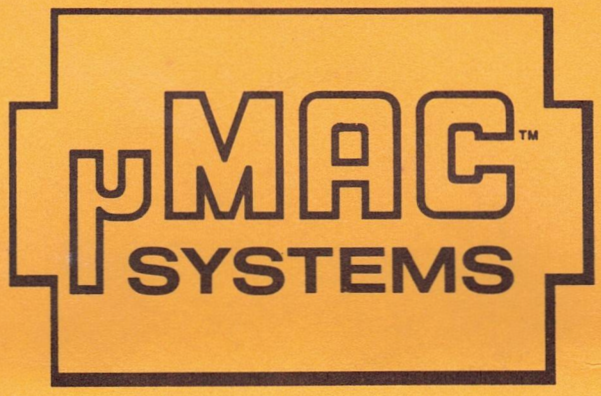
# TRS-80 SET1

## Instruction Manual




MICROCOMPUTER
MEASUREMENT
AND
CONTROL



CMC
CONNECTICUT microCOMPUTER
Brookfield, Connecticut 06804

# TRS-80 SET1 Instructions

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## I. INTRODUCTION

The world we live in is full of variables we want to measure. These variables include weight, temperature, pressure, humidity, speed and fluid level. These variables are continuous and their values may be represented by a voltage. This voltage is the analog of the physical variable.

By analog we mean one measurable quantity is substituted for another measurable quantity, e.g. voltage for temperature or pressure. The term analog is generally used in reference to a continuous quantity such as pounds or degrees rather than a count such as the number of eggs in a basket.

An analog voltage signal is a voltage which represents a continuously variable quantity such as light intensity, temperature, humidity, liquid level, pressure, pH, etc. A device which converts a physical, mechanical or chemical quantity to a voltage is called an electrical transducer. Examples of electrical transducers are: meters, thermistors, photocells, etc. To extract this information, it is usually necessary to compare the value or magnitude of the analog data signal to a standard or a reference voltage. It is also necessary to convert the analog data to digital data in an analog-to-digital converter (ADC) before it is usable by a digital computer.

The CmC AIM16 (Analog Input Module) is a 16 channel analog to digital converter designed to work with most microcomputers. With the appropriate adapter and cabling available from CmC the AIM16 can be plugged into most microcomputers with no special wiring requirements. Each of the 16 inputs is converted, in turn to an 8 bit digital signal.

## II. CONNECTING THE TRS-80 SET1 TO THE TRS-80

The TRS-80 SET1 includes:

1. a TRS-80 MOD which plugs into the TRS-80
2. a CABLE A24 which plugs into the TRS-80 MOD
3. an AIM16
4. a POW1 which plugs into the AC line and AIM16
5. and a MANMOD1 which plugs into the AIM16 for connecting the analog inputs.

Turn off the power to the TRS-80 and Expansion Interface if you are using one.

Plug the 40 pin connector on the end of the flat cable of the TRS-80 MOD into the TRS-80 Interface Port of the keyboard, or into the Screen Printer Port of the Expansion Interface. Be sure the cable hangs downward as shown in photo number 1. The TRS-80 MOD is addressed as port 223.

Plug one end of the cable A24 into the small edge connector on the TRS-80 MOD and plug the other end of the cable into the COMPUTER PORT of the AIM16. Do not force the connectors. They are slotted and keyed. Be sure the cable hangs down from both connectors as shown in photo number 2.

Plug the MANMOD1 into the ANALOG PORT of the AIM16. The black barrier strips with screws should face up. The MANMOD1 connector to the AIM16 is not keyed.

Plug the POW1 cable into the POWER PORT of the AIM16. See photo number 2. Do not plug the POW1 into the AC line yet. (The TRS-80 MOD gets its required power from the AIM16 through the CABLE A24. If the XPANDR1 is used a separate power supply for the TRS-80 MOD is required. Contact the factory.)

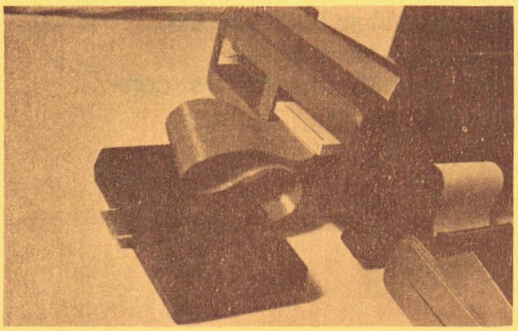


PHOTO #1

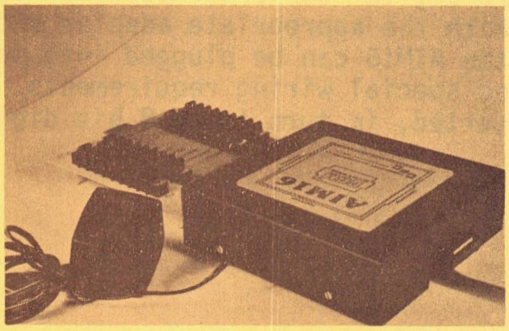



PHOTO #2

## III. TESTING THE TRS-80 SET

Turn the power on to the TRS-80 and Expansion Interface and enter the following program.

```
100 P=223                       :REM  TRS-80 PORT ADDRESS
110 K=128+64                    :REM  PARAMETER FOR SS* AND EN BOTH HIGH
120 OUT P,K                     :REM  SET EN AND SS* BOTH HIGH
130 DIM D(15)                   :REM  INPUT ARRAY
1000 FOR N=0 TO 15              :REM  GET DATA FOR ALL 15 CHANNELS
1010 OUT P,N                    :REM  SEND CHANNEL ADDRESS AND START STROBE
1020 OUT P,K                    :REM  RESET START STROBE AND ENABLE DATA
1030 D(N)=INP(P)                :REM  READ CHANNEL N DATA INTO D(N) OF ARRAY
1040 NEXT N                     :REM  LOOP UNTIL DONE
2000 FOR N=0 TO 15              :REM  PRINT DATA FOR ALL 16 CHANNELS
2010 PRINT N,D(N),              :REM  PRINT CHANNEL NUMBER AND DATA
2020 NEXT N                     :REM  LOOP UNTIL DONE
3000 C$=INKEY$                  :REM  CHECK THE KEYBOARD
3010 IF C$=A$ GOTO 3000         :REM  LOOP UNTIL A KEY IS DEPRESSED
3020 PRINT                      :REM  SKIP A LINE
3030 GOTO 1000                  :REM  READ DATA AND PRINT AGAIN
```

LIST the program on the screen and check it to be sure it was entered properly.

RUN the program.

The TRS-80 should print 16 lines. Each line should have the channel number and the data value printed. The data value should be 255 for all 16 channels.

Press any key. The TRS-80 should print all 16 lines again with 255 the data value for all 16 channels.

Plug the POW1 into an AC power outlet. Now press any key on the TRS-80 keyboard. Once again the TRS-80 should read and print all 16 channels of data. Now, however, the data values are random and should range from about 75 to 180. Read and display all 16 channels several times. The data values will not necessarily be the same each time. This is because there are no connections made to the analog inputs and the AIM16 is converting electrical noise (radio waves and AC) picked up from the air.

Connect a wire between the GND (ground) and the ANALOG INPUT channel 0 to the MANMOD1. Connect a wire between the VREF (5.12 volts reference voltage) and the ANALOG INPUT channel 1 on the MANMOD1. Now, display all 16 channels, again by pressing any key on the TRS-80 keyboard. This time channel 0 should have a value of 0 and channel 1 should have a value of 255. The other channels will have random numbers.

Connect a standard 1.5 volt battery between GND and ANALOG INPUT channel 2 on the MANMOD1. BE SURE THE NEGATIVE SIDE OF THE BATTERY IS CONNECTED TO GND AND THE POSITIVE SIDE OF THE BATTERY IS CONNECTED TO THE ANALOG INPUT. INCORRECTLY CONNECTING A SIGNAL MAY DAMAGE THE AIM16.

Display all 16 channels of the TRS-80. Channel number 2 should read about 77. This is 1.54 volts divided by 20 millivolts per count. A fresh battery is 1.54 volts. 20 millivolts per count is the conversion factor of the AIM16.

Connect the positive side of the battery to each of the remaining inputs (3 through 15) displaying the data each time. Leave the negative side of the battery connected to GND. The reading for the connected channel should not vary by more than 1 from the value read from channel 2 when the battery was connected to it.

## IV. THE FUNCTION OF THE TRS-80 MOD

The purpose of the TRS-80 MOD is to generate a μMAC SYSTEMS bus from the TRS-80 computer. The TRS-80 MOD contains an 8 bit latch, an 8 bit tri-state buffer and the necessary decoding logic. An OUT statement to the TRS-80 MOD (port 223) causes 8 bits to be latched by the TRS-80 MOD onto the address and control lines of the AIM16. An INP statement to the TRS-80 MOD enables the 8 bits of the AIM16's converted data to be read by the TRS-80 computer.

The pinouts for the μMAC SYSTEMS port are described below.

| μMAC SYSTEMS PORT | FUNCTION | TRS-80 PORT 223 BITS | |
|---|---|---|---|
| TOP ROW | | TO TRS-80 | FROM TRS-80 |
| 1 | GND | | |
| 3 | D0 | D0 | |
| 5 | D1 | D1 | |
| 7 | D2 | D2 | |
| 9 | D3 | D3 | |
| 11 | +12V | | |
| 13 | MSEL0 | | D4 |
| 15 | MSEL2 | | D6 |
| 17 | ADD0 | | D0 |
| 19 | ADD1 | | D1 |
| BOTTOM ROW | | | |
| 2 | GND | | |
| 4 | D4 | D4 | |
| 6 | D5 | D5 | |
| 8 | D6 | D6 | |
| 10 | D7 | D7 | |
| 12 | +12V | | |
| 14 | MSEL1 | | D5 |
| 16 | SS* | | D7 |
| 18 | ADD2 | | D2 |
| 20 | ADD3 | | D3 |

GND is the common voltage reference for all signals.

D0 through D7 are the 8 bits of the converted signal to the TRS-80 from the AIM16.

+12V is the power supply input from the POW1 through the AIM16, to the TRS-80 MOD.

MSEL0 through MSEL2 are the three Module SELect lines. The TRS-80 SET1 has one module-the AIM16. MSEL2 (pin 15) is the ENable line for the AIM16. When the XPANDR1 module is used these three Module SELect lines are decoded to allow up to eight conversion modules to be used.

ADD0 through ADD3 are the four ADDress lines which select the one of sixteen analog inputs to be converted.

SS* is the Start Strobe signal. When this line goes low (0 volts, logic level 0) a conversion is started on the selected input. When this line goes high (over 2 volts, logic level 1) and MSEL2 is high the converted data is placed on D0 through D7 of the μMAC port.

See the AIM16 data sheet for more information.

## V. USING THE TRS-80 SET1

The general procedure for using the AIM16 is:

1. Set the start strobe line high (SS*=1) to initialize the system. The SS* line is the eighth bit (most significant bit) of port 223. This is accomplished by OUTing a 128 or larger number into port 223.
2. Send the address of the analog signal to be read (low order four bits of port 223) along with SS* set to 0. This starts the AIM16 converting the selected analog signal to an 8 bit digital number.
3. Enable the converted 8 bit data onto the TRS-80 MOD by sending the enable signal (seventh bit of port 223) high and the SS* signal also high at the same time. This is done by OUTing a 128 + 64 into port 223. A 255 can be OUTed instead since the analog signal address is no longer needed.
4. Read the data into the TRS-80 using an INP statement.

The following program assumes eight TEMPSENS2P1s are connected to the MANMOD1 providing 16 temperature probes. The program continually reads the probes and, for each probe, stores the lowest temperature and highest temperature read. The TRS-80 screen is updated with the new data for channels 0 to 12 as fast as it is read.

```
100 REM INITIALIZE VARIABLES
110 DIM D(15),MN(15),MX(15)
120 P=223
130 K=128+64
140 OUT P,K
200 REM INITIALIZE MIN AND MAX ARRAYS
210 FOR N=0 TO 15
220 OUT P,N
230 OUT P,K
240 MN(N)=INP(P)-20
250 MX(N)=MN(N)
260 NEXT N
1000 REM INITIALIZE SCREEN
1010 CLS:PRINT," MIN","CURRENT"," MAX"
1020 PRINT
1030 REM READ DATA ARRAY
1040 REM SET MIN AND MAX VALUES IF NEW
1050 REM   DATA VALUES EXCEED OLD VALUES
1100 FOR N=0 TO 12
1110 OUT P,N
1120 OUT P,K
1130 D(N)=INP(P)-20
1140 IF D(N)>MX(N) THEN MX(N)=D(N)
1150 IF D(N)<MN(N) THEN MN(N)=D(N)
1160 PRINT N,MN(N),D(N),MX(N)
1170 NEXT N
1180 PRINT@64,
1190 GOTO 1100
```

The following examples of bit patterns, when written to the μMAC port, perform the indicated operation. See appendix B.

| DECIMAL VALUE | SS* | EN MSEL2 | MSEL1 | MSEL0 | ADD3 | ADD2 | ADD1 | ADD0 | OPERATION |
|---|---|---|---|---|---|---|---|---|---|
| BIT VALUE | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | |
| 6 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | Starts conversion for channel 6 if SS* was previously 1. |
| 7 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | Starts conversion for channel 7 if SS* was previously 1. |
| 192 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | Enables converted data and resets SS*. |

The following is the start of a sequence to read several channels in order.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 255 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | Resets SS* |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Starts conversion of channel 0. |
| 192 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | Enables converted data of channel 0 to be read and resets SS*. |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | Starts conversion of channel 1. |
| 192 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | Enables converted data of channel 1 to be read and resets SS*. |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | Starts conversion of channel 2. |
| 192 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | Enables converted data of channel 2 to be read and resets SS*. |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | Starts conversion of channel 3. |

## VI. CONNECTING TO THE ANALOG PORT

There are two types of inputs that can be connected to the AIM16 analog input port. The first type uses the 5.12 volt reference (VREF) in a divider network. The second type supplies its own power and generates a voltage using its own reference voltage.

The first type of input is called a ratiometric input. The inputs are measured as a percentage of full-scale and are not necessarily related to an absolute standard. Potentiometers, joysticks, thermistor bridges, and strain guauges are examples of ratiometric transducers. The 5.12 volt reference is applied to the divider and the centertap produces a voltage that is a ratio of the position of the centertap to the full-scale (5.12 volts) voltage.

The second type of input is called an absolute input. The input voltage is compared, by the AIM16, to its internal 5.12 volt reference voltage. The absolute voltage must be in the range of 0 volts to 5.12 volts and produces a digital output that corresponds to the input as 1 count for each 20 millivolts of the input voltage.

To connect a potentiometer, one end of the pot is connected to the GND, the other end of the pot is connected to VREF and the centertap is connected to one of the ANALOG INPUTS. With a joystick the two pots (one for X and one for Y) are connected in the same way. One end of each pot is connected to GND, the other end of each pot is connected to VREF. The centertap of the X pot is then connected to one of the ANALOG INPUTS and the centertap of th Y pot is then connected to one of the other ANALOG INPUTS.

To connect an absolute voltage the negative side of the voltage must be connected to the GND, and the positive side of the voltage must be connected to one of the ANALOG INPUTS. VREF is not used.

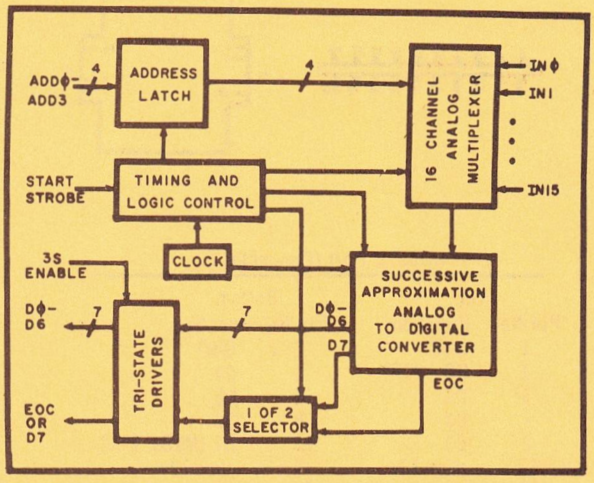
USE EXTREME CAUTION. THE INPUT VOLTAGE MUST NOT BE LESS THAN -.3 VOLTS AND MUST NOT BE GREATER THAN +5.4 VOLTS.

# AIM16 DATA SHEET

ANALOG PORT - 16 Channels - Specifications for each channel -
Vina - analog input voltage conversion range: 0 to 5.12 volts
Vin (max) - absolute maximum input voltage: -.3 to plus 5.4 volts
Iina (max) - maximum analog input current: 2 microamps
Vref - - reference voltage: 5.120 volts plus or minus .01 volts

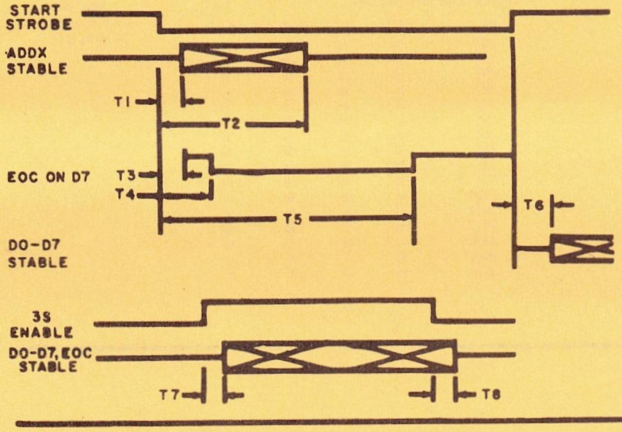
Conversion data -
Tc - conversion time, per channel: 100 microsec max, 80 typ
counts per channel: 256
output range (each channel): 00-FF (hex)
0-255 (decimal)
000-377 (octal)
0000 0000-1111 1111 (binary)
Absolute maximum error: .7%
Typical maximum error: .5%

Physical Dimensions - 5 1/4 x 6 1/4 x 2 1/4.




AIM16 BLOCK DIAGRAM

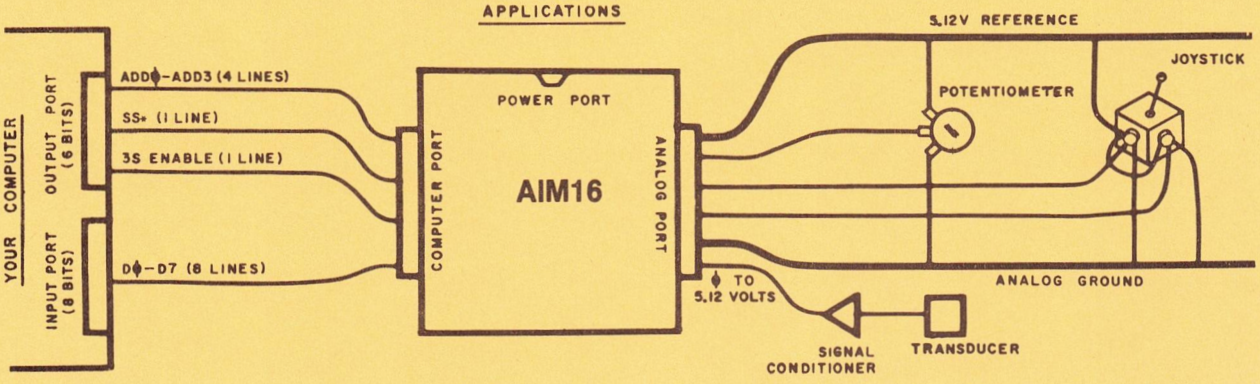
## AIM 16 TIMING




AIM 16 Timing Diagram

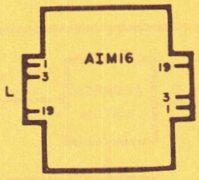
| SYMBOL | CHARACTERISTIC | MIN | MAX | UNIT |
|---|---|---|---|---|
| T1 | ADDX must become stable | | 1 | microsec |
| T2 | ADDX must remain stable | 3 | | microsec |
| T3 | EOC becomes stable on D7 | | 60 | nanosec |
| T4 | EOC is reset | | 100 | nanosec |
| T5 | EOC goes high indicating conversion complete | | 100 | microsec |
| T6 | DO-D7 becomes stable after SS goes high | | 290 | nanosec |
| T7 | DO-D7 or EOC becomes stable after 3S enable goes high | | 290 | nanosec |
| T8 | DO-D7 or EOC enter tri-state after 3S enable goes low | | 290 | nanosec |

APPLICATIONS



# PORT PIN FUNCTIONS


TOP VIEW




## Computer Port (Connector L)

| Top | | Bottom | |
|---|---|---|---|
| Pin No. | Function | Pin No. | Function |
| 1 | GND | 2 | GND |
| 3 | D0 (LSB) | 4 | D4 |
| 5 | D1 | 6 | D5 |
| 7 | D2 | 8 | D6 |
| 9 | D3 | 10 | D7 (MSB), EOC |
| 11 | plus 12v | 12 | plus 12v |
| 13 | | 14 | |
| 15 | 3s enable | 16 | Start Strobe (SS*) |
| 17 | Add 0 | 18 | Add 2 |
| 19 | Add 1 | 20 | Add 3 |

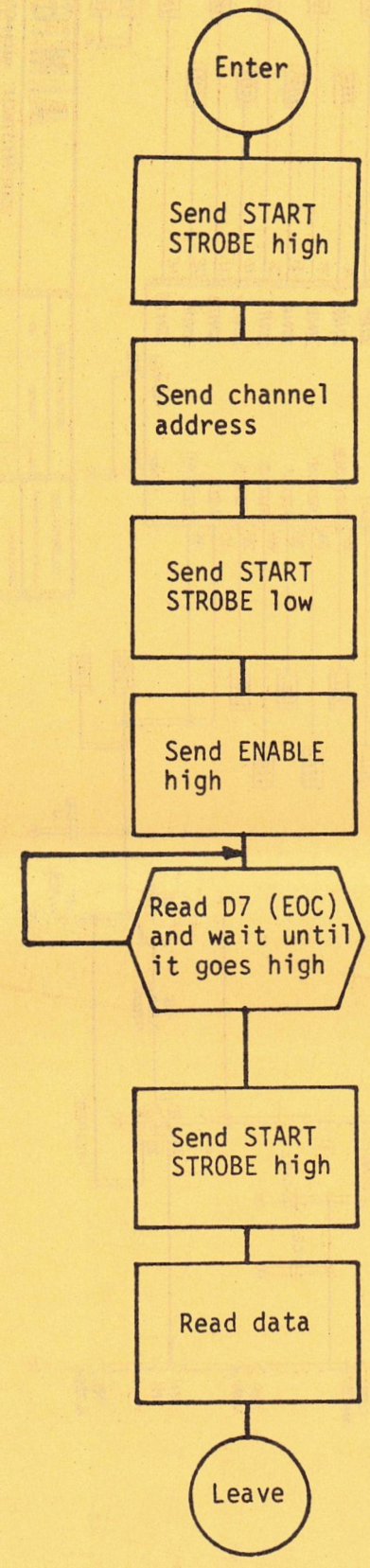
## Analog Port ( Connector R )

| Top | | Bottom | |
|---|---|---|---|
| Pin No. | Function | Pin No. | Function |
| 1 | GND | 2 | 5.120 VREF |
| 3 | IN0 | 4 | IN8 |
| 5 | IN1 | 6 | IN9 |
| 7 | IN2 | 8 | IN10 |
| 9 | IN3 | 10 | IN11 |
| 11 | IN4 | 12 | IN12 |
| 13 | IN5 | 14 | IN13 |
| 15 | IN6 | 16 | IN14 |
| 17 | IN7 | 18 | IN15 |
| 19 | 5.120 VREF | 20 | GND |

## COMPUTER PORT PIN FUNCTIONS

| PIN | NAME | DIRECTION WITH RESPECT TO THE AIM16 | FUNCTION | Loading or Drive |
|---|---|---|---|---|
| 1 | GND | | Signal ground - tied to analog ground | |
| 2 | GND | | | |
| 3 | DP (LSB) | out | Digital output for analog inputs. | 1 TTL Load |
| 5 | D1 | out | D0 is the least significant bit. D7 is the most significant | |
| 7 | D2 | out | bit. A lo voltage is a logical 0. A hi voltage is a logical | |
| 9 | D3 | out | 1. | |
| 4 | D4 | out | D7 (when SS* pin 16, is lo) is the end of conversion | |
| 6 | D5 | out | signal, EOC, When EOC is lo, the AIM16 is busy. When EOC is | |
| 8 | D6 | out | hi, the AIM16 has finished a conversion and the converted | |
| 10 | D7 (MSB) | out | valve may be read. | |
| 11 | plus 12 volts | in or out | 12 volts DC power from a DAM SYSTEMS power pack or other | 60 ma in |
| 12 | plus 12 volts | in or out | source. If a DAM SYSTEMS power pack is used at the POWER PORT then this voltage is available to supply other DAM SYSTEMS modules. If a DAM SYSTEMS power pack is not used at the POWER PORT then a positive 12 volts (well-filtered DC) must be supplied at these pins. | |
| | | | !!CAUTION!! DO NOT USE A DAM SYSTEMS POWER PACK AT THE POWER PORT WHILE POWER IS APPLIED TO THESE PINS. | |
| 13 | not used | | | |
| 14 | not used | | | |
| 15 | 3S ENABLE | in | Three state enable. A lo voltage disables the outputs D0-D7. a hi voltage enables D0-D7. | 1 LSTTL Load |
| 16 | SS* | in | Start Strobe not. A hi to lo transition resets the AIM 16 and starts the comversion of the analog input selected by the digital inputs on pins 17 to 20. While SS* remains lo, and the 3S ENABLE is hi, the EOC (End of Conversion) signal appears on pin 10. When is SS* is hi, and the 3S ENABLE is hi, D7 is on pin 10 and D0 to D6 are on pins 3 to 9. respectively. | 1 LSTTL Load |
| 17 | ADD0 | in | Address lines - select the analog input to be converted according to the following table: | Vin(hi)-3.5 volts min |
| 19 | ADD1 | in | | Vin(lo)-1.5 volts max |
| 18 | ADD2 | in | | |
| 20 | ADD3 | in | | |

| Analog input | ADD3 | ADD2 | ADD 1 | ADD 0 |
|---|---|---|---|---|
| IN0 | lo | lo | lo | lo |
| IN1 | lo | lo | lo | hi |
| IN2 | lo | lo | hi | lo |
| IN3 | lo | lo | hi | hi |
| IN4 | lo | hi | lo | lo |
| IN5 | lo | hi | lo | hi |
| IN6 | lo | hi | hi | lo |
| IN7 | lo | hi | hi | hi |
| IN8 | hi | lo | lo | lo |
| IN9 | hi | lo | lo | hi |
| IN10 | hi | lo | hi | lo |
| IN11 | hi | lo | hi | hi |
| IN12 | hi | hi | lo | lo |
| IN13 | hi | hi | lo | hi |
| IN14 | hi | hi | hi | lo |
| IN15 | hi | hi | hi | hi |




SS*=1.

ADD0 (least significant bit) to ADD3 (most significant bit)

SS*=0
This starts the conversion and puts EOC on D7.

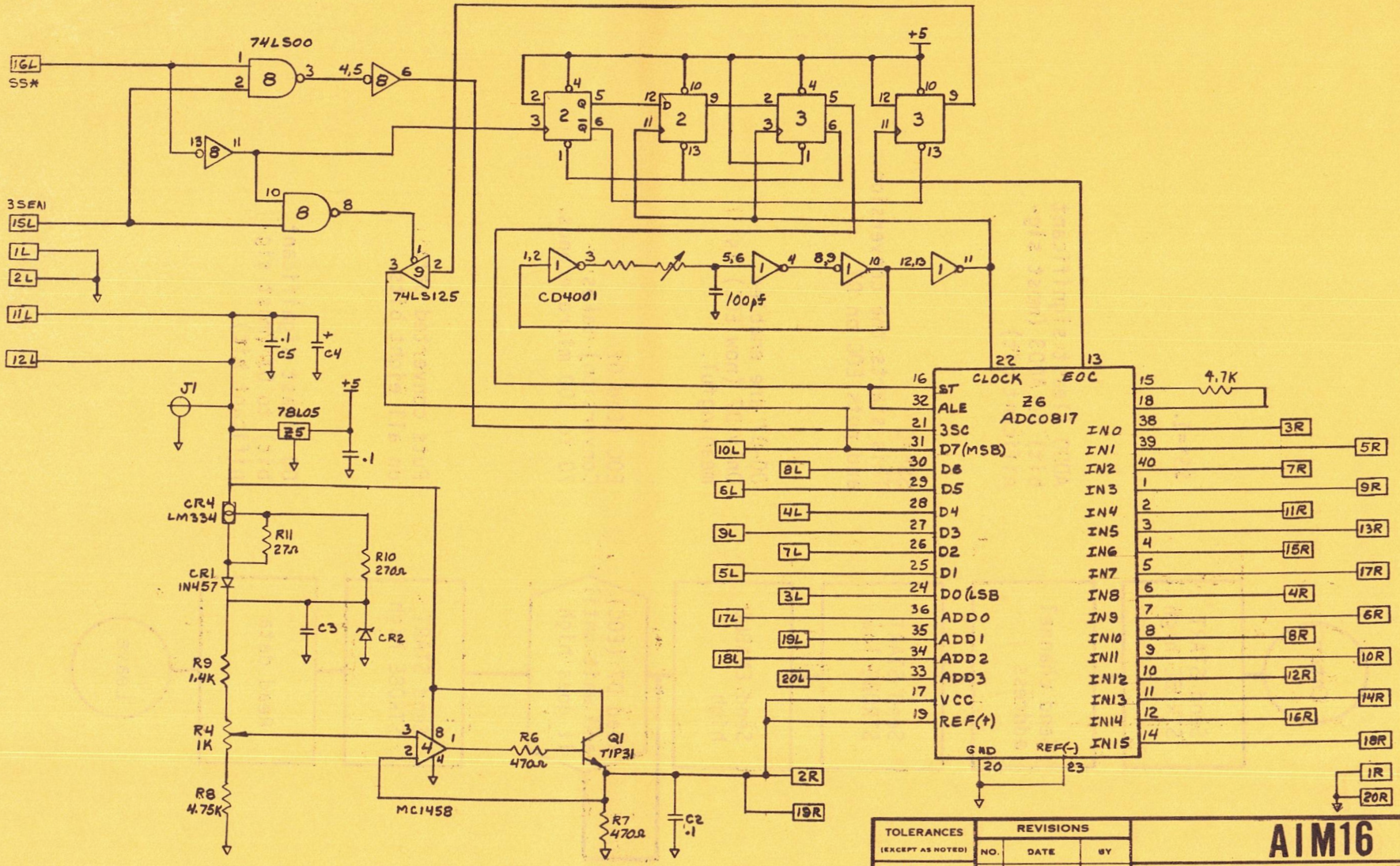
D0-D7 are enabled.
Only D7 (now EOC) is meaningful.

EOC (End Of Conversion) takes 70 to 100 microseconds.

Puts converted data on all eight bits.

D0 (least significant bit) to D7 (most significant bit)

Flowchart for reading one channel of data from the AIM16.




| TOLERANCES (EXCEPT AS NOTED) | REVISIONS | | |
|---|---|---|---|
| DECIMAL ± | NO. | DATE | BY |
| FRACTIONAL ± | 1 | | |
| ANGULAR ± | 2 | | |
| | 3 | | |
| | 4 | | |
| | 5 | | |

# AIM16

CONNECTICUT microCOMPUTER, Inc.
150 POCONO ROAD
BROOKFIELD, CONNECTICUT 06804

| DRAWN BY | SCALE | MATERIAL |
|---|---|---|
| DM | | |
| CHKD RAR | DATE 1/15/80 | DRAWING NO. |
| TRACED | APP'D | |

| D | H | BINARY | D | H | BINARY | D | H | BINARY | D | H | BINARY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 00 | 0000 0000 | 64 | 40 | 0100 0000 | 128 | 80 | 1000 0000 | 192 | C0 | 1100 0000 |
| 1 | 01 | 0000 0001 | 65 | 41 | 0100 0001 | 129 | 81 | 1000 0001 | 193 | C1 | 1100 0001 |
| 2 | 02 | 0000 0010 | 66 | 42 | 0100 0010 | 130 | 82 | 1000 0010 | 194 | C2 | 1100 0010 |
| 3 | 03 | 0000 0011 | 67 | 43 | 0100 0011 | 131 | 83 | 1000 0011 | 195 | C3 | 1100 0011 |
| 4 | 04 | 0000 0100 | 68 | 44 | 0100 0100 | 132 | 84 | 1000 0100 | 196 | C4 | 1100 0100 |
| 5 | 05 | 0000 0101 | 69 | 45 | 0100 0101 | 133 | 85 | 1000 0101 | 197 | C5 | 1100 0101 |
| 6 | 06 | 0000 0110 | 70 | 46 | 0100 0110 | 134 | 86 | 1000 0110 | 198 | C6 | 1100 0110 |
| 7 | 07 | 0000 0111 | 71 | 47 | 0100 0111 | 135 | 87 | 1000 0111 | 199 | C7 | 1100 0111 |
| 8 | 08 | 0000 1000 | 72 | 48 | 0100 1000 | 136 | 88 | 1000 1000 | 200 | C8 | 1100 1000 |
| 9 | 09 | 0000 1001 | 73 | 49 | 0100 1001 | 137 | 89 | 1000 1001 | 201 | C9 | 1100 1001 |
| 10 | 0A | 0000 1010 | 74 | 4A | 0100 1010 | 138 | 8A | 1000 1010 | 202 | CA | 1100 1010 |
| 11 | 0B | 0000 1011 | 75 | 4B | 0100 1011 | 139 | 8B | 1000 1011 | 203 | CB | 1100 1011 |
| 12 | 0C | 0000 1100 | 76 | 4C | 0100 1100 | 140 | 8C | 1000 1100 | 204 | CC | 1100 1100 |
| 13 | 0D | 0000 1101 | 77 | 4D | 0100 1101 | 141 | 8D | 1000 1101 | 205 | CD | 1100 1101 |
| 14 | 0E | 0000 1110 | 78 | 4E | 0100 1110 | 142 | 8E | 1000 1110 | 206 | CE | 1100 1110 |
| 15 | 0F | 0000 1111 | 79 | 4F | 0100 1111 | 143 | 8F | 1000 1111 | 207 | CF | 1100 1111 |
| 16 | 10 | 0001 0000 | 80 | 50 | 0101 0000 | 144 | 90 | 1001 0000 | 208 | D0 | 1101 0000 |
| 17 | 11 | 0001 0001 | 81 | 51 | 0101 0001 | 145 | 91 | 1001 0001 | 209 | D1 | 1101 0001 |
| 18 | 12 | 0001 0010 | 82 | 52 | 0101 0010 | 146 | 92 | 1001 0010 | 210 | D2 | 1101 0010 |
| 19 | 13 | 0001 0011 | 83 | 53 | 0101 0011 | 147 | 93 | 1001 0011 | 211 | D3 | 1101 0011 |
| 20 | 14 | 0001 0100 | 84 | 54 | 0101 0100 | 148 | 94 | 1001 0100 | 212 | D4 | 1101 0100 |
| 21 | 15 | 0001 0101 | 85 | 55 | 0101 0101 | 149 | 95 | 1001 0101 | 213 | D5 | 1101 0101 |
| 22 | 16 | 0001 0110 | 86 | 56 | 0101 0110 | 150 | 96 | 1001 0110 | 214 | D6 | 1101 0110 |
| 23 | 17 | 0001 0111 | 87 | 57 | 0101 0111 | 151 | 97 | 1001 0111 | 215 | D7 | 1101 0111 |
| 24 | 18 | 0001 1000 | 88 | 58 | 0101 1000 | 152 | 98 | 1001 1000 | 216 | D8 | 1101 1000 |
| 25 | 19 | 0001 1001 | 89 | 59 | 0101 1001 | 153 | 99 | 1001 1001 | 217 | D9 | 1101 1001 |
| 26 | 1A | 0001 1010 | 90 | 5A | 0101 1010 | 154 | 9A | 1001 1010 | 218 | DA | 1101 1010 |
| 27 | 1B | 0001 1011 | 91 | 5B | 0101 1011 | 155 | 9B | 1001 1011 | 219 | DB | 1101 1011 |
| 28 | 1C | 0001 1100 | 92 | 5C | 0101 1100 | 156 | 9C | 1001 1100 | 220 | DC | 1101 1100 |
| 29 | 1D | 0001 1101 | 93 | 5D | 0101 1101 | 157 | 9D | 1001 1101 | 221 | DD | 1101 1101 |
| 30 | 1E | 0001 1110 | 94 | 5E | 0101 1110 | 158 | 9E | 1001 1110 | 222 | DE | 1101 1110 |
| 31 | 1F | 0001 1111 | 95 | 5F | 0101 1111 | 159 | 9F | 1001 1111 | 223 | DF | 1101 1111 |
| 32 | 20 | 0010 0000 | 96 | 60 | 0110 0000 | 160 | A0 | 1010 0000 | 224 | E0 | 1110 0000 |
| 33 | 21 | 0010 0001 | 97 | 61 | 0110 0001 | 161 | A1 | 1010 0001 | 225 | E1 | 1110 0001 |
| 34 | 22 | 0010 0010 | 98 | 62 | 0110 0010 | 162 | A2 | 1010 0010 | 226 | E2 | 1110 0010 |
| 35 | 23 | 0010 0011 | 99 | 63 | 0110 0011 | 163 | A3 | 1010 0011 | 227 | E3 | 1110 0011 |
| 36 | 24 | 0010 0100 | 100 | 64 | 0110 0100 | 164 | A4 | 1010 0100 | 228 | E4 | 1110 0100 |
| 37 | 25 | 0010 0101 | 101 | 65 | 0110 0101 | 165 | A5 | 1010 0101 | 229 | E5 | 1110 0101 |
| 38 | 26 | 0010 0110 | 102 | 66 | 0110 0110 | 166 | A6 | 1010 0110 | 230 | E6 | 1110 0110 |
| 39 | 27 | 0010 0111 | 103 | 67 | 0110 0111 | 167 | A7 | 1010 0111 | 231 | E7 | 1110 0111 |
| 40 | 28 | 0010 1000 | 104 | 68 | 0110 1000 | 168 | A8 | 1010 1000 | 232 | E8 | 1110 1000 |
| 41 | 29 | 0010 1001 | 105 | 69 | 0110 1001 | 169 | A9 | 1010 1001 | 233 | E9 | 1110 1001 |
| 42 | 2A | 0010 1010 | 106 | 6A | 0110 1010 | 170 | AA | 1010 1010 | 234 | EA | 1110 1010 |
| 43 | 2B | 0010 1011 | 107 | 6B | 0110 1011 | 171 | AB | 1010 1011 | 235 | EB | 1110 1011 |
| 44 | 2C | 0010 1100 | 108 | 6C | 0110 1100 | 172 | AC | 1010 1100 | 236 | EC | 1110 1100 |
| 45 | 2D | 0010 1101 | 109 | 6D | 0110 1101 | 173 | AD | 1010 1101 | 237 | ED | 1110 1101 |
| 46 | 2E | 0010 1110 | 110 | 6E | 0110 1110 | 174 | AE | 1010 1110 | 238 | EE | 1110 1110 |
| 47 | 2F | 0010 1111 | 111 | 6F | 0110 1111 | 175 | AF | 1010 1111 | 239 | EF | 1110 1111 |
| 48 | 30 | 0011 0000 | 112 | 70 | 0111 0000 | 176 | B0 | 1011 0000 | 240 | F0 | 1111 0000 |
| 49 | 31 | 0011 0001 | 113 | 71 | 0111 0001 | 177 | B1 | 1011 0001 | 241 | F1 | 1111 0001 |
| 50 | 32 | 0011 0010 | 114 | 72 | 0111 0010 | 178 | B2 | 1011 0010 | 242 | F2 | 1111 0010 |
| 51 | 33 | 0011 0011 | 115 | 73 | 0111 0011 | 179 | B3 | 1011 0011 | 243 | F3 | 1111 0011 |
| 52 | 34 | 0011 0100 | 116 | 74 | 0111 0100 | 180 | B4 | 1011 0100 | 244 | F4 | 1111 0100 |
| 53 | 35 | 0011 0101 | 117 | 75 | 0111 0101 | 181 | B5 | 1011 0101 | 245 | F5 | 1111 0101 |
| 54 | 36 | 0011 0110 | 118 | 76 | 0111 0110 | 182 | B6 | 1011 0110 | 246 | F6 | 1111 0110 |
| 55 | 37 | 0011 0111 | 119 | 77 | 0111 0111 | 183 | B7 | 1011 0111 | 247 | F7 | 1111 0111 |
| 56 | 38 | 0011 1000 | 120 | 78 | 0111 1000 | 184 | B8 | 1011 1000 | 248 | F8 | 1111 1000 |
| 57 | 39 | 0011 1001 | 121 | 79 | 0111 1001 | 185 | B9 | 1011 1001 | 249 | F9 | 1111 1001 |
| 58 | 3A | 0011 1010 | 122 | 7A | 0111 1010 | 186 | BA | 1011 1010 | 250 | FA | 1111 1010 |
| 59 | 3B | 0011 1011 | 123 | 7B | 0111 1011 | 187 | BB | 1011 1011 | 251 | FB | 1111 1011 |
| 60 | 3C | 0011 1100 | 124 | 7C | 0111 1100 | 188 | BC | 1011 1100 | 252 | FC | 1111 1100 |
| 61 | 3D | 0011 1101 | 125 | 7D | 0111 1101 | 189 | BD | 1011 1101 | 253 | FD | 1111 1101 |
| 62 | 3E | 0011 1110 | 126 | 7E | 0111 1110 | 190 | BE | 1011 1110 | 254 | FE | 1111 1110 |
| 63 | 3F | 0011 1111 | 127 | 7F | 0111 1111 | 191 | BF | 1011 1111 | 255 | FF | 1111 1111 |

Appendix B. Binary to hexadecimal to decimal conversion chart.

| $b_4$ $b_3$ $b_2$ $b_1$ | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| 0 0 0 0 | NUL | DLE | SP | 0 | @ | P | ` | p |
| 0 0 0 1 | SOH | DC1 | ! | 1 | A | Q | a | q |
| 0 0 1 0 | STX | DC2 | " | 2 | B | R | b | r |
| 0 0 1 1 | ETX | DC3 | # | 3 | C | S | c | s |
| 0 1 0 0 | EOT | DC4 | $ | 4 | D | T | d | t |
| 0 1 0 1 | ENQ | NAK | % | 5 | E | U | e | u |
| 0 1 1 0 | ACK | SYN | & | 6 | F | V | f | v |
| 0 1 1 1 | BEL | ETB | ' | 7 | G | W | g | w |
| 1 0 0 0 | BS | CAN | ( | 8 | H | X | h | x |
| 1 0 0 1 | HT | EM | ) | 9 | I | Y | i | y |
| 1 0 1 0 | LF | SUB | * | : | J | Z | j | z |
| 1 0 1 1 | VT | ESC | + | ; | K | [ | k | { |
| 1 1 0 0 | FF | FS | , | < | L | \ | l | \| |
| 1 1 0 1 | CR | GS | - | = | M | ] | m | } |
| 1 1 1 0 | SO | RS | . | > | N | ^ | n | ~ |
| 1 1 1 1 | SI | US | / | ? | O | _ | o | DEL |

Appendix C. ASCII conversion chart