MetraBus User's Guide

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Revision F - July, 1994
Part Number: 62470

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Contents

Contents

Contents

Contents

Contents

■ ■ ■

Chapter 1

INTRODUCTION

1.1 GENERAL

The MetraBus system provides a low-cost means of connecting real-world I/O devices to a computer. The system is available in two configurations: (1) tightly coupled to an IBM PC bus system or (2) remotely operated through RS-232/422 serial communications from any computer.

Under the supervision of a PC, MetraBus digital, analog, and counter-timer measurement, and control interfaces can control cost-effective industrial I/O systems. Each MetraBus system can measure and control hundreds of analog, digital, and counter/timer I/O points. Several MetraBus systems can simultaneously control thousand of I/O points.

MetraBus fills the gap between I/O plug-in boards and dedicated industrial controllers. Plug-in boards and a personal computer are finding applications in process measurement and control applications and product test stations. However, the large number of data I/O points required, the proximity of the sensors to the control room combined with a finite number of expansion slots available in a personal computer often require versatile systems that are flexible, provide for enhanced expansion capability and are inexpensive. The MetraBus family of industrial data acquisition products retains the close link of the personal computer to a data acquisition system while offering extreme flexibility at a price that rivals many plug-in I/O boards.

Key MetraBus features include:

- Low cost I/O
- Ease of programming
- Simple packaging and interconnection
- Reliability
- 100% personal computer compatible
- Local, high speed interfaces
- Remote capability, up to 1.2 km from computer

1.2 THE METRABUS

The MetraBus system is an extension of the computer bus to real world measurement and control devices. All MetraBus I/O boards share the 50-conductor cable illustrated in Figure 1-1. The MetraBus cable consists of:

- 6 Address lines

- 8 Data lines
- 4 Control/status lines
- 3 Power supplies
- Ground conductors between all address data and control

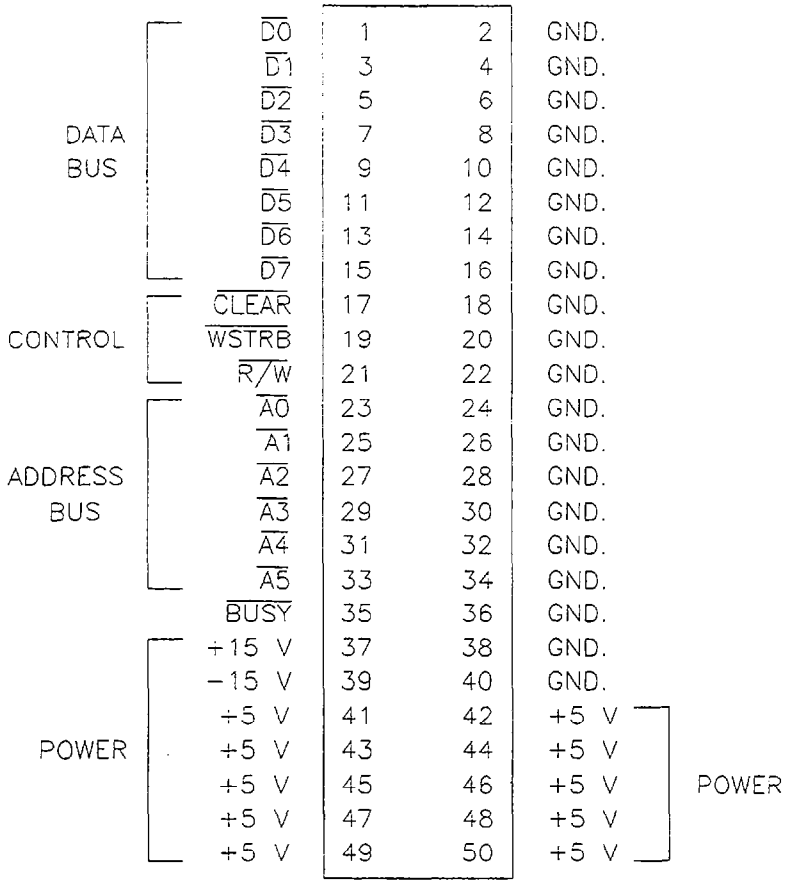

Figure 1-1. The MetraBus Connector

Six address lines yield 26 = 64 individual addresses on the MetraBus. Each MetraBus address may control any one of the following:

- 8 Digital I/O points
- One 8-bit A/D point
- One half of a 12-bit A/D
- One 8-bit D/A
- One 8-bit counter/timer

1.3 AVAILABLE METRABUS BOARDS

MetraBus I/O boards are controlled by the PC through one of the MetraBus controller/driver cards. These I/O Boards are as follows:

- μCMDB-64: PS/2 compatible MetraBus controller board
- MDB-64: IBM PC compatible MetraBus controller board
- MID-64: IBM PC compatible controller card with full optical isolation between PC and MetraBus.

  REM-64: Remote MetraBus controller. Communication via RS-232/422 serial. Multidrop up 16 REM-64 per computer serial port.
- INTMDB-64: Intelligent MetraBus controller board. This board is described in a separate manual.

Both local and remote MetraBus systems control the same family of signal acquisition and control boards. The boards and their various functions are as follows:

- MID-16/MSS-16: 16 solid-state relays
- MEM-8: 8 electromechanical relays
- MEM-32: 32 electromechanical relays
- MIO-32: 32-channel, optically isolated TTL output
- MII-32: 32-channel, optically isolated TTL input
- MAI-16: 16-channel, 12-bit A/D
- MAO-8: 8-channel, 8-bit D/A
- MAO-12: 12-Channel, 12-bit A/D
- MCN-8: 8 Channel, 8-bit counter timer
- MBB-32: 32-bit prototype board with four fully decoded addresses
- MDG-1: Diagnostic/training board with LEDs
- MBUS-PWR: MetraBus power supply
- MSSR-32: 32-channel, solid-state relay board
- MCPT-8X8: Cross-point relay board
- MTHERM-20: 20-channel thermocouple
- MTAP-1: Power supply tap board

1.4 PACKAGING & INTERCONNECTION

All MetraBus I/O boards are 19" rack mountable using either the RMT-02 housing, a standard NEMA cabinet, or any 7" x 6"x 2" enclosure. A 50-way, 0.05" spacing ribbon cable connects the MetraBus controller/driver card to the I/O boards. This MetraBus cable operates at lengths of up to 100'. Connectors are standard, 50-pin insulation-displacement type; their parallel architecture allows placement at any point along the MetraBus cable.

1.5 CONCEPTUAL VIEW OF METRABUS

MetraBus is an extension of the PC I/O control address space. The MetraBus controller card implements three control functions, as follows:

- An address Ppinter
- A data input/output path
- A reset/clear line

An I/O OUT command from the PC sets the address pointer to a MetraBus I/O board at its address. Data may then move to or from the selected I/O boards. A RESET/CLEAR may come from the PC at any time, clearing all I/O boards and resetting the address pointer to zero.

1.6 PROGRAMMING METRABUS

MetraBus is programmable from any PC-usable language having INPUT and OUTPUT commands capable of manipulating the I/O bus. Examples of such languages are:

- C
- BASICA
- Microsoft PASCAL
- Assembly
- GWBASIC
- TURBO PASCAL

In addition, the REM-64 MetraBus controller allows connection of a MetraBus system to any computer with an RS-232/RS-422 interface. A REM-64 can be controlled from any language capable of writing and reading the computer's serial ports.

Programming the MetraBus is a two-step procedure: (1) set the address pointer then (2) read or write the data. The following discussion will use the variables DATAIO, ADRPTR, and MRESET in order to help clarify MetraBus programming technique. These variables are generally set at the beginning of your programs for ease of manipulation as follows:

```
10 DATAIO = 768          'Declare MetraBus data I/O path
20 ADRPTR = 769          'Declare address pointer location
30 MRESET = 770          'MetraBus reset location
40 OUT ADRPTR, 01        'Set the address pointer to address #1
50 OUT DATAIO,45         'Write data 45 to address 1
```

Set the MetraBus address pointer by issuing a single command to the MetraBus controller board. Once set, the address pointer is latched and need not be reset until a different address is required.

Writing and reading data from a MetraBus I/O board is transparent once the address pointer is set. Issuing an OUT command will write data to the targeted I/O board. Likewise, issuing an INP command will retrieve data from the I/O board via the data I/O path.

```
40 OUT ADRPTR,01         'Set address to 1
50 OUT DATAIO,45         'Write data 45 to address 1
60 VAL = INP(DATAIO)     'Read back data from 1
```

The MetraBus controller board and all attached MetraBus I/O boards may be reset by writing to the reset address. Here is an example in BASIC:

```
40 OUT MRESET, 00       'Clear the MetraBus
```

Examples of all MetraBus programming features are available on the MetraBus diskettes.

MDB-64 vs. REM-64 Programming

Direct bus plug-in controller boards (MDB-64 and MID-64) program differently than the REM-64 MetraBus serial controller board. Commands to the MDB-64 and MID-64 are direct statements to an I/O port. For example, in BASIC:

```
40 OUT ADRPTR, 01       'Set address pointer to #1
50 OUT DATAIO, 44       'Write data 44 to board #1
```

REM-64 commands are writes to a COM1 or COM2 serial port. The REM-64 has an on-board microprocessor which interprets commands from the personal computer. The REM-64 issues commands to the I/O boards (via the MetraBus cable) identical to those issued by an MDB-64 or MID-64. For example, in BASIC:

```
10 PRINT #1,"B" ; 1     'Activate REM-64 #1
20 PRINT #1, "A" ; 4    'Set address pointer to MetraBus address 4
30 PRINT #1, "W" ; 44   'Write data "44" to I/O board #1
```

Since the MDB-64 and REM-64 use different hardware connections, programs for the MDB-64 are not compatible with those for the REM-64.

Programming I/O Boards

MetraBus I/O boards fall into three major categories:

- Digital in and out
- Analog in and out
- Counter/timer

Digital MetraBus I/O boards program with byte wide (8 bits) write and read commands. Driving a single digital line high or reading the status of a single line requires one bit. Therefore, 8 lines (or bits) are controlled when writing to or reading from the digital I/O boards.

Data to a MetraBus digital output board is latched and may be read back from the board. This data readable feature is usable when manipulating the I/O lines, thus making digital programming easy.

Analog output boards are controlled as an 8-byte port, one byte per channel. The analog equivalent of the 8-bit data is output by the DAC on the MetraBus analog output board.

Analog input for the MetraBus is full-featured, allowing user control of application specific parameters. Prior to reading A/D data from a MetraBus MAI-16, the range channel and type (12-bit or 8-bit) must be set. An A/D conversion is triggered by software only.

The MCN-8 counter/timer board has two functions available from software: clear counter and read counter. Writing to a counter will clear it while reading a counter will retrieve the current count in the register.

1.7 SUMMARY

The remainder of this manual covers the individual MetraBus controller boards and I/O function boards. The electrical interfacing and programming aspects of each board are explained.

All explanations and example programs are as if the I/O board is under the control of an MDB-64. The MDB-64 is a complete and simple implementation of the MetraBus concept. The MID-64 and REM-64 embody additional features, and are treated in this manual with programming examples for each.

The INTMDB-64 is an intelligent stand-alone driver/controller board for the MetraBus. It is usable as a dedicated, low-cost controller, or as a satellite controller monitored/controlled by a larger host computer. This board is described in the INTMDB-64 user's manual.

Schematics for the MetraBus are available in the MetraBus schematic package.

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MDB-64 DRIVER BOARD

2A.1 GENERAL

The MDB-64 driver board is the functional heart of the MetraBus system. This board supervises all I/O operations between the computer and MetraBus I/O boards within your system. Since the MBD-64 generates all necessary control signals, it controls system-level data transfer. Because of its design, a single MDB-64 is capable of addressing up to 64 MetraBus I/O boards. Figure 2A-1 is a functional block diagram of the MDB-64.

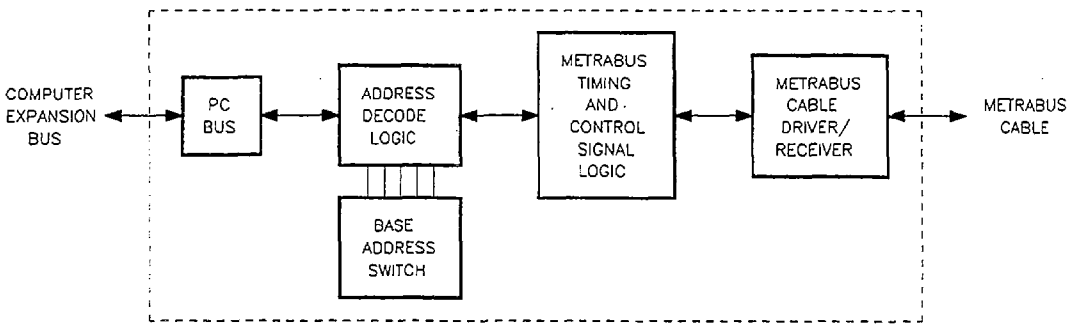


Figure 2A-1. MDB-64 Functional Block Diagram

The MDB-64 is a "half-slot" board that installs in any PC expansion slot. A 50-pin connector extends through the rear of the computer and connects to the MetraBus cable. Functionally, MetraBus has a parallel-bus architecture with the MetraBus cable carrying all data, address, and control signals, as well as distributing power to the MetraBus I/O boards. Ground conductors are interleaved between all signal lines to reduce system noise. The MDB-64 allows MetraBus cable lengths of up to 100 feet.

The MetraBus industrial data acquisition and control interface allows higher speed, greater accuracy, and total autonomous operation to otherwise slow and troublesome applications.

A.2 FEATURES

- Interfaces with IBM PC/XT, PC AT or other bus-compatible computers.
- Allows placement of MetraBus I/O boards at up to 100 feet from the computer.
- Compatible with many off-the-shelf software packages.
- Controls up to 512 digital I/O lines.
- Controls up to 256 (8 or 12-bit) A/D.
- Controls up to 64 (8-bit) DACs.

- Extremely cost effective.
- Adapts to your changing requirements.

2A.3 SPECIFICATIONS

Number of addressable MetraBus ports:	64
Maximum MetraBus data transfer rate:	80 kbytes/s
Maximum drivable cable length:	100 feet at full speed 200 feet at reduced speed
MetraBus cable type:	50 conductor ribbon cable
MetraBus connector:	3M 3425-6050
Power required:	+ 5 V: 250 mA typical, 325 mA maximum

2A.4 SETTING THE BASE ADDRESS SWITCH

The MDB-64 uses four consecutive locations in the PC I/O address space. This address space extends from decimal 512 to 1023. The MDB-64 base address switch is preset by the factory for 768 (300h), as shown in Figure 2A-2.

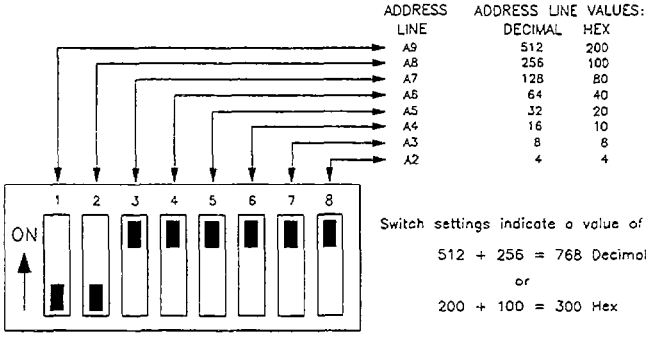


Figure 2A-2. Default Base Address Switch Settings. (768 decimal, 300h)

If I/O address 768 (300h) is occupied by another device, you must reset the base address switch. Refer to your PC manual for available addresses in the I/O space.

Once you have selected an address, change the base address switch accordingly. For assistance with the settings, use the INSTALL.EXE program provided on your MetraBus diskette.

> NOTE: Setting the base address to a location used by another device may cause erratic operation or PC system failure.

To run the INSTALL.EXE program, change to the appropriate directory and at the DOS prompt, and type **INSTALL** followed by [Enter]. When the program asks for the desired

base address, enter the new base address in decimal and press [Enter]. The program rounds your address to the nearest 4-bit boundary and checks for conflicts with other devices. Choosing an address less than 512 or greater than 1023 results in an error message. When the program determines an address is suitable, it displays the settings you must make on the Base Address Switch.

INSTALL.EXE performs an additional function: it generates a file named MBUS.ADR containing the newly selected Base Address Switch settings. The address in the file MBUS.ADR may then be read by application programs as an alternative to re-defining the MDB-64 address in every program. The following short BASIC program shows how to obtain the address from the MBUS.ADR file.

```
10 OPEN "MBUS.ADR" FOR INPUT AS #1
20 INPUT #1,BASADR
30 PRINT BASADR
40 CLOSE #1
```

The base address location is returned to the variable BASADR for use by your application program.

2A.5 INSTALLING THE MDB-64 FUSE (F1)

MBD-64 fuse F1 allows the PC to supply +5 VDC to the MetraBus I/O boards via the MetraBus cable. Large systems and those using +15 V will require an additional high-quality power supply such as the MBUS-PWR (see Contents). In this case, Fuse F1 must be removed. Failure to remove the fuse when using the MDB-64 with an external power supply causes the fuse to blow.

If the MetraBus System is to draw power from the PC power supply, the fuse F1 must be installed. This fuse is a Littlefuse #312001, 3AG 2A fast blow.

2A.6 INSTALLING THE MDB-64 DRIVER CARD

1. Unplug your computer.
2. Remove the cover of your computer and select any empty expansion slot. Remove the backplate from the selected slot. If you are using an IBM PC/XT, note that the MDB-64 does not operate correctly in the short expansion slot farthest to the right (J8) next to the power supply. This slot is reserved for the IBM expander card and is not available for peripherals since the bus signals are slightly different from the other slots.
3. Make certain that the base address switch is properly set and fuse F1 is installed/removed (as needed).
4. Insert the MDB-64 into a PC expansion slot. If needed, straighten the locking tabs on the ends of the connector prior to insertion.
5. Once the board is in place, plug the MetraBus cable into the MDB-64. Make sure the locking tabs are locked around the mating portions of the MetraBus connector. The mating portions of the connectors are keyed and should plug-in easily. Check the keyways for correct alignment prior to insertion. Avoid applying force to the connector.
6. Secure the MDB-64 backplate to the computer frame with a screw and replace the computer cover.

NOTE: The MDB-64 is shipped with two resistor networks. These termination resistors are to be installed in sockets RN1 and RN2 on the last MetraBus I/O board in your system. These resistor networks are used to minimize signal reflection due to long MetraBus cable lengths. They are optional, however, and have little effect for cables of 50 feet or less.

2A.7 THE MDB-64 METRABUS CONNECTOR

The MDB-64 passes information to and receives data from the MetraBus I/O boards via the MetraBus cable. Figure 2A-3 shows the physical and functional layout of this cable.

NOTE: The +15 VDC pins are active only when the MDB-64 is used in conjunction with an external power supply such as the MBUS-PWR.

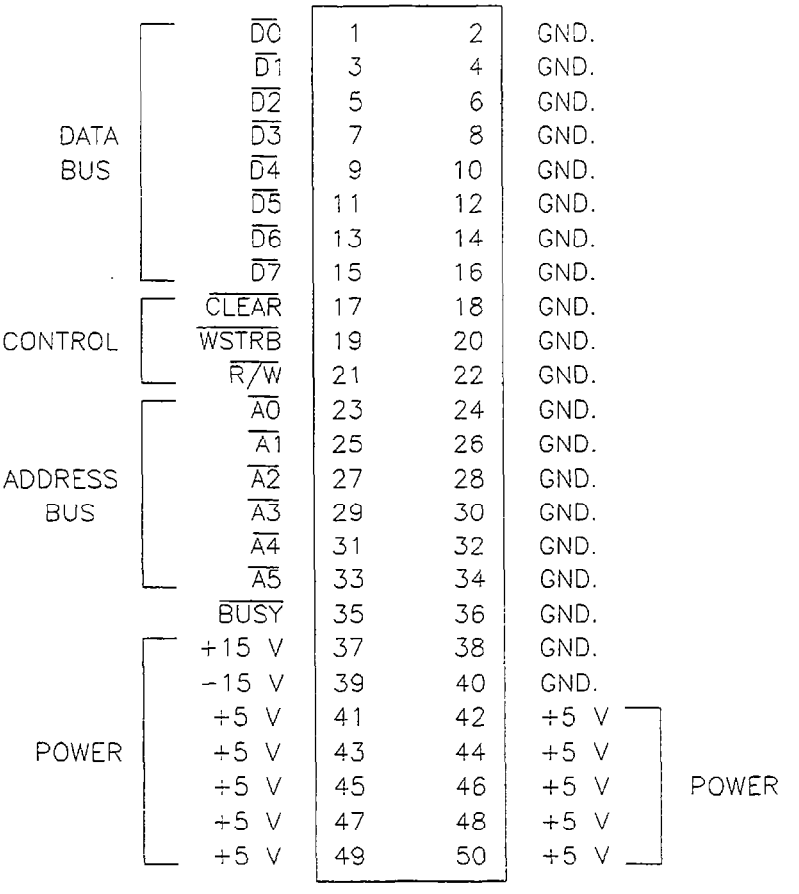


Figure 2A-3. MetraBus Connector Pinouts

2A.8 PROGRAMMING THE MDB-64

As mentioned earlier, the PC has I/O address locations for such things as disk drives, printers, serial ports, and other peripherals. The MDB-64 Base Address is located within this I/O space. The three MDB-64 locations and their functions are as follows:

LOCATION	I/O ADDRESS (Decimal)	Function
Base Address +0h	768	Data I/O path (DATAIO)
Base Address +1h	769	Address pointer (ADRPTR)
Base Address +2h	770	Software reset (MRESET)
Base Address +3h	771	Unassigned

For the sake of clarity, all references to specific address locations use the variable names DATAIO, ADRPTR, and MRESET as specified in the table above. Normally, variable assignments are made at the beginning of your application program. For example,

```
10 DATAIO = 768          'Declare data I/O location
20 ADRPTR = 769          'Declare address pointer location
30 MRESET = 770          'Declare RESET location
```

The following sections discuss address location functions in order of typical programming use. All references to the above locations assume a base address of 768 decimal (300h).

The Address Pointer (ADRPTR)

The function of the MDB-64 address pointer is to point to the specific MetraBus I/O board to be accessed. Each MetraBus I/O Board must have a unique, non-overlapping board address in order to identify it from other boards in the MetraBus system. (Refer to the section "Setting the board address" for the relevant I/O board.) Writing the board address to ADRPTR sets the current MetraBus address and targets the specific I/O board for use. Once the address pointer is set to a particular board address, data can be written to or read from that board. The BASIC commands INP and OUT control the read and write functions respectively. It should be noted that while the example are written using BASIC, many computer languages supporting data I/O operations may be used. Refer to the programming manual for the language that you are using for the correct syntax. The following example illustrates how to set the address pointer to a MetraBus I/O board (MEM-8) at address 12.

```
10 ADRPTR = 769          'Declare address pointer location
20 DATAIO = 768          'Declare data I/O location
30 MRESET = 770          'Declare MetraBus RESET location
40 MEM8 = 12             'Declare MEM-8 board address
50 OUT ADRPTR, MEM8      'Point to MEM-8 at address 12
```

Once the MetraBus address pointer is set, it does not change until another OUT command changes it. Setting the address pointer is a fast operation on the personal computer bus, taking less than 10 μs.

Remember that the address pointer is used to point to a MetraBus I/O board address. Since this address is latched on the MDB-64, it can be read back using the BASIC INP command, as follows:

```
60 ADDRESS = INP(ADRPTR)
```

The BASIC variable ADDRESS contains the current MetraBus I/O board address. If the above INP command were issued immediately after the previous OUT command, the ADDRESS variable would contain a valued of 12. Reading the address pointer returns six bits of address information and two bits of status information (R/W and BUSY), as shown below:

Address Byte

BIT	D7	D6	D5	D4	D3	D2	D1	D0
	BUSY	R/W	A5	A4	A3	A2	A1	A0

NOTE: The driver board inverts the polarity of the actual bus control signals.

Normally, the BUSY and R/W status bits are low (non-zero). When this is true, the data returned is identical to the contents of the address pointer. See *Programming The MDB-64 To Control The I/O Boards* for an example and an explanation of how to monitor the status bits.

The Data I/O Register (DATAIO)

Once the address pointer has been set, data may be written to and read from a MetraBus I/O board. All data transfer takes place through DATAIO. Accessing specific functions on the MetraBus I/O board and passing data back to the computer via DATAIO may be accomplished using the BASIC OUT command

```
70 OUT DATAIO, 128
```

This command calls for a value of 128 which might activate a relay on the MEM-8 relay board. The actual functions that it specifies is dependent on the board accessed.

You may read data from the data I/O with a single INP command, as follows:

```
80 DAT = INP(DATAIO)
```

The BASIC variable DAT contains data from the MetraBus I/O board previously targeted by the ADRPTR. All MetraBus output boards latch data sent to them and therefore, have data readable capability. This means that if the above INP command were issued after the previous OUT command, variable DAT would contain a value of 128.

The Software RESET (MRESET)

A software reset causes all MetraBus I/O boards connected to the MetraBus cable to be reset to a known state. See the description of the I/O board for more details. The following shows how to use the software RESET feature for all MetraBus I/O boards.

```
80  OUT MRESET, 00
90  START = TIMER
100 IF (TIMER - START) < .02 THEN 100
```

The BASIC Timer command is used to insure a wait of 20 ms for the reset pulse to finish.

Notes On The Use Of Compiled Or Assembled Languages

Execution speeds with compiled and assembled languages may call for precautions. As mentioned earlier, when reading the currently latched MetraBus I/O address, the lowest six bits contain address information while the two most significant bits carry status information.

Prior to any BASIC Inp or Out command, check the status bits (R/W and Busy). The following example shows the proper status checks.

```
10  DATAIO = 768                              'Declare I/O location
20  ADRPTR = 769                              'Declare address pointer location
30  MRESET = 770                              'Declare MetraBus RESET location
40  MAI16 = 8                                 'Declare MAI-16 board address
50  OUT MRESET, 00
60  START = TIMER                             'Input Time
70  IF (TIMER - START) < .02 THEN 70          'Wait 20 ms
80  IF (INP(ADRPTR) AND 192) THEN 80          'Check status
90  OUT ADRPTR, MAI16+2                       'Point to 8-bit A/D resolution
100 IF (INP(ADRPTR) AND 192) THEN 100         'Check status
110 OUT DATAIO, 18                            'Set gain to +5 V range on chan 2
120 IF (INP(ADRPTR) AND 192) THEN 120         'Check status
130 OUT ADRPTR, MAI16+1                       'Point to result of conversion
140 IF (INP(ADRPTR) AND 192) THEN 140         'Check status
150 AIN = INP(DATAIO)                         'Return result to computer
```

Programming The MDB-64 To Control The I/O Boards

As described above, the three MDB-64 I/O locations have quite distinct functions. Their order of execution generally follows a consistent pattern when programming any MetraBus I/O board. The following examples illustrate programming techniques used with both digital and analog I/O Boards. For programming information on a specific board, refer to the board description.

Digital I/O Boards

Digital I/O boards are the easiest to control. Data can be written to DATAIO soon after setting the address pointer. Digital output boards typically have several 8-bit ports. In the following example, a digital output board (MIO-32) is at board address 0 and the MDB-64 is at computer I/O Address 768 decimal (300h).

```
10 DATAIO = 768          'Declare data I/O location
20 ADRPTR = 769          'Declare address pointer location
30 MRESET = 770          'Declare MetraBus RESET location
40 MIO32 = 0             'Declare MIO-32 board address
50 OUT ADRPTR, MIO32     'Point to MIO-32 at address 0
60 OUT DATAIO, 255       'Output bit pattern 1111 1111
```

Lines 10 through 40 declare the locations of the MetraBus DATAIO, ADRPTR, and the MRESET functions, as well as declare the MIO-32 board address. Line 50 sets the address pointer to the MIO-32 digital output board. Line 60 outputs a value of 255 to the MIO-32, setting all outputs high.

Digital input board (MII-32) programming is similar to that for digital output boards. Digital input boards typically have several 8-bit ports. After the address pointer has been set, data can be read from the DATAIO, as follows:

```
10 DATAIO = 768          'Declare Data I/O Location
20 ADRPTR = 769          'Declare Address Pointer Location
30 MRESET = 770          'Declare MetraBus RESET Location
40 MII32 = 4             'Declare MII-32 Board Address
50 OUT ADRPTR, MII32     'Point to MII-32 at Address 4
60 DATIN = INP(DATAIO)   'Get data from DATAIO
```

Lines 10 through 40 declare the locations of the MetraBus DATAIO, ADRPTR, and the MRESET functions, as well as declare the MII-32 board address. Line 50 sets the address pointer to the MII-32 digital input board. Line 60 reads the contents of one of the four 8-bit ports on the MII-32 and stores the result in the BASIC variable DATIN.

Analog I/O Boards

Analog output boards (MAO-8) use one MetraBus I/O address per channel. Setting the Address Pointer to the appropriate address and writing data to the DATAIO will produce an analog output. The following example shows how to set the address pointer and output a voltage.

```
10 DATAIO = 768          'Declare Data I/O Location
20 ADRPTR = 769          'Declare Address Pointer Location
30 MRESET = 770          'Declare MetraBus RESET Location
40 MAO8 = 8              'Declare MAO-8 Board Address
50 OUT ADRPTR, MAO8      'Point to MAO-8 at Address 8
60 OUT DATAIO, 255       'Output Full Range Voltage
70 OUT DATAIO, 0         'Start A/D Conversion
80 OUT ADRPTR, MAI16     'Select the MSB's address
```

Lines 10 through 40 declare the locations of the MetraBus DATAIO, ADRPTR, and the MRESET functions, as well as declare the MAO-8 board address. Line 50 sets the address pointer to channel 0 of the MAO-8 board. Line 60 outputs the highest voltage possible for its selected range.

Analog Input boards (MAI-16) require additional steps, however, in order to set the gain and resolution for the desired channel prior to taking data. Assume an MAI-16 board has been set at Board Address 8.

```
10 DATAIO = 768          'Declare Data I/O Location
20 ADRPTR = 769          'Declare Address Pointer Location
30 MRESET = 770          'Declare MetraBus RESET Location
35 MAI16 = 8             'Declare MAI-16 Board Address
40 OUT ADRPTR, MAI16+2   'Point to 8-bit A/D resolution
50 OUT DATIO,18          'Set gain to + 5 V range on channel 2
60 OUT ADRPTR, MAI16+1   'Point to result of conversion
90 AIN = INP(DATAIO)     'Return result to computer
```

Lines 10 through 35 declare the locations of the MetraBus DATAIO, ADRPTR, and the MRESET functions, as well as declare the MAI-16 board address.

Line 40 selects the gain/channel selection mode for the board at address 8 (see MAI-16 description for full explanation).

Line 50 sets the gain to + 5V full scale range on channel 2.

Line 60 points to the 8-bit conversion mode for the board and channel previously selected.

Line 70 starts the A/D conversion process.

Line 80 points to the results of the A/D conversion.

Line 90 returns the result to the computer and stores the data in the variable AIN.

■ ■ ■

MID-64 DRIVER BOARD

2B.1 GENERAL

The MID-64 driver board optically isolates the computer bus from the MetraBus data acquisition and control system. The MID-64 supervises all I/O operations between the computer and MetraBus I/O boards within your system. All necessary control signals are generated within the MID-64, so you don't have to worry about system level data transfer. Because of its design, a single MID-64 is capable of addressing up to 64 MetraBus I/O boards. The MID-64 contains an on-board, programmable counter/timer capable of periodic system interrupt generation. This allows the MetraBus operation in a foreground/background mode emulating many common multitasking environments. A functional block diagram of the MID-64 is provided in Figure 2B-1.

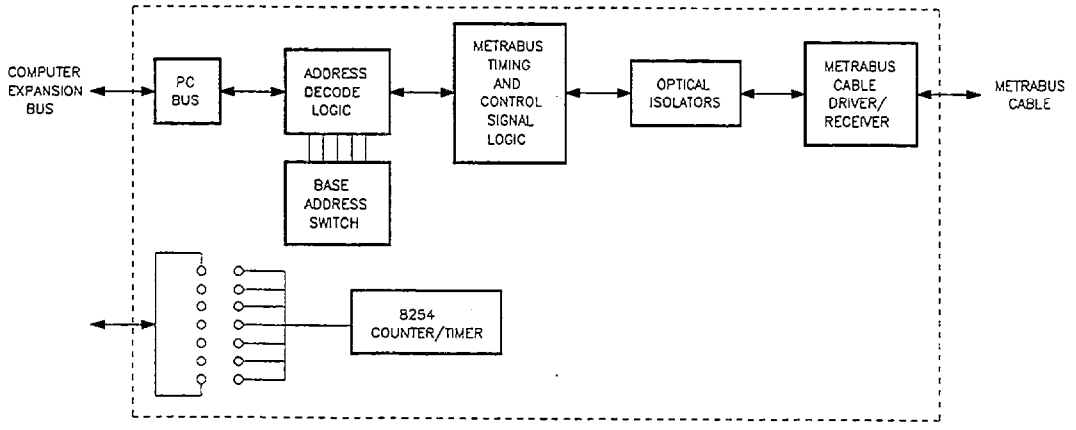


Figure 2B-1. MID-64 Functional Block Diagram

When installed, a 50-pin connector extends out the rear of the computer and connects to the MetraBus cable. Functionally, the MetraBus has a parallel bus architecture with the MetraBus cable carrying all data, address, and control signals, as well as distributing power to the MetraBus I/O boards. Ground conductors are interleaved between all signal lines to increase system noise immunity. The MID-64 has been designed to allow MetraBus cable lengths of up to 100 feet.

The MetraBus industrial data acquisition and control interface, in conjunction with your present computer, allows higher speed, greater accuracy, and total autonomous operation to previously slow, troublesome, applications.

2B.2 FEATURES

- Connects with IBM PC/XT, PC AT, or other bus compatible computers.
- Allows placement of MetraBus I/O at up to 100 feet from the PC.
- Full optical isolation to 500 Volts.
- Fully compatible with software written for the MDB-64 driver board.
- Interrupt generation capability.
- Controls up to 512 digital I/O lines.
- Controls up to 256 (8 or 12-bit) A/D.
- Controls of 64 (8-bit) DACs.
- Controls up to 64 counter/timers.
- Extremely cost effective.
- Adapts to your changing requirements.

2B.3 SPECIFICATIONS

Number of Addressable MetraBus Ports:	64
Maximum MetraBus Data Transfer Rate:	80 kbytes/s
Maximum Drivable Cable Length:	100 feet at full speed 200 feet at reduced speed
Power Required:	+ 5 V: 250 mA typical, 325 mA maximum
PC to MetraBus Isolation:	500 volts (minimum)

2B.4 SETTING THE BASE ADDRESS SWITCH

The MID-64 uses four consecutive locations in the PC I/O address space. This address space extends from decimal 512 to 1023. The MID-64 Base Address Switch is preset by the factory for 768 (300h), as shown in Figure 2A-2.

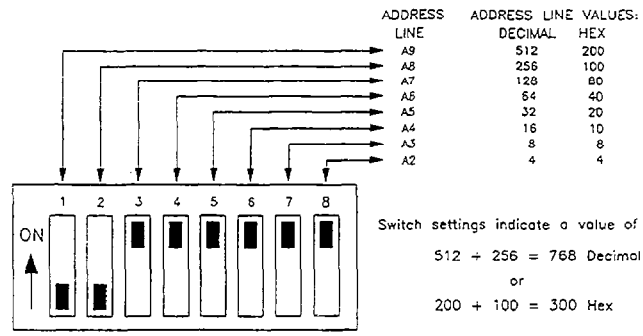


Figure 2B-2. Default Base Address Switch Settings. (768 decimal, 300h)

If I/O address 768 (300h) is occupied by another device, you must reset the base address switch. Refer to your PC manual for available addresses in the I/O space.

Once you have selected an address, change the base address switch accordingly. For assistance with the settings, use the INSTALL.EXE program provided on your MetraBus diskette.

> NOTE: Setting the base Aadress to a location used by another device may cause erratic operation or PC system failure.

To run the INSTALL.EXE program, change to the appropriate directory and at the DOS prompt, and type **INSTALL** followed by [Enter]. When the program asks for the desired base address, enter the new base address in decimal and press [Enter]. The program will round your address to the nearest 4-bit boundary and check for conflicts with other devices. Choosing an address less than 512 or greater than 1023 results in an error message. When the program determines an address is suitable, it displays the settings you must make on the base address switch.

INSTALL.EXE also generates a file named MBUS.ADR containing the newly selected base address switch settings. The address in the file MBUS.ADR may then be read by application programs as an alternative to re-defining the MID-64 address in every program. The following short BASIC program shows how to obtain the address from the MBUS.ADR file.

```
10 OPEN "MBUS.ADR" FOR INPUT AS #1
20 INPUT #1,BASADR
30 PRINT BASADR
40 CLOSE #1
```

The base address location is returned to the variable BASADR for use by your application program.

2B.5 USE OF THE AUXILIARY POWER SUPPLY

An auxiliary power supply such as the MBUS-PWR is required for operation of the MID-64, since it does not distribute power from the computer's supply. See the chapters of this manual dealing with the MBUS-PWR for specifications and installation instructions.

2B.6 INSTALLING THE MID-64 DRIVER CARD

1. Unplug your computer.
2. Remove the cover of your computer and select any empty expansion slot. Remove the back-plate from the selected slot.
3. Make certain that the base address switch is properly set.
4. Insert the MID-64 into the expansion slot. It may help to straighten the locking tabs on the ends of the connector prior to insertion.

5. Once the board has been inserted, plug the MetraBus cable into the MID-64. Make sure that the locking tabs are locked around the mating portions of the MetraBus connector. The mating portions of the connectors are keyed and should plug-in easily. Check the keyways for correct alignment prior to insertion. Avoid applying force to the connector.
6. Secure the MID-64 back-plate to the computer frame with a screw and replace the computer cover.

NOTE: The MID-64 is shipped with two resistor networks. These termination resistors are to be installed in sockets RN1 and RN2 on the last MetraBus I/O board in your system. These resistor networks are used to minimize signal reflection due to long MetraBus cable lengths. They are optional, however, and have little effect for cables of 50 feet or less.

2B.7 THE MID-64 METRABUS CONNECTOR

The MID-64 passes information to and receives data from the MetraBus I/O boards via the MetraBus cable. Figure 2B-3 shows the physical and functional layout of this cable.

NOTE: The +15 VDC pins are active only when the MID-64 is used in conjunction with an external power supply such as the MBUS-PWR.

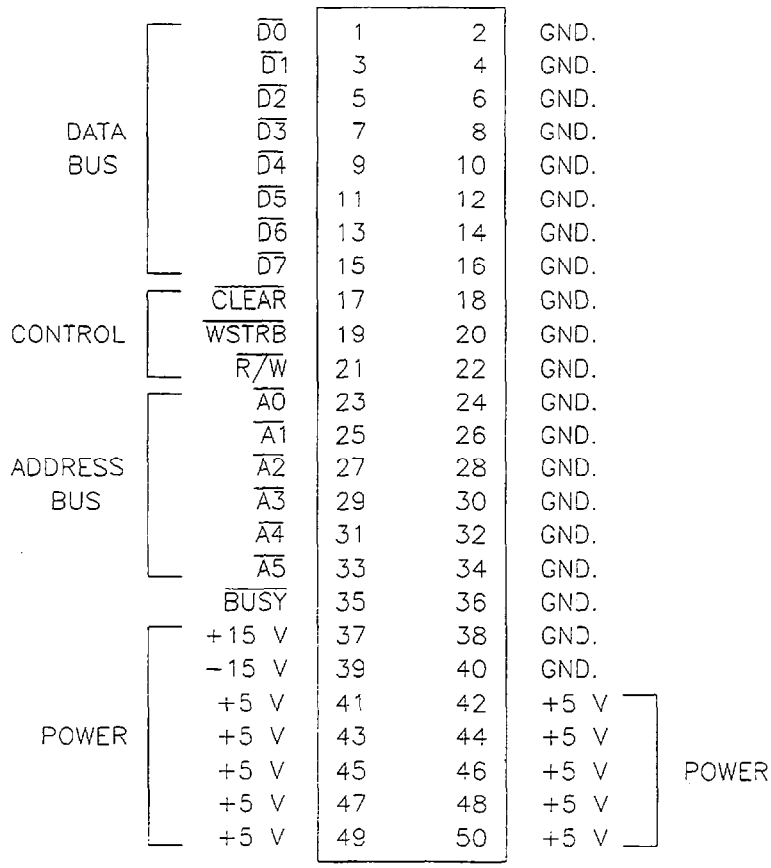


Figure 2B-3. The MetraBus Connector

2B.8 PROGRAMMING THE MID-64

As mentioned earlier, the PC has I/O address locations for such things as disk drives, printers, serial ports, and other peripherals. The MID-64 base address is located within this I/O space. The eight MID-64 locations and their associated functions are as follows:

LOCATION	I/O ADDRESS (Decimal)	Function
Base Address +0h	768	Data I/O pPath (DATAIO)
Base Address +1h	769	Address pPointer (ADRPTR)
Base Address +2h	770	Software rReset (MRESET)
Base Address +3h	771	Unassigned
Base Address +4h	772	Counter 0 (COUNT0)
Base Address +5h	773	Counter 1 (COUNT1)
Base Address +6h	774	Unassigned
Base Address +7h	775	Counter cControl (CNTCTRL)

NOTE: Most applications do not require counter/timer interrupt implementation. For those that do, a short section is included in this manual. The discussion below will deal with the majority of applications and will, for the moment, ignore interrupt implementation.

There are three important address locations:

Address pointer (ADRPTR)
Data I/O path (DATAIO)
Software reset (MRESET)

The following sections discuss address location functionality in order of typical programming use. All references to the above locations will assume a base address of decimal 768. For the sake of clarity, all references to specific address locations will use the variable names DATAIO, ADRPTR, and MRESET as specified in the table above. Normally, variable assignments are made at the beginning of your application program, as follows:

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

The Address Pointer (ADRPTR)

The function of the MID-64 address pointer is to point to the specific MetraBus I/O board to be accessed. Each MetraBus I/O board must have a unique, non-overlapping board address in order to identify it from other boards in the MetraBus system. (Refer to the section "Setting the Board Address" for the relevant I/O board.) Writing the Board Address to ADRPTR sets the current MetraBus address and targets the specific I/O board for use. Once the address pointer is set to a particular board address, data can be written to or read from that board. The BASIC commands INP and OUT control the read and write functions respectively. It should be noted that while the examples are written using BASIC, many computer languages supporting data I/O operations may be used. Refer to the programming manual for the

language that you are using for the correct syntax. The following example illustrates how to set ADRPTR to address 12 for a MEM-8 board:

```
10 ADRPTR = 769          'Declare address pointer location
20 DATAIO = 768          'Declare data I/O location
30 MRESET = 770          'Declare MetraBus RESET location
40 MEM8 = 12             'Declare MEM-8 board address
50 OUT ADRPTR, MEM8      'Point to MEM-8 at address 12
```

Once the MetraBus address pointer is set, it does not change until another OUT command changes it. Setting the Address pointer is a fast operation on the personal computer bus, taking less than 10 microseconds. Since this address is latched on the MID-64, it can be read back using the BASIC INP command, for example:

```
60 ADDRESS = INP(ADRPTR)
```

The BASIC variable ADDRESS contains the address of the MetraBus I/O board currently targeted. If the above INP command is issued soon after the previous OUT command, the ADDRESS variable would contain a value of 12. Reading the address pointer returns 6 bits of address information and two bits of status information (R/W and BUSY), as follows:

Address Byte

BIT	D7	D6	D5	D4	D3	D2	D1	D0
	BUSY	R/W	A5	A4	A3	A2	A1	A0

NOTE: The driver board inverts the polarity of the actual bus control signals.

Normally, the BUSY and R/W status bits will be low (non-zero). When this is true, the data returned is identical to the contents of the address bus. See *Programming The MID-64 To Control The I/O Boards* for an example and an explanation of how to monitor the status bits.

The Data I/O Register (DATAIO)

Once the address pointer has been set, data may be written to and read from a targeted MetraBus I/O board. All data transfer takes place through DATAIO. Accessing specific functions on the MetraBus I/O board and passing data back to the computer via DATAIO may be accomplished using the BASIC OUT command:

```
70 OUT DATAIO, 128
```

This command outputs a value of 128 which might activate a relay on the MEM-8 relay board. The actual functions that it specifies is dependent on the board accessed.

Data can be read from the Data I/O with a single INP command, as follows:

```
80 DAT = INP(DATAIO)
```

The BASIC variable DAT will contain data from the MetraBus I/O board previously targeted by the ADRPTR. All MetraBus output boards latch data sent to them and therefore, have data

readback capability. This means that if the above INP command were issued after the previous OUT command, variable DAT would contain a value of 128.

The Software RESET (MRESET)

A software reset causes all MetraBus I/O boards connected to the MetraBus cable to be reset to a known state. See the description of the I/O board for more details. The following shows how to use the software RESET feature for all MetraBus I/O boards.

```
80  OUT MRESET, 00
90  START = TIMER
100 IF (TIMER - START) < .3 THEN 100
```

The BASIC Timer command is used to insure a wait of 300 ms for the reset pulse to finish.

Notes On The Use Of Compiled Or Assembled Languages

The execution speed of compiled and assembled languages calls for precautions. As mentioned earlier, when reading the currently latched MetraBus I/O address, the lowest six bits contain address information while the two Most Significant Bits carry status information.

Prior to any BASIC Inp or Out command, you should check the status bits (R/W and Busy). The following example shows the proper status checks.

```
10  DATAIO = 768                          'Declare I/O location
20  ADRPTR = 769                          'Declare address pointer location
30  MRESET = 770                          'Declare MetraBus RESET location
40  MAI16 = 8                             'Declare MAI-16 board address
50  OUT MRESET, 00
60  START = TIMER                         'Input Time
70  IF (TIMER - START) < .3 THEN 70       'Wait 300 ms
80  IF (INP(ADRPTR) AND 192) THEN 80      'Check status
90  OUT ADRPTR, MAI16+2                   'Point to 8-bit A/D resolution
100 IF (INP(ADRPTR) AND 192) THEN 100     'Check status
110 OUT DATAIO, 18                        'Set gain to +5 V range on chan 2
120 IF (INP(ADRPTR) AND 192) THEN 120     'Check status
130 OUT ADRPTR, MAI16+1                   'Point to result of conversion
140 IF (INP(ADRPTR) AND 192) THEN 140     'Check status
150 AIN = INP(DATAIO)                     'Return result to computer
```

Programming The MID-64 To Control The I/O Boards

As described above, the eight MID-64 I/O locations have distinct functions. Their order of execution generally follows a consistent pattern when programming any MetraBus I/O board. The following examples illustrate programming techniques used with both Digital and Analog I/O Boards. Detailed programming information on a specific board, refer to the board description.

Digital I/O Boards

Digital I/O boards are the easiest to control. Data can be written to DATAIO soon after setting the Address Pointer. Digital output boards typically have several 8-bit ports. In the following example, a digital output board (MIO-32) is at board address 0 and the MID-64 is at computer I/O Address 768 decimal (300h).

```
10 DATAIO = 768          'Declare Data I/O Location
20 ADRPTR = 769          'Declare Address Pointer Location
30 MRESET = 770          'Declare MetraBus RESET Location
40 MIO32 = 0             'Declare MIO-32 Board Address
50 OUT ADRPTR, MIO32     'Point to MIO-32 at Address 0
60 OUT DATAIO, 255       'Output bit pattern 1111 1111
```

Lines 10 through 40 declare the locations of the MetraBus DATAIO, ADRPTR, and the MRESET functions, as well as declare the MIO-32 board address. Line 50 sets the address pointer to the MIO-32 digital output board. Line 60 outputs a value of 255 to the MIO-32, setting all outputs high.

Digital input board programming is similar to that for digital output boards. Digital input boards (MII-32) typically have several 8-bit ports. After the address pointer has been set, data can be read from the DATAIO, for example:

```
10 DATAIO = 768          'Declare Data I/O Location
20 ADRPTR = 769          'Declare Address Pointer Location
30 MRESET = 770          'Declare MetraBus RESET Location
40 MII32 = 4             'Declare MII-32 Board Address
50 OUT ADRPTR, MII32     'Point to MII-32 at Address 4
60 DATIN = INP(DATAIO)   'Get data from DATAIO
```

Lines 10 through 40 declare the locations of the MetraBus DATAIO, ADRPTR, and the MRESET functions, as well as declare the MII-32 board address. Line 50 sets the address pointer to the MII-32 digital input board. Line 60 reads the contents of one of the four 8-bit ports on the MII-32 and stores the result in the BASIC variable DATIN.

Analog I/O Boards

Analog output boards (MAO-8) use one MetraBus I/O address per channel. Setting the address pointer to the appropriate address and writing data to the DATAIO will produce an analog output. The following example shows how to set the address pointer and output a voltage.

```
10 DATAIO = 768          'Declare Data I/O Location
20 ADRPTR = 769          'Declare Address Pointer Location
30 MRESET = 770          'Declare MetraBus RESET Location
40 MAO8 = 8              'Declare MAO-8 Board Address
50 OUT ADRPTR, MAO8      'Point to MAO-8 at Address 8
60 OUT DATAIO, 255       'Output Full Range Voltage
```

Lines 10 through 40 declare the locations of the MetraBus DATAIO, ADRPTR, and the MRESET functions, as well as declare the MAO-8 board address. Line 50 sets the address pointer to channel 0 of the MAO-8 board. Line 60 outputs the highest voltage possible for its selected range.

Analog input boards (MAI-16) require additional steps, however, in order to set the gain and resolution for the desired channel prior to taking data. Assume an MAI-16 board has been set at Board Address 8.

```
10 DATAIO = 768          'Declare Data I/O Location
20 ADRPTR = 769          'Declare Address Pointer Location
30 MRESET = 770          'Declare MetraBus RESET Location
35 MAI16 = 8             'Declare MAI-16 Board Address
40 OUT ADRPTR, MAI16+2   'Point to 8-bit A/D resolution
```

```
50 OUT DATIO,18          'Set gain to + 5 V range on channel 2
60 OUT ADRPTR, MAI16+1 'Point to result of conversion
90 AIN = INP(DATAIO)    'Return result to computer
```

Lines 10 through 35 declare the locations of the MetraBus DATAIO, ADRPTR, and the MRESET functions, as well as declare the MAI-16 board address.

Line 40 selects the gain/channel selection mode for the board at address 8 (see MAI-16 description for full explanation).

Line 50 sets the gain to + 5V full scale range on channel 2.

Line 60 points to the 8-bit conversion mode for the board and channel previously selected.

Line 70 starts the A/D conversion process.

Line 80 points to the results of the A/D conversion.

Line 90 returns the result to the computer and stores the data in the variable AIN.

Interrupt Generation Via The 8254 Counter/Timers

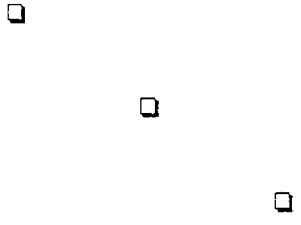
The following discussion is for MetraBus users familiar with the 8254 and its associated registers as well as IBM PC interrupts and interrupt service routines. See the 8254 Data Sheet for further information.

For this discussion, we will simply show how to generate the interrupt. It is left to the user to actually implement interrupt functionality. There are several good books dealing with IBM PC interrupts and how to service them as well as vector tables and related interrupt information, such as: Inside the IBM PC by Peter Norton and Assembler for the IBM PC and PC-XT by Peter Abel.

The MID-64 has an INTEL 8254 programmable interval timer I.C. in conjunction with a 6 MHz clock. The output from these counters may be connected to the PC bus. The counter can be programmed to generate periodic interrupts for any of the IBM PC interrupt levels 2 through 7. This allows an interrupt service routine to be controlling the MetraBus in the background while the computer is doing some other function in the foreground.

Timing is accomplished as follows: the output of counter 0 is cascaded to the input of counter 1 creating a 32-bit counter (this provides a maximum interrupt time of once every 11.9 seconds). The output from counter 1 is brought to the interrupt jumpers on the MID-64. There are typically 6 interrupt levels number 2 through 7, (level 1 is reserved). Level 2 has the highest priority if more than one peripheral is requesting interrupt service at the same time. To enable an interrupt request (IRQ), simply connect the counter output to the computer bus by placing the IRQ level jumper on the desired level. Then, write the desired control word to the 8254 control register. Next, point to counter 0 and/or counter 1 via the ADRPTR and write a data word (clock multiplier) to the high and low byte registers of the 8254. This sets up the timer. Writing to the base address +7 starts the timer.

■ ■ ■



µCMDB-64 DRIVER BOARD

2C.1 GENERAL

The µCMDB-64 MetraBus controller board allows you to integrate your IBM PC System 2 (PS/2) computer (models 50 through 80) with a MetraBus industrial data acquisition and control system. The MetraBus system is a low-cost solution for slow, troublesome data acquisition applications.

The µCMDB-64 Board supervises all I/O operations between the PS/2 and the MetraBus I/O boards in your system (refer to Chapter 1 for a list of compatible boards). One µCMDB-64 board controls up to 64 external MetraBus I/O boards. The µCMDB-64 is capable of controlling up to 512 Digital I/O lines, 256 (8 or 12 bit) A/D lines, and 64 (8 bit) D/A lines. All timing and control signals are generated from the µCMDB-64.

The µCMDB-64 is easily programmable using any of the following languages: C, BASICA, Microsoft Pascal, TURBO PASCAL, Assembly, or GWBASIC. A Utility Disk, containing sample programs, is provided with the µCMDB-64 to aid in creating custom programs.

2C.2 SPECIFICATIONS

Physical

Size:	11.50" L x 3.47" H (29.17 cm L x 8.61 cm H)
Weight:	18 ounces (509.40 g.)
MetraBus Cable Type:	50-Conductor Ribbon cable.
MetraBus Connector:	3M 3425-6050

Environmental

Operating Temperature:	+32 to +158° F (0 to +70° C)
Storage Temperature:	-104 to +212° F (-40° to +100° C)
Humidity:	0 to 95%, non-condensing

2C.3 USE OF AN AUXILIARY POWER SUPPLY

If you have more than one MCPT-8x8 or other MetraBus I/O boards installed in your MetraBus system or do not wish to use the PC +5 V power, an auxiliary power supply may be required. Refer to the MBUS-PWR sections for more information.

2C.4 SYSTEM CONFIGURATION

The µCMDB-64 design is in accordance with the IBM PS/2 POS (Programmable Option Select) rules and there are no user jumpers or switches. The Board Identifier Number (602Bh) is registered with IBM. If you need a special ID number for O.E.M. applications, contact our technical support department as instructed in *Instructions For Factory Returns* .

If you are familiar with installing peripheral boards in your PS/2, you may want to skim over most of this section. It is important, however, that you read the section *Configuring the System* . The system configuration procedure differs slightly from typical ones.

If you have never installed a peripheral board in your PS/2, you might find it helpful to have your PS/2 User's Guide handy.

Installing The Board

Before installing the µCMDB-64, be sure that you have created a working diskette containing the @602b.ADF file and the contents of the IBM PS/2 Reference Disk (provided with your computer). This section provides general instructions for installing the µCMDB-64 Board. For more detailed information regarding installation of peripheral boards, refer to the *Installing Options* section of the IBM Personal System/2 Model XX Quick Reference provided with your computer.

WARNING

DO NOT ATTEMPT TO INSERT OR REMOVE ANY ADAPTER BOARD WITH THE COMPUTER POWER ON, OR YOU RISK DAMAGING YOUR COMPUTER!

IBM PS/2 Model 50

To install the µCMDB-64 Board,

1. Turn off power to the PS/2 and to all attached options.
2. Unplug the power cords of the PS/2 and all attached options from the electrical outlets. Note where all the cables and cords are attached to the rear of the system unit, and disconnect.
3. Make certain the cover lock is unlocked.
4. Remove the cover of the PS/2.
5. Choose an available option slot. Loosen the screw at the base of the blank adapter plate. Then slide the plate up and out to remove.
6. Hold the µCMDB-64 in one hand. With the other hand, touch any metallic part of the PS/2 cabinet. This will safely discharge any static electricity from your body.

7. Align the gold edge connector with the edge socket and the back adapter place with the adapter plate screw. Note that a slot in the µCMDB-64 edge connector mates with a key in the socket, located at the front of the computer. Gently press the board downward into the socket. You may need to loosen the adapter plate screw more in order to push the board fully into the socket. Do not be concerned if µCMDB-64 connector does not use all sections of the socket connector. Re-tighten the adapter plane screw.
8. Replace the computer's cover. Tilt the cover up and slide it onto the system's base, making sure the front of the cover is under the rail along the front of the frame. Install the two mounting screws.
9. Plug in all cords and cables. Turn the power to the computer back on.

You should now be ready to configure your system.

IBM PS/2 Models 60 and 80

To install the µCMDB-64 Board,

1. Turn the power to the PS/2 and to all attached options OFF.
2. Unplug the power cords of the PS/2 and all attached options from the electrical outlets. Make a note of where all the cables and cords are attached to the rear of the system unit and disconnect.
3. Make certain the cover lock is unlocked.
4. Loosen the two cover screws with a coin (these screws should remain in the cover). Remove the cover.
5. Choose an available option slot. Loosen the screw on the expansion slot cover. Then, slide the cover out and remove. Store the cover in a safe place for future use.
6. Hold the µCMDB-64 in one hand. With the other hand, touch any metallic part of the PS/2 cabinet. This will safely discharge any static electricity from your body.
7. Firmly press the µCMDB-64 board into the expansion slot connector until the adapter clicks into place. Then, tighten the screw.
8. Find the square cut-outs in the bottom of the computer cabinet. Align the cover latches with the cut-outs and install the cover. Tighten the two cover screws using a coin.
9. It is suggested that you lock the cover to help protect the devices and options inside the computer.
10. Connect all cables and cords to the rear of the computer. Then, plug all computer power cords into electrical outlets.

You should now be ready to configure your system.

Power Supply To The MetraBus

Because PS/2 design specifications limit power draw from the MicroChannel Bus, power for the MetraBus system must come from an external supply. The presence of an active power supply to the MetraBus can be monitored, however, by using the power supply control register.

The µCMDB-64 is electro-optically coupled to the +15 volt line of the MetraBus. If the + 15 volts is absent, a bit in the control register will be read high (1). Note that a low control bit does not insure that the +15 volts is within specification nor that the + 5 and -15 volts are present at all.

Creating a Back-Up Disk

Before you do anything with the µCMDB-64, it is strongly advised that you back-up your IBM PS/2 model XX reference disk and the MetraByte CMDR-64 utility disk. This procedure is detailed in the IBM PS/2 operator's manual and is briefly outlined in this section.

To copy the reference disk, make certain you have a blank, unformatted, 2.0 MB high-density disk. Then,

1. Turn OFF the power to your computer.
2. Place the reference disk into the floppy disk Drive A.
3. Turn ON the power to your computer.
4. The IBM logo will now be displayed. Press [Enter].
5. The IBM PS/2 main menu will appear. Select

   `2. Backup the Reference Diskette`

6. The IBM PS/2 will prompt you through the backup procedure. When you receive the `Copy complete....` message, remove the copy of the Reference Disk. Label the copy and use this from now on. DO NOT WRITE-PROTECT THIS DISK! Be sure to place the original Reference Disk in a safe place.

Making a Working Copy

Because your original reference disk is write-protected, you can not copy any .ADF files onto it. Therefore, you must use the copy of the reference disk you created. Gather your copies of the reference disk and the utility disk and follow these steps:

1. Turn the power to your computer OFF.
2. Place the copy of the reference disk in floppy disk Drive A.
3. Turn the power to your computer ON.
4. The IBM logo will now be displayed. Press [Enter].
5. The IBM PS/2 main menu will appear. Select

   `5. Copy an Option Diskette`

   Press [Enter].
6. The PS/2 will prompt you through creating a working disk. When `Copy complete...` appears, turn OFF the power to the computer.

You are now ready to install the µCMDB-64 Board.

Configuring The System

Before configuring your system, you should have made a working diskette and installed the µCMDB-64 Board. To configure the µCMDB-64 Board,

1. With your computer OFF, place the working disk in floppy disk Drive A.
2. Turn ON the power to the computer. The computer will now run its memory check. After the memory check has been run, the Error Code `165... Adapter Configuration Error` appears followed by two beeps. This indicates that the computer has recognized a change of configuration. Press [Enter].
3. You now need to configure the system. If your current system configuration allows you to assign a base address of 300h to the µCMDB-64 Board, you can automatically configure the system. To do this, at the prompt `Run Automatic Configuration` press `Y`.
4. If a base address other than 300h must be assigned, press `N` at the `Run Automatic Configuration` prompt. This returns you to the main menu.
5. In the main menu, select

   `3. Set Configuration`

6. This enters you into the configuration menu. Select

   `2. Change Configuration`

7. Use the cursor keys to scroll down through the configuration list until you reach `MetraByte µCMDB-64 MetraBus Controller` with the slot in which it is installed. Highlight the base address. Use [F5] and [F6] to select the desired address.

   If you need help making this decision, press [F1].

8. Press [F10] to store the configuration in RAM.
9. Remove the working disk from the drive and store it in a safe place.

The system should now be configured. Upon power-up, the computer will boot normally and you will have full use of the µCMDB-64.

> NOTE: Although the µCMDB-64 is capable of supporting up to 255 choices of Base Addresses, its @602b.ADF file contains only 16. This is because IBM's setup program allows a choice of only 16 different Base Addresses. If you wish to use a base address other than what appears in the menu, you can modify the @602b.ADF file.

Modifying The @602B.ADF File

IBM's configuration program allows 16 possible choices for each selection. In the case of the base address, the µCMDB-64 supports 255 possible choices for any named item. If the default selections are not to your liking, use the GENADF.EXE to generate a .ADF file including your choices of base addresses. Be sure to copy the .ADF file to your working disk and proceed with the configuration procedure described above.

Common Configuration Errors

If you have taken short cuts and skipped steps, you may have already encountered an error message. Table 4-1 lists and describes some of the most common errors.

Table 4-1. Common Configuration Errors

ERROR MESSAGE	MEANING	SOLUTION
165	Computer doesn't recognize the adapter board.	Re-Install and Configure the system.
* **Conflict**	Two adapter boards have been assigned the same address.	Select another address for the µCMDB-64 board.
Setup cannot find the appropriate .ADF file	.ADF does not appear to be on the working disk.	Verify that the .ADF file has been copied to the working disk.
Setup cannot read the .ADF file.	The .ADF file has been altered using the incorrect syntax.	Use GENADF.EXE to alter the .ADF file.

System Connections

This section describes the connectors and cables used in making the system connections. The CMDR-64 is equipped with a DB37P connector which is used to interface the board to the MetraBus. Figure 2C-1 describes each signal conductor in the connector.

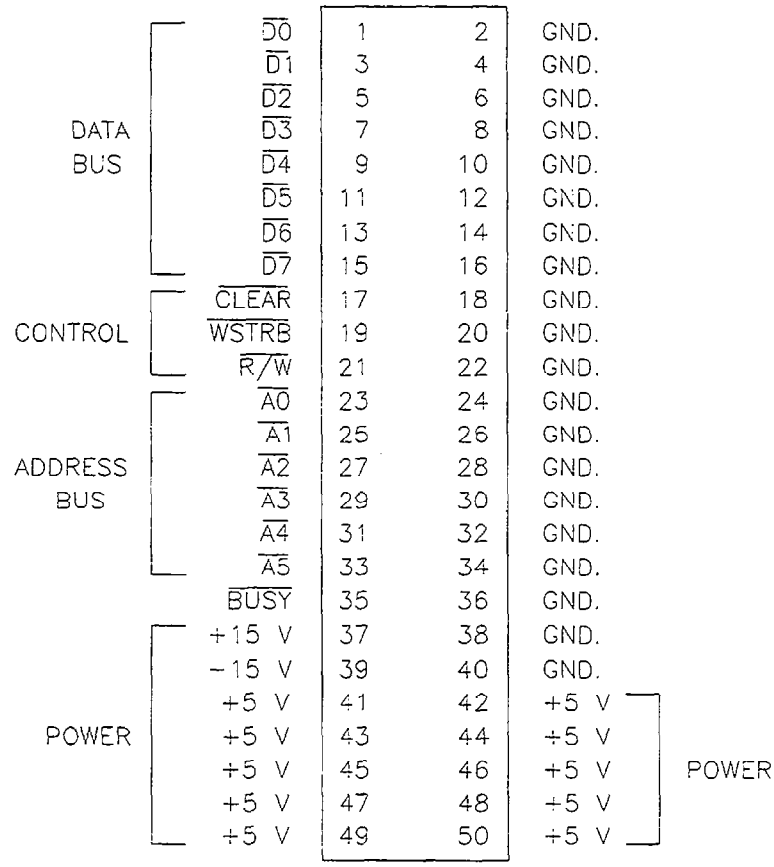


Figure 2C-1. MetraBus Connector Pin-outs

Once you have installed the µCMDB-64 Board and have configured it properly, you will need to connect the Board to the MetraBus I/O Boards Make this connection using either the MetraBus adapter cable (MetraByte Part #UCM-37-50) or a 37-Pin MetraBus cable (MetraByte Part #UCM-10-4-7).

If you are using the 37-Pin MetraBus cable, plug the end with the 37-pin D-type connector into the 37-pin connector on the back of the µCMDB-64 board. Then connect the other end to the MetraBus.

If you have elected to use the adapter cable, you will also need a standard MetraBus cable. Plug the end of the adapter cable with the 37-pin connector into the connector on the rear of the µCMDB-64 board. Then, connect the other end (with 50-pin connector) into one end of the standard MetraBus cable.

2C.5 PROGRAMMING

This section describes how to program the µCMDB-64. Examples are provided when necessary to clarify syntax or programming procedures.

Sample Programs

The utility disk provided with your µCMDB-64 contains additional sample programs illustrating the features of the various MetraBus I/O boards. Refer to these programs if you have any difficulty programming the µCMDB-64 to accomplish a specific task.

The sample programs and their descriptions can be accessed by typing: BASICA MENU at the system prompt. You are then presented with a menu of MetraBus I/O Boards. Select the appropriate board by following the instruction list on your computer screen. After you select a board, an introductory description of the program will appear. Then, follow the instructions on the screen to run the program.

Using The µCMDB-64 To Control The MetraBus

The PS/2 has I/O locations for such things as disk drives, printers, serial ports, and other peripherals. The µCMDB-64 base address is located within this I/O space. The µCMDB-64 responds to four byte addresses during normal operation. Table 4-2 describes these.

Table 4-2. µCMDB-64 I/O Addresses

I/O ADDRESS	FUNCTION	VARIABLE NAME	READ DATA	WRITE DATA
Base Address +0	Data I/O Path	DATAIO	Data In	
Base Address +1	Address Pointer	ADRPTR	Address + Status	Data Out
Base Address +2	Power Check/Reset	MRESET	POS Byte 102	Address
Base Address + 3*				Reset

* This address is unassigned.

All references to specific address locations will use the variable names DATAIO, ADRPTR, and MRESET as indicated in Table 3-1. Normally, variable assignments are done at the beginning of your application program. For example:

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

The following sections discuss address location functions in order of typical programming use. All references to the above locations assume a base address of 768 decimal (300h).

The Address Pointer (ADRPTR)

The µCMDB-64 Address Pointer points to a specific MetraBus I/O Board function to be accessed. Most MetraBus I/O boards respond to more than one address (typically 4 or 2) corresponding to different registers on the same board. Writing or reading to the different registers on a board initiates different actions or transfers different sets of data. Each MetraBus I/O board must have a set of unique, non-overlapping addresses to identify it from the other boards in the MetraBus system. The set of addresses for a board is set by a switch which determines the board base address. (Refer to the section of the MetraBus manual describing the specific I/O board.) The base address fixes the address of the first board register and the address of successive registers is found by adding 1 to the previous address.

Once the MetraBus address pointer is set, it does not change until another OUT command changes it. The actual time necessary for the address pointer to latch and stabilize the MetraBus address is less than 10 microseconds.

The address pointer is used to point to a MetraBus I/O board address. Since this address is latched on the CMDR-64, it can be read back using the BASIC INP command, for example 60 ADDRESS = INP(ADRPTR). Reading the address pointer returns 6 bits of address information and two bits of status information. These status bits are R/W and BUSY as shown in the following diagram.

Address Byte

BIT	D7	D6	D5	D4	D3	D2	D1	D0
	BUSY	R/W	A5	A4	A3	A2	A1	A0

NOTE: The driver board inverts the polarity of the actual bus control signals.

Normally, the BUSY and R/W status bits are low (zero). When this is true, the data returned is identical to the contents of the address bus.

Example 1. Setting an Address Pointer

The following example illustrates how to set the address pointer to a MetraBus I/O board (MEM-8) at address 12.

```
  10 ADRPTR=769       'Declare Address Pointer
Location
  20 DATAIO=768       'Declare Data I/O Location
  30 MRESET=770       'Declare MetraBus Reset Location
  40 MEM8 = 12        'Declare MEM-8 Board Address
  50 OUT ADRPTR, MEM8 'Point to MEM-8 at Address 12
```

The Data I/O Register (DATAIO)

Once the address pointer has been set, data may be written to and read from a MetraBus I/O board. All data transfer takes place through the DATAIO. Accessing specific functions on the MetraBus I/O board and passing data back to the computer via the DATAIO may be accomplished using the BASIC OUT command, for example 70 OUT DATAIO, 128. This command outputs a value of 128 which might, for example, activate a relay on the MEM-8 relay board. The actual function that it specifies is dependent upon the board accessed.

Data can be read from the Data I/O with a single INP command, as follows:

```
80 DAT = INP(DATAIO)
```

The BASIC variable DAT contains data from a MetraBus output board. This means that if the above INP command is issued after the previous OUT command, variable DAT will contain a value of 128.

Power Check/Software RESET (MRESET)

A software reset causes all MetraBus I/O boards connected to the MetraBus cable to be reset to a known state.

Example 2. Programming a Software RESET

The following example illustrates use of the software RESET feature for all MetraBus I/O boards. Note that the value 00 is an arbitrary value and has no significance except as a space marker following the mandatory comma.

```
80 OUT MRESET, 00
```

Checking the Power Supply to the MetraBus

The MRESET value also allows you to read Bit 7 of the POS byte 102. This contains the state of the + 15 volt power supply. If the bit contains a 1, power is OFF. If the bit holds a 0, then the power is ON.

Note that the absence of a status bit does not guarantee the quality of the power supply. Its main utility is to determine if the remote power supply has been inadvertently shut-off.

By ANDing 128 with the read MRESET Address, the state of the external power supply can be determined, for example:

```
70 STATUS = INP(MRESET) AND 128 'check power status bit
80 IF STATUS = 1 THEN PRINT "POWER OFF";    'flag problem
```

Programming The µCMDB-64 Board

The three µCMDB-64 I/O locations have distinct functions. Their order of execution generally follows a consistent pattern when programming any MetraBus I/O board. The following is a brief overview of programming techniques associated with the various types of I/O boards. Detailed information concerning programming of specific boards are provided later in this manual.

Digital I/O Boards

Digital I/O boards are the easiest boards to control. Data can be written to DATAIO immediately after setting the address pointer. Both digital output and digital input boards typically have several 8-bit ports.

Example 3. Programming a Digital Output Board

In this example, a digital output board (MIO-32) is at Board Address 0 and the µCMDB-64 is at base address 768 (decimal).

- Lines 10 - 40 declare the locations of the MetraBus DATAIO, ADRPTR, and the MRESET functions, as well as declare the MIO-32 board address.
- Line 50 sets the address pointer to the MIO-32 digital output board.
- Line 60 outputs a value of 255 (decimal) to the MIO-32 setting all outputs high.

```
10 DATAIO = 768     'Declare Data I/O Register
20 ADRPTR = 769     'Declare Address Pointer location
30 MRESET = 770     'Declare RESET address
40 MIO32 = 0        'Declare MIO-32 board address
50 OUT ADRPTR, MIO32      'Point to MIO-32 at address 0
60 OUT DATAIO, 255 'Output bit pattern `1111 1111`
```

Example 4. Programming a Digital Input Board

In this example, the digital input board (MII-32) board address 0 and the µCMDB-64 is at base address 768 (decimal).

- Lines 10 - 30 declare the locations of the MetraBus DATAIO, ADRPTR, and the MRESET functions.
- Line 40 declares the board address of the MII-32.
- Line 50 sets the address pointer to the MII-32.
- Line 60 reads the contents of the 8-bit port and stores the result in the BASIC variable DATIN.

```
10 DATAIO = 768     'Declare Data I/O Register
20 ADRPTR = 769     'Declare Address Pointer location
30 MRESET = 770     'Declare RESET address
40 MII32 = 4        'Declare MII-32 board address
50 OUT ADRPTR, MII32      'Point to MII-32 at address 4
60 DATIN = INP(DATAIO)    'Store contents of 8-bit port in DATIN
```

Analog Boards

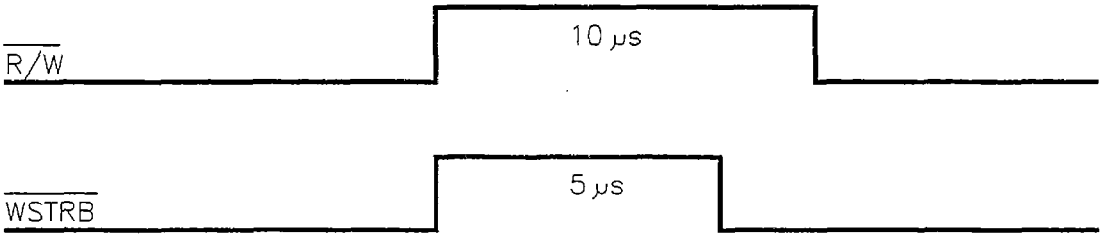
Analog output boards use one MetraBus address per channel. Setting the address pointer to the appropriate address and writing data to the DATAIO will produce an analog output (refer to Example 5).

Analog input boards require additional steps, however, in order to set the gain and resolution for the desired channel prior to taking data. Refer to Example 6 for an illustration of programming an Analog input board.

Using Compiled Or Assembled Languages

Execution speeds with compiled and assembled languages may call for precautions. As mentioned earlier, when reading the currently latched MetraBus I/O address, the lowest six bits contain address information while the two most significant bits carry status information.

The R/W bit goes high (non-zero) during a data write transfer for 10 microseconds. Additional data should not be written or read from the DATAIO while the R/W status bit is non-zero. The address pointer can be read, however, to determine when the R/W status bit returns to zero. 10 microseconds is very fast compared to BASIC interpreter execution speed for compiled (including BASIC) and assembled languages. Therefore, the R/W bit should be monitored in all non-interpreted computer languages. Refer to the following timing diagram for visualization of this sequence.



Several MetraBus boards use the BUSY status bit to indicate that their data is not ready for reading. Two such examples are the MAI-16 and the MTHERM-16 boards. The following diagram shows the BUSY bit for the MAI-16.

NOTE: The actual bus signals are inverted from the status bits and waveforms shown above. Note also that the WSTRB signal is a hardware feature and can not be found via software.

When monitoring the status bits or when only status information is required, ANDing the address pointer with 192 ($2^7 + 2^6 = 192$) returns the desired status information, as follows:

```
90 STATUS = INP(ADRPTR) AND 192
100  PRINT STATUS
```

The BASIC variable STATUS contains either 0, 64, 128, or 192 indicating the state of the D7 and D6 (the two MSBs) bits.

Device Interface

To aid the user in writing software for the µCMDB-64, on the PS/2, a device interface is included in the µCMDB-64 demo programs. The interface is essentially a device driver which can pass the base address to user-written code. The interface greatly aids the user in porting code from computer to computer with possibly different µCMDB-64 board settings.

The device interface gets installed during boot-up of the computer. The interface can handle up to five different µCMDB-64 boards in the system. The following is sample syntax for loading the device interface in the DOS CONFIG.SYS file with the first board at address 300h.

```
DEVICE = MDB64DI.SYS/B:&h300 [/B:BASE #2.../B:BASE #5]
```

In this case, the MDB64DI.SYS file is assumed to be in the boot drive. A path may be added to search for the file in other directories. The /B: tells the driver that the number following is a base address in either hex "&H" or decimal format. The driver requires at least one µCMDB-64 to be present and checks each µCMDB-64 base address against values stored in the PS/2 Programmable Option Select (POS) registers. After finding a match, the device interface goes on to match the next base address in line. If an error is encountered, the computer will beep and display the text in question with an explanatory message.

The ECONFIG.EXE program generates a new CONFIG.SYS file while preserving the old in a file called CONFIG.BAK. Before running ECONFIG.EXE, make sure that the device interface program MDB64DI.SYS is on your boot disk.

To read information about an individual µCMDB-64 once all µCMDB-64s check successfully, a unique ID name is opened and can be read like a file with a record size of four bytes. During boot-up, the interface assigns an ID name starting from "MDB64ID1" up to "MDB64ID5," corresponding to each Base Address appearing in the CONFIG.SYS file. Note that the interface accepts ID name "MDB64ID" which always returns information about the µCMDB-64 referenced by "MDB64ID1". In BASIC, this would look as follows:

```
xxx00 OPEN "MDB64IDx" AS #1 LEN=4 'open device interface for board x
xxx10 FIELD #1,2 AS B$,2 AS H$    'describe the interface record
xxx20 GET #1                'read in the interface information
xxx30 BASE=CVI(B$)          'GET base address to an integer
xxx40 HOS=CVI(H$)           'GET host 0 - PC/AT, 1 - PS/2
```

POS Byte Format

This section describes the POS (Programmable Option Select) addresses to which the µCMDB-64 will respond upon power-up. Table 4-3 lists and describes each POS byte address used.

Table 4-3. POS Byte Addresses

POS ADDRESS(hex)	FUNCTION/FORMAT
100	Returns 2BH - low byte of ID (Read Only)
101	Returns 60H - high byte of ID (Read Only)
102	Card Enable (Read/Write) Bit 7: MetraBus Power Status (1 = OFF, 0 = ON) Bits 1-6: not used (Read as 1's) Bit 0: Card Enable
103	Base Address (Read/Write) Bits 0-7: Top byte of base address Bottom byte of base address always 0
104 and up	Not implemented

The PS/2 interrogates the I/O cards to determine their type by reading the lower two bytes of the board registers. The third byte is a control register with the bit assignments as indicated in Table 4-4 (it can also be read at base address +2).

Table 4-4. Third Byte Bit Assignments

BIT NO.	DESCRIPTION
0	Card Enable (R/W)
1 - 6	Unused (Read as 1)
7	MetraBus Power Status (RO) (1 = Off, 0 = On)

The fourth byte contains the high byte of the µCMDB-64 address.

■ ■ ■

REM-64 DRIVER BOARD

2D.1 GENERAL

The REM-64 is one of four available controller/driver boards for use with the MetraBus industrial data acquisition and control system. As the serial communication card for the MetraBus, it allows MetraBus compatibility with virtually all makes and models of computers regardless of manufacturer. Remote control of the MetraBus system is possible for distances of up to 5000 feet. Data transfer rates of up to 19.2 kBaud are attainable between the computer and the REM-64 while internal MetraBus data transfer rates exceed 80 kBaud.

RS-232C and (20 mA current loop) and RS-422 protocols are supported with user selectable baud rate, bus control signal enable/disable (CTS, RTS, DTR, etc.), parity check, data format echo/no echo, etc. Every REM-64 has two RS-232 and two RS-422 I/O ports allowing up to 16 REM-64s to be operated from a single computer I/O port. Two LEDs on the REM-64 indicate the status of the on-board microprocessor, as well as the activity status of the REM-64 (whether it is the currently active REM-64). A functional block diagram of the REM-64 is provided in Figure 2D-1.

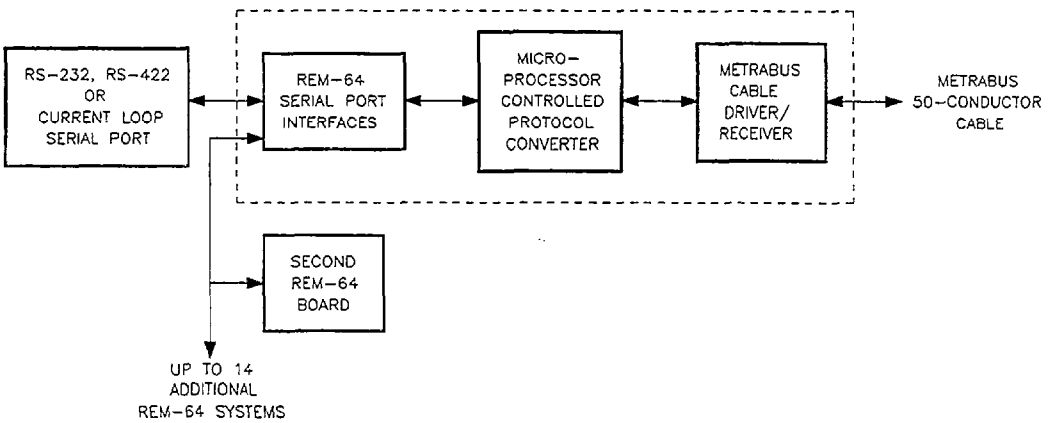


Figure 2D-1. REM-64 Functional Block Diagram

The REM-64 supervises all I/O operations between the computer and MetraBus I/O boards within your system. All necessary control signals are generated within the REM-64 so that the user need not be concerned with system-level data transfer.

A 50-pin connector on the REM-64 connects to the MetraBus I/O boards via the MetraBus cable. Functionally, the MetraBus has a parallel-bus architecture with the cable carrying all data, address, and control signals as well as distributing power on the MetraBus. Ground conductors are interleaved between all signal lines to increase system noise immunity. The MetraBus has been designed to allow cable lengths of up to 100 feet.

The MetraBus industrial data Aaquisition and control system in conjunction with your present computer allows higher speed, greater accuracy, and totally autonomous operation in previously slow, troublesome applications.

2D.2 FEATURES

- Connects to virtually all computers regardless of manufacturer.
- MetraBus remote operation up to 1.2 km.
- Baud rates up to 19,200 bits per second.
- Control up to 16 MetraBus systems from one serial port.
- Control up to 512 Digital I/O lines per system.
- Control up to 256 (8 or 12-bit) ADCs per system.
- Control of 64 (8-bit) DACs per system.
- Extremely cost effective.
- Adapts to your changing requirements.

2D.3 SPECIFICATIONS

Number of Serial I/O Ports:	(2) RS-232C and 20 mA Current Loop (2) RS-422A
Serial Port Configuration:	Data Terminal Equipment (DTE)

Power Consumption

+5 Volts:	285 mA (typical), 325 mA (max.)
+15 Volts:	30 mA (typical), 45 mA (max.)
-15 Volts:	30 mA (typical), 45 mA (max.)

Environmental

Operating Temperature:	0 to 70° C
Storage Temperature:	-55 to +125° C
Humidity:	0 to 95%, noncondensing

Physical

Size:	16 x 4.75 inches (40.63 x 12.06 cm)
MetraBus Cable Type:	50-conductor ribbon cable
MetraBus Connector:	3M 3425-6050

2D.4 SWITCHES

This section describes the board address switch, serial bus selection switch, and the protocol selection switch.

The REM-64 Board Address Switch

The multi-drop design of the REM-64 allows control of up to 16 REM-64s from a single computer serial port. Every REM-64 must have a distinct bus address in order to differentiate it from other REM-64s on the serial bus. Available bus addresses range from 0 to 15 and are selected via the board address switch located to the far left of the REM-64. The numbers silk-screened above the switch assembly indicate the values of the switches immediately below them. The numbers have value only in the ON position. Setting the board address switch is a matter of selecting an unused address and setting the corresponding switch(es) ON. For example, in order to set a bus address of 4, the switch with the value of 4 immediately above it would be turned ON while the others would be OFF. Figure 2D-2 shows the board address switch set for a bus address of 10.

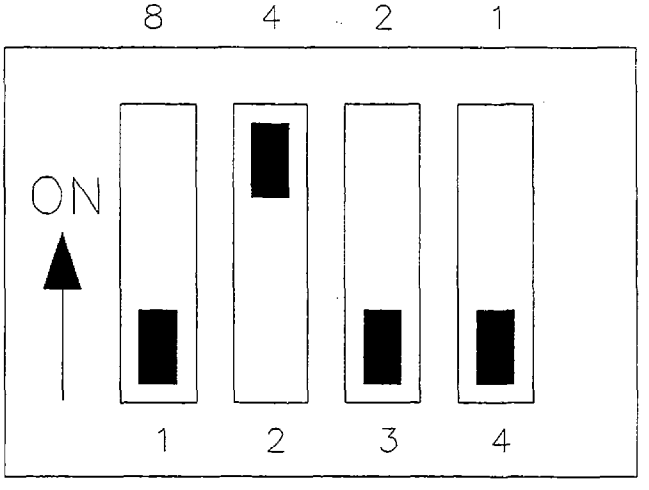


Figure 2D-2. Setting the Board Address Switch

The Serial Bus Selection Switch

The serial bus selection switch is a 3-gang DIP switch located to the right center of the REM-64 driver card. There are three available serial bus choices: RS-232C, RS-422, and 20 mA current loop configuration. You are not required to understand these three bus configurations to operate the REM-64 since your choice is dictated by the available serial interface of your computer. Check the technical reference manual for your PC to determine which of the three interfaces you will use. Then, set the REM-64 serial bus selection switch accordingly. (See Figure 2D-3.)

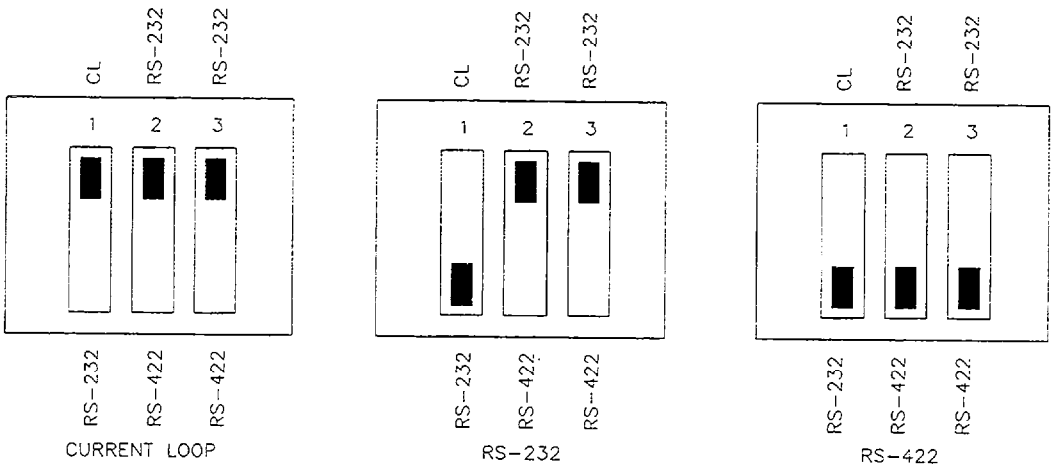


Figure 2D-3. Setting the Serial Bus Address Switch

The Protocol Selection Switch

The REM-64 design provides maximum serial protocol flexibility. The protocol select switch is an 8-gang DIP switch, located to the center left of the REM-64. This switch allows user selection of data transfer rate (Baud rate) , parity, # of data bits, echo on/off, and enable disable of various bus control lines. For the purpose of operating the MetraBus system, it is not necessary that you understand the protocol terms or even their functionality. However, some of these are explained in the serial communication tutorial provided in Appendix A.

Check the technical reference manual for the computer and/or serial interface card that you are using to find out which lines are implemented at the computer end of things. Once you have this information, set the switches on the REM-64 protocol select switch (See Figure 2D-4.) to match. Table 2D-1 lists the switches and their functions.

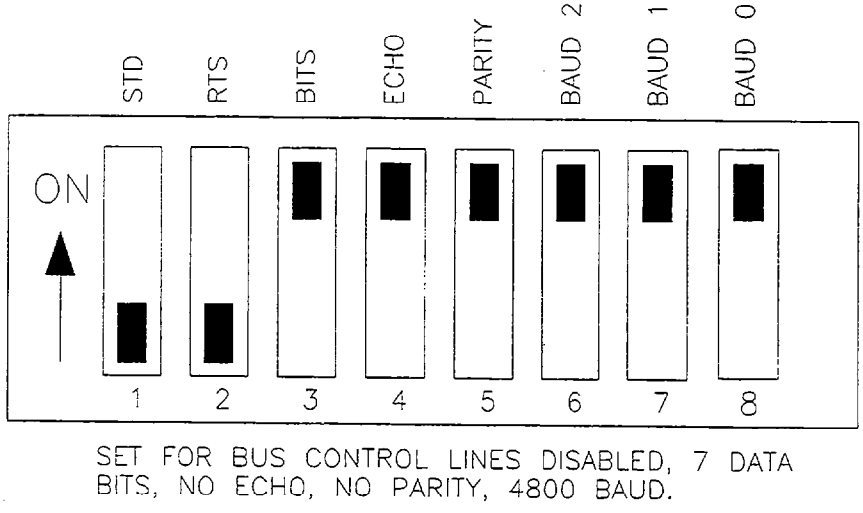


Figure 2D-4. The Protocol Selection Switch

Table 2D-1. Protocol Selection Switch Settings

Switch #	Function
1,2	Bus Control Lines Enable/Disable. Both switches set to ON = Enable. Both switches set to OFF = Disable.
3	# of Data Bits. ON = 7 Data Bits. OFF = 8 Data Bits.
4	Echo/No Echo. ON = Echo. OFF = No Echo.
5	Parity. ON = No Parity. OFF = Even Parity.
6,7,8	Baud Rate. Switches are used to select Baud Rate as follows:

Baud Rate	6	7	8
300	ON	ON	ON
600	ON	ON	OFF
1200	ON	OFF	ON
4800	ON	OFF	OFF
9600	OFF	ON	ON
19200	OFF	ON	OFF

Protocol slection notes:

1. The REM-64 is configured to transmit 1 Stop Bit.
2. The RS-232 protocol supports all standard IBM asynchronous control lines when ENABLED and only the transmit (pin 2), receive (pin 3), and signal ground (pin 7) when DISABLED.
3. The RS-422 protocol supports the Clear To Send (CTS) and Ready To Send (RTS) lines, in addition to transmit, receive, and ground when ENABLED and only transmit (pins 4 and 5), receive (pins 8 and 9), and signal ground (pin 1) when DISABLED.
4. EIA standard current loop configurations support the transmit lines (pins 9 and 11) and the receive lines (pins 18 and 25).

2D.5 CONNECTORS

This section describes the MetraBus connector and the cerial connectors.

MetraBus Connector

The REM-64 passes information to and receives data from the MetraBus I/O boards via the MetraBus cable. The MetraBus pin-out diagram below shows the physical layout of this interface connector.

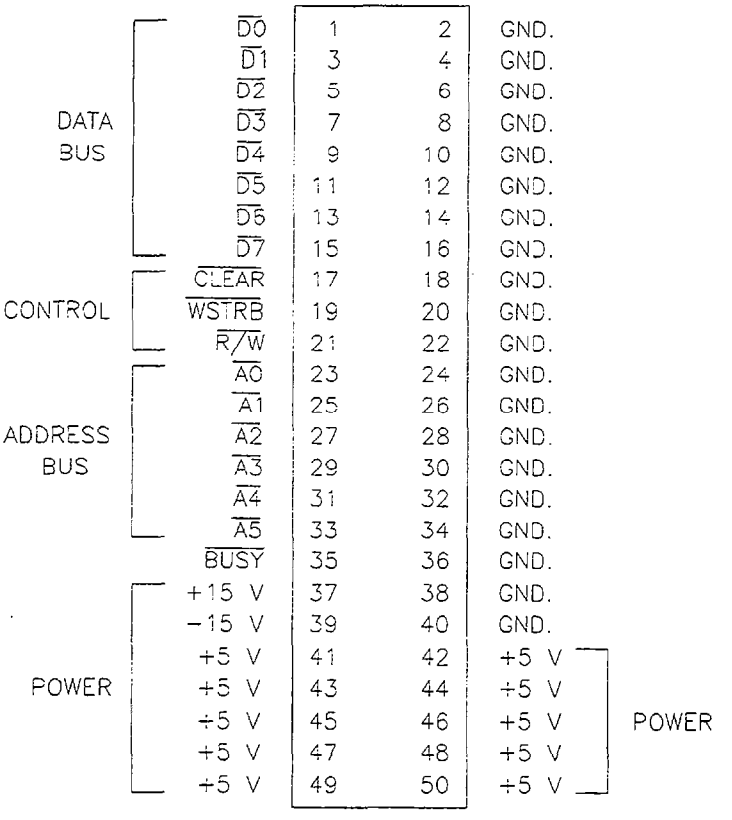


Figure 2D-5. MetraBus Connector Pinouts

Serial Connectors

The REM-64 driver card contains four serial connectors: two are RS-232 compatible, and two are for RS-422. Note that your PC may require a null modem, depending upon its serial port configuration (DTE/DCE). The REM-64 is shipped as Data Terminal Equipment (DTE), allowing connection of additional REM-64s using standard serial cables. The current loop communication interface is not multi-drop compatible. Figure 2D-6 illustrates the pin assignments for both the RS-232 and RS-422 interfaces.

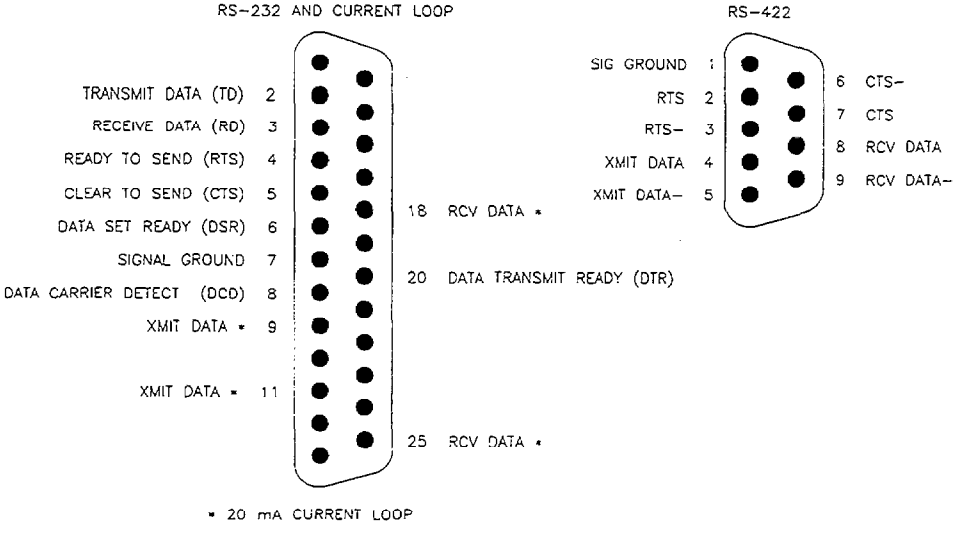


Figure 2D-6. Serial Connector Pinouts

Multiple REM-64 Connections

Every REM-64 contains two sets each of RS-232 and RS-422 connectors. Each set of connectors is configured in parallel so that multiple REM-64s may be interconnected. In a typical multi-drop wiring scheme, the REM-64s might be networked in a "T" type system. All REM-64s in the network monitor the serial bus at all times. Only the active REM-64, as targeted by the board select command, decodes the REM-64 commands and enables those MetraBus I/O boards connected to it.

2D.6 USE OF THE AUXILIARY POWER SUPPLY

The REM-64 does not draw power from the PC. As a result, an auxiliary power supply such as Keithley MetraByte's MBUS-PWR is required to operate the REM-64 as well as all MetraBus I/O Boards in your system. The use of other supplies is permitted as long as they meet the MBUS-PWR specifications. See the MBUS-PWR section of this manual for specifications and installation procedure.

2D.7 INSTALLATION OF THE REM-64

The REM-64 is a serial I/O board specifically designed for use with the MetraBus system. Its level of serial protocol support is equivalent to the standard IBM PC/XT asynchronous adapter board. You should bear this in mind when interfacing the REM-64 to other serial devices (computer, terminals, controllers, etc.). As mentioned earlier, the use of a null modem (crossing pins 2 and 3) may be required for devices configured as Data Communication Equipment (DCE).

Once you have configured your REM-64, you will want to connect it to the computer and MetraBus I/O Board(s). The procedure outlined below will aid in the installation of your REM-64. You should also refer to those sections of this manual that deal specifically with the MetraBus I/O boards that you are using for a full discussion of their functionality.

You may want to refer to the serial communication tutorial provided in Appendix A. This explains the basics of serial communication protocol interfacing.

To install the REM-64,

1. Remove power from the computer.
2. Connect one end of your serial cable (RS-232 or RS-422 cable) to the computer's serial port and secure it using the two small screws on the cable connector. Connect the other end to one of the REM-64 serial ports. Since each pair of ports is wired in parallel, it doesn't matter which port your use. Additional REM-64's may be connected at any time. Follow the procedure below for each additional REM-64 being used.
3. Connect the REM-64 to the first MetraBus cable connector. Make sure that the locking tabs are indeed locked around the mating portion of this connector.
4. Unplug the power supply from line current prior to MetraBus cable interconnection. Connect the MBUS-PWR to a second MetraBus connector.
5. Connect all other MetraBus I/O boards to the cable.
6. Repower your computer and plug in the power supply.

NOTE: Two resistor termination networks are shipped with every REM-64. These resistors should be installed on the MetraBus I/O board furthest from the REM-64. The sockets RN1 and RN2 are provided for this purpose. These resistors minimize signal reflections due to long cable lengths. They are optional, however, and have little effect upon cables of 50 feet or less.

2D.8 PROGRAMMING THE REM-64 TO CONTROL THE METRABUS

Programming the REM-64 uses a set of eight simple commands. Designed for maximum power and flexibility while maintaining the elegant simplicity that is evident throughout the MetraBus line, the REM-64 command syntax provides the user with immediate access to MetraBus I/O board functionality. The commands may be sent in either upper or lower case. A command interpreter on board the REM-64 detects any transmitted errors in command syntax, data parameters out of range, etc. and generates an error message describing the type of error detected. The REM-64 commands are listed in Table 2D-2.

Table 2D-2. REM-64 Commands

Command	Name	Function
B	Board Select	Targets specified REM-64 by Bus Address.
A	Address Pointer	Selects the specified MetraBus I/O Board.
W	Write Data	Transmits instructions to the selected I/O board.
R	Read Data	Retrieves data from the I/O board via the REM-64.
C	Clear MetraBus	Resets entire MetraBus to power-up status.
S	Status	Retrieve current Board Address and status bits.
H	Hex	All data transmitted and retrieved in Hexadecimal.
D	Decimal	All data transmitted and retrieved in Decimal.

The commands are further described below. Note that all of the provided examples are written in IBM BASICA as implemented on IBM PC/XT and PC AT compatibles. Similar routines can be written in other languages on other computers.

HINT: When first writing application programs for the REM-64, it is good idea to return all data to string variables. This is because typing errors, illegal parameters, etc. are flagged by the REM-64 and error messages are transmitted to the COMM buffer. You will never see these messages if you assume that integer data should be returned. Characters that are printed as integers will have a value of zero. This could cause a great deal of wasted time if you assume that the I/O boards are not operating correctly. Once the program is working and debugged, change back to the integer variables.

The "B" Command - Board Select

Before any MetraBus I/O board can be addressed, the REM-64 must be targeted. This is done using the B command, followed by the REM-64 address. The examples assume an asynchronous communication board such as Keithley MetraByte's COM-422 configured as "COM1" and a REM-64 with an address of 4.

When communicating with the REM-64 via the serial communication port on your computer, the BASIC PRINT # and INPUT # statements may be used to respectively send information to and receive data from the MetraBus system.

```
10 OPEN "COM1:9600,N,8,1" AS #1   'Open COM1 port @ 9600 baud,
                                  'no parity, 8 data bits, and
                                  '1 stop bit as FILE #1
20 PRINT #1, "B4"                 'Print "B4" to FILE#1 thus selecting
                                  'REM-64 Address 4.
```

Once a REM-64 is targeted, commands may be issued to any MetraBus I/O boards connected to that REM-64 via the MetraBus cable. The address pointer, write data, and read data commands (A,W,and R respectively) are used to instruct the various I/O boards connected to the targeted REM-64 MetraBus cable. These commands are discussed below in order of common usage.

The "A" Command - Address Pointer

The function of the address pointer is to point to a specific MetraBus I/O board. There are 64 available MetraBus I/O addresses that may be "pointed to" by the REM-64. Each MetraBus I/O board must have a unique, non-overlapping board address in order to identify it from other boards in the MetraBus system. (Refer to the section "Setting the board address" for the relevant I/O board.) Some MetraBus I/O boards use more than one MetraBus address, so that caution must be exercised when setting a board address. Again, the sections of this manual delaying with your specific I/O boards should be consulted prior to attempting use of the REM-64 and I/O boards. Writing the board address to the MetraBus address pointer sets the current I/O board address and targets that board for use. Once the address pointer is set to a particular board address, data can be written to or read from the board. The following example illustrates how to set the address point to the I/O board (an MIA-16, for example) at address 12.

```
10 1REM64 =4                      'Declare REM-64 address
20 MAI16 = 12                     'Declare MAI-16 Board Address
30 OPEN "COM1:4800,N,7,1" AS #1   'Open COM1 @ 4800 baud, no
                                   'parity, 7 data bits, and 1
                                   'stop bit as file #1
40 PRINT #1, "B";1REM64           'Target REM-64 at Address 4
50 PRINT #1, "A";MAI16            'Point to MAI16 at Address 12
```

Note that in the above example we have defined the I/O board address as a variable. This is standard programming technique since it allows for reassignment of any I/O board (with a simple redefinition of the address rather than an entire restructure of the program) with the routine that follows. This practice will be followed in all examples in order to make them generally applicable.

Variable declaration is generally done at the beginning of your application program for ease of access as follows:

```
10 MEM8 = 0                       'Declare MEM-8 address
20 MAI1 = 4                       'Declare first MAI-16 address
30 MAI12 = 8                      'Declare second MAI-16 address
```

Once the MetraBus address pointer is set, it does not change until another A command changes it.

The "S" Command - Status

Since the board address is latched on the REM-64, it may be read back using the S command as follows:

```
90    PRINT #1, "S"                    'Send Status command to
                                       'target REM-64
100   INPUT #1, ADDRESS                'Get data from the
                                       'Communication Buffer
```

The BASIC variable ADDRESS contains the current MetraBus I/O board address.

Reading the status returns six bits of address information and two bits of status information. These status bits are R/W and BUSY as shown below.

Address Byte

BIT	D7	D6	D5	D4	D3	D2	D1	D0
	BUSY	R/W	A5	A4	A3	A2	A1	A0

Normally, the BUSY and R/W status bits will be low (zero). (Note that the driver board inverts the polarity of the actual Bus control signals.) When this is true, the data returned will be identical to the address. The REM-64 may be used with assembled or compiled languages with no fear of active status bits since the serial nature of the data transfer in conjunction with communication buffer access times are quite slow in comparison to A/D conversion times.

The "W" Command - Write Data

Once the address pointer has been set, data may be written to and read from a MetraBus I/O board. Writing to the current I/O board involves no more than sending the W command followed by the data value corresponding to the function to be accessed (see those sections of this manual dealing with the specific board). The following example accesses an MEM-8 electromechanical relay board and closes switch 3.

```
10 MEM8 = 4                           'Declare MEM-8 Board Address
20 1REM64 = 0                         'Declare REM-64 at Address 0
30 OPEN "COM1:9600,N,7, 1" AS #1      'Open COMM port as File #1
40 PRINT #1,"B";1REM64                'Select REM-64 at address 0
50 PRINT #1,"A";MEM8                  'Point to MEM-8
60 PRINT #1,"W"; 2^3                  'Activate switch 3 of MEM-8
```

This program outputs a value of 8 (2^3) which closes relay number 3 on the MEM-8 relay board (see the MEM-8 section of this manual for a complete discussion of MEM-8 functionality).

The "R" Command - Read Data

Reading data from MetraBus input (analog and digital) boards may be accomplished through the use of the R command. In addition, all MetraBus Output Boards contain a data readback feature that enables the user to verify transmission of data to the board. This allows for

verification of data integrity which may become important when using a REM-64 at very high baud rates over long distances or where the MetraBus system is used in an electrically noisy environment. For example, if we use the above program and wish to make sure that the correct relay was closed we could add the following lines of code:

```
70 PRINT #1, "R"                    'Read data from the MEM-8
80 INPUT #1, RELAY                  'Get data from the COMM buffer
90 PRINT RELAY                      'Display data on the CRT
```

The BASIC variable RELAY will contain data from the MetraBus I/O board previously targeted by the address pointer. All MetraBus output boards latch data sent to them, and therefore, have data readback capability.

Data may be read from MetraBus input boards in exactly the same way. For example, to read the status of the inputs lines from a MII-32 digital input board, the following program may be used:

```
10 MII32 = 8                        'Declare MII-32 Board Address
20 1REM64 = 1                       'Declare REM-64 Address
30 OPEN "COM1:4800,N,7,1" AS #1     'Open COMM port as file #1
40 PRINT #1,"B";1REM64              'Select REM-64 at address 1
50 PRINT #1,"A";MII32               'Point to MII-32
60 PRINT #1,"R"                     'Send data from MII-32 (block 0)
70 INPUT #1,BLOCK0                  'Get data from COMM buffer
80 PRINT BLOCK0                     'Display data on CRT
```

The "C" Command - Clear MetraBus

A software reset causes all MetraBus I/O boards connected to the MetraBus cable to be reset to a known state. This reset state is described in the section covering each MetraBus I/O board.

The following example illustrates use of the software RESET feature for all MetraBus I/O boards connected to the selected REM-64 MetraBus cable.

```
10 OPEN "COM1:9600,N,8,1" AS #1     'Open serial COMM port
20 PRINT #1, "B2"                   'Select REM-64 at address 2
30 PRINT #1,"C"                     'Send system CLEAR command
```

The "H" and "D" Commands - Hexadecimal and Decimal

These two data format commands can be used to specify whichever data format you are comfortable with. The power-up/default status is decimal. A subsequent PRINT #1, "H" command will change this to hex format.

Programming The REM-64 To Control The I/O Boards

As described above, the execution of REM-64 commands generally follows a consistent pattern when programming any MetraBus I/O board. The following is a brief overview of programming techniques associated with the various types of I/O boards. The following examples illustrate programming techniques used with both digital and analog I/O boards. Detailed information concerning programming for specific boards can be found in the board's description.

Digital I/O Boards

Digital I/O boards are the easiest to control. Data can be written to the board immediately after setting the address pointer. Digital output boards typically have several 8-bit ports. In the following example, a digital output board is at boarda address 4 and the REM-64 is at address 0.

```
10 MIO32 = 4                          'Declare MIO-32 address
20 1REM64 = 0                         'Declare REM-64 address
30 OPEN "COM1:9600,N,8,1" AS #1       'Open COM1 port as file #1
40 PRINT #1,"B";1REM64                'Select REM-64 at address 0
50 PRINT #1, "A";MIO32                'Point to MIO-32 at address 4
60 PRINT #1, "W255"                   'Output bit pattern 1111 1111
70 CLOSE #1                           'Close file #1
```

Lines 10 and 20 declare the address locations of the REM-64 and MIO-32, respectively.

Line 30 opens the serial communications port as file #1 with a data I/O format of 9600 Baud, no parity bit, eight data bits, and one stop bit.

Line 40 selects the REM-64 declared previously.

Line 50 points to the MIO-32.

Line 60 outputs a value of 255 to the digital output card setting all outputs of block 0 high.

Digital input boards, like digital output board, typically have several 8-bit ports. After the address pointer has been set to the MetraBus board address, data can be read from the board using the R command. In the following example, a digital input board (MII-32, for example) is at MetraBus address 4 while the REM-64 is at address 2.

```
10 MII32 = 4                          'Declare MII-32 address
20 1REM64 = 2                         'Declare REM-64 at address 2
30 OPEN "COM1:9600,N,7,1" AS #1       'Open COM1 port as file #1
40 PRINT #1, "B"; 1REM64              'Select REM-64 at address 2
50 PRINT #1, "A"; MII32 + 2           'Point to Block 2 of MII-32
60 PRINT #1, "R"                      'Transmit data from MII-32
70 INPUT #1, BLOCK2                   'Retrieve data from COMM buffer
80 PRINT BLOCK2                       'Display data on CRT
90 CLOSE #1                           'Close file #1
```

Lines 10 and 20 declare the addresses of the MII-32 and the REM-64.

Line 30 opens the serial communication I/O port as file #1 at 9600 baud, no parity, 7 data bits, and 1 stop bit.

Line 40 selects the REM-64 previously declared.

Line 50 points to the MII-32.

Line 60 tells the REM-64 to send the data from the MII-32 back to the computer.

Line 70 retrieves this data from the communication buffer.

Line 80 displays this data on the CRT screen.

Analog I/O Boards

Analog output boards use one of the available 64 MetraBus addresses per channel. Setting the address pointer to the appropriate address and writing data to the board will produce an analog output. The following example shows how to set the address pointer and output a voltage.

```
10 MAO8 = 8                              'Declare MAO8 Board Address
20 2REM64 = 8                            'Declare REM-64 at address 8
30 OPEN "COM1:9600,N,7,1" AS #1          'Open COMM port as file #1
40 PRINT #1, "B"; 2REM64                 'Select REM-64 at address 8
50 PRINT #1, "A"; MAO8 +                 'Point to channel 3 of MAO-8
60 PRINT #1, "W192"                      'Output corresponding voltage
70 CLOSE #1                              'Close file #1
```

Lines 10 and 20 declare MAO-8 and REM-64 addresses. Notice that these addresses are the same. This is alright since the REM-64 address is essentially an address on the serial bus and is not related in any way to the 64 available MetraBus addresses.

Line 30 opens the serial communication port as file #1 for data transfer at 9600 baud, no parity bit, seven data bits, and one stop bit.

Line 40 selects the REM-64 previously declared.

Line 50 points to the MA0-8 .

Line 60 tells the MAO-8 to output a voltage corresponding to the integer 192. (See the MA0-8 description for more information.)

Line 70 and 80 close file #1 and end the program.

Analog input boards require additional steps in order to set the gain and resolution for the desired channel prior to collecting data.

```
10   MAI16 = 16                          'Declare MAI-16 address
20   1REM64 = 1                          'Declare REM-64 at address 1
30   OPEN "COM1:9600,N,7,1" AS #1        'Open COMM port as file #1
40   PRINT #1, "B";1REM64                'Select REM-64 at address 1
50   PRINT #1, "A"; MAI16+2              'Point to GAIN/CH selection mode
60   PRINT #1, "W";18                    'Set gain to +/- 5V range on Ch 2
70   PRINT #1, "A"; MAI16                'Point 12-bit conversion mode
80   PRINT #1,"W00"                      'Starts 12-bit A/D conversion
90   PRINT #1, "A";MAI16                 'Point to data LSB's
100  PRINT #1, "R"                       'Read data back to COMM buffer
110  INPUT #1, LSB                       'Store data in variable LSB
120  PRINT #1, "A"; MAI16                'Point to data MSB's
130  PRINT #1, "R"                       'Read data back to COMM buffer
140  INPUT #1, MSB                       'Store data in variable MSB
150  CLOSE #1                            'Close file #1 (COMM port)
160  AIN=MSB*16 + LSB/16                 'Combine bytes to form data value
170  PRINT AIN
```

Lines 10 and 20 declare MAI-16 and REM-64 addresses.

Line 30 opens the serialcCommunication port as specified parameters.

Line 40 selects REM-64 at address 1.

Line 50 points to GAIN/CH select mode of MAI-16.

Line 60 sets the gain to +5 V on channel 2.

Line 70 points to 12-bit conversion mode of MAI-16.

Line 80 starts the A/D conversion process.

Line 90 points to LSB data from the A/D conversion process.

Line 100 reads the LSBs back to the computer COMM buffer.

Line 110 gets the data from the buffer and stores it is a variable LSB.

Line 120 points to MSB data from A/D conversion process.

Line 130 reads the data MSBs back to the computer COMM buffer.

Line 140 gets the data from the buffer and stores it in variable MSB.

Line 150 closes file #1 (the COMM port).

Line 160 combines the LSBs and MSBs to form a single data byte.

Line 170 displays the data on the CRT screen.

There is a good deal of redundancy in the above routine that would normally be eliminated in actual usage. It is shown here only for the sake of step-by-step instruction. See the MAI-16 for details concerning the various functions on the board.

Using Compiled & Assembled Languages With The REM-64

The use of compiled and assembled languages requires no special precautions when used with the REM-64 since even at very high data transfer rates (19,200 baud) the serial nature of the data transfer combined with buffer access times are magnitudes slower than most A/D conversions. When using the REM-64, we are, therefore, not "talking" directly to it or any of the I/O board but must pass through this data buffer. You can see that with very fast program execution times i.e., compiled or assembled programs, you are actually monitoring the status of the communication buffer and not I/O board activity. The S command (STATUS) is implemented for address verification and for future use as far as the status bits are concerned.

> NOTE: If your data-monitoring routines attempt to write data or commands to the MBB-32 while the circuitry is busy, problems will arise. Therefore, when gathering data from slow circuitry, design your data collection routines so that they actually retrieve data and/or poll the BUSY bit using the S command prior to assuming that no data has been produced. Generally, it is a good idea to have the computer simply time-out while waiting for data from the COMM buffer. See the IBM DOS manual for further information concerning time out definition.

■ ■ ■

PWR-55/PWR-100 BOARDS

3A.1 GENERAL

The PWR-55 and PWR-100 are auxiliary power supplies for the MetraBus industrial data acquisition and control system. These boards are predecessors to the newer MBUS-PWR board (see Chapter 3, Part B). The PWR-55 and PWR-100 supply required power for all MetraBus I/O boards. When a PWR-55/PWR-100 is used, the only power drawn from the host PC is for the MetraBus controller/driver card. Both the PWR-55 and the PWR-100 are 19" rack-mountable in either a standard NEMA type enclosure or the MetraByte RMT-02.

The PWR boards furnish +5 VDC, +15 VDC, -15 VDC, and ground signals on the MetraBus cable. PWR-55 is 55 W supply, PWR-100 power is 100 W. Either board must match the anticipated power draw of your MetraBus system. Both supplies contain AC line filters that exceed UL478 and UL1283 specifications and comply with UL, VDE, CSA, and IEC safety standards.

> NOTE: Connect only a single power supply to a single MetraBus cable. For a MetraBus requiring more than 100 watts of power, contact the factory for assistance.

Input voltages of 90 to 125 VAC or 180 to 250 VAC along with input frequencies of 45 to 65 Hz (4 to -63 Hz for PWR-100) allow the use of both U.S. and European standard line current. The PWR-55 works with either 110 or 220 VAC interchangeably, while the PWR-100 requires a jumper change for 220 VAC operation. The jumper is clearly marked on the board. The supplies are approximately 65% efficient while providing 4000 Vrms of isolation from standard 120/220 VAC lines. The PWR-55 and the PWR-100 are switching type supplies with hold times of 16 ms (20 ms for the PWR-55). Both supplies feature a soft start mode, are current limiting and have linear regulation on all outputs. Extra line filters and optional power capacitors are available for various applications. Contact the factory (See Chapter 21.) for further details concerning those applications that may require these power options.

Certain MetraBus I/O boards require the use of either power supply. Any system using the MID-64, or REM-64 interface/driver cards, the MAI-16 analog input board, the MAO-8 analog output board, certain configurations of the MCN-8, and any MetraBus system that draws more than 2 Amps will require the use of an auxiliary power supply.

3A.2 FEATURES

- Plugs into any MetraBus cable connector
- Meet UL, VDE, IEC, and CSA approval
- 90-120 VAC or 180-250 VAC switch selectable
- Isolation to 4000 V_{rms}

- AC line filter built-in
- Status LEDs and multiple test points
- Convection cooled
- 45-65 Hz (47 - 63 Hz for PWR-100) input allows European voltages

3A.3 SPECIFICATIONS

Input Voltage:	90 to 130 VAC 180 to 250 VAC
Input Frequency:	47 to 63 Hz (45 to 65 Hz for PWR-55)
Isolation:	4000 Vrms
Operating Temperature:	0 - 70° C (derate 2.5% per degree over 45° C)
Hold up Time:	16 ms (20 ms for PWR-55)
Output Ratings:	5 VDC @ 12 A (5 A for PWR-55) +15 VDC @ 3 A (2 A for PWR-55) -15 VDC @ 3 A (2 A for PWR-55)
MetraBus Cable Type:	50-conductor ribbon cable.
MetraBus Connector:	3M 3425-6050

3A.4 INSTALLING THE PWR-55/PWR-100

Using the PWR-55 or PWR-100 requires a line cord with a plug for the available type of power (110/220 VAC). The cord should be long enough to reach from the wall outlet to the MetraBus cable.

> NOTE: Perform the following procedure only under no-power conditions.

1. Visually inspect the PWR-55 or PWR-100 for loose wires, screws, or components.
2. Secure the three line wires to the line input terminals (J2) of the PWR-55/PWR-100 and replace the plastic cover for protection. Be sure to install the green earth-ground line.
3. Select an unused MetraBus cable connector and plug the power supply into the cable, making certain that the locking tabs on the connector are locked around the mating portion. The connectors are keyed for your protection. Check the keyways for correct alignment prior to plugging them together. Avoid the use of force with these connectors.
4. Plug the line cord to a source of power.

3A.5 USE OF OTHER POWER SUPPLIES

You may use power supplies other than the PWR-55/PWR-100 so long as they supplies meet PWR-55/PWR-100 specifications.

3A.6 THE MTAP-1

The MTAP-1 is a power break-out board for the MetraBus system. The board can bring power to the MetraBus from an external supply or can extract power from the MetraBus power supply to support user circuitry. Three LEDs show power supply status. A green LED lights to show that +5 V power is on, while red and yellow LEDs display power on conditions for +15 V and -15 V supplies, respectively.

A 3 X 1.5 inch breadboard area is included on the board to facilitate the installation of user circuitry. Terminal posts connected to the power supply inputs are at the edge of the breadboard area.

The MTAP-1 provides direct connections to the power distribution conductors in the cable. To power a MetraBus system with an external power supply, plug the MTAP-1 into the MetraBus cable and connect the supply inputs to their corresponding screw terminals on the MTAP-1.

CAUTION

Do not connect external power supplies to any MetraBus system containing a PWR-55 or PWR-100 board or that has Fuse F1 installed on an MDB-64.

■ ■ ■

MBUS-PWR BOARDS

3B.1 GENERAL

The MBUS-PWRs are auxiliary power supplies for the MetraBus industrial data acquisition and control system. A 120 VAC version is for use in North America and carries a /NA designation; similarly, a 220/240 VAC version is intended for the European market and carries a /EURO designation. Both versions are 19" rack-mountable in either a standard NEMA type enclosure or the MetraByte RMT-02 frame. Both versions also meet applicable IEC, UL, CSA, and VDE safety requirements. MBUS power supplies are replacements for the PWR-100/55 and provide multiple supply operation.

The MetraBus power distribution system is modular to accommodate the needs of small and large systems. This feature allows you to minimize the cost of power supply components without limiting the size of the system. However, in configuring the power distribution system, you must first estimate the power load on the basis of your intended board complement. The three basic power distribution systems are PC power, single power supply, and multiple power supplies.

For a small system that will use only digital boards requiring under 2 A of +5 VDC power, the PC can power the boards directly. In this configuration, you must install fuse F1 (1 A) on the MDB-64 driver board for the PC to power the digital boards. Boards such as the MID-64, REM-64, MAI-16, MAO-8, and the MCN-8 require +15 or -15 VDC and must use an MBUS-PWR board. A typical small system configuration is depicted in Figure 3B-1.

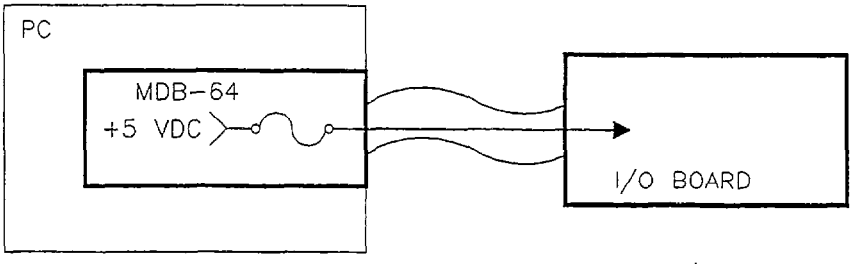


Figure 3B-1. Small System

In a medium-size system, where the power load is under 100 W, attach an MBUS-PWR board to the MetraBus cable. Remove Fuse F1 from the MDB-64 board, and plug the cable into either power connector of the MBUS-PWR board. Use the other power connector of the MBUS-PWR board to further daisy-chain I/O boards. For even power distribution under near-full loads, place the MBUS-PWR board in the middle of the daisy chain, as shown in Figure 3B-2.

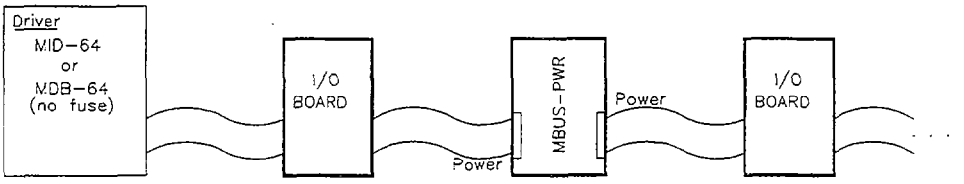


Figure 3B-2. Medium System

In a system whose expected power draw is beyond 100 W, use multiple MBUS-PWR supplies. Connections for multiple MBUS-PWR boards utilize the expansion (EXP) connectors, as shown in Figure 3B-3. These connectors pass the communication signals to the next set of I/O boards but isolate the power distribution structure. The MBUS-PWR power (PWR) connectors supply system power to the ribbon cable. Be sure to properly estimate the load of each group of I/O boards, and **do not** connect the PWR connectors of any two MBUS-PWR boards.

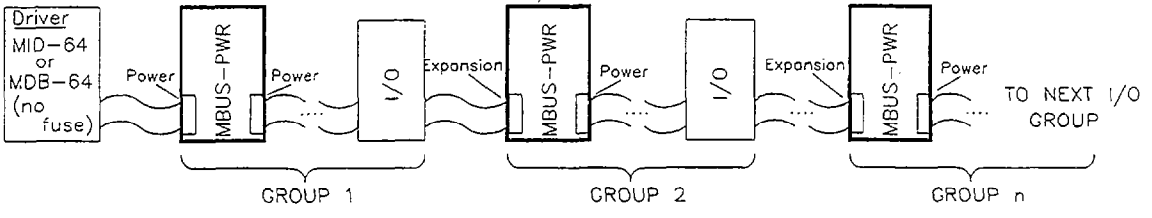


Figure 3B-3. Large System

3B.2 FEATURES

- Plugs into any MetraBus cable connector
- Designed to meet UL, VDE, IEC, and CSA requirements
- 90 to 120 VAC or 180 to 250 VAC versions
- AC line filter built-in
- Power Status LEDs
- Convection cooled

3B.3 SPECIFICATIONS

Input Voltage:	90 to 132 VAC 180 to 264 VAC
Input Frequency:	47 to 63 Hz
Operating Temperature:	0 to 70° C (derate 2.5% per degree over 50° C)
Hold up Time:	20 ms
Output Ratings:	5 VDC @ 15 A +15 VDC @ 4 A -15 VDC @ 1 A
MetraBus Cable Type:	50-conductor ribbon cable.

MetraBus Connector:	3M 3425-6050
Status Indicators:	+5, +15, -15 V available (green LEDs)
Terminal Blocks:	+5, +15, -15 V and common
Output Ground Jumper:	Float or utilities ground

3B.4 INSTALLATION

NOTE: Perform the following procedure only under no-power conditions.

1. Visually inspect the MBUS-PWR for loose wires, screws, or components.
2. Determine the power distribution configuration and connector utilization.
3. Select an unused MetraBus cable connector and plug the power supply into the cable, making certain that the locking tabs on the connector are locked around the mating portion. The connectors are keyed for your protection. Check the keyways for correct alignment prior to plugging them together. Avoid the use of force with these connectors.
4. Plug the line cord to a source of power.
5. Turn on power switch.

3B.5 USE OF OUTPUT GROUND JUMPER

To provide maximum flexibility and minimize ground loops within multiple-supply systems, MBUS-PWR boards contain an output ground jumper. If desired, this jumper can connect the utilities chassis ground directly to the DC common of each supply. Such a connection in no way affects the chassis ground of the supply itself. In most cases, you will elect to minimize system noise by floating all output commons except one—to remove ground loop paths.

3B.6 THE MTAP-1

The MTAP-1 is a power break-out board for the MetraBus system. The board can bring power to the MetraBus from an external supply or can extract power from the MetraBus power supply to support user circuitry. Three LEDs show power supply status.

3B.7 THE MBUS-PWR CONNECTORS

The MBUS-PWR connectors allow you to split the power distribution in a MetraBus system between multiple power supplies. Using the expansion connector passes the bus and control signals but isolates the power structure.

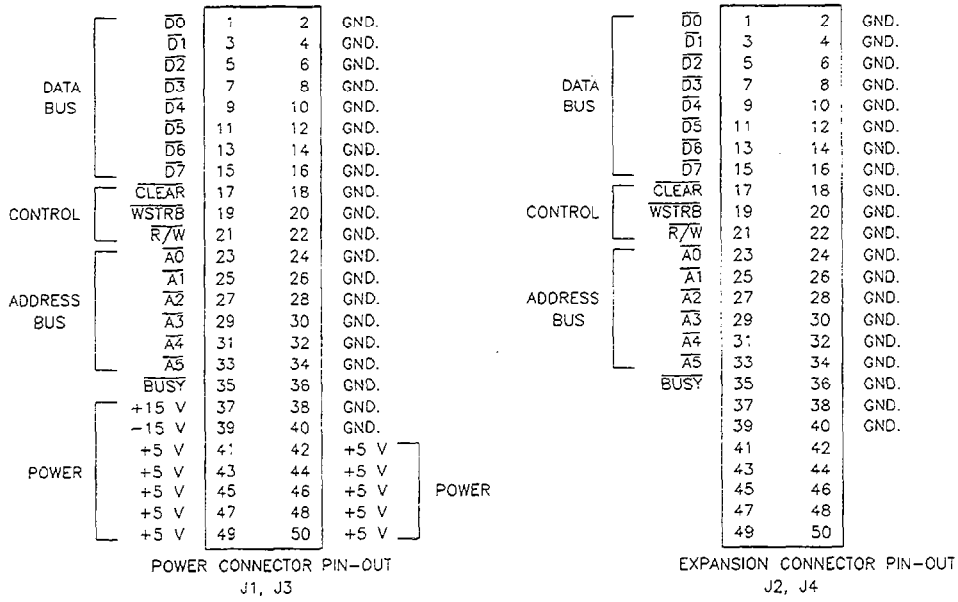


Figure 3B-4. MBUS-PWR Connector Pin Assignments

■ ■ ■

Chapter 4

MDI-16/MSS-16 SOLID STATE SWITCHING I/O SYSTEM

4.1 GENERAL

The MDI-16/MSS-16 is a modular 2-board system providing complete optical isolation for both high and low power switching applications. Each MDI/MSS-16 monitors and controls 16 individual I/O points via optically isolated solid-state, plug-in modules. A variety of these modules is available for both input and output. Voltages of 120/130 VAC, 0 to 60 VDC, etc. as well as standard European line voltages may be sensed and controlled. Control and sense modules are also usable on a single MSS-16. Screw terminals on the MSS-16 accept 12 to 22 AWG wire.

The MDI-16/MSS-16 connects directly to any of the MetraBus controller/driver cards through the MetraBus cable. You may install the driver card in your computer while positioning the MDI-16/MSS-16 combination adjacent to its point of use for easy signal connection.

The MetraBus cable carries all data, address, and status information, and it distributes power on the MetraBus. A total of 20 ground lines interleaved among the data and address lines ensure noise immunity. The MetraBus system allows 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 1.2 km. The MDI-16R/MSS-16 is 19" rack-mountable in either a standard NEMA type enclosure or the MetraByte RMT-01. The MDI-16/MSS-16 mounts on any flat panel or other flat surface.

A total of 32 MDI-16/MSS-16s can connect to a single MetraBus cable, allowing monitoring and control of up to 512 individual I/O points. Like other MetraBus I/O boards, the MDI-16/MSS-16 has a data read-back allowing the user to verify data integrity in data output modes. For applications requiring more power than your PC can deliver, a choice of auxiliary power supplies is available.

Some common uses of the MDI-16/MSS-16 include computer control of Pump Cycling, ON/OFF Motor Control, Energy Management, Signal Multiplexing, alarm Activation, Temperature Cycling, Product Life Cycle testing, etc.

4.2 FEATURES

- Interfaces directly to IBM PC/XT/AT and compatibles
- Remote signal connections
- Senses/Controls up to 512 I/O points per computer expansion slot
- Extremely cost effective
- Adapts to your changing requirements
- Optically isolated to 1500 VDC (nominal)

4.3 SPECIFICATIONS

Number of I/O Channels:	16
Isolation Type:	Optical
Isolation Rating:	4000 Vrms typical
I/O Module Life Expectancy:	Infinite
I/O Modules Installed:	None (must be ordered separately)
MetraBus Cable Type:	50-conductor ribbon.
MetraBus Connector:	3M 3425-6050

Environmental

Operating Temperature:	0 to 70° C
Storage Temperature:	-40 to 100° C

Power Consumption

+ 5 VDC:	325 mA (typical); 40 mA maximum

Physical

Size:	14.5 x 3.5 inches (MSS-16) 5.0 x 3.5 inches (MDI-16)

4.4 USING AN AUXILIARY POWER SUPPLY

You may power a single MDI-16/MSS-16 from the PC power supply since only +5 VDC is required. However, if you have more than one combination board in your MetraBus system or if you have other MetraBus I/O boards, an auxiliary power supply may be required. See the MBUS-PWR sections of this manual for specifications and installation procedure.

> NOTE: If you use an auxiliary power supply in conjunction with an MDB-64 MetraBus Controller/Driver card, remember to remove Fuse F1 from the MDB-64.

If you use an internal power supply, be certain that the links at each end of the edge connector of the MSS-16 are installed. You may power the MDI-16/MSS-16 with an external +5 VDC supply by removing the links and connecting the supply to the two-position power supply barrier block on the MSS-16.

4.5 CONFIGURING THE MSS-16

The MSS-16 is a standard PB-16A mounting rack for solid-state, I/O plug-in modules. Each MSS-16 will hold up to 16 solid-state I/O modules, which are available in several different versions and may be ordered from Keithley MetraByte or several other manufacturers. When ordering I/O modules from other manufacturers, bear in mind that the MSS-16 uses +5 VDC

for module activation. A short list of the various I/O modules available for the MSS-16 follows.

VAC OUTPUT (control)

OAC5 -- 120 VAC @ 3 Amps
OAC5A -- 240 VAC @ 3 Amps
OAC5A5 -- 120/240 VAC @ 3 Amps (normally closed)

VAC INPUT (sense)

IAC5 -- 120 VAC/DC @ 11 mA
IAC5A --240 VAC/DC @ 6.5 mA

VDC OUTPUT (control)

ODC5 -- 60 VDC @ 3 Amps
ODC5A -- 200 VDC @ 1 Amp

VDC INPUT (sense)

IDC5 -- 10 to 32 VDC @ 25 mA
IDC5B -- 4 to 16 VDC @ 45 mA (fast switching)

> NOTE: The MSS-16 contains 5 A miniature replacement fuses that may open in the event of external circuit failure.

4.6 INSTALLING THE MDI-16

The MDI-16 adapter board is available in two versions. The difference between versions is the placement of the edge connector. The MDI-16R is a right-angle version of the MDI-16. The MDI-16R was specifically designed to allow mounting of the two-board combination in a 19" rack mount (a depth of 5" is required). Our RMT-02 is a straight inline version with an overall length (including the MSS-16) of 19 1/4 inches. It is commonly mounted on a flat panel of at least 20" or it may be mounted in 24" racks.

Each MDI-16/MSS-16 combination connected to a single MetraBus cable must be set to a unique, non-overlapping MetraBus I/O board address. Each MDI-16 uses 2 of the available 64 MetraBus addresses. These are consecutive locations starting from the board address. Setting the board address is outlined below (Figure 4-1 shows a typical board address switch setting).

Prior to installing the MDI-16/MSS-16, make certain that a MetraBus controller/driver board has been installed. These boards are described in the first section of this manual.

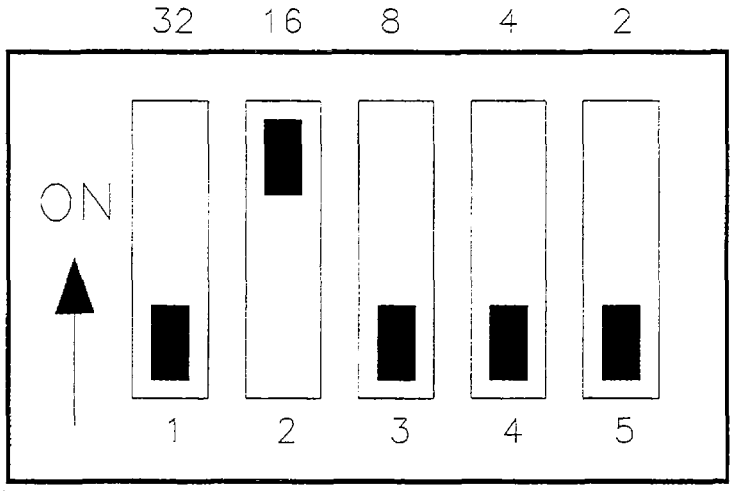


Figure 7-1. Setting the Board Address

To set the board address,

1. The board-address DIP switch is located in the lower left corner of every MDI-16. The numbers silk-screened above the switch indicate the value of the switch immediately below it. The numbers have value only in the ON position.
2. Select an unused board address and turn ON those switches corresponding to the address that you have chosen. For example, in order to set a board address of 24, switches with corresponding values of 8 and 16 would be ON while the others would remain OFF. It is important to remember that each MDI-16 must be set to an unused, non-overlapping Board Address in order to avoid address conflicts when being targeted by the driver card.
3. After setting the board address, you may connect the MDI-16 to the MSS-16. Then, connect the MDI-16 to the MetraBus driver card via the MetraBus cable. The MetraBus cable connector is keyed for your protection and should plug in easily. Check the keyways for correct alignment prior to plugging in the MetraBus cable.
4. If you have only one MDI-16 or if one of your MDI-16s is the last board in your system, you should install the resistor terminating networks that are provided with your driver card. The sockets marked RN1 and RN2 immediately above the MetraBus connector are for this purpose. These resistor networks are used to minimize signal reflection due to long cable lengths. They are optional, however, and have little effect for cables of 50 feet or less.

4.7 PROGRAMMING THE MDI-16/MSS-16

MDI-16 programming is very simple due to MetraBus supervision by the driver board. Since all necessary control signals are automatically generated within the driver board, the user need not be concerned with control registers, PEEKing or POKEing memory locations, shifting bits, PUSHing or POPing stacks, learning new languages, or other system level headaches. Refer to the driver board descriptions provided in Part 1 of this manual.

Two programs (in BASIC) are included on the MetraBus diskette. In one, MSS16.BAS loops through and sequentially activates each I/O module while displaying the status of all I/O modules on the CRT screen. The second program illustrates the BASIC OR command for

activating I/O modules while maintaining the status of the present module configuration. The programs link back and forth for easy access. They are heavily commented so that even the beginning programmer should have little, if any, trouble following the flow of logic within. These, in conjunction with the examples below, should answer most of the question that arise concerning MDI-16/MSS-16 usage.

MDI-16 Terminology & Data Format

Like all MetraBus I/O boards, there is a standard programming sequence that is followed when controlling the MDI-16/MSS-16. This sequence consists of the following:

1. Targeting the MDI-16 via the ADRPTR.
2. Sending a data value (corresponding to the I/O modules to be accessed) to the DATAIO.

MetraBus treats the 16 modules on the MSS-16 as two (8-bit) blocks corresponding to two MetraBus I/O addresses. The data format for each of the two blocks is the same and corresponds to the following:

BIT	D7	D6	D5	D4	D3	D2	D1	D0
	CH7	CH6	CH5	CH4	CH3	CH2	CH1	CH0

Because of this arrangement, control of the various I/O modules on the board is accomplished by writing a single byte whose value is associated with the modules to be accessed. For example, to activate module #4 on block 0, write a data value of 16 (24 = 16) to the DATAIO. Similarly, if we wanted to activate modules #3 and #5, we would write a value of 40 (23 + 25 = 40) to the DATAIO. To access module 3 of block 1 (relays 8-15), target block one via the ADRPTR and write a data value of 8(23 = 8) to the DATAIO. This arrangement makes it a very simple matter to specify modules using a BASIC integer variable as shown in the examples below.

The BASIC OUT and INP commands are used to respectively send information to and receive information from the MetraBus I/O board. While the examples are in BASIC, they are equally applicable to many other computer languages supporting data I/O operations such as C, PASCAL, Assembly, and others. The following examples assume a MetraBus driver card is installed at base address 768 (300h) and an MDI-16/MSS-16 at board address 20.

Example 1

This example illustrates the use of a BASIC variable to sequentially access each relay on the MSS-16.

```
10 DATAIO = 768                    'Declare Data I/O location
20 ADRPTR = 769                    'Declare Address Pointer location
30 MSS16 = 20                      'Declare MSS-16 Board Address
40 OUT ADRPTR,MSS16                'Point to MSS-16 at address 20
50 FOR I= 0 TO 7                   'Begin BASIC control loop
60 OUT DATAIO, 2^I                 'Sequentially close each relay
70 NEXT I                          'End control loop
```

Example 2

Reading back the data value sent to the MSS-16 can be very useful for detecting data transmission errors. Such might be the case if you are transmitting data over long distances at high baud rates or if you are in an area of excessive electrical noise. The following program illustrates the data read-back feature. For the sake of clarity, the above program will be used with lines added only as necessary.

```
10 DATAIO = &H300                          'Declare Data I/O location
20 ADRPTR = 769                            'Declare Address Pointer location
30 MSS16 = 20                              'Declare MSS-16 Board Address
40 OUT ADRPTR,MSS16                        'Point to MSS-16 at address 20
50 FOR I= 0 TO 7                           'BASIC control loop
60 OUT DATAIO, (2^I)                       'Activate "I" relay
70 RLYCHK=INP(DATAIO)                      'Get data just written
80 IF RLYCHK <> (2^I) THEN PRINT "ERROR" :END
90                                         'Data integrity check
100  NEXT I                               'Close control loop
110  END
```

Example 3

It is often useful to be able to activate a relay while leaving the others intact, regardless of their state. The most efficient way to do this is to read back the state of all relays then OR those relays with the new relay to be activated.

```
10 DATAIO = 768                            'Declare Data I/O location
20 ADRPTR = 769                            'Declare Address Pointer location
30 MSS16 = 20                              'Declare MSS-16 Board Address
40 OUT ADRPTR,MSS16                        'Point to MSS-16 at address 20
50 INPUT "NEW RELAY "; RLY                 'Get user input for new relay
60 RLYSTAT = INP(DATAIO)                   'Read back current status of
                                            'relays
70 OUT DATAIO, (2^RLY) OR RLYSTAT          'Activate new relay leaving the
                                            'old ones the way they were
80 GOTO 50                                 'Loop-back for next relay
```

■ ■ ■

MEM-8 ELECTROMECHANICAL RELAY I/O SYSTEM

5A.1 GENERAL

The MEM-8 is an 8-channel, double-pole, double-throw (DPDT) electromechanical relay board designed for use with the MetraBus industrial data acquisition and control system. As shipped, the board contains eight electromechanical relays with the silver-button type contacts rated for 100 thousand operations at load (120 VAC/28 VDC at 5 A resistive). The relays are configured with two poles normally open and two poles normally closed when in the OFF state. Unlike solid-state relays, electromechanical relays offer zero-current leakage when OFF. Since the MEM-8 uses industry-standard R10 type plug-in relays, it accepts substitutions with other relays having contact ratings of your choice. There are also provisions for relays with other than the standard 5 VDC coils (see the section describing alternative relays). Figure 5A-1 is a block diagram of the MEM-8.

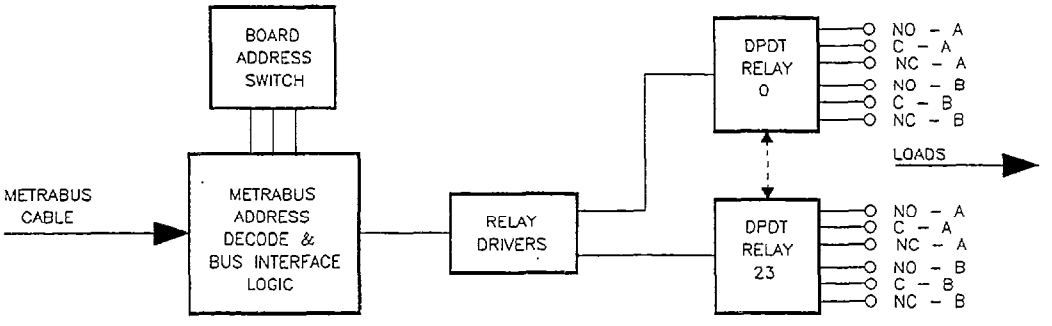


Figure 5A-1. MEM-8 Block Diagram

Screw terminals on the board will accept 12 to 22 AWG wire. The MEM-8 is 19" rack-mountable in either a standard NEMA type enclosure or Keithley MetraByte's RMT-02 remote enclosure. The MEM-8 may also be mounted on any flat panel or other flat surface.

The MEM-8, like other MetraBus output boards, has a data read-back feature allowing the user to verify data integrity. Each relay on the MEM-8 also has an annunciator LED associated with it so that visual verification is given when the relay is active. Upon power-up and MetraBus system CLEAR, all relays return to the INACTIVE state.

The MEM-8 connects directly to any of the available MetraBus driver cards via a 50-conductor ribbon cable. This MetraBus cable carries all data, address, and control signals as well as distributing power on the MetraBus. The MEM-8 may be positioned adjacent to its point of use (up to 100 feet from the computer) for easy signal connections.

Because of its design, the MetraBus system is capable of controlling up to 512 relays (64 MEM-8s) per computer expansion slot. For those applications requiring greater power than is available from your computer supply alone, a choice of auxiliary power supplies is available.

Various relay types may be mixed and matched within the same MEM-8 or the board may be dedicated to a single relay type making this the most versatile, cost effective relay switching board available.

Uses of the MEM-8 include computer control of pump cycling, ON/OFF motor control, energy management, signal multiplexing, alarm activation, temperature cycling, and much more.

5A.2 SPECIFICATIONS

Relays

Quantity and Type:	8 DPDT
Contact Material and Type:	Silver-cadmium oxide buttons
Contact Rating:	5 A at 120 VAC (resistive) 5 A at 28 VDC (resistive)
Operate Time:	30 ms maximum
Release Time:	10 ms maximum

Relay Life Expectancy

Mechanical:	100 million operations
Electrical:	100 thousand operations (at load)
Isolation:	1000 Vrms

Environmental

Operating Temperature:	0 to 70° C
Storage Temperature:	-40 to 100° C

Power Consumption

+5 VDC:	120 mA (+180 mA per relay)

Physical

Size:	16 x 4.74 inches (40.63 x 12.06 cm)
Weight:	11.5 oz (326 gm)
MetraBus Cable type:	50-conductor ribbon cable
MetraBus Connector:	3M 3425-6050

5A.3 USING AN AUXILIARY POWER SUPPLY

You may power one MEM-8 from the PC power supply, since only +5 VDC is required. However, if you have more than one combination board in your MetraBus system or if you have other MetraBus I/O boards, you may require an auxiliary power supply. See the MBUS-PWR chapter of this manual for specifications and installation procedure.

> NOTE: If an auxiliary power supply is used in conjunction with an MDB-64 MetraBus Controller/Driver card, remember to remove fuse F1 from the MDB-64.

5A.4 SETTING THE MEM-8 BOARD ADDRESS

Each MEM-8 connected to a single MetraBus cable must be set for a unique, non-overlapping MetraBus I/O address if the driver card is to target that specific MEM-8. Setting the board address is outlined below. Figure 5A-2 shows a typical board address switch Setting.

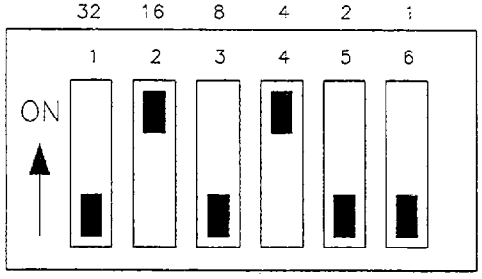


Figure 5A-2. Setting the Board Address

To set the board address,

1. The board address DIP switch is located in the lower-left side of the board just above the MetraBus connector. The numbers silk-screened above the switch indicate the value of the switch immediately below it. The numbers have value only in the ON position.
2. Select an unused board address and turn ON those switches corresponding to the address that you have chosen. For example, in order to set a board address of 24, switches with corresponding values of 8 and 16 would be ON while the others would remain OFF. It is important to remember that each MEM-8 must be set to an unused, non-overlapping board address in order to avoid address conflicts when being targeted by the driver card.
3. After setting the board address, connect the MEM-8 to the MetraBus driver card via the MetraBus cable. The MetraBus cable connector is keyed for your protection and should plug in easily. Check the keyways for correct alignment prior to plugging in the MetraBus cable.

   > NOTE: It is always good practice to remove power from the MetraBus cable prior to connecting any I/O boards.

4. If you have only one MEM-8 or if one of your MEM-8s is the last board in your system, you should install the resistor terminating networks that are provided with your driver card. The sockets marked RN1 and RN2 immediately above the MetraBus connector are for this purpose. These resistor networks are used to minimize signal reflection due to long cable lengths. They are optional, however, and have little effect for cables of 50 feet or less.

5A.5 PROGRAMMING THE MEM-8

MEM-8 programming is very simple due to MetraBus supervision by the driver board. Since all necessary control signals are automatically generated within the driver board, the user need not be concerned with control registers, PEEKing or POKEing memory locations, shifting bits, PUSHing or POPing stacks, learning new languages, or other system level headaches. Refer to the driver board descriptions provided in Part 1 of this manual.

Two programs (in BASIC) have been included on the MetraBus diskette. MEM8.BAS loops through and sequentially activates each relay while displaying the status of all relays on the CRT screen. The second program illustrates the BASIC OR command for activating relays while maintaining the status of the present module configuration. The programs are heavily commented so that even the beginning programmer should have little, if any, trouble following the flow of logic within. These, in conjunction with the examples below, should answer most of the question that arise concerning MEM-8 usage.

MEM-8 Terminology and Data Format

Like all MetraBus I/O boards, there is a standard programming sequence that is followed when controlling the MEM-8. This sequence consists of the following:

1. Targeting the MEM-8 via the ADRPTR.
2. Sending a data value (corresponding to the relays to be accessed) to the DATAIO.

MetraBus treats the eight relays on the MEM-8 as a single data byte. The relays, numbered 0 through 7, are associated with MetraBus data control lines as follows:

BIT	D7	D6	D5	D4	D3	D2	D1	D0
	CH7	CH6	CH5	CH4	CH3	CH2	CH1	CH0

Because of this arrangement, control of the various I/O modules on the board is accomplished by writing a byte whose value is associated with the relays to be closed. For example, to close relay #4, write a data value of 16 (24=16) to the driver board. Similarly, if we wanted to close relays #3 and #5, we would write a value of 40 (23 + 25 = 40) to the DATAIO. This arrangement makes it a very simple matter to specify modules using a BASIC integer variable as shown in the examples below.

The BASIC OUT and INP commands are used to respectively send information to and receive information from the MetraBus I/O board. While the examples are in BASIC, they are equally applicable to many other computer languages supporting data I/O operations such as C, PASCAL, Assembly, and others. The following examples assume a MetraBus driver card is installed at base address 768 (300h) and an MEM-8 at board address 20.

Example 1

This example illustrates the use of a BASIC variable to sequentially access each relay on the MEM-8.

```
10 DATAIO = 768                    'Declare Data I/O location
20 ADRPTR = 769                    'Declare Address Pointer location
30 MEM8 = 20                       'Declare MEM-8 Board Address
40 OUT ADRPTR,MEM8                 'Point to MEM-8 at address 20
50 FOR I= 0 TO 7                   'Begin BASIC control loop
60 OUT DATAIO, 2^I                 'Sequentially close each relay
70 NEXT I                          'End control loop
```

Example 2

Reading back the data value sent to the MEM-8 can be very useful for detecting data transmission errors. Such might be the case if you are transmitting data over long distances at high baud rates or if you are in an area of excessive electrical noise. The following program illustrates the data read-back feature. For the sake of clarity, the above program will be used with lines added only as necessary.

```
10 DATAIO = &H300                  'Declare Data I/O location
20 ADRPTR = 769                    'Declare Address Pointer location
30 MEM8 = 20                       'Declare MEM-8 Board Address
40 OUT ADRPTR,MEM8                 'Point to MEM-8 at address 20
50 FOR I= 0 TO 7                   'BASIC control loop
60 OUT DATAIO, (2^I)               'Activate "I" relay
75 RLYCHK=INP(DATAIO)              'Get data just written
80 IF RLYCHK <> (2^I) THEN PRINT "ERROR" : END
85                                 'Data integrity check
90 NEXT I                          'Close control loop
95 END
```

Example 3

It is often useful to be able to activate a relay while leaving the others intact, regardless of their state. The most efficient way to do this is to read back the state of all relays then OR those relays with the new relay to be activated.

```
10 DATAIO = 768                    'Declare Data I/O location
20 ADRPTR = 769                    'Declare Address Pointer
                                    'location
30 MEM8 = 20                       'Declare MEM-8 Board Address
40 OUT ADRPTR,MEM8                 'Point to MEM-8 at address 20
50 INPUT "NEW RELAY "; RLY         'Get user input for new relay
60 RLYSTAT = INP(DATAIO)           'Read back current status of
                                    'relays
70 OUT DATAIO, (2^RLY) OR RLYSTAT  'Activate new relay leaving
                                    'the old ones the way they
                                    'were
80 GOTO 50                         'Loop-back for next relay
```

5A.6 USE OF ALTERNATIVE RELAYS

Since industry standard plug-in relays are used, it is possible to substitute other relays with higher or lower contact ratings, contact types, and coil voltages. When selecting alternative relays, bear in mind that relays with 5 V coils may be driven directly and, therefore, most cost

effectively from your computer's own internal power supply or from our PWR-55 or PWR-100 power supplies. The standard relays supplied with the MEM-8 board have 28 ohm coils and will, therefore, draw about 1.5 A at 5 VDC with all the relays ON. This means that a PWR-100 will drive 7 boards (56 relays) if there is a possibility that all relays will be on at the same time. Some applications require that you power more than 56 relays without resorting to a heavier supply. In these cases, a "super sensitive" relay may be substituted, e.g. Potter & Brumfield type R10S-E1-Y2-J500. This relay requires only 7 mA to activate the coil. This is less then 1/20th the current drain of standard relay coils and allows for as many as 512 relays to be driven from a single PWR-100.

However, it is not always possible to use relays having 5V coils. Such applications are generally confined to either high current (7.5 or 10 A) or where low level (mV) voltages requiring gold crossbar contacts are used. These applications may require the use of relays with 6 V or 12 V coils. Provisions have been made for the addition of a LM-317K voltage regulator mounted on a Thermalloy 6254B heat sink. The output voltage from the regulator is set by R11 and R12, as shown on the schematic diagram provided. The regulator draws +15V from the power supply, therefore, an auxiliary supply (PWR-55 and PWR-100) is required. When using the optional regulator, link W1 on the MEM-8 must be removed. The voltage regulator and additional components can be installed by the factory. Contact the factory for pricing and availability. See Chapter 21.

The following list of alternative relays is intended to aid MetraBus users who are not familiar with the various relay manufacturers and their products. As such, it does not constitute an endorsement of any one manufacturer nor of their products. There are certainly many excellent manufacturers that are not listed below.

Potter & Brumfield

Super Sensitive	R10S-E1-Y2-J500	(5 V coil, 2 A contacts)
High Current Contact	R10-E1-X2-V28	(5 V coil, 5 A contacts)
Higher Current	R10-E1-W2-V185	(12 V coil, 7.5 A contacts)
Low Level	R10-E1-P2-V185	(12 V coil, 150 mA contacts)

Other suppliers of R10 type relays include

American Zettler - series AZ420
Aromat - series K2E
Allied - series T154 or T163

■ ■ ■

MEM-32/A & MEM-32/W ELECTROMECHANICAL RELAY SYSTEM

5B.1 GENERAL

The MEM-32/W and MEM-32/A are 32-channel, SPST, relay boards for the MetraBus system. The MEM-32/W has Mercury-wetted contacts rated at 2 A. The wetted contact configuration of the MEM-32/W allows it to be mounted within +30° of vertical. The MEM-32/A uses Mercury Amalgam relays that have slightly less current capability (0.5 A max.) but can be mounted without regard to relay position. A block diagram of the MEM-32 is provided in Figure 5B-1.

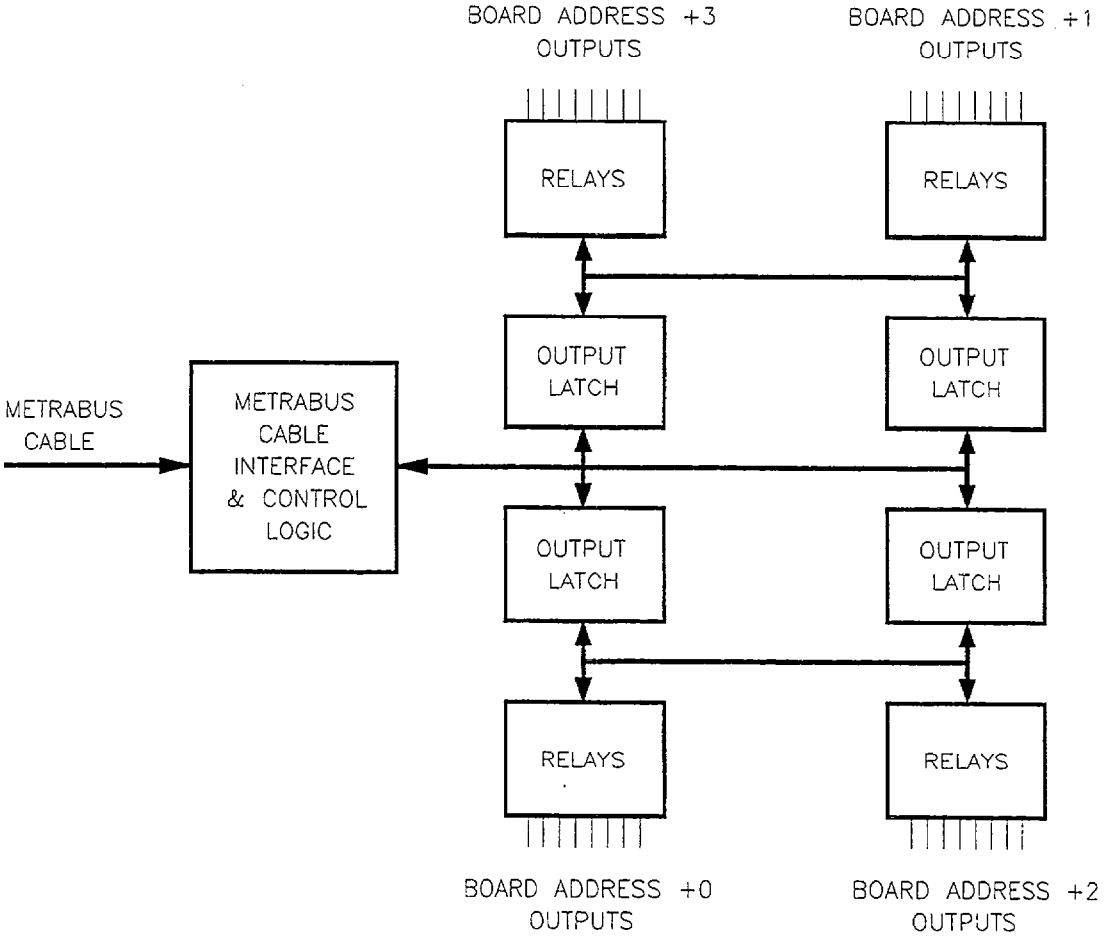


Figure 5B-1. MEM-32 Functional Block Diagram

The MEM-32 boards use four consecutive addresses on the MetraBus. This allows control of up to 16 MEM-32 boards by a single MetraBus driver board providing control of 512 independent relays. The board is divided into four 8-bit ports. Writing to a port loads data

into the output latches and to the relays themselves. Reading data back from a port returns the data currently on the output latch without changing it. This feature allows the user to verify that data on the outputs has been received correctly. The MEM-32 has been designed so that all relays are set in their off state at power-up.

The MEM-32 is connected to the MetraBus system via a 50-conductor ribbon cable that carries all address, and data signals as well as distributing all power on the MetraBus. The standard MetraBus cable is 10 feet long, and includes connectors for four interface boards. Keithley MetraByte can also build special cables up to 100 feet for your application.

Screw terminals on the MEM-32 offer easy connection to user field wiring, and accept wire sizes 12-22 AWG. The screw terminals are detachable for added ease while installing or removing boards. The MEM-32 can be mounted in standard 19-inch racks (such as the RMT-02) or in standard NEMA enclosures.

5B.2 FEATURES

- 32 SPST Mercury-wetted contacts (MEM-32/W)
- 32 SPST Amalgam contacts (MEM-32/A)
- Mercury-wetted contacts rated to 2 A at 50 watts (resistive)
- Amalgam Contacts rated at 0.5 A at 10 watts (resistive)
- Up to 512 outputs per expansion slot
- 100 VDC Isolation
- Very useful for switching in high or low current applications
- Allows very dense packaging in control applications
- Very low cost per channel

5B.3 SPECIFICATIONS

Number of Outputs:	32 SPST relays
Isolation:	1000 VDC
Operation Time:	2.0 ms maximum

MEM-32/W Contact Ratings

Contact Type:	Mercury-wetted (position-sensitive, board must be mounted +30° of vertical)
Contact Rating:	50 W at 2 A or 500 VDC (resistive)
Contact Resistance:	50 mΩ maximum
Contact Life:	107 operations at rated load

MEM-32/A Contact Ratings

Contact Type:	Mercury amalgam
Contact Rating:	10 W at 0.5 A or 200 VDC maximum
Contact Resistance:	50 mΩ maximum
Contact Life:	107 operations at rated load

Environmental

Operating Temperature:	0 to 70° C
Storage Temperature:	-40 to 100° C
Humidity:	0 to 90% noncondensing
Mounting:	The MEM-32/W must be mounted within +30° of vertical. The MEM-32/A can be mounted at any angle

Power Consumption

+5 V:	510 mA plus 22 mA per activated relay maximum
+15 V:	Not used

5B.4 USING AN AUXILIARY POWER SUPPLY

Because of low power drain, the MEM-32 does not require an auxiliary power supply unless you have more than two MEM-32 boards in your system. However, if you have other MetraBus I/O boards or more than 2 MEM-32s in your MetraBus system, you need a high-quality auxiliary power supply such as the MBUS-PWR.

> NOTE: If an auxiliary power supply in used in conjunction with an MDB-64 MetraBus Controller/Driver card, remember to remove fuse F1 from the MDB-64.

5B.5 SETTING THE MEM-32 BOARD ADDRESS

The I/O address for each MEM-32 connected to a single MetraBus cable must be unique and non-overlapping for the driver card to target that specific MEM-32. These addresses allow the boards in a MetraBus system to be operated independently. Each MEM-32 uses four of the available 64 MetraBus addresses. These four addresses run consecutively starting from the MEM-32 board address. Setting the board address is outlined below. Figure 5B-2 shows a typical board address switch Setting.

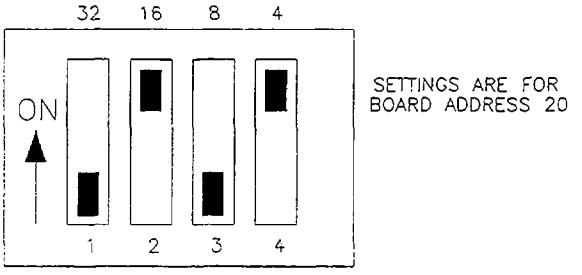


Figure 5B-2. Setting the Board Address

To set the board address,

1. The board-address DIP switch is on the far-left side of the board just above and to the left of the MetraBus connector. The numbers silk-screened above the DIP switch indicate the values of the corresponding individual switches; these numbers have value only in the ON position.

2. Select an unused board address and set the DIP switch accordingly. For example, in order to set a board address of 24, switches with corresponding values of 8 and 16 would be ON while the others would remain OFF. Remember that each MEM-32 uses four consecutive addresses of the 64 that are available and must be set to an unused, non-overlapping address order to avoid conflicts.

3. After setting the board address, connect the MEM-32 to the MetraBus driver card via the MetraBus cable. The MetraBus cable connector is keyed for your protection and should plug in easily. Check the keyways for correct alignment prior to plugging in the MetraBus cable.

   NOTE: It is always good practice to remove power from the MetraBus cable prior to connecting any I/O boards.

4. If you have only one MEM-32 or if your MEM-32 is the last board in your system, install the resistor-terminating networks provided with your driver card. The sockets marked RN1 and RN2 immediately above the MetraBus connector are for this purpose. These resistor networks minimize signal reflection caused by long cable lengths. They are optional, however, and have little effect for cables of 50 feet or less.

5B.6 TYPICAL OUTPUT CONNECTIONS

The MEM-32 was designed to interface with a variety of devices. Figure 5B-3 depicts typical output connections.

5B.7 PROGRAMMING THE MEM-32

MetraBus supervision by the driver board simplifies MEM-32 programming. Since all necessary control signals are automatically generated within the driver board, the user need not be concerned with control registers, PEEKing or POKEing memory locations, shifting bits, PUSHing or POPing stacks, learning new languages, or other system level headaches. Refer to the driver board descriptions in this manual.

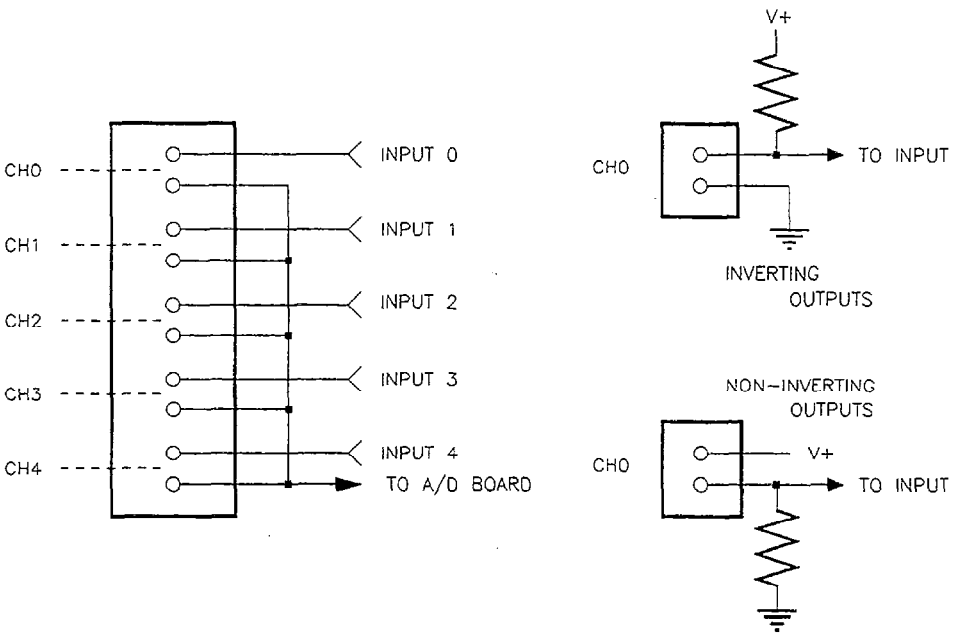


Figure 5B-3. Typical Output Connections

A program (in BASIC) is included on the MetraBus diskette. The program deals with the MEM-32 and its associated functions. MEM32.BAS displays the status of all 32 output bits and allows you to change any bit using the cursor keys (, , ,).

This program is heavily commented so that even the beginning programmer should have little, if any, trouble following the flow of logic within. These, in conjunction with the examples below, should answer most of the question that arise concerning MEM-32 usage.

MEM-32 Terminology & Data Format

Like all MetraBus I/O boards, there is a standard programming sequence that is followed when controlling the MEM-32. This sequence consists of the following:

1. Targeting the MEM-32 and the 8-bit block desired via the ADRPTR.
2. Sending a data value (corresponding to the desired state of the outputs) to the DATAIO.

The MEM-32 has four blocks (numbered 0-3) of eight channels (numbered 0-7). In order to select block number 2, you must specify that block when targeting the MEM-32 at its Base Address as follows:

```
10 OUT ADRPTR, MEM32 + 2     'point to block 2 of MEM-32
```

The BASIC OUT and INP commands send instructions to and retrieve data from the MEM-32.

```
10 DATAIO = 768                 'Declare Data I/O location
20 ADRPTR = 769                 'Declare Address Pointer location
30 MEM32 = 4                    'Declare MEM-32 MetraBus address
40 OUT ADRPTR, MEM32            'Point to block 0 of MEM-32
50 OUT DATAIO, 63               'Set the lowest 6-bits (0011 1111)
```

Example 1

The above example sets Bits 0, 1, 2, 3, 4, and 5 to their active states. To sequentially toggle (ON then OFF) each of the 32 bits of the MEM-32, use nested BASIC FOR ... NEXT loops as follows:

```
10 DATAIO = 768                 'Declare Data I/O location
20 ADRPTR = 769                 'Declare Address Pointer location
30 MEM32 = 4                    'Declare MEM-32 Board Address
40 FOR I = 0 TO 3               'Set up block access control loop
50 OUT ADRPTR, MIO32 + I        'Point to block "I" of MEM-32
60 FOR J = 0 TO 7               'Channel access control loop
70 OUT DATAIO, 2^J              'Set each bit sequentially high
80 NEXT J                       'Increment channel variable and loop
90 NEXT I                       'Increment block.  Loop back to 40
```

Example 2

It can be useful to be able to turn certain output bits ON while leaving the other output bits in their present state. Do this with the BASIC OR command as follows:

```
10 DATAIO = 768                   'Declare Data I/O location
20 ADRPTR = 769                   'Declare Address Pointer location
30 MEM32 = 4                      'Declare MEM-32 Board Address
40 OUT ADRPTR,MEM32 + 4           'Point to block 4 of MEM-32
50 INPUT "Bit number ON " ; BIT   'Get user input (bit number)
60 OLDBITS=INP(DATAIO)            'Retrieve present status
70 OUT DATAIO, 2^BIT OR OLDBITS   'OR new bit with old
80 GOTO 60                        'Loop back for next bit
```

As shown above, the MEM-32 has data read-back capability allowing for data integrity verification. This lets the user read-back the data just sent to the MEM-32 and compare it to the data value specified.

In order to verify data via the data read-back feature, the following program will be helpful. We will use the above program with changes (lines 10 to 50 remain the same as above).

```
60 OUT DATAIO, 2^BIT              'Turn ON targeted bits
70 BITCHEK = INP(DATAIO)          'Get data just sent
80 IF BITCHEK <> 2^BIT THEN PRINT "ERROR!!": END
90 GOTO 50
```

Note that in all the above examples, we used a variable to set various bits to the specified states. Calculating the integer that represents various bits is a simple matter as shown below. Bit calculations are based on binary arithmetic (base 2) as follows:

$$2^4 + 2^7 = 16 + 128 = 144$$

Therefore, to set bits 4 and 7 ON, we would output a data value of 144 to the DATAIO, after we had targeted the MEM-32.

```
40 OUT ADRPTR, MEM32 + 1          'Point to block 1 of MEM-32
50 OUT DATAIO, 144                'Set bits 4 and 7 high
```

Use this procedure for each block of eight bits being monitored. That is, calculation of digital output line values do not correspond to lines 0 - 32, but simply 0 - 7.

5B.8 USING COMPILED OR ASSEMBLED LANGUAGES

Program execution speed of compiled and assembled languages is such that their use requires a few precautions. A WRITE DATA (R/W) time of 10 microseconds necessitates the monitoring of the R/W and BUSY status bits prior to accessing the digitized data or attempting other operations on the MetraBus. This monitoring operation can be accomplished by reading the currently latched MetraBus address and "looking" at bit #6. This information is contained in the ADRPTR location. The data storage format is:

BIT	D7	D6	D5	D4	D3	D2	D1	D0
	BUSY	R/W	A5	A4	A3	A2	A1	A0

For a period of 10 microseconds after a data output (WRITE) operation, the R/W status bit will be active (high). The R/W status bit must be in its quiescent state prior to attempting another operation on the MetraBus. Returning the value of only the R/W bit can be accomplished as follows:

```
90 STATUS=INP(ADRPTR) AND 64      'Get status information
100  IF STATUS <> THEN GOTO 90
```

The BASIC variable STATUS will contain either 0 or 64 indicating the state of the D6 bit. Again, it should be stressed that this procedure need only be done when using compiled (including compiled BASIC) and assembled languages.

■ ■ ■

MSSR-32 SOLID STATE SWITCHING I/O MODULE

5C.1 GENERAL

The MSSR-32 is a 32-channel digital I/O module providing complete optical isolation for both high and low power switching applications. This module monitors and controls 32 individual I/O points via optically isolated, solid-state, plug-in modules. The 32 digital channels perform as four 8-bit I/O ports for easy programming. These modules are available for both input and output. Voltages of 120/130 VAC, 0 to 60 VDC, 10 to 32 VDC, etc. as well as standard European line voltages can be sensed and/or controlled. Control and sense modules can be mixed on a single MSSR-32. Removable screw terminals on the MSSR-32 accept 12 to 22 AWG wire. A functional block diagram of the MSSR-32 is provided in Figure 5C-1.

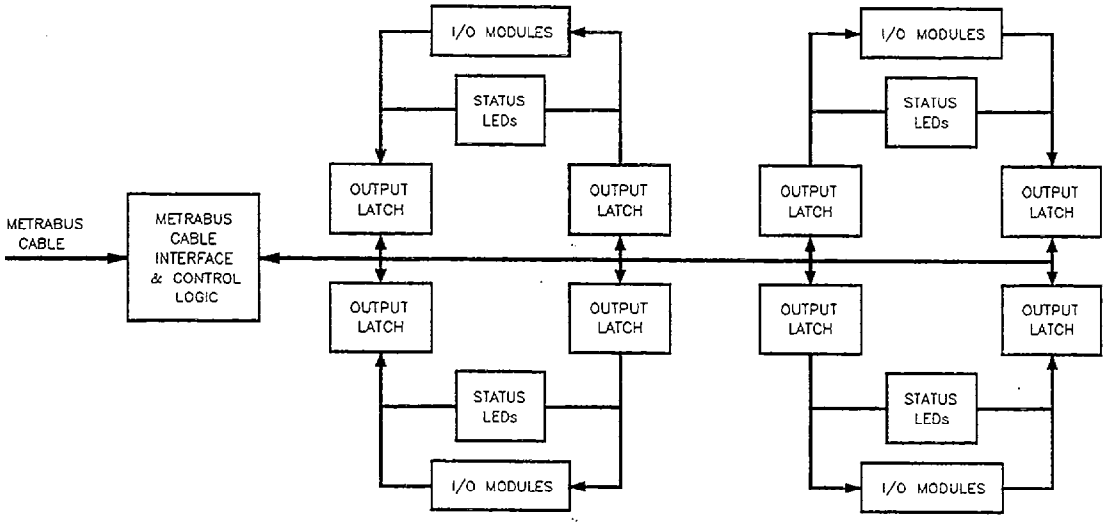


Figure 5C-1. MSSR-32 Block Diagram

The MSSR-32 connects directly to one of the MetraBus controller/driver cards (MDB-64, MID-64, µCMDR-64, or REM-64) through the MetraBus cable. The driver card is in your PC, while the MSSR-32 may be adjacent to its point of use for easy signal connection. The MetraBus cable connects the MSSR-32 to the driver card 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 system noise immunity. The MetraBus system allows MetraBus cable lengths of up to 100 feet. The MSSR-32 is 19" rack-mountable in any standard NEMA type enclosure and also mounts on any panel or other flat surface.

A total of 16 MSSR-32s can connect to a single MetraBus driver card via the MetraBus cable, allowing up to 512 individual I/O points for monitor and control. Like other MetraBus I/O boards, the MSSR-32 has a data readback feature allowing user verification of data integrity. For those applications requiring greater power than your PC supply normally furnishes, a choice of auxiliary MetraBus power supplies is available (MBUS-PWR).

The MSSR-32 is a versatile, cost-effective solution to many industrial and laboratory applications including: computer control of pump cycling, ON/OFF motor control, energy management, signal multiplexing, alarm activation, temperature cycling, product life cycle testing, etc.

5C.2 FEATURES

- Interfaces directly to IBM PC/XT, PC AT, and compatibles
- Remote connections with removable screw terminals
- Sense/control up to 512 I/O points per computer expansion slot
- Extremely cost effective
- Adapts to your changing requirements
- Optically isolated to 1500 VDC (nominal)
- Uses Industry Standard plug-in modules

5C.3 SPECIFICATIONS

Number of I/O Channels:	32
Isolation Type:	Optical
Isolation Rating:	1500 Vrms typical
I/O Module Life Expectancy:	Infinite
I/O Modules Installed:	None (must be ordered separately)
MetraBus Cable Type:	50-Conductor Ribbon
MetraBus Connector:	3M 3425-6050

Environmental

Operating Temperature:	0 to 70° C.
Storage Temperature:	-40 to 100° C.

Power Consumption

+5 VDC:	325 mA typical; 500 mA maximum

5C.4 USE OF AN AUXILIARY POWER SUPPLY

The PC power supply can power a single MSSR-32 since the Board requires only +5 VDC (@ 500 mA, max). However, if you are installing more than one MSSR-32 board in your MetraBus system or if you have other MetraBus I/O boards, an auxiliary power supply may be required. See the MBUS-PWR section of this manual for more information.

NOTE: If you are using an auxiliary power supply in conjunction with an MDB-64 MetraBus controller/driver board, remember to remove fuse F1 from the MDB-64.

5C.5 CONFIGURING THE MSSR-32

The MSSR-32 is a mounting rack for solid-state, I/O plug-in modules. Each MSSR-32 will hold up to 32 solid-state I/O modules that are available in several versions and may be ordered from the factory or other sources. When ordering I/O modules from other manufacturers, bear in mind that the MSSR-32 uses +5 VDC for module activation. A short list of the various I/O modules available for the MSSR-32 follows:

OUTPUT (control)

SMOAC5 -- 120 VAC @ 3 A
SMODC5 -- 0 to 60 VDC

INPUT

SM-IAC5 -- 120 VAC/DC @ 11 mA
SM-IDC5 -- 10 to 30 VDC

NOTE: The MSSR-32 contains 5 A miniature replacement fuses that may open in the event of external circuit failure.

5C.6 INSTALLING THE MSSR-32

Each MSSR-32 connected to a single MetraBus driver card must be set to a unique, non-overlapping MetraBus I/O board address. Each MSSR-32 uses four of the available 64 MetraBus addresses. These are consecutive locations starting from the board address. Setting this board address is outlined below. Figure 5C-2 shows a typical board-address switch setting.

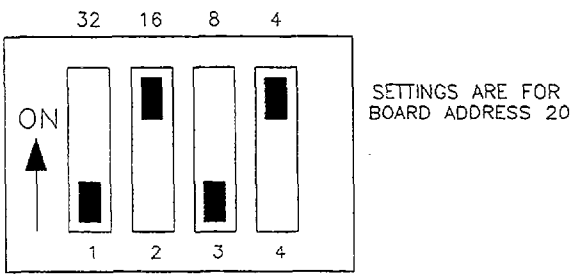


Figure 5C-2. Typical Board Address Switch Setting

To set the board address,

1. The board address DIP switch is located in the lower-left corner of the MSSR-32. The numbers silk-screened above the DIP indicate the values of the switches immediately below them. The numbers have value only in the ON position.

2. Select an unused board address and turn ON the corresponding DIP switches. For example, to set a board address of 24, turn on the switches for values 8 and 16. Remember to choose an unused, non-overlapping board address to avoid conflicts.
3. After setting the board address, you may connect the MSSR-32 to the MetraBus driver card via the MetraBus cable. The MetraBus cable connector is keyed for your protection and should plug in easily. Check the keyways for correct alignment prior to plugging in the MetraBus cable.
4. If you have only one MSSR-32 or if one of your MSSR-32s is the last board in your system, install the resistor terminating networks provided with your driver card. The sockets marked RN1 and RN2 immediately above the MetraBus connector are for this purpose. These resistor networks minimize signal reflection caused by long cable lengths. They are optional, however, and have little effect for cables of 50 feet or less.

MSSR-32 Terminology and Data Format

Follow a standard programming sequence when controlling the MSSR-32/MSSR-32. This sequence consists of the following:

1. Targeting the MSSR-32 and desired 8-bit block via the ADRPTR.
2. Sending a data value (corresponding to the I/O modules to be accessed) to the DATAIO.

MetraBus treats the 32 modules on the MSSR-32 as four (8-bit) blocks corresponding to 4 MetraBus I/O addresses (board address +0 through board address +3). The data format for each of the two blocks is the same and corresponds to the following digital I/O lines (DO-D7):

BIT	D7	D6	D5	D4	D3	D2	D1	D0
	CH7	CH6	CH5	CH4	CH3	CH2	CH1	CH0

This arrangement enables control of I/O modules on the board to be accomplished by writing a single byte whose value is associated with the modules to be accessed. For example, to activate module 4 on block 0, write a data value of 16 ($2^4 = 16$) to the DATAIO. Similarly, to activate modules 3 and 5, write a value of 40 ($2^3 + 2^5 = 40$) to the DATAIO. To access module 3 of block 1 (relays 8 to 15), target block one via the ADRPTR (base address +1) and write a data value of 8 ($2^3 = 8$) to the DATAIO. This arrangement allows you to specify modules using a BASIC integer variable as shown in the examples below.

The BASIC OUT and INP commands respectively send information to and receive information from the MetraBus I/O board. While the examples are in BASIC, they are equally applicable to many other computer languages supporting data I/O operations such as C, PASCAL, Assembly, and others. The following examples assume a MetraBus driver card is installed at base address 768 (300h) and an MSSR-32 at board address 20.

Example 1

This example illustrates the use of a BASIC variable to sequentially access each relay on the MSSR-32.

```
10 DATAIO = 768                    'Declare Data I/O location
20 ADRPTR = 769                    'Declare Address Pointer location
30 MSSR32 = 20                     'Declare MSSR-32 Board Address
40 FOR J = 0 TO 3                  'J represents the various 8-bit blocks
50 OUT ADRPTR,MSSR32 + J           'Point to MSSR-32 at address 20
60 FOR I= 0 TO 7                   'Begin BASIC control loop
70 OUT DATAIO, 2^I                 'Sequentially close each relay
80 NEXT I                          'End first block
90 NEXT J                          'End control loop
```

Example 2

Reading back the data value sent to the MSSR-32 can be useful for detecting data transmission errors if you are transmitting data over long distances at high baud rates or if you are in an area of excessive electrical noise. The following program illustrates the data readback feature. For the sake of clarity, the above program will be used with lines added only as necessary.

```
10   DATAIO = &H300               'Declare Data I/O location
20   ADRPTR = 769                 'Declare Address Pointer location
30   MSSR32 = 20                  'Declare MSSR-32 Board Address
40   FOR J = 0 TO 3               'J represents the various 8-bit blocks
50   OUT ADRPTR,MSSR32            'Point to MSSR-32 at address 20
60   FOR I= 0 TO 7                'BASIC control loop
70   OUT DATAIO, (2^I)            'Activate "I" relay
80   RLYCHK=INP(DATAIO)           'Get data just written
90   IF RLYCHK <> (2^I) THEN PRINT "ERROR" : END
100                               'Data integrity check
110  NEXT I                       'Close control loop
120  NEXT J
120  IF J>3 THEN END
```

Example 3

It can be useful to be able to activate a relay while leaving the others intact, regardless of their state. The most efficient way to do this is to read back the state of all relays then OR those relays with the new relay to be activated.

```
10 DATAIO = 768                    'Declare Data I/O location
20 ADRPTR = 769                    'Declare Address Pointer location
30 MSSR32 = 20                     'Declare MSSR-32 Board Address
40 OUT ADRPTR,MSSR32               'Point to MSSR-32 at address 20
50 INPUT "NEW RELAY "; RLY         'Get user input for new relay
60 RLYSTAT = INP(DATAIO)           'Read back current status of relays
70 OUT DATAIO, (2^RLY) OR RLYSTAT
71                                 'Activate new relay leaving the old
                                     'ones the way they were
80 GOTO 50                         'Loopback for next relay
```

■ ■ ■

MCPT-8X8 CROSS-POINT, MATRIX RELAY BOARD

5D.1 GENERAL

The MCPT-8X8 features 64 I/O relay points in an 8 x 8 array. The relays are single-pole, form A, mercury amalgam, non-position sensitive contact reed type. As an option, position-sensitive wetted relays are available. Figure 5D-1 shows a block diagram of the MCPT-8X8.

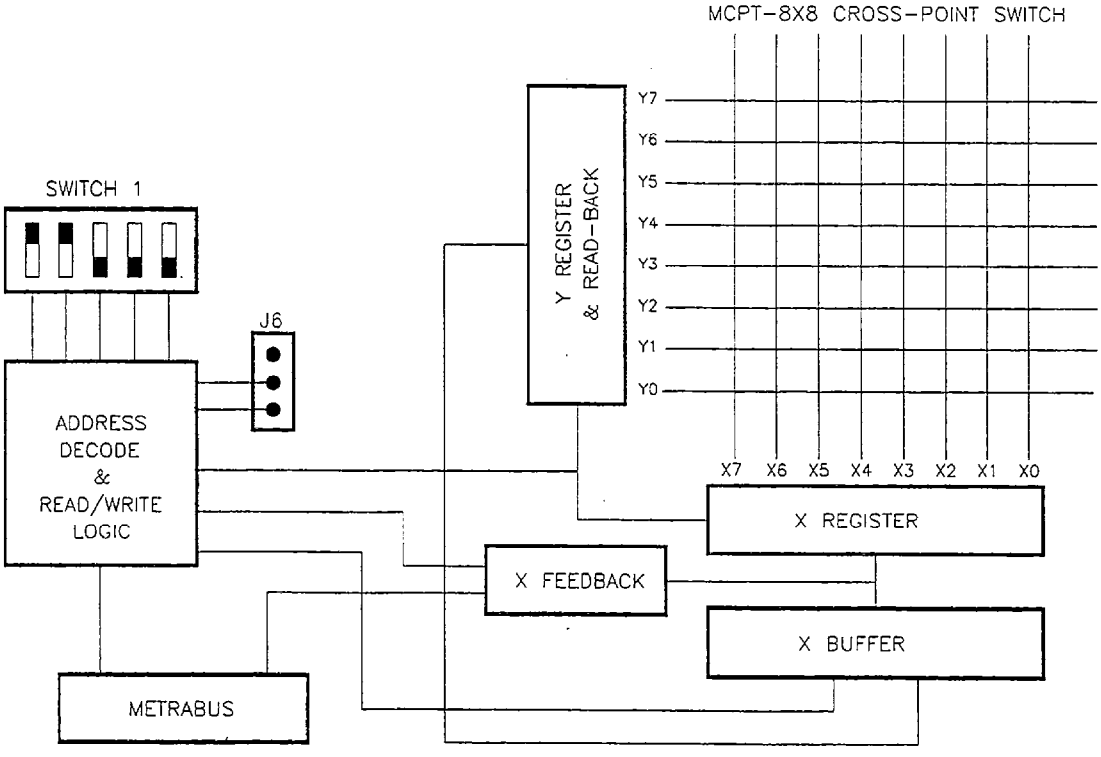


Figure 5D-1. MCPT-8X8 Functional Block Diagram

The MCPT-8X8 is programmable in any language with I/O control such as C, Assembly, Microsoft Pascal, TURBO PASCAL, GWBASIC, or BASICA. The relays are mapped to an X/Y (consecutive byte) Cartesian matrix for ease of configuration and control. The MCPT-8x8 uses 2 consecutive addresses on the MetraBus allowing a maximum of 32 separately addressable MCPT-8x8 boards (2048 I/O points) from a single MetraBus controller board. Also, any number of boards may be assigned the same board address providing 2,3,or N pole switches, making it possible to expand relay matrices in a linear (1 dimension), Cartesian (2 dimensions), or geometric (3 dimensions) fashion. This allows the creation of versatile, multi-dimensional input and control schemes.

The MCPT-8x8 connects to the MetraBus via a 50-conductor ribbon cable and connector (3M Part # 3425-6050) carrying all address, data, and control signals from the controller/driver and distributing power on the MetraBus. Removable screw terminals on the MCPT-8x8 offer easy signal connection and interchange.

5D.2 SPECIFICATIONS

Relay Specifications

Number of I/O points:	64 (8 x 8 matrix)
Type of Relay:	Single-pole, Form A, reed type
Contact Type:	Mercury amalgam (not position-sensitive); Optional-wetted mercury (position-sensitive)
Contact Power Rating:	200 VDC @ 0.5 A maximum
Contact Resistance:	50 mΩ minimum
Relay Life:	>10,000,000 operations at full load
Operate and Release Time:	2 ms maximum

Environmental

Operating Temperature:	+32 to +122° F (0 to +50° C)
Storage Temperature:	-104 to +212° F (-40 to +100° C)
Humidity:	0 to 95%, noncondensing

Power Supplies

@ +5 Volts:	+5 VDC @ 200 mA maximum plus 20 mA per energized relay.

Physical

Size:	4.75" H x 16.00" L (12.06 cm H x 40.64 cm L).
Weight:	20 ounces (566.00 gm).
MetraBus Cable Type:	50-conductor ribbon cable.
MetraBus Connector:	3M 3425-6050.

5D.3 USE OF AN AUXILIARY POWER SUPPLY

If you have more than one MCPT-8x8 or other MetraBus I/O boards in your MetraBus system, or you do not wish to use the PC +5 V power, you may require an auxiliary power supply. Refer to the MBUS-PWR chapter for more information.

NOTE: When using an auxiliary power supply with an MDB-64 MetraBus controller/driver board, remember to remove fuse F1 from the MDB-64.

5D.4 JUMPERS AND SWITCHES

This section describes how to configure the MCPT-8x8. One DIP switch (S1) sets the board address, and one jumper block (J1) selects the read-data feature.

Setting the Board Address

Set each MCPT-8x8 on a single MetraBus cable for a unique, non-overlapping MetraBus I/O address, unless using multiple boards as two of n pole switches. This distinct address allows the various boards in a MetraBus system to operate independently. Each MCPT-8x8 uses two of the 64 available addresses on the MetraBus.

NOTE: The MCPT-8x8 uses two of the 64 consecutive addresses on the MetraBus. The MCPT-8x8, like all MetraBus I/O boards, requires a non-overlapping address in order to avoid address conflicts. Since any MetraBus I/O board may be connect to a single MetraBus cable, an address overlap is possible. Take care to avoid this.

To configure the board address, locate switch S1 on the board. This switch allows you to set board addresses ranging from 2 to 62. S1 is illustrated in Figure 5D-2.

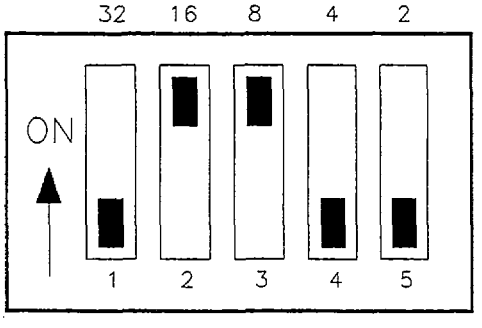


Figure 5D-2. Switch S1

To set the board address, move the appropriate combination of S1 switches into the ON position. For example, to set a board address of 24, move switches 2 and 3 into the ON position as shown in Figure 5D-2.

Setting the Read Data Jumper

Jumper J6 permits the read-data feature of the MCPT-8x8 to be suppressed. This jumper is normally factory-configured to allow data to be read (in its OFF position). Some system configurations may require this feature to be disabled. For example, if multiple boards assigned the same board address are installed in a multi-pole switch configuration (this

configuration helps to avoid data conflict). To disable this function, move the jumper plug to the ON position (between posts 1 and 2). Figure 5D-3 shows the read-data jumper.

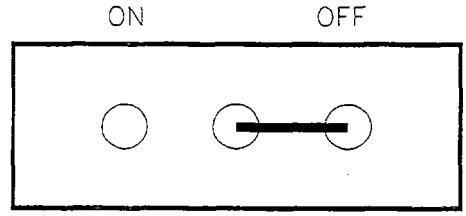


Figure 5D-3. Read Data Jumper Block (J6)

If multiple boards use the same MetraBus address (they are in a multi-pole configuration), only one read-data jumper should be ON. That is,the Read Data Jumper on one board should be in the ON position. Read-data jumpers on all other boards should be in the OFF position.

5D.5 RESISTOR TERMINATION NETWORKS

If the MCPT-8X8 is the last board on the MetraBus network, you may need to install the two resistor termination networks provided with the MetraBus controller board (refer to the section describing your controller board for more information). These networks are installed in sockets RN1 and RN2.

5D.6 INSTALLING THE MCPT-8X8

Before installing the MCPT-8X8, make certain that a MetraBus controller/driver board has been installed. To install the board,

1. Select an unused board address and set S1 accordingly. Remember that each MCPT-8X8 uses eight of the 64 MetraBus I/O addresses and must be set to an unused, non-overlapping board address to avoid address conflicts.
2. After setting the board address, connect the MCPT-8X8 to the MetraBus cable. The MetraBus cable connector is keyed for your protection.

   NOTE: Remove power from the MetraBus cable prior to connecting it to any I/O boards.
3. If you have only one MCPT-8X8 or if your MCPT-8X8 is the last board in your system, install the resistor terminating networks provided with your driver card. The sockets marked RN1 and RN2 immediately above the MetraBus connector are for this purpose. These resistor networks minimize signal reflection from long cable lengths. They are optional, however, and have little effect for cables of 50 feet or less.

5D.7 PROGRAMMING THE MCPT-8X8

Since the driver board generates all control signals, there is no need for concern with control registers, PEEKing or POKEing memory locations, shifting bits, PUSHing or POPing stacks, learning new languages, or other system level headaches.

MCPT-8X8 Terminology and Data Format

The MCPT-8x8 uses two of the 64 consecutive addresses on the MetraBus. Access to these two addresses uses an offset from the MetraBus Driver Board Base Address. The addresses are listed and described in the following table.

I/O ADDRESS	READ	WRITE
Base Address +0h	X Data In	X Data Out
Base Address +1h	Y Data In	Y Data Out

The 2-byte (X/Y) address structure simplifies MCPT-8X8 programming. A single 2-byte word controls any or all of the 64 relays on the board. For example, the following short BASIC routine loads both the X and Y bytes to the MCPT-8x8, then activates the relays.

```
100 OUT ADRPTR, 8          'MCPT-8X8 board address (8)
110 OUT DATAIO, &H80       'select X7.  Do not activate.
120 OUT ADRPTR,9           'Address Y register
130 OUT DATAIO, &H04       'select Y2,X7.  Activate relays.
```

Notice that to prevent intermediate states between applying data, the X data is double-buffered and will not be written to the matrix until the Y data has been loaded.

All data should be written in the X, then the Y sequences. The relays may not break before make. An intermediate X = 0, Y = 0, however, will accomplish this. Note that high-speed machines as well as compiled or assembled languages on slower machines may require a wait loop (2 ms minimum) for the reed relays to settle after switching.

■ ■ ■

MIO-32 ISOLATED DIGITAL OUTPUT BOARD

6A.1 GENERAL

The MIO-32 is a 32-channel output board whose channels are DTL/TTL, NMOS/CMOS, and 0 to 5 V compatible. Outputs can be as high as 20 V. Each channel on the MIO-32 is optically isolated to 500 V (continuous). Screw terminals on the board accept 12 to 22 AWG wire. Figure 6A-1 is a block diagram of the MIO-32.

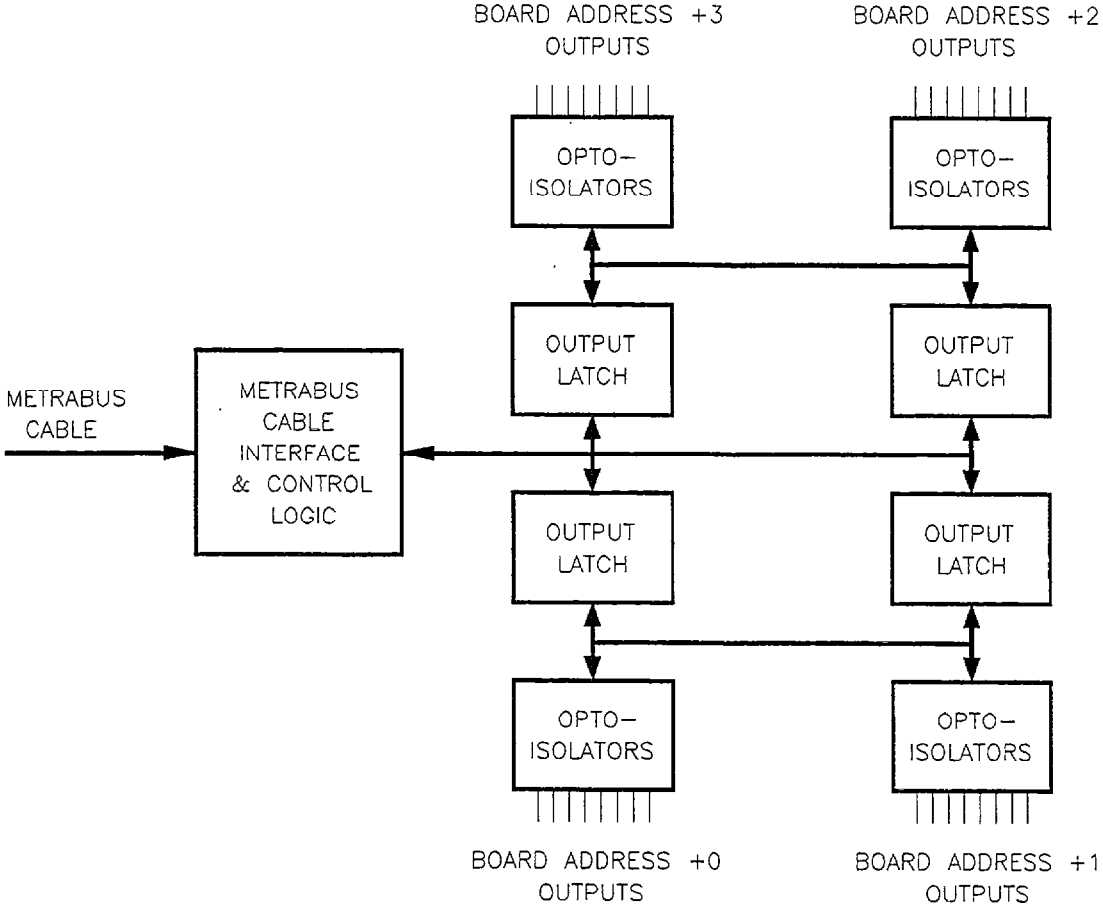


Figure 6A-1. Block Diagram

The MIO-32 connects directly to any of the MetraBus controller/driver cards via a 50-conductor ribbon cable. The MetraBus cable connects the MIO-32 to the driver card 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 provides MetraBus cable lengths of up to 100 feet, allowing the MIO-32 to be positioned adjacent to its point of use for easy signal

connection. Remote control of the MetraBus system is possible via the REM-64 serial driver card at distances of up to 1.2 km. The MIO-32 is 19" rack-mountable in either a standard NEMA type enclosure or the MetraByte RMT-02; it may also be mounted on any panel or other flat surface.

The MetraBus system allows control of up to 512 digital output channels from a single computer expansion slot. This allows the development of extremely powerful and cost-effective Industrial Data Acquisition and Control systems.

Some uses of the MIO-32 include computer control of relays, pumps, solenoids, and other ON/OFF feedback control, computerized test benches, programmable square wave generator, etc.

6A.2 FEATURES

- Interface with IBM PC/XT, PC AT, and compatibles
- Remote signal connections
- Up to 512 outputs per computer expansion slot
- Cost effective
- Compatible with most computer languages
- Optically isolated to 500 Volts

6A.3 SPECIFICATIONS

Output Lines:	32 (four blocks of 8 lines)
Overvoltage Isolation:	500 VDC (continuous)
Isolation Type:	Optical
Maximum Output Voltage:	20 VDC
Output OFF Current:	1 µA maximum
Output OFF Voltage:	Set by user
Output drive current:	1.8 mA minimum
Output ON Voltage:	0.5 V maximum

Environmental

Operating Temperature:	0 to 70° C
Storage Temperature:	-55 to 125° C
Humidity:	0 to 95% non-condensing

Power Consumption

@ +5 V: 520 mA typical; 600 mA maximum

Physical

Size: 16 x 4.75 inches (40.63 x 12.06 cm)

MetraBus Cable Type: 50-conductor ribbon cable

MetraBus Connector: 3M 3425-6050.

6A.4 USING AN AUXILIARY POWER SUPPLY

The MIO-32, due to its low power drain, does not require an auxiliary power supply unless you have more than 2 MIO-32 boards in your system. However, if you have other MetraBus I/O boards or more than 2 MIO-32s in your MetraBus system, you will need a high quality auxiliary power supply such as the MBUS-PWR.

> NOTE: If you use an auxiliary power supply in conjunction with an MDB-64 MetraBus controller/driver card, remember to remove fuse F1 from the MDB-64.

6A.5 INSTALLING THE MIO-32

Prior to installing the MIO-32, make certain that a MetraBus controller/driver board is installed. These boards are described in the Chapter 2.

Each MIO-32 on a single MetraBus cable must be set to a unique, non-overlapping MetraBus I/O address. This distinct address allows the various boards in a MetraBus system to be operated independently. Each MIO-32 uses four of the available 64 MetraBus addresses. These four addresses run consecutively starting from the MIO-32 board address. Setting the board address is outlined below. Figure 6A-2 shows a typical board address setting.

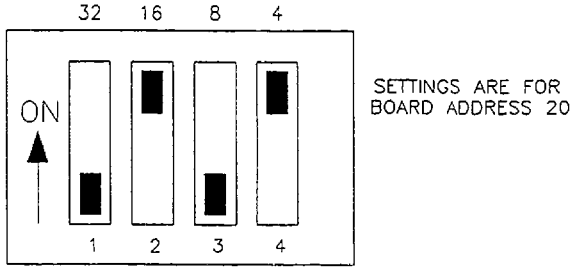


Figure 6A-2. Typical Board Address Address Setting

To set the board address,

1. The board address DIP switch is located on the far-left side of the board, just above and to the left of the MetraBus interface connector. The numbers silk-screened above the DIP indicate the values of the adjacent switches. The numbers have value only in the ON position.

2. Select an unused board address and set the DIP switches accordingly. For example, to set a board address of 24, turn on switches with values of 8 and 16. Remember that each MIO-32 uses four of the available 64 MetraBus I/O addresses and must be set to an unused, non-overlapping board address in order to avoid address conflicts when being targeted by the driver card.

3. After setting the board address, connect the MIO-32 to the MetraBus cable. The MetraBus cable connector is keyed for your protection and should plug in easily.

   NOTE: It is always good practice to remove power from the MetraBus cable prior to connecting any I/O boards to it.

4. If you have only one MIO-32 or if your MIO-32 is the last board in your system, you should install the resistor terminating networks that are provided with your driver card. The sockets marked RN1 and RN2 immediately above the MetraBus connector are for this purpose. These resistor networks are used to minimize signal reflection due to long cable lengths. They are optional, however, and have little effect for cables of 50 feet or less.

6A.6 TYPICAL OUTPUT CONNECTIONS

To ensure proper operation of the MIO-32 with a variety of logic-level circuitry, follow this discussion and associated illustrations when wiring your application.

The MIO-32 allows access to both the emitter and collector of the opto-couplers output. This allows maximum flexibility when connecting the MIO-32 to your application. Figure 6A-3 depicts typical wiring schemes that could be used to interface to the devices indicated.

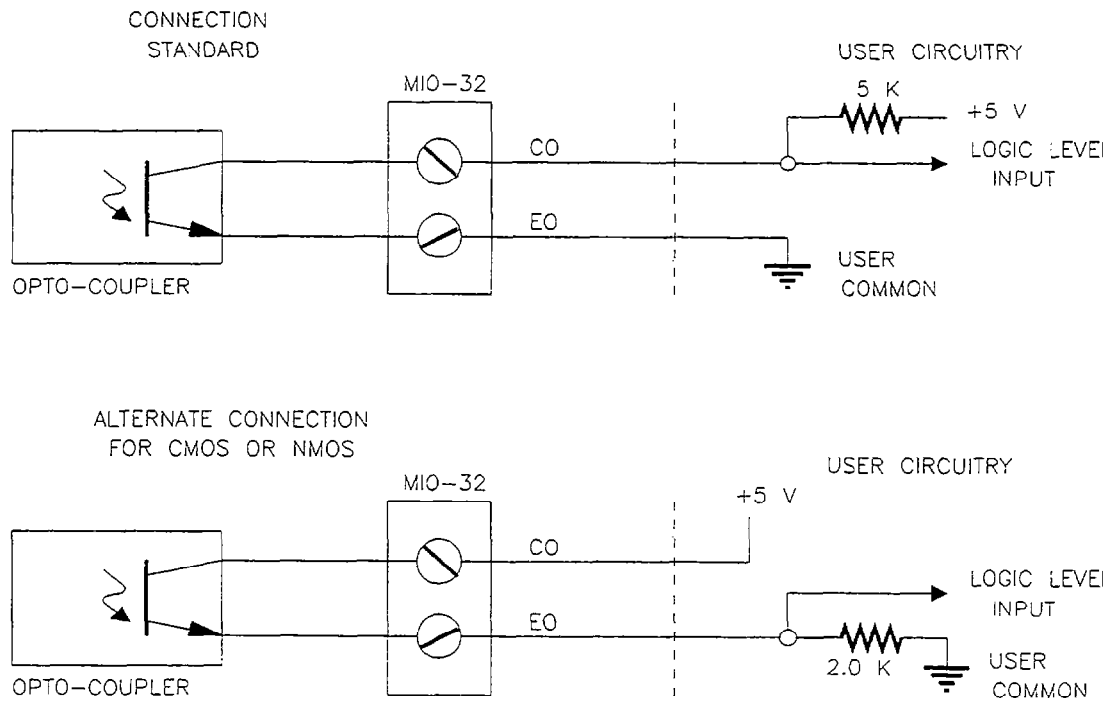


Figure 6A-3. Typical Output Connections

User supplied source current (normally +5 VDC to +20 VDC) must be used with both standard and alternative connection schemes. The output from the MIO-32 is then wired to

the user's "logic level input." Note that when using the standard connection scheme, a logical "OFF" command causes the photo-emitter not to emit, thus eliminating the low-resistance ground path and causing current flow through the user input circuitry. This "inversion" of logic level is easily compensated for by software. Issuing a MetraBus system RESET command in conjunction with the standard connection configuration will cause all outputs to go high. The alternate method shown above does not invert the data, but offers less drive current because of the 2.0 kOhm ground path and is not recommended for use with TTL inputs.

6A.7 PROGRAMMING THE MIO-32

MetraBus supervision by the driver board tends to simplify MIO-32 programming. Since the driver board generates all necessary control signals, the user need not be concerned with control registers, PEEKing or POKEing memory locations, shifting bits, PUSHing or POPing stacks, learning new languages, or other system level headaches. Refer to the driver board descriptions Chapter 1 of this manual.

The MetraBus diskette includes a program in BASIC to deal with the MIO-32 and its associated functions. MIO32.BAS displays the status of all 32 output bits and allows a change of any bit with the arrow keys.

The program is heavily commented. Though the programs are in BASIC, the general flow of the programs should be very similar in other languages, and on other machines. This program in conjunction with the examples below should answer most of the questions that arise concerning MIO-32 usage.

MIO-32 Terminology and Data Format

The MIO-32 uses four of the available 64 MetraBus locations. These locations correspond to the four blocks of 8-bits making up the 32 channels on the I/O board. Setting the state of an output bit is accomplished by

1. Targeting the MIO-32 and the desired 8-bit block via the ADRPTR.
2. Sending a data value (corresponding to the desired state of the outputs) to the DATAIO.

The MIO-32 has four blocks (numbered 0 - 3) of eight channels (numbered 0 to 7). To select block 2, you must specify that block when targeting the MIO-32 at its base address as follows:

```
40 OUT ADRPTR, MIO32 + 2        'Point to block 2 of MIO-32
```

Use the BASIC OUT and INP commands to send instructions to and retrieve data from the MIO-32.

```
10 DATAIO = 768              'Declare Data I/O location
20 ADRPTR = 769              'Declare Address Pointer location
30 MIO32 = 4                 'Declare MIO-32 Board Address
40 OUT ADRPTR,MIO32          'Point to block 0 of MIO-32
50 OUT DATAIO,63             'Set the lowest 6-bits (0011 1111)
```

Example 1

The above example sets bits 0, 1, 2, 3, and 5 to their active states. To sequentially toggle (ON then OFF) each of the 32 bits of the MIO-32, you could use the nested BASIC FOR ... NEXT loops as shown in this example.

```
10 DATAIO = 768                    'Declare Data I/O location
20 ADRPTR = 769                    'Declare Address Pointer location
30 MIO32 = 4                       'Declare MIO-32 Board Address
40 FOR I = 0 TO 3                  'Set up block access control loop
50 OUT ADRPTR,MIO32 + I            'Point to block I of MIO-32
60 FOR J = 0 TO 7                  'Channel access control loop
70 OUT DATAIO, 2^J                 'Set each bit sequentially high
80 NEXT J                          'Increment channel variable and loop
90 NEXT I                          'Increment block. Loop back to 40
```

Example 2

It is often useful to be able to turn certain output bits ON while leaving the other output bits in their present state. This can be done with the BASIC OR command as shown below.

```
10 DATAIO = 768                     'Declare Data I/O location
20 ADRPTR = 769                     'Declare Address Pointer location
30 MIO32 = 4                        'Declare MIO-32 Board Address
40 OUT ADRPTR,MIO32 + 4             'Point to block 4 of MIO-32
50 INPUT "Bit number ON "; BIT      'Get user input (bit number)
60 OLDBITS=INP(DATAIO)              'Retrieve present status
70 OUT DATAIO, 2^BIT OR OLDBITS     'OR new bit with old
80 GOTO 60                          'Loop back for next bit
```

As shown above, the MIO-32 has data readback capability allowing for data integrity verification. This lets the user read back the data just sent to the MIO-32 and compare it to the data value specified.

In order to verify data via the data readback features, the following program will be helpful.

```
10 DATAIO = 768                       'Declare Data I/O location
20 ADRPTR = 769                       'Declare Address Pointer location
30 MIO32 = 4                          'Declare MIO-32 Board Address
40 OUT ADRPTR,MIO32 + 4               'Point to block 4 of MIO-32
50 INPUT "Bit number ON "; BIT        'Get user input (bit number)
60 OUTDATAIO,  2^BIT                  'Turn ON targeted bits
70 BITCHEK = INP(DATAIO)              'Get data just sent
80 IF BITCHEK <> 2^BIT THEN PRINT "ERROR!!": END
90 GOTO 50
```

Note that in all the above examples, a variable set various bits to the specified states. Calculating the integer that represents various bits is as shown in the example below. Bit value calculations are based on binary arithmetic (Base 2) as follows:

$$2^4 + 2^7 = 16 + 128 = 144$$

Therefore, to set bits 4 and 7 on requires outputting a data value of 144 to the DATAIO after targeting the MIO-32, as follows:

```
40 OUT ADRPTR,MIO32 + 1                'Point to block 1 of MIO-32
50 OUT DATAIO, 144                     'Set bits 4 and 7 high
```

Follow this procedure each block of eight bits being monitored. That is, calculation of digital output line values do not correspond to Lines 0 to 32 but to 0 to 7 for each block.

6A.8 USING COMPILED OR ASSEMBLED LANGUAGES

Program execution speed of compiled and assembled languages calls for a few precautions. A WRITE DATA (R/W) time of 10 microseconds requires monitoring the R/W status bit prior to attempting other operations on the MetraBus. This monitoring is accomplished by reading the currently latched MetraBus address and "looking" at Bit 6. This information is contained in the ADRPTR location. The data storage format is

BIT	D7	D6	D5	D4	D3	D2	D1	D0
	BUSY	R/W	A5	A4	A3	A2	A1	A0

For a period of 10 μs after a data output (WRITE) operation, the R/W status bit is active (high). The R/W status bit must be in its quiescent state prior to attempting another operation on the MetraBus. Returning the value of the R/W bit is accomplished as follows:

```
90   STATUS=INP(ADRPTR) AND 64      'Get status information from bit 6
100  IF STATUS <> 0 THEN 90
```

The BASIC variable STATUS contains either 0 or 64, indicating the state of the D6 bit. Again, do this procedure only when using compiled (including compiled BASIC) and assembled languages.

■ ■ ■

MII-32 ISOLATED DIGITAL INPUT BOARD

6B.1 GENERAL

The MII-32 is a 32-channel isolated digital input board whose channels are DTL/TTL, buffered CMOS, and 0 to 5 V compatible. Provisions are included for monitoring higher voltages using customer-modifiable resistors. Each 8-bit block on the MII-32 is optically isolated to 500 V (continuous). Screw terminals on the board will accept 12 to 22 AWG wire. Figure 6B-1 provides a functional block diagram of the MII-32.

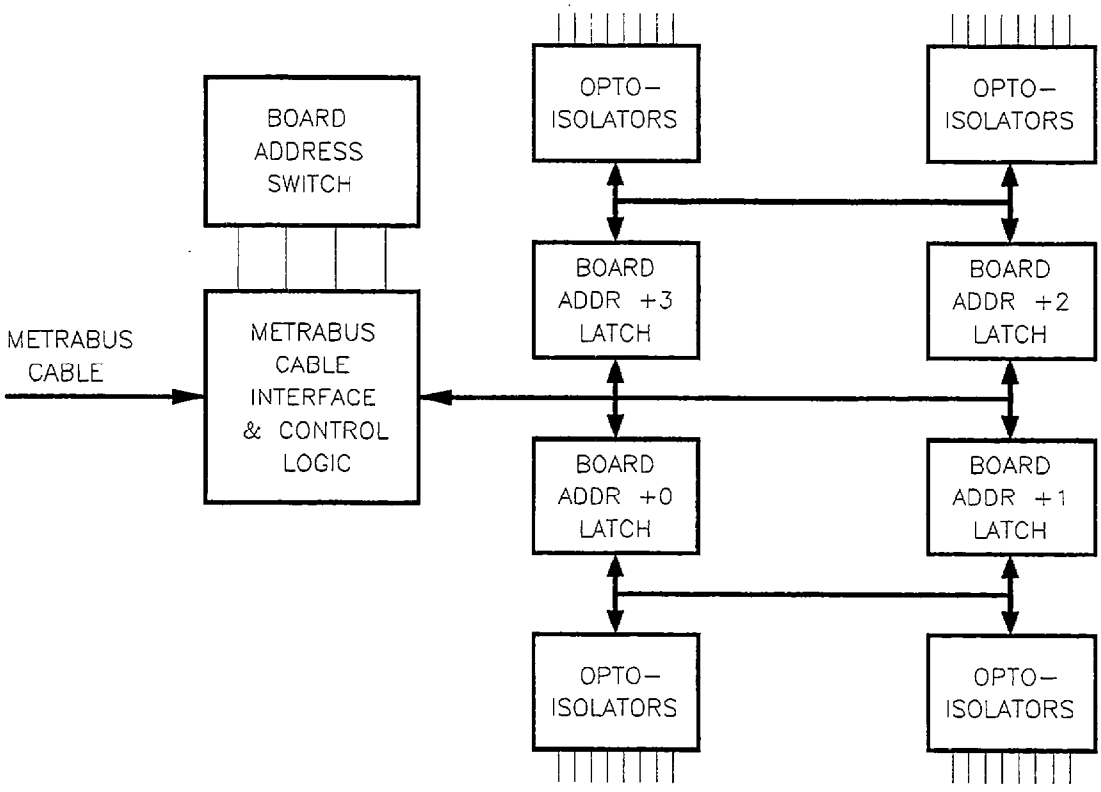


Figure 6B-1. Block Diagram

The MII-32 connects directly to any of the MetraBus controller/driver cards via the 50-conductor MetraBus ribbon cable. The cable carries all data, address, and status information as well as power distribution. A total of 20 ground lines are interleaved among the data and address lines to ensure noise immunity. The MetraBus system was designed to provide MetraBus cable lengths of up to 100 feet allowing the MII-32 to be positioned for easy signal connection. Remote control of the MetraBus system is possible via the REM-64 serial driver card at distances of up to 1.2 kilometers. The MII-32 is 19" rack-mountable in either a standard NEMA type enclosure or the MetraByte RMT-02; it may also be mounted on any panel or other flat surface.

Because of its design, the MetraBus system allows control of up to 512 digital input channels from a single computer expansion slot. Some of the more common uses of the MII-32 include computer monitoring of relay contact status, limit switch status, automated data collection from BCD instrumentation, computerized test benches, etc.

6B.2 FEATURES

- Connects directly to IBM PC/XT, PC AT, and compatibles
- Remote signal connections
- Up to 512 inputs per computer expansion slot
- Extremely cost effective
- Compatible with most computer languages
- Optically isolation to 500 V

6B.3 SPECIFICATIONS

Input Lines:	32
Overvoltage Isolation:	500 VDC (continuous)
Isolation Type:	Optical
HIGH Threshold Voltage:	2.2 VDC minimum
HIGH Threshold Current:	3.2 mA minimum
LOW Threshold Voltage:	1.3 VDC maximum
LOW Threshold Current:	0.25 mA maximum
Maximum Input Voltage:	11 VDC maximum

Environmental

Operating Temperature:	0 to 70° C
Storage Temperature:	-55 to 125° C
Humidity:	0 to 95% non-condensing

Power Consumption

@ +5 V:	220 mA typical; 300 mA maximum

Physical

Size:	16 x 4.75 inches (40.63 x 12.06 cm).
MetraBus Cable Type:	50-conductor ribbon cable.
MetraBus Connector:	3M 3425-6050.

6B.4 USING AN AUXILIARY POWER SUPPLY

Because of low power drain, the MII-32 does not require an auxiliary power supply unless you have more than three MII-32 boards in your system. However, if you have other MetraBus I/O boards or more than 3 MII-32s in your MetraBus system, you need an auxiliary power supply such as the MBUS-PWR.

> NOTE: If you use an auxiliary power supply with an MDB-64 MetraBus controller/driver card, remember to remove fuse F1 from the MDB-64.

6B.5 INSTALLING THE MII-32

Before installing the MII-32, make certain you install a MetraBus controller/driver board.

Set each MII-32 on a single MetraBus cable to a unique, non-overlapping MetraBus I/O address. This distinct address allows the various boards in a MetraBus system to operate independently. Each MII-32 uses four of the 64 MetraBus addresses. These four addresses run consecutively, starting from the MII-32 board address. The procedure for setting the board address is outlined below. Figure 6B-2 shows an example setting.

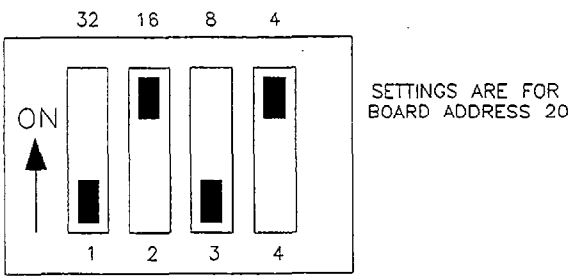


Figure 6B-2. Setting the Board Address

To set the board address,

1. The board address DIP switch is located on the far-left side of the board, just above and to the left of the MetraBus interface connector. The numbers above the DIP switch indicate the value of the switches immediately below. The numbers have value only in the ON position.
2. Select an unused board address and set the switches accordingly. For example, to set a board address of 24, switches with corresponding values of 8 and 16 must be ON. Remember that each MII-32 uses four of the 64 MetraBus I/O addresses and must be set to an unused, non-overlapping board address in order to avoid address conflicts.
3. After setting the board address, connect the MII-32 to the MetraBus cable. The MetraBus cable connector is keyed for your protection and to facilitate alignment.

NOTE: Always remove power from the MetraBus cable prior to connecting any I/O boards.

4. If you have only one MII-32 or if your MII-32 is the last board in your system, install the resistor terminating networks provided with your driver card. Use the sockets marked RN1 and RN2, immediately above the MetraBus connector. These resistor networks minimize signal reflection from long cable lengths. They are optional, however, and have little effect for cables of 50 feet or less.

6B.6 CONFIGURING THE MII-32 FOR NON-STANDARD INPUTS

The MII-32 is capable of accepting input signals greater than 5 V with a simple resistor change on each input channel. These resistors are R1 to R32 on the I/O board as well as on the schematic diagram supplied in The MetraBus schematic package. The resistors on the MII-32 are 220 Ω, current-limiting resistors. The size of the replacement resistors will depend the amount of power to be dissipated by the input signal. See the wiring diagrams in the "Typical Input Connection" section for actual signal hook-up.

6B.7 TYPICAL INPUT CONNECTIONS

The MII-32 is compatible with digital inputs from a variety of input sources. To ensure proper operation of the MII-32, follow the guidelines outlined below and refer to Figure 6B-3 when wiring your input signals.

Both TTL and CMOS outputs are much better at sinking current than at sourcing it. Therefore, when monitoring these outputs, supply +5 V to the high side of the channel input and tie the output from the TTL or CMOS signal to the low side. A "low" signal from the TTL/CMOS gate then causes the MII-32 to sense a "high," thereby inverting the data. This inversion is software-correctable.

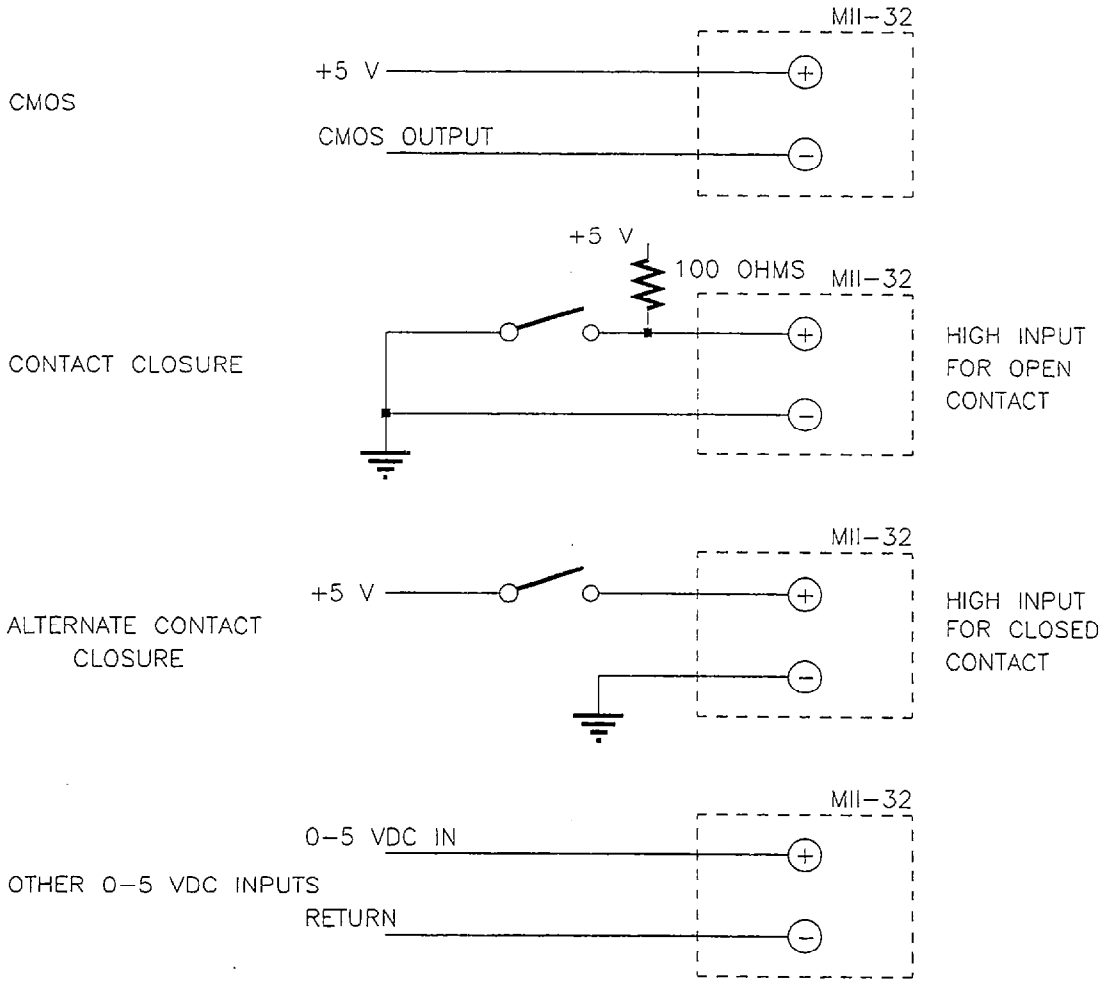


Figure 6B-3. Typical Input Connections

6B.8 PROGRAMMING THE MII-32

Programming the MII-32 is facilitated by MetraBus supervision by the driver board. Since the driver board generates all necessary control signals, you need not be concerned with control registers, PEEKing or POKEing memory locations, shifting bits, PUSHing or POPing stacks, learning new languages, or other system level headaches. Refer to the driver board descriptions for more information.

The MetraBus diskette includes a program in BASIC dealing with the MII-32 and its functions. MII32.BAS displays the status of all 32 bits, and the program is heavily commented. This program and the following examples should cover most questions concerning MII-32 usage.

MII-32 Terminology and Data Format

The MII-32 uses four of the 64 MetraBus locations. These locations correspond to the four blocks of 8-bits making up the 32 channels on the I/O board. Reading the status of the input lines is accomplished by

1. Targeting the MII-32 and the desired 8-bit block via the ADRPTR.
2. Retrieving the data from the DATAIO.

The BASIC OUT and INP commands send instructions to and retrieve data from the MII-32. The following example will help to illustrate this.

```
10 DATAIO = 768                    'Declare Data I/O location
20 ADRPTR = 769                    'Declare Address Pointer location
30 MII32 = 4                       'Declare MII-32 Board Address
40 OUT ADRPTR,MII32                'Point to block 0 of MII-32
50 BLOCK0 = INP(DATAIO)            'Retrieve data to variable BLOCK0
60 PRINT BLOCK0                    'Display data
```

Example 1

The above example retrieves data from the first eight lines (one block) of the MII-32. In order to get data from all 32 lines of the MII-32, you may use a BASIC FOR ... NEXT loop, as shown in this example.

```
10 DATAIO = 768                              'Declare Data I/O location
20 ADRPTR = 769                              'Declare Address Pointer
                                              'location
30 MII32 = 4                                 'Declare MII-32 Board Address
40 FOR I = 0 TO 3                            'Set up block access control
                                              'loop
50 OUT ADRPTR,MII32 + I                      'Point to block I of MII-32
60 BLOCK(I) = INP(DATAIO)                    'Get data from successive
                                              'blocks
70 NEXT I                                    'Increment variable and loop
80 PRINT BLOCK0, BLOCK1, BLOCK2,BLOCK3       'Display results and loop
90 NEXT I                                    'Increment block. Loop back to
                                              '40
```

Example 2

In Example 1, the values printed are integers representing the binary state (base 2) of the input blocks. While this is useful to the computer for high-speed data manipulation and data storage to disk, it may not be convenient if you wishes to view the status of each line. This example illustrates how to break the blocks down into individual lines.

```
10   DATAIO = 768                            'Declare Data I/O location
20   ADRPTR = 769                            'Declare Address Pointer
                                              'location
30   MII32 = 4                               'Declare MII-32 Board Address
40   FOR I = 0 TO 3                          'Set up block control loop
50   OUT ADRPTR,MII32 + I                    'Point to block "I" of MII-32
60   BLOCK(I) = INP(DATAIO)                  'Get data from successive
                                              'blocks
70   NEXT I                                  'Increment control variable
                                              'and loop
80   FOR J = 0 TO 3                          'BLOCK increment control loop
90   FOR K = 0 TO 7                          'BIT increment control loop
100  PRINT "bit";k;"=";BLOCK(J)/2^K          'Display of each bit
110  NEXT K                                  'Close loop
120  NEXT J                                  'Close loop
130  END
```

Note that in this program, we have three routines. These are the variable declaration routine (lines 10 to 30), the data collection routine (lines 40 to 70), and the sequential breakdown and display of digital input lines (lines 80 to 110). There are also other ways the same end could be achieved.

Example 3

Monitoring all 32 lines is often not needed, unless they are all in use. It may be desirable to "look" at certain lines to see when they become active. Using the BASIC AND statement accomplishes this quite easily, as illustrated below.

```
10   DATAIO = 768                        'Declare Data I/O location
20   ADRPTR = 769                        'Declare Address Pointer
                                           'location
30   MII32 = 4                           'Declare MII-32 Board Address
40   OUT ADRPTR, MII+2                   'Point to block 2 of MII-32
50                                       '(digital input lines 16-24)
60   BLOCK3 = INP (DATAIO)               'Get data from block
70   BITTEST = BLOCK3 AND 144            'Test bits 4 and 7 for activity
80   IF BITTEST = 0 THEN GO TO 60        'If no activity, then go back
                                           'and get more data.  Note that
                                           'we need not point to block 3
                                           'again since we have not
                                           'changed it.
120  IF BITTEST = 16 THEN PRINT "Bit 4 Active"
130  IF BITTEST = 128 THEN PRINT "Bit 7 Active"
140  IF BITTEST = 144 THEN PRINT "Bits 4 and 7 Active"
150  GOTO 60
```

Note that a value of 144 is used to test activity of bits 4 and 7. Bit calculations are based on binary arithmetic (base 2) as follows:

$$2^4 + 2^7 = 16 + 128 = 144$$

Follow this procedure for each block of eight bits being monitored. That is, calculation of digital input line values do not correspond to Lines 0 to 32, but to 0 to 7 for each of the four blocks.

6B.9 USING COMPILED OR ASSEMBLED LANGUAGES

Execution speed of compiled and assembled programs requires a few precautions. A WRITE DATA (R/W) time of 10 microseconds necessitates the monitoring of the R/W status bit prior to attempting other operations on the MetraBus. You may monitor operations by reading the currently latched MetraBus address and "looking" at bit 6. This information is contained in the ADRPTR location. The data storage format is

BIT	D7	D6	D5	D4	D3	D2	D1	D0
	BUSY	R/W	A5	A4	A3	A2	A1	A0

The R/W status bit is active (high) for 10 ms after a data output (WRITE) operation. The R/W status bit must be in its quiescent state prior to attempting another operation on the MetraBus. You may accomplish the return of the the R/W bit value as follows:

```
90 STATUS=INP(ADRPTR) AND 64      'Get status information from Bit 6
```

The BASIC variable STATUS will contain either 0 or 64, indicating the state of the D6 bit. Again, do this procedure only when using compiled (including compiled BASIC) and assembled languages.

■ ■ ■

Chapter 7

MCN-8 COUNTER/TIMER BOARD

7.1 GENERAL

The MCN-8 counter/timer board contains eight counters with 8-bit resolutions (1 part in 256) each. Cascading the counters produces a 4 x 16-bit, 2 x 24-bit, 2 x 32-bit, or a single 64-bit counter. Each channel on the MCN-8 accepts a variety of input types including TTL (at rates up to 25 MHz), comparator (with 50 mV hysteresis), mechanical contact closures (10 ms debounce period), and even has on-board, optically isolated inputs (to 1000 V) that eliminate problems associated with large common and normal mode voltages, ground loop currents, and also offers protection for large voltage transients. The MCN-8 has a pulsed output channel with periods of 0.125, 0.25, 0.5, 1, 2, 4, and 8 s for generating TTL compatible output pulses. Screw terminals on the board will accept 12 to 22 AWG wire. Figure 7-1 is a block diagram of the MCN-8.

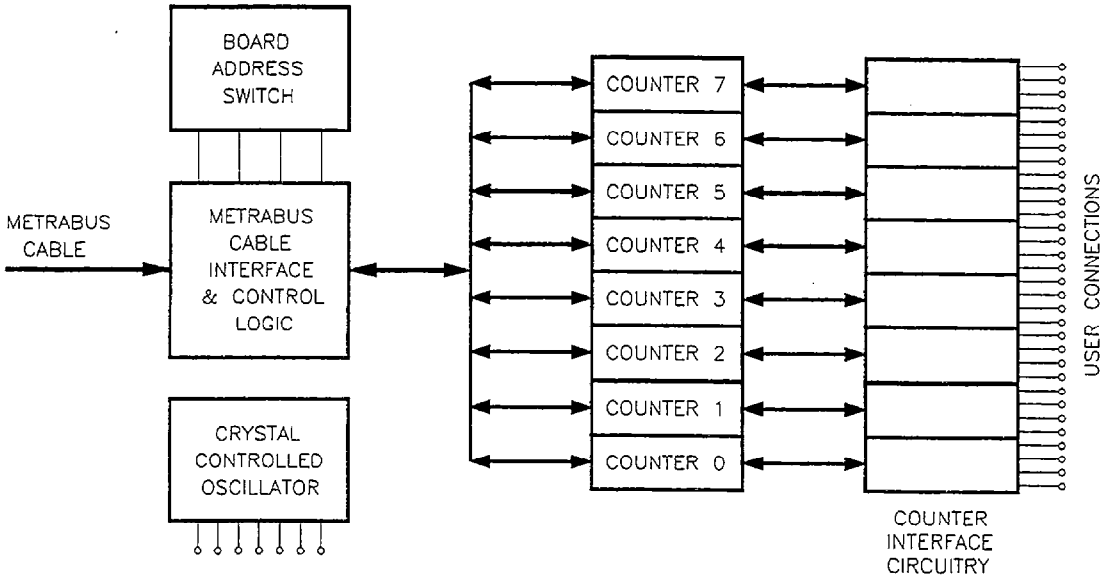


Figure 7-1. Block Diagram

The MCN-8 connects directly to any MetraBus controller/driver cards (MDB-64, MID-64, or REM-64) through the MetraBus cable. The MetraBus system accommodates cable lengths up to 100 feet, which allows positioning the MCN-8 for convenient signal connection. The MetraBus cable 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. Remote control of the MetraBus system is possible via the REM-64 serial driver card at distances of up to 1.2 km. The MCN-8 is 19" rack-mountable in either a standard NEMA-type enclosure or the MetraByte RMT-02, and it may also be mounted on a panel or other flat surface.

The MetraBus system allows control of up to 64 counter/timer channels (and 8 pulsed outputs) from a single computer expansion slot. Some of the more common uses of the MCN-8 include computer monitoring of relay contact closures, high speed (up to 25 MHz) frequency measurements, comparator trigger monitor, data logging from turbine flow meter (gas and liquid), instrument calibration, electronic troubleshooting, programmable low speed frequency generator, etc.

7.2 FEATURES

- Interfaces directly to IBM PC/XT, PC AT, and compatibles
- 25 MHz input frequency (max TTL)
- TTL, comparator, isolated, and debounced inputs
- Cost-effective
- Compatible with most computer languages
- Cascadable counters to 64-bits (1 part in 1.8 x 1019)

7.3 SPECIFICATIONS

Number of Counters:	8
Counter Resolution:	8-bit (cascadable to higher resolution)
Counter Input Types:	TTL logic level Comparator (0 to 10 VDC adjustable) Opto-isolated (isolated to 1000 VDC) Mechanical contact closures
Counter Output Type:	Overflow pulse (CARRY OUT)
Periodic Pulse Outputs:	8 s period 4 s 2 s 1 s 0.5 s 0.25 s 0.125 s

Environmental

Operating Temperature:	0 to 70° C
Storage Temperature:	-55 to 125° C
Humidity:	0 to 95% non-condensing

Power Supplies

@ +5 V:	330 mA typical; 500 mA maximum
@ +15 V:	10 mA typical; 15 mA maximum
@ -15 V:	2 mA typical; 4 mA maximum

Physical

Size:	16 x 4.75 inches (40.63 x 12.06 cm)
Weight:	13.5 oz. (378 gm)
MetraBus Cable Type:	50-conductor ribbon cable
MetraBus Connector:	3M 3425-6050

7.4 USE OF AN AUXILIARY POWER SUPPLY

Because of low power drain, the MCN-8 does not require an auxiliary power supply, unless your system contains than two MCN-8 boards or you wish to use the comparator inputs. However, if your system contains other MetraBus I/O boards or more than two MCN-8s, it requires a MetraBus MBUS-PWR or other high-quality power supply.

> NOTE: When using an auxiliary power supply with an MDB-64 MetraBus controller/driver card, remember to remove Fuse F1 from the MDB-64.

7.5 INSTALLING THE MCN-8

Before installing the MCN-8, make certain your PC contains a MetraBus controller/driver board.

Set each MCN-8 on a single MetraBus cable for a unique, non-overlapping MetraBus I/O address. Each MCN-8 uses eight of the 64 MetraBus I/O addresses. These eight addresses run consecutively starting from the MCN-8 board address. Setting the board address is outlined below. Figure 7-2 shows an example board address setting.

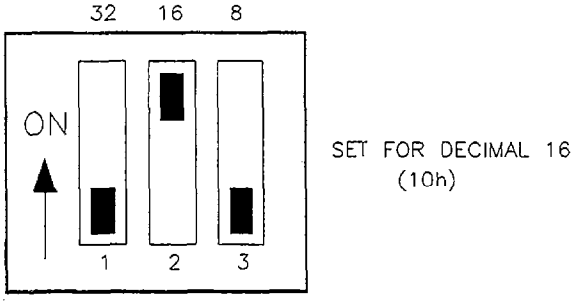


Figure 7-2. Setting the Board Address

To set the board address,

1. The board address DIP switch is located on the far-left side of the board, just above and to the left of the MetraBus Interface connector. The numbers silk-screened above the DIP indicate the values of the adjacent switches. The numbers have value only in the ON position.
2. Select an unused board address and turn ON those switches corresponding to the address you have chosen. For example, to set a board address of 24, turn ON switches with values

of 8 and 16. Remember that each MCN-8 uses 8 of the 64 MetraBus I/O addresses and must be set to an unused, non-overlapping board address to avoid conflicts.

3. After setting the board address, connect the MCN-8 to the MetraBus cable. The MetraBus cable connector is keyed.

   NOTE: Remove power from the MetraBus cable before connecting any I/O boards.

4. If you have only one MCN-8 or if your MCN-8 is the last board in your system, install the resistor terminating networks provided with your driver card. The sockets marked RN1 and RN2 immediately above the MetraBus connector are for this purpose. The resistor networks minimize signal reflection from long cable lengths. They are optional, however, and have little effect for cables of 50 feet or less.

7.6 CASCADING THE MCN-8 COUNTERS

The MCN-8 has eight counters of 8-bit resolutions. This number allows each counter to count and store up to 256 events. Some applications may require storage of larger amounts of data (counts). These applications are generally high-speed measurements or long periods of unattended operation.

MCN-8 design allows the output of one counter to be cascaded into the input of another. You may use cascading to handle overflow. For example, if Counter 0 fills to a maximum 256 counts, it transmits a pulse to the input of Counter 1. Then, for Counter 1 to fill takes 256 x 256 or 65,536 counts (making a single 16-bit counter). To cascade two counters on the MCN-8, take the TTL output from one counter and connect it to the ISO-IN terminal of a second counter; connect the ISO-COM terminal to GND.

NOTE: When reading the data stored in cascaded counters, the primary counter (the one that the signal first enters) contains the Least Significant Bits while the last counter (furthest from the input signal) contains the most significant bits.

Some applications require counters larger than 16-bits. These tend to be very high speed inputs for prolonged periods of time. In order to cascade a third counter onto the output of the 16-bit counter described above, simply wire from the CARRY OUT terminal of the MSB counter to the ISO-IN input of the next counter, and connect the ISO-COM terminal to GND. Remember that this last counter will now become the MSB counter when retrieving data. This same scheme holds true for 32-bit, 40-bit, etc. counters up to a single 64-bit counter.

NOTE: Creating counters of 8-bit multiples (16,32, 48, and 64) requires cascading more than one counter together wiring the output of the first 16-bit counter to the input of a second 8-bit counter.

7.7 TYPICAL INPUT CONNECTIONS

The MCN-8 is compatible with inputs from a wide variety of input sources. To ensure proper operation of the MCN-8, refer to the following discussion and associated illustration when wiring your input signals. The input termination strip is illustrated below for channel 0. All channels have identical input configurations.

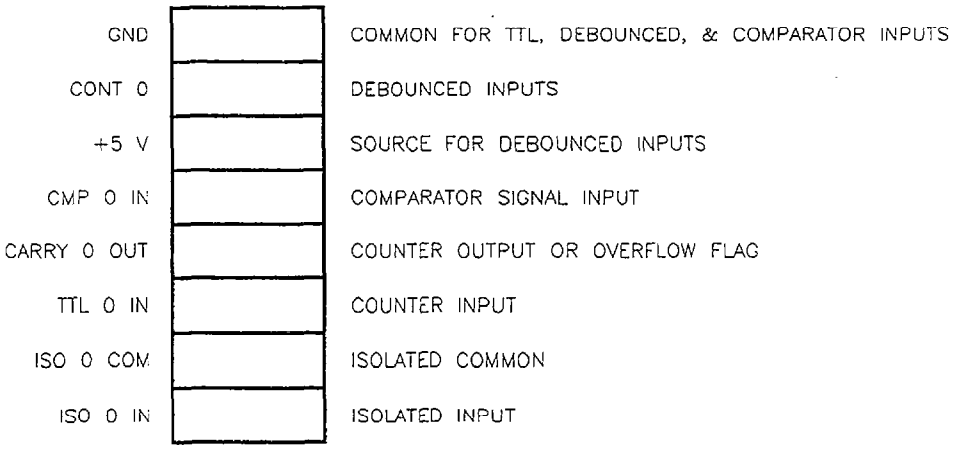


Figure 7-3. Typical Input Connections

TTL Inputs

TTL compatible signals are a common type output from electronic equipment and most industrial sensors with digital outputs. Some examples are vortex, paddle wheel, and turbine flow meter, many older types of time-based measurement systems, frequency generators, etc. TTL threshold levels are defined as follows:

Positive going pulses:	1.4 V minimum
Negative going pulses:	1.0 V maximum
Hysteresis:	0.4 V minimum
Input high current:	-0.3 mA maximum
Input low current:	-1.0 mA maximum

Wiring TTL signals to the counter inputs is simply a matter of connecting the signal to the TTL "X" IN and signal ground to the GND terminal. Refer to *PROGRAMMING THE MCN-8* for software access routines.

Comparator Inputs

Comparator inputs are compared to a threshold level. When these inputs exceed the threshold level, they increment the counter. Every input channel of the MCN-8 has an independently adjustable threshold level (from 0 to 10 V) that is set with a small potentiometer located just above the terminator connector for that channel.

> NOTE: You require an auxiliary power supply, such as the MBUS-PWR, when using the comparator inputs.

There are two methods of setting the threshold level. One is to wire a precision voltage source of the desired threshold value between CMP "X" IN (+) and GND (-) and then monitor the channel via software while adjusting the potentiometer. When the trigger trips the counter, back off slightly. The threshold is now set to the level of the input source.

The other method uses a Digital Voltmeter. The DVM is placed between GND and either pin 2 (for channels 0, 2, 4, 6) or pin 6 (for channels 1, 3, 57) of the LM393 for every two channels. The trigger-point voltage is adjusted via the potentiometer associated with that channel while reading the DVM. Schematic diagrams are available in the MetraBus schematic package.

Wire input signals the same as above, with the ground going to GND and the signal going to CMP "X" IN.

Comparator inputs should conform to the following specifications:

Maximum Counting Frequency:	500 kHz
Trigger Edge:	Falling
Switching Threshold:	Adjustable between 0 to 10 V
Hysteresis:	50 mV

Opto-Isolated Inputs

The optically isolated inputs are generally used to eliminate problems such as large common-mode voltages, ground loops, and general normal or common-mode noise. They also provide protection from large voltage transients. These inputs are TTL compatible and require at least 6.3 mA for full speed operation (10 MHz maximum).

Contact Closure Inputs

Count the times a piece of equipment changes state or some other electrical event occurs by monitoring a strategic relay on the equipment. The mechanical nature of power relays causes the contacts to go through a series of bounces with each closure. The MCN-8 take this bouncing into consideration when monitoring these types of events. A 10 ms debounce period is built into every CONT "X" channel, so that there is no chance of counting the same "event" twice due to bouncing contacts. The maximum count rate for these channels is 100 Hz (100 contact closures per second). Input signals are wired across an unused pole of the relays using the +5 V and the CONT "X" terminals on the (MCN-8) termination strip for that channel. When the relay closes, the +5 V is sent to the CONT "X" input and an event is logged.

Periodic Pulsed Outputs

The MCN-8 contains seven different periodic pulsed outputs. Periods of 0.125, 0.25, 0.5, 1, 2, 4, and 8 s are available at all times. That is, these outputs run continuously and may all be used at the same time. The outputs are TTL compatible and may be used for a variety of purposes such as a time base for any of the counter channels, allowing a real-time averaging of counts-per-time on any of the input channels.

The Clear Timing and Latching

Counter data is latched into the DATAIO registers when the counter address is selected by the MetraBus driver card. This factor is important when programming the MCN-8, as it affects system timing. Once the counter is addressed, the data in the DATAIO buffer is not updated until the MetraBus Address is changed to another address and then back to the counter to be read. However, the counter continues to count after the data is latched into the data buffer, and no counts are lost.

Reset a single counter by writing to the counter's DATAIO register. Writing to a counter resets both the actual counter contents and the DATAIO register contents. To read new data from the counter, enter a new MetraBus address and then return to the desired counter. This change is necessary since it is the address selection action that actually causes the counter contents to load into the DATAIO register.

7.8 PROGRAMMING THE MCN-8

MetraBus supervision by the driver board tends to simplify MCN-8 programming. Since the driver board generates all necessary control signals, you need not be concerned with control registers, PEEKing or POKEing memory locations, shifting bits, PUSHing or POPing stacks, learning new languages, or other system level requirements.

The MetraBus diskette includes a program in BASIC dealing with the MCN-8 and its functions. This program illustrates the use of the MCN-8 as a frequency counter; one channel is a time base. The program is heavily commented. Though the programs are in BASIC, their general flow should be similar in other languages and on other machines. This program and the examples below should answer most questions concerning MCN-8 usage.

The counters are free-running, rollover counters and will begin counting as soon as they "see" a valid pulse input. Therefore, to get accurate readings, clear the counters immediately prior to data collection by writing to the DATAIO. This move ensures that the counter is empty immediately prior to counting.

MCN-8 Terminology and Data Format

The MCN-8 uses eight of the 64 addressable MetraBus locations. These locations correspond to the eight channels on the I/O board. Reading the status of the input channels by

1. Targeting the MCN-8 and desired channel number via the ADRPTR.
2. Initialize the counter by writing to the DATAIO. This cannot be done with the CLR/EN jumper in the enable position.
3. Reset the ADRPTR to the channel desired.
4. Retrieving data from that channel via the DATAIO.

The BASIC IN and OUT commands send instructions to and retrieve data from the MCN-8. The following example will help to illustrate this.

```
20 DATAIO = 768                    'Declare Data I/O location
30 ADRPTR = 769                    'Declare Address Pointer location
40 MCN8 = 8                        'Declare MCN-8 MetraBus address
50 OUT ADRPTR, MCN8                'Point to channel 0 of the MCN-8
                                    'and latch the channel 0 counter
60 CNTR0 = INP(DATAIO)             'Retrieve data to variable CNTR0
70 PRINT CNTR0                     'Display data
```

Example 1

The above example retrieves data from a single channel of the MCN-8. To retrieve data from all eight channels, use a FOR...NEXT loop, as follows:

```
10 DATAIO = 768                    'Declare Data I/O location
20 ADRPTR = 769                    'Declare Address Pointer Location
30 MCN8 = 8                        'Declare MCN-8 MetraBus Address
40 FOR I = 0 TO 7                  'Set up block control loop
50 OUT ADRPTR, MCN8 + I            'Point to channel "I" of MCN-8 51
                                    'and latch the counter.
60 CNTR(I) = INP(DATAIO)           'Get data from successive 61 channels
70 PRINT CNTR(I)                   'Display data
80 NEXT I                          'Increment variable and loop
```

Example 2

This example illustrates the use of a 16-bit counter (channel 2 output cascaded to channel 3 input) and the calculations for converting to actual counts.

```
10   DATAIO = 768                  'Declare Data I/O Location
20   ADRPTR = 769                  'Declare Address Pointer Location
30   MCN8 = 8                      'Declare MCN-8 MetraBus Location
40   OUT ADRPTR, MCN8 + 2          'Point to LSB (channel 2) of MCN-8
50   OUT DATAIO,00                 'Clear counter 2
60   OUT ADRPTR, MCN8 + 3          'Point to MSB (channel 3) of MCN-8
70   OUT DATAIO, 00                'Clear counter 3
80   OUT ADRPTR MCN8 + 2           'Point to LSB (counter 2)
90   LSB = INP(DATAIO)             'Get data from DATAIO
100  OUT ADRPTR, MCN8 + 3          'Point to MSB (channel 3) of MCN-8
110  MSB = INP(DATAIO)             'Get data from DATAIO
120  COUNTS = LSB + 256 * MSB      'Calculate 16-bit results
130  PRINT COUNTS                  'Display results
```

Example 3

As mentioned earlier, you may create 24-bit, 32-bit, 40-bit, etc. counters by tying the output of one counter to the input of another. This example uses a 32-bit counter (1 part in 4,294,967,296) and calculates the results.

```
10   DATAIO = 768                        'Declare DATAIO location
20   ADRPTR = 769                        'Declare ADRPTR location
30   MCN8 = 8                            'Declare MCN-8 MetraBus Address
40   FOR J = 0 TO 3                      'Begin control loop to clear
                                           'counters
50   OUT ADRPTR, MCN8 + J                'Sequentially point
60   OUT DATAIO, 00                      'Clear each counter in turn
70   NEXT J                              'End control loop
80   FOR I = 3 TO 0 STEP -1              'Control loop for data
                                           'retrieval
90   OUT ADRPTR, MCN8 + I                'Point to and
                                           'latch each
                                           'channel
100  CT(I) = INP(DATAIO)                 'Get data from
                                           'each channel
110  NEXT I                              'End loop
120  TOTAL = CT0+(CT1*2^8) + (CT2*2^16) + (CT3*2^24)  'Calculate Total
130  PRINT TOTAL                         'Display data
```

The program sequentially clears the relevant counters then comes back and reads them. Lines 70 to 100 actually collect the data. Note that data is collected from the MSB to the LSB counter for best accuracy. This direction is important because the timer is so large and is probably counting high-speed events. If the program collected data starting with the LSB, several 10s of milliseconds would elapse (depending on the programming language) and events might not be counted in the time taken to reach the MSB.

7.9 USING COMPILED OR ASSEMBLED LANGUAGES

You may use assembled and compiled languages for the MCN-8 with no special precautions. Be aware of the precautions for any other MetraBus I/O boards you may be using.

■ ■ ■

MAO-8 ANALOG OUTPUT BOARD

8A.1 GENERAL

The MAO-8 is an 8-channel analog output board with eight independent output channels, each with 8-bit (1 part in 256) resolution. The MAO-8 has four standard switch-selectable voltage output ranges as well as 4 to 20 mA output capability. Screw terminals on the board accept 12 to 22 AWG wire. Figure 8A-1 is a block diagram.

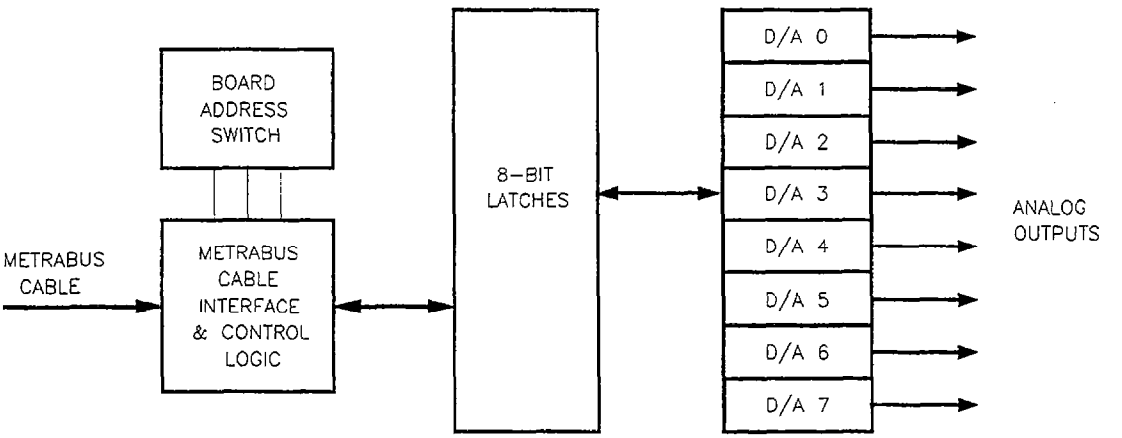


Figure 8A-1. Block Diagram

The MAO-8 connects to any of the MetraBus driver cards via a 50-conductor ribbon cable. The MetraBus cable connects the MAO-8 to one of the driver cards and carries all data, address, status information, and power distribution. A total of 20 ground lines are interleaved among the data and address lines to ensure noise immunity. The MetraBus system allows 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 km. The MAO-8 is 19" rack mountable in either a standard NEMA type enclosure or the MetraByte RMT-02; it may also mount on any panel or other flat surface.

Like all MetraBus output boards, the MAO-8 contains a data readback feature allowing the user to verify data integrity. The MetraBus system allows control of up to 64 analog output channels (eight MAO-8s) from a single computer expansion slot, making it a cost-effective data acquisition and control System.

Some uses of the MAO-8 include computer control of 4 to 20 mA process-control equipment, single-board function generation, ON/OFF servo-motor control, digital attenuation, variable voltage supply, etc.

8A.2 FEATURES

- Connects directly to IBM PC/XT, PCAT, and compatibles
- Unipolar, bipolar, and 4 to 20 mA outputs
- Remote signal connections
- Up to 64 analog outputs per computer expansion slot
- Extremely cost-effective
- Compatible with most computer languages
- Cascadable DACs for 16-bit resolution

8A.3 SPECIFICATIONS

Output Channels:	8
Output Ranges:	0 to 5 V FS (Volts Full Scale) 0 to 10 V FS -5V to +5 V FS -10 V to +10 V FS 4 to 20 mA current loop
D/A Resolution:	8 bits (1 part in 256)
Relative Accuracy:	0.5% maximum
Differential Linearity:	1/4 LSB maximum
Temperature Coefficient of gain:	+75 ppm per ° C (w/ reference) +10 ppm per ° C (w/o reference)
Zero Drift:	+10 ppm per ° C
Voltage Output Impedance:	0.1 + maximum
Voltage Output Drive Current:	+5 mA maximum
4-20 mA Compliance:	8 to 36 V
Current Input Range:	0 to 2 mA maximum
Input Reference Resistors:	4.99 kΩ (10 V FS) 2.495 kΩ (5 V FS)

Environmental

Operating Temperature:	0 to 70° C
Storage Temperature:	-55 to 125° C
Humidity:	0 to 95% non-condensing

Power Supplies

@ +5 V:	330 mA typical; 535 mA maximum
@ +15 V:	54 mA typical; 88 mA maximum

@ -15 Volts:	75 mA typical; 105 mA maximum
Total power dissipation:	3.58 W typical

Physical

Size:	16 x 4.75 inches (40.63 x 12.06 cm)
Weight:	14 oz (392 g)
MetraBus Cable Type:	50-conductor ribbon cable
MetraBus Connector:	3M 3425-6050.

8A.4 USE OF AN AUXILIARY POWER SUPPLY

Since, the MAO-8 requires +15 V (in addition to the standard +5 V), it also requires an external power supply such as the MetraBus MBUS-PWR.

> NOTE: When using an auxiliary power supply with an MDB-64 MetraBus controller/driver board, remember to remove fuse F1 from the MDB-64.

8A.5 INSTALLING THE MAO-8

Before installing the MAO-8, make certain the system contains a MetraBus controller/driver board. Set each MAO-8 on a single MetraBus cable to a unique, non-overlapping MetraBus I/O address. Each MAO-8 uses eight of the 64 MetraBus I/O addresses. These eight addresses run consecutively starting from the MAO-8 board address. Set the board address as outlined below. Figure 15-2 shows an example board address setting.

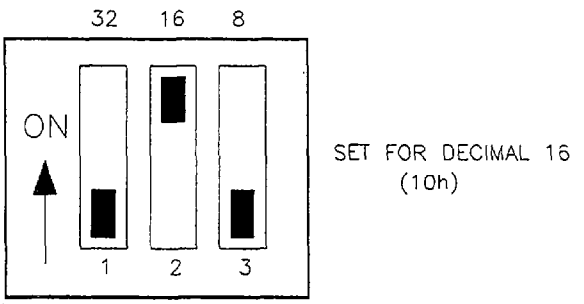


Figure 8A-2. Typical Board Address Setting

To set the board address,

1. The board address DIP switch is located on the far-left side of the board, just above and to the left of the MetraBus Interface connector. The numbers silk-screened above the DIP indicate the values of the switches immediately below. The numbers have value only in the ON position.
2. Select an unused board address and turn ON the corresponding switches. For example, in order to set a board address of 24, turn ON the switches with corresponding values of 8 and 16. Remember to set the DIP to an unused, non-overlapping board address in order to avoid conflicts.
3. After setting the board address, connect the MAO-8 to the MetraBus cable. The MetraBus cable connector is keyed for your protection; check the keyways for correct alignment.

   NOTE: Remove power from the MetraBus cable before connecting it to any I/O boards.

4. If you have only one MAO-8 or if your MAO-8 is the last board in your system, install the resistor terminating networks provided with your driver card. The sockets marked RN1 and RN2 immediately above the MetraBus connector are for this purpose. These resistor networks minimize signal reflection from long cable lengths. They are optional, however, and have little effect for cables of 50 feet or less.

MAO-8 Output Range, Polarity, and Reference Selection

Each channel on the MAO-8 sets to any of the standard output ranges (0 to 5 V, ±5 V, 0 to 10 V, ±10 V, 4 to 20 mA). Use jumpers to select the range for each channel, as shown in Figure 8A-3.

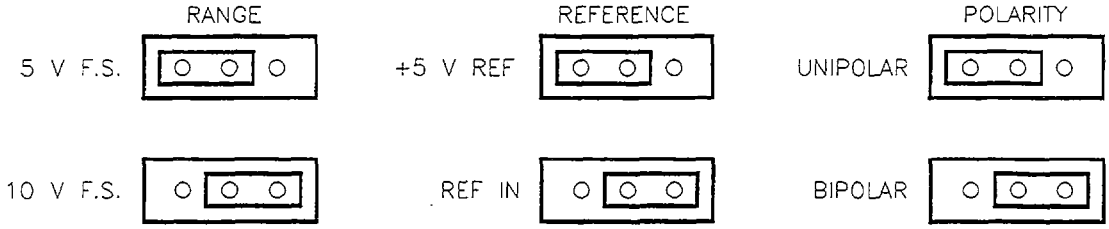


Figure 8A-3. The Output Range, Polarity, and Reference Jumpers

Use the following table to configure your MAO-8.

	Jumper #		
Channel	**Range**	**Reference**	**Polarity**
CH 0	W5	W13	W21
CH 1	W6	W14	W22
CH 2	W7	W15	W23
CH 3	W8	W16	W24
CH 4	W4	W12	W20
CH 5	W3	W11	W19
CH 6	W2	W10	W18
CH 7	W1	W9	W17

Selecting the 4 to 20 mA Output Range

The MAO-8 supports a 4 to 20 mA current output, which is useful when connecting the MAO-8 to certain types of industrial instrumentation. The 4 to 20 mA current output consists of a precision current sink formed by a VMOS power FET and reverse protection diode. Figure 8A-4 illustrates this circuit.

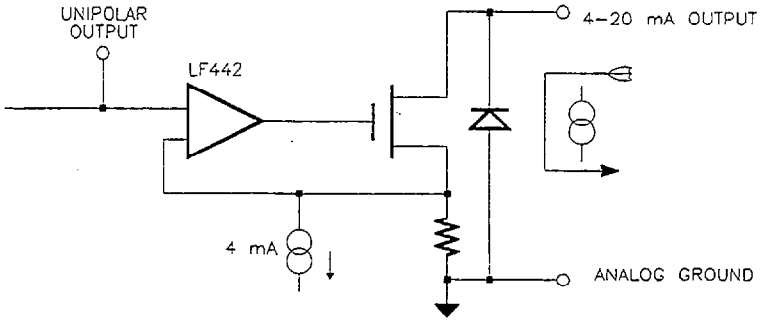


Figure 8A-4. 4 to 20 mA Current Output Circuit

Maintain a minimum of 6 V across the output circuit for proper operation. The maximum voltage across this circuit should not exceed 36 V for power dissipation reasons. Therefore, a 36 V or 24 V loop supply such as ACCULEX model PSLOOP-175 (24 VDC @ 175 mA) makes an excellent source.

When using the 4 to 20 mA output from the MAO-8, 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 you to power many loops from the same supply but dictates that the load be 2-wire floating. The wiring schemes for both configurations is illustrated in Figure 8A-5.

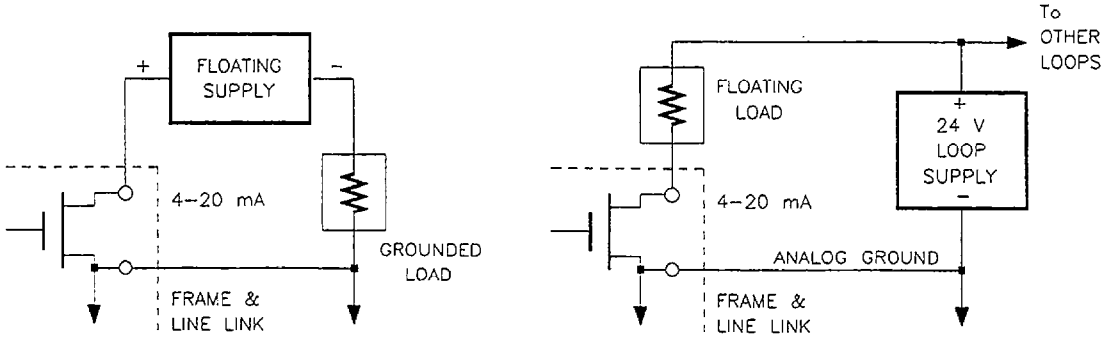


Figure 8A-5. Power Supply Configurations

To configure for 4 to 20 mA output range, you must

1. Set the channel output range to 5 V FS Unipolar, as instructed in the previous section.
2. Wire the (+) side of the floating supply to the (+) side of the sensing load, then wire the (-) side of the load to the I OUT terminal of the MAO-8, as indicated in Figure 8A-5.
3. Wire the (-) side of the supply or the other side of the load to the ANAGND terminal of the MAO-8.

Use of External Reference Sources

Each output channel of the MAO-8 is capable of operating from either the internal +5 V reference source or via an externally supplied voltage. This allows the output of one channel to be used as the reference for another channel, effectively cascading the two channels and increasing the D/A resolution.

You may also use the MAO-8 with a variable or fixed external reference voltage provided the voltage remains above 0 volts. This allows, for example, the MAO-8 to be a programmable voltage attenuator in conjunction with a non-negative sine wave, saw tooth, or other source. Most applications do not require an external reference source; the internal +5 V REF should be used.

Configuring the MAO-8 for Non-standard Output Ranges

Since the output range for any channel of the MAO-8 depends on the amount of current feeding the REF IN pin of the D/A converter, the output varies with this current. Place a resistor between the +5REF and the REF IN pins to determine the desired range according to Ohm's Law (E = IR). Thus, changing the range of the MAO-8 is actually varying the resistance between these two points. Resistors R98-R105 (refer to the MAO-8 schematic in the MetraBus schematic package) are optional and for this purpose. The use of 0.1% tolerance precision resistors is highly recommended.

NOTE: The optional resistor is in parallel with the standard 4.99 kΩ resistor. For example, when switching from +5 V FS to + 10 V FS, you are actually adding another 4.99 kΩ resistor. This can be confirmed by referring to the schematic and by calculating the total resistance of parallel resistors, as follows:

$$1/R = (1/R1) + (1/R2)$$

Thus:

$$1/R\ (total) = 1/4999 + 1/4999$$
$$R\ (total) = 2499\ \Omega$$

You can see that changing from +5 V FS to +10 V FS is actually halving the output resistance, thereby doubling the full scale range of the output voltage.

Using an external reference with a non-standard full scale range selection, you may customize any channel on the MAO-8 for your specific application.

8A.6 PROGRAMMING THE MAO-8

MetraBus supervision by the driver board tends to facilitate MAO-8 programming. Because the driver board generates all necessary control signals, the user need not be concerned with control registers, PEEKing or POKEing memory locations, shifting bits, PUSHing or POPing stacks, learning new languages, etc.

The MetraBus diskette includes a program in BASIC (MAO8.BAS) dealing with the MAO-8 functions. This program illustrates the use of the MAO-8 as a programmable function generator (in this case, generating a sine wave).

The program is heavily commented. Though the program is in BASIC, its general flow is similar in other languages. This program with the examples below should answer most questions about MAO-8 usage.

MAO-8 Terminology and Data Format

The MAO-8 uses eight of the 64 addressable MetraBus locations. These locations correspond to Channels 0-7.

The MAO-8, like all MetraBus output boards, contains a data readback feature for verification of channel output status. Data readback is accomplished by reading from DATAIO. Writing to the MAO-8 sets the output level for that channel. In BASIC, these are accomplished using the INP and OUT commands. A master clear command (MRESET) resets all outputs to zero and clears the data latches. The address registers of the MAO-8 card are as follows:

MetraBus Address	Read	Write
Board Address +0h	CH 0 Status	CH 0 Data
Board Address +1h	CH 1 Status	CH 1 Data
Board Address +2h	CH 2 Status	CH 2 Data
Board Address +3h	CH 3 Status	CH 3 Data
Board Address +4h	CH 4 Status	CH 4 Data
Board Address +5h	CH 5 Status	CH 5 Data
Board Address +6h	CH 6 Status	CH 6 Data
Board Address +7h	CH 7 Status	CH 7 Data

Use the variable MAO-8 for all data writes and status reads. For example, to write a data value of 192 to CH 5, do the following:

```
10 MAO8 = 16                    'Declare MAO-8 MetraBus Address
20 DATAIO = 768                 'Declare Data I/O location
30 ADRPTR = 769                 'Declare Address Pointer location
40 OUT ADRPTR, MAO8+5           'Point to CH #5 OF MAO-8 at address 16
50 OUT DATAIO, 192              'Write data value of 192
```

Data is written to the MAO-8 in straight binary format for the unipolar mode and offset binary for the bipolar mode. This is illustrated in the table below.

DATA BITS								OUTPUT		
B7	B6	B5	B4	B3	B2	B1	B0	BYTE	UNIPOLAR	BIPOLAR
1	1	1	1	1	1	1	1	255	+V FS	+V FS
1	0	0	0	0	0	0	0	128	1/2 scale	0
0	0	0	0	0	0	0	0	0	0	-V FS

MAO-8 control uses a standard programming sequence. This sequence consists of

1. Targeting the desired MetraBus I/O board and Channel number by writing to the Board Address + Channel Number.
2. Writing the data value corresponding to the desired function to the DATAIO.

The following examples are in interpreted BASIC. However, the MAO-8 functions of the MAO-8 can be illustrated in other languages such as C, PASCAL, Assembly, etc. In these examples, assume an MDB-64 driver card at computer I/O address 768 and an MAO-8 with a MetraBus board address of 32.

Example 1

In the above example, voltage output levels are specified as a function of the Full Scale Output Range in conjunction with a D/A resolution of eight bits (28 = 256). While this arrangement is useful for the computer when calculating proportional voltage outputs or when describing a ramped output, it is sometimes desirable to specify the output as an actual voltage. Line 60 does the conversion from voltage to the corresponding D/A integer. The assumed setup parameters are Unipolar operation with +5 V REF and a Full Range of 5 V.

```
10 DATAIO = 768                              'Declare Data I/O location
20 ADRPTR = 769                              'Declare Address Pointer
                                               'Location
30 MAO8 = 32                                 'Declare MAO-8 MetraBus
                                               'Address
40 OUT ADRPTR, MAO8 + 4                      'Point the CH #4 of MAO-8
50 INPUT "Output Voltage (CH#4)" ; VOLTS     'Get voltage output level
60 VOLTS = INT(VOLTS*256)/5                  'Convert voltage to D/A
                                               'integer
70 OUT DATAIO, VOLTS                         'Set output voltage on CH #4
```

The D/A output integer is calculated as a simple ratio of

For 8-bit bipolar operation:
D/A integer = ((specified volts * 256)/voltage span) + 128

For 4-bit unipolar operation:
D/A integer = (specified volts * 256)/voltage span

The calculation below may clarify this concept. Suppose the MAO-8 setup parameters are bipolar operation (+5 VREF, and Full Scale Range of 5 V), and we wished to convert 3.26 volts to a D/A integer.

Voltage Span:	10 V (span is 10 V due to bipolarity).
D/A Resolution:	256.
Specified Voltage:	+3.26.

*D/A Integer = (3.26 * 256)/(10)+128*
D/A Integer = 211

For unipolar operation at 5 V REF and Full Scale Range of 5 V:

Voltage Span: 5 V (unipolar).
D/A Resolution: 256.
Specified Voltage: +3.26.

*D/A Integer = (3.26 * 256)/ 5*
D/A Integer = 167

Example 2

Reading back the data value sent to the MAO-8 can be useful for detecting data transmission errors (for example, if you are transmitting data over long distances at high baud rates or if you are in an area of excessive electrical noise). The following program illustrates the data readback feature (it uses the above program with required changes).

```
10   DATAIO = 768                                'Declare Data I/O Location
20   ADRPTR = 769                                'Declare Address Pointer
                                                   'Location
30   MAO8 = 32                                   'Declare MAO-8 MetraBus
                                                   'Location
40   OUT ADRPTR, MAO8+3                          'Select CH #3 on MAO-8
50   INPUT "Output Voltage (CH #3); VOLTS        'Get Output Voltage
60   VOLTS = INT (VOLTS*256)/5                   'Calculate D/A integer
                                                   'value
70   OUT DATAIO, VOLTS                           'Set output to specified
                                                   'level
80   VOLTCHK = INP(DATAIO)                       'Readback voltage just
                                                   'sent
90   IF VOLTCHK <> VOLTS THEN PRINT "ERROR!!!" : END
100                                              'Data integrity check
110  GOTO 50                                     'Loop back and get new
                                                   'voltage
```

Using Compiled Or Assembled Languages

The execution speed of compiled and assembled languages calls for precautions when used with the MAO-8. Typical A/D conversion times of 80 ns minimize the wait for BUSY status bit to settle. However, a WRITE DATA (R/W) time of 10 µs may require monitoring the R/W and BUSY status bits prior to accessing the digitized data or attempting other operations (except reading the ADRPTR for status information) on the MetraBus. Perform this monitoring by reading the currently latched MetraBus address and "looking" at Bit 6. This information is contained in the ADRPTR location. The data storage format is

BIT	D7	D6	D5	D4	D3	D2	D1	D0
	BUSY	R/W	A5	A4	A3	A2	A1	A0

For a period of 10 µs after a data output (WRITE) operation, the R/W status bit will be active (high). The R/W status bit must be in its quiescent state prior to attempting another operation on the MetraBus. Returning the value of only the R/W bit can be accomplished as follows:

```
90 STATUS=INP(ADRPTR) AND 64      'Get status information
100  IF STATUS <> THEN GOTO 90
```

The BASIC variable STATUS will contain either 0 or 64, indicating the state of the D6 bit. Again, do this procedure only when using compiled (including compiled BASIC) and assembled languages.

8A.8 CALIBRATION AND ADJUSTMENT OF THE MAO-8

Calibrate the MAO-8 periodically to maintain the highest accuracy. For laboratory environments, use an 8 month to 1 year interval. For more rigorous conditions where large temperature gradients are experienced or where vibration an humidity are prevalent, use a 6 month interval.

To facilitate calibration, the MAO-8 package contains a software calibration program called *CALMAO.BAS* . The minimum equipment requirement is a 4 1/2 digit Digital Multimeter. This section is brief and intended for use with CALMAO.BAS.

CALMAO.BAS has four sections. The first section instructs the user to set the MDB-64 Base Address to 768 (300h) and the MAO-8 board Address to 8. If your MAO-8 card is at a different address, you may change it without removing it from the bus cable, provided no other card occupies that board address. Note that the MAO-8 requires an auxiliary power supply.

The second CALMAO.BAS section tests the latches on the MAO-8 by writing to and reading from each bit of each latch. Errors, if any, are be displayed as they are encountered. The third section tests analog zero offset. Each channel's offset resistor (R1-R8) should be adjusted until a zero reading is established. The final CALMAO.BAS section tests the gain adjustment. In this case, all channels should read 5 V on a 5 V Unipolar Full Scale. Steps three and four should be repeated until no further adjustment is necessary. CALMAO.BAS will allow for this looping.

8A.9 SERVICEABLE PARTS

As a convenience, "critical" components are mounted in sockets. These components are those that may be damaged by large external transients, etc.

To perform your own service, plug the MAO-8 into the MetraBus cable and operate it normally. The voltmeter is required to probe various voltages as follows:

If the +5 V reference does not meet specification, replace U33 (LF442CN) or Q10 2N2222. If any of the D/As cannot be adjusted for gain or are dropping bits or non-linear, replace either the DAC-08 or LF442CN (U25-U32) associated with that channel. If the offset for the 4-20 mA current range is out of specification, replace U33 (LF442CN). If the current output does not change with the voltage output of that channel, replace the corresponding (LF442CN) (U25-U32).

■ ■ ■

MAO-12 ANALOG OUTPUT BOARD

8B.1 GENERAL

The MAO-12 is an 8-channel analog output board. Each of the output channels is independent and has a 12-bit (1 part in 4095) resolution. The MAO-12 has five standard switch-selectable, voltage-output ranges as well as 4 to 20 mA output capability. The board's screw terminals accept 12 to 22 AWG wire. Figure 8B-1 is a block diagram of the MAO-12.

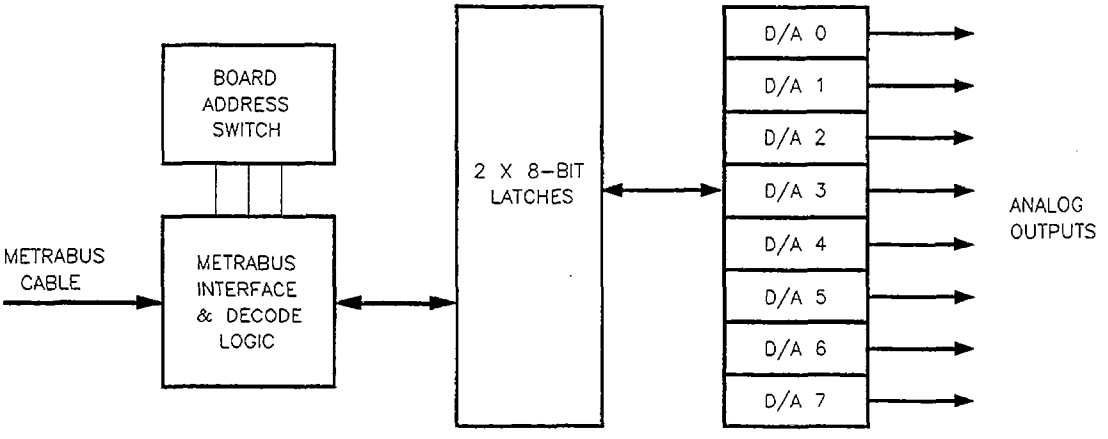


Figure 8B-1. Block Diagram

The MAO-12 connects directly to any of the MetraBus driver boards via the 50-conductor MetraBus ribbon cable. This cable connects the MAO-12 to one of the driver cards and carries all data, address, and status information, and power distribution for the MetraBus. A total of 20 ground lines are interleaved among the data and address lines to ensure noise immunity. The MetraBus system allows 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 km. The MAO-12 is 19" rack mountable in either a standard NEMA type enclosure or the MetraByte RMT-02; it also mounts on any panel or other flat surface.

The MetraBus system allows control of up to 64 analog output channels (8 MAO-12s) from a single computer expansion slot.

Some common uses of the MAO-12 include computer control of 4 to 20 mA process control equipment, single-board function generation, ON/OFF servo motor control, digital attenuation, variable voltage generation, etc.

8B.2 FEATURES

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

8B.3 SPECIFICATIONS

Output Channels:	8
Output Ranges:	0 to +5 V 0 to +10 V ±5 V. ±10 V. 4 to 20 mA current loop
D/A Resolution:	12 bits (1 part in 4096)
Relative Accuracy:	1/2 LSB (0.01%) maximum
Differential Linearity:	1/2 LSB maximum
Temperature Coefficient of Gain:	+35 ppm per ° C (unipolar) +55 ppm per ° C (bipolar)
Zero Drift:	+10 ppm per ° C
Voltage Output Impedance:	0.1 Ω maximum
Voltage Output Drive Current:	5 mA maximum
4 to 20 mA Compliance:	6 to 36 V

Environmental

Operating Temperature:	0 to 70 ° C
Storage Temperature:	-55 to 125 ° C
Humidity:	0 to 95% non-condensing

Power Supplies

@ +5 V:	590 mA maximum
@ +15 V:	28 mA maximum
@ -15 V:	75 mA maximum
Total power dissipation:	4.5 W typical

Physical

Size:	16 x 4.75 inches (40.63 x 12.06 cm)
MetraBus Cable Type:	50-conductor ribbon cable
MetraBus Connector:	3M 3425-6050

8B.4 USE OF AN AUXILIARY POWER SUPPLY

The MAO-12 requires +15 V in addition to the standard +5 V required by all MetraBus I/O boards. The board therefore requires an external power supply such as the MetraBus MBUS-PWR-55.

> NOTE: When using an auxiliary power supply with an MDB-64 MetraBus controller/driver board, remember to remove fuse F1 from the MDB-64.

8B.5 INSTALLING THE MAO-12

Before installing the MAO-12, make certain that a MetraBus controller/driver board is in place. These boards are described earlier in this manual.

Set each MAO-12 on a single MetraBus cable to a unique, non-overlapping MetraBus I/O address. Each MAO-12 uses eight of the 64 MetraBus I/O addresses. These eight addresses run consecutively starting from the MAO-12 board address. Setting the board address is outlined below. Figure 8B-2 shows an example board address setting.

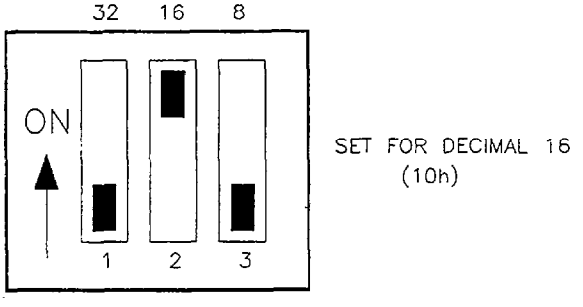


Figure 8B-2. Setting the Board Address

To set the board address,

1. The board address DIP switch is located on the far-left side of the board, just above and to the left of the MetraBus interface connector. The numbers silk-screened above the switch indicate the value of the switch immediately below it. The numbers have value only in the ON position.

2. Select an unused board address and set the DIP switches accordingly. For example, to set a board address of 24, set the switches with corresponding values of 8 and 16 to ON. Remember that each MAO-12 uses 8 of the 64 MetraBus I/O addresses and must be set to an unused, non-overlapping board address in order to avoid address conflicts.

3. After setting the board address, connect the MAO-12 to the MetraBus cable. The MetraBus cable connector is keyed for your protection and should plug in easily.

   NOTE: Remove power from the MetraBus cable prior to connecting any I/O boards to it.

4. If you have only one MAO-12 or your MAO-12 is the last board in your system, install the resistor-terminating networks provided with your driver card. The sockets marked RN1 and RN2 immediately above the MetraBus connector are for this purpose. The resistor networks minimize signal reflection from long cable lengths. They are optional, however, and have little effect for cables of 50 feet or less.

MAO-12 Output Range Selection

You may set any channel of the MAO-12 for any of five output ranges (see the following table). Range selection for each channel uses a 3-station switch, whose assignments are shown in the table. The switch is depicted in Figure 8B-3.

Range	SW1	SW2	SW3
±5 VDC	UP	DOWN	UP
±2.5 VDC	UP	UP	UP
±10 VDC	DOWN	DOWN	UP
0-5 VDC	UP	DOWN	DOWN
0-10 VDC	DOWN	DOWN	DOWN

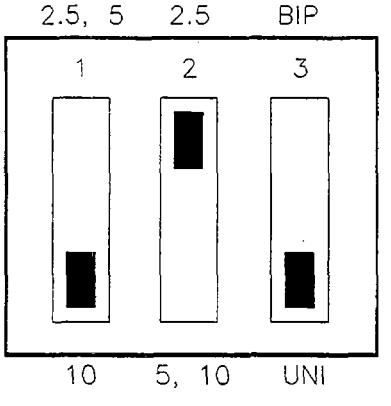


Figure 8B-3. The Output Range Switch

Selecting the 4 to 20 mA Output Range

The MAO-12 supports a 4 to 20 mA current output, which may be useful for connecting some types of industrial instrumentation. The 4 to 20 mA current output consists of a precision current sink formed by a VMOS power FET and reverse protection diode. Figure 8B-4 illustrates this circuit.

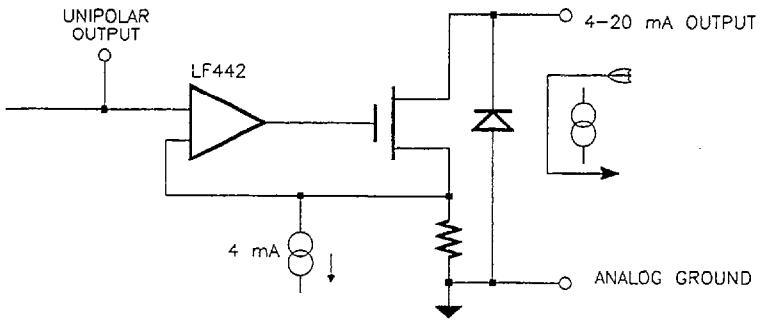


Figure 16-4. 4 to 20 mA Current Output Circuit

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

When using the 4 to 20 mA output from the MAO-12, you must select the required type of power supply and determine its configuration. As mentioned above, you need an external supply. 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 may 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 in Figure 8B-5.

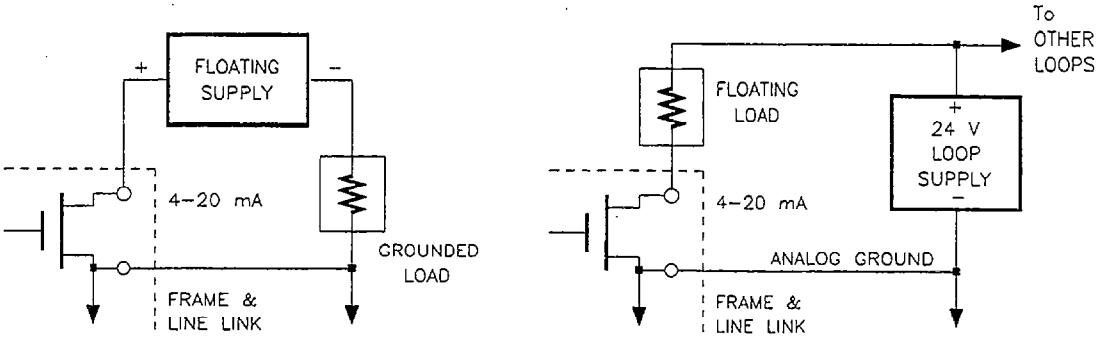


Figure 8B-5. Power Supply Configuration

To configure for 4 to 20 mA output range, you must

1. Set the channel output range to 5 VFS uUnipolar, as instructed in the previous section.
2. Wire the + side of the floating supply to the + side of the sensing load, then wire the - side of the load to the I OUT terminal of the MAO-12 (see Figure 8B-5).
3. Wire the - side of the supply or the other side of the load to the ANAGND terminal of the MAO-12.

8B.6 PROGRAMMING THE MAO-12

MAO-12 programming tends to be made easier because of MetraBus supervision by the driver board. Since the driver board generates all necessary control signals, the user need not be concerned with control registers, PEEKing or POKEing memory locations, shifting bits,

PUSHing or POPing stacks, learning new languages, or other system level headaches. Refer to the driver board descriptions provided earlier in this manual.

The MetraBus diskette includes a program in BASIC dealing with the MAO-12. The program illustrates the use of the MAO-12 as a programmable function generator (in this case, generating a sine wave).

The program is heavily commented. Though written in BASIC, the general flow of the programs should be similar to that of other languages. This program, with the examples below, should answer most of the questions concerning MAO-12 usage.

MAO-12 Terminology & Data Format

The MAO-12 uses eight of the 64 MetraBus I/O addresses. In BASIC, use INP and OUT commands to write data to and read data from the MAO-12. Data goes in bytes via the DATAIO register to the MAO-12 board address targeted with the ADRPTR. The eight functional MAO-12 locations are offsets from the MAO-12 board address. The MAO-12 is double-buffered and contains data latches that hold output data until the update trigger (board address +4 thru +7) is written.

The address registers of the MAO-12 card are as follows:

MetraBus Address	Read	Write
Board Address +0h	None	Write data (high byte)
Board Address +1h	None	Write data (low byte)
Board Address +2h	Channel readback	Channel select

The map for the channel select byte is as follows:

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

	Channel Number							
CH SEL Bit	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 Address +3 (Write Only)

Selects any or all channels for simultaneous update mode. Channel selection is accomplished by setting the specific bit(s):

BIT	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 four addresses is written, all previously selected DACs are updated with data from high and low data bytes (Board Addresses +0 and +1).

For clarity, use the variable MAO-12 for all data writes and status reads. For example, to write a data value of 192 to CH 5, do the following:

```
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             'Write data value of 192
80 OUT ADRPTR, MAO12+4         'Update selected DAC output
```

Control of the MAO-12 uses a standard programming sequence, consisting of:

1. Target the desired I/O board via the ADRPTR and channel select location.
2. Select channel via DATAIO and channel #.
3. Point to data output location via ADRPTR.
4. Write the data value corresponding to the desired function to the DATAIO.
5. Update selected DAC.

Data writes to the MAO-12 are in 2-byte straight binary (right-justified format) for unipolar and 2-byte offset binary for bipolar mode, as follows:

High Byte								Low Byte						
B7	B6	B5	B4	B3	B2	B1	B0	B7	B6	B5	B4	Data Value	Unipolar	Bipolar
1	1	1	1	1	1	1	1	1	1	1	1	4095	+V FS - 1 bit	-V FS + 1 bit
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	+V FS

The following examples below are in interpreted BASIC. However, the programming of MAO-12 functions can also use C, PASCAL, Assembly, etc. In these examples, 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

Note in the example below that voltage output levels are specified as a function of the full-scale output range with a D/A resolution of 12-bits (1 part in 4096). While this may be useful for the computer when calculating proportional voltage outputs or when describing a ramped output, it may also be useful to specify the output as an actual voltage. Line 70 does the conversion from voltage to the corresponding D/A integer. The assumed setup parameters are unipolar operation with +5 V REF and a full range of 5 V.

```
10   DATAIO = 768                              'Declare data I/O location
20   ADRPTR = 769                              'Declare address pointer
                                                 'Location
30   MAO12 = 32                                'Declare MAO-12 MetraBus
                                                 'Address
40   OUT ADRPTR, MAO12 + 2                     'Point the channel select
50   OUT DATAIO, 4                             'Select channel 4
60   INPUT "Output Voltage (CH#4)" ; VOLTS     'Get voltage output level
70   VOLTS = INT(VOLTS*4096)/5                 'Convert voltage to
                                                 'integer (high byte)
80   FOR I = 11 TO 4 STEP -1                   'Set up high byte loop
90   IF VOLTS => 2^I                           'Check bits in high byte
100  HIBYTE = HIBYTE + 2^(I-3)                 'Create high byte for
                                                 'output
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                           'Check bits in low byte
150  LOBYTE = LOBYTE + 2 ^(I+4)                'Create low byte for
                                                 'output
160  VOLTS = VOLTS - 2^I                       'Subtract bit value from
                                                 'Volts
170  NEXT I
180  OUT ADRPTR, MAO12                         'Point to high byte
                                                 'Location
190  OUT DATAIO, HIBYTE                        'Output Hhgh byte of volts
200  OUT ADRPTR, MAO12+1                       'Point to low byte
                                                 'Location
210  OUT DATAIO, LOBYTE                        'Output low byte of volts
220  OUT ADRPTR, MAO12+4                       'Update DAC and output
                                                 'voltage
```

The D/A output integer is calculated as follows:

For 12-bit bipolar operation

D/A integer = 2048 - ((specified volts * 4096)/Full Scale Voltage Span)

For 12-bit unipolar Operation

D/A integer = (specified volts * 4096)/Full Scale Voltage Span

NOTE: A 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 a matter of establishing these two bytes. If 12-bit precision is not required for your specific application, you may ignore the low byte (it will be output as 0) and use only the high byte. In this case, use 256 rather than 4096 for the calculations. A 12-bit data calculation is illustrated below.

Suppose the MAO-12 is configured for bipolar operation with an output range of ±5 V and you want to convert 2.5 V to a D/A integer.

D/A integer = 2048 - (specified volts * 4096)/(voltage span)
D/A integer = 2048 - ((2.5*4096)/10.0)
D/A integer = 1024

Suppose the MAO-12 is configured for unipolar operation with an output range of 0 to 10 V and you want to convert 5.0 V to a D/A integer.

D/A integer = (specified volts * 4096)/(voltage span)
D/A integer = (5.0*4096)/10.0
D/A integer = 2048

Example 2

Reading back the data value sent to the MAO-12 is useful for detecting data transmission errors or for computer calculation of ramped or proportional outputs. The following program illustrates the data readback feature. For the sake of clarity, use the above program with required changes.

```
10   DATAIO = 768                                'Declare data I/O
                                                   'location
20   ADRPTR = 769                                'Declare address pointer
                                                   'Location
30   MAO12 = 32                                  'Declare MAO-12 MetraBus
                                                   'Address
40   OUT ADRPTR, MAO12 + 2                       'Point the channel
                                                   'select
50   OUT DATAIO, 4                               'Select channel 4
60   INPUT "Output Voltage (CH#4)" ; VOLTS       'Get voltage output
                                                   'level
70   VOLTS = INT(VOLTS*4096)/5                   'Convert voltage to
                                                   'integer (high byte)
80   FOR I = 11 TO 4 STEP -1                     'Set up high byte loop
90   IF VOLTS => 2^I                             'Check bits in high byte
100  HIBYTE = HIBYTE + 2^(I-3)                   'Create high byte for
                                                   'output
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                             'Check bits in low byte
150  LOBYTE = LOBYTE + 2 ^(I+4)                  'Create low byte for
                                                   'output
160  VOLTS = VOLTS - 2^I                         'Subtract bit value from
                                                   'Volts
170  NEXT I
180  OUT ADRPTR, MAO12                             'Point to high byte
                                                   'Location
190  OUT DATAIO, HIBYTE                            'Output high byte of
                                                   'Volts
200  VOLTCHK = INP(DATAIO)                         'Readback data just
                                                   'sent
210  IF VOLTCHK <> HIGH BYTE THEN PRINT "ERROR!!!":END
220  OUT ADRPTR, MAO12+1                           'Point to low byte
                                                   'Location
230  OUT DATAIO, LOBYTE                            'Output low byte of
                                                   'volts
240  VOLTCHK=INP(DATAIO)                           'Readback data just
                                                   'sent
250  IF VOLTCHK <> LOBYTE THEN PRINT "ERROR!!!":END
260  OUT ADRPTR, MAO12+4                           'Update DAC and
                                                   'output voltage
```

■ ■ ■

MAI-16 ANALOG INPUT BOARD

8C.1 GENERAL

The MAI-16 is a 16-channel analog input board. The board uses a 12-bit successive approximation A/D converter that may be operated at 8-bit resolution for higher speed applications. Software-selectable input ranges of +10 VDC, +2.5 VDC, and +1.25 VDC as well as 4 to 20 mA are available on each channel. The board accepts resistors that allow a variety of input ranges. A 50 Hz, single-pole, low-pass filter working with the differential inputs virtually eliminates troublesome 50/60 Hz line noise. Each channel of the MAI-16 has an annunciator LED for visual verification of channel access. Screw terminals on the board accept 12 to 22 AWG wire. Figure 8C-1 is a block diagram of the MAI-16.

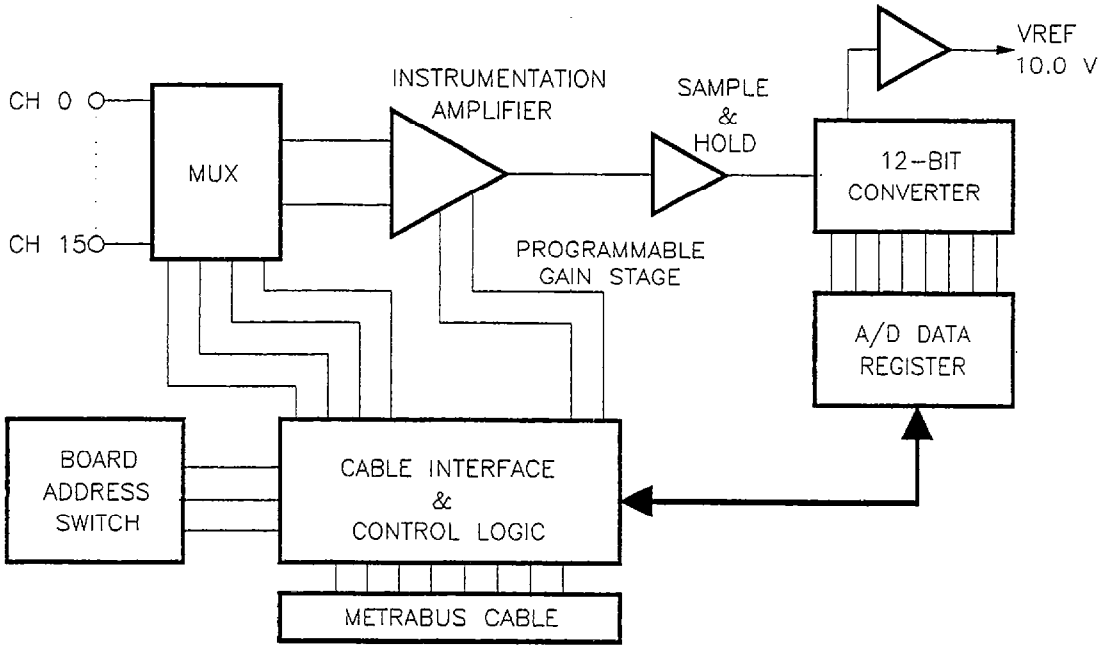


Figure 8C-1. Block Diagram

The MAI-16 connects directly to any of the MetraBus driver cards via a 50-conductor ribbon cable. This MetraBus cable carries all data, address, control signals, and power. The MAI-16 is 19" rack-mountable in either a standard NEMA-type enclosure or the RMT-02 housing.

The MetraBus system can address up to 256 analog input channels (16 MAI-16 boards) per computer expansion slot. Some uses of the MAI-16 include signal analysis, process trend and correlation analysis, data logging, Q.C. and life-cycle Testing, general voltage and current measurements, component test beds, and temperature, pressure, and flow measurements.

8C.2 FEATURES

- Interfaces directly with IBM PC/XT, PC AT, and compatibles
- Remote location for easy signal connections
- Up to 256 analog channels per computer expansion slot
- Very low cost per channel
- Software selectable ranges
- Wide variety of input ranges including 4 to 20 mA
- Full differentially measured inputs
- Designed for standard 19" rack mount
- Choice of 8 or 12-bit resolution

8C.3 SPECIFICATIONS

Input Channels:	16 fully differential
Input Ranges:	Four standard (software- or hardware-selectable) +10 V, +5 V, +2.5 V, or +1.25 V
A/D Converter type:	Successive approximation
A/D Resolution:	Twelve bits (can be set to eight bits)
A/D Accuracy:	0.01% +1 bit
A/D Speed (Inhibit Conv):	50 kHz (8-bit) 33.3 kHz (12-bit)
A/D Speed (Auto Conver):	14.2 kHz (8-bit) 12.5 kHz (12-bit)
Multiplexer type:	Solid state (HI 506)
Temperature Coefficient:	+45 ppm per ° C
Data Format:	Binary offset
Input Bias Current:	2 nA typical; 6 nA maximum
Input Impedance:	100 MΩ
Common Mode Voltage:	+10 V maximum
Input Overvoltage:	+30 V continuous maximum
Reference Voltage:	+10 V (+0.1 V)
Reference Drive Current:	10 mA maximum

Environmental

Operating Temperature:	0 to 70° C
Storage Temperature:	-40 to 100° C
Humidity:	0 to 95% non-condensing

Power Requirments

@ +5 V:	180 mA typical; 220 mA maximum
@ +15 V:	33 mA typical; 40 mA maximum
@ -15 V:	44 mA typical; 50 mA maximum

Physical

Size:	16 x 4.75 inches (40.63 x 12.06 cm)
Weight:	11.5 oz (326 gm)
MetraBus Cable Type:	50-conductor ribbon cable
MetraBus Connector:	3M 3425-6050

8C.4 USING AN AUXILIARY POWER SUPPLY

The MAI-16 requires +15 VDC in addition to the normal +5 VDC. For this reason, a MetraBus MBUS-PWR power supply is required.

> NOTE: When using an auxiliary power supply with an MDB-64 MetraBus controller/driver card, remember to remove fuse F1 from the MDB-64.

8C.5 INSTALLING THE MAI-16

Before installing the MAI-16, make certain your system contains a MetraBus controller/driver board. Set each MAI-16 on a single MetraBus cable to a unique, non-overlapping MetraBus I/O address. This address allows the boards in a MetraBus system to operate independently. Each MAI-16 uses four of the 64 MetraBus addresses. These four addresses run consecutively starting from the MAI-16 board address. Instructions for setting the board address appear below. Figure 8C-2 shows an example board address setting.

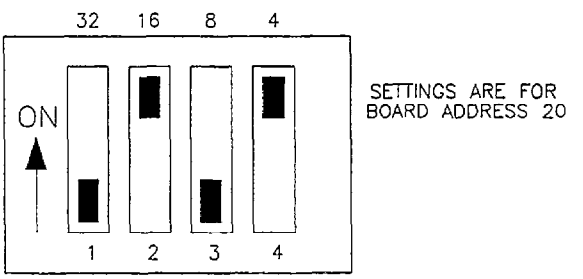


Figure 8C-2. Setting the Board Address

To set the board address,

1. The board address DIP switch is located on the far-left side of the board, just above and to the left of the MetraBus Interface connector. The numbers above the DIP indicate the values of the corresponding switches. The numbers have value only in the ON position.
2. Select an unused board address and set the DIP switches accordingly. For example, to set a board address of 24, set the switches with corresponding values of 8 and 16 to ON. Remember that each MAI-16 uses four of the 64 MetraBus I/O addresses and must be set to an unused, non-overlapping board address.
3. After setting the board address, connect the MAI-16 to the MetraBus cable. The MetraBus cable connector is keyed for your protection. Check the keyways for correct alignment prior to plugging in the MetraBus cable.

   NOTE: Remove power from the MetraBus cable prior to connecting any I/O boards.

4. If your system has only one MAI-16 or if one of your MAI-16s is the last board in the system, install the resistor-terminating networks provided with your driver card. The sockets marked RN1 and RN2 immediately above the MetraBus connector are for this purpose. These resistor networks minimize signal reflection from long cable lengths. They are optional, however, and have little effect for cables of 50 feet or less.

8C.6 MAI-16 TYPICAL ANALOG INPUT CONNECTIONS

The MAI-16 analog input channels use screw-type terminal strips for easy signal connections. All input channels of the MAI-16 measure signals differentially (positive is measured against negative, which is not necessarily 0 V). This means that external noise (fluorescent lights or 50/60 Hz line noise, for instance) has little affect on the measured signal since this external noise affects both + and - lines. You may connect analog signals having common ground directly to the + and - terminals while tying those from isolated voltage sources to the negative side of the Analog Ground terminal. Figure 8C-3 shows several signal hook-ups.

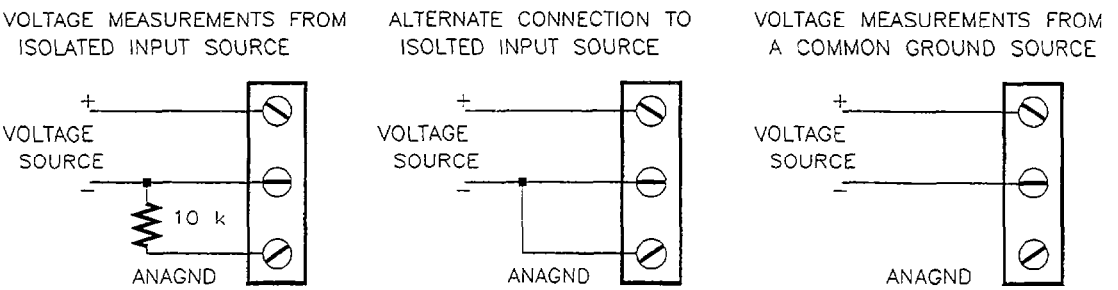


Figure 8C-3. Typical Input Connections

8C.7 INPUT SIGNAL ATTENUATION

It may be useful to measure signals that are either greater or lesser in magnitude than the standard input ranges allowed by the MAI-16. For this reason, the MAI-16 can accommodate a range of analog input configurations via custom-installed resistors. The standard input stage contains a 50 Hz single-pole, low-pass filter. The filter cut-off frequency may be easily changed or the filter may be removed entirely. The circuit and layout diagrams in Figure 8C-4

are the input section of one MAI-16 channel. Every input channel on the MAI-16 has the same physical layout.

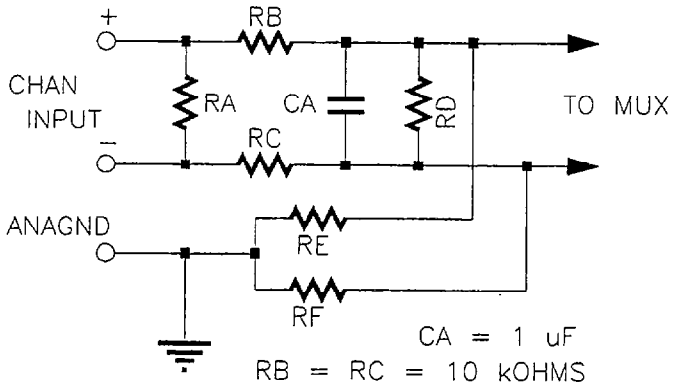


Figure 8C-4. MAI-16 Input Channel

In Figure 8C-4, Resistors RA, RD, RE, and RF are optional, to be installed only if required. Applications requiring installation of these resistors are outlined in the following sections.

8C.8 MEASURING SIGNALS GREATER THAN +10 VDC

The input of the MAI-16 allows you to install voltage divider circuits. These voltage dividers decrease the gain of the input channel, allowing measurement of larger voltages. The simplest voltage divider is created by installing RD, (R97-R112, corresponding to channels 0 to 15). Since the circuit has 20 kΩ (RB and RC) in series with the input legs, the insertion of RD decreases the gain accordingly. For example, to halve the input gain by allowing for measurement of +20 V. You do this halving by matching the value of RB + RC. Therefore, RD should have a value of 20 kΩ.

For applications requiring common-mode voltages greater than +10 V, use a divider with RE and RF (where RE and RF are the same value).

8C.9 MEASURING SIGNALS SMALLER THAN +1.25 VDC

The input gain for the MAI-16 is defined by the ratio of R116 to R115, according to the following formula:

$$\text{Gain} = 20 * (R115/R116)$$

where R115 < 20 kΩ and R116 > 100 Ω.

If R115 is large with respect to R116 (within the specified limits), the gain of the MAI-16 is increased. For example, to increase the gain by a factor of 2 (allowing a minimum full range scale of +0.625 V), change R115 from a 5 kΩ to a 10 kΩ resistor (both R115 and R116 are precision resistors of similar tolerance). Note that R115 and R116 are located after the multiplexer and before the A/D converter. A change in value of either of these resistors affects all channels of the MAI-16.

Since the reference of the A/D converter is set at +5 V, select input gains to keep the maximum input voltage times the gain less than or equal to 5 V for proper operation.

For example, the factory-installed values of R115 and R116 on the MAI-16 are 5 kΩ and 200 kΩ, respectively. This equals a gain of 1.2 (20*5000/200000 = 0.5). Thus, when the MAI-16 is in the +10 V full-scale range, the A/D "sees" signals no greater than 5 V. Selecting ranges of +5, +2.5, or +1.25 attenuates the signal by factors of 2, 4, or 8, respectively.

8C.10 MEASURING CURRENT WITH THE MAI-16

Current measurements require installation of shunt resistors on the MAI-16. The shunt provides a low-resistance bypass that converts the input current into a corresponding input voltage. A shunt resistor is always connected in parallel with the measurement circuit. RA is the shunt resistor. The value of RA is dictated by the magnitude of the current being measured. To measure a current range of 4 to 20 mA in the +5 V full-scale range, calculate (using Ohms Law (E = IR)) as follows:

Maximum Current: 0.020 A
Maximum Full Scale Voltage: 5 V
Using R = E/I, R = 5 V/0.2 A = R = 250 Ω

Minimum Current: 0.004 A
Resistance: 250 Ω
Using E = IR, E = 0.004 X 250
Minimum Full Scale Voltage: 1 V

Therefore, a current range of 4 to 20 mA used with a 250 Ω precision shunt in the +5 V range results in readings of 1-5 V. This range and the 12-bit A/D resolution (1 part in 2048) allows a minimum detectable current change of 9.8 μA.

As an example, if an MAI-16 configured as above is used with a 4 to 20 mA thermocouple transmitter having a fixed range of 0 to 400 °F, the minimum detectable temperature change is 0.25° F.

20 mA / 2048 counts = .0098 mA per count
400° / 16 mA = 25° per 1 mA

Therefore,

25° per mA / 0.0098 mA per count = 0.245° per count
(minimum detectable change)

8C.11 AUTO CONVERT MODE OF OPERATION

AUTO CONVERT causes an A/D conversion every time the Gain/Channel select address is written. This feature is for users who will be programming in interpreted BASIC. AUTO CONVERT avoids two programming steps (pointing to the Gain/Channel Select mode and setting the gain) and thus speeds up program execution. Since the BASIC interpreter typically executes a short line of code in about 10 ms, the time savings with the AUTO CONVERT is substantial. Select the AUTO CONVERT mode by placing jumper W1 in the AUTO CONVERT position. Execution of the A/D conversion starts approximately 50 ms after the Gain/Channel Select command is issued, so that precise timing is sacrificed for the sake of

speed. However, this is not really a factor when using interpreted BASIC since the programmer has little control over timing anyway. When using the AUTO CONVERT mode, the entire board must be set (via hardware) for either 8 or 12-bit operation. See the next section for a full explanation.

8C.12 A/D RESOLUTION VIA HARDWARE

The MAI-16 gives you total control over A/D variables that are application specific. One of these variables is the resolving power of the A/D itself. A/D resolution is the minimum detectable voltage change within the full-scale range of the A/D. For example, setting the gain of an A/D converter for a full-scale range of +5 V (giving a voltage span of 10 volts), and 8-bit A/D converter has a theoretical resolution limit of (10,000 mV/28) = 39.1 mV.

Similarly, a 12-bit A/D operating on the same 10 V span results in a theoretical resolving limit of 10,000 mV/212 = 2.4 mV. On a functional basis, this means that an 8-bit A/D can sense the difference between 2.0000 and 2.0391 V, where a 12-bit A/D senses the difference between 2.0000 and 2.0024 V.

In an application program, you may either set the MAI-16 A/D resolution via software or fix it at 8 or 12 bits via hardware jumper W2. Locate the jumper (W2) in the upper left corner of the MAI-16 and install it in the desired position. Installing the jumper in the 8-bit mode of operation fixes all channels on the MAI-16 at 8-bits. The 12-bit mode allows 8-bit functionality via software. This, in conjunction with the AUTO CONVERT mode saves time when controlling the MAI-16 under interpreted BASIC.

8C.13 GAIN SELECTION VIA HARDWARE

As mentioned earlier, the MAI-16 allows total control over important application specific A/D variables. Another of these variables is the full-scale input range of each channel. This full-scale range is normally set by applying a multiplier to the standard input range of the A/D. The multiplier (signal amplifier) is applied to the input signal prior to A/D conversion. The available multiplication factors are x1, x0.5, x.25, and x0.125, resulting in full-scale ranges of +10 V, +5 V, +2.5 V, and +1.25 V, respectively.

You may set the MAI-16 input range either by an application program via software or by disabling the software selection feature with a setting for fixed hardware gain. A 3-gang DIP switch, located to the far left side of the MAI-16, serves this purpose. When operating the MAI-16 in the fixed gain mode, all channels on the board are fixed at the selected gain. The following table gives the selections, while Figure 8C-5 shows the Gain Selection Switch.

Input Range	Fixed Gain	G1	G2
Software-Selected	Off	--	--
+10.00 V F.S.	Off	Off	Off
+5.00 V F.S.	On	Off	On
+2.50 V F.S.	On	On	Off
+1.25 V F.S.	On	On	On

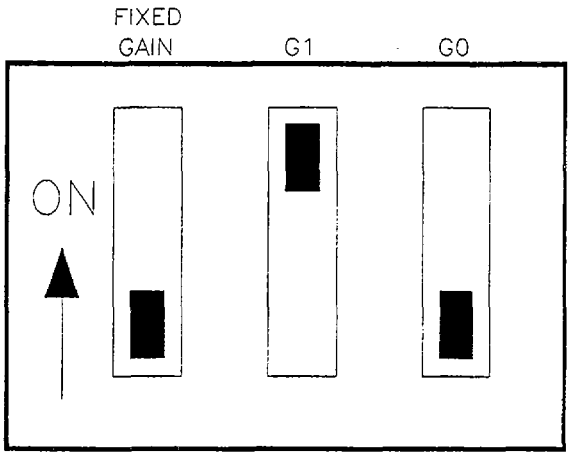


Figure 8C-5. Gain Selection Switch

8C.14 PROGRAMMING THE MAI-16

MetraBus supervision by the driver board tends to simplify MAI-16 programming. Since the driver board generates all necessary control signals, the user need not be concerned with control registers, PEEKing or POKEing memory locations, shifting bits, PUSHing or POPing stacks, learning new languages, or other system level nuisances.

The MetraBus diskette includes two programs (in BASIC) dealing with MAI-16 functions. The programs are linked together under the name MAI16.BAS. The first program is an application program that scans all 16 channels of the MAI-16 and allows gain changes on the fly. The next application program is a graphic display program that allows you to graph a channel of your choice on the CRT screen. It also allows you to change gain "on the fly" and to see the effects on the CRT screen. These programs are heavily commented. Though the programs are written in BASIC, their general flow should be similar in other languages. These programs and the examples below should answer most questions you might have on MAI-16 usage.

MAI-16 Terminology & Data Format

The MAI-16 uses four of the 64 addressable MetraBus locations. Writing to these addresses initiates A/D conversions, sets input ranges, and selects the input channel and its gain. Reading from these locations will return digitized analog data. The function of three of these four addresses is as follows:

MetraBus Address	Read	Write
Board Address	A/D MSB Data	Start 12-bit Conv (CNV12)
Board Address +1	A/D LSB Data	Start 8-bit Conv (CNV8)
Board Address +2	---	Select Gain/Channel (SGC)

Note that the fourth address is currently unassigned.

Also note that you may set 12-bit or 8-bit resolution by writing either CNV12 or CNV8 to the DATAIO. As before, use the variable names defining MAI-16 functionality. Note that in this example a Board Address of 4 is assumed.

```
40 CNV12 = 4            'Declare board address and CNV12
50 CNV8 = 5             'Declare CNV8 address location
60 SGC = 6              'Declare gain/channel Select
```

The MAI-16 has a standard programming sequence as follows:

1. Point to the gain/channel select mode at the board address via the ADRPTR.
2. Assign the gain for the specific channel on the board via the DATAIO.
3. Select required the A/D resolution via the ADRPTR.
4. Start the A/D Conversion process via the DATAIO.
5. Point to the converted data via the ADRPTR.
6. Retrieve digitized data from the MAI-16 via the DATAIO.

The following short program uses the BASIC commands OUT and INP for writing data to and reading data from the MAI-16 via the driver card at computer I/O address 768. The examples use a MetraBus address of 4 for the MAI-16. Although the example is in BASIC, the procedure is applicable to many computer languages supporting data I/O operations.

The example below illustrates how to set the gain for a specified channel and set the A/D resolution to eight bits. Recall that most of these programming steps are hardware selectable.

```
10 DATAIO = 768          'Declare Data I/O location
20 ADRPTR = 769          'Declare address pointer location
30 CNV12 = 4             'Declare Board Address and CNV12 mode
40 CNV8 = 5              'Declare 8-bit resolution address
60 SGC = 6               'Declare SCG address
70 OUTADRPTR, SGC        'Point to SGC for specified board
80 OUT DATAIO, 16        'Set channel 0 to + 5V full scale
90 OUT ADRPTR, DNV8      'Point to 8-bit conversion mode
```

Once the preliminary work above is complete, A/D conversion can begin and the results obtained. The following lines would do this.

```
100  OUT DATAIO, 00       'Initiate A/D conversion
110  OUT ADRPTR, 4        'Point to A/D result
120  AIN = INP (DATAIO)   'Get result to variable AIN
```

Gain Selection Via Software

The preceding program introduces a concept that is unexplained: that of setting the full-scale range for a specified channel via software. Select the input channel and range by writing a single data byte to the SGC (line 80 above). The data format for the SGC byte is as follows:

BIT	D7	D6	D5	D4	D3	D2	D1	D0
	-	-	GS1	GS0	CS3	CS2	CS1	CS0

Where

GS1, GSO

Gain Selection These bits are used to define the full scale range for the selected channel. Available ranges are as follows:

GS1	GS0	Full Scale Range
0	0	±10 V
0	1	±5 V
1	0	±2.5 V
1	1	±1.25 V

CS3-CS0

Channel Select These bits select the channel to be programmed. Channels are as follows:

CS3	CS2	CS1	CS0	Selected Channel
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7
1	0	0	0	8
1	0	0	1	9
1	0	1	0	10
1	0	1	1	11
1	1	0	0	12
1	1	0	1	13
1	1	1	0	14
1	1	1	1	15

The above chart shows that finding the value of the data byte to be written to the SGC is a matter of adding the values for the desired range and channel. Note also that the value for CH5 is 5, for CH15, is 15, and so on.

For example, to set the channel to a full-scale range of +2.5 V, the value is 32 + 7 = 39. This value is then sent to the SGC via the DATAIO as follows:

```
70 OUT ADRPTR, SGC          'Point to SGC at board address
80 OUT DATAIO, 39           'Set range for specified channel
```

A/D Conversion Process

The BASIC example below illustrates the actual steps involved in an A/D conversion process. Note that the value in line 90 (00) is irrelevant and is a space marker following the mandatory comma.

```
10   DATAIO = 768          'Declare data I/O location
20   ADRPTR = 769          'Declare address pointer location
30   MAI = 4               'Declare MAI-16 board address
40   CNV8 = 5              'Declare CNV8 address
50   SGC = 6               'Declare select gain/channel
```

```
55                          'select address
60   OUT ADRPTR, SGC        'Point to SGC at board address
70   OUT DATAIO, 18         'Set CH2 to + 5 V range
80   OUT ADRPTR, CNV8       'Point to 8-bit conversion mode
90   OUT DATAIO, 00         'Initiate A/D conversion
100  OUT ADRPTR, MAI          'Point to digitized result
110  AIN=INP(DATAIO)          'Result returned to AIN
120  PRINT AIN                'Display results
```

Reading 12-bit Conversion Data

Example 1 illustrates an 8-bit conversion with the resultant digitized value returned as a single 8-bit word. Do 12-bit conversions same way, but store the results in two consecutive bytes rather than one. Therefore, both bytes must be returned and added together. The Most Significant 8 bits (MSBs) of a 12-bit conversion (and all bits of an 8-bit conversion) are stored at the board address, while the remaining four bits are stored at the next consecutive location: board address +1. For those interested in the exact data storage format, it is straight binary offset with the lowest four bits of the LSB byte being zeros, as follows:

Board Address								Board Address +1							
B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0	0	0	0	0
MSB											LSB				

To illustrate this conversion, use Example 1 with lines 10-90 unchanged and with the following lines added:

```
100  OUT ADRPTR, MAI          'Point to MSBs
110  MSB = INP(DATAIO)        'Result returned to MSB
120  OUT ADRPTR, MAI + 1      'Point to LSBs
130  LSB = INP(DATAIO)        'Result returned to LSB
140  AIN = MSB*16+LSB/16      'Combine MSB and LSB bytes
150  PRINT AIN                'Display results
```

Converting Digitized Results To Voltage

The results in the above programs will be the digitized value of the A/D conversion. In many cases, this is enough; but often the actual voltage value is of more relevance. To change an 8-bit or 12-bit digitized value to voltage, use the following steps. Again, use Example 1 with 10 through 140 unchanged and the following lines added:

```
150  VFS = 5                          'Variable VFS set to A/D range
160  VOLTAGE = -VFS+AIN*VFS/2048      'Convert results to voltage
170  PRINT VOLTAGE                    'Display results
```

More Example Programs for the MAI-16

When using the MAI-16 in variable controlled scanning loops, there are parameters that make programming easier. One of these is using OR'd channel numbers for setting the gain. In Example 2, the channel number is OR'd to set a +5 V range for that channel. If the range were at +10 V, there would be no need to OR it because the +10 V range has a data value of zero. The program uses 8-bit A/D resolution; 12-bit resolution could also be used.

Example 2

```
10   MAI = 4                    'Declare MAI-16 board address
20   DATAIO = 768               'Declare DATAIO location
30   ADRPTR = 769               'Declare address pointer Location
40   CNV8 = 5                   'Declare 8-bit MetraBus Address
50   SGC = 6                    'Declare gain/channel select
                                 'MetraBus address
60   I = 0 to 15                'Start BASIC control loop
70   OUT ADRPTR,SGC             'Point to SGC mode at address 4
80   OUT DATAIO, 16 OR I        'Ch I OR'd with 16s bit for +5V range
90   OUT ADRPTR, CNV8           'Select 8-bit conversion mode
100  OUT DATAIO, 0              'Start A/D conversion
110  OUT ADRPTR, MAI            'Point to digitized result
120  AIN = INP(DATAIO)          'Get digitized result
130  VFS = 5                    'Set full-scale variable to 5V
140  VOLTAGE = -VFS+AIN*VFS/2048  'Convert to voltage
150  LOCATE 3 + I:PRINT "CH "; I; "IS: "; VOLTAGE; "Volts"
160  NEXT I
170  GOTO 60
```

Example 3

You sometimes require high precision over a broad input range. In these cases, auto-ranging routines are useful. The following program uses Example 2 with the required changes. Actual practice, however, would use a 12-bit resolution.

```
10   MAI = 4                      'Declare MAI-16 board address
20   DATAIO = 768                 'Declare DATAIO location
30   ADRPTR = 769                 'Declare address pointer Location
40   CNV8 = 5                     'Declare 8-bit conversion address
50   SGC = 6                      'Declare gain/channel select
55                                 'Address
60   GAIN = 48                    'Declare gain variable
70   FOR I = 0 to 15              'Start BASIC control loop
80   OUT ADRPTR,SGC               'Point to SGC mode at address 4
90   OUT DATAIO, GAIN OR I        'Start at highest gain (+ 1.25 V)
100  OUT ADRPTR, CNV8             'Point to 8-bit conversion mode
110  OUT DATAIO, 0                'Start A/D conversion
120  OUT ADRPTR, MAI              'Point to digitized result
130  AIN = INP(DATAIO)            'Get digitized result
140  IF AIN => 255 THEN GAIN = GAIN -16  'Compare input for high
                                   'value.
141                                'Change gain, then loop.
150  IF AIN < 190 THEN GAIN= GAIN + 16   'Compare input for low value
151                                'Change gain, then loop if needed
160  IF 0 < GAIN THEN GAIN= 0 ELSE IF GAIN>48 THEN GAIN = 48:GOTO 80
170                               'Check for low and high range errors
                                   'and correct if needed
180  VFS = 5                       'Set Full Scale to 5V
190  VOLTAGE=-VFS+AIN*VFS/127.5 'Convert to volts
200  LOCATE 3+I:PRINT"CH ";I;" IS";VOLTAGE;" Volts"
210  NEXT I
220  GOTO 70
```

8C.15 USING COMPILED OR ASSEMBLED LANGUAGES

The difference in execution speed of compiled and assembled languages is cause for few precautions when used with the MAI-16. Typical A/D conversion times are in the order of 55 µs. This speed, along with a write-data (R/W) time of 10 µs calls for monitoring the R/W and BUSY status bits prior to accessing the digitized data or attempting other operations (except

reading the ADRPTR for status information) on the MetraBus. You may perform this monitoring operation by reading the currently latched MetraBus address and "looking" at the two MSBs. The address and status information is contained in the ADRPTR location. Its information is stored as follows:

BIT	D7	D6	D5	D4	D3	D2	D1	D0
	BUSY	R/W	A5	A4	A3	A2	A1	A0

For a period of 10 µs after a data output (write) operation, the R/W status bit is active (high). Similarly, for a period of 50, 20, or 30 µs (depending upon MAI-16 operating mode) the BUSY status bit goes high. The status bit must be in its quiescent state prior to attempting another operation on the MetraBus (except for reading ADRPTR).

Since the status information is at Bits 6 and 7 ($2^6 + 2^7 = 192$), these bits may be monitored as follows:

```
90 STATUS=INP(ADRPTR) AND 64      'Get status information
```

The BASIC variable STATUS contains 0, 64, 128, or 192 indicating the state of the D6 and D7 bits, where

0 indicates both bits low.	Okay to go on.
64 indicates bit D6 high.	R/W bit active, wait!
128 indicates bit D7 high.	BUSY bit active, wait!
192 indicates both bits high.	Wait!

8C.16 CALIBRATION PROCEDURE FOR MAI-16

The MAI-16 may require periodic recalibration to ensure accuracy over prolonged periods of time. 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 high humidity are prevalent, a 6-month interval is recommended.

To facilitate calibration, a floppy-disk containing a calibration procedure is shipped with your driver card. A precision voltage source with absolute accuracy of accuracy of +10.000 (+1 mV) and -10.000 (+1 mA) is required to perform a satisfactory calibration. Calibration may be performed using the MAI-16TE.BAS program. This is a pictorial explanation along with a monitoring program for a complete recalibration and functional test. Alternatively, the following procedure may be used:

1. Set the driver board to desired address (normally 768).
2. Set the desired MAI-16 address (MAI-16TE.BAS uses address 12.).
3. Perform the procedures in the following subsections.

Amplifier Offset Adjustment

To adjust the amplifier offset, use the following procedures:

1. Set switch S1 for 1.25 V full-scale.
2. Apply 0.0 mV to each input channel (or short these inputs).
3. Set the voltage between TP1 and TP2 for 0 V (< 200 μV) by adjusting R125. TP1 is U10 pin 9; TP2 is U13 pin 9.

A/D Offset & Gain Adjustment

To adjust the A/D offset and gain, use the following procedure:

1. Set jumper W1 to INHIBIT CONV.
2. Set switch S1/1 to ON (fixed gain mode).
3. Set jumper W2 to 12 BIT.
4. Wire precision - 10.000 VDC (+ 1 mV) source to each input channel.
5. Adjust potentiometer R118 (Zero Out) to read 0 counts (+1 count) while monitoring the channels (a FOR... NEXT loop with a PRINT USING command will do).
6. Wire a precision +10.000 VDC (+1 mV) source to each input channel.
7. Adjust potentiometer R124 (GAIN) for a reading of 4095 counts (+1 count) while monitoring each channel.

Functional Test (Software Gain)

To perform a functional test using software gain, use the following procedure:

1. Set Gain Setting switch to software gain (all switches OFF).
2. Set jumper W1 to AUTO CONV.
3. Wire precision +1.000 VDC source to channels 0 to 3. Check only one bank of four switches, since all banks are already calibrated.
4. Write a short program that reads a channel and increments the gain by a factor of 1, then reads the next channel. If the gain setting scheme proceeds from minimum gain (+ 10 VDC) to maximum gain (+1.25 VDC), the following readings should be observed:

   Channel 0 : 2252 counts (+ 10 counts)
   Channel 1 : 2457 counts (+ 10 counts)
   Channel 2 : 2867 counts (+ 10 counts)
   Channel 3 : 3686 counts (+ 10 counts)

■ ■ ■

MTHERM-20 THERMOCOUPLE INPUT BOARD

8D.1 GENERAL

The MTHERM-20 is a fully isolated, 20-differential, thermocouple input board. The board is capable of computing and converting low-level analog signals to ° C or F and of reporting directly in mV. When used with the appropriate MetraBus interface board, a single MTHERM-20 access up to 320 thermocouples. Built-in cold-junction-compensation, choice of normal or short cycling, digital filtering, and reduced full-scale ranges make this board a versatile, low cost thermocouple interface for a variety of industrial and laboratory applications. Figure 8D-1 is a block diagram.

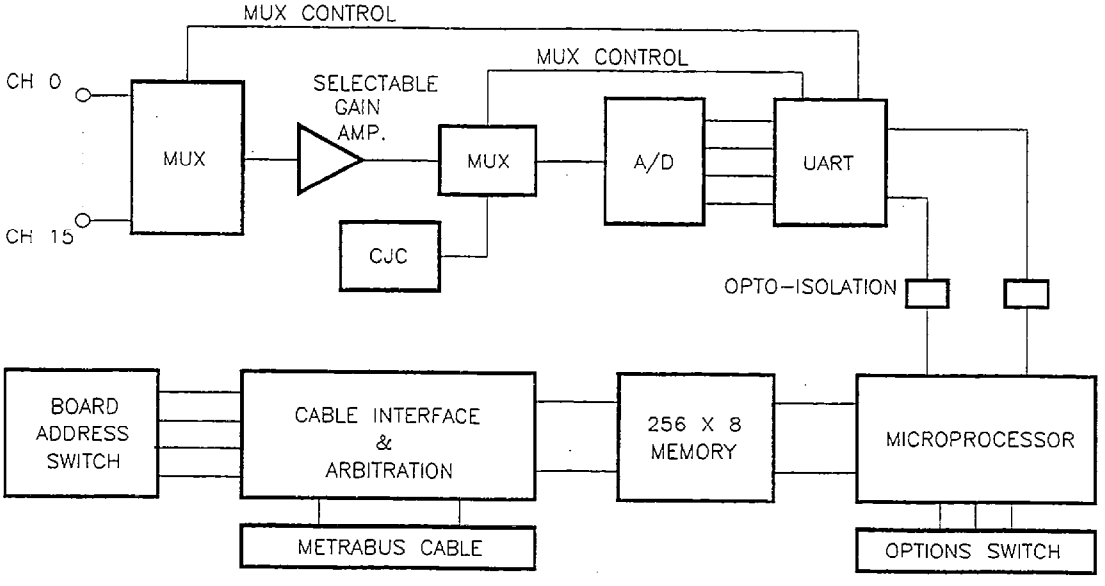


Figure 8D-1. Block Diagram

The isolated, integrating A/D converter on the MTHERM-20 has excellent 60-Hertz noise rejection characteristics. Analog signals are measured, cold junction compensation applied, and results stored on-board until retrieved by the MetraBus system. Values in RAM are updated every second (min) for all channels. DIP-switch-selectable thermocouple type (J, K, T, E, S, R, or B) and choice of degrees (Celsius or Fahrenheit) or millivolts are set on a per-board basis. Removable screw terminals will accept 14 AWG or smaller thermocouple wire.

The MTHERM-20 connects directly to any of the MetraBus driver cards via the 50-conductor MetraBus ribbon cable. The cable carries all data, address, control signals, and power for the MetraBus. The MTHERM-20 may therefore be positioned adjacent to its point of use (up to 100 feet from the computer) for easy signal connection. The MTHERM-20 is 19" rack mountable in either a standard NEMA type enclosure or one the MetraByte housings (RMT, RFM-06, or RTT-02).

8D.2 FUNCTIONAL DESCRIPTION

Data from the MTHERM-20 is available to the MetraBus by a shared 256x8 memory matrix. This matrix is updated for each of the 20 channels at least every second. An arbitration circuit keeps the data in memory unchanged (HOLD mode) while the MetraBus is accessing new data.

Channel and gain selection and converted data move to and from the UART (Universal Asynchronous Receiver Transmitter) via optical isolation circuitry. Power is routed to the isolation measurement circuits by means of a DC to DC converter to ensure accurate, full-scale readings.

8D.3 FEATURES

- Compatible with IBM PC/XT, PC AT, or compatibles, VME computers, or other computers supporting serial data transfer.
- Expandable to a maximum of 320 thermocouples
- Data in degrees C or F (resolution to 1/10 degree)
- Built-in cold-junction-compensation circuitry
- On-board microprocessor
- Standard 19" rack mountable (NEMA or MetraBus enclosures)
- Full input isolation from computer bus
- Supports J, K, T, R, S, B, or E type thermocouples
- Auto-zero and gain tracking
- Local and remote capability
- Differential channel measurement

8D.4 SPECIFICATIONS

Thermocouple Inputs:	20
Thermocouple Types:	T, S, R, B, J, K, and E
Measurement Resolution:	0.8 through 0.1 (type and range dependent)
Accuracy:	0.5° C or twice resolution (whichever greater, after calibration)
Voltage Ref Error:	25 ppm/° C maximum
Readout:	Degrees C or F or mV
Filtering (optional):	Four sample time constant
CJC Temperature Error (0 to 50° C):	0.5° C (after calibration)
A/D Converter Type:	Integrating for one 60 Hertz period.
Full-Scale Ranges:	76.4, 25, 15, or 5 mV

A/D Resolution:	12 bits plus sign
A/D Accuracy:	+1 bit
Update Rate:	1.25 second (20 channels) 0.31 second (5 channels)
Voltage Isolation:	500 VDC
Isolation Resistance:	1000 Mohms T/C to MetraBus
Power Requirement:	+5 VDC @ 500 mA typical
MetraBus Cable:	50 conductor ribbon cable
MetraBus Connector:	3M 3425-6050

Environmental

Operating Temperature:	0 to 70° C
Storage Temperature:	-40 to 100° C
Humidity:	20 to 95% non-condensing

Physical

Size:	16 x 4.75 inches (40.63 x 12.06 cm)

8D.5 INSTALLING THE MTHERM-20

Each MTHERM-20 connected to a single MetraBus cable must have its own board address so that the MetraBus driver card can distinguish it from other boards within the system. Set the MTHERM-20 board address with the switch shown in the Figure 8D.2.

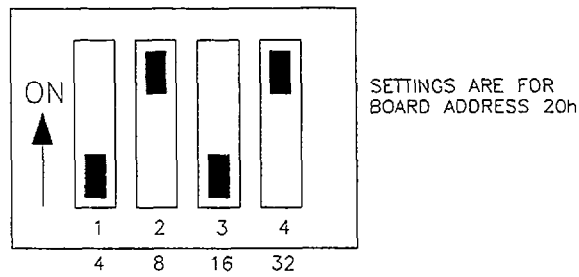


Figure 8D-2. Board Address Switch

1. The board address DIP switch on the MTHERM-20 is located in the lower left corner of the board.

2. The numbers below the DIP indicate the value of the switch immediately above it; the switches have their indicated value only when On. For example, a base address of 20 corresponds to switch positions 1 and 3, as shown in Figure 8D-2.

   NOTE: The MTHERM-20 uses four of the 64 MetraBus I/O addresses. To prevent a conflict in board addresses, be sure each board has an address that differs from the others.

3. The MTHERM-20 connects to the MetraBus driver board via the MetraBus cable. The mating portions of the cable connectors are keyed; check the keyways for correct alignment before plugging them together.

   NOTE: Remove power from the MetraBus cable prior to connecting any I/O boards.

4. Each MetraBus driver card comes with two resistor terminating networks. Install these networks on the last I/O board in your MetraBus system. The (empty) sockets RN1 and RN2 on the MTHERM-20 are for this purpose. These resistor networks minimize signal reflection from long cable lengths. They are optional, however, and they have little effect on cables of 50 feet or less.

MTHERM-20 Typical Thermocouple Connections

Each thermocouple input uses two screw-terminal connections. Available screw-terminal connections are labelled TC1+ and TC1- through TC20+ and TC20-. Ground terminals are also available for the optional shielding. Connect the positive side (red wire) of the thermocouple to the + Terminal and the other wire to the - Terminal for the desired channel. A 1.0 kΩ resistor protects the MTHERM-20 from overvoltage. All thermocouple inputs are pulled to -5 mV through 1 MΩ to indicate an open thermocouple reading. Each channel employs a 0.47 µF capacitor filter.

Note that using the "short cycle" option causes channels 1 through 5, 1 through 10, 1 through 15, or all channels (1 through 20) to be measured. Be sure the thermocouples are within the range of selected channels (see *Short Cycle Option* for details). Figure 8D-3 shows a typical input channel.

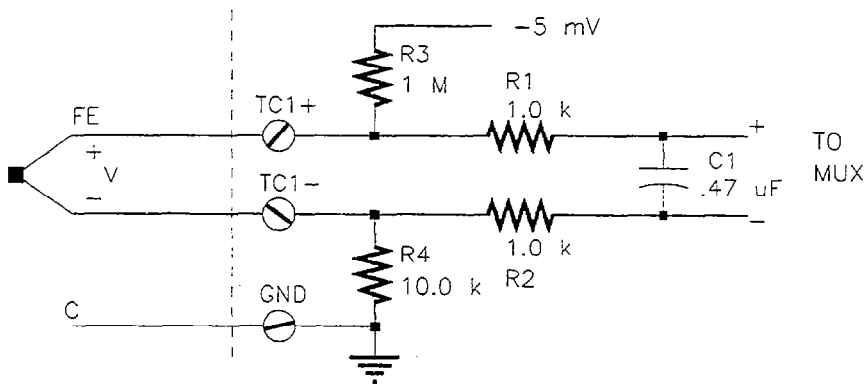


Figure 8D-3. Thermocouple Connections & Input Circuit

MTHERM-20 Options And Switch Settings

The MTHERM-20 has several options to be set prior to installation and operation. These options are thermocouple type, degrees Celsius or Fahrenheit, digital filtering, normal or reduced range and short cycle last channel. Selection of these options uses the Options DIP Switch, as discussed below.

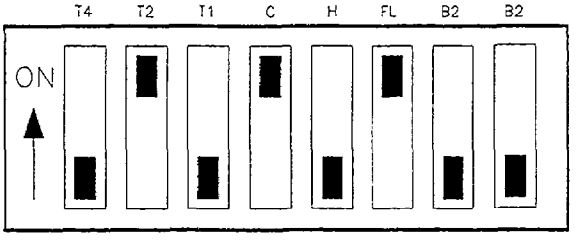


Figure 8D-4. MTHERM-20 Options Switch

Setting Thermocouple Type

Select one of seven thermocouple types (J, K, T, R, S, B, and E) using switches T4, T2, and T2. The factory default setting is for type E thermocouple (T1, T2, and T4 OFF). Note that changing switch T4 requires re-adjustment of the full-scale reference (see Reference Adjustment section). The T4,T2, and T1 switch settings are shown by the following table.

Thermocouple Type	T4	T2	T1
E	OFF	OFF	OFF
K	Off	ON	OFF
J	OFF	ON	ON
B	ON	OFF	OFF
R	ON	OFF	ON
S	ON	ON	OFF
T	ON	ON	ON

Degrees Celsius/Fahrenheit

Switch C selects between degrees Celsius or Fahrenheit (OFF for Fahrenheit, ON for Celsius). In both cases, temperature is reported to 0.1° resolution.

Full Scale/Reduced Input Range

Full-scale and reduced temperature ranges are available for the MTHERM-20. The reduced range is approximately 1/5 the full scale range. Note that decreasing the range by 1/5th will increase resolution by a factor of 5. This option is selected by Switch N (OFF for full scale, ON for 1/5). The quoted resolutions are either minimum measurement resolution for the specific thermocouple or the display resolution of 0.1 degree, whichever is greater. Switches N and T4 control the selectable gain amplifier. If your application requires changing either N or T4 from the factory setting (76.4 mV, calibrated at 75 mV, type E thermocouple), you must redo the reference adjustment (see Reference Adjustment) for accurate results.

Thermocouple Range & Measurement Resolution

Thermocouple Type	Full Res	Full Min/Max	1/5 Res	1/5 Min/Max
T	0.1	-229/402	0.1	-166/95
S	0.6	0/1768	0.1	0/460
R	0.5	0/1775	0.1	0/420
B	0.8	40/1827	0.2	40/650
J	0.3	-205/1375	0.1	-205/260
K	0.5	-207/1375	0.1	-207/370
E	0.2	-207/1000	0.1	-207/200

Full-Scale Millivolt Input Versus Type & Range

Thermocouple Type	Range	Full-Scale Input +/- (mV)
T,S,R,B	Full	25
T,S,R,B	1/5	5
J,K,E	Full	76.4
J,K,E	1/5	15

Digital Filtering

The low-pass digital filter filters out small deviations by averaging four consecutive readings and reporting this average as the actual measurement. Switch FL enables the filter (enabled = ON). CJC and reference data are always averaged.

Short Cycle Option

Switches B1 and B2 set MTHERM-20 channel scanning to end on any 5-channel boundary (up to 20). If you use less than a full complement of channels, you gain faster update rates. Settings for B1 and B2 are given in the following table.

Last Channel (B2, B1) Switch Settings

TC Type	B2	B1
5	ON	ON
10	ON	OFF
15O	FF	ON
20	OFF	OFF

The channel update rate appears in the following table for the various short cycles. Note that a CJC measurement takes place approximately every five scans.

Channel Update Rate

Channels	Measurements Per Channel
1 to 5	3.2/s
1 to 10	1.6/s
1 to 15	1.1/s
1 to 20	0.8/s

CJC Enable/Disable Jumper

Jumper J2 enables or disables Cold Junction Compensation (CJC). Position the jumper according to the adjacent labels (CJC or NO CJC).

8D.6 PROGRAMMING THE MTHERM-20

Each MTHERM-20 uses four the 64 addressable MetraBus locations. Writing to any of these locations sets the board into the HOLD mode and latches the thermocouple channel number, CJC number, or reference channel number (ID number) into a register. Reading from these locations returns data. The ID number corresponds to the upper six address bits of the on-board, dual-ported memory. The HOLD mode locks out the MTHERM-20 microprocessor, thus halting update and avoiding read/write conflicts. The HOLD mode clears on access to any remaining address; it must clear to update subsequent measurements.

The MetraBus BUSY signal may be asserted during an MTHERM-20 update cycle. Monitor the BUSY signal before attempting data retrieval. Memory updates will occur while the HOLD mode is in force. Measurements are still taken, however, and placed in an internal update queue until the HOLD mode clears. Once the HOLD mode clears, the collected data loads into MTHERM-20 RAM. Note that CJC, zero, and full-scale reference channels are updated at a slower rate than the thermocouple channels.

The MTHERM-20 is programmed using a combination of the MetraBus driver board base address and the MTHERM-20 Board Address.

MTHERM-20 Functional Board Addresses

As mentioned earlier, each MTHERM-20 in your MetraBus system uses four consecutive addresses, as follows:

Address	Read	Write
Board Address +0h	ID Number	Access board (HOLD mode)
Board Address +1h	A/D low byte data	same as above
Board Address +2h	A/D high byte data	same as above
Board Address +3h	Options switch	same as above

NOTE: Writing to any location other than the above clears the HOLD mode. A READ or WRITE is not required to clear HOLD.

Since the MTHERM-20 is continually measuring and storing data, data retrieval is a matter of accessing the MTHERM-20 and reading two bytes of data for the selected channel. Input channel numbering runs consecutively from 1 to 20. Channel 0 is for CJC.

MTHERM-20 Data Format

Data is stored in MTHERM-20 memory is in a twos complement, 16-bit format. CJC and linearization for the measured data occurs prior to MTHERM-20 memory storage for the selected thermocouple type. Each count represents 0.1° (F or C depending on the options switch). Data formation is as follows and represents temperatures from -3276.8 through 3276.7° (the user must scale the result by one-tenth). Board address +3 reads the status of the option switch (1 = off, 0 = on).

Board Address +1

BIT	D7	D6	D5	D4	D3	D2	D1	D0
	12.8							0.1
								LSB

Board Address +2

BIT	D7	D6	D5	D4	D3	D2	D1	D0
		1638.4						25.6

D7 = Polarity sign (where 1 = minus).

Board Address +2

BIT	D7	D6	D5	D4	D3	D2	D1	D0
	12.8							0.1
								LSB

Example

```
10   DATAIO = 768      'Define DATAIO
20   ADRPTR = 769      'Define ADRPTR
30   MTHERM = 20       'Board aAddress
40   OTHER = 0
50   FOR I = 0 TO 20
60   ID = I
70   GOSUB 1000        'Get CJC/channel temperature
80   PRINT ID, NO      'ID should equal no
90   PRINT COUNT/10    'Display temperature
100  PRINT DIP         'Display options switch
110  NEXT I
120  REM *** THE FOLLOWING IS FOR TEST CALIBRATION ONLY ***
130  FOR I = 0 TO 20   'Test mode
140  ID= I + 32
150  GOSUB 1000        'Get CJC/channel millivolts
```

```
160  PRINT ID, NO 'ID should equal no
170  PRINT COUNT/400  'Millivolts
180  PRINT DIP        'Options switch
190  NEXT I
200  FOR I = 21 TO 22       'Test mode
210  ID = I + 32
220  GOSUB 1000       'Get references
230  PRINT ID, NO     'ID should equal no
240  PRINT COUNT      'Counts
250  PRINT DIP        'Options switch
260  NEXT I
.
1000 '*****SUBROUTINE TO READ ONE CHANNEL OF MTHERM-20****
1001 'Input: ID = Channel Number
1002 'Output: NO = Channel Number (as read)
1003 'MSB, LSB = Data
1004 'DIP = Options Switch
1005 'Count = Combined MSB and LSB
1010 'OUT ADRPTR, MTHERM    'Address board, set HOLD
1020 OUT DATAIO,ID    'Channel ID number
1030 X = INP(ADRPTR) AND 128      'Test for BUSY
1040 IF X = 128 THEN GOTO 1030    'Wait for BUSY to clear
1050 NO=INP(DATAIO) 'Channel number
1060 OUT ADRPTR, MTHERM + 1
1070 LSB=INP(DATAIO)  'Read LSB
1080 OUT ADRPTR, MTHERM + 2
1090 MSB=INP(DATAIO)  'Read MSB
1110 OUT ADRPTR, MTHERM + 3
1120 DIP=INP(DATAIO)  'Read DIP switch
1130 OUT ADRPTR, OTHER      'Clear HOLD mode
1140 COUNT=LSB+MSB+*256
1150 IF COUNT>32767 THEN COUNT=COUNT-65535
1160 RETURN
```

8D.7 OTHER MEMORY LOCATIONS

The following section is for test and calibration purposes only.

The MTHERM-20 communicates with the MetraBus via a 256x8 memory matrix. All MTHERM-20 data is stored in this matrix for MetraBus retrieval. The MetraBus reads the data by addressing a block of four bytes with an ID written to the MTHERM-20. The lower six bits of the written ID are the upper six bits of the address. The lowest bits of the memory address are the A0 and A1 lines of the MetraBus. The memory map of the 256x8 is shown in the following table. Note that the section of memory starting at 128 is addressed with an ID number of 32 and is the start of the data, and the reference voltage is millivolts x 400. Millivolt readings are not CJC corrected. Temperature readings are converted from the sum of the thermocouple and the CJC equivalent millivolt readings.

The MTHERM-20 software calibrates according to a measured zero and full-scale reference. These numbers are stored in memory (starting at ID number 53) and may be examined for test and calibration purposes. Stability of the reference signals is a measure of continued circuit performance.

Memory Map

Address	ID	+0h	+1h	+2h	+3h	Channel Description
0	0	0	LSB	MSB	DIPSW	CJC Degree*10
4	1	1	LSB	MSB	DIPSW	Thermocouple #1, Deg*10
.						
80	20	20	LSB	MSB	DIPSW	Thermocouple #20, Deg*10
84	21	0	0	0	0	Not used.
.						
124	31	0	0	0	0	Not used.
128	32	33	LSB	MSB	DIPSW	CJC Millivolt*400
132	33	33	LSB	MSB	DIPSW	Thermocouple #1, mV*400
.						
208	52	52	LSB	MSB	DIPSW	Thermocouple #20, mV*400
212	53	53	LSB	MSB	DIPSW	Zero-Reference, cnts*8
216	54	54	LSB	MSB	DIPSW	Fullscale, counts*8
220	55	0	0	0	0	Not used.
.						
252	63	0	0	0	0	Not used.

8D.8 CALIBRATION PROCEDURE

CJC Adjustment

None Required.

Reference Adjustment

After selecting the thermocouple type and/or range with the options DIP switch, set the appropriate reference test point to 75.000, 25.000, 15.000, or 5.000 mV by adjusting potentiometer R30. Note that there is only one adjustment for both full-scale references; thus, when thermocouple type or range is changed, the reference has to be readjusted if the full-scale has changed. When one full scale is adjusted, the others are only approximately correct (not that only one reference is used for any options setup).

Reference Adjustments

TC Type	Full Range Reference	1/5 Range Reference
E	75.000 mV	15.000 mV
K	75.000 mV	15.000 mV
J	75.000 mV	15.000 mV
B	25.000 mV	5.000 mV
R	25.000 mV	5.000 mV
S	25.000 mV	5.000 mV
T	25.000 mV	5.000 mV

Offset Adjustment

This adjustment is factory set and normally does not require readjustment. The offset adjustment corrects for the initial operational amplifier offset voltage. Use the following procedure to set the offset adjustment.

1. Adjust potentiometer R28 for the best zero-reference counts (ID = 53) + 150 counts while in the 75 mV range.
2. Note the electronics automatically adjusts for drift in this offset.
3. For other ranges check that the zero reading is 0 + 1000 counts and that full-scale reference is 30000 + 2500 counts.

■ ■ ■

MBB-32 PROTOTYPE/BREADBOARD

9A.1 GENERAL

The MBB-32 is a 32-bit digital I/O breadboard that allows you to connect custom circuitry quickly and efficiently to the MetraBus system. The MBB-32 has four ports of 8-bit widths, for a total of 32 separate I/O points. Each of the four ports has separate read/write control lines. The board also contains provisions for the standard data readback feature available on all MetraBus I/O boards. In addition, the BUSY status line is available for applications requiring long (> 100 µs) system timing control. All MBB-32 inputs and outputs are buffered LSTTL and are compatible with a wide variety of logic types. Figure 9A-1 is a block diagram.

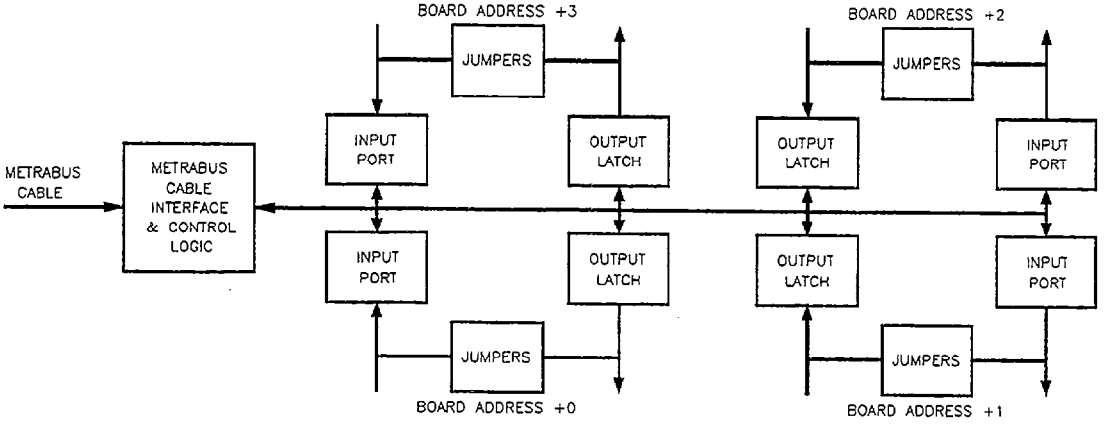


Figure 9A-1. Block Diagram

MetraBus I/O connections, +5 VDC power, and address-control lines are available on the large breadboard matrix adjacent to the channel-access logic on the face of the MBB-32. Bordering the breadboard area are four 12-connection termination strips with screw-type terminals for easy connection between custom-designed circuitry and external signals. These termination strips accept 12 to 22 AWG wire.

For user circuitry requiring more power than is available from the computer power supply, the MBUS-PWR board is available. The MSS-32 connects directly to any of the MetraBus driver boards (MDB-64, MID-64, or REM-64) and computer via the 50-conductor MetraBus ribbon cable. The MetraBus cable connects the driver card to the MBB-32 and carries all data, address, status information, and power distribution. A total of 20 ground lines are interleaved among the data and address lines to ensure noise immunity. The MetraBus system accommodates 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 km.

The MBB-32 mounts in a standard 19" NEMA-type enclosure or the MetraByte RMT-02 and on any panel or other flat surface. Up to 8 MBB-32s (256 I/O points) may be controlled from a single computer expansion slot.

9A.2 FEATURES

- 32 separate inputs and outputs
- Large user prototype area
- Allows custom circuitry interface to MetraBus system
- Compatible with wide variety of logic types
- Data readback feature for all outputs

9A.3 SPECIFICATIONS

Channel:	32 digital input 32 digital output
Input High Voltage:	2.0 V minimum
Input Low Voltage:	0.8 V maximum
Output High Voltage:	2.4 V (-3 mA)
Output Low Voltage:	0.5 V (24 mA)
Output Short Circuit Current:	-40 mA minimum

Power Requirements

@ +5 V:	220 mA typical; 300 mA maximum
@ +15 V:	Available with MBUS-PWR
@ -15 V:	Available with MBUS-PWR

Physical

Size:	16 x 4.75 in. (40.63 x 12.06 cm)
MetraBus Cable Type:	50-conductor ribbon cable
MetraBus Connector:	3M 3425-6050

9A.4 INSTALLING THE MBB-32

Before installing the MBB-32, make certain a MetraBus controller/driver board is installed. These boards are described in the first section of this manual.

You must set each MBB-32 on a single MetraBus cable to a unique, non-overlapping MetraBus I/O address. This address allows the various boards in a MetraBus system to operate independently. Instructions for setting the board address are outlined below. Figure 9A-2 shows an example board address setting.

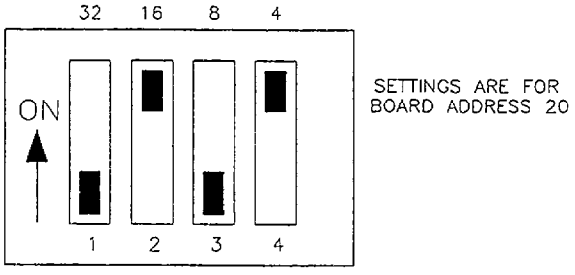


Figure 9A-2. Setting the Board Address

To set the board address,

1. The board address DIP switch is located on the far-left side of the board, just above and to the left of the MetraBus interface connector. The numbers above the DIP indicate the values of the adjacent switches. The numbers have value only in the ON position.
2. Select an unused board address and set the switches accordingly. For example, to set a board address of 24, set the switches with values of 8 and 16 to ON.
3. After setting the board address, connect the MBB-32 to the MetraBus cable. The MetraBus cable connector is keyed and should plug in easily.

   NOTE: Remove power from the MetraBus cable before connecting it to any I/O boards.

4. If you have only one MBB-32 or if one of your MBB-32s is the last board in your system, install the resistor terminating networks provided with your driver card. The sockets marked RN1 and RN2 immediately above the MetraBus connector are for this purpose. These resistor networks minimize signal reflection from long cables; they are optional, however, and have little effect for cables of 50' or less.

9A.5 MBB-32 I/O CONNECTIONS

Make your access to input lines, output lines, read/write and status lines, and +5 VDC and +15 VDC power through the plated-through holes adjacent to the large prototyping area. The prototyping area consists of a 27 x 78 matrix, from which you may connect large and small circuits to the MetraBus. Four plug-in jumper networks (W1 to W4) allow connections between the inputs and outputs of each I/O port, thus enabling the standard MetraBus data readback feature. Removing these jumper networks gives access to the separate inputs and outputs of the corresponding MetraBus I/O port. Data to the output bits is latched (and may be read back for verification) and is valid within 30 ns of the rising edge of the WRITE (driven by BASIC OUT) signal. Data from the inputs is not latched but is read "on-the-fly" approximately 50 µs after the READ (driven by BASIC INP) signal. For this reason, it is suggested that user circuitry latch and hold input data on the falling edge of the READ signal for that port and not allow data changes until the READ signal returns high (non-active). You may bring external signals to user circuitry via the 48 screw-type terminators on the MBB-32.

9A.6 THE READ/WRITE STATUS LINES

As earlier, the READ (input) and WRITE (output) lines may be monitored to determine MBB-32 activity. These lines are brought out to the MBB-32 and are located just above and to the left of the prototyping area. The READ lines are marked RBAS+0, RBAS+1, RBAS+2, and RBAS+3, while the WRITE lines are marked W+0, W+1, W+2, and W+3. READ lines are active low and WRITE are active high. In order to "see" their activity, you might want to hang an LED off these lines and sequentially READ or WRITE to each I/O port using the BASIC INP and OUT commands.

9A.7 PROGRAMMING THE MBB-32

MetraBus supervision by the driver board tends to facilitate MBB-32 programming. Since all necessary control signals are automatically generated by the driver board, the user need not be concerned with control registers, PEEKing or POKEing memory locations, shifting bits, PUSHing or POPing stacks, learning new languages, or other system level headaches.

The MetraBus diskette includes two programs (in BASIC) dealing with the MBB-32 functions. MBB32.BAS loops through and sequentially reads each input bit of all four ports on the MBB-32. This program links to the second program, which illustrates the BASIC OR command for driving output bits while maintaining the present bit status. These programs are heavily commented for easier following.

MBB-32 Terminology and Data Format

As with all MetraBus I/O boards, you follow a standard programming sequence when controlling the MBB-32. This sequence is as follows:

1. Targeting the MBB-32 and associated I/O port via the ADRPTR.
2. Sending a data value corresponding to the bits to be accessed (Read/Write) to the DATAIO.

MetraBus treats the eight bits of each I/O port as a single data byte. The MBB-32 uses four MetraBus I/O addresses corresponding to the four MBB-32 I/O ports. Each bit of the I/O port corresponds to a signal input or output line, depending upon the specified function. The BASIC OUT and INP commands are for writing data to and reading data from the MBB-32. The data byte sent to the MBB-32 during a WRITE (BASIC OUT) command specifies either a high or low state for the output lines. For example, to drive Bits 4 and 7 high , send a data value of 144 ($2^4 + 2^7 = 144$) to the DATAIO as follows:

```
OUT DATAIO, 144
```

Reading data values from the MBB-32 inputs is just as easy. Using the BASIC INP command in conjunction with the DATAIO, we can read the input status as follows:

```
DATVALU = INP(DATAIO)
```

You can see that this provides access to the various bits (I/O lines) on the board by reading or writing a single byte. This arrangement makes it easy to specify input or output lines using a

BASIC integer variable as shown in the examples below. While the examples are in BASIC, they are applicable to many other computer languages supporting data I/O operations such as C, PASCAL, Assembly, etc. The following examples assume a MetraBus driver board at address 768 (300h) and an MBB-32 board at various MetraBus addresses.

Programming MBB-32 Output Port

The following three examples deal with the outputs of the MBB-32 to illustrate some of the functions of the output bits. The data readback feature requires that the jumper networks be in place.

Example 1

This example illustrates the use of the BASIC variable to sequentially drive each output line high on the MBB-32 board. Note that when the successive bits are driven high, all others are driven low.

```
10 DATAIO = 768              'Declare Data I/O location
20 ADRPTR = 769              'Declare address pointer Location
30 MBB32 = 4                 'Declare MBB-32 MetraBus address
40 FOR J = 0 TO 3            'Control loop for port increment
50 OUT ADRPTR, MBB32+J       'Point to MBB-32 port J
60 FOR I = 0 TO 7            'Begin BASIC control loop
70 OUT DATAIO, 2^I           'Sequentially drive each bit high
80 NEXT I                    'End control loop
90 NEXT J
```

Example 2

Reading back the data value just sent to the MBB-32 can be valuable for detecting data transmission errors. Such errors might occur when transmitting data over long distances at high baud rates or if you are in an area of excessive electrical noise. The following program illustrates the data readback feature.

```
10 DATAIO = &H300            'Declare Data I/O location
20 ADRPTR = 769              'Declare address pointer Location
30 MBB32 = 4                 'Declare MBB-32 board address
40 OUT ADRPTR, MBB32+3       'Point to port 3 of MBB-32
50 OUT DATAIO, 100           'Drive bits 6,5, and 2 high
60 BITVALU = INP(DATAIO)     'Get active byte value from DATAIO
70 IF BITVALU <> 100 THEN PRINT "ERROR!": END
```

The above program drives Bits 6, 5, and 2 high; then it gets the latched data (see the "MBB-32 I/O Connection" section for required hardware connections for data readback enable) from the DATAIO and compares the two values. If a discrepancy is found, an error message is displayed.

Example 3

It may be useful to be able to activate certain bits while leaving the others intact regardless of their state. The most efficient way to do this is to read back the state of all bits then OR those bits with the new bits that are to be activated.

```
10 DATAIO = 768              'Declare Data I/O location
20 ADRPTR = 769              'Declare address pointer Location
30 MBB32 = 20                'Declare MBB-32 board address
```

```
40 OUT ADRPTR, MBB32            'Point to MBB-32 at address 20
50 INPUT "NEW BIT"; BIT         'Get user input for new bits
60 BITVALU = INP(DATAIO)        'Read back current status of bits
70 OUT DATAIO, BIT OR BITVALU   'Drive new bits high leaving the
                                 'old ones the way they were
80 GOTO 50                      'Loop back for next relay
```

Programming the MBB-32 Input Ports

Programming the MBB-32 inputs is similar to output programming. The following examples illustrate input programming and functions of the MBB-32 inputs.

Example 1

Reading the input bits of the MBB-32 calls for targeting one of the input ports of the MBB-32 and retrieving a byte of data via the DATAIO.

```
10 DATAIO = 768              'Declare DATAIO location
20 ADRPTR = 769              'Declare ADRPTR
30 MBB32 = 4                 'Declare MBB32 MetraBus address
40 OUT ADRPTR, MBB32 + 1     'Point to port 1 of MBB-32
50 BITVALU = INP(DATAIO)     'Retrieve a data byte from the DATAIO
60 PRINT BITVALU             'Display data byte on the CRT screen
70 GOTO 50                   'Go back and get another byte
```

Example 2

The example retrieves a data byte from a single I/O port of the MBB-32. In many cases, however, it is useful to get data from all 32 lines. A FOR...NEXT loop will do this.

```
10 DATAIO = 768                          'Declare DATAIO location
20 ADRPTR = 769                          'Declare ADRPTR
30 MBB32 = 8                             'Declare MBB-32 MetraBus address
40 FOR I = 0 TO 3                        'Begin BASIC control loop
50 OUT ADRPTR, MBB32 + I                 'Point to port I of MBB-32
60 PORT(I) = INP (DATAIO)                'Get data byte from port "I"
70 NEXT I                                'Increment variable and loop
80 PRINT PORT0, PORT1, PORT2, PORT3      'Display data
```

Example 3

Both of the above programs retrieve data as a byte. It may be useful to decode this byte of information into its respective bits in order to "see" activity at a glance. The following program decodes and displays collected data bytes.

```
10   DATAIO = 768              'Declare DATAIO location
20   ADRPTR = 769              'Declare ADRPTR
30   MBB32 = 12                'Declare MBB-32 MetraBus Address
40   FOR I = 0 TO 3            'Begin port access control loop
50   OUT ADRPTR, MBB32 + I     'Point to port I of MBB-32
60   PORT(I) = INP(DATAIO)     'Get data byte from DATAIO
70   NEXT I                    'Increment and loop
80   FOR J = 0 TO 3            'Port increment control loop
90   FOR K = 0 TO 7            'Bit increment control loop
100  PRINT "BIT ";K;"="; (PORT(J) AND 2^K)/2^K
110  NEXT K                    'Close bit control loop
120  NEXT J                    'Close port control loop
```

NOTE: Additional examples are available in any of the MetraBus Digital I/O parts (MIO-32, MII-32, MEM-8, etc.) of this manual.

9A.8 POSSIBLE USES FOR THE MBB-32

- **Programmable Multi-Function Output Generator.**
  Using an XR series chip and a few passives, a powerful function generator can be built. These versatile ICs will produce square wave, sine wave, saw tooth, and combinations of the above at output frequencies of 0.1 Hz to at least 1 MHz in conjunction with the MBB-32.

- **Custom LED Readout Display Panel.**
  Since the MetraBus is a parallel bus, setting the same board address on any two boards targets both boards for I/O. Using several BCD encoders and display drivers with a couple of numerical LED displays allows you to view the status of data transfer from the targeted MetraBus module to and from the computer.

- **Industrial Mass Flow Meter/Controller.**
  The combination of miniaturized packaging of various industrial electronic mass flow meters and controllers and the MBB-32 allow for extremely versatile computer control and monitoring schemes for gas flow. The MBB-32 is an ideal board for these applications because of its large breadboard area and the 32 digital I/O lines.

- **Industrial Turbine Flow Meter.**
  You may monitor various liquids (both corrosive and non-corrosive) via a series of flow meters with the signal conditioning module mounted on the MBB-32 (the flow meters are often inline types). Several manufacturers also make miniaturized turbine flow meters that mount directly on the MBB-32 and have digitally pulsed outputs that connect directly to the MBB-32 digital input lines or that accumulate with custom circuitry for read back to the computer via the digital lines at a later time.

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MDG-1 DIAGNOSTIC BOARD

9B.1 GENERAL

The MDG-1 is a MetraBus diagnostics board. LEDs on the board display the current MetraBus address, the last data byte written to the board, and the status of the MetraBus power supplies.

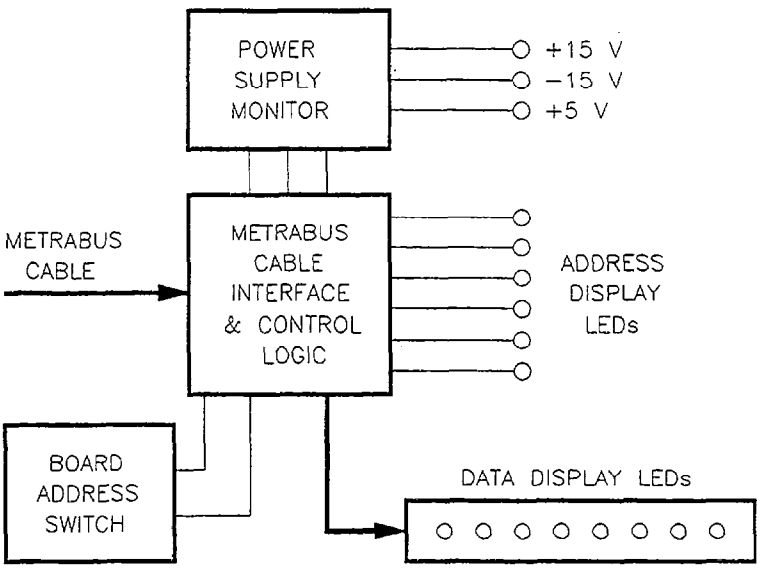

Figure 9B-1. Block Diagram

A DIP switch on the board sets the MDG-1 at any unused MetraBus address. Data to the MDG-1 board address is displayed by red LEDs. Data to any other MetraBus address is ignored by the MDG-1. Two slide switches allow the testing of the BUSY status line. With the enabled/disabled switch set in the enabled position, the BUSY/FREE status line is controlled by a second slide switch. When the enable/disable switch is in the disabled position, the BUSY/FREE line is in high-impedance state. Note that for normal system operation, the enabled/disabled switch should be in the disabled position.

The MetraBus data readback feature can be tested with the board. Reading data from the MDG-1 will return the last data written to the board without changing it.

9B.2 FEATURES

- Tests for proper operation of the MetraBus system
- LEDs display current MetraBus address, status of power supplies, and data written

- Allows complete test of MetraBus status bits and data readback features
- Simplifies effort to learn MetraBus programming

9B.3 INSTALLING THE MDG-1

Before installing the MDG-1, be certain that a MetraBus controller/driver board is installed. These boards are described in the first section of this manual.

Set each MDG-1 on a single MetraBus cable to a unique, non-overlapping MetraBus I/O address. The unique addresses allow the various boards in a MetraBus system to operate independently. Instructions for setting the board address are outlined below. Figure 9B-2 shows an example board address setting.

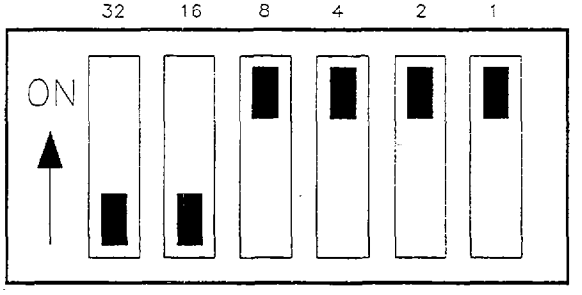

Figure 9B-2. Setting the Board Address

To set the board address,

1. The board address DIP switch is located on the far-left side of the board, just above and to the left of the MetraBus Interface connector. The numbers above the DIP indicate the values of the switches immediately below. The numbers have value only in the ON position.
2. Select an unused board address and set the DIP switches accordingly. For example, to set a board address of 24, set the switches with values of 8 and 16 to ON.
3. After setting the board address, connect the MDG-1 to the MetraBus cable. The MetraBus cable connector is keyed and should plug in easily. Check the keyways for correct alignment prior to plugging in the MetraBus cable.

   NOTE: Remove power from the MetraBus cable before connecting it to any I/O boards.

4. If you have only one MDG-1 or if one of your MDG-1s is the last board in your system, install the resistor terminating networks provided with your driver card. The sockets marked RN1 and RN2 immediately above the MetraBus connector are for this purpose. These resistor networks minimize signal reflection from long cable lengths; they are optional, however, and have little effect for cables of 50 feet or less.

9B.4 EXAMPLE PROGRAM

The following is an example of programming the MDG-1. The base address of the MDB-64 driver board is 768 (300h), and the MDG-1 is at board address 32.

```
10 BASEADR = 768 : BRDADR = 32   'Set Base and Board Addresses
20 OUT (BASEADR + 1), 63         'Selects MetraBus address 63
                                  'corresponds to all address high (all
                                  'address LEDs lit)
30 OUT (BASEADR + 1), BRDADR     'Select MDG-1 board address (A5 LED
                                  'will be on)
40 OUT (BASEADR), 255            'Write 255 to MDG-1 (turns all data
                                  'LEDs red)
50 OUT (BASEADR),15              'Turn on D0-D3 LEDs
60 DD=INP(BASEADR)               'Read back data
70 IF DD <> 15 THEN PRINT "ERROR"  'Test readback feature
```

■ ■ ■

Chapter 10

FACTORY RETURNS

Before returning any equipment for repair, please call 508/880-3000 to notify the Keithley MetraByte technical support personnel. If possible, a technical representative will diagnose and resolve your problem by telephone. If a telephone resolution is not possible, the technical representative will issue you an RMA (Return Material Authorization) number and ask you to return the equipment. Please reference the RMA number in any documentation regarding the equipment and on the outside of the shipping container.

Note that if you are submitting your equipment for repair under warranty, you must furnish the invoice number and date of purchase.

When returning equipment for repair, please include the following information:

1. Your name, address, and telephone number.
2. The invoice number and date of equipment purchase.
3. A description of the problem or its symptoms.
4. Be sure to reference the RMA number on the outside of the package!

Repackage the equipment. Handle it with ground protection; use its original anti-static wrapping, if possible.

Ship the equipment to

Repair Department
Keithley MetraByte
440 Myles Standish Boulevard
Taunton, Massachusetts 02780

Telephone 508/880-3000
Telex 503989
FAX 508/880-0179

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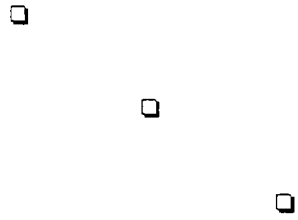


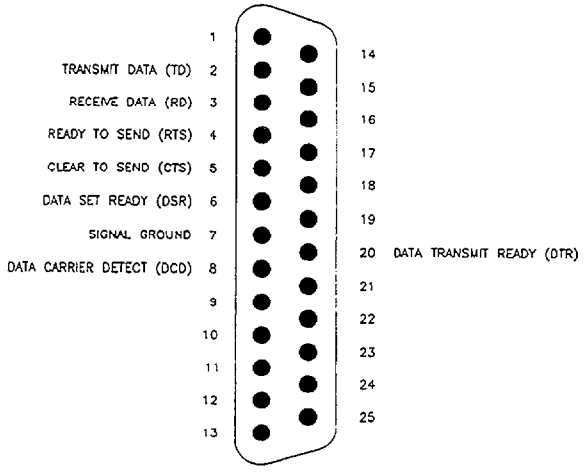
Appendix A

Serial Communications Tutorial

This appendix is specific to RS-232 protocol, but its principles apply to other serial protocols (including RS-422), as well. Use it as an aid to configuring the PC serial communication protocol for the MetraBus REM-64. For more detail, refer to the book *RS-232 MADE EASY* by Martin Seyer (PRENTICE-HALL, Inc).

A.1 THE RS-232 STANDARD

When two or more devices communicate with one another, they must listen and talk over the same wires. While EIA RS-232C does not specify a pin-out for serial connectors, a standard is established. The following diagram shows the connector and pin-out of a Data Terminal Equipment (DTE), such as the REM-64. A Data Communication Equipment (DCE) pin-out is the samer except that transmit and receive pins are reversed, as are several control lines.



To get your computer to talk, have it talk to itself through the serial communication port. First, make a short cable or purchase a breakout box. The cable must have an interface connector that plugs into your computer serial port with wires connected to Pins 2-8 and 20.

CAUTION

Before plugging this cable into your computer serial connector, make certain that there is no contact between wires. Several of the control lines may be high (between 5 and 12 V) at power-up or upon port initialization. Contact between these wires may cause damage to the serial driver card. Also be certain that your serial port is set for COM1, or modify the program below as required.

Plug the cable or breakout box into the computer serial port, and wire pins 2 and 3 together. Then, use software to open the port, send a message from the port, and get the message from the COMM buffer. You may use the short program that follows for this purpose; it is written in BASIC, as implemented on the IBM PC.

```
10 OPEN "COM1;9600,N,7,1" AS #1
20 PRINT #1,"METRABUS"
30 INPUT #1, MSG$
40 PRINT MSG$
50 GOTO 20
```

If your computer is talking, the message **METRABUS** should scroll down the CRT screen. If the computer hangs up or displays a TIMEOUT error, you might want to add line 25 (below) and try again.

```
25 IF EOF 1 = 1 THEN 25
```

Line 25 performs a check of file #1 (the COMM port) for an **END OF FILE** (EOF) character (a carriage return/line feed). You may consider this line a wait loop to give the output enough time to get back to the COMM buffer input. If the check finds an EOF, the logic will fall through to the next line and get the message from the COMM buffer. If no message appears and the computer still hangs or times out, read the section on control lines below.

If the computer is talking to itself but not to the REM-64, then using a NULL MODEM should resolve any problems since this would indicate that the computer is configured as DCE equipment. The alternative method is to cross lines 2 and 3 at one end of your RS-232 cable.

You may determine whether your computer is transmitting on pin 2 and listening on pin 3 (like the REM-64) using one of several methods. One method is to connect an oscilloscope between the transmit pin (2) and signal ground pin (7), then write a program that opens the serial port and continually transmits a short message. In BASIC (as implemented on the IBM PC), you may do this as follows:

```
10 OPEN "COM1:300,N,8,1" AS #1
20 PRINT #1,"METRABUS"
30 GOTO 20
```

The actual message does not matter. The baud rate is slowed down to see the bits toggle high (1) as the message is sent. An alternative means of checking the transmit pin is to connect an LED between pins 2 and 7 (cathode to 2, anode to 7) and send the same message. The LED should light if pin 2 is transmit. If not, hook the cathode to pin 3 and try it. If it still does not light, read the next section. Be certain that the LED is 12 V compatible since the RS-232 standard allows for voltages to 12 VDC.

If your computer is transmitting on pin 3, obtain a null modem and null modem cable, or make your own cable. A null modem is the simplest option; it is generally a small connector that crosses pins 2 and 3.

A.2 RS-232 CONTROL LINES: CTS, RTS, DSR, DCD, ETC

There are primary and secondary control lines that may or may not be implemented on your machine. These control lines establish a talker/listener relationship and make sure that the

listener is listening and the talker is ready to talk. This discussion covers only the most common control lines, as implemented on the IBM asynchronous serial card. These lines are as follows:

- RTS - REQUEST TO SEND (pin 4)
- CTS - CLEAR TO SEND (pin 5)
- DSR - DATA SET READY (pin 6)
- DCD - DATA CARRIER DETECT (pin 8)
- DTR - DATA TERMINAL READY (pin 20)

In addition to these lines, the signal lines are as follows:

- TD - TRANSMIT DATA (pin 2)
- RD - RECEIVE DATA (pin 3)
- SG - SIGNAL GROUND (pin 7)

Several computers allow you to implement or ignore the various control lines by specifying their state in software. Many machines are hard-wired with these lines implemented. If you have read this far and your machine is still not talking, you may want to purchase a breakout box for the next section; although, you can may also make your own cable, as above. A breakout box is a small box with two serial interface connectors (DB-35) and LEDs on many of the 25 RS-232 lines and generally has provisions for jumpering one line to another. Some breakout boxes also have ON/OFF switches for the more important control lines. The boxes are plugged between the computer and the other piece of equipment that you wish to interface. Good ones can run as much as $200 or more; but the simple ones (no switches, just LEDs and jumpers) are cheaper and much easier to use. The least expensive is about $65 but may be used for applications from computers and printers to industrial controllers, teletypes, and virtually anything with a serial port.

A.3 COMMON CONTROL LINE USAGE

You can try a few other methods before investing in a breakout box. The commonly implemented control signals can be jumpered together, brought to ground, or driven high depending upon the line and what it wants to "see" before transmitting or receiving data. The normal chain of events is as follows:

1. When power is on, pin 20 (DTR) is high. This line is normally connected to pin 6 (DSR) of the other machine, which constantly listens for a high signal.
2. RTS (pin 4) goes high from the transmitter when a message is to be sent.
3. DCD (pin 8) from the listener receives the RTS signal and responds by sending a CTS signal (pin 5) to the transmitter.
4. CTS (pin 5) from the receiver then signals the transmitter to go ahead with the message.

One of the most common wiring schemes requires tying pins 5, 6, and 20 together, thus indicating to the talker that the listener is listening. Pin 4 is then tied to pin 8.

The Request to Send (RTS, pin 4) line is generally held high during the length of the transmission. If it drops low, DCD no longer asserts CTS, which no longer signals the transmitter to transmit.

The Data Terminal Read (DTR, pin 20) is a common control line that must often signal the talker. It will be high as long as power remains ON.

This scheme should give you some practical knowledge concerning serial communications and should also help you with the odd wiring.

■ ■ ■

Appendix B

Configuration Worksheets

Feel free to copy any of the attached configuration worksheets for record-keeping purposes. The worksheets may be useful as references when you write applications programs.

DRIVER BOARD CONFIGURATION WORKSHEET

Base Address _____

Board Address	I/O Board

MDI-16/MSS-16/MSSR-32 CONFIGURATION WORKSHEET

Driver Card Type, SN, & Base Address _____

_____

Purchase Date _____ **Board Address** _____

Application/Usage _____

Block/Module	Signal	Voltage	Comments
0/0			
0/1			
0/2			
0/3			
0/4			
0/5			
0/6			
0/7			
1/0			
1/1			
1/2			
1/3			
1/4			
1/5			
1/6			
1/7			

MEM-8 CONFIGURATION WORKSHEET

Driver Card Type, SN, & Base Address _____

_____

Purchase Date _____ **Board Address** _____

Application/Usage _____

Relay No.	Signal	Voltage	Comments
0			
1			
2			
3			
4			
5			
6			
7			

MEM-32/MIO-32/MII-32 CONFIGURATION WORKSHEET

Driver Card Type, SN, & Base Address _____

_____

Purchase Date _____ **Board Address** _____

Application/Usage _____

Line No.	Signal	Comments
0		
1		
2		
3		
4		
5		
6		
7		

MAI-16 CONFIGURATION WORKSHEET

Driver Card Type, SN, & Base Address _____

_____

Purchase Date _____ **Board Address** _____

Application/Usage _____

Channel No.	Voltage/Current	Comments
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

MAO-8 CONFIGURATION WORKSHEET

Driver Card Type, SN, & Base Address _____

_____

Purchase Date _____ **Board Address** _____

Application/Usage _____

Channel No.	Voltage/Current	Comments
0		
1		
2		
3		
4		
5		
6		
7		

MCN-8 CONFIGURATION WORKSHEET

Driver Card Type, SN, & Base Address _____

_____

Purchase Date _____ **Board Address** _____

Application/Usage _____

Counter No.	Type Of Input	Comments

MBB-32 CONFIGURATION WORKSHEET

Driver Card Type, SN, & Base Address _____

_____

Purchase Date _____ **Board Address** _____

Application/Usage _____

	BYTE FUNCTION							
	0	1	2	3	4	5	6	7
Port 0								
Port 1								
Port 2								
Port 3								

■ ■ ■