

**MAO-12**

**Addenda to the MetraBus User's Manual**

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by

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# MAO-12 ANALOG OUTPUT BOARD

## Features of the MAO-12:

- o Interfaces directly with IBM PC/XT/AT and compatibles
- o Unipolar, Bipolar, and 4-20 mA outputs
- o 12-bit Resolution (1 part in 4095)
- o Remote signal connections
- o Up to 64 analog outputs per computer expansion slot
- o Extremely cost effective
- o Compatible with most computer languages

MetraByte's MAO-12 is an 8 channel analog output board for use with the MetraBus Industrial Data Acquisition and Control System. It has 8 independent output channels, each with 12-bit (1 part in 4095) resolution. The MAO-12 has five standard switch selectable voltage output ranges as well as 4-20 mA output capability. Provisions have been made for the installation of additional resistors allowing a wider range of output gains to be selected. Screw terminals on the board will accept 12 to 22 AWG wire.

The MAO-12 connects directly to one of three MetraBus driver cards (MDB-64, MID-64, or REM-64) and computer via a 50 conductor ribbon cable. The MetraBus cable connects the MAO-12 to one of the driver cards and carries all data, address, and status information as well as distributing power on the MetraBus. A total of 20 ground lines are interleaved among the data and address lines to ensure noise immunity. The MetraBus system was designed to allow MetraBus cable lengths of up to 100 feet. Remote control of the MetraBus system is possible via the REM-64 serial driver card at distances of up to 1.2 Kilometers. The MAO-12 is 19" rack mountable in either a standard NEMA type enclosure or the MetraByte RMT-02. The MAO-12 may also be mounted on any flat panel or other flat surface.

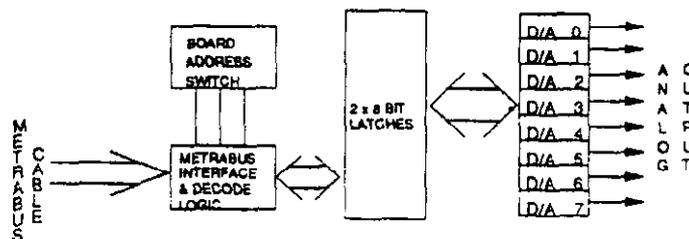
Because of its design, the MetraBus system allows for control of up to 64 analog output channels (8 MAO-12s) from a single computer expansion slot making it the most cost effective Industrial Data Acquisition and Control System available.

Some of the more common uses of the MAO-12 include computer control of 4-20 mA Process Control Equipment, single board Function Generator, ON/OFF Servo Motor Controller, Digital Attenuator, Variable voltage source, and much more.

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## MAO-12 Functional Block Diagram

The MAO-12 acts as the interface between your application signals and the MetraBus driver card and computer. The block diagram below will aid in visualizing control signal flow from the driver card through the MetraBus cable and out to the MAO-12 and your application signals.



## Auxiliary Power Supply

The MAO-12 requires  $\pm 15$  V in addition to the standard +5 V required by all MetraBus I/O boards. Therefore a high quality external power supply such as the PWR-55 or PWR-100 is needed (see current MetraByte Catalog for details of the PWR-55 or PWR-100). The use of an auxiliary supply in conjunction with the MDB-64 driver card, requires that **fuse F1 be removed** from the driver card.

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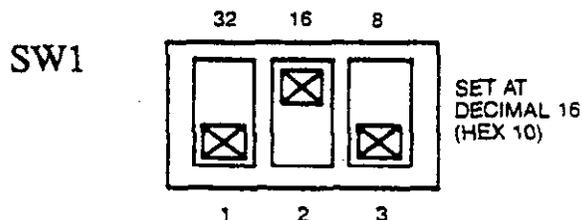
## Installing the MetraBus Controller/Driver Card

In order to use your MAO-12 or any other MetraBus I/O board, you must configure and install one of three interface/driver cards (MDB-64, MID-64, or REM-64). See the relevant sections of this manual for the installation procedure.

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## Setting the MAO-12 Board Address

Each MAO-12 connected to a single MetraBus cable must be set to a unique, non-overlapping MetraBus I/O address. Each of the eight channels on the MAO-12 uses one of the available 64 MetraBus I/O addresses. The eight channel addresses run consecutively starting from the MAO-12 Board Address. Setting the Board Address is outlined below. (The diagram shows a typical BOARD ADDRESS switch setting):



- 1) The address DIP switch on the MAO-12 is located above and to the left of the MetraBus interface connector. The numbers silk-screened above each switch indicates its value when enabled.
- 2) To set the Board Address, simply turn **ON** those switches corresponding to the address you have chosen. For example, in order to set a Board Address of 16, the switch with a value of 16 immediately above it should be turned ON while the others would remain OFF. The MAO-12 uses 8 of the available 64 MetraBus I/O addresses. The MAO-12, like all MetraBus I/O boards, requires a **non-overlapping** address in order to avoid address conflicts when being accessed by the driver card. Since any MetraBus I/O board may be connected to a single MetraBus cable address overlap is possible. Use caution to avoid this.
- 3) After setting the MAO-12 Board Address, you may connect it to the MetraBus cable. It is good practice to remove power from the MetraBus cable prior to connecting I/O boards. The connectors are keyed for your protection. Check the keyways for correct alignment prior to plugging in the MetraBus cable. Do not force the connectors!

- 4) If you have only one MAO-12 or if your MAO-12 is last board in your system, you should install the resistor terminating networks that were provided with your MetraBus driver card. The sockets RN1 and RN2 on the MAO-12 are for this purpose. These resistor networks are used to minimize signal reflections due to long cable lengths. They are optional, however, and have little effect for MetraBus cables of 50 feet or less.

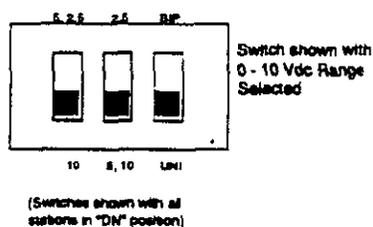
### Reset Respond Jumper

The MAO-12 may be configured to RESET all DAC outputs to 0 volts, CLEAR the simultaneous update register, and RESET the channel selection to CH0. Placing jumper J2 over the rightmost two pins will cause the MAO-12 to CLEAR and RESET the board as defined above, whereas jumper placement over the leftmost two pins will cause the MAO-12 to maintain status quo at power-up or software clear.

### MAO-12 Output Range, Polarity, and Reference Selection

Each channel on the MAO-12 can be set at any of 5 standard output ranges ( $\pm 2.5V$ ,  $+5V$ ,  $\pm 5V$ ,  $+10V$ ,  $\pm 10V$ ). Range selection is accomplished via a 3 station slide actuated switch assigned to each channel. The channel/switch assignments are marked on the MAO-12 and are shown below. The position of each switch with respect to Full Scale Output Range is also shown below.

		<u>RANGE</u>	<u>SW1</u>	<u>SW2</u>	<u>SW3</u>
CH #0 -->	SW6	0-5Vdc	UP	DN	DN
CH #1 -->	SW7	0-10Vdc	DN	DN	DN
CH #2 -->	SW8	$\pm 5Vdc$	UP	DN	UP
CH #3 -->	SW9	$\pm 2.5Vdc$	UP	UP	UP
CH #4 -->	SW5	$\pm 10 Vdc$	DN	DN	UP
CH #5 -->	SW4				
CH #6 -->	SW3				
CH #7 -->	SW2				

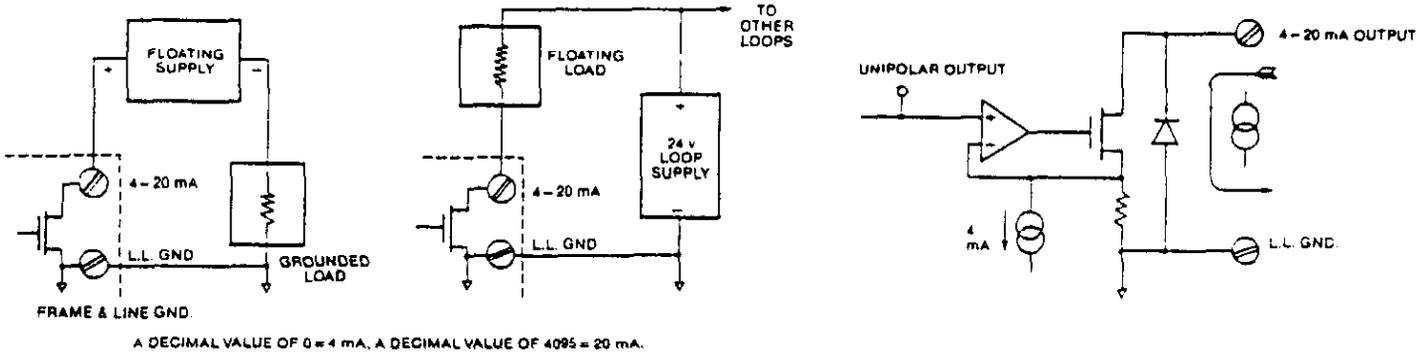


### MAO-12 OUTPUT SIGNAL CONNECTIONS

Output signals from the MAO-12 may be wired directly to the output connector. The connector has output assignments silk-screened adjacent to their assigned terminals on the board.

## 4-20 mA Output

The MAO-12 has provisions for 4-20 mA current output. This is often useful when connecting the MAO-12 to certain types of industrial instrumentation. The 4-20 mA current output consists of a precision current sink formed by a VMOS power FET and reverse protection diode. The drawing below illustrates such a circuit.



A minimum of 6 volts must be maintained across the output circuit for proper operation. The maximum voltage across this circuit should not exceed 36 volts for power dissipation reasons. Therefore, a 36 V or 24 V loop supply such as the ACCULEX model PSLOOP-175 (24 Vdc @ 175 mA) is ideal.

The 4-20 mA output from the MAO-12 requires that several decisions be made prior to use. They concern the type of power supply and its rating. As mentioned above, a 24V or 36V supply is needed to supply adequate power to the output circuit. There are two ways to configure the process loop; grounded load with floating supply or floating load with grounded supply. The grounded supply-floating load configuration allows several loops to be powered from the same supply but dictates that the load be 2 wire floating. The wiring scheme for both of these configurations is illustrated below. Choose the one which best suits your needs then wire your output accordingly.

- 1) Set the channel output range to 5 VFS Unipolar as instructed in the "Output Range, Polarity, and Reference Selection" section above.
- 2) Wire either the (+) side of the Floating supply or one side of the Floating load (depending upon the configuration chosen) to the I OUT terminal of the MAO-12 as illustrated above.
- 3) Wire the (-) side of the supply or the other side of the load to the Analog RTN terminal of the MAO-12.

## Programming the MAO-12

### MetraBus Driver Card Terminology:

The following brief discussion of the driver card and its associated functional address locations is meant as a quick review for MAO-12 users. It is not intended as a substitute for the expanded discussion concerning specific driver cards. See those sections of this manual dealing with your specific driver card for a rigorous treatment of its functionality.

The driver card uses four consecutive addresses within the computers I/O address space. Three of these addresses are of importance (the fourth is reserved). The factory default setting of location 768 will be used in the examples.

The three driver card addresses of importance are:

<u>I/O ADDRESS</u>	<u>IBM PC I/O LOCATION</u>	<u>FUNCTION</u>	
Base Address	768	Data I/O Path	(DATAIO)
Base Address +1	769	Address Pointer	(ADRPTR)
Base Address +2	770	Software RESET	(MRESET)

The Address Pointer (ADRPTR) points to any of 64 consecutive MetraBus locations.

Normally these locations are assigned variable names within a program, making it easier to change the address later, if desired.

10 DATAIO = 768	'Declare Data I/O location
20 ADRPTR = 769	'Declare Address Pointer location
30 MRESET = 770	'Declare RESET location

'MRESET resets all outputs to zero selects CH0, and deselects all channels for simultaneous update.

## MAO-12 Terminology and Data Format:

Each MAO-12 uses 8 of the available 64 MetraBus locations. Writing data to the MAO-12, in BASIC, is accomplished using the OUT command. Data is sent (in bytes) via the DATAIO register to the specific (MAO-12) Board Address after the board has been targeted via the ADRPTR. The 8 functional MAO-12 locations are specified as offsets from the Board Address (of the MAO-12). The MAO-12 is double buffered and contains data latches where output data is held until the update trigger (Board Address + 4 thru 7) is written. Outputting data from any channel via the simultaneous update feature requires that the channel first be selected for simultaneous update (via Board Address +3). Individual channels may be updated via the Board Address +0.

The 8 functional addresses and their corresponding function are:

<u>ADDRESS</u>	<u>READ</u>	<u>WRITE</u>
<b>BOARD ADDRESS+ 0</b>		Load DATA (High Byte)
<b>+ 1</b>		Load DATA (Low Byte)
<b>BOARD ADDRESS+ 2</b>	Channel Readback	Channel Select

The Channel Select byte is mapped as follows:

D7	D6	D5	D4	D3	D2	D1	D0
					CS-C	CS-B	CS-A

CH Sel Bit	CHANNEL#							
	0	1	2	3	4	5	6	7
D2	0	0	0	0	1	1	1	1
D1	0	0	1	1	0	0	1	1
D0	0	1	0	1	0	1	0	1

**BOARD + 3 (WRITE ONLY)** selects any or all channels for simultaneous update mode. Channel selection is accomplished by setting the specific bit(s):

D7	D6	D5	D4	D3	D2	D1	D0
SIM7	SIM6	SIM5	SIM4	SIM3	SIM2	SIM1	SIM0

**BOARD ADDRESS + 4 thru + 7 (WRITE ONLY)** are update triggers for previously selected channels (via BOARD ADDRESS +2 OR +3). When any of these 4 addresses is written, all previously selected DAC's are updated with data from high and low data bytes (Board Addresses + 0 and + 1).

### Programming Examples:

For the sake of clarity, we will use the variable MAO12, assigning it the board address, for all data writes and status reads. For example, in order to write a data value of 192 to CH #5, we would do the following (the following illustrates MAO-12 usage in the 8-bit mode):

```

10 MAO12 = 16           'Declare MAO-12 MetraBus Address
20 DATAIO = 768       'Declare Data I/O location
30 ADRPTR = 769       'Declare Address Pointer location
40 OUT ADRPTR, MAO12+2 'Point to Channel Select address
50 OUT DATAIO, 5     'Select Channel 5 via Data Value (5)
60 OUT ADRPTR, MAO12  'Point to HIGH Data Byte
70 OUT DATAIO, 192   'Output data

```

The MAO-12 is controlled using a standard programming sequence as follows:

- 1) Target the desired I/O board (MAO-12) via the ADRPTR & Channel Select location (Board Address + 2)
- 2) Select Channel via DATAIO & CH #.
- 3) Point to Data Output location via ADRPTR
- 4) Write the data value corresponding to the desired function to the DATAIO.

Data is written to the MAO-12 in two byte straight binary (right justified format for the Unipolar mode and two byte complementary offset binary for the bipolar mode. This is illustrated in the table below:

HIGH BYTE					DATA BITS				LOW BYTE				DATA VALUE	Uni	Bipolar
B7	B6	B5	B4	B3	B2	B1	B0	B7	B6	B5	B4				
1	1	1	1	1	1	1	1	1	1	1	1	4095	+ VFS	- VFS	
1	0	0	0	0	0	0	0	0	0	0	0	2048	+ 1/2 FS	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	+ VFS	

The examples below are written using interpreted BASIC. However, the underlying technique and associated functions of the MAO-12 could as easily have been illustrated using a multitude of other computer languages such as C, PASCAL, Assembly, etc. In these examples, we assume an MDB-64 driver card at computer I/O address 768 while the MAO-12 has a MetraBus Board Address of 32.

### Example 1:

You may have noticed from the example above that voltage output levels are specified as a function of the Full Scale output Range in conjunction with a D/A resolution of 12-bits ( $2^{12}-1 = 4095$ ). While this is often very useful for the computer when calculating proportional voltage outputs or when describing a ramped output, humans don't, generally, think in binary terms so that it is often desirable to specify the output as an actual voltage and let the computer do the conversion to a data value. Line 70 below does the conversion from voltage to the corresponding D/A integer. The setup parameters assumed are Unipolar operation and a Full Range Scale of 5V.

```
10 DATAIO = 768           'Declare Data I/O location
20 ADRPTR = 769           'Declare Addr Pointer location
30 MAO12 = 16             'Declare MAO-12 Address
40 OUT ADRPTR, MAO12+2    'Point the CH Select
50 OUT DATAIO, 0         'Select Channel 0
60 INPUT "Output Voltage (CH #0)";VOLTS 'Get voltage output level
70 VOLTS = INT(VOLTS*4096)/5 'Convert to Integer (High Byte)
80 HBYTE = 0
90 FOR I = 11 TO 4 STEP -1 'Set up High Byte loop
100 IF VOLTS =>2^I THEN HIBYTE = HIBYTE + 2^(I-4) ELSE 120
110 VOLTS = VOLTS - 2^I   'Subtract bit value from Volts
120 NEXT I
130 FOR I = 3 TO 0 STEP -1 'Set up low byte loop
140 IF VOLTS =>2^I THEN LOBYTE = LOBYTE + 2^(I+4)
                               'Create low byte for output
                               'Subtract bit value from Volts
160 VOLTS = VOLTS - 2^I
170 NEXT I
180 OUT ADRPTR, MAO12 + 1   'Point to Low Byte Location
190 OUT DATAIO, LOBYTE    'Output Low Byte of Volts
200 OUT ADRPTR, MAO12      'Point to High Byte Location
210 OUT DATAIO, HIBYTE    'Output High Byte of Volts
```

The D/A output integer is calculated as a simple ratio for both Bipolar and Unipolar operation:

<b>BIPOLAR (-10 to +10V)</b>		<b>UNIPOLAR (0 to +5V)</b>	
Decimal	Volts	Decimal	Volts
0	+10	0	0
1024	+ 5	1024	1.25
2048	0	2048	2.50
4095	-10	4095	5.00

NOTE: 12-bit output requires two bytes of data; a High byte and a Low byte. Converting from an output integer to two data bytes is simply a matter of establishing these two bytes. If 12-bit precision is not required for your specific application, you may simply ignore the low byte (it will be output as 0) and use only the high byte.

## DATA FORMAT

Data format for the D/A registers is as follows:

### Low Byte:

	D7	D6	D5	D4	D3	D2	D1	D0
(Base Adr +1)	B9	B10	B11	B12	X	X	X	X
				(LSB)		(X = Don't Care)		

### High Byte:

(Base Adr +0)	D7	D6	D5	D4	D3	D2	D1	D0
	B1	B2	B3	B4	B5	B6	B7	B8
	(MSB)							

## Calibration and Adjustment of the MAO-12

Calibration of the MAO-12 should be performed periodically to maintain its inherent high accuracy. For laboratory environments, an 8 month to 1 year interval is recommended. For more rigorous conditions where large temperature gradients are experienced or where vibration and humidity are prevalent, a 6 month interval is recommended.

A 5 1/2 digit digital multimeter and small slot head screwdriver are required to perform a satisfactory calibration.

Using the 5 1/2 digit DMM, adjust the MAO-12 as follows:

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### Reference Adjustment:

- 1) Adjust voltage between TP2 (-5VREF) and TP1 (GND) to -5.0000VDC.
- 2) Adjust voltage between TP3 (-10VREF) and TP1 (GND) to -10.000VDC.

### Voltage Offset Adjustment:

- 1) Set the Range Select switch for the desired range and wire the DMM between "VOUT" on any output channel and "ANALOG RTN". Output all 0's to that channel.
- 2) For bipolar +/-5V; adjust potentiometer "BIP ZERO ADJ" for 5.000V.
- 3) For bipolar +/-10V; adjust "BIP ZERO ADJ" for 10.000V.
- 4) Unipolar operation does not require Offset Adjustment.

### Voltage Gain Adjustment:

- 1) Set Gain Select switch x1 and leave the DMM wired as above. Output all 1's to the output channel.
- 2) For bipolar +/-5V; adjust "GAIN ADJ" for -4.9976V.
- 3) For bipolar +/-10V; adjust "GAIN ADJ" for -9.9951V.
- 4) For unipolar 0 to 5V; adjust "GAIN-ADJ" for +4.9988V.
- 5) For unipolar 0 to 10V; adjust "GAIN ADJ" for +9.9976V.

### 4-20mA Offset and Gain Adjustments:

- 1) Set Range Switch for 0 to 5V unipolar, wire the DMM between "IOUT" and "ANALOG GND" of any channel. Output all 0's to that channel. Adjust "4-20mA ADJUST" for 4mA of output current.
- 2) Output all 1s to the output channel. Adjust "GAIN ADJUST" for 20mA output current.

## SERVICEABLE PARTS

In the unlikely event that service is required, call our technical support department (508 880-3000) for a discussion of the problem. All "critical" components, which may be damaged by large external transient voltages, are socketed.

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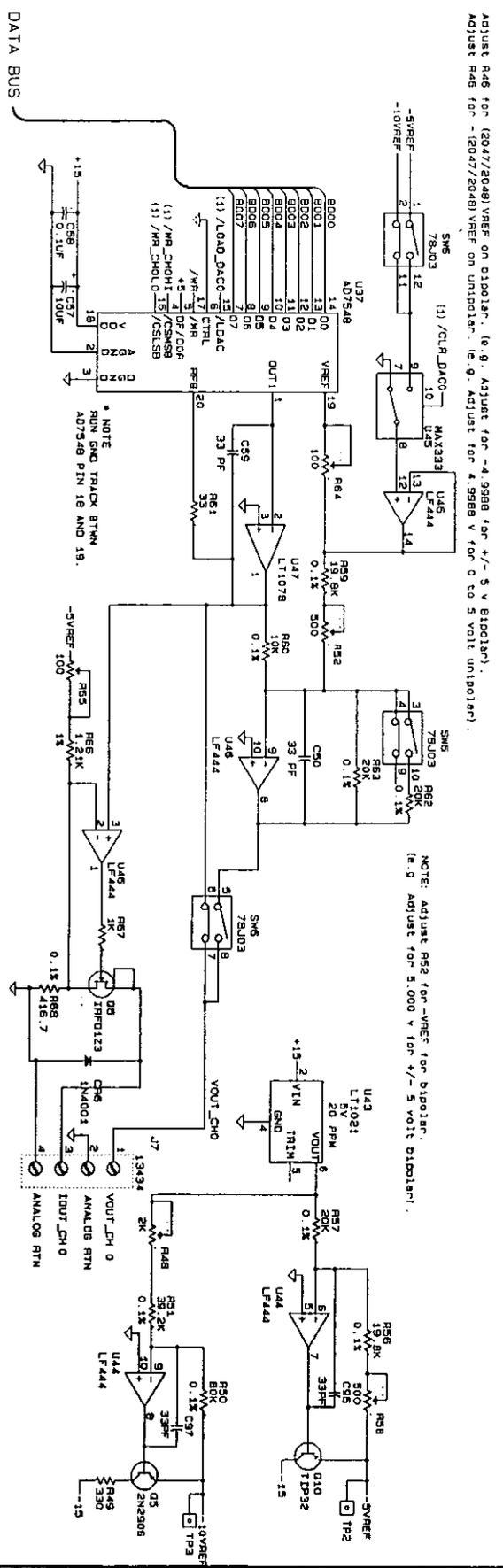
## MAO-12 SPECIFICATIONS

Output Channels:	8
Output Ranges:	0 to +5 V 0 to +10 V -2.5 to +2.5 V -5 to +5 V -10 to +10 V 4-20 mA current loop
D/A Resolution:	12 bits (1 part in 4095)
Relative Accuracy:	1/2 LSB (0.01%, max)
Differential Linearity:	1/2 LSB (max)
Temperature coefficient of gain:	±35 ppm per Deg C (Unipolar) ±55 ppm per Deg C (Bipolar)
Zero Drift:	±10 ppm per Deg C
Voltage output impedance:	0.1 Ohm (max)
Voltage output drive current:	±5 mA (max)
4-20 mA compliance:	6 to 36 V
MetraBus Cable Type:	50 Conductor ribbon cable
MetraBus Connector:	3M 3425-6050
Power Supply Consumption	
@ +5 Volts:	590 mA, max
@ +15 Volts:	28 mA, max
@ -15 Volts:	75 mA, max
Total power dissipation:	4.5 watts typical
Environmental	
Operating temperature:	0 to 70 Deg C
Storage Temperature:	-55 to +125 Deg C
Humidity:	0 to 95% non-condensing
Physical Size:	16 x 4.75 inches (40.63 x 12.06 cm)
Settling Time:	150 µSec to 0.01% (typ) for one full scale Step





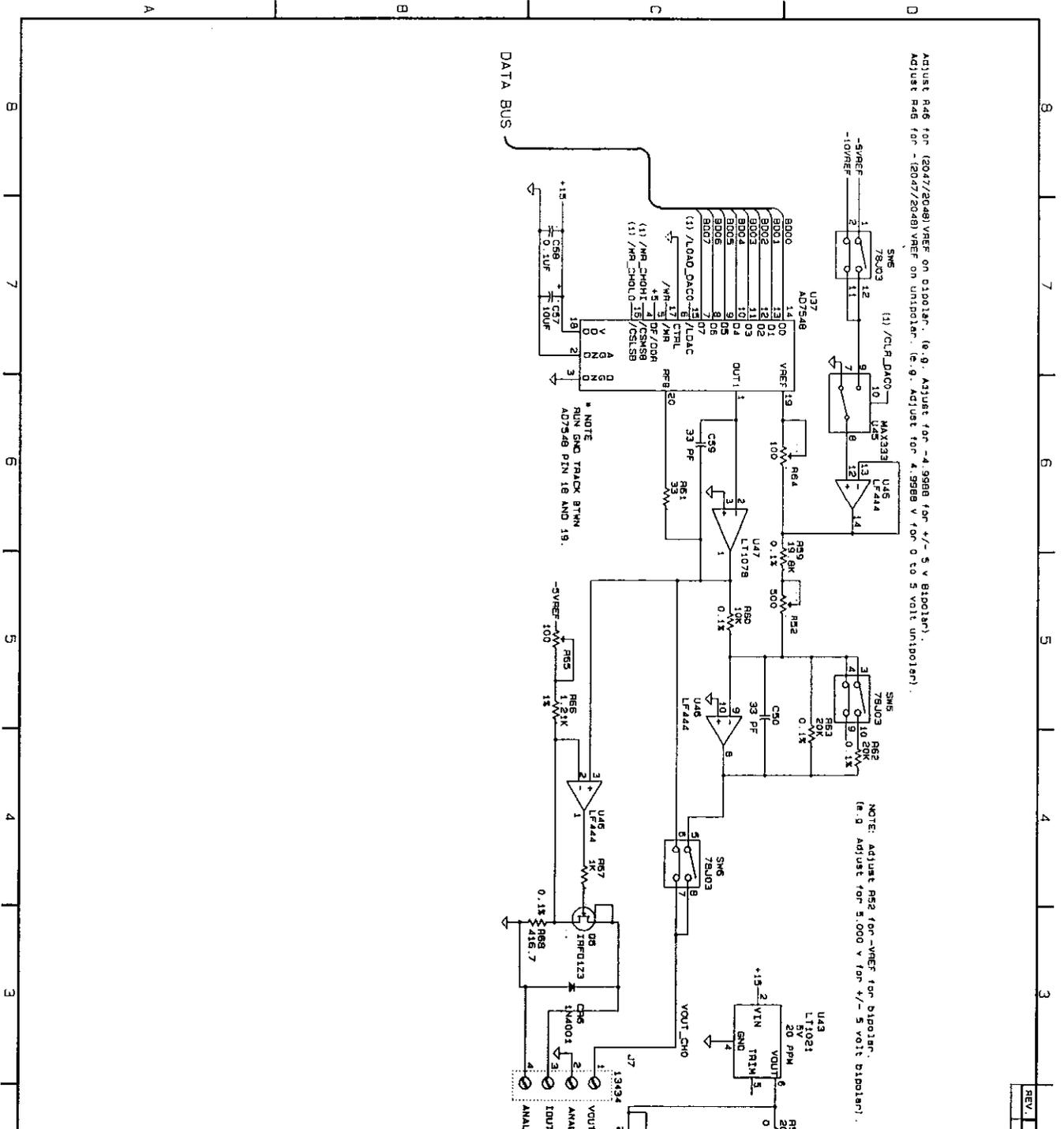
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440 WYLES STANDISH BLVD. TAUNTON, MA 02780

**SCHMATIC - MA0-12**

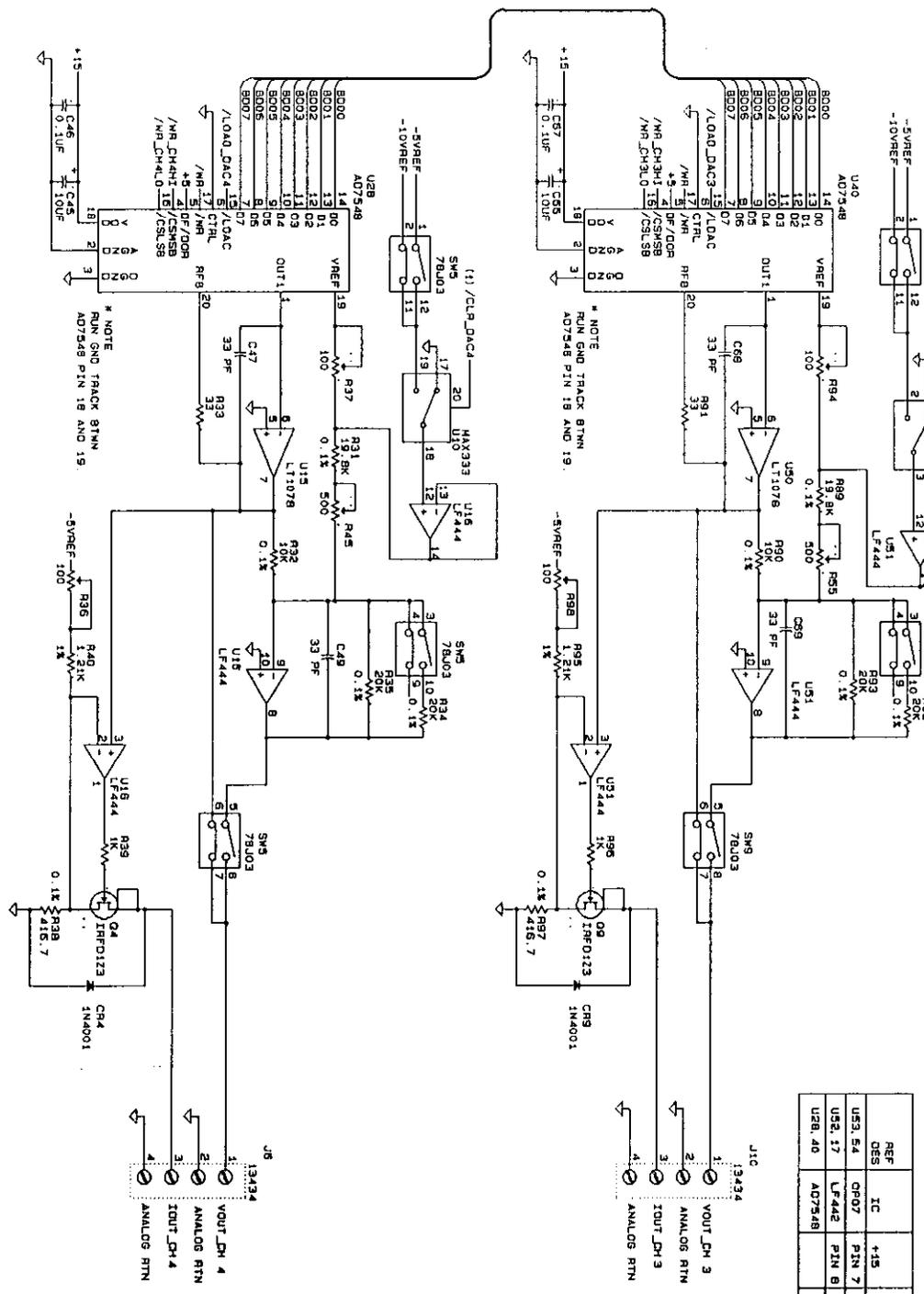
DATE: 10/18/89 SHEET 2 OF 6





REV.	DESCRIPTION	DATE	APP.
2	SEE SHEET 1		

REF DES	IC	+15	-15	SUPPLY CURRENT (mA)
				TYP
				MAX
U53, S4	OP07	PIN 7	PIN 4	3.5
U55, 17	LF442	PIN B	PIN 4	0.25
U28, 40	AD7548			1.0
				3.0




  
 440 WYLES STAMFORD BLVD., TAINTON, MA 02780

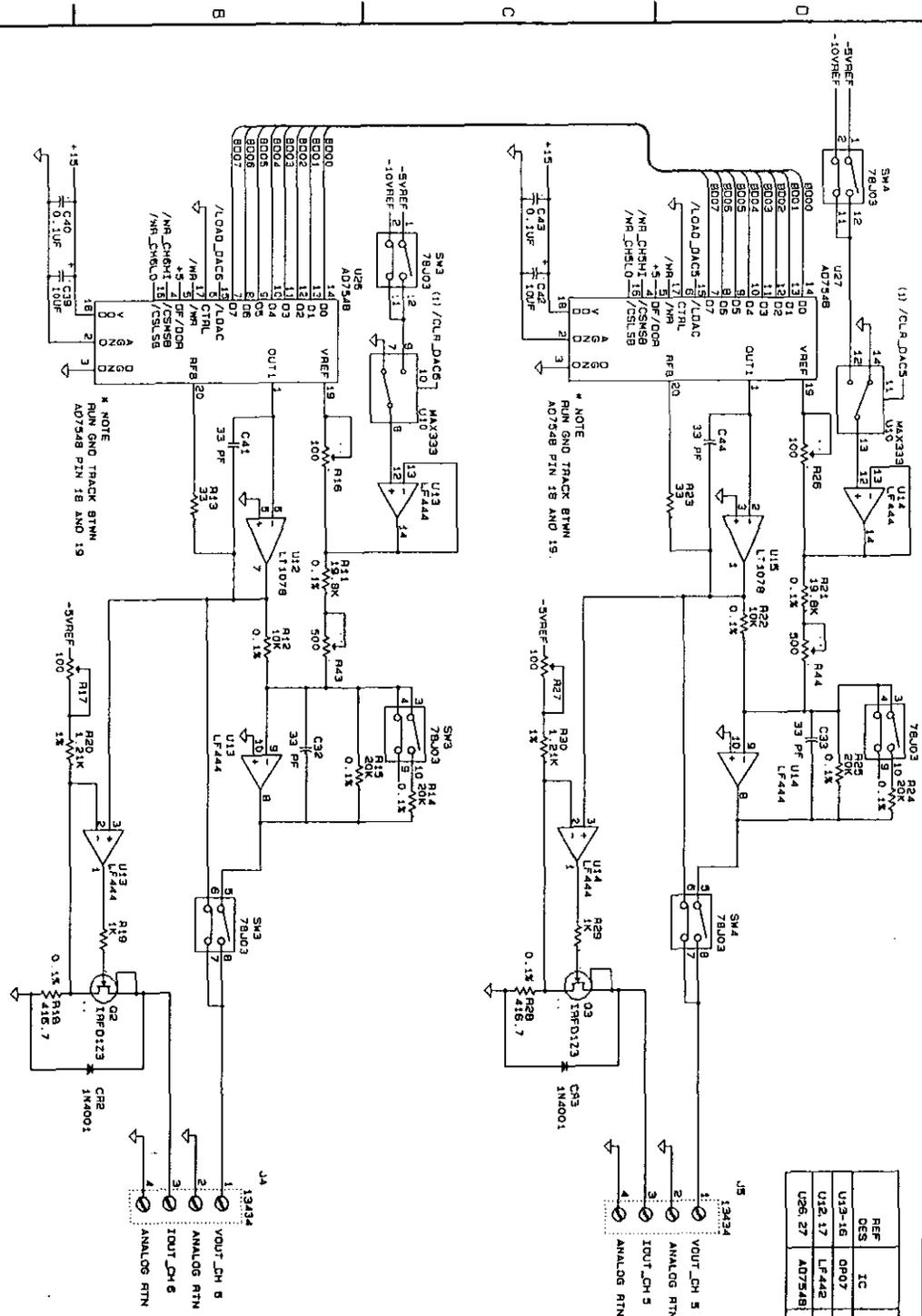
SCHEMATIC - MAO-12

DATE: 10/18/99 SHEET 4 OF 6

8  
 7  
 6  
 5  
 4  
 3  
 2  
 1

REV.	DESCRIPTION	DATE	APPRO.
2	SEE SHEET 1		

REF DES	IC	+15	-15	SUPPLY CURRENT (MA)
U13-16	OP07	PIN 7	PIN 4	3.5
U12, 17	LF442	PIN 8	PIN 7	0.25
U26, 27	AD7548			1.0
				3.0



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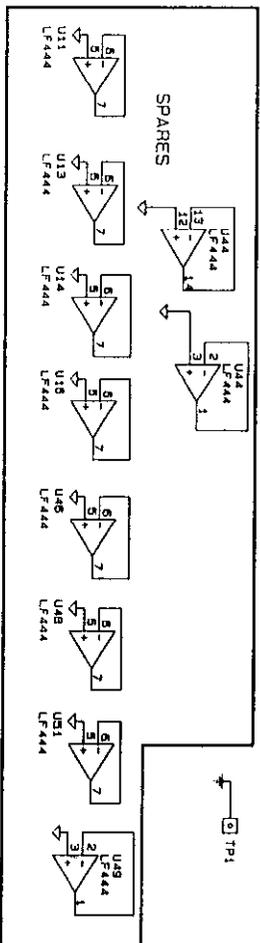
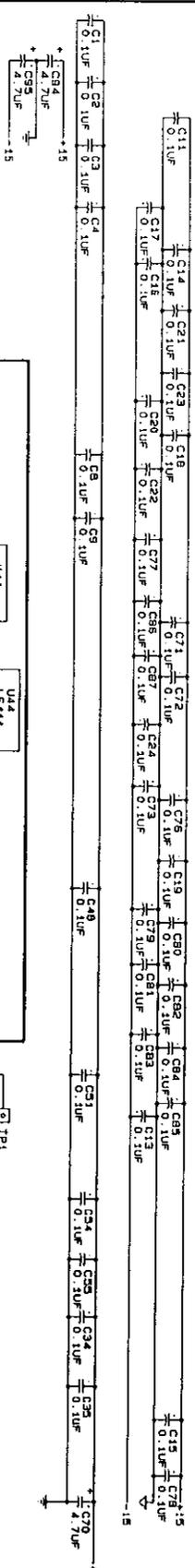
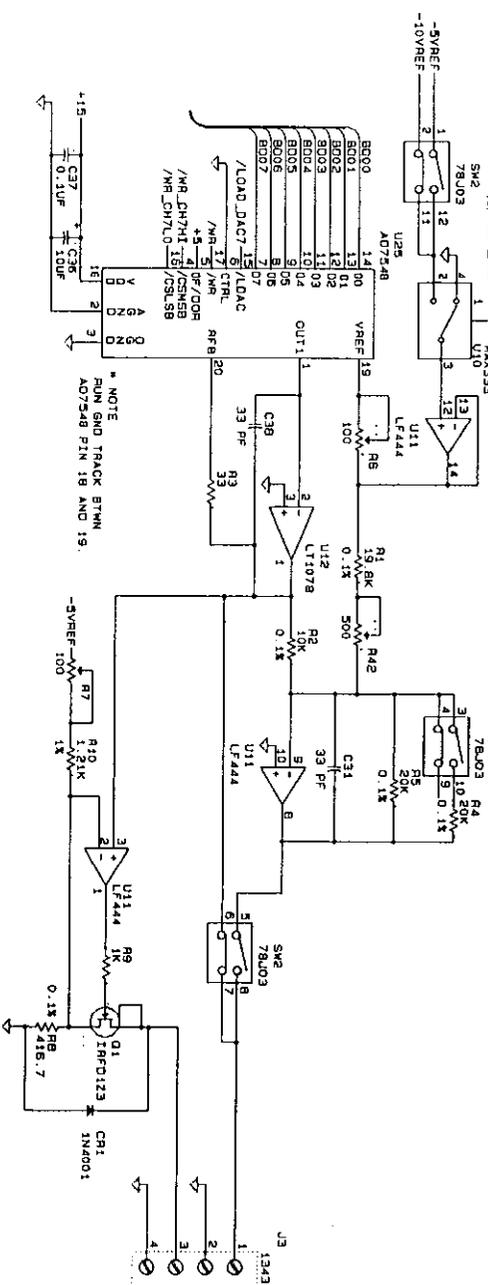
**MicroVita**

SCHEMATIC - MA0-12

REV A

DATE: 10/18/89 SHEET 5 OF 8

REV.	DESCRIPTION	DATE	APPD.
2	SEE SHEET 1		



**RadioShack**  
 440 NYLES STANISH BLDG. FAUNTON, MA 02780  
 SCHEMATIC - MAO-12  
 REV. A  
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 SHEET 6 OF 6