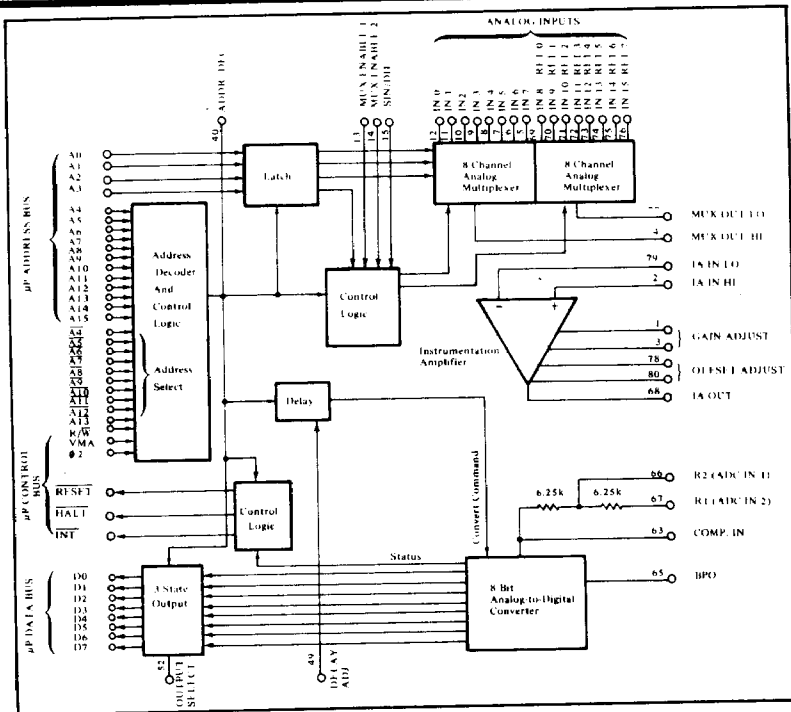


100063.
MP21

Microprocessor-Interfaced 8-BIT ANALOG INPUT SYSTEM



FEATURES

- **COMPATIBLE WITH:**
 - 6800
 - 650X
 - F-8
- **EASY TO PROGRAM**
Choice of ways to interface:
Memory-mapped
Interrupt capability
- **SAVES DEVELOPMENT TIME AND MONEY**
- **EASY TO USE**
PIA is not needed
No external logic needed
No external adjustments
Low or high level analog inputs
Unlimited expansion
- **COMPLETELY SELF-CONTAINED**
- **LOW COST**

International Airport Industrial Park - P.O. Box 11400 - Tucson, Arizona 85734 - Tel. (602) 746-1111 - Twx: 910-952-1111 - Cable: BBRCORP - Telex: 66-6491

DESCRIPTION

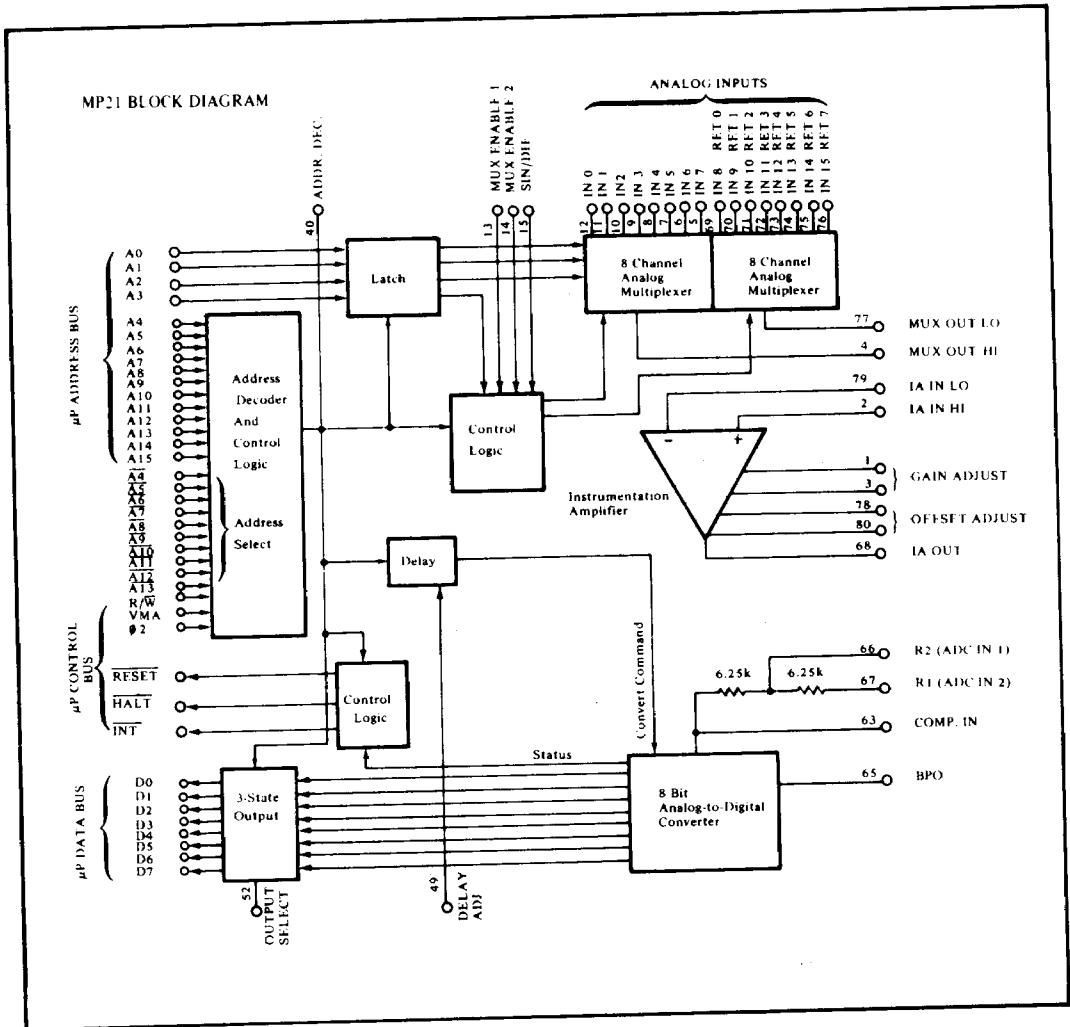
The MP21 is a complete analog input system packaged in a 80-pin quad-in-line package. It is completely compatible with 6800 microprocessors. It is also compatible with the 650X and with the F-8. The MP21 contains a high speed 8-bit A/D converter, an instrumentation amplifier, an input multiplexer that can accept up to 16 single-ended signals or 8 differential signals as well as interface, timing and address decoding logic. The gain and offset are internally laser trimmed so that no external adjustments are required on the $\pm 5V$ or 0 to $+5V$ input range to obtain an absolute accuracy of better than $\pm 0.4\%$ (1 LSB). The system can digitize low level or high level analog signals. The gain of the internal instrumentation amplifier can be programmed with a single external resistor to allow input signal ranges as low as ± 10 mV. This means that the MP21 can be connected to low level sensors such as thermocouples and strain

gauges without external signal amplification.

All control lines are fully compatible with the microprocessor bus and operate at low power Schottky TTL levels. The MP21 input lines present one LS TTL load while all outputs can drive up to 20 LS TTL loads.

PROGRAMMING

When programming these peripherals, the user treats them as memory. Each analog input channel occupies one memory location. Any memory reference instruction can be used. Pins A4 to A13 are made available so that the microperipheral address can be hardwired for any of 1024 possible memory location bands. Since these units are treated as memory, a minimum of instructions are needed to read an input channel. The MP21's versatile memory mapped operation allows it to be used with or without halting the CPU or in the interrupt mode.



SPECIFICATIONS

Typical at 25°C unless otherwise noted.

ELECTRICAL

TRANSFER CHARACTERISTICS

Resolution 8 bits binary
 Number of channels 16 single-ended 8 differential
 Throughput rate⁽¹⁾ (max) 40µsec/channel

ANALOG INPUTS

ADC gain ranges 0-5V, 0-10V, ±2.5V, ±5V, ±10V
 2 to 250
 Amplifier gain range 2 to 250
 Amplifier gain equation $G = 2 + 50k\Omega R_{ext}^{(2)}$
 Max input voltage without damage⁽³⁾ ±23 volts
 Max input voltage for multiplexer operation ±6 volts
 Input impedance $5 \times 10^3 \Omega \parallel 10 \text{ pF}$ - OFF channel
 $5 \times 10^3 \Omega \parallel 100 \text{ pF}$ - ON channel
 Bias current 25°C 100 nA
 0 - 70°C 200 nA
 Amplifier output noise 400µV rms (10 Hz to 10 kHz)
 Gain = 100, $R_s = 500\Omega$ ±1 mV
 Amplifier input offset voltage (max) ±(6 + 50 G)µV °C
 Amplifier offset voltage drift ±(6 + 50 G)µV °C
 Amplifier settling time (to .1% FSR)
 G = 2 20µs
 G = 10 25µs
 G = 50 50µs
 G = 100 100µs
 G = 200 200µs
 CMRR (for differential inputs) (G = 2) 70 dB (DC to 60 Hz)

ACCURACY

Throughput accuracy
 ±5V, ±2.5V, ±1.25V range (max)⁽⁴⁾ ±0.4% of FSR⁽⁵⁾
 0-5V, 0-2.5V range (max)⁽⁴⁾ ±0.4% of FSR
 ±50 mV range (max)⁽⁴⁾ ±0.8% of FSR
 0-50 mV range (max)⁽⁴⁾ ±0.8% of FSR
 Linearity (max)⁽⁴⁾ ±0.2% of FSR
 Differential linearity⁽⁴⁾ ±0.2% of FSR
 Quantizing error ±1/2 LSB
 Gain error (max)⁽⁴⁾ ±0.1%
 Offset error (max)⁽⁴⁾ ±0.1% of FSR
 Power supply sensitivity
 ±15V ±0.02% $\% \Delta V_{CC}$
 +5V ±0.002% $\% \Delta V_{CC}$

STABILITY OVER TEMPERATURE

System accuracy drift⁽⁷⁾ (max) ±40 ppm °C
 Linearity (max) ±20 ppm °C
 Monotonicity (0°C to +70°C) Guaranteed

DIGITAL INPUT/OUTPUT

All signals are compatible with Microprocessor bus
 Output coding Binary or Binary two's complement
 Logic loading All digital inputs are one LSTTL load
 Output drive (D0 - D7) 5 FTL loads or 20 LSTTL loads
 An analog input channel is selected by: A0 - A3
 The output data bus are read into: D0 - D7

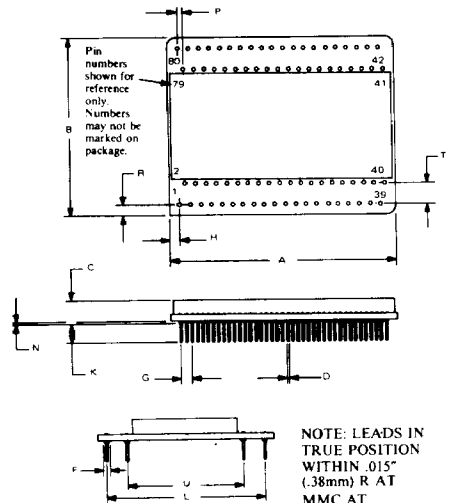
POWER REQUIREMENTS

Rated voltages ±15V, +5V
 Range for rated accuracy 4.75 to 5.25 and ±14.5 to ±15.5V
 Supply drain ±15V ±30 mA
 +5V +90 mA

TEMPERATURE RANGE

0°C to +70°C

MECHANICAL



DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	2.120	2.180	53.85	55.37
B	1.670	1.720	42.42	43.69
C	170	230	4.32	5.84
D	0.018	0.021	0.46	0.53
F	0.035	0.050	0.89	1.27
G	100 BASIC		2.54 BASIC	
H	100 BASIC		2.54 BASIC	
K	150	250	3.81	6.35
L	1500 BASIC		38.1 BASIC	
N	0.02	0.10	0.05	0.25
P	0.50 BASIC		1.27 BASIC	
R	100 BASIC		2.54 BASIC	
T	200 BASIC		5.08 BASIC	
U	1100 BASIC		27.94 BASIC	

NOTE: LEADS IN TRUE POSITION WITHIN .015" (.38mm) R AT MMC AT SEATING PLANE.

MATERIAL: Ceramic
 WEIGHT: 32 grams (1.2 oz)
 PINS: Pin material and plating composition conform to Method 2003 (solderability) of Mil-Std-883 (except paragraph 3.2) MATING CONNECTOR: 2350MC (Set of four 20 pin strips)

PIN CONNECTIONS

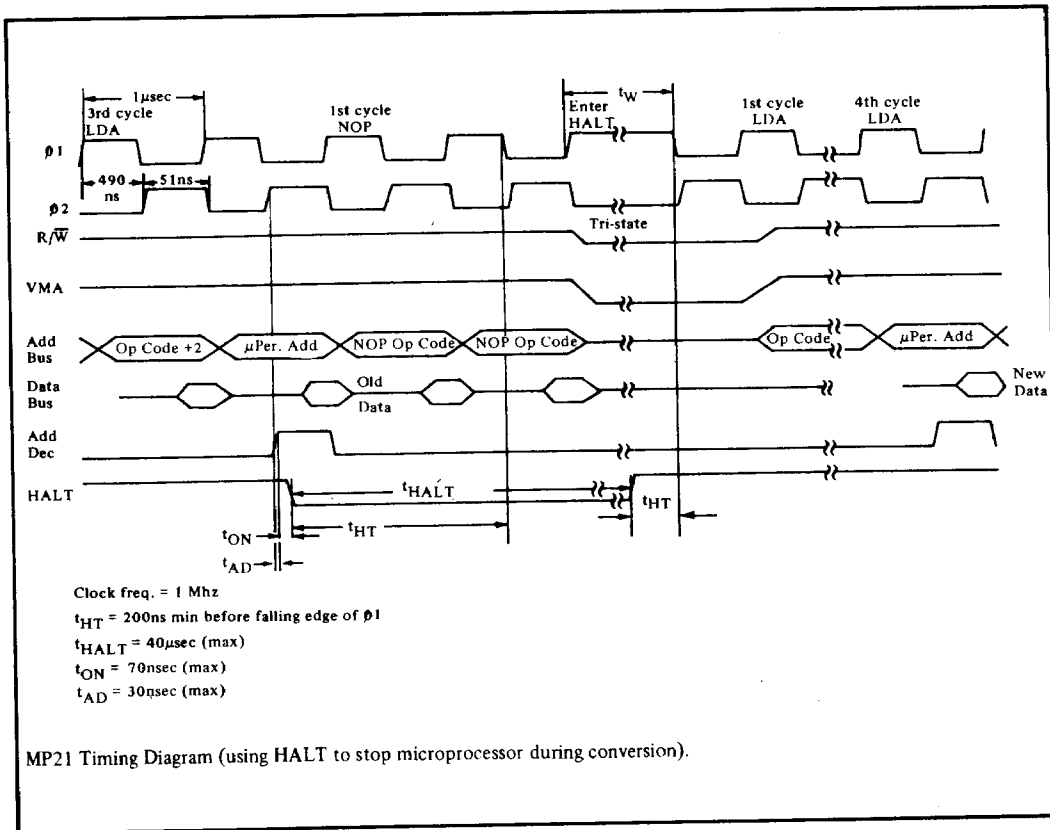
Pin		Pin	
1	I _A GAIN ADJ 10	41	A14
2	I _N IN HI	42	W
3	I _A GAIN ADJ 11	43	ADJ
4	MUX D ₀ F ₀ HI	44	INT
5	I _N *	45	AMA
6	I _N *	46	RE
7	I _N *	47	RESET
8	I _N *	48	TEST
9	I _N *	49	DELAY ADJ
10	I _N *	50	AK
11	I _N *	51	DIG. COM
12	I _N *	52	GROUP SELECT
13	MUX ENABLE 1	53	D ⁺ MSB
14	MUX ENABLE 2	54	D ⁻ MSB
15	MS ₀ HI	55	D ₀
16	D ₀	56	D ₁
17	A ₀	57	D ₂
18	A ₁	58	D ₃
19	A ₂	59	D ₄
20	A ₃	60	D ₀ ENB
21	A ₄	61	INT
22	A ₅	62	AMA
23	A ₆	63	INT
24	A ₇	64	COMP IN
25	A ₈	65	ANA. COM
26	A ₉	66	BPO
27	A ₁₀	67	R ₁ GAIN IN 1
28	A ₁₁	68	R ₁ GAIN IN 2
29	A ₁₂	69	TA G ₀ 1
30	A ₁₃	70	IN 8 REF 1
31	A ₁₄	71	IN 9 REF 1
32	A ₁₅	72	IN 10 REF 1
33	A ₁₆	73	IN 11 REF 1
34	A ₁₇	74	IN 12 REF 1
35	A ₁₈	75	IN 13 REF 1
36	A ₁₉	76	IN 14 REF 1
37	A ₂₀	77	IN 15 REF 1
38	A ₂₁	78	IN 16 REF 1
39	A ₂₂	79	IN 17 REF 1
40	ADDR DECODE 0	80	IN 18 REF 1

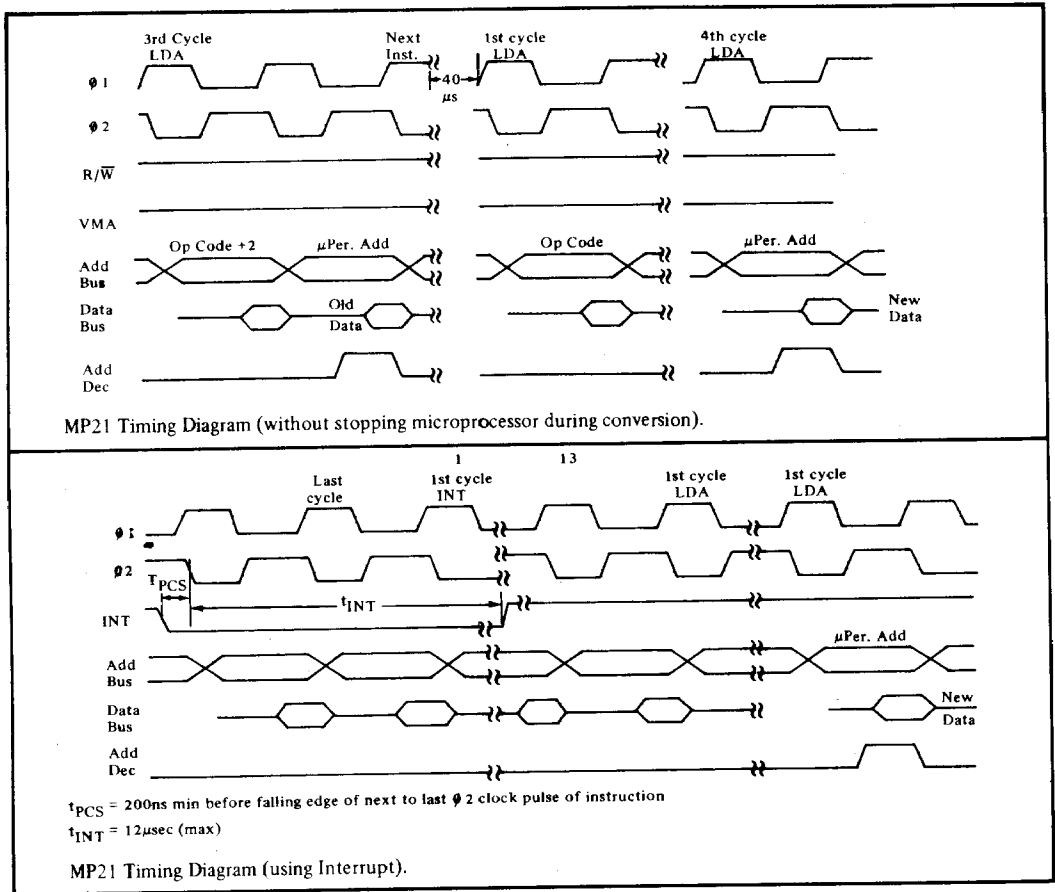
- (1) Includes 35µsec for max and amplifier time and 5µsec for ADC conversion time.
- (2) R_{ext} is an external resistor connected between pins 1 and 3.
- (3) With power applied.
- (4) With no external adjustments.
- (5) FSR is Full Scale Range (FSR is 10V for ±5V range).
- (6) Gain = 100 with external gain and offset trim.
- (7) Includes gain drift, offset drift and linearity drift.

PIN FUNCTIONS

IA GAIN ADJUST	(Optional). Pin 1 and Pin 3. By connecting a resistor between pin 1 and 3 the gain of the internal instrumentation amplifier can be set as follows: $\text{Gain} = 2 + 50k\Omega/R_{ext}$ Where R_{ext} is the gain setting resistor. The IA is factory adjusted for a gain of 2 without any external resistor. Important: If a gain greater than 10 is required an external capacitor must be connected from "DELAY" (pin 49) to +5V. This increases an internal delay to allow for the increased settling time of the instrumentation amplifier. (See page 6-224)	ADDR DEC	Pin 40. A positive pulse will appear when a valid address appears on the MP21 address lines and when R/\overline{W} (pin 42), and $\emptyset 2$ (pin 46) and VMA (pin 45) are high. The rising edge of this pulse strobes the input channel select information (A0 - A3) into a latch. It can also be used for external purposes.
IA IN HI	Pin 2. This is the positive input of the internal instrumentation amplifier. This should be connected to pin 4 (MUX OUT HI) for normal operation.	R/\overline{W}	Pin 42. Read/Write control line. Connect to R/\overline{W} of 6800.
MUX OUT HI	Pin 4. This is the output of the analog input multiplexer. This is connected to pin 2 (IA IN HI) for differential operation. It is connected to pin 77 (MUX OUT LO) and pin 2 for single-ended input operation.	\overline{INT}	Pin 44. Interrupt output. Connect to \overline{IRQ} or \overline{NMI} of the 6800 if interrupt operation is desired. When conversion has been completed, a 10 μ sec pulse (negative) is generated on this line. (Not an open collector output.)
IN7 - IN0	Pins 5 - 12. The first 8 (of 16) analog inputs for single-ended operation or the 8 positive inputs for 8 channel differential input operation.	VMA	Pin 45. Connect to VMA on 6800.
MUX ENABLE 1	Pin 13. Leave open for single-ended input operation. Connect to pin 14 (MUX ENABLE 2) for differential input operation.	$\emptyset 2$	Pin 46. Connect to $\emptyset 2$ on 6800.
MUX ENABLE 2	Pin 14. Connect to pin 15 (SIN/DIF) for single-ended input operation. Connect to pin 13 (MUX ENABLE 1) for differential input operation.	\overline{RESET}	Pin 47. A "Low" on this line is required to reset the MP21. Connect to the \overline{RESET} input of the 6800.
SIN/DIF	Pin 15. Single/Differential input operation connect to pin 14 (MUX ENABLE 2) for single-ended operation. Leave open for differential input operation.	\overline{HALT}	Pin 48. When the MP21 is "Read" by the microprocessor via any memory reference instruction the \overline{HALT} line will go "Low" until conversion is complete. If the \overline{HALT} line is used to halt the CPU, the 6800 will halt upon completion of the next instruction. When the multiplexer, instrument amp, and A/D converter have completed converting the analog data to a binary 8 bit code (40 μ sec with gain \leq 10) the \overline{HALT} line will then return to its "High" state which releases the processor. The output data can then be read with a second memory reference instruction. (Not an open collector output.)
A0 - A3	Pin 16 - 19. Address lines that select one of 16 analog input signals (IN0 - IN15). 0000 selects channel 0 and 1111 selects channel 15 when the correct address is presented to the MP21. Note: A3 should be connected to DIG COM for 8 channel differential input operation.	DELAY ADJ	Pin 49. When the MP21 is addressed, an internal delay of approximately 35 μ sec is initiated to allow for multiplexer and instrumentation amplifier settling time. When the IA is operated with gain $>$ 10 this delay must be increased (see Figure 4) to allow for the increased settling time of the IA. This is done by adding a capacitor between pin 49 and +5V. (See Figure 5)
A4 - A15	Address lines. Pins 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 41, and 43. Connect to A4 - A15 of the 6800.	+5V	Pin 50. +5 volt at 140 mA maximum, 90 mA typical.
$\overline{A4} - \overline{A13}$	Address select lines. Pin 21, 23, 25, 27, 29, 31, 33, 35, 37, and 39. By connecting these lines to DIG COM or +5 volts (through a 1k Ω resistor) any of 1024 address bands can be assigned to the MP21. For example, if A4 is connected to GND., the correct (valid) address for A4 is a "1" ($>$ + 2.4V).	DIG COM	Pin 51. Digital common. This pin should be connected to analog common (pin 64) as close to the MP21 as possible for optimum performance.
		OUTPUT SELECT	Pin 52. This pin should be connected to DIG COM to obtain binary data at D0 - D7. To obtain two's complement data (bipolar mode) connect pin 52 to +5V through a 1k Ω resistor.

D7 - D0	Pin 53 - 60. 8 bit data bus. 3-state low power Schottky TTL compatible.	bipolar operation. Leave open for $\pm 5V$ input bipolar operation.
-15V	Pin 61. -15 volt at 30 mA typical.	R1
+15V	Pin 62. +15 volt at 30 mA typical.	Pin 67. A/D converter input resistor. Connect to IA out for ± 5 volt operation.
COMP	Pin 63. Comparator input of 8 bit A/D converter (successive-approximation). Leave open for unipolar operation or connect to "BPO" (pin 65) for bipolar operation.	Connect to Pin 63 for 0 to +2.5V and $\pm 1.25V$ ranges.
IN		IA OUT
		Pin 68. Instrumentation amplifier output. Connect to R1 (pin 67) or R2 (pin 66) for normal operation.
ANA COM	Pin 64. Analog common should be connected to digital common (pin 51) as close to the MP21 as possible for optimum performance.	IN8-IN15 RET0-RET7
		Pin 69-76. Analog inputs 8 through 15 for single-ended operation or analog returns 0 through 7 for differential input operation.
BPO	Pin 65. A/D converter bipolar offset. It should be connected to ANA COM (pin 64) for unipolar operation or COMP IN (pin 63) for bipolar operation.	MUX OUT LO
		Pin 77. Multiplexer output for IN8-IN15 or RET0-RET7. Connect to "MUX OUT HI" (pin 4) and "IA IN HI" (pin 2) for single-ended input operation or connect to "IA IN LO" (pin 79) for differential input operation.
R2	Pin 66. A/D converter input resistor. Connect to IA out (pin 68) for 0 to +5V input unipolar operation or $\pm 2.5V$ input	OFFSET NULL
		Pin 78, 80. Optional instrumentation amplifier offset adjust (see Figure 1).
		IA IN LO
		Pin 79. Negative input of instrumentation amplifier. Connect to ANA COM (pin 64) for single-ended input operation or "MUX OUT LO" (pin 77) for differential input operation.





OPERATING INSTRUCTIONS

PROGRAMMING

The MP21 is easily programmed since it is treated as memory. It uses any memory reference instruction that can read data.

The MP21 can be operated in four modes:

1) Start data conversion, halting the microprocessor for the 40µsec* conversion time. This is the simplest approach. It should be used if 40µsec of software time is available. (MP21's $\overline{\text{HALT}}$ line, pin 48, connected to the 6800's $\overline{\text{HALT}}$ input, pin 2.)

Example: LDA XXXX starts conversion of channel at location XXXX
 NOP CPU halts at the end of this instruction
 LDA XXXX transfers data from channel at location XXXX to accumulator

2) Start data conversion, then go to a different part of the program. When 40µsec* or more have passed, come back

to the MP21 to read the converted data. This mode uses the least amount of time; it should be used when software time is at a minimum. (MP21's $\overline{\text{HALT}}$ line, pin 48, is open.)

Example: LDA XXXX starts conversion of the channel at location XXXX

• } at least 40µsec* of software here

LDA XXXX transfers data from channel at location XXXX to accumulator

* The conversion time of the MP21 may be between 40 and 200 microseconds depending upon the gain of the internal instrumentation amplifier. See Figure 4.

3) Start data conversion, then go to a different part of the program. Periodically, check the MP21's $\overline{\text{HALT}}$ line (pin 48) to detect if conversion is complete. This mode should

be used if a positive check of a complete conversion is needed. (MP21's HALT line, pin 48, could be interfaced to a 6820 PIA for instance.)

```

Example: LDA $XXXX starts conversion of channel at
         location XXXX
         .
         .
         .
         LDA $YYYY loop to determine if conversion
         is complete
AA ANDA $ZZ      YYYYY is location of 6820 PIA
                 with HALT information
                 ZZ is mask used for determin-
                 ing if end of conversion bit
                 is set
BEQ AA
LDA $XXXX transfers data from channel at
         location XXXX to accumulator
  
```

4) Start conversion, then go to a different part of the program. The MP21 will interrupt at the end of conversion. The interrupt mode is very useful when the MP21 is at high gains with conversion times longer than 40µsec, see Figure 4. (MP21's INT line, pin 44, connected to the 6800's IRQ line, pin 4.)

Example: MP21 used with a 6800. MP21 base address 92E0. Processor halted operation. Read and Print the value of all 16 input channels and then stop.

```

          E0BF  OUT2H  EQU  $E0BF  MP21
          F1D1  OUTEEE  EQU  $F1D1
          E1AC  INEEE  EQU  $E1AC
0100      ORG  $100
0100  CE 92E0  START  LDX  =$92E0  Base address for MP21
0103  SF
0104  A6 00   CONV   LDA  A,X      Clear Counter
                                Initiate Conversion
0106  01 01   NOP
0107  A6 00   LDA  A,X      Read Data
0109  FF 0137  STX  STRE1  Store Index Reg.
010C  F7 0139  STA  B  STRE2  Store Counter
010F  B7 013B  STA  A  STRE3  Store Data
0112  CE 013B  LDX  =STRE3
0115  BD E0BF  JSR  OUT2H  Print Data
0118  86 0D   LDA  A  =S0D
011A  BD E1D1  JSR  OUTEEE
011D  86 0A   LDA  A  =S0A
011F  BD E1D1  JSR  OUTEEE
0122  F6 0139  LDA  B  STRE2
0125  FE 0137  LDX  STRE1
0128  5C      INC  B
0129  C1 10   CMP  B  =S10  Next Channel
                                Have 16 channels been
                                read?

012B  27 04   BEQ  STOP  Yes
012D  08      INX
012E  7E 0104  JMP  CONV  Do another conversion
0131  BD E1AC  STOP  JSR  INEEE  Input character
                                to begin again

0134  7E 0100  JMP  START
0137  0002  STRE1  RMB  2
0139  0001  STRE2  RMB  1
013A  0001  STRE3  RMB  1
          END
  
```

This program assumes that the system is under the control of the MIK BUG monitor, Revision 9. To read and print the value of all 16 channels again, input any character from the keyboard.

ADDRESS SELECTION

The base address of the MP21 is set by inputs $\overline{A4}$ through $\overline{A13}$. Address lines $\overline{A4}$ through $\overline{A13}$ respond to the inverse of inputs $\overline{A4}$ through $\overline{A13}$. For instance, if $\overline{A6}$ is grounded, $\overline{A6}$ will respond to a "High" input. $\overline{A14}$ and $\overline{A15}$ are internally connected to respond to a "High" input.

ANALOG INPUT RANGE SELECTION

The MP21 may be set for any range between $\pm 5V$ and ± 10 mV. Table I shows the pin connections for the various high level ranges available.

MP21 Input Range	Gain	ADC Range	Pin Connections
$\pm 5V$	2	$\pm 10V$	65 to 63; 66 open; 67 to 68
$\pm 2.5V$	2	$\pm 5V$	65 to 63; 66 to 68; 67 open
$\pm 1.25V$	2	$\pm 2.5V$	65 to 63; 66 to 68; 63 to 67
0 - 5V	2	0 - 10V	65 to 64; 66 to 68; 67 open
0 - 2.5V	2	0 - 5V	65 to 64; 66 to 68; 63 to 67

Table I. Analog Input Range Pin Connections

The MP21 may be set to output data with straight binary coding (pin 52 grounded) or two's complement coding (pin 52 to +5VDC through a 1kΩ resistor). Straight binary coding is typically used with unipolar input ranges and two's complement coding with bipolar input ranges. Table II describes the coding.

The internal instrumentation amplifier is factory set for a gain of 2. This gain can be increased to 250 by adding an external resistor (R_{ext}) between pins 1 and 3. R_{ext} should be a stable resistor (10 ppm/°C) since this temperature drift will add to the accuracy temperature coefficient. The gain of the amplifier can be determined by this formula:

$$\text{Gain} = 2 + \frac{50k\Omega}{R_{ext}}$$

With pins 1 and 3 open, the gain is 2.

Since the amplifier input offset will be multiplied by the amplifier gain, an offset adjust may be required at high gains (see Figure 1b).

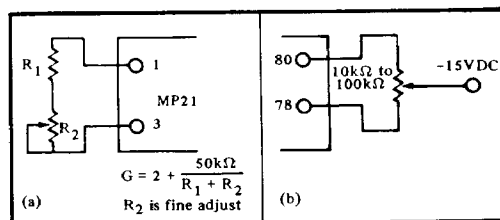


FIGURE 1. (a) MP21 Gain Adjust; (b) Offset Adjust

SINGLE-ENDED VS. DIFFERENTIAL INPUTS

The MP21 analog inputs may be connected as single-ended, differential or pseudo-differential. Single-ended operation may be used for high level (over one volt full scale) signals in low noise environments (Figure 3). Differential operation will reject common-mode noise appearing on both inputs (Figure 2). It should be used in noisy environments or with any low level signal (less than one volt). In the pseudo-differential mode, the MP21 is

		DIGITAL OUTPUT		ANALOG INPUT		
Straight Binary Code	Two's Complement Code			±5V	0 to +5V	±10mV
1111 1111 (FF ₁₆)	0111 1111 (7F ₁₆)	+ Full Scale		+4.961V	+4.980V	+9.92mV
1000 0000 (80 ₁₆)	0000 0000 (00 ₁₆)	Mid-Scale		0.000V	2.500V	0.000V
0000 0000 (00 ₁₆)	1000 0000 (80 ₁₆)	- Full Scale		-5.000V	0.000V	-10.00mV
		One LSB		39mV	19.5mV	78μV

TABLE II. Analog Input Values

connected as for the single-ended mode in Figure 3 except the IA low input, pin 79, is not grounded. Pin 79 is connected to an external ground that is common to all of the analog inputs. In cases with a noisy remote ground where little noise will be picked up between sensor and MP21, the pseudo-differential mode may be used.

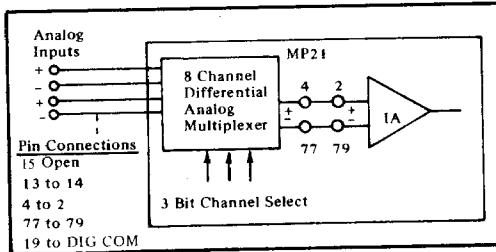


FIGURE 2. Differential Input Connections

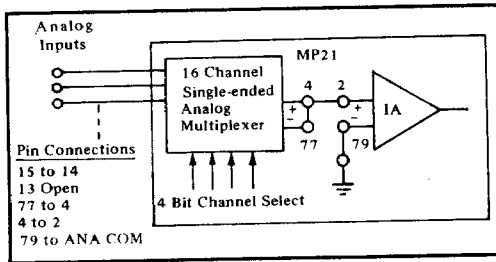


FIGURE 3. Single-ended Input Connections

DELAY TIMING

A delay time between channel selection and start of conversion is built into the MP21 to allow the analog multiplexer and instrumentation amplifier (IA) time to settle before starting the A/D converter. As the gain of the amplifier is increased, the settling time required increases. The factory set delay time (35μsec) is sufficient for gains of up to 10. At higher gains, a capacitor must be added from pin 49 to the +5 VDC supply to increase the delay time. Figure 4 shows the settling time of the MP21 vs. gain. Figure 5 shows the value of capacitance required to increase the delay.

The only external factor, other than gain, that affects the MP21 settling time is the impedance of the source connected to a channel. Figure 6 shows a circuit model of an "ON" channel.

The signal at the output of the multiplexer must be allowed to settle to ±0.1% (six time constants) to maintain the full accuracy of the system. The multiplexer

time constant can be calculated with the formula: $\tau = (R_s + R_{on} + R_{on}*)C_o$. For $R_s = 1k\Omega$ and $C_o = 50pF$, $\tau = (1.5 + 1)k\Omega \times 50pF = 125ns$ (single-ended operation). Thus $0.75\mu s$ is needed to settle to ±0.1%. For high input impedances requiring more than 10 microseconds for multiplexer settling time, the required delay time may be calculated

with this formula: $T_D = \sqrt{T_{mux}^2 + T_{IA}^2}$, where T_{mux} is the settling time of the multiplexer and T_{IA} is the settling time of the instrumentation amplifier as shown in Figure 4. If the source bandwidth can be limited, high impedance sources may be accurately handled by placing a large capacitance across the multiplexer input. An analysis of such a circuit shows that a capacitor of $0.5\mu F$ is sufficient. For such a capacitance the multiplexer time constant becomes 80ns.

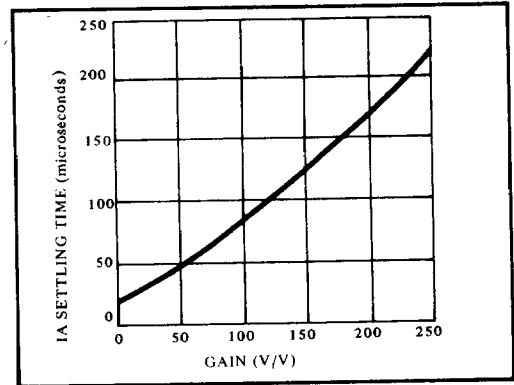


FIGURE 4. Typical IA Settling Time vs. Gain (Output Settling to ±0.1%).

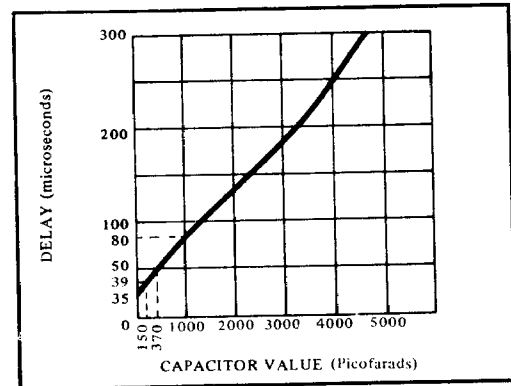


FIGURE 5. Typical Delay Time vs. Capacitor Value.

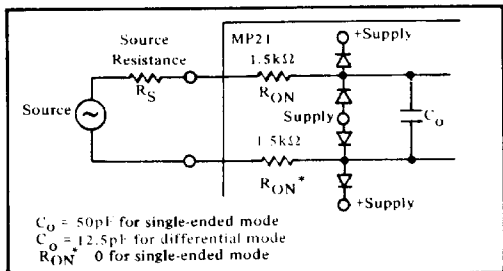


FIGURE 6. "ON" Channel Circuit Model.

INPUT OVERVOLTAGE PROTECTION

As shown in Figure 6, the analog inputs have reverse biased diode circuits which protect from damage by overvoltage (such as static). It is still advisable to take precautions against static discharge. The same circuitry protects the inputs from steady-state overvoltage damage during operation. The MP21's overvoltage protection can be increased by adding series resistors at each input. The input resistance must limit the current flowing through the input protection diodes to 10mA. For instance, if 15kΩ resistors are added to each input, the protection is increased to 165V (16.5kΩ x 10mA). Increased input resistance will, of course, increase the amount of time necessary for the multiplexer to settle as described in the previous section and increase the offset voltage by the drop caused when the bias current passes through this resistance.

NON 6800 OPERATION

The circuitry used to enable the 3-state output lines (D7 - D0) and begin conversion on the MP21 can be connected in such a way as to meet a wide variety of timing requirements. The output is enabled only when a valid address appears on the address inputs and when VMA (pin 45), $\overline{R/W}$ (pin 42), and $\emptyset 2$ (pin 46) are high. Any other combination of digital signals on these lines will result in D7 - D0 being in a high impedance state (see Figure 7).

All that is required to use the MP21 with a system other than a 6800, is that these signals be brought to their active levels. When this occurs, operation begins as previously

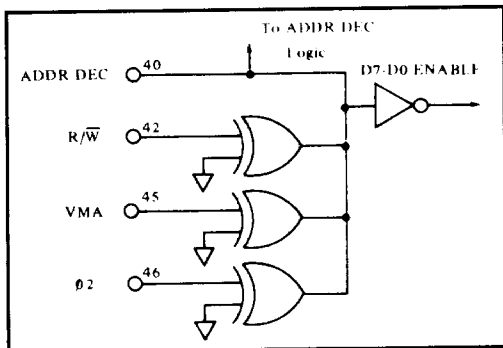


FIGURE 7. Output Enable Circuitry

described. Applications using the MP21 with other processors are shown in Figure 10 and 11.

RESET

It is important to reset the MP21 on startup with a low pulse on the $\overline{\text{RESET}}$ line (pin 47). The reset pulse clears an internal flip-flop and guarantees that the next read instruction to the unit will start a conversion. Thereafter, every other read instruction will initiate a conversion as previously described.

CONVERTER INITIALIZATION

On power-up, the state of the ADC internal circuitry is indeterminate. One conversion cycle is required to initialize the converter after power is applied.

HIGHER SPEED OPERATION

The MP21's internal instrumentation amplifier requires 35 microseconds to allow for settling time. If this internal amplifier is not used, substantial improvements in throughput rate can be obtained. This is easily done since neither the inputs nor the output of the instrument amplifier are internally connected. For instance, Burr-Brown's 3622 high speed instrument amplifier (for differential inputs) or 3505J high speed op amp (for single-ended inputs) may be used, with a settling time of 1μsec for gains of up to 100. The total delay time necessary may be calculated by this formula.

$$T_D = \sqrt{T_{MUX}^2 + T_{IA}^2}$$

where T_{MUX} is the settling time of the multiplexer (750ns) and T_{IA} is the settling time of the instrument amplifier. For a T_{IA} of 1μsec we have $T_D = 1.3μsec$. Using 3μsec for the delay time to allow for unit to unit variation, the total throughput time will be 8μsec (including 5 microseconds for ADC conversion time) or 125 kHz. A resistor between pin 49 and +5 VDC will reduce the delay time from the factory set value of 35 microseconds (see Figure 8).

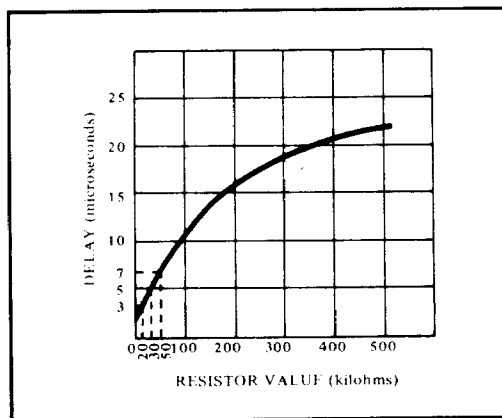


FIGURE 8. Typical Resistor Value to Decrease Delay Time.

CALIBRATION

The MP21 is laser trimmed at the factory to $\pm 0.4\%$ accuracy when using the $\pm 5V$, $\pm 2.5V$, $\pm 1.25V$, 0 to $+2.5V$ or 0 to $+5V$ ranges. If one of these ranges is used, no adjustments are required. For other ranges ($G \neq 2$), both the gain and offset must be adjusted. Figure 1 shows the adjustment connections. The offset adjustment should be made such that the transition to minus full scale output (0000 0001 to 0000 0000 for straight binary) occurs with an input of negative full scale plus $1/2$ LSB. One least significant bit (LSB) is equal to the full scale range (FSR) divided by 2^n where n is the number of bits of the A/D converter. For the MP21, 1 LSB is $FSR/2^8 = FSR/256$. The gain adjustment should be made such that the transition to a full scale output (1111 1110 to 1111 1111 for straight binary) occurs with an input of positive full scale less $1/2$ LSB. Since 128 states are used for negative inputs and one state is used for zero, only 127 states are available for the remaining positive range. Thus the positive full scale voltage is 1 LSB less than nominal full scale. For a range of ± 50 mV, $1 \text{ LSB} = 100 \text{ mV} / 256 = 0.39 \text{ mV}$. The gain adjustment should be made at $+49.61 \text{ mV} * -(0.5)(0.39 \text{ mV}) = +49.42 \text{ mV}$. The offset adjustment should be made at $-50 \text{ mV} + (0.5)(0.39 \text{ mV}) = -49.80 \text{ mV}$. Table III shows offset and gain calibration values for typical ranges.

* (50mV - 1 LSB = 49.61mV)

MP21 Input Range	Instrument Amp Gain	ADC Range	Calibration Values	
			Offset	Gain
$\pm 5V$	2	$\pm 10V$	-4.980V	+4.941V
0 to $+5V$	2	0 to $+10V$	+9.8mV	+4.971V
$\pm 2.5V$	2	$\pm 5V$	-2.490V	+2.471V
0 to $+2.5V$	2	0 to $+5V$	+4.9mV	+2.485V
$\pm 1.25V$	2	$\pm 2.5V$	-1.245V	+1.235
0 - 50mV	100	0 to $+5V$	+98 μ V	+49.7mV
± 25 mV	100	$\pm 2.5V$	-24.9mV	+24.7mV
0 - 25mV	200	0 to $+5V$	+49 μ V	+24.9mV

Table III. Calibration Values.

The following program may be used to adjust gain and offset.

```

START 0100 86 ORG $100
        LDA A # $64
        0102 B7 STA A COUNT
        01 1A
        0105 4F CLR A      Clear Accumulators.
        0106 5F CLR B
CONV 0107 B6 LDA A $92 E0 Begin Conversion.
        92 E0
        010A 01 NOP
        010B B6 LDA A $92 E0 Read Data.
        92 E0
        010E 81 CMP A #REF IS Data = REF?
        REF
        0110 26 BNE AA     No. Do not count.
        01 01
        0112 5C INC B     Yes. Do count.
AA 0113 7A DEC COUNT    Have 100 conversions
                        been done.
        01 1A
        0116 26 BNE CONV  No. Do another.
        EF
        0118 20 BRA START Yes. Begin next run.
        E6
COUNT 011A RMB 1
        END
    
```

This program assumes that the program is under control of the Motorola EXORciser EXbug monitor. If the Mikbug monitor is available, the following printout software may be added by using it to replace all codes starting from location 0118. In addition the references to count at 0104 and 0115 must be replaced with 2E.

```

OUT 2H EQU $E0 BF
OUT EEE EQU $E1 D1

0118 F7 STA B STRO
        01 2E

011B CE LDX #STRO
        01 2E

011E BD JSR OUT 2H Print no. of true conversions.
        E0 BF

0121 86 LDA A #0D
        0D

0123 BD JSR OUTEEE
        E1 D1

012E RMB 1 COUNT
012F RMB 1 STRO
        END
    
```

This program may be used for both offset and gain calibration. The system offset should be adjusted first, followed by the gain adjustment.

The address of channel zero is assumed to be 92E0. If it is not, the LDA instructions should reflect that change. The reference values for Ref assume straight binary coding. Offset Ref = 00 and Gain Full Scale Ref = FF. For two's complement binary coding, Offset Ref = 80 and Gain Full Scale Ref = 7F.

A 100;G command to Exbug will begin program execution. For Mikbug the user's stack must be loaded with 100 and then a G command executed to begin program execution. For those applications not using the printer portion of the program insert a breakpoint via a 118;V command. After 100 conversions have been made, the value (in hex) of the B accumulator will be printed if using Mikbug program. This value represents the number of times the data read from the board was equal to "REF" (00 for offset; FF for gain).

Calibration is performed by connecting a voltage source capable of 0.01% accuracy to input channel zero (this could also be a DC voltage source of less absolute accuracy whose output is monitored by a 0.01% DVM).

The offset adjustment is made first by using the appropriate offset calibration voltage and REF value. Run the calibration program and adjust the offset potentiometer until the B register contains a value between $1E_{16}$ and 46_{16} (30_{10} and 70_{10}).

To perform the gain adjustment, change the data labeled "REF" in the calibration program to its correct gain value. Set the input voltage to the correct value as shown in Figure 8 and adjust the gain potentiometer in the same manner as described for offset.

If EXbug is used the program will halt and the B accumulator can be examined from the program register display produced by the breakpoint.

THERMOCOUPLE TEMPERATURE ACQUISITION

Thermocouples are often used as temperature sensors for process control systems. Thermocouples are characterized by temperature coefficients of 10 to 70 $\mu\text{V}/^\circ\text{C}$ and operating ranges of minus hundreds to plus thousands of degrees centigrade. When the MP21 is operated with an instrumentation amplifier gain of 100 or more, it may be connected directly to these devices. The wire runs from thermocouple to measuring device often pick up large common-mode noise signals of 60 Hz or higher frequencies. When the MP21 is used as an eight channel differential input system, the high common-mode rejection of the instrument amplifier will reject common-mode noise. To minimize differential mode noise, the signal wire should be twisted and if possible shielded. As a rule, an unshielded twisted pair is better than a coax, and a shielded, twisted pair is still better. In applications where these wiring practices cannot always be observed, a differential RC filter may be used. Figure 9 shows such a system.

The 10 k Ω resistors and 10 μF capacitor provide low pass filtering ($f_c = 0.8 \text{ Hz}$) while the optional 1 M Ω resistors supply bias current to the instrumentation amplifier. The

remote sensor should be earth grounded to prevent common-mode voltages from exceeding the ± 5 volt range of the multiplexer. If the sensor is earth grounded, the 1 M Ω resistors are not required. The 1 M Ω resistors do not enter into an error calculation for input errors because the low resistance of the sensor shorts any differential voltage that might be caused by the offset (difference current) of the amplifier. Offset or difference current is merely the difference between the bias current of each input. See the overvoltage protection section for a discussion of the effects of the 10k Ω resistors in the input filter. The 1M Ω resistors could have been put on the output side of the multiplexer eliminating the need for repeating them for each input; however, this would have loaded the 10k Ω resistors of the filter causing a possible 1% error for static conditions.

To complete a thermocouple system it is necessary to terminate all thermocouple wire pairs at an isothermal box or connector strip of some type. An ordinary barrier strip may be monitored to allow the observed thermocouple emf to be cold junction compensated. Figure 9 shows an excellent circuit for this purpose. Its output is connected to one of the input channels to supply ambient temperature data to the system computer. Its output sensitivity is approximately 2 mV/ $^\circ\text{C}$.

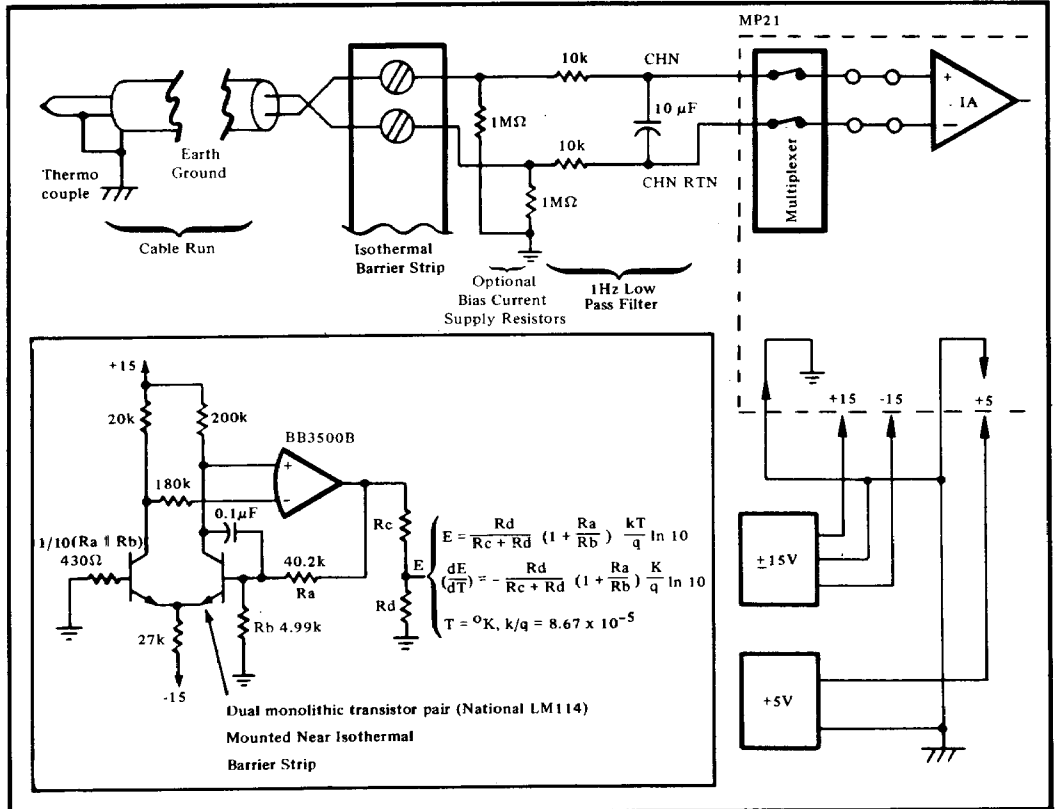


FIGURE 9. Thermocouple Input System Using MP21.

PIN CONNECTION SUMMARY

	JUMPER		JUMPER
Single-ended Multiplexer	4 to 2; 4 to 77; 79 to 64; 15 to 14; 13 open	Address Bus (A0 - A15)	Connect to 6800's address bus A0 - A15
Differential Multiplexer	4 to 2; 77 to 79; 13 to 14; 15 open	Address Select (A $\bar{4}$ - A $\bar{13}$)	Connect to +5V* or Ground
Amplifier	1 and 3 open for G = 2; R _{EXT} between 1 and 3 for G \neq 2.	Control Bus	42 to 6800's R/ \bar{W} (pin 39) 44 optionally to 6800's IRQ (pin 4) 45 to 6800's VMA (pin 5) 46 to 6800's $\emptyset 2$ (pin 37) 47 to 6800's $\bar{R}ESET$ (pin 40) 48 to 6800's $\bar{H}A L T$ (pin 2) open for operation without halting CPU.
Input Range $\pm 5V$ $\pm 2.5V$ $\pm 1.25V$ 0 - 5V 0 - 2.5V	65 to 63; 66 open; 67 to 68 66 to 63; 66 to 68; 67 open 65 to 63; 66 to 68; 63 to 67 65 to 64; 66 to 68; 67 open 65 to 64; 66 to 68; 63 to 67		
Output Coding	52 to 51 for binary; 52 to 50* for two's complement.	Data Bus (D0 - D7)	Connect to 6800's data bus.

* Through a 1k Ω resistor.

MICROPROCESSOR INTERCONNECTION

The following diagrams show interconnections of the MP21 (described in this data sheet) and also of Burr-Brown's MP10 and MP11 analog output microperipherals (PDS-363) with Motorola's 6800, MOS Technology's 650X, and Fairchild's F-8. Although Burr-Brown's analog microperipherals are optimized for 8 bit microprocessors, with the addition of a few external components, they can be used with any 4 through 16 bit microprocessors.

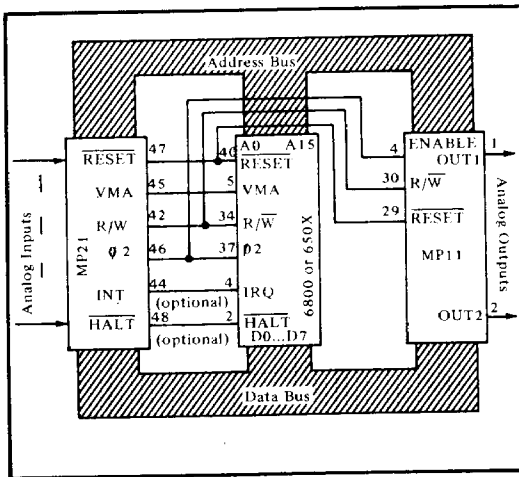


FIGURE 10. MP21 and MP11 Used With the 6800 or 650X.

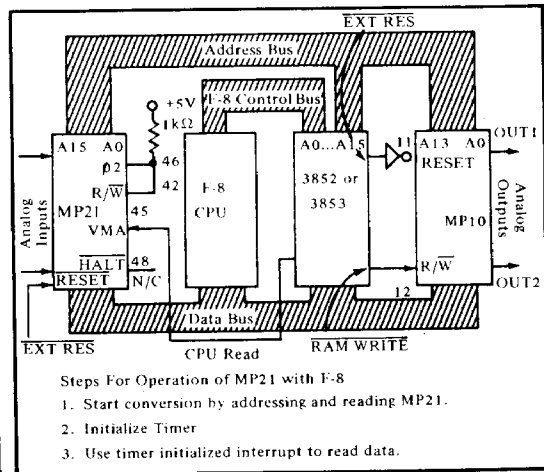


FIGURE 11. MP21 and MP10 Used With the F-8.