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MICROCOMPUTER-BASED MONITERING AND CONTROL SYSTEM*

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This report describes a microcomputer-based monitoring and control system devised within, and used by, the Cryogenic Operations group at SLAC. Presently, a version of it is operating at the one meter liquid hydrogen bubble chamber augmenting the conventional pneumatic and human feedback system. Its use has greatly improved the controlled tolerances of temperature and pulse shape, and it has nearly eliminated the need for operating personnel to adjust the conventional pneumatic control system. The latter is most important since the rapid cycling machine can demand attentions beyond the operator's skill. Similar microcomputer systems are being prepared to monitor and control cryogenic devices situated in regions of radiation which preclude human entry and at diverse locations which defy the dexterity of the few operators assigned to maintain them.

An IMSAI 8080 microcomputer is basic to the system. This product is quite familiar to microcomputer enthusiasts and hobbiests, but what is perhaps not appreciated is that it can form the basis of a monitoring and control system costing one-tenth that of one conventionally involving a minicomputer and its available interface products. Furthermore, it is sufficiently simple that one can quickly learn to service it; it does not require a trained, company technician or engineer. The fact that it is only an 8-bit machine with an average instruction time of four micro-seconds is no disadvantage, since, even using "Basic" language, and calling machine language subroutines for rapid input and output of data, the relatively slow "industrial processes" can be monitored and controlled. For example, during 30 miliseconds of the bubble chamber's pulse, 256 12-bit readings are taken and stored in memory by machine language for analysis in Basic. Each reading is comprised of two inputs in succession. The key to the use of the IMSAI 8080 in this system was in the development of unique interface circuitry, and the report is mostly concerned with this.

Figure 1 depicts the entire system as described in this paragraph. The IMSAI 8080 can access 64 K bytes of memory and 256 each of input and output ports. It has interrupt capability. It is linked with mini-floppy disc drives. One disc can store 90 K bytes, but a typical Basic program is only one to three K bytes in length. Data can be transferred from the disc at the rate of 16 K bytes per second. The microcomputer communicates to a 64 by 16 character, scrolling video display and with a teletype machine. The cost of this portion of the system comprising all the commercially available elements is under $5000. This includes six memory cards (48K RAM), a "Fast Basic" card for performing arithmetic fifty times faster than conventional software, a clock card for general timing and interrupts, the cards for video and teletype, a disc operating system card and two floppy-disc drives. The interface circuitry includes a DRIVER/RECEIVER card which plugs onto the computer's S-100 bus. This card latches the computer's output data and sends it via line drivers to the remoted interface subsystem circuitry, and it receives data from that subsystem. This can be at a distance of one mile. There, it is optically coupled on the SIXTEEN CHANNEL MUX A/D card to a floating ground system. This card has a 12-bit analog to digital converter, and, on this card, one of 256 information channels is selected. These channels are located on other cards of 16 channels each, and data is exchanged with them and sent back to the microcomputer via optical couplers and line drivers. The SIXTEEN CHANNEL AMPLIFIER-FILTER MUX card contains second order amplifier-filters having elective components for a choice of gain, offset, polarity and corner frequency. Thus, the amplifier channels can be made compatible with a variety of transducer outputs. The SIXTEEN CHANNEL TC AMPLIFIER-FILTER MUX card is used exclusively for amplifying and filtering the outputs of arbitrarily grounded thermocouples. The SIXTEEN CHANNEL DAC-TO-CURRENT MUX card converts 12-bit data to a proportional current to drive sixteen-miliamp E/P converters for actuating air operated values. Finally, back at the computer, there is the TWO CHANNEL DAC card which plugs onto the computer's S-100 bus. It converts 12-bit data to analog form for oscilloscope displays or pen recorders. These cards will now be described in detail but not exhaustively.

The DRIVER/RECEIVER card, parallel data version and serial data version, in the computer is designed to exchange data between the computer and the remote interface subsystem via the SIXTEEN CHANNEL MUX A/D card. Figure 2 is its functional diagram. The card communicates with the computer's S-100 bus via the edge connector P1. The data appears on the output lines DO Ø through DO 7 and input lines DI Ø through DI 7 respectively. The address of the output or input port appears on the lines A Ø through A 7. The response of the D/R card to a port number is selected by jumpers at the address comparator. The first four addresses are not used because ports Ø, 1, 2 and 3 are assigned to the video and TTY cards. The diagram indicates address select jumpers installed for ports 4, 5 and 6; however, any other three ports can be used, provided, of course, there is no conflict with ports on other cards. A computer output to the D/R card is effected when the addresses match and when a logical low appears on the $\overline{\text{WR}}$ line while the OUT line is high. A computer input from the D/R card follows an address match and conincident highs on the INP and DBIN lines. On the card, the output data corresponding to output ports 4, 5 and 6 is latched and made output from line drivers to connectors P2, P4 and P5. And on the card, the input data, through connectors P3 and P5 and line receivers, is selected as input ports 4 and 5 by the digital multiplexers. This data, which is latched at its source in the remote interface subsystem, is strobed onto the computer's data input lines. Parallel data transfer between the D/R card and the remote interface subsystem is via 100 ohm twisted-pair lines between the four connectors on the card and four on the SIXTEEN CHANNEL MUX A/D card in the subsystem: Connector P2 outputs 8 bits (output port 4) of latched data plus a four microsecond strobe pulse. This byte selects one of the subsystems 256 possible channels, and the strobe pulse starts the analog to digital or digital to analog conversion. This will become clear when the A/D card is described. Connector P3 inputs 12 bits (input port 4 and 1/2 input port 5, L.O.) of data from the subsystem, the latched 12 bits from the A/D converter. Connector P4 outputs 12 latched bits (output port 5 and 1/2 output port 6, L.O.) for a selected DAC-TO-CURRENT channel. Connector P5 outputs 4 latched bits (1/2 output port 6, H.O.) and inputs 4 bits (1/2 input port 5, H.O.). These 8 bits can be used for control functions.

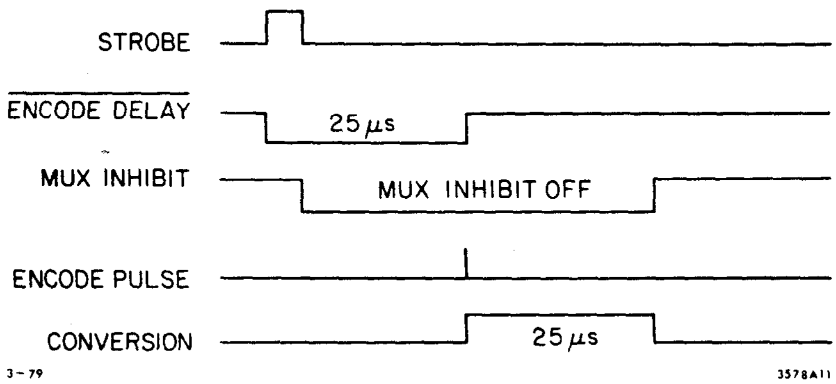
Serial data transfer from the DRIVER/RECEIVER-SERIAL card is comprised of three bytes: Port 5 first, then port 6, and finally port 4. A start bit precedes each byte, and a stop bit follows each byte. Since the data rate is 250K bits per second, the data transfer time is 120 microseconds plus, of course, the line propagation time.

The remote interface subsystem, Figure 3, has a 100 line bus, Figure 4, connecting all of its cards, the 16 CHANNEL A/D MUX being the main card. The bus communicates +15, -15, +5 and -5 volts to all cards. The ground is floating. In addition, the A/D card receives +5 volts and earth ground for its driver - receiver - optical coupler section. Sixteen lines, each paired with floating grounds, transmit analog data from the amplifier cards to the A/D card or transmit encode pulses from the A/D card to the 16 CHANNEL DAC-TO-CURRENT cards. Twelve lines carry the 12-bit data from the A/D card to the DAC cards. Five lines are used to select one of 16 channels on the cards and inhibit (open) all multiplexer channels, and four lines are used to select the isolated cards. Several uncommitted lines are available.

The SIXTEEN CHANNEL A/D MUX card, parallel data version and serial data version, in the remote interface subsystem exchanges data between the subsystem and the computer via the DRIVER/RECEIVER card. There are 16 analog, and 16 digital, MUX channels on the A/D card. The two types allow communication with both the amplifier cards and the DAC-TO-CURRENT cards through the 16 signal lines on the 100 line subsystem bus. A line can conduct an analog signal from an amplifier card to an analog MUX channel on the A/D card. Or a line can conduct an encode pulse from a digital MUX channel on the A/D card to a DAC-TO-CURRENT card. The user makes the choice by placing jumpers between the signal line pads near the A/D card's edge connector P1 and pads linked to the two types of multiplexers. A glance at the functional diagram, Figure 5, will help clarify this.

In the parallel data version, the channel select byte enters on connector P2 and passes through line receivers and optical couplers. The high order 4 bits select one analog/digital channel on the A/D card, opening a path to one of the 16 signal lines on the 100 line bus. Since each of the other cards, amplifier or DAC-TO-CURRENT cards, is jumpered to one of these signal lines, the high order 4 bits effectively select one of up to 16 cards. The low order 4 bits select one channel on all other cards plugged onto the 100 line bus. Since each card has 16 channels, 256 channels are selectable. The strobe pulse also enters on connector P2 and passes through a line receiver and optical coupler to the strobe logic. It will be worthwhile to go through this carefully, since it will reveal the speed limitation of the subsystem as well as suggest how it can be improved.

The strobe section serves to remove the inhibit from the analog multiplexers and to provide a delay for the channel select byte and amplifier settling time and then to start the analog to digital conversion process: the 4 microsecond strobe pulse starts a 25 microsecond encode delay pulse. At the end of the strobe pulse, the analog MUX inhibit is removed, and at the end of the encode delay, the encode pulse is issued to the analog to digital converter which takes 25 microseconds to digitize. Afterwards, the analog MUX inhibit is reestablished. (The encode pulse is also sent to the digital MUX which sends out an encode pulse to a particular DAC-TO-CURRENT card.) The timing cycle is shown below.



The effective conversion time is, therefore, 50 microseconds. Now the analog multiplexers used in the subsystem are the CMOS type chosen for their low "on" resistance. The 16 CHANNEL TC AMPLIFIER-FILTER card design objective dictated this. Since these multiplexers do not have a "break before make" feature, it is provided in the strobe logic. The operational amplifiers used throughout are a low offset, low drift type, the OP-07CP, again dictated by the thermocouple amplifier design. But they have a slow slewing rate of about 0.2 volts per microsecond. Thus, a 25 microsecond settling time is required. In critical locations, i.e., the followers after the multiplexers and the final amplifier stages, they could easily be replaced with a fast slewing rate type, the OP-15FP, exhibiting about fifteen volts per microsecond. Then the encode delay could be shortened to less than eight microseconds. Furthermore, a high speed analog to digital converter could replace, but not so easily, the type now used, and then the effective conversion time could be reduced to ten or twelve microseconds. Considering the processes being monitored and controlled, however, 50 microseconds is considered adequate.

To this point it has been explained that incoming on connector P2, in the parallel data version, one byte selects a channel and a coincident strobe pulse initiates the analog to digital conversion. The 12-bit data passes through optical couplers and line drivers and is output on connector P3. But the strobe pulse also initiates a pulse to an appropriate DAC-TO-CURRENT card where 12-bit data is converted to a proportional current if the channel select byte's high order 4 bits "match" such a card. This data is input on P4 and passes through line receivers and optical couplers to lines of the bus. It must, however, be present before the channel select byte is sent out by the computer. The other connector, P5, inputs 4 bits and outputs 4 bits for miscellaneous purposes.

Serial data transfer from the SIXTEEN CHANNEL A/D MUX-SERIAL card is comprised of two bytes. The data transfer time is 80 microseconds plus, of course, the line propagation time.

One final feature of the A/D card is an output from its voltage reference I.C. This device, in addition to providing 5 volts stable to less than one milivolt, produces a voltage proportional to ambient temperature. This can be sent through a channel for a remote reading.

Setting up the A/D card involves adjusting the analog to digital converter's gain and offset, adjusting the gain and offset of the final amplifier stages, and placing the appropriate jumpers between the 16 signal lines' pads and pads at the digital and analog multiplexers.

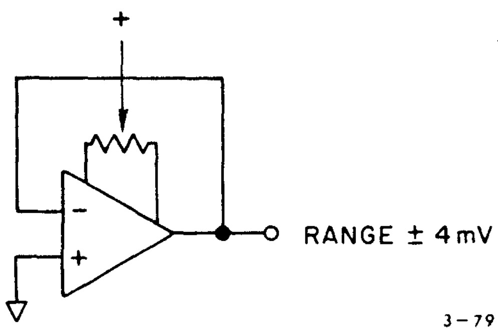
The 16 CHANNEL AMPLIFIER-FILTER MUX card's functional diagram is shown in Figure 6. Connectors P2 and P3 input 16 analog signals from transducers. There are convenient pads at these connectors for mounting precision resistors; these are used if the signals are from constant current devices. The signals are routed through second order, low pass amplifier-filters and on to a 16 channel analog MUX. The gain, offset, polarity and corner frequency of each amplifier is selectable as shown in Figure 7. Beyond the MUX, the signal passes through a follower to one of 16 signal lines on the 100 line subsystem bus via a jumper wire.

There is another version of this card which must be discussed. Since the subsystem has a floating ground and since it is possible that not all tranducer outputs will be floating, the other, isolated version has a 16 dual channel MUX. It allows arbitrarily grounded transducers and arbitrarily grounded thermocouples to share the same bus.

The 16 CHANNEL TC AMPLIFIER-FILTER MUX card's functional diagram is shown in Figure 8. Each amplifier-filter circuit has a gain of 500 and a corner frequency of one Hertz. The circuit is similar to that employed on the card previously discussed; however, each circuit has its own minature +15, -15 volt power supply. Because there is an individually-powered amplifier circuit for each thermocouple, and since 60 Hz noise is attenuated by 70 db, it is possible to read signals from arbitrarily grounded, unshielded thermocouples to a very high degree of accuracy and resolution and at very high speed. (In fact, the thermocouple card's design objective sets standards for the entire subsystem.) Beyond the amplifier circuits, the signals and their grounds pass through a 16 dual-channel analog MUX which is output to a follower. The signal is then jumpered to one of the 16 signal lines on the 100 line subsystem bus, and the card-select address is set.

As mentioned before, the analog multiplexers used throughout the subsystem are the CMOS type. These were chosen for their low "on" resistance, typically 100 ohms. Even with this value, however, a ground current of 10 microamps can create one milivolt, the design resolution, across the ground channel. To minimize this current, the entire subsystem, except for the driver-receiver-optical coupler section on the A/D card, is floating, and it is most important to match the AC line phasing on all power supplies, the main ones as well as those on the thermocouple amplifiers. This is accomplished directly by trial and error. Since on milivolt is considered the resolution of the subsystem, and since the amplifier gain is 500, it was necessary to choose an operational amplifier having an input offset drift of no more than + and - 2 microvolts over an ambient temperature change of + and - 10 degrees centigrade! The OP-07CP has a maximum input offset of 150 microvolts which is nulled on the card, and its drift is a maximum of 1.6 microvolts per degree. Its long term drift is typically one-half microvolt per month. About 30% of these amplifiers exhibit less than one-tenth microvolt per degree input offset, and with the microprocessor, they are readily selected. (The remaining amplifiers are used in less critical locations, and due to its low input offset, the OP-07CP is quite compatible with the design objective of one milivolt resolution.) Since this corresponds to 2 microvolts of thermocouple voltage, a copper-constantan pair can be read to + and - one-tenth degree centigrade at liquid nitrogen temperature.

Setting up the thermocouple card involves nulling the input offset of each amplifier and setting their gains at 500. This large gain demands a stable milivolt source. As shown below, the OP-07CP can be used:



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The potentiometer adjusts the input offset over a range of + and - 4 milivolts. Of course, a thermocouple can be used as an input for gain adjustment. The output from the analog MUX is jumpered to one of the 16 signal lines on the 100 line subsystem bus, and the card-select address is set.

The 16 CHANNEL DAC-TO-CURRENT card's functional diagram is shown in Figure 9. The 12 bits to be converted from the A/D card, enter from the subsystem's 100 line bus. They are input in parallel to a 12-bit latch at each digital to analog converter. A digital demultiplexer converts the low order 4 bits of the channel select byte to one of 16 on-card lines to the latchs' strobe inputs. The encode pulse, from the A/D card, is sent over one of the 16 jumper-selected signal lines through the DEMUX to the selected on-card line to one of the 16 latches. The data is thus transferred to the selected DAC, and its output is converted to a proportional current to operate an E/P converter. This in turn can power a valve operator.

An E/P converter is generally adjusted to produce a "zero" pressure at 4 miliamps and a full-scale pressure at 20 miliamps. Since the DAC's are 12-bit devices, having therefore, 4095 increments of output, it takes 20% of this to produce 4 miliamps. Thus, the resolution is 1/3276. In fact, this can be improved by adjustment of the E/P converter's gain and offset. Furthermore, if a 4 miliamp offset current is introduced at the voltage-to-current converter at each DAC, the full scale resolution of 1/4095 can be obtained. Considering the processes involved, however, adjustment of valves with a resolution of 1/3276 is considered adequate.

The DAC-TO-CURRENT card is set up by adjusting the gain and offset of each DAC, and by adjusting each voltage-to-current converter. The DEMUX's strobe input is jumpered to one of the 16 signal lines, over which the encode pulse is sent, on the 100 line subsystem bus.

To complete this description of the remote interface subsystem, a review of how it is used will now be presented. Suppose it is desired to read the output of a transducer, which is input to a 16 CHANNEL AMPLIFIER-FILTER MUX card, or the output of a thermocouple pair, which is input to a 16 CHANNEL TC AMPLIFIER-FILTER MUX card. Accordingly, the appropriate channel-select byte plus strobe is sent out from the microcomputer through the DRIVER/RECEIVER card to the 16 CHANNEL A/D MUX card. After 50 microseconds, the selected channel's signal is digitized and ready to be read into the microcomputer through the DRIVER/RECEIVER card. If it is desired to move a valve operator, two bytes in succession are output and then the channel select byte plus strobe will cause the chosen DAC to convert 12 bits into a proportional current.

It remains now to describe the TWO CHANNEL DAC card which plugs onto the microcomputer's S-100 bus. It is shown functionally in Figure 10. This card has two channels, each of which convert 12-bit data to analog form. It is useful in producing oscilloscope or recorder displays of accumulated data. The input circuitry is similar to that of the DRIVER/RECEIVER card, and the data is output from the computer in two successive bytes through port-pairs 8 and 9 or 10 and 11 corresponding to analog A and B respectively. Actually, only the lower 4 bits of the second byte, port 9 or 11, is used in the conversion, but bit 7 of the second byte is used to produce a trigger for use externally, and bits 4,5 and 6 can be used to switch an external multiplexer to produce eight oscilloscope or recorder traces from one line of analog data.

The card is set up by adjusting the gain and offset of each DAC and by selecting the output port response with jumpers. Ports 8, 9, 10 and 11 were used as examples above; however, any other four ports can be used if they do not conflict with those used by other cards on the computer's bus.

The overall cost of a complete microcomputer monitoring and control system will, of course, depend upon the number of channels to be accessed. For example, a complete system including the computer and its cards, the remote interface subsystem with enough cards to read 48 thermocouples at a rate of about 10,000 per second, 48 tranducers at the same rate, operate 16 valves, and including some transducers would cost between ten and fifteen-thousand dollars.

FIGURE CAPTIONS

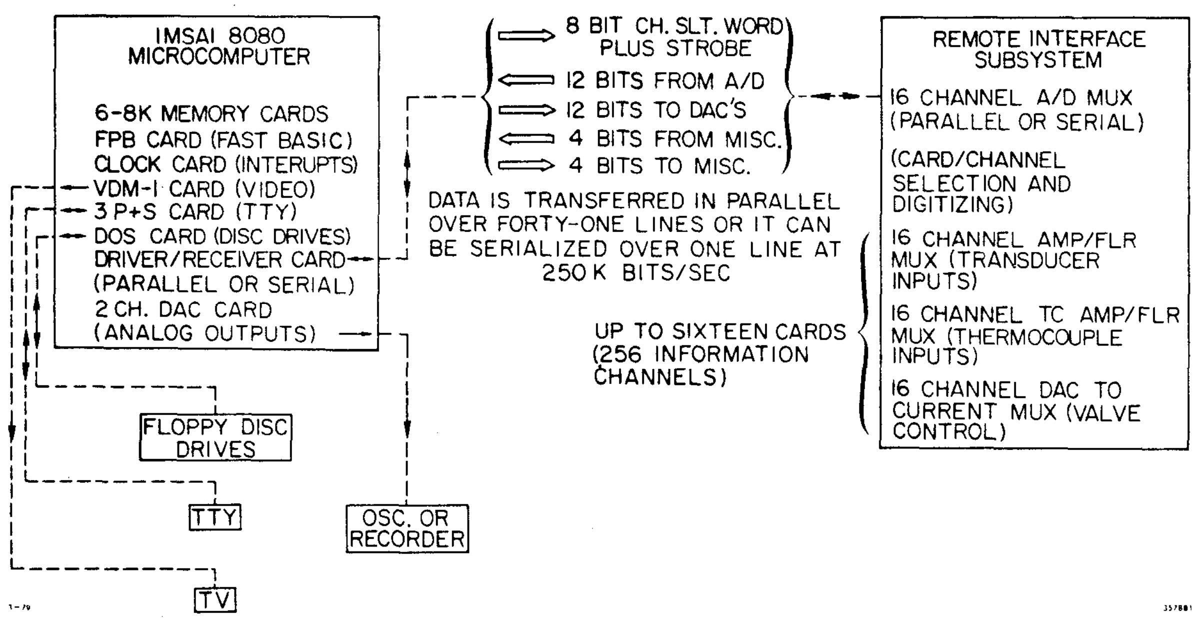

IMSAI 8080
MICROCOMPUTER
6-8K MEMORY CARDS
FPB CARD (FAST BASIC)
CLOCK CARD (INTERUPTS)
VDM-1 CARD (VIDEO)
3 P+S CARD (TTY)
DOS CARD (DISC DRIVES)
DRIVER/RECEIVER CARD
(PARALLEL OR SERIAL)
2 CH. DAC CARD
(ANALOG OUTPUTS)
8 BIT CH. SLT. WORD
PLUS STROBE
12 BITS FROM A/D
12 BITS TO DAC'S
4 BITS FROM MISC.
4 BITS TO MISC.
DATA IS TRANSFERRED IN PARALLEL
OVER FORTY-ONE LINES OR IT CAN
BE SERIALIZED OVER ONE LINE AT
250 K BITS/SEC
UP TO SIXTEEN CARDS
(256 INFORMATION
CHANNELS)
REMOTE INTERFACE
SUBSYSTEM
16 CHANNEL A/D MUX
(PARALLEL OR SERIAL)
(CARD/CHANNEL
SELECTION AND
DIGITIZING)
16 CHANNEL AMP/FLR
MUX (TRANSDUCER
INPUTS)
16 CHANNEL TC AMP/FLR
MUX (THERMOCOUPLE
INPUTS)
16 CHANNEL DAC TO
CURRENT MUX (VALVE
CONTROL)
FLOPPY DISC
DRIVES
TTY
OSC. OR
RECORDER
TV

Fig. 1

THE SERIAL VERSION OF THIS BOARD HAS A DATA RATE OF 250 K BITS/SEC

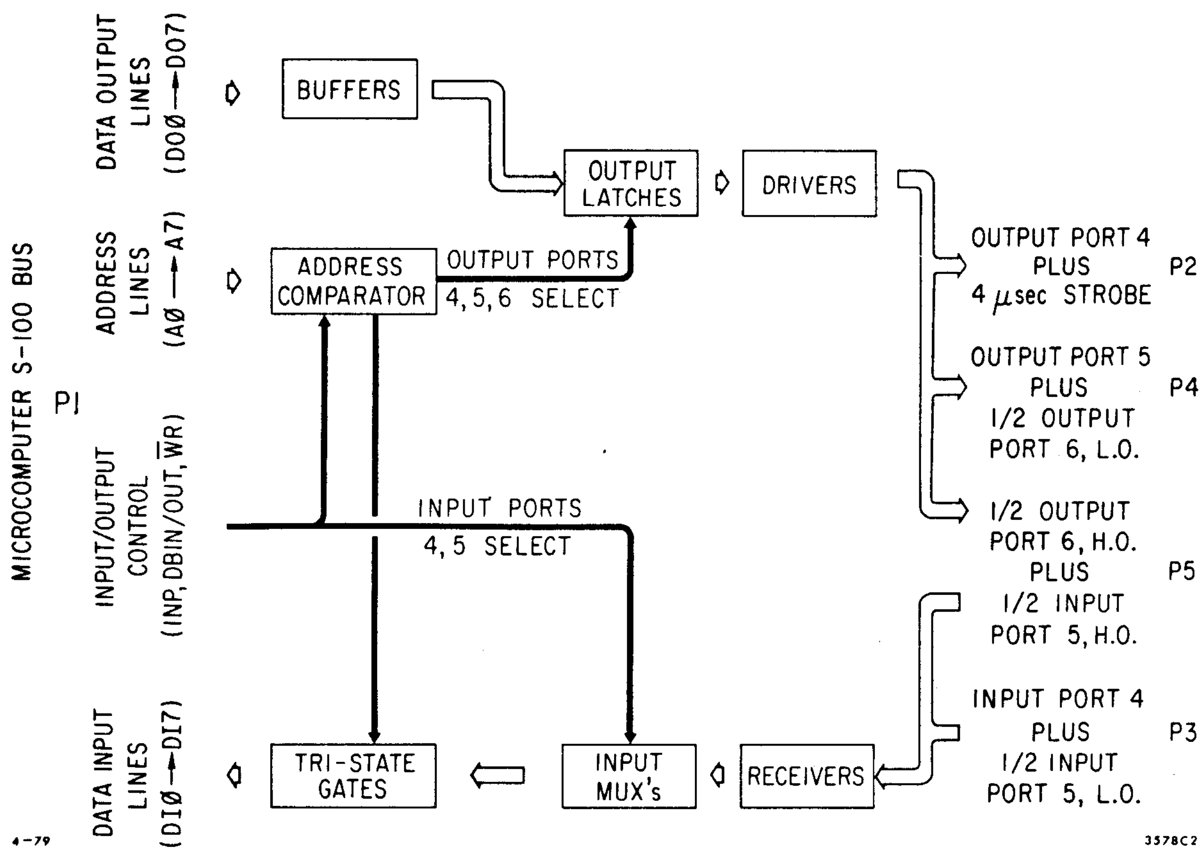
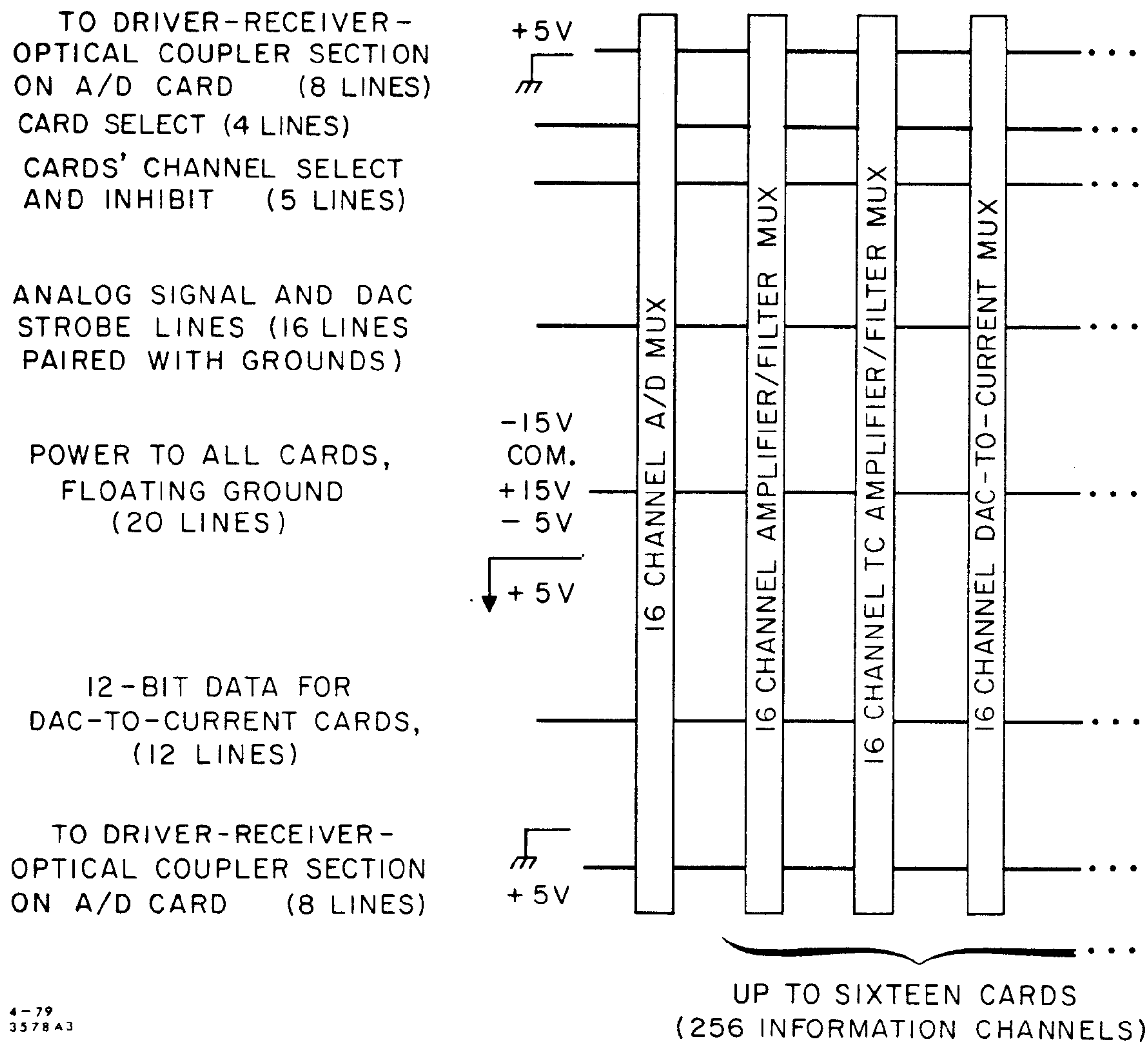


Fig. 2


TO DRIVER-RECEIVER-
OPTICAL COUPLER SECTION
ON A/D CARD (8 LINES)
CARD SELECT (4 LINES)
CARDS' CHANNEL SELECT
AND INHIBIT (5 LINES)
ANALOG SIGNAL AND DAC
STROBE LINES (16 LINES
PAIRED WITH GROUNDS)
POWER TO ALL CARDS,
FLOATING GROUND
(20 LINES)
12-BIT DATA FOR
DAC-TO-CURRENT CARDS,
(12 LINES)
TO DRIVER-RECEIVER-
OPTICAL COUPLER SECTION
ON A/D CARD (8 LINES)
+5V
-15V
COM.
+15V
-5V
+5V
+5V
16 CHANNEL A/D MUX
16 CHANNEL AMPLIFIER/FILTER MUX
16 CHANNEL TC AMPLIFIER/FILTER MUX
16 CHANNEL DAC-TO-CURRENT MUX
UP TO SIXTEEN CARDS
(256 INFORMATION CHANNELS)
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3578A3

Fig. 3

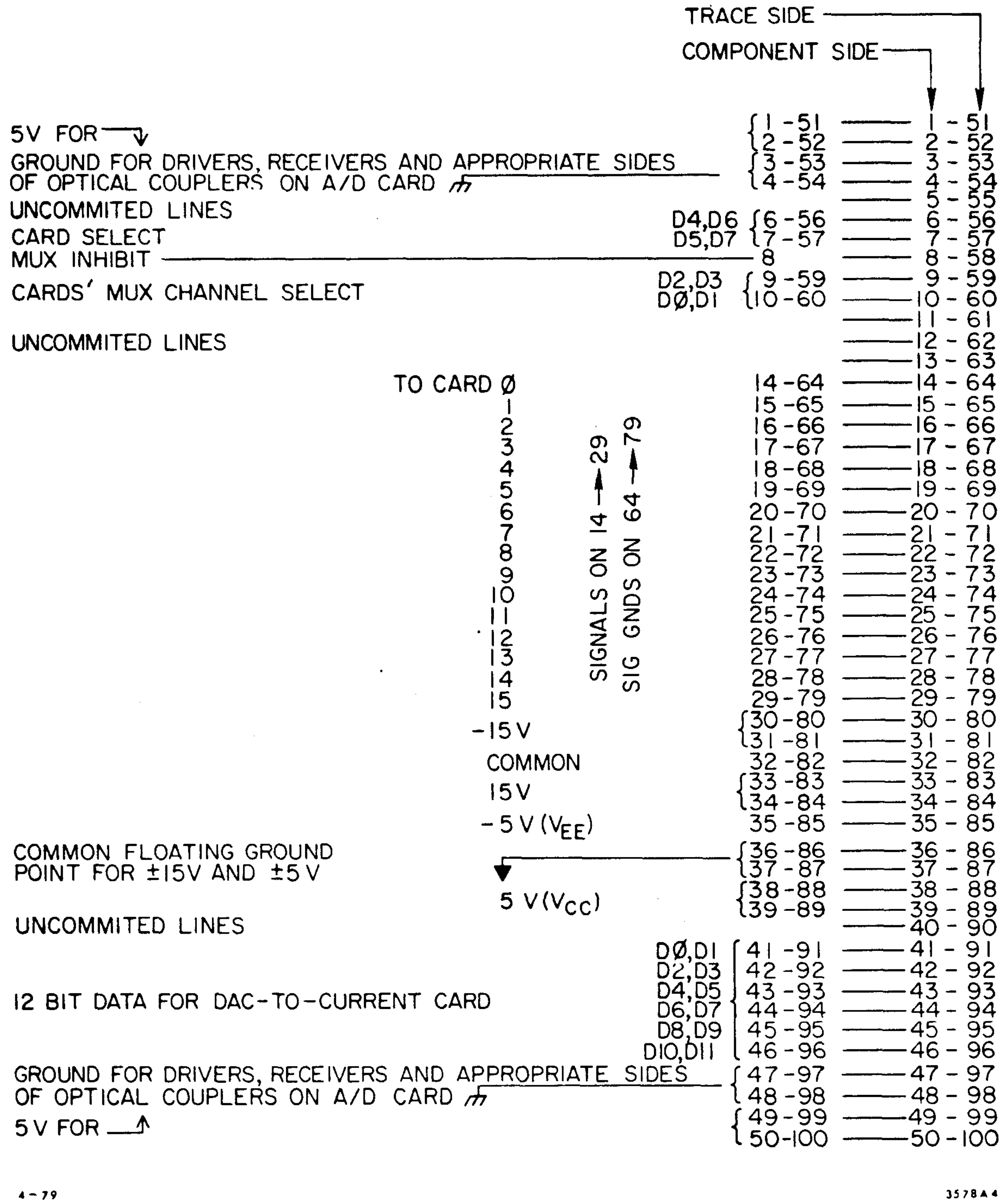
TRACE SIDE
COMPONENT SIDE
5V FOR
GROUND FOR DRIVERS, RECEIVERS AND APPROPRIATE SIDES OF OPTICAL COUPLERS ON A/D CARD
UNCOMMITED LINES
CARD SELECT
MUX INHIBIT
CARDS' MUX CHANNEL SELECT
UNCOMMITED LINES
D4,D6
D5,D7
D2,D3
DØ,D1
TO CARD Ø
SIGNALS ON 14 → 29
SIG GNDS ON 64 → 79
-15V
COMMON
15V
-5 V (VEE)
COMMON FLOATING GROUND POINT FOR ±15V AND ±5V
5 V(VCC)
UNCOMMITED LINES
12 BIT DATA FOR DAC-TO-CURRENT CARD
DØ,D1
D2,D3
D4,D5
D6,D7
D8,D9
D10,D11
GROUND FOR DRIVERS, RECEIVERS AND APPROPRIATE SIDES OF OPTICAL COUPLERS ON A/D CARD
5 V FOR
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Fig. 4

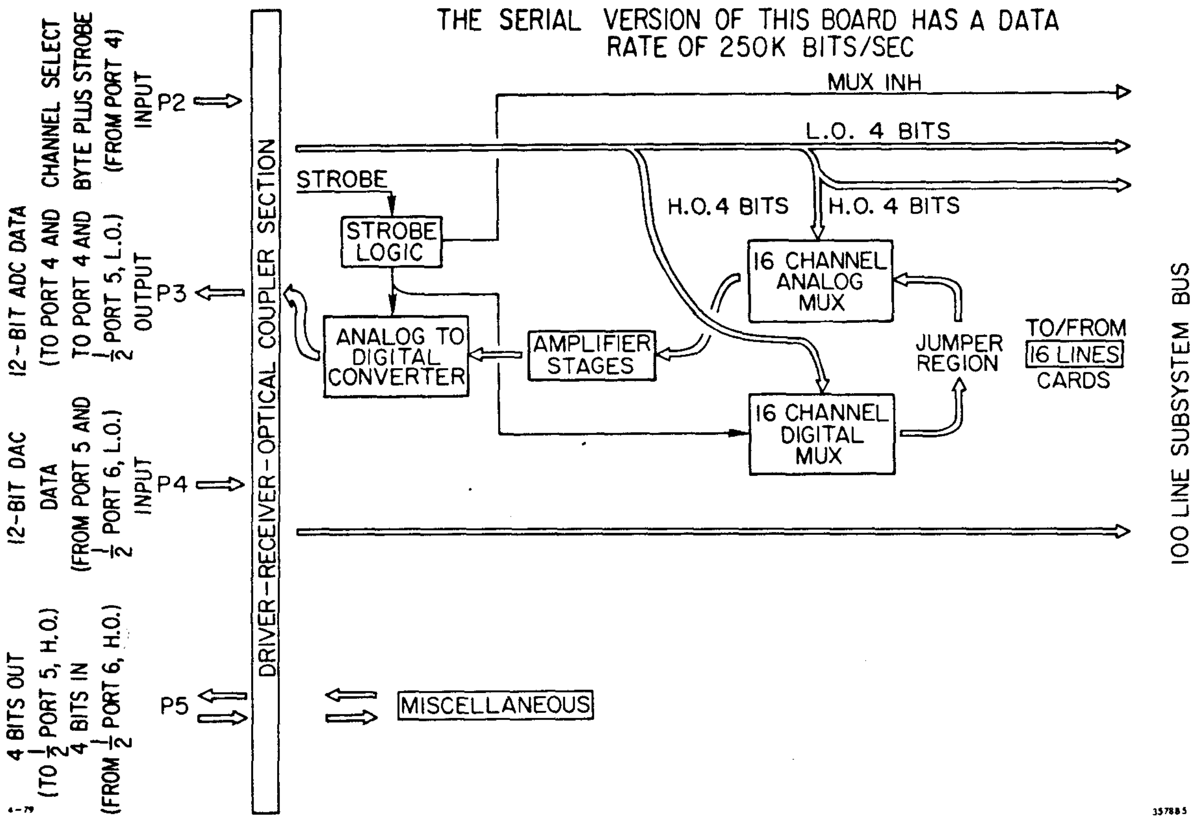

THE SERIAL VERSION OF THIS BOARD HAS A DATA RATE OF 250K BITS/SEC
CHANNEL SELECT BYTE PLUS STROBE (FROM PORT 4) INPUT
P2
12-BIT ADC DATA (TO PORT 4 AND TO PORT 4 AND 1/2 PORT 5, L.O.) OUTPUT
P3
12-BIT DAC DATA (FROM PORT 5 AND 1/2 PORT 6, L.O.) INPUT
P4
4 BITS OUT (TO 1/2 PORT 5, H.O.) 4 BITS IN (FROM 1/2 PORT 6, H.O.)
P5
DRIVER-RECEIVER-OPTICAL COUPLER SECTION
MUX INH
L.O. 4 BITS
STROBE
H.O. 4 BITS
H.O. 4 BITS
STROBE LOGIC
16 CHANNEL ANALOG MUX
ANALOG TO DIGITAL CONVERTER
AMPLIFIER STAGES
JUMPER REGION
TO/FROM 16 LINES CARDS
16 CHANNEL DIGITAL MUX
MISCELLANEOUS
100 LINE SUBSYSTEM BUS

Fig. 5

The isolated version of this board has a 16 DUAL CHANNEL ANALOG MUX. It allows input of arbitrarily grounded transducers, and the board can then share the same bus as a thermocouple board having arbitrarily grounded inputs.

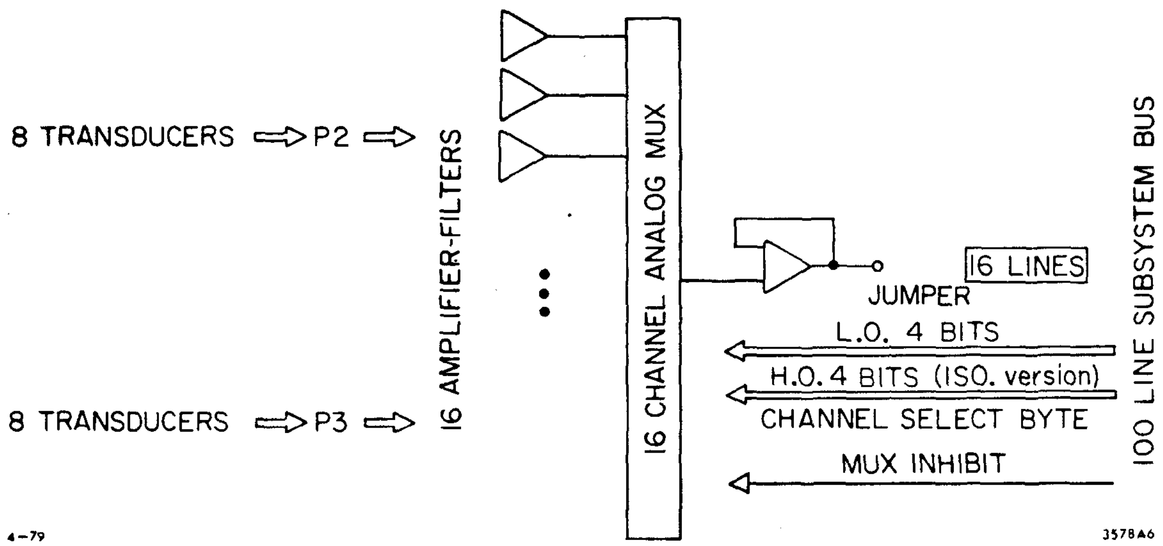
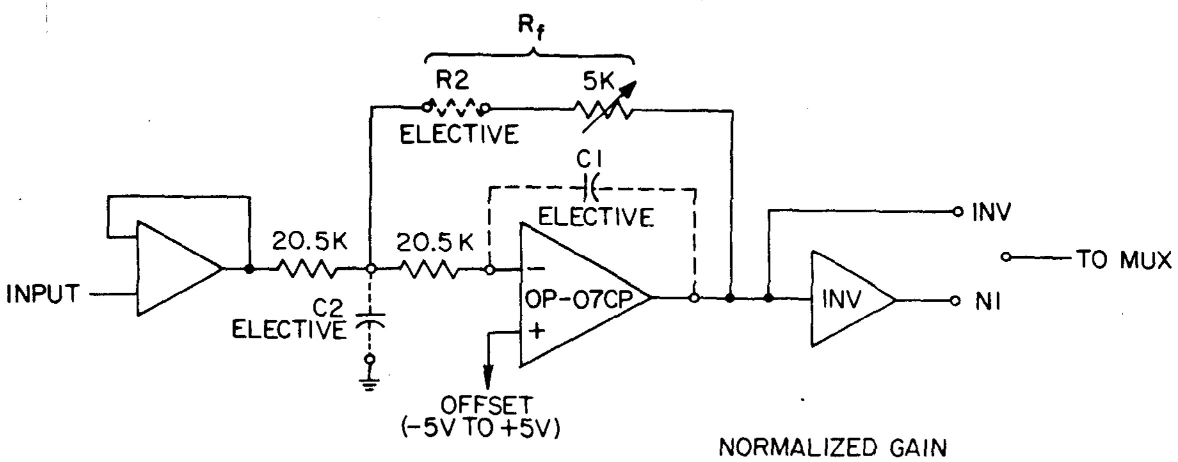
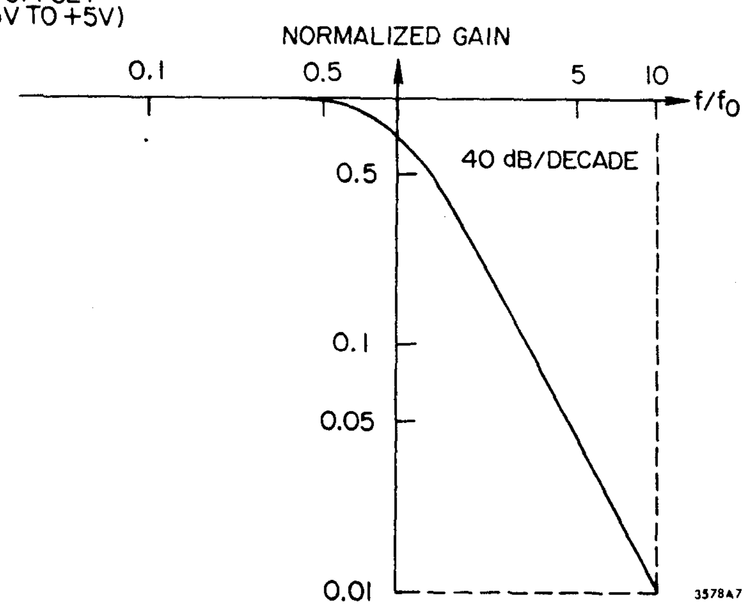


Fig. 6





$$\text{D.C. GAIN} = -\frac{R_f}{20.5K}$$

$$C2 = \frac{0.113}{f_0}\left(\frac{2}{20.5K} + \frac{1}{R_f}\right)$$

$$C1 = \frac{0.224}{f_0(2*R_f + 20.5K)}$$

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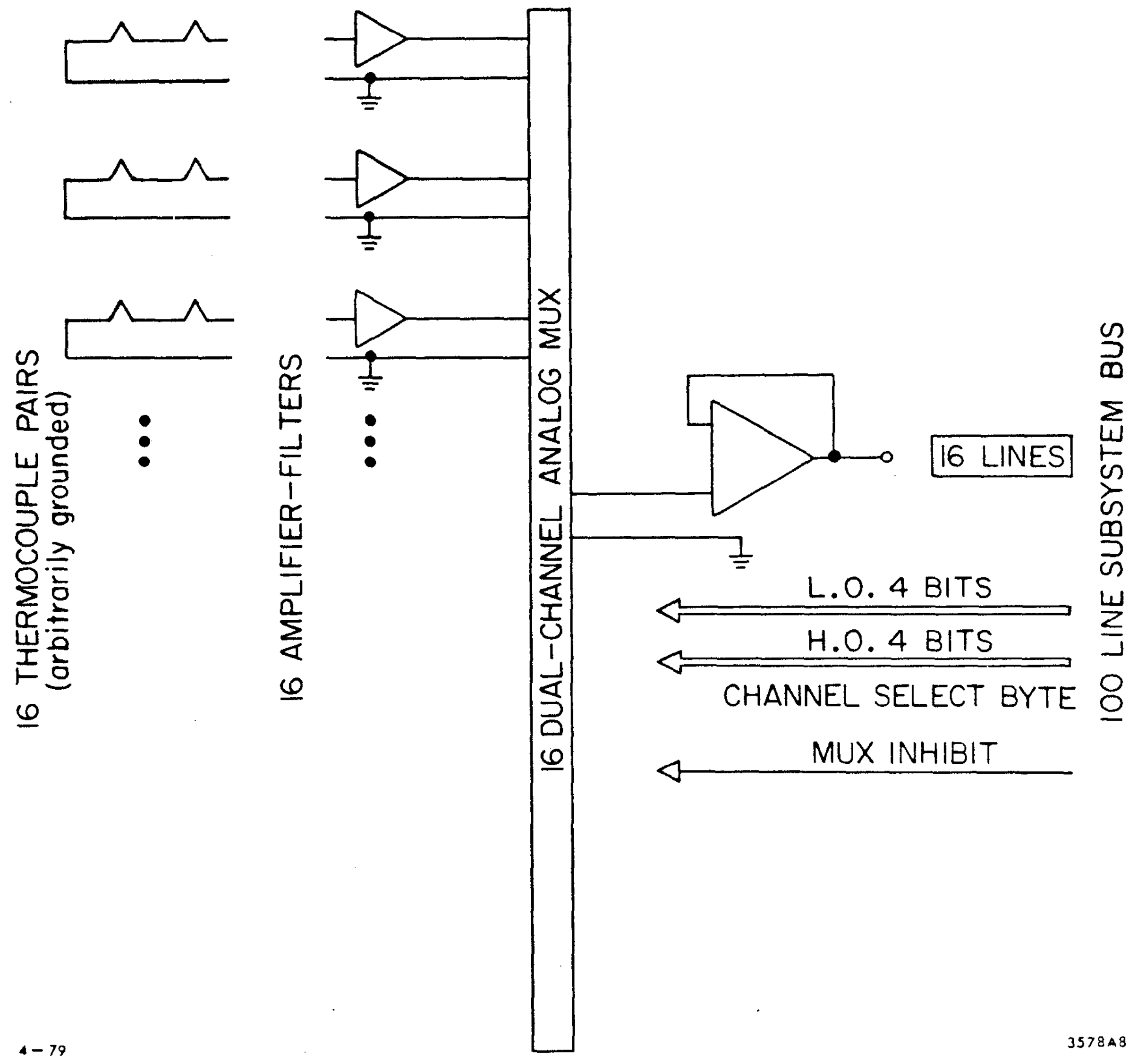
Fig. 7


16 THERMOCOUPLE PAIRS
(arbitrarily grounded)
16 AMPLIFIER-FILTERS
16 DUAL-CHANNEL ANALOG MUX
16 LINES
L.O. 4 BITS
H.O. 4 BITS
CHANNEL SELECT BYTE
MUX INHIBIT
100 LINE SUBSYSTEM BUS
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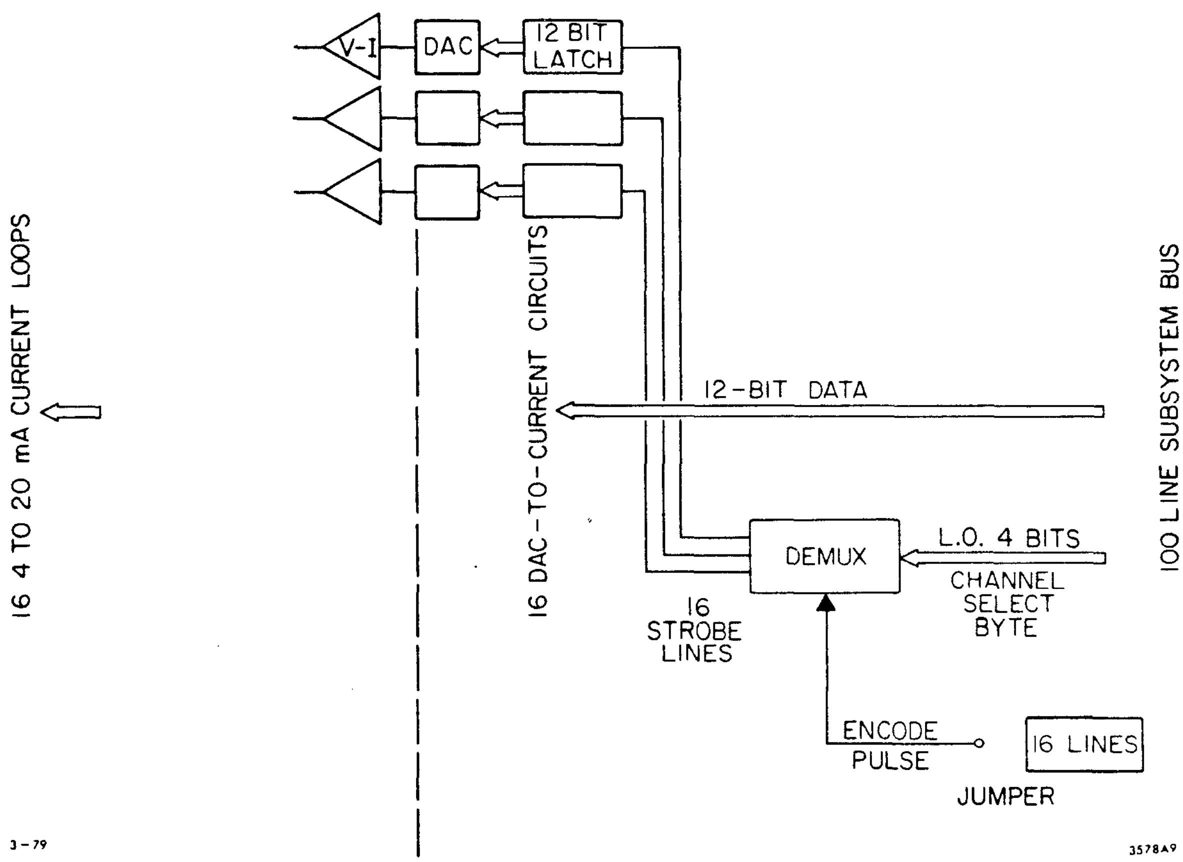
3578A8

Fig. 8


16 4 TO 20 mA CURRENT LOOPS
V-I
DAC
12 BIT LATCH
16 DAC-TO-CURRENT CIRCUITS
12-BIT DATA
100 LINE SUBSYSTEM BUS
DEMUX
L.O. 4 BITS
CHANNEL SELECT BYTE
16 STROBE LINES
ENCODE PULSE
16 LINES
JUMPER
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3578A9

Fig. 9

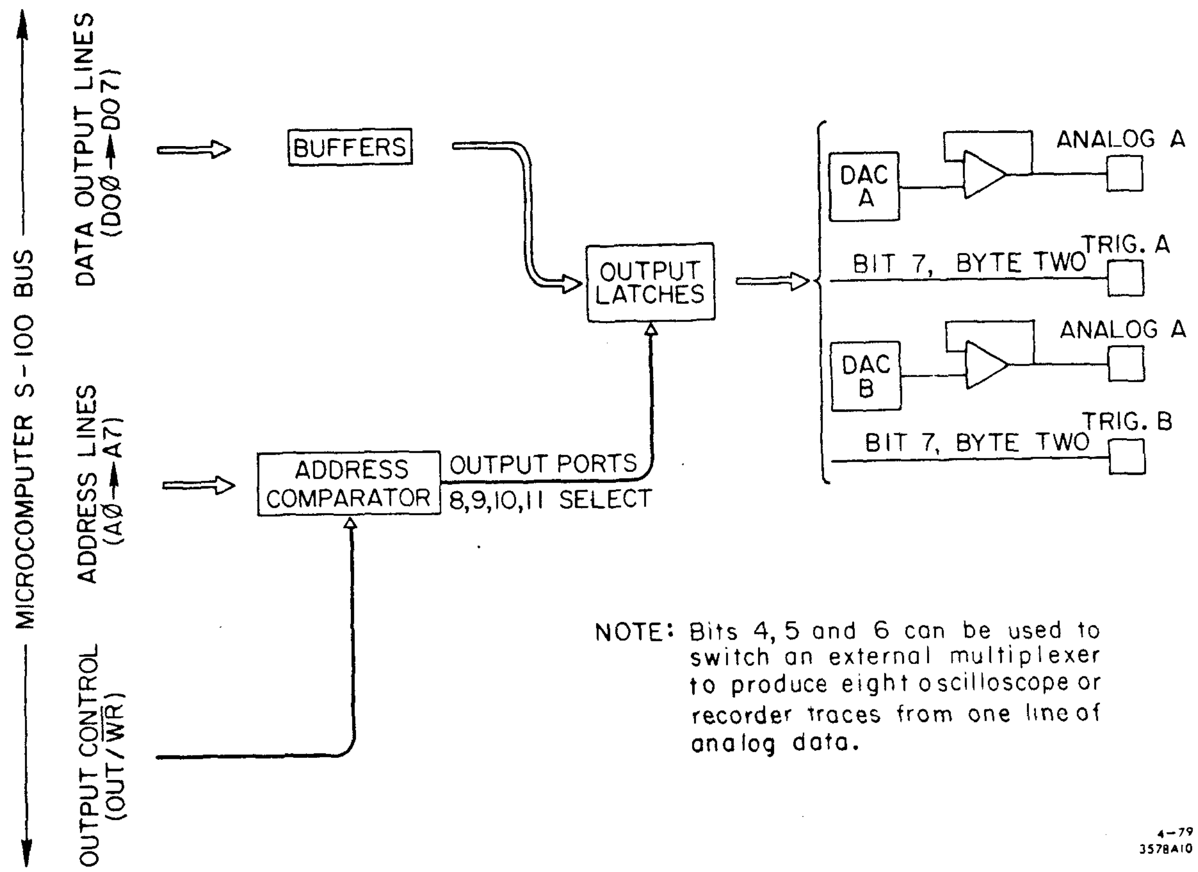
MICROCOMPUTER S-100 BUS
DATA OUTPUT LINES (DOØ→DO7)
ADDRESS LINES (AØ→A7)
OUTPUT CONTROL (OUT/WR)
BUFFERS
OUTPUT LATCHES
ADDRESS COMPARATOR
OUTPUT PORTS 8,9,10,11 SELECT
DAC A
ANALOG A
BIT 7, BYTE TWO
TRIG. A
DAC B
ANALOG A
BIT 7, BYTE TWO
TRIG. B
NOTE: Bits 4, 5 and 6 can be used to switch an external multiplexer to produce eight oscilloscope or recorder traces from one line of analog data.
4-79
3578A10

Fig. 10