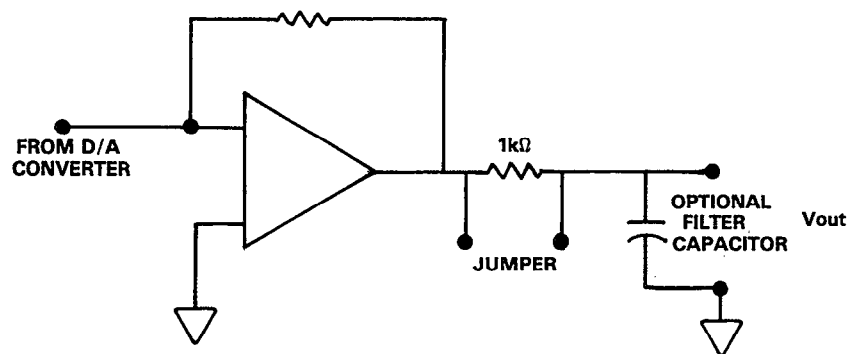


Figure 3. AOM2 Output Stage

Commands

AOM2 module commands are listed in Table 3. Table 4 summarizes the locations for slot-dependent commands.

Table 3. Commands Used with the AOM2 Module

Command	Location
D/A CONTROL	Slot-dependent CMDA
D/A DATA STROBE	Slot-dependent CMDB
Location: CFF9D	

Table 4. Locations for Slot-dependent Commands

Slot	CMDA	CMDB
Slot 1	CFF80	CFF81
Slot 2	CFF82	CFF83
Slot 3	CFF84	CFF85
Slot 4	CFF86	CFF87
Slot 5	CFF88	CFF89
Slot 6	CFF8A	CFF8B
Slot 7	CFF8C	CFF8D
Slot 8	CFF8E	CFF8F
Slot 9	CFF90	CFF91
Slot 10	CFF92	CFF93

D/A CONTROL

Location: Slot-dependent CMDA

D/A CONTROL always precedes D/A DATA, indicating to the AOM2 module which channel of analog output to update, and which byte of data to load.

The high and low bytes may be updated independently and in any order; there is no hardware reason that both bytes must be updated at the same time. Similarly, channels can be updated independently and in any order.

Note that the byte/channel selection is retained by the module; if a single byte/channel will be updated several times in succession, the D/A CONTROL command need not be reissued.

Table 5. Values Written to the D/A Control Location

Function	Binary	Hex	Decimal
Channel 0 Low Byte	0000	H0	0
Channel 0 High Byte	0001	H1	1
Channel 1 Low Byte	0010	H2	2
Channel 1 High Byte	0011	H3	3

Note: AOM2/1 has channel 0 only.

D/A DATA

Location: Slot-dependent CMDB

D/A DATA is used when loading actual data values into the D/A converter. This command should always be preceded by D/A CONTROL, which selects the channel and the byte to be loaded. The data must be separated into low and high bytes prior to loading, and each byte must be prefaced by D/A CONTROL. If a byte/channel will be updated repeatedly, D/A CONTROL need not be reissued.

When the strobe feature is disabled, the output of the converter is updated immediately. This implies that the low and high bytes are updated independently. When the strobe is enabled, no outputs are updated until the STROBE command is issued in the issue data mode.

The digital value loaded into the converter varies according to the output range selected via switch sets S101-S102. To determine the digital value to input for a given voltage, the output range must be known. With 16-bit conversion, there are 65,536 possible voltage levels, specified with digital values 0-65,535. The voltage of each step equals the range divided by 65,535. For an input range of 0 to 10V, for example, the voltage of each step is 10/65,535, or 0.0001525. A formula for each voltage range is provided below.

Table 6. Digital Value to Volts

<u>Output Range</u>	<u>Voltage</u>
0 to +10V	$V = D * 0.0001525$
-10 to +10V	$V = -10 + (D * 0.0003050)$

Where V is volts, and D is the digital value loaded into the converter. Similarly, the following equations determine the digital value to use when a particular voltage is required:

Table 7. Volts to Digital Value

<u>Output Range</u>	<u>Digital Value</u>
0 to +10V	$D = \text{INT}(V/0.0001525)$
-10 to +10V	$D = \text{INT}(V/0.0003050) + 32768$

STROBE

Location: CFF9D

The STROBE command is used to make possible the synchronous updating of two or more analog output channels. STROBE is issued in three modes: strobe enable, strobe disable, and issue data. The STROBE feature must either be enabled or disabled at the start of any program, or the D/A converters will not function.

When the strobe feature is disabled, all data given to a D/A converter is immediately placed in that converter's primary data latch, and the voltage output updated. The low byte and high byte are thus updated asynchronously.

When the strobe is enabled, no data is updated until the STROBE command has been issued in the issue data mode. Instead, new data is placed in a secondary data latch within the D/A converter. When the STROBE command (to issue data) is given, the new data is released to the primary latch, updating the voltage output, and old data in other channels is reissued, leaving the voltage output of these channels unchanged. The strobe is completely flexible. Any amount of data - from a single byte to any number of channels - can be updated when the strobe is enabled.

To use the strobe, issue the strobe enable command early in the program. Use the D/A CONTROL and D/A DATA commands to load the secondary latches of the appropriate converters. This can be done as far in advance as required. To issue the new data, load STROBE with 1 (to issue data), releasing all data loaded since the last issue data command and leaving unchanged the outputs of other channels. See Table 8 for a summary of values written to the STROBE location.

The STROBE feature is global, affecting all D/A modules installed in the Series 500.

Table 8. Values Written to STROBE

<u>Function</u>	<u>Binary</u>	<u>Hex</u>	<u>Decimal</u>
Strobe Enable	01000000	H40	64
Strobe Disable	10000000	H80	128
Issue Data	00000001	H01	1

AOM2 Module Calibration

The AOM modules should be calibrated whenever the range is changed. Because a considerable amount of programming is necessary, a program is presented in this manual as an aid in calibrating these modules. Program 1 is intended for the AOM2. Use the following procedure when calibrating this module.

1. Place the AOM module to be calibrated in slot 5. Set the output range as indicated in Table 9.
2. Enter the program into the computer.
3. Connect the DMM high input lead to the signal terminal of the channel being calibrated. Connect the DMM low lead to module ground. For maximum accuracy, connect the usual load resistance between the signal terminal and ground.
4. Run the program and follow its instructions. Refer to Figure 4 for adjustment locations. Make sure the output range of the module is set correctly. The program will prompt with the correct range switch settings.
5. Repeat the procedure as necessary with the remaining channels.

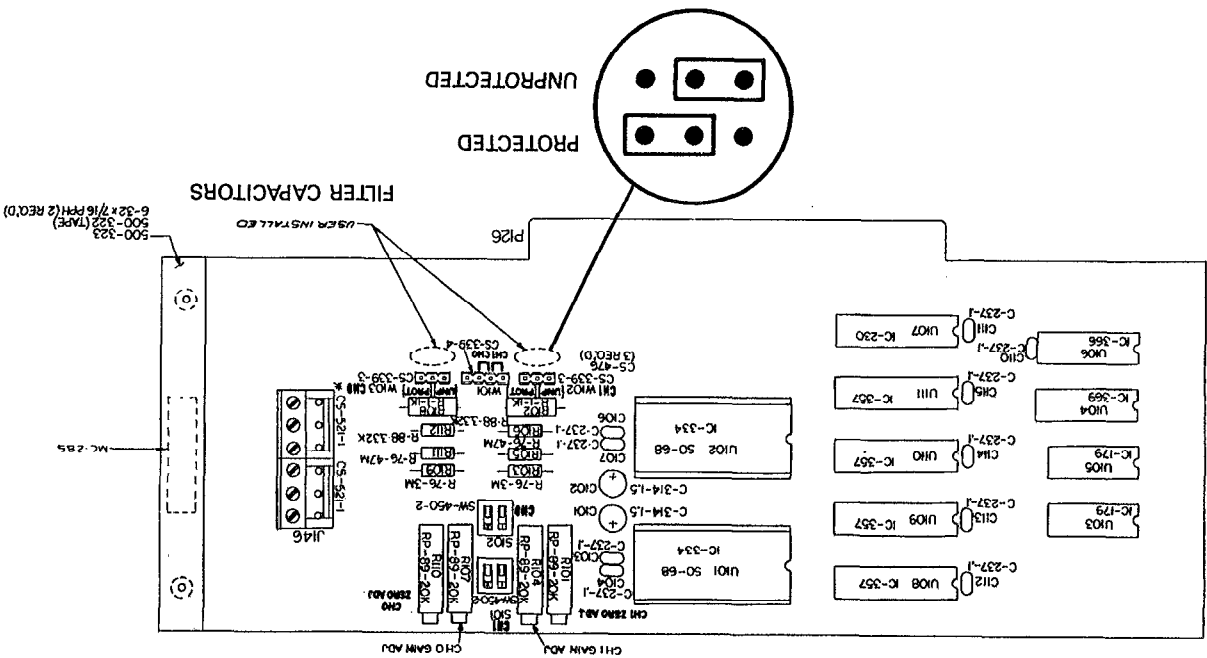


Figure 4. AOM2 Module Calibration Adjustments

Table 9. AOM2 Output Range

<u>Range</u>	<u>S101</u>	<u>S102</u>
	1	2
0 to +10V	C	O
-10 to +10V	O	C

Note: O = Open, C = Closed
S101 = Channel 1
S102 = Channel 0

Program 1. AOM2 Calibration

```
10 DEF SEG = &HCFF0: CLS
20 CA = &H88: CB = &H89: ST= &H9D
30 POKE ST, 64
40 PRINT "INSERT AOM2 INTO SLOT 5"
50 PRINT: INPUT"AOM2 CHANNEL (0-1)"; CH
60 IF CH < 0 OR CH > 1 THEN 50
70 PRINT: PRINT "CONNECT DMM TO CHANNEL"; CH
80 PRINT: PRINT "RANGE SWITCH POSITIONS"
90 PRINT" 1 2"
100 PRINT "1 0 TO +10V C O"
110 PRINT"2 -10 TO +10V O C"
120 PRINT: INPUT"RANGE (1-2)"; R
130 PRINT: IF R < 1 OR R > 2 THEN 120
140 ON R GOSUB 280, 300
150 POKE CA, 2*CH: POKE CB, LB
160 POKE CA, 2*CH + 1: POKE CB, HB
170 POKE ST, 1
180 PRINT: PRINT"ADJUST CHANNEL"; CH;"OFFSET FOR "; L$;"VOLT READING
    ON DMM"
190 INPUT "PRESS RETURN TO CONTINUE"; A$
200 ON R GOSUB 290, 310
210 POKE CA, 2*CH: POKE CB, LB
220 POKE CA, 2*CH + 1: POKE CB, HB
230 POKE ST, 1
240 PRINT: PRINT"ADJUST CHANNEL"; CH;"GAIN FOR"; H$" VOLT READING ON
    DMM"
250 INPUT"PRESS RETURN TO CONTINUE"; A$
260 PRINT: INPUT"AGAIN"; A$
270 IF LEFT$(A$,1) = "Y" THEN 50
275 END
280 LB = 0: HB = 0: L$ = "0.000": RETURN
290 LB = 255: HB = 255: H$ = "9.999": RETURN
300 LB = 0: HB = 128: L$ = "0.000": RETURN
310 LB = 0: HB = 0: H$ = "-10.000": RETURN
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Theory of Operation

For the following description, refer to schematic number 500-226.

The circuitry on the AOM2 falls into three functional groups: the components providing D/A conversion and data-latching capabilities for each channel, the components for command development, and a single IC which buffers the data lines.

A hybrid, 16-bit D/A converter is provided for each channel on the AOM2 module. These converters, designated U101 and U102 on the schematic diagram, are complete, containing precision voltage references, output amplifiers, and data latches. Four 8-bit transparent data latches, U108-U111 (74LS373), provide a secondary level of data latching, supporting the system strobe feature. The enable line for each of these latches is driven by one of the four commands set up by U104.

Potentiometers R101, R104, R107 and R110 calibrate the gain and offset for the D/A converters (R104 and R107 calibrate the gain, R101 and R110 the offset). DIP switches S101 and S102 set the output ranges independently for the two converters.

W102 and W103 allow control of output protection. For added output protection, place the jumper in the PROT position. W101 is used to select the channel (0 or 1) to be routed to the AN OUT signal path. A third position is intended to hold the jumper when neither channel is to be routed.

Commands are decoded by components U103-U106. U106 is a quad transparent data latch (74LS75) which stores the 4 bit command select data. U106 is refreshed by the negative transition of command line A (CMDA, D/A CONTROL). A NOR gate segment of U103 (74LS02) buffers and inverts CMDA before it reaches U106.

U104 is a one-of-ten binary to decimal decoder (74LS42) that generates four separate command lines based on the 4 bit command word stored in U106. These four command lines enable the secondary data latches of the D/A converters, and are gated by CMDB (D/A-16 DATA) in quad NOR gate segments of U105 (74LS02). Buffering of the eight data lines is accomplished by U107 (74LS245), configured as a buffer.

AOM2 Specifications

Output channels: 2 (1 on the AOM2/1)

Output ranges: $\pm 10V$, 0 to +10V, switch selectable for each channel

Resolution: 16 bits, 1 part in 65,536

Nonlinearity: $\pm 0.003\%$ of F.S. (± 1 lsb)

Output impedance: 0.1

Load characteristics: $2k\Omega$ min, 1000pf max short-circuit protected

Slew rate: $0.2V/\mu\text{sec}$

Settling time: $20\mu\text{sec}$ to 0.006% of F.S. transition

Temperature coefficient:

Gain:

0.0007%/°C of F.S., 0 to +10V range

0.0009%/°C of F.S.*, -10 to +10V range

Offset:

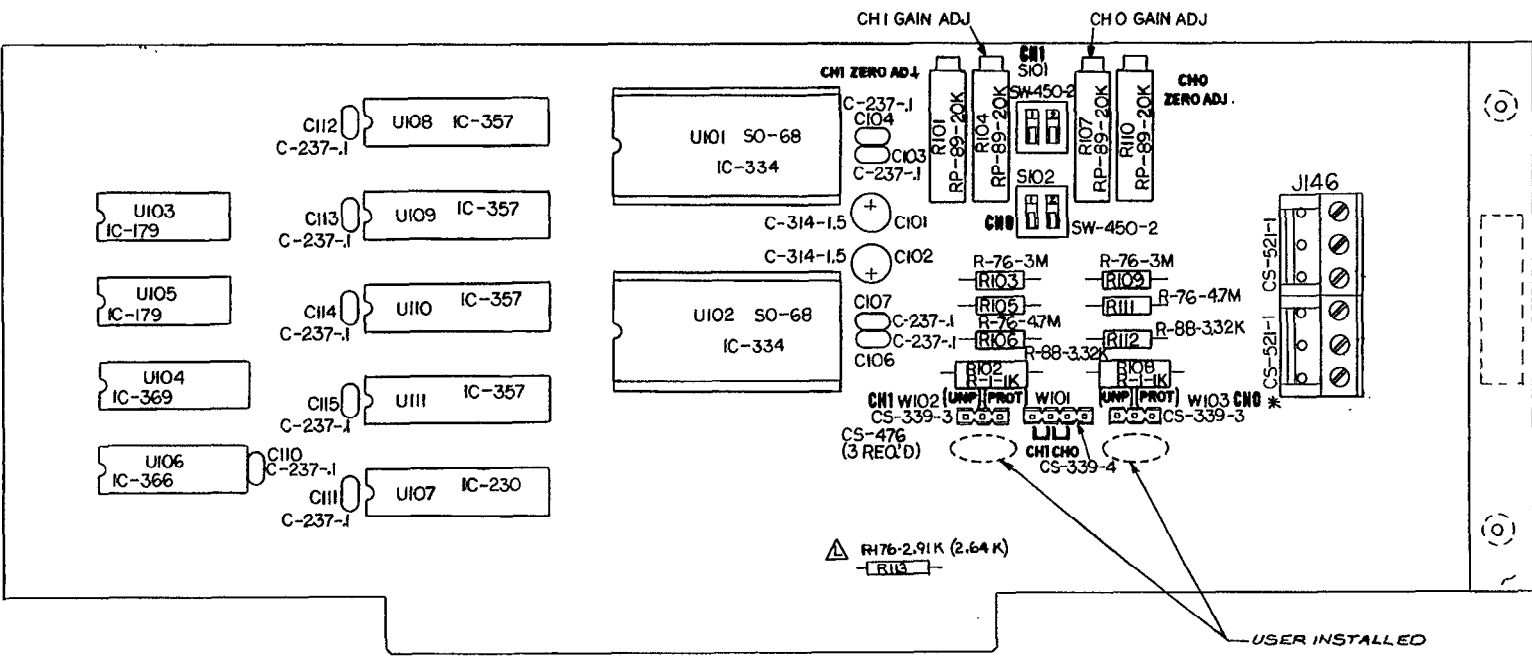
0.0009%/°C of F.S., 0 to +10V range

0.0011%/°C of F.S.*, -10 to +10V range

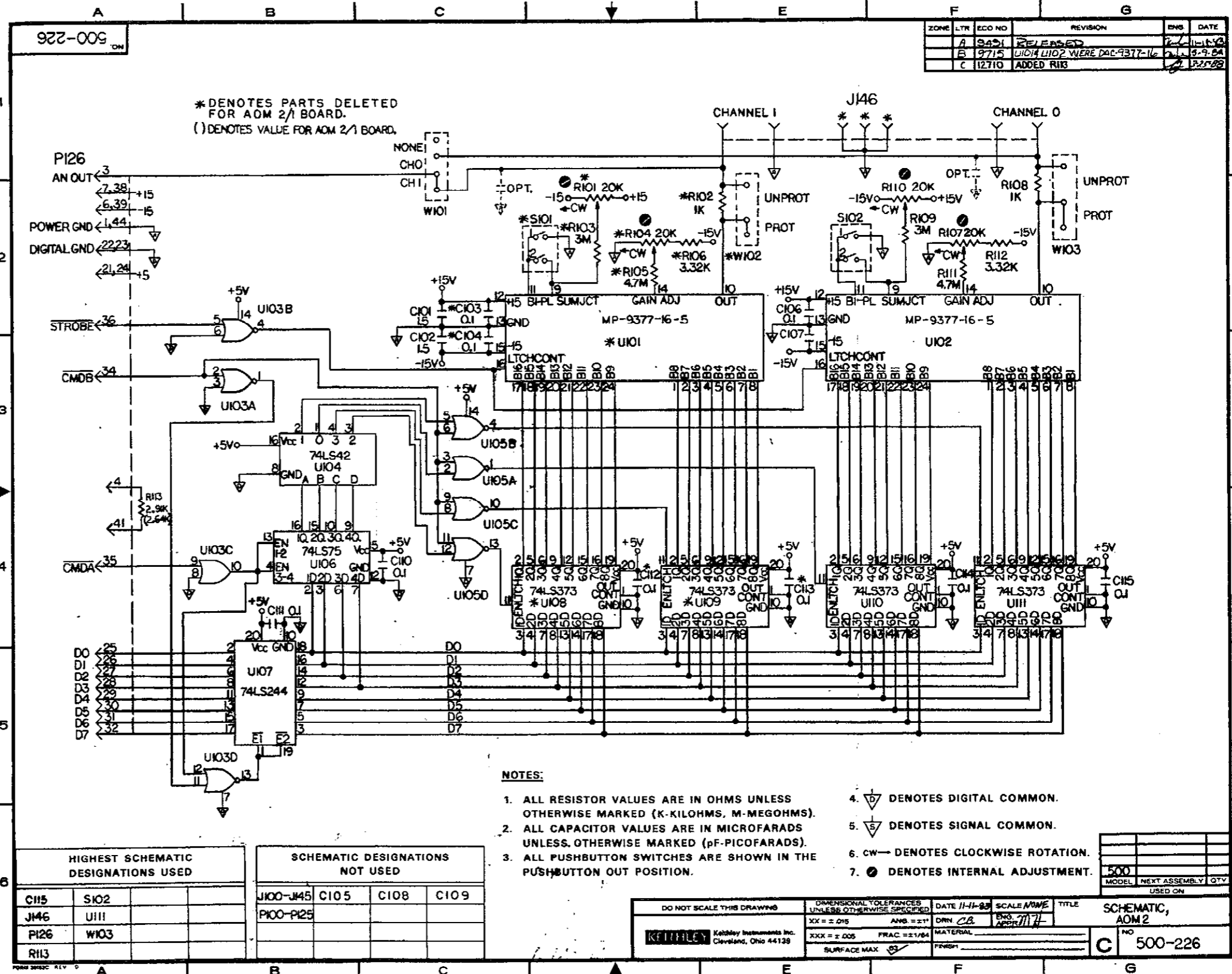
*Full scale for bipolar ranges is defined as $-V_{FS}$ to $+V_{FS}$

AOM2 COMPONENT LAYOUT

ZONE	LTR	ECO NO	REVISION	DATE
	A		PRELIMINARY	
	B	9482	RELEASED	11-4-83
	C	9494	ADDED PARTS LIST FOR ACHIEVE	1-7-83
	D	9620	CHG B AET FROM REV B TO REV C	1/30/84
	E	9772	CHG U107 FROM IC-357 TO IC-230	3/27/84
	F	9715	ITEN 15 U101 U102 WERE IC-370	6-9-84
	G	10051	DEL SO'S ON U108-111	7-20-84
	H	10469	CHG J146 FROM CS-457-1 TO CS-521-1	2-8-85
	J	11708	CAGE CLAMP SCREWS WERE 6-32 X 7/16 IN.	10/1/86
	K	11928	DELETED TAPE	10/31/87
	L	12710	ADDED R118 PER REV D	3-24-88



AOM2-13/AOM2-14



AOM2 SCHEMATIC DIAGRAM