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Design of a Microprocessor-Based Control, Interface and Monitoring (CIM) Unit for Turbine Engine Controls Research

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DESIGN OF A MICROPROCESSOR-BASED CONTROL, INTERFACE, AND MONITORING (CIM) UNIT FOR TURBINE ENGINE CONTROLS RESEARCH

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E-1725

SUMMARY

High speed minicomputers have been used in the past to implement advanced digital control algorithms for turbine engines. These minicomputers are typically large and expensive. It is desirable for a number of reasons to use microprocessor-based systems for future controls research. They are relatively compact, inexpensive, and are representative of the hardware that would be used for actual engine-mounted controls. The Control, Interface, and Monitoring Unit (CIM) contains a microprocessor-based controls computer, necessary interface hardware and a system to monitor the control while it is running an engine. It is presently being used to evaluate an advanced turbofan engine control algorithm.

INTRODUCTION

In recent years, advanced turbine engine control algorithms have been successfully implemented on high speed minicomputers (refs. 1 to 3). However, there is a distinct disadvantage to this approach. Minicomputers typically occupy several large cabinets (fig. 1). In addition, the minicomputer shown required interface hardware occupying a double 19 inch relay rack (fig. 1) (ref. 4). Obviously, actual engine controls would not be implemented on a processor this size. So, to lend credibility to future research, hardware similar to that which would be used by manufacturers of engines and controls is desired. Off-the-shelf 16-bit microprocessors are now available which are capable of executing advanced control software in real-time. Because of their small size and low cost, these microprocessors could then make research in distributed controls and multiprocessing feasible at a reasonable cost. Thus, it would be desirable to verify that implementing advanced control algorithms on one of these processors is indeed possible.

Several features are necessary in the system on which this research is to be carried out. First, the hardware must be portable so that it can be moved to either a simulation facility or an engine test facility as needed. Second, since this is a research environment, one must be able to interrogate the control while it is running to verify that it is indeed doing what it is supposed to. Lastly, the unit should have the flexibility to adapt to future applications so that new hardware does not have to be fabricated for each new research undertaking that arises.

The Control, Interface, and Monitoring (CIM) Unit has been designed to meet these needs. An overall description of the unit, along with detailed design information are presented in this report. A typical user session is presented in the appendix.

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OVERALL DESCRIPTION

The CIM unit consists of two major functional blocks (fig. 2), housed in a double relay rack (fig. 3). The first functional block is the Microcomputer Control. It consists of a commercially available single board computer, input/output boards which interface to the single board computer, and a pair of floppy disk drives and their controller board. The circuit boards are mounted in a standard-width chassis which also contains the necessary power supplies.

The Intel 8086 was chosen for the processor on which to base the microcomputer control unit. It was a readily available 16 bit processor and was felt to have the speed necessary to execute advanced turbine engine control algorithms. Also, it supported an arithmetic co-processor which could eventually allow controls to be implemented using floating point arithmetic.

The second major functional block of the CIM unit is the Interface and Monitoring Module (fig. 2). The interface portion of this module consists of three elements. Connectors in the base of the CIM unit bring signals in and out of the unit. A patch panel is used to correlate signals from outside the CIM unit with signals inside the CIM unit. Lastly, buffer amplifiers are provided in case any of these signals should require buffering. These elements and how they relate to the rest of the CIM unit are shown in figure 4. Also shown in figure 4 are the functional elements used for monitoring. If an operational control were being designed, the control and its interface hardware would be sufficient. However, since the CIM unit is being used in a research environment, it is necessary to be able to interrogate the control while it is running to determine if it is operating correctly. The monitoring system provides this capability. Any signal in the CIM unit can be selected at the front panel by the user. This signal is then displayed in either volts or engineering units, whichever is more meaningful to the user.

To accomplish the monitoring function, all the I/O signals to and from the CIM unit are fed to a many input, single output multiplexer. This multiplexer then selects the desired channel and outputs it to a scaling circuit which can scale the signal so that it looks like either volts or engineering units. The user selects the desired readout with a switch on the front panel. The output of the scaling circuit is then displayed on a digital volt meter (DVM) on the CIM unit front panel. An alphanumeric display is provided to inform the user what units are being displayed on the DVM.

A microcomputer is used to control all the monitoring functions. A single board system was custom-designed for this purpose. It incorporates an Intel 8085 and the necessary peripherals and memory. The 8085 was chosen because of familiarity with the processor and because Intel development hardware and software had already been acquired to support the 8086 used for the control microcomputer. Also, the performance required for the monitoring system did not warrant the increased hardware complexity of a system designed around the 8086 microprocessor. The 8085 microcomputer, then, provides an intelligent monitoring system which in turn provides through software, the flexibility to add features as well as modify and enhance existing ones.

Finally, figure 4 shows the switches and indicator lights which are also part of the monitoring system. These are located on the CIM unit display panel (fig. 3). Their inputs and outputs are available at the patch panel so that their function can be defined by the user. Potential applications for these include mode switches and status lights for the control microcomputer.

All the electronics for the monitoring system are contained in two rack-mountable chassis. The analog electronics are in one chassis and the digital electronics in the other. These chassis are isolated to prevent coupling of digital noise into the analog signals which are being monitored. They are the two chassis shown in the right side of figure 3.

DETAILED SYSTEM DESCRIPTION

Controls Hardware

As mentioned earlier, the control microcomputer is based on the Intel 8086. An off-the shelf, single board computer, the iSBC 86/12A is used (fig. 5). This is a printed circuit board containing a 5 Mhz 8086 as its central processing unit (CPU). In addition the board contains 32 kilobytes of dynamic random access memory (RAM), 32 kilobytes of expansion RAM, and 32 kilobytes of erasable, programmable read only memory (EPROM). The board also has 24 parallel input/output lines, a serial input/output port, and 2 programmable counter/timers. The board can accept an 8087 (iSBC 337) numerics coprocessor which gives the 8086 the ability to handle floating-point arithmetic. This is very useful for converting scaled integers, which the control uses, into engineering units which are easily readable by the user. Lastly, the 86/12A is Multibus compatible. The Multibus/IEEE 796 is a standard microprocessor backplane interface bus originally developed by Intel. There is a multitude of boards from a variety of vendors compatible with this bus. This allows the user to select as off-the-shelf just about whatever support boards are required.

The iSBC 86/12A is mounted in a chassis which contains the Multibus interface and the necessary power supplies. This chassis has slots for eight Multibus compatible circuit boards and is shown in figure 6. The iSBC 86/12A uses one of these eight slots. Six of the remaining seven slots in the chassis are used in the present configuration shown in figure 7. The first slot below the processor card contains the floppy disk controller. This board provides on-line floppy disk support and allows the use of a disk operating system in conjunction with the control hardware and software. The controller used, supports up to four drives and can read and write either single or double density disks. Presently, two double density drives are being supported by this one controller board.

Three boards are used for analog I/O. Two are analog output boards and the third is an analog input board. Both analog output boards use 12-bit digital to analog converters (DAC's). One board contains eight DAC's and the other contains four DAC's for a total of twelve DAC's altogether. The analog input board, can support up to 32 differential inputs. These inputs are multiplexed to a single 12-bit, analog to digital converter.

There are two boards which support discrete I/O. The first supports 24 discrete contact closure inputs. The second has 32 contact closure (relay closure) outputs. The disk controller and all of the I/O boards are controlled through the Multibus by the 8086 processor.

Controls Software

The controls hardware runs under the control of a commercially available disk operating system, CP/M-86, which occupies about 12 kilobytes of the 64 kilobytes of RAM available on the 86/12A board. This operating system loads programs and data from disk into processor memory and manipulates programs and data on the disks. User programs can also make use of CP/M-86 facilities. One program which makes use of these facilities is the Microprocessor Interactive Data System (MINDS) developed at NASA Lewis. This software is used to extract data from the control while it is running. MINDS can examine variables which are internal to the control software. It pulls these values directly from the control computer's memory and saves them for display on a user terminal or for output to a plotting device or mainframe computer. A program similar to MINDS but less sophisticated is described in reference 5. MINDS makes extensive use of the 8087 math co-processor and occupies about 16 kilobytes of RAM. The remaining 36 kilobytes of memory are available for the actual control algorithm software and other user programs.

Interface Hardware

The patch panel, which was shown in figure 4, is the heart of the CIM unit interface hardware. It consists of two 34x24 connection panels joined together and divided into groups of three connections (fig. 8). This allows high, low, and shield connections for each signal to be passed through the patch panel. The signals available at the patch panel include the trunk lines and outputs to the data recorders from the base connectors, all the analog and discrete I/O signals from the controls computer, the buffer amplifier inputs and outputs, and the status light inputs and switch outputs from the display panel. Thus, any signal at the base connectors can be made available to the controls microcomputer with or without buffering, the lights and switches on the display can be tied to the control discrete I/O if desired, or any signal can be fed to an external device such as a chart recorder. In addition to the signals mentioned, the patch panel also has +5 volt, +10 volt, and ground areas for testing, and jumper areas A1-A4 for signals which need to go to more than one place.

The base connectors, located in the bottom of the CIM unit are shown in figure 9. These connectors are each configured to carry 10 signal pairs with shield. The 128 trunk line signals which are used to interface to an engine or simulation are brought through these connectors along with twenty signals reserved for interfacing with external data recording devices such as chart recorders.

The final components of the interface hardware are the buffer amplifiers. The operational amplifiers chosen are particularly good for stable driving of capacitive loads such as trunk line cabling. The inputs and outputs of these amplifiers are brought to the patch panel so that any signal being input to or output from the CIM unit can be buffered if desired. A diagram of the circuit incorporating these buffer amplifiers can be found in figure 10.

Monitoring Hardware

All the signals going to and coming from the CIM unit and all the signals going to and coming from the controls microcomputer are brought to the switching matrix (fig. 11). The switch matrix acts as a 256 differential input, single differential output multiplexer. To reduce common mode capacitance and leakage current effects, a two stage configuration is used (fig. 12). The first stage is composed of sixteen groups of solid-state switches, each group having sixteen inputs and one output (fig. 13). The second stage accepts the sixteen ouputs of the first stage and produces the final output of the system. Eight address lines allow selection of any one of 256 channels. Four address lines go to each stage of the switch matrix. The four least significant address lines are tied to each of the sixteen groups of switches in the first stage and the four most significant address lines are tied to the single group of switches in the second stage.

CMOS analog switches were chosen to implement the switch matrix. The specific analog switches chosen exhibit low on impedance, have overvoltage and latchup protection, and low leakage current. The inputs to the switches are TTL compatible. A CMOS multiplexer (U1 on fig. 13) was chosen to drive the inputs to the switches. These multiplexers have low power consumption and when driven from a 5 volt power supply, satisfy the input requirements of the analog switches. Also, their rise time is slower than a compatable TTL part which in turn reduces the chance of high frequency noise coupling into the analog signals being multiplexed.

In designing the switch matrix, efforts were made to minimize crosstalk between channels and to minimize loading of the signals being multiplexed. In this way , the switch matrix is close to invisible to the signals. To help minimize crosstalk between channels during switching, an open channel is selected between selected channels to insure that the deselected channel turns completely off before the selected channel starts to turn on. Also, the twisted pair, shielded cables used to carry the signals through the CIM unit are tied directly to the backplane of the switch matrix to minimize crosstalk and noise (fig. 9).

The output of the switching matrix is fed to the scaling circuit shown in figure 14. This circuit uses a very high input impedance instrumentation amplifier to prevent loading of the input signal. This amplifier is configured for unity gain. Its output is used as the reference input to a 14-bit multiplying digital to analog converter (MDAC). The MDAC then multiplies the input signal by one or a fraction thereof and feeds this signal to a 4 1/2 digit, digital voltmeter (DVM) located on the CIM Unit display panel. This causes the voltage on the DVM to appear as volts or, when multiplied by the appropriate fraction, as engineering units. The DVM decimal point, which is controlled externally to the DVM, is then placed to cause the display to appear as the proper units.

A switch is provided on the CIM unit display panel (fig. 15) to allow the user to select whether volts or engineering units should be displayed on the DVM. This switch also lights the appropriate half of its panel face to inform the user which units have been selected.

A keyboard on the display panel allows the user to input to the monitoring system. This keyboard has eighteen keys: ten keys for the numbers 0-9 and the other eight for functions. The numeric keys are used to select the channel number which the user wishes to monitor. The SET key then enters this channel number into the monitoring system. Keys are provided to increment and decrement the channel number, and also to switch back to the previously selected channel. These allow rapid scanning of channels. A shift key is provided to allow each of the keys to take on two functions if desired. Finally, the monitoring system reset is also at the keyboard. Two keys, labeled A and B presently have no defined function.

In addition to the DVM there are three other displays on the CIM unit display panel. A numeric display is provided to inform the user which channel has been selected. This display consists of four single-digit seven-segment LED displays grouped together. These accept Binary-Coded-Decimal (BCD) input. The second display is a 40 character, 5x7 dot matrix, vacuum flourescent alphanumeric display. It accepts either parallel or serial ASCII data and is designed to be interfaced directly to a microprocessor. Examples of its use are in figure 15 and 16. The third display is a five digit alphanumeric display which is not used at present.

Also on the display panel are the input switches and the indicator lights (fig. 15). The switches are alternate action, double-pole switches. When activated they close across the inputs brought to them and also light their front panel face. The indicator lights have the same panel face as the switches. They are lighted by closing across their inputs. In addition, there are 16 spares which can be used as either lights or switches.

Monitoring System Microcomputer

All the monitoring functions are controlled by a microprocessor-based system. This system consists of a single board computer, custom designed and fabricated at NASA Lewis, which is based on the 8085 microprocessor (fig. 17). This board contains the microprocessor, 8 kilobytes of eraseable, programmable, read only memory (EPROM), 1 kilobyte of Random Access Memory (RAM), a keyboard-display controller, 2 parallel port chips, and all the necessary buffering and interface hardware. A block diagram showing the major parts of this microcomputer can be found in figure 18. Further information on the 8085 and its peripherals can be found in reference 5. The circuit diagram for the 8085 microprocessor and its address, data and control bus buffers is shown in figure 19. The 8085 microprocessor has its lower eight address lines and the eight data lines multiplexed onto the same pins (AD0-7). The two 8212 input/output ports shown in figure 19 are used to demultiplex these lines and also to buffer the address lines. The data lines require bidirectional buffers. Two 8216 bidirectional bus drivers are used for this purpose with the RD/ line controlling the data direction. A third 8216 is used to buffer the control bus signals. The buffered address, data, and control signals are used throughout the monitoring system microcomputer. In addition, these signals are also bussed across the backplane of the digital chassis. This makes it possible to expand the capabilities of the microcomputer, if necessary, by adding cards to the digital chassis.

The memory and all of the peripherals in the monitoring system microcomputer are memory mapped, that is, they are addressed as if they were locations in memory. Several 3205 one-out-of-eight decoders are used with the address bus to generate the chip select signals for the memories and peripherals. This insures that each memory and peripheral chip has an unique address. A map of these addresses is shown in figure 20.

Two types of memory are used in this microcomputer. The first type is Erasable, Programmable, Read Only Memory or EPROM. This memory retains its data when the power is turned off and so is used to store the microcomputer program. Two kilobyte, ultraviolet erasable 2716 memory chips are used for this purpose (fig. 21). However, these memories have an access time slower than the 8085 microprocessor which is reading data from them. A wait-state generator circuit, shown schematically in figure 22, is used to compensate for these slower memories. It halts the 8085 for one machine cycle whenever one of the 2716 EPROM chips is selected. The second type of memory used is Random Access Memory or RAM. This memory is volatile, that is it does not hold its data when the power is turned off. Thus, this memory is used for temporary data storage while the program is running. A pair of 2114 static RAMS are used (fig. 21). These 1024x4 bit memories are fast enough that no wait-state generator circuitry is required.

The display panel keyboard and channel display interface to the microcomputer through the 8279-5 keyboard/display controller (fig. 23). This controller accepts data from the 8085 processor for output to the channel display and supplies data to the 8085 as to which key, if any, has been pressed. It controls all scanning and encoding/decoding functions required for this interface. Parallel I/O ports are needed to provide the scale factor to the multiplying DAC, the address to the switch matrix and to drive the DVM decimal points. In addition, one I/O line is used to read the Engineering Units/Volts switch on the display panel. Two 8255 programmable peripheral interface chips are used for these purposes (fig. 23). Each has three 8-bit parallel ports. Two ports are used for the 15-bit MDAC scale factor, one port is used for the 8-bit switch matrix address, one port is used for the 4 bit DVM decimal point drivers and one line is used to sense the Engineering Units/Volts switch. The decimal point drivers are buffered to withstand the high off-voltage of the DVM decimal points.

The 5x7 dot matrix alphanumeric display interfaces directly to the 8085 address, data, and control buses (fig. 24). Data is written to the display and status read from the display as if it were an 8085 peripheral. This makes interfacing to the display very straightforward.

Monitoring System Software

The software for the monitoring system microcomputer is divided into seven functional modules called CMMAIN, CIMINT, CIMIN, CIMCMP, CIMEUT, CIMOUT, and CIMDAT. The organization of these modules is shown in figure 25.

The monitoring software executive, CMMAIN, is jumped to whenever the RESET button is pushed or the power turned on. It initializes the stack, calls the initialization routine CIMINT, and then goes into a loop which calls CIMIN, CIMCMP, and CIMOUT continuously. A flow chart of CMMAIN can be found in figure 26.

CIMINT initializes all the monitoring system peripherals (fig. 27). These include the 8279 and 8255 chips, the displays, the switch matrix address, the MDAC scale factor, and the DVM decimal point placement. The routine outputs an initialization message to the alphanumeric display during this process. When finished, it then outputs a message requesting the user to select a channel for display.

The input routine, CIMIN, checks for input from either the EU/Volts switch or the display panel keyboard (fig. 28). It stores the input and sets a flag indicating there has been input.

CIMCMP determines what action to take depending on what the user input was. It then supplies the appropriate outputs to the output routine (fig. 29). If the EU/volts switch has been changed, it fetches the new scale factor, decimal point placement, and message for the alphnumeric display from memory. If a key has been pressed, CIMCMP determines if it is a number or a function key. If it is a number, a flag is set telling the output routine to output the number to the channel display. If it is a function key, then the appropriate function is carried out. CIMEUT is the subroutine used by CIMCMP to fetch DVM decimal point placement, alphanumeric display messages, and MDAC scale factors from memory (fig. 30). This data is then saved for output by the output routine. All of the data required by CIMEUT is contained in CIMDAT. The way the data is set up in CIMDAT is shown in figure 31.

The last subroutine is the output routine, CIMOUT. This routine takes the data supplied by CIMCMP and outputs it to the alphanumeric message display, the channel number display, the multiplying DAC, the DVM decimal point drivers, and the switch matrix (fig. 32). It outputs characters to the message display from the address supplied by CIMCMP until FF hex is encountered. Output to the channel display, the MDAC, the DVM decimal points, and the switch matrix are through the peripheral devices mentioned in the hardware section of this report.

At present, all the monitoring system software is contained in the first 4 kilobytes of the microcomputer memory. The code, consisting of the six routines, is contained in the first 2 kilobyte EPROM. The data in CIMDAT is in the second 2 kilobyte EPROM. This was done so that the data, which is application specific, could be programmed for each application without changing the code. The data EPROM for each application can then be plugged into the microcomputer as required.

TESTING AND VERIFICATION

All the hardware and software in the CIM unit has been thoroughly tested for proper operation. The Controls Microcomputer has been used to run programs under the control of CP/M-86. This verified correct operation of the microcomputer and also of the disk controller. The control I/O boards have been tested and calibrated using routines written for that purpose. All signal routing through the CIM unit has been verified as correct. The Monitoring System underwent three phases of testing and verification. First, the monitoring system hardware was exercised and debugged using an In Circuit Emulator (ICE-85). Next the software was executed with the hardware, again using ICE-85. Most recently the CIM unit has been used to evaluate an implementation of the Multivariable Control for the Pratt and Whitney F-100 turbofan engine. The Control, Interface and Monitoring systems have all been used extensively during this evaluation and have performed properly.

DISCUSSION

The CIM unit has been designed to be user friendly. A sample user session can be found in the Appendix. This is a typical session during the evaluation of the F-100 Multivariable control and demonstrates how the CIM unit interacts with the user. It also shows how the CIM unit functions as a research tool.

The CIM unit has also been designed to meet the needs of the future by providing the flexibility to adapt to future needs and programs. Possible expansions to the CIM unit include: (1) Dynamic Data Taking ability, (2) a Serial Data Interface, (3) Line Filters, (4) Audio (Voice) Output. The dynamic data taking system might consist of a large memory and the software to scan all the data passing through the CIM unit during a transient and store it. The serial data link could then be used to transfer the transient data to a mainframe computer for massaging and plotting. Filters could become necessary if the CIM unit were used in a noisy environment such as an engine test cell. Audio and/or voice output would allow the CIM unit to warn the user if a problem occured, such as exceeding a temperature or pressure limit. All of the electronics necessary to implement these features could be incorporated into the digital or analog electronics chassis already contained in the CIM unit.

Lastly, since the CIM unit design is processor independent, the Controls Microcomputer could be changed if desired. This allows future state-of-the-art microprocessors or systems such as distributed processors or multiple processors to be exchanged for the present 8086 based system.

CONCLUSIONS

The Control, Interface and Monitoring unit has fulfilled all its design requirements. It is being used successfully at present, and provides the ability to meet the needs of future programs.

APPENDIX

The following is a step by step example of how the Monitoring System in the CIM Unit would be used during the evaluation of a control program. A terminal with an RS-232 port should be connected to the serial port of the controls microcomputer. The terminal used for this example is shown in figure 3 of the report.

1. Turn the CIM Unit power on. This causes the Monitoring System to be reset. The Alphanumeric message display shows

"Initializing CIM Unit"

All the segments on the channel display are lighted to ensure that they are working properly. The channel display shows

8888

There is a delay of about four seconds and then the channel display is cleared. The Alphanumeric display then prompts the user with:

"Select a Channel"

At this point the monitoring system is ready for operation.

2. Next, the controls microcomputer must be initialized. A CP/M-86 system disk with the control program on it is placed in floppy disk drive A. The RESET button on the iSBC 660 chassis is pushed. The terminal prints:

```
BOOTING CP/M-86
CP/M-86 VERSION 1.0 DOUBLE DENSITY
SEGMENT ADDRESS = 0040
LAST OFFSET = 2975
SYSTEM GENERATED 2 June 81
A>
```

The controls microcomputer is now ready for operation. To run the control program the user must type in the name of the program. For the F100 MVC the user would type:

```
A> MVC
```

The control program is now running.

3. The monitoring system can now be used to interrogate the control's I/O signals. The user must key in the desired channel number. For instance, if the user wants to monitor channel three, the keys '3' and 'SET' are pressed. The channel display now shows:

3

and the message display shows:

'OUTPUT IN VOLTS'

The DVM will display the signal on channel three in volts.

If the user wants to see channel three in engineering units, the EU/VOLTS switch is pressed. This causes the DVM to display channel three in the appropriate engineering units and the alphanumeric display to identify what those units are. For the F100 MVC, the message display would show:

"AJ NOZZLE AREA SQ. FT."

and the DVM would display the nozzle area in square feet.

To change channels, say to channel eleven, the user would push the keys '1', '1' and SET. The channel display would now show

11

and the DVM and message display would show the engineering units and a description of those units respectively.

At this point, pressing the Previous Channel key would cause the monitoring system to switch back to channel three since this was the channel selected just before the present channel. If the user pushed Scan Up instead, channel twelve would be displayed or pushing Scan Down would cause channel ten to be displayed.

At any time, the monitoring system can be restarted by pushing the 'RST' key on the display panel. The controls microcomputer is restarted by pushing the RESET button on the front of the iSBC 660 chassis.

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5. MCS-80/85 Family User's Manual. Number 21506-001, Intel Corporation, Oct. 1979.

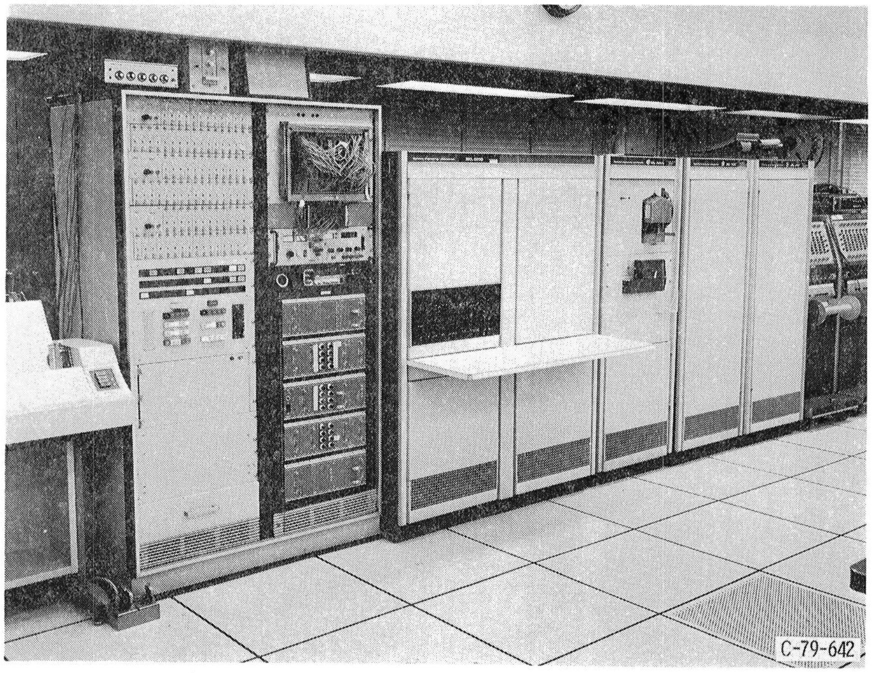


Figure 1. - 810B minicomputer and signal processing unit.

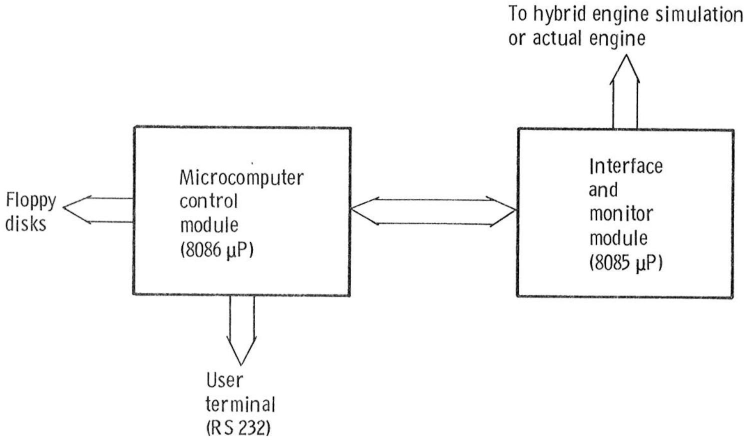


Figure 2. - CIM Unit organization.

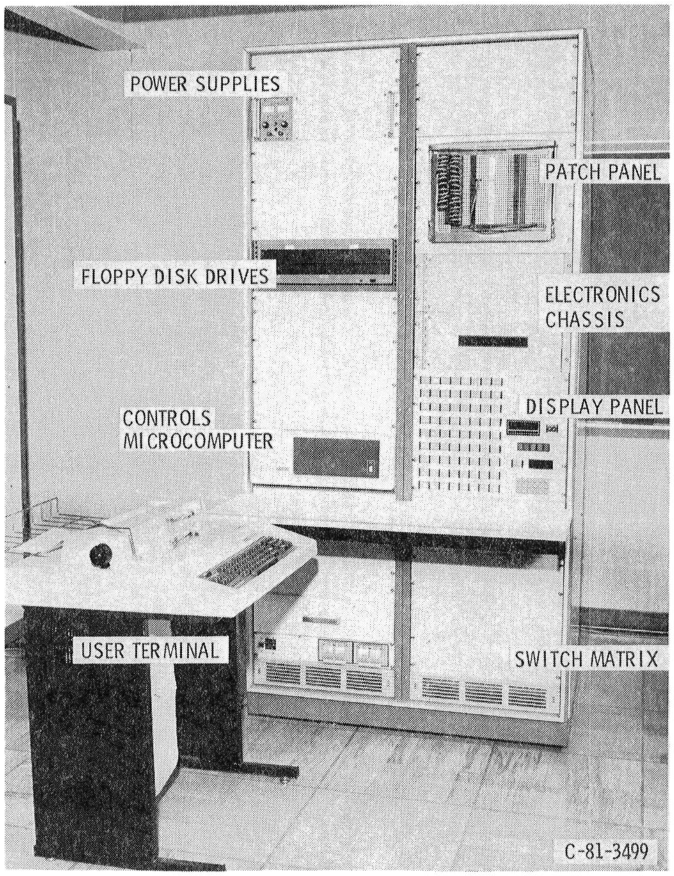


Figure 3. - CIM unit and terminal.

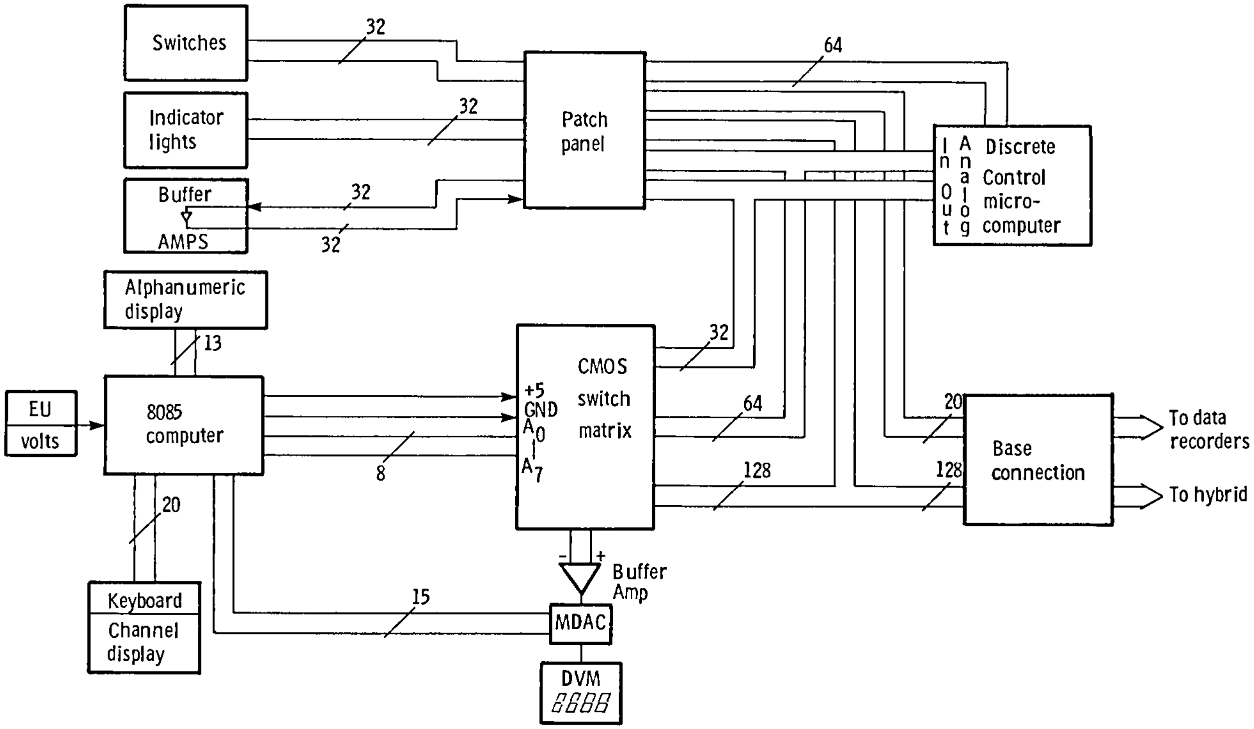


Figure 4. - CIM Unit block diagram.

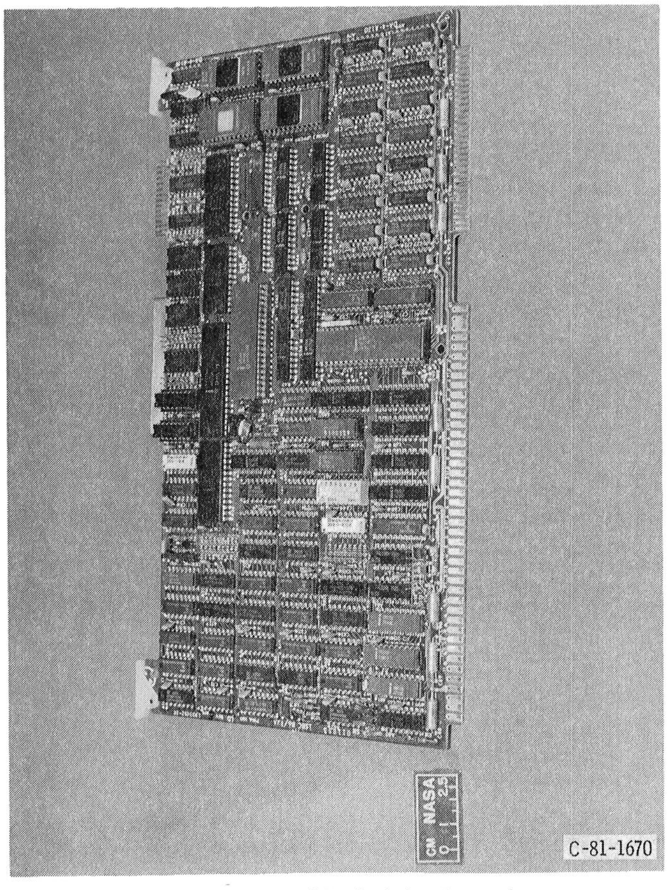


Figure 5. - ISBC 86/12a single board computer.

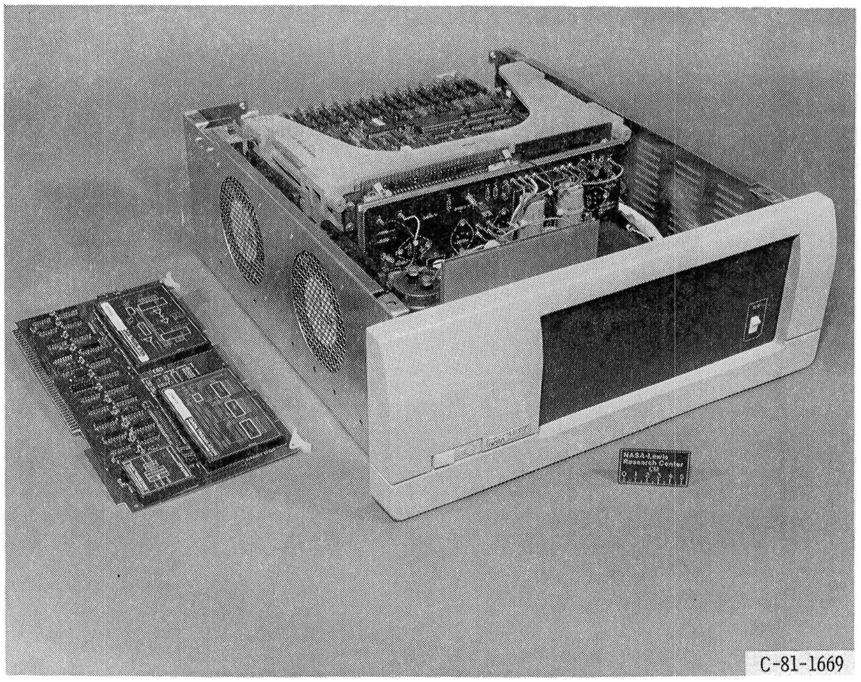


Figure 6. - ISBC 660 multibus chassis.

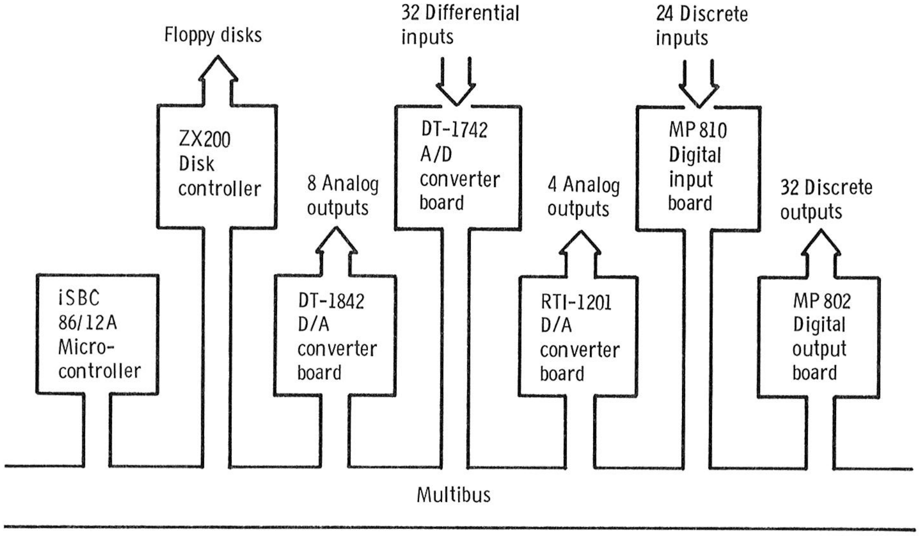


Figure 7. - Control microcomputer hardware organization.

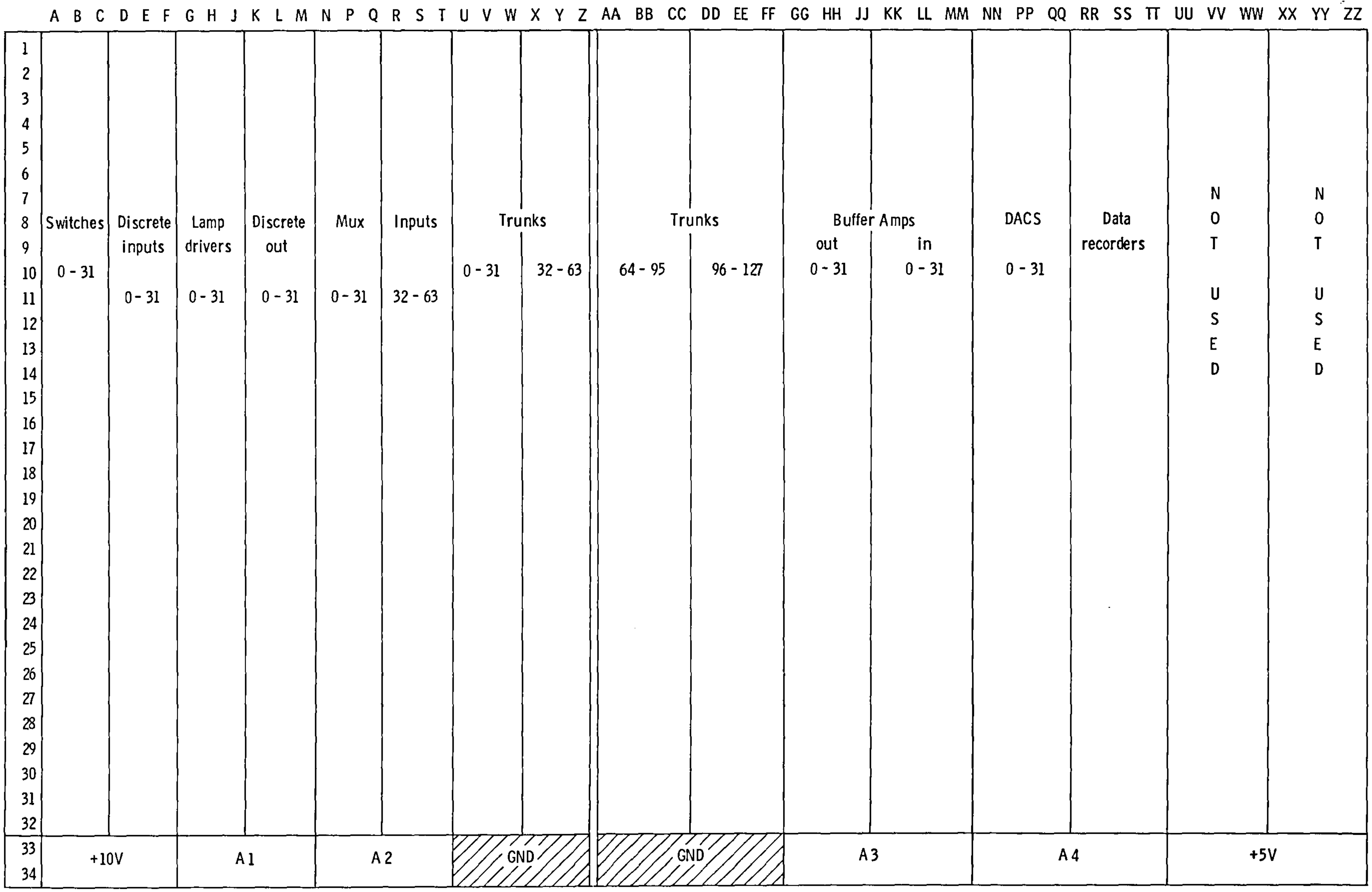


Figure 8. - CIM unit patch panel layout.

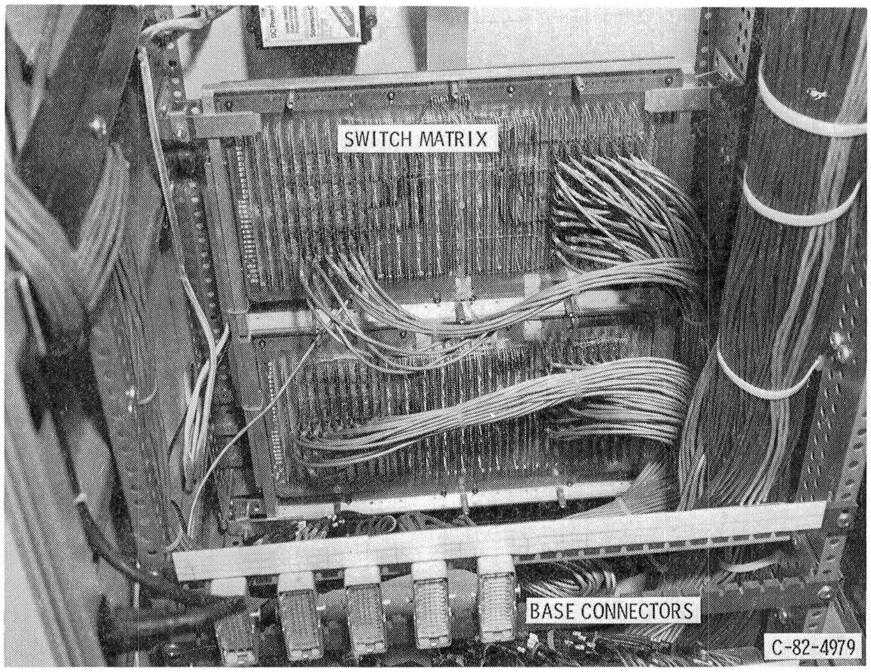


Figure 9. - Inside back view of CIM unit.

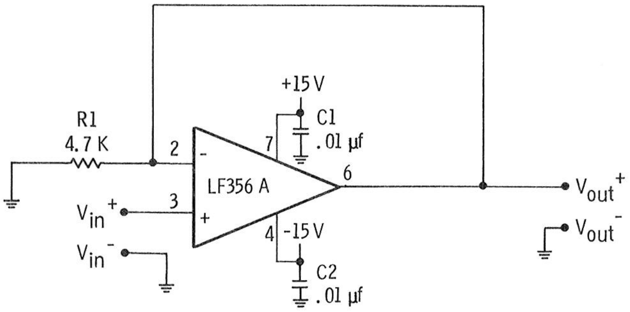


Figure 10. - Buffer amplifier circuit.

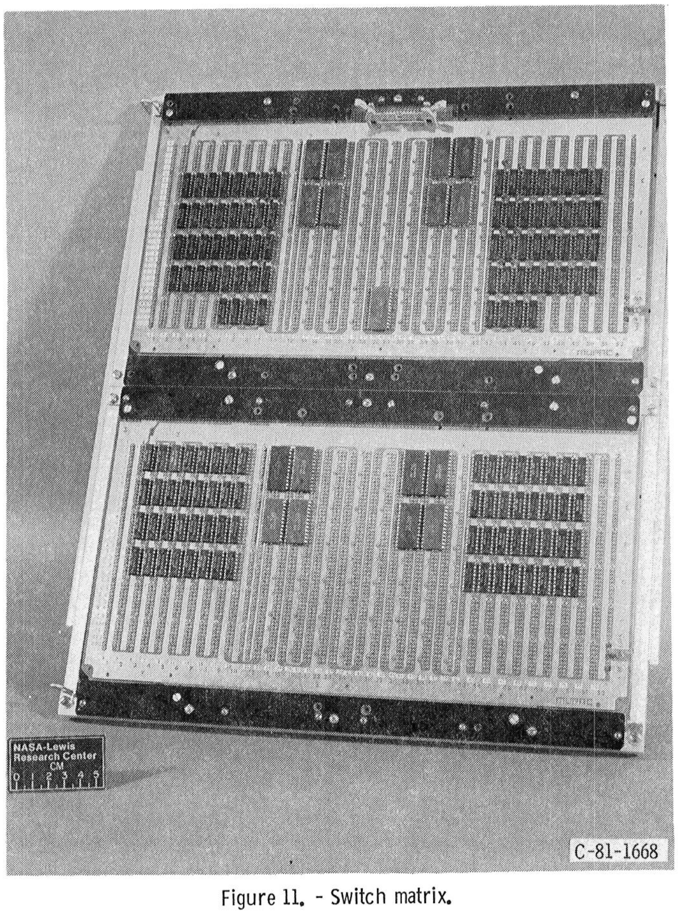


Figure 11. - Switch matrix.

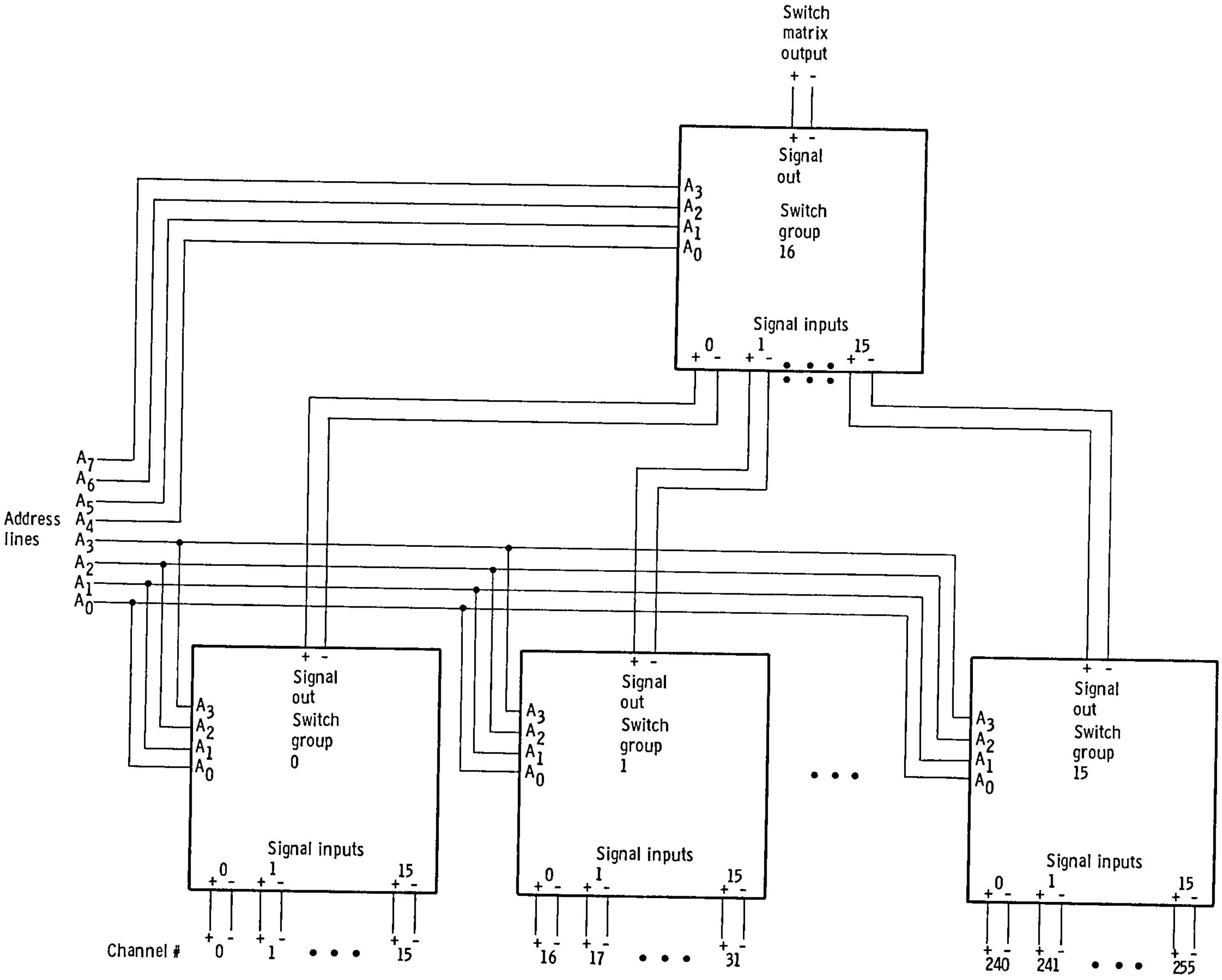
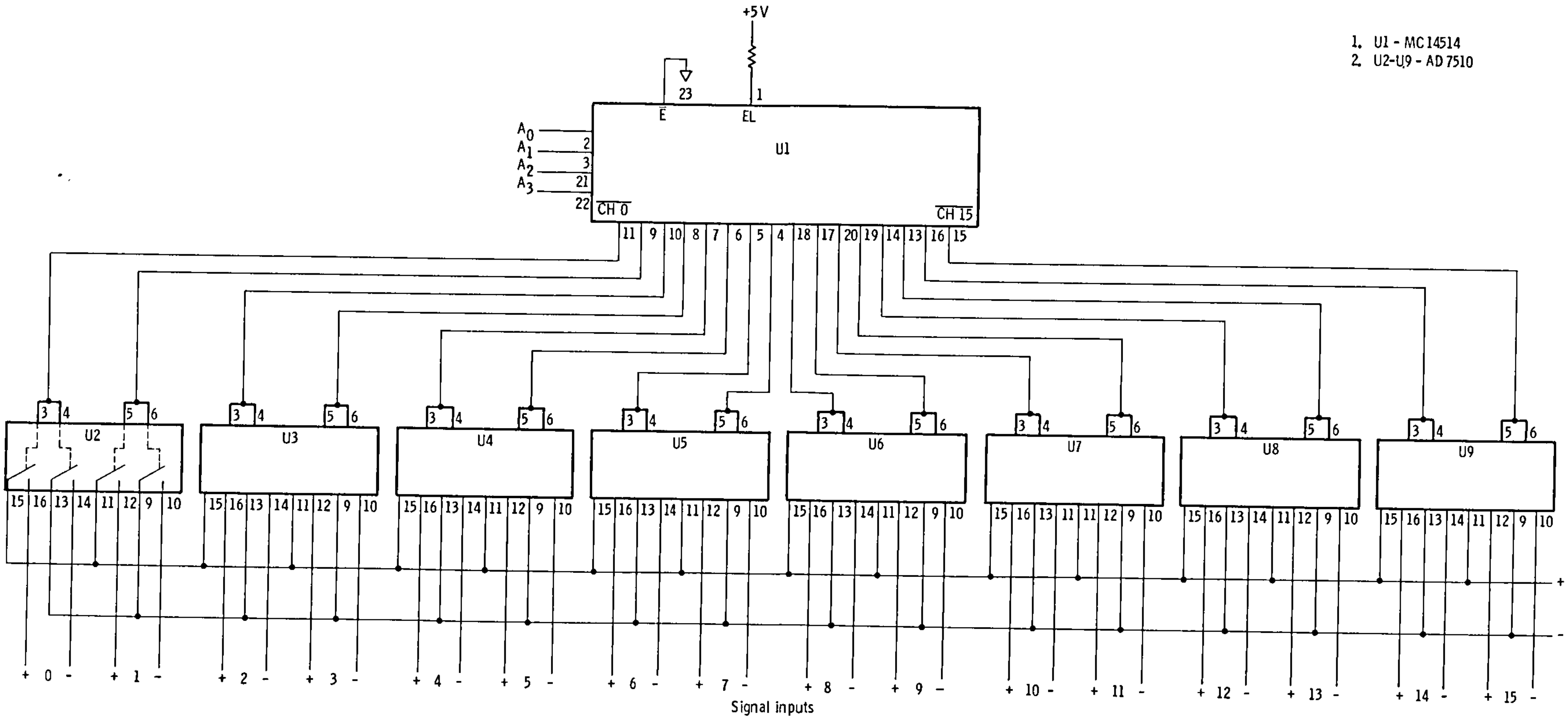


Figure 12. - Switch matrix block diagram.



1. U1 - MC14514
2. U2-U9 - AD7510

Figure 13. - Switch matrix switch group.

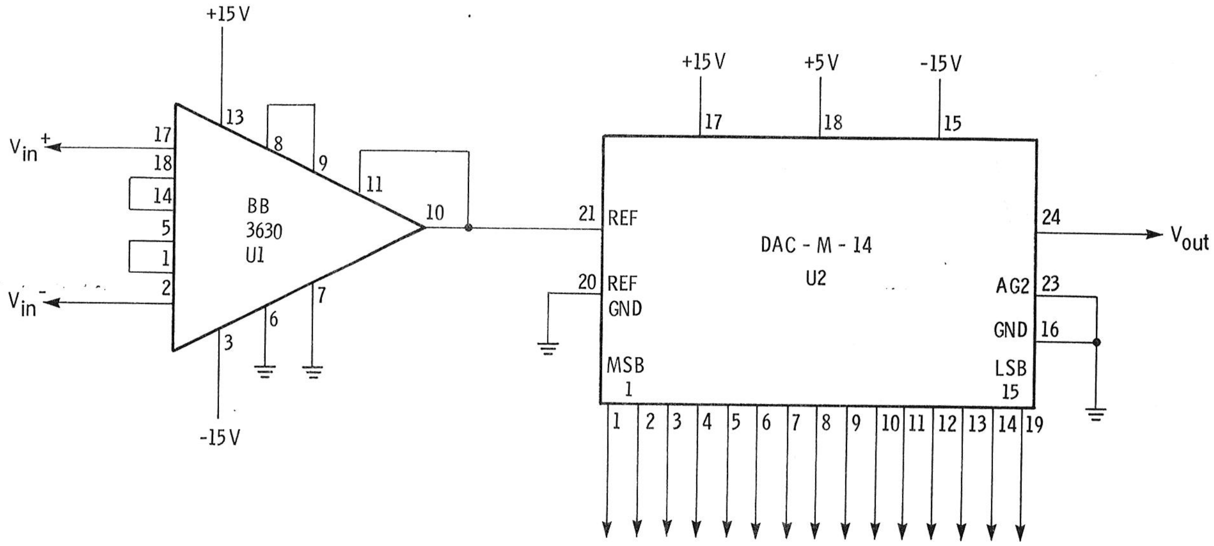


Figure 14. - Scaling circuit.

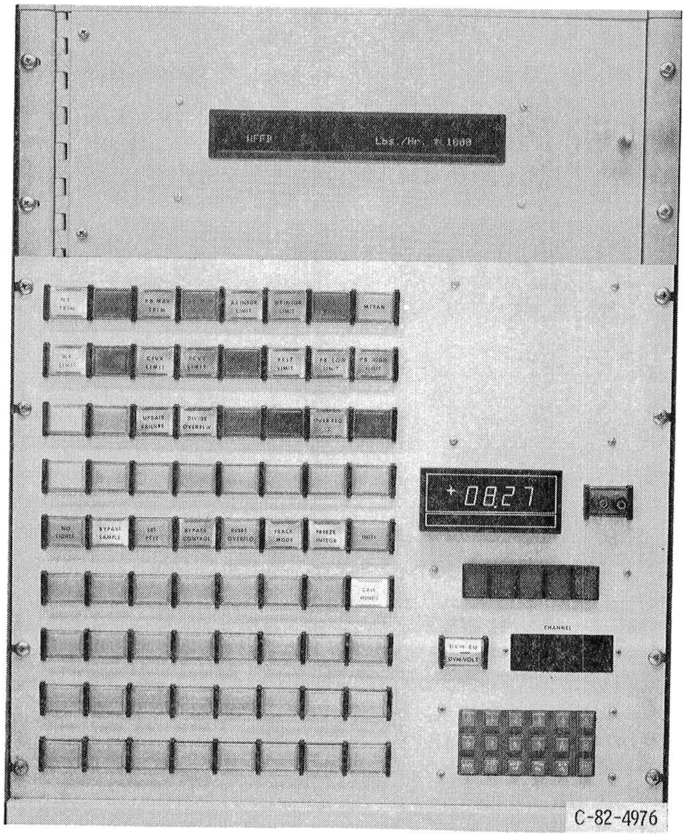
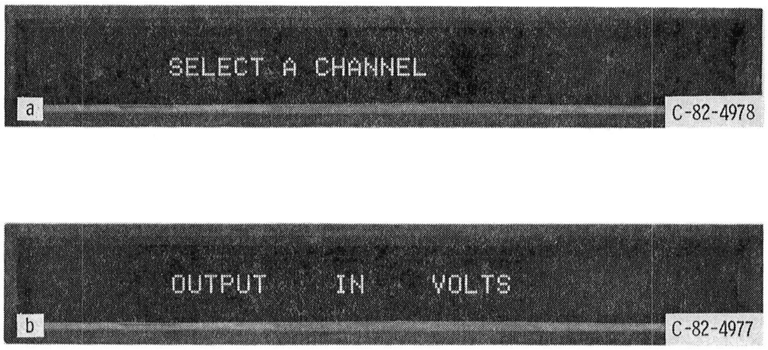


Figure 15. - CIM unit display panel.



(a) To direct user's course of action.

(b) To identify units of DVM readout.

Figure 16. - Examples of alphanumeric display usage.

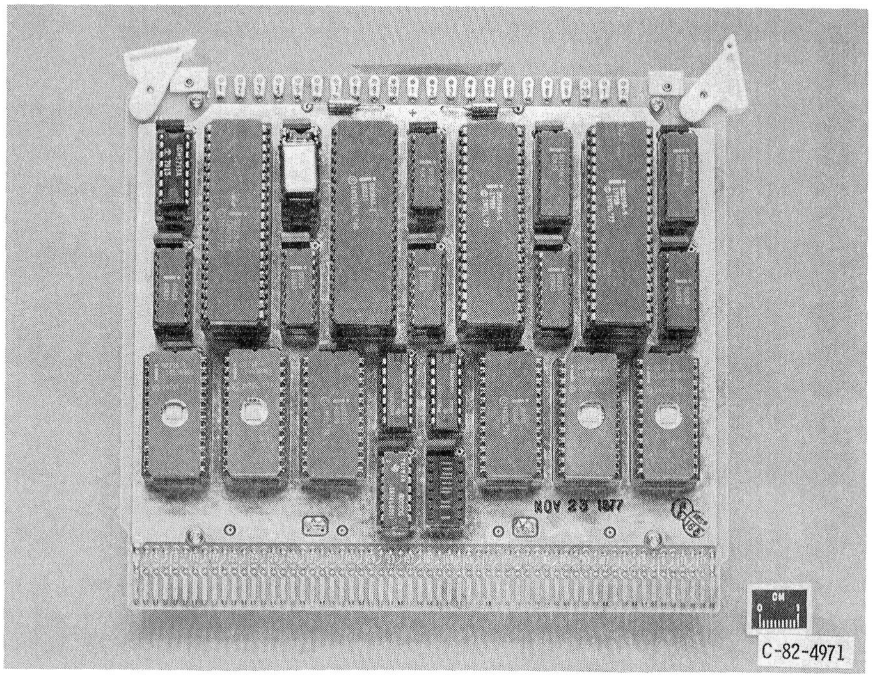


Figure 17. - 8085 single board computer.

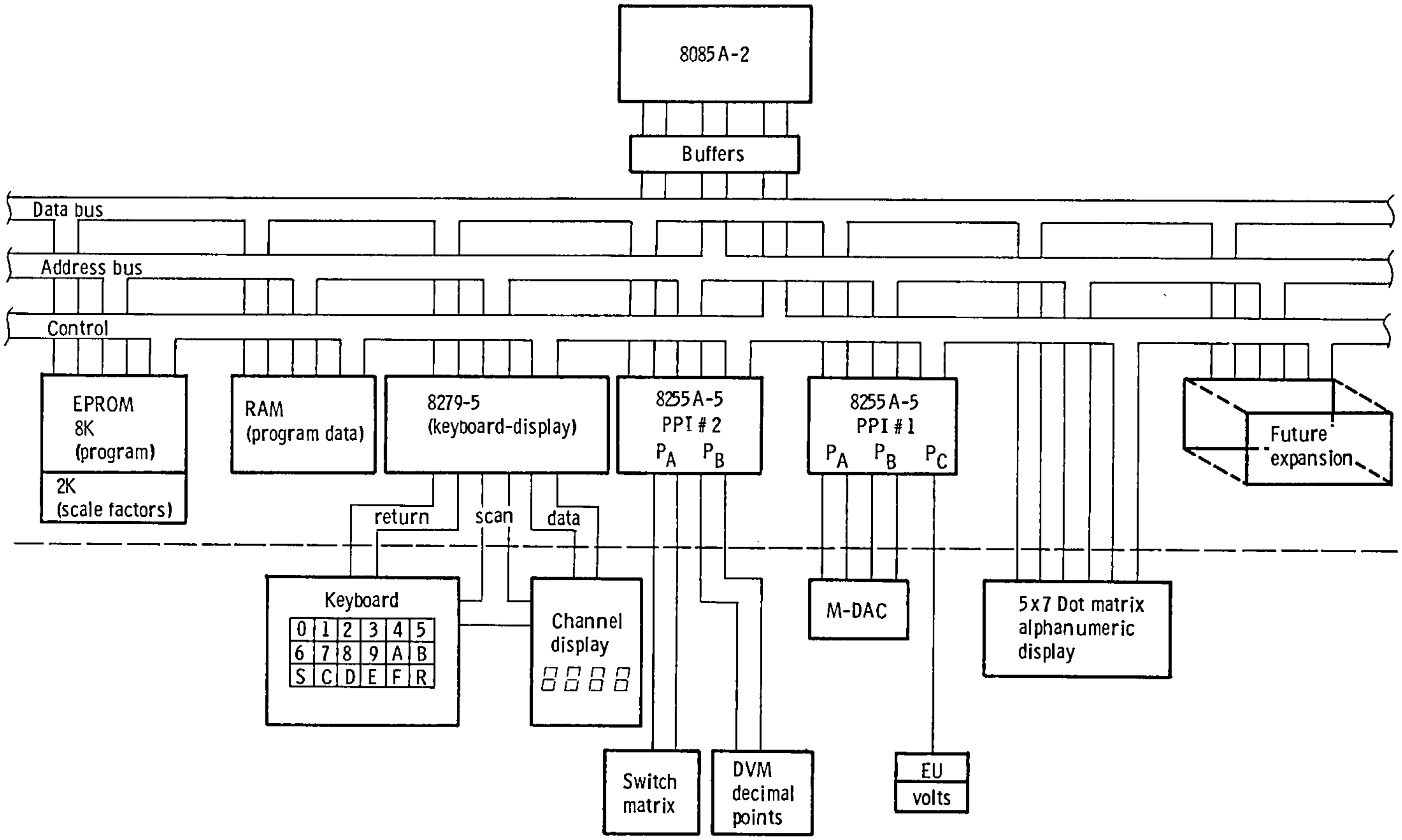
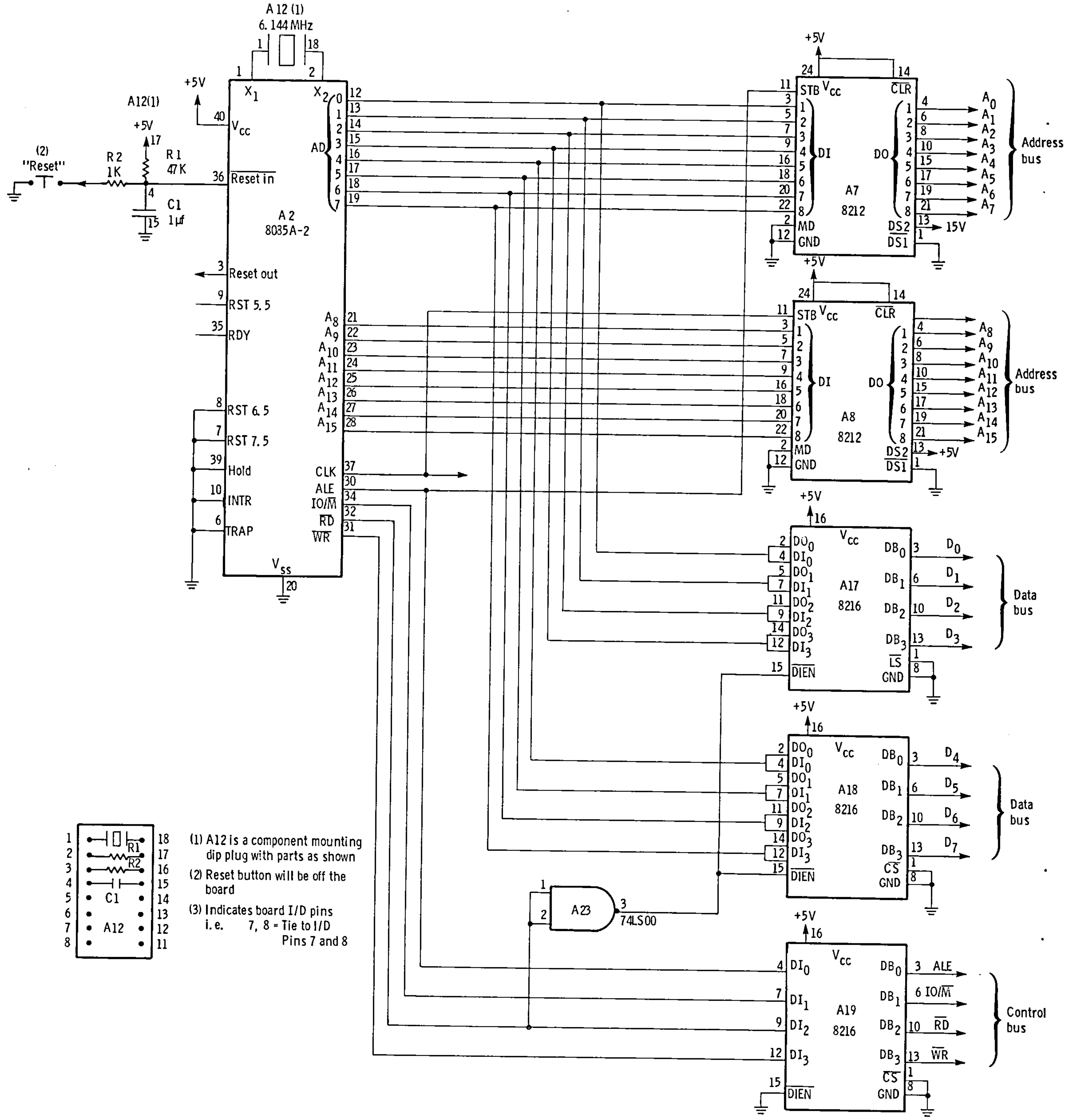


Figure 18. - 8085 Computer block diagram.



(1) A12 is a component mounting dip plug with parts as shown

(2) Reset button will be off the board

(3) Indicates board I/D pins
i. e. 7, 8 = Tie to I/D Pins 7 and 8

Figure 19. - 8085 Processor and bus buffers.

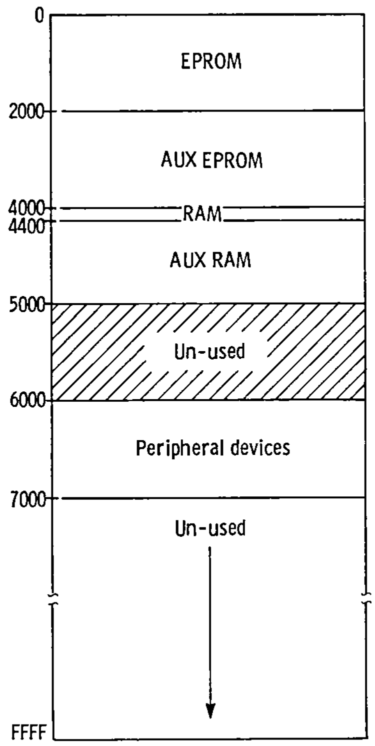


Figure 20. - 8085 Computer memory map.

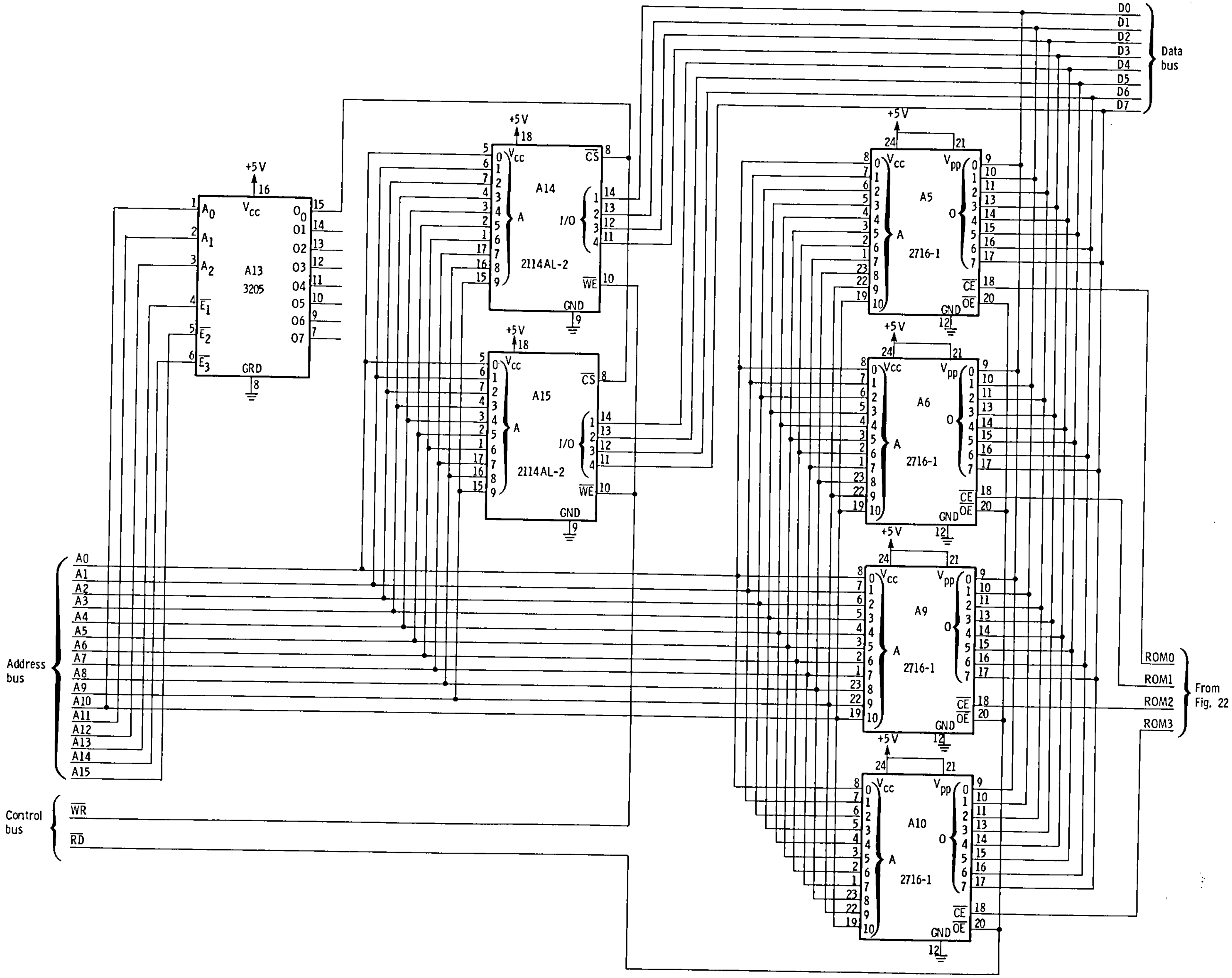


Figure 21. - 8085 Computer memory.

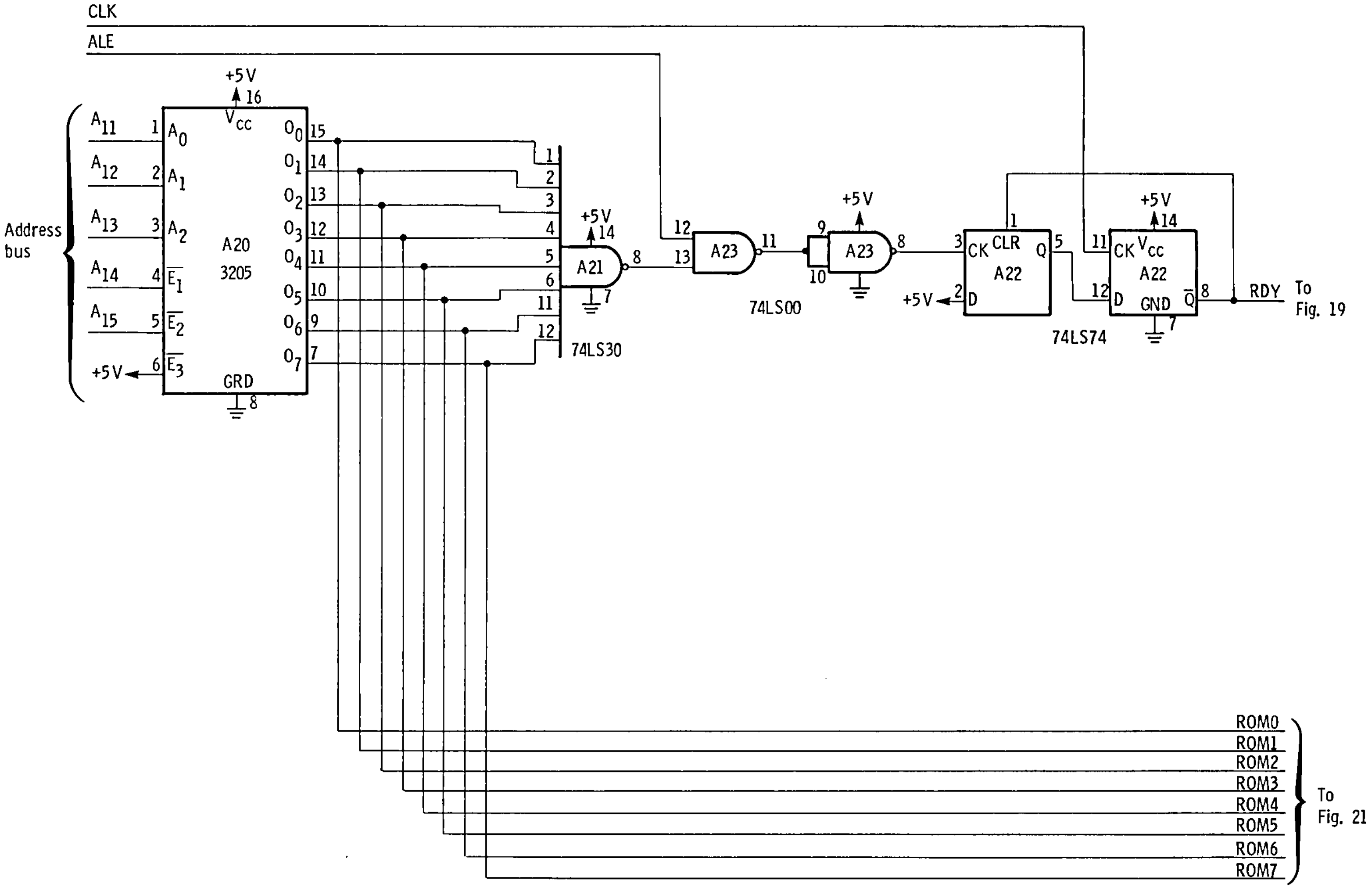


Figure 22. - Wait state generator.

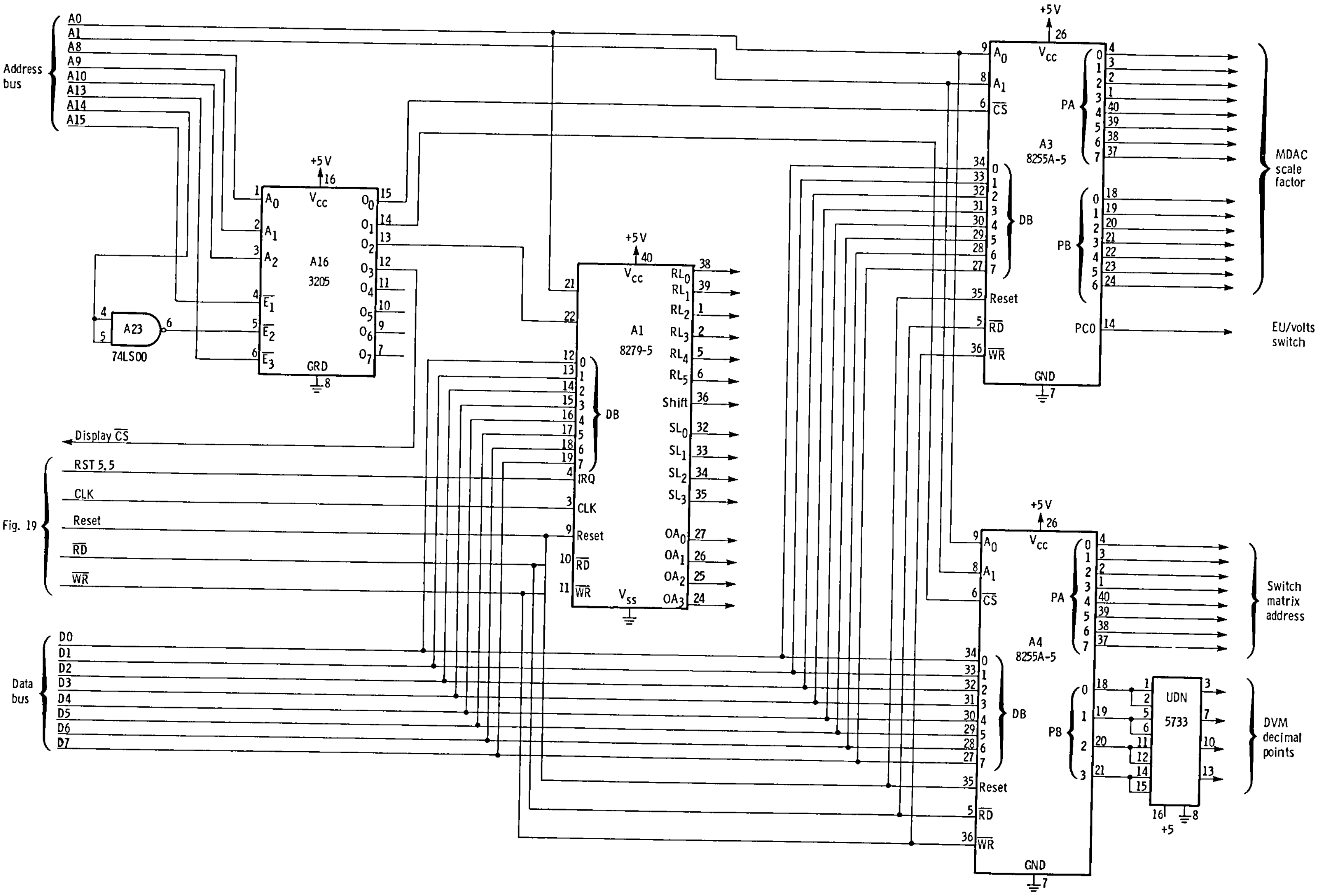


Figure 23. - Keyboard-display controller and parallel I/O.

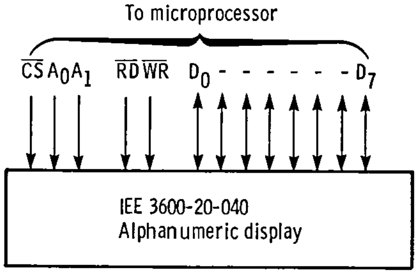


Figure 24. - Interface to alphanumeric message display.

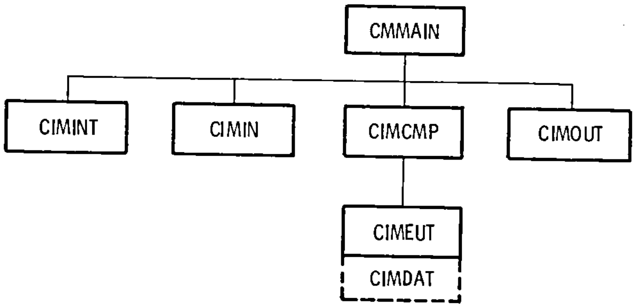


Figure 25. - 8085 Software organization.

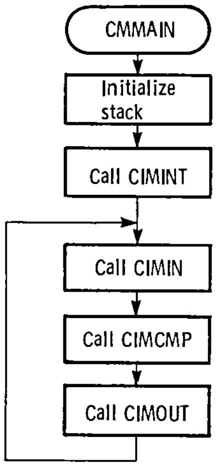


Figure 26. - CMMAIN block diagram.

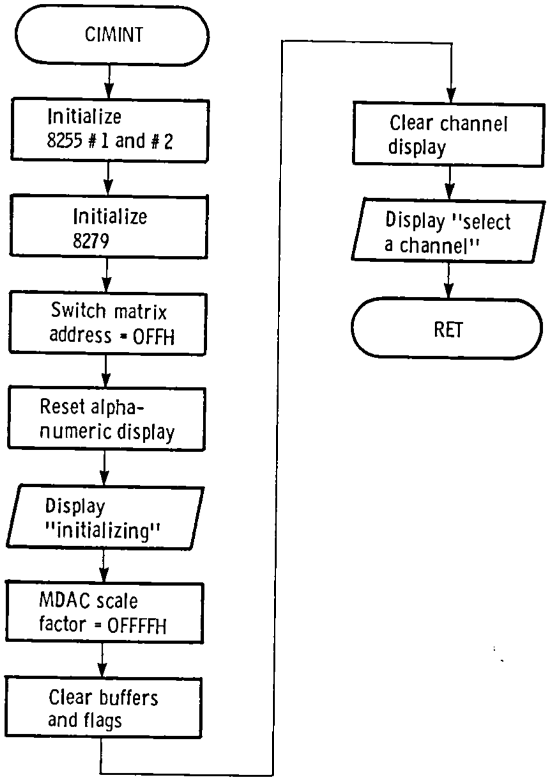


Figure 27. - CIMINT Block diagram.

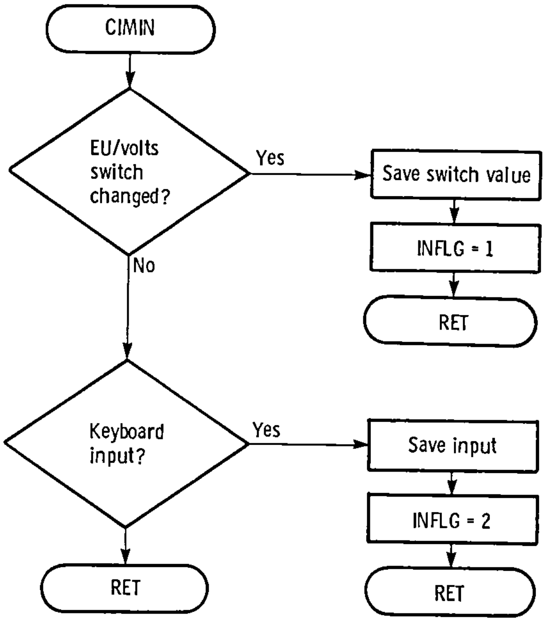


Figure 28. - CIMIN Block diagram.

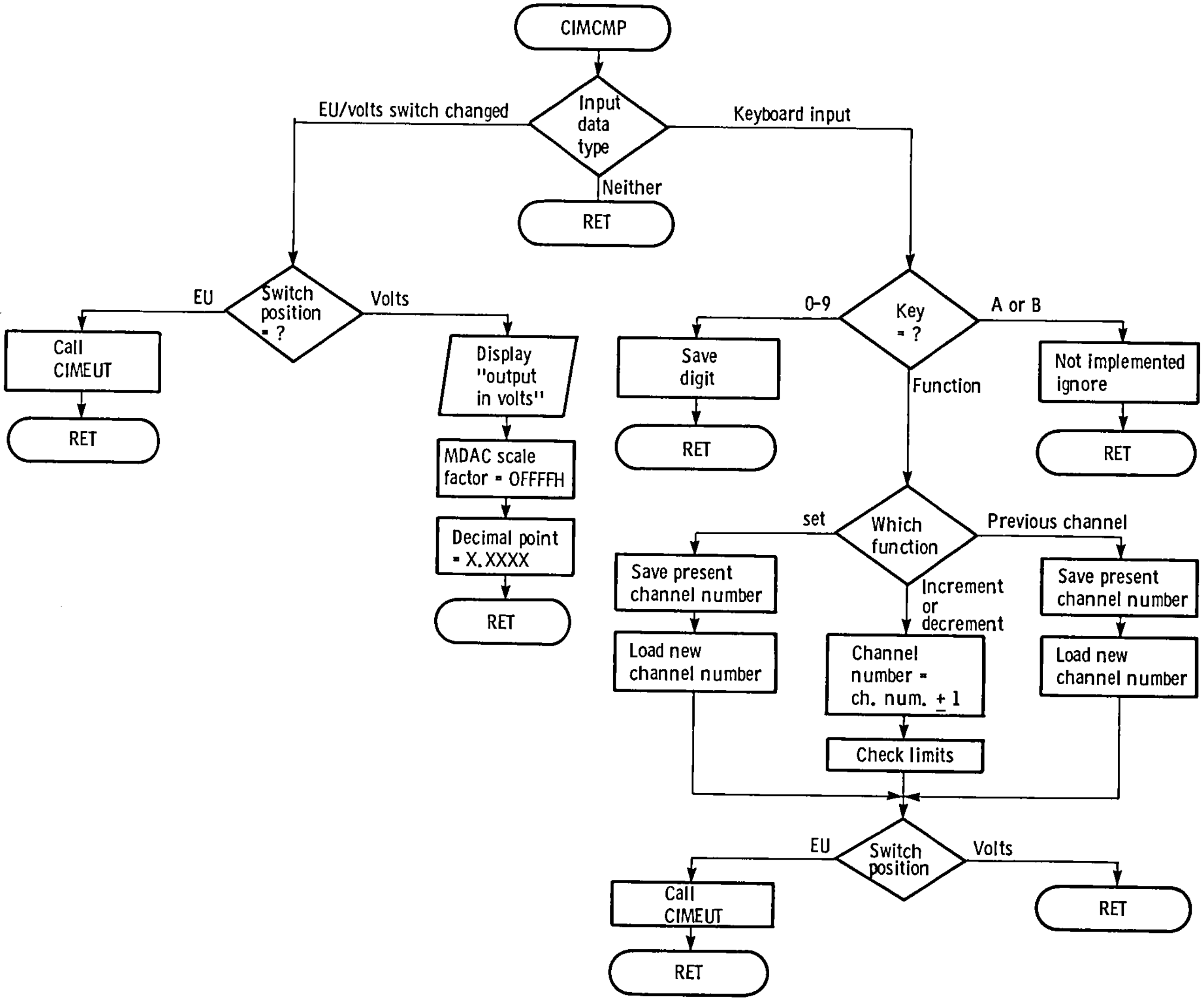


Figure 29. - CIMCMP Block diagram.

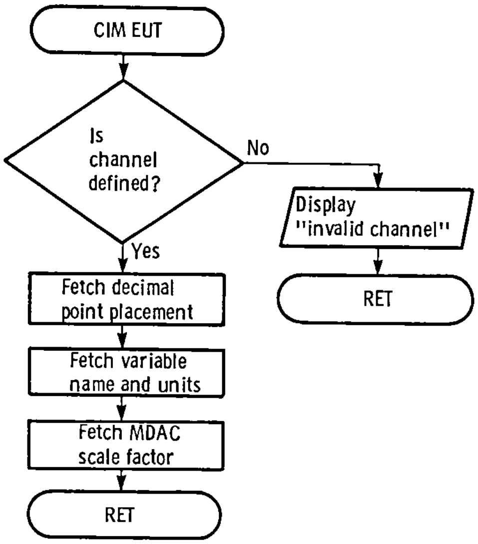


Figure 30. - CIMEUT block diagram.

Table name	Contents
CHNDAT	Defines which channels are valid
JT 1	Decimal point placement data
JT 2	MDAC scale factors
JT 3	Channel variable names
JT 4	Jump table to units messages
JT 5	Units messages

Figure 31. - CIMDAT organization.

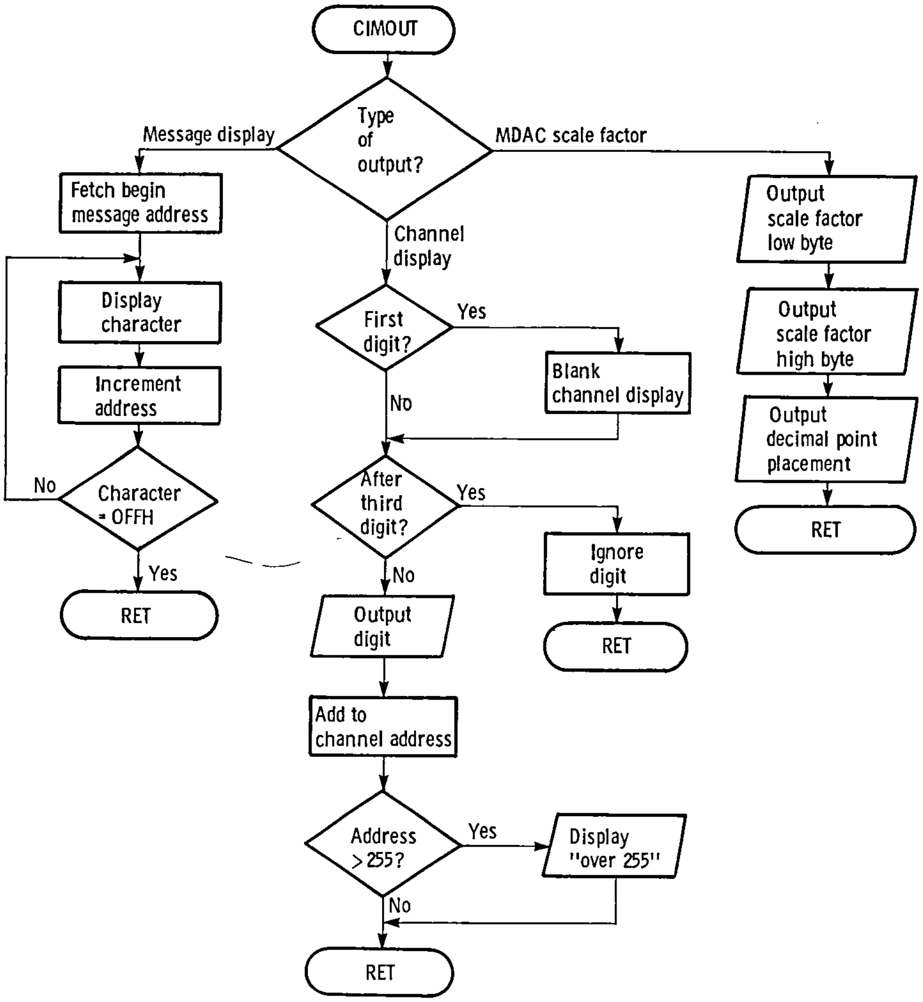


Figure 32. - CIMOUT Block diagram.

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16. Abstract

High speed minicomputers have been used in the past to implement advanced digital control algorithms for turbine engines. These minicomputers are typically large and expensive. It is desirable for a number of reasons to use microprocessor-based systems for future controls research. They are relatively compact, inexpensive, and are representative of the hardware that would be used for actual engine-mounted controls. The Control, Interface, and Monitoring Unit (CIM) contains a microprocessor-based controls computer, necessary interface hardware and a system to monitor the control while it is running an engine. It is presently being used to evaluate an advanced turbofan engine control algorithm.

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