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A CP/M VMEBUS CONTROL
SYSTEM

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Introduction

A control system based on a MC68000 microprocessor in VMEbus is described. At present it is used to monitor and control a set of up to 16 channels of MultiWire Proportional Chamber High Voltage power supplies. Of course also commercial and other special-developed systems are available for this task ; however we chose to make use of the already available power supplies and to adopt the VMEbus standard, taking advantage of its flexibility, high-performance and easiness of program development in high-level language. The system can be extended to include other types of equipment in the control loop and also represents an exercise for the integration of VME in the data acquisition.

The VMEbus configuration

The VMEbus configuration is intended to be cheap and dedicated to the control task, but at the same time it should allow a flexible usage in stand-alone mode. It is based on a 8-Mhz MC68000 CPU with 256 Kbyte RAM [1] and a 9-slot VME crate with two 5" Floppy Disc drives.

The CP/M single-user operating system is well suited for this application, as it allows the recording of programs and permanent parameters on floppy disc. The program development is done using Cross-software on VAX computers. The user programs are written entirely in FORTRAN 77, using RTF/68K [2]. Some lines of embedded assembler code are necessary to access the VME analog boards described below. The resulting assembler source is processed by the Cross-Assembler M68MIL [3] and by the chain of CERN standard CUFOM processors [4], producing a S-record file which is finally down-loaded and stored in executable form on floppy disc.

The VME ADC board

An ADC board with 12-bit resolution and 128 multiplexed single-ended inputs has been designed and built as a wire-wrap prototype. The commercially available boards had a lower number of input channels or were too sophisticated for this monitoring task which does not require a wide and variable dynamic range.

The block diagram of the board is shown in Fig. 2 . The analog components are the ADC80 converter, the SHC298AM Sample/Hold and the MPC16S Multiplexer [5].

The board occupies 128 16-bit words in the address range of the MC68000. The base address is switch-selectable in 256-byte steps.

The board is used in polling mode, the interrupt capability was not considered essential. Only 16-bit Read/Write cycles are acknowledged. The End of Conversion or Busy condition are returned as 0 or 1 respectively in bit 15 of the data word itself. When bit 15 is 0, the 12 lower bits contain the valid ADC digital output.

The initialization is performed by a Reset from the VMEbus or by a Write at any address on the board. When the board is in the initial state, the CPU starts the conversion by a Read request to one of the 128 addresses. The Read enables the addressed Multiplexer channel, starts the acquisition time of the Sample/Hold and after 10 μ sec the ADC conversion. The VMEbus Read is immediately completed, returning a bit 15 high (Busy, data not available). The CPU can execute more Read cycles on

the card, recognizing the End of Conversion by bit 15 being 0 in the data word. The card is again in the initial state, next Read starts a new conversion.

The operating range is jumper-selectable among the possible ranges of the ADC80. Also the digital output coding is bridge-selectable within the codes available for the positive and bipolar ranges [5].

A subset of the analog inputs, defined by a hardwired decoding of the address lines, can be amplified by a fixed gain factor 10. At present the amplification is enabled for the even channels.

The minimum overall conversion time could be about 35 μ sec, taking into account the MPX and S/H switching and acquisition time and 25 μ sec for 12-bit ADC conversion. However the overall characteristics of the circuit, mounted on a wire-wrap board, even with soldered analog paths, impose an acquisition time of at least 100 μ sec to keep the 12-bit accuracy in the case of maximum input step between two consecutive readings.

The VME DAC and Control boards

The power supplies are controlled using a commercial DAC board with 16 analog outputs, 12-bit resolution [6].

An additional VME Control Board (Fig.3) has been built, to ensure a full protection of the system, in particular defined conditions (no HV output) at VME power-up. It includes:

- a 16-bit Read/Write register controlling the 16 DAC outputs by means of analog switches. At power-up the register is cleared, thus disabling the DAC outputs. A front panel LED array shows the pattern of enabled channels;
- an 8-bit output register, one bit is used to activate an audible alarm;
- an 8-bit input register, for example to sense a set of switches for a limited control of the system.

Characteristics of the analog circuits

A distribution panel connects the VME analog boards and four power supplies [7] for a total of 16 HV channels (Fig.1). The power supplies are monitored by the Monitor outputs, 1 V/KV for HV and 1 mV/ μ A for current, with the actual polarity (negative) of the HV output. The ± 5 V bipolar ADC range is used, with 2.44 mV resolution. The Current monitors, typically few mV, are measured by the even ADC channels, amplified by 10.

The DAC outputs are connected to the EXT.IN inputs of the power supplies (1KV/V, always positive, the polarity being chosen by jumpers in the supply), via the Control Board. The ADC monitors also the DAC outputs.

In test conditions at 4000 V and 20 μ A current on a load resistor, both the high voltage and the current are measured with a standard deviation comparable or lower than the LSB resolution, 2.44 V and .244 μ A respectively.

The ADC board has three calibration points, ADC gain, ADC offset and Sample/Hold offset, common to all multiplexed inputs. The DAC board has one gain and one offset adjustment common to all outputs. The absolute calibration is done adjusting the end-points of the range, using a 5 1/2 digit DVM, following the procedure described in [5] [6].

The overall temperature coefficient of the system is approximately 40 ppm in the range 15 \div 35 $^{\circ}$ C.

The Control Program

The control program monitors the high voltages and currents of the set of HV power supplies continuously, and accepts commands from the CP/M console to control the system. Its size is about 38 Kb, a considerable amount of space being used by the decoding and validation of user commands and quite a few parameters and calibration constants for the individual channels. The Fortran library requires 32 more Kb.

Essentially the commands allow to:

- display the status table ;
- set the value of a channel or a set of channels ; the actual values are displayed and a confirm is requested ;
- set all channels to the reference values, or to the same value (for example at stand-by), or to 0 Volt ;
- break any setting in progress ;
- modify the program and set-up parameters ;
- load or save the set-up on disc files ;
- enable or disable the analog switches controlling the DAC outputs; this command is accepted only if the DAC output is at 0 V ;
- enter a debug mode, in which the ADC readings, the DAC setting commands and the intermediate results are dumped to the terminal. The program stops after each loop to accept a command, or to continue the dump ;
- list the available commands (HElp command, Fig.4) ;
- terminate the program and return to CP/M .

The power supply configuration and all program parameters can be read/written on disc files. At start-up the program loads them from the file STAND.DAT, which should be consistent with the actual configuration of the system. If not, the set-up can be corrected interactively or loaded from the appropriate file. All parameters the user may need modify can be changed on-line by menus and dialogues, to avoid the need of editing and re-compiling the program. When the program is terminated regularly, the complete status is saved, overwriting the same file.

The control program can be terminated, and some other activity executed in CP/M, while leaving the high voltages on, under DAC control and manual monitoring. The program, when rescheduled, reloads the status and resumes the control loop without any special action.

A particular care is necessary at power-up. The basic hardware protection is ensured by the Control board, which initially disables the control of the power supplies; afterwards a channel can be enabled only if the corresponding DAC channel was explicitly reset. On the other hand there is no mean of power-fail recovery.

Four voltage values are defined for each channel: the Monitor and the DAC output, continuously updated in the control loop, the Control, updated to the requested value when a setting is executed, and the Reference, used to set all channels at the working value. The control loop signals an error if :

- the HV Monitor or the DAC output are beyond a given tolerance with respect to the Control value;
- the current is larger than a limit defined for each channel;

An error interrupts any setting in progress. In the normal mode of operation there is no other automatic action; when the program runs in 'unattended' mode, the HV is lowered on the elements causing an error, until the error condition ceases.

The table of the status of the system is displayed on the terminal at request or any time an error condition appears or disappears, with warning flags reported on the line of the elements in error.

To change the setting of a channel, the HV monitor, the DAC output and the last DAC code are checked and used to determine the start value, then the DAC code is changed in ± 1 steps to approach the final value, for all elements being set. After each 'set cycle', the normal control loop is executed. If no error is sensed, the next set cycle is executed. If an error occurs, the setting is suspended, of course for all elements being set, and restarts if the alarm condition ceases. In case of errors the setting can be explicitly forced, to allow the recovery of anomalous conditions.

An additional constraint can be imposed, requiring that the high voltages within a set of channels, defined by a common Group number, do not differ more than a predetermined value (the number 0 identifying a single channel, which can be set freely). This option can be used for example if in a MWPC different wire planes are powered by different HV supplies. The channels of a same Group should be set at the same time, to raise/lower their HV in parallel. If the gap limit is reached, the setting is suspended, and restarts when also the other elements in the Group are set accordingly.

The HV setting is fairly slow, due to the unit code DAC step and the large amount of control operations (including floating-point arithmetics) at each step. The maximum rate is about 200 V/sec, when setting one single channel. In the actual case of control of MWPC's, it must be further reduced: a software delay is added at each loop, limiting it to a user-defined parameter.

Finally, a command allows a relative calibration of the ADC channels with respect to the DAC. Two calibration constants can be determined for each ADC channel, to compensate the small residual differences after the absolute calibration and the different characteristics of the power supply monitor outputs. The check of the calibration of the HV monitor channels can be obtained in parallel with the setting of the working voltages. The DAC setting and the HV monitor reading are stored in a calibration table at 200 Volt intervals, whenever a setting is executed. After the HV has been raised from 0 to the nominal value on all planes, the table can be processed, fitting straight lines through the points, and the calibration constants of any channel can be updated if necessary. The Current monitor channels can be calibrated in a similar way, for example in the range $0 \div 20 \mu\text{A}$, but connecting a 200 M Ω load resistor to the HV output.

Conclusions

This system has been used satisfactorily to control a maximum of 15 HV channels in the experiment PS172 at LEAR, CERN, with no major problems and no hang-up in several days of continuous operation. Some small improvements are under way, for example the interfacing of a large-size liquid cristal display to provide a dedicated representation of the system status. It is planned to include other functions in the control loop, in a modular way, via table definitions and subroutine calls. To speed up the software development, the available 'native' version of the programming tools should be installed on a second MC68000 CPU, keeping one CPU and the VMEbus dedicated to the execution of the monitoring task.

References

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- [3] M68MIL Cross Macro Assembler, H. von Eicken, CERN 83-12
- [4] CUFOM Processors Write-ups, J.Montuelle, CERN/DD/US/83 and 84, Feb. 16, 1982
- [5] Burr-Brown Product Data Book, July 1984
- [6] MPV904 Operating Manual, Burr-Brown Ltd, 1985
- [7] High Voltage Power Supply WENZEL N1130



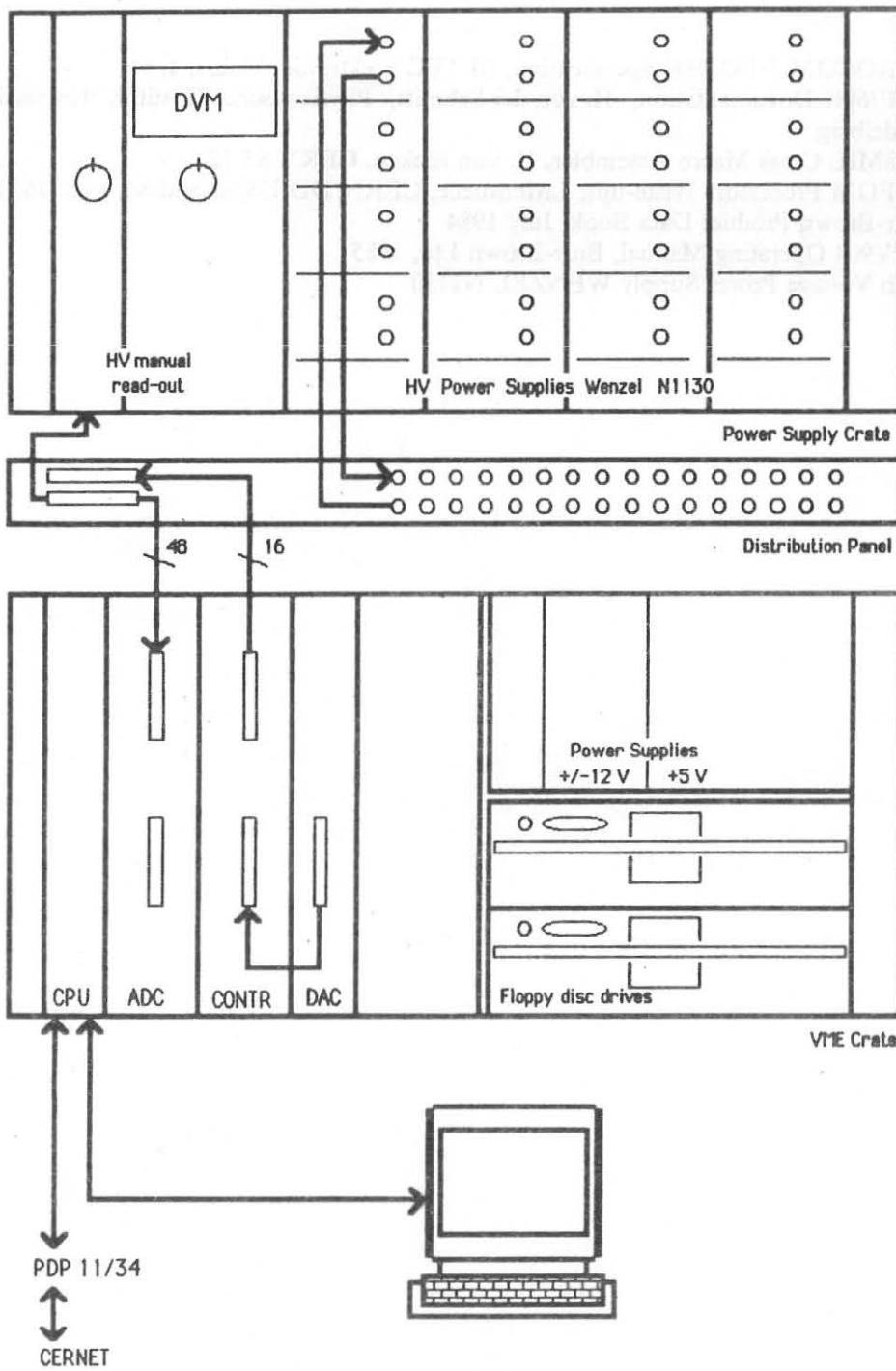


Fig. 1 - Block diagram of the system

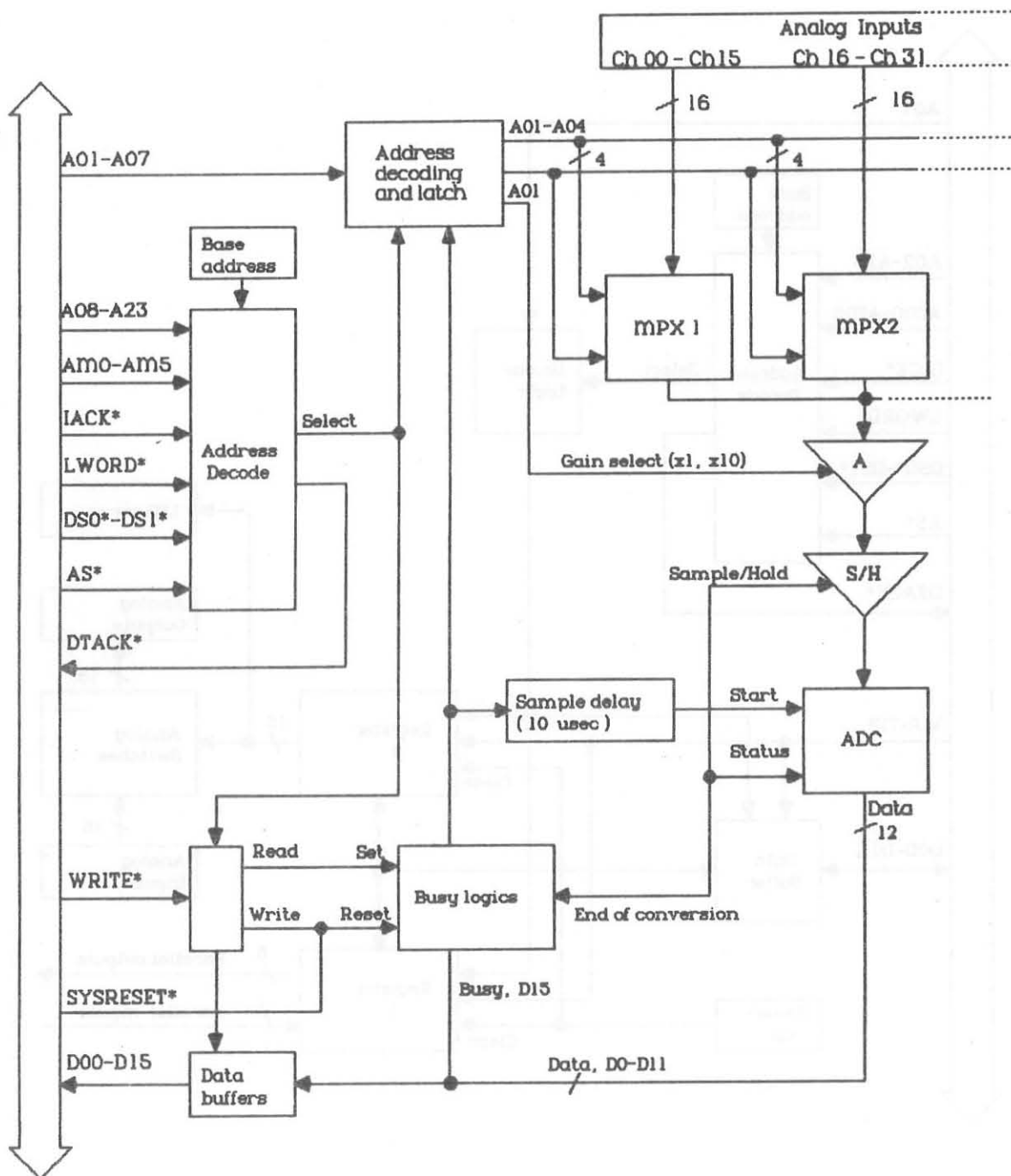


Fig. 2 - Block diagram of the ADC board.

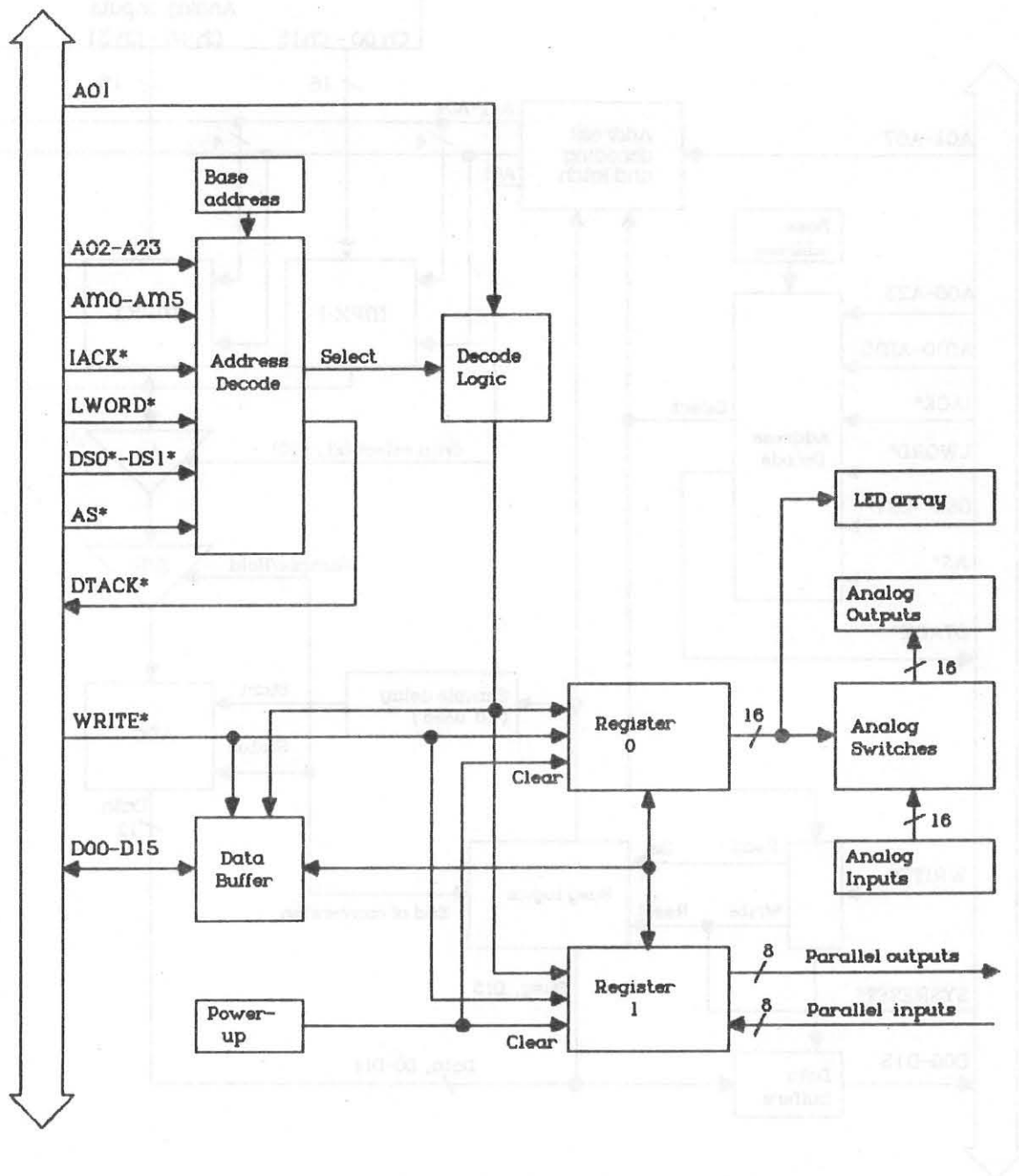


Fig. 3 - Block diagram of the Control Board.

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CP/M-68K(tm) Version 1.1
Copyright (c) 1982 Digital Research, Inc.

ELTEC Bios (C) 1983, Version 3.0
without Harddisk
No Ramdisk (0) 128K RD (1) 256K RD (2) 512K RD (3) 1M RD (4) 0
A>STARTUP

A>UNILIB

A>CONTR
Control start
Read file STAND.DAT
End of file, 16 channels defined
Channels enabled on the Control Board:
 1  2  3  4  6  7  8  9 10 11 12 13 14 15 16
Program initialized
Command ? HE

Available commands :

DI  display status
SE[,n,v] set channel n to v Volt
SE,RE  set all ch.s to Reference values
SE,AL  set all ch.s to the same value
UF      set all ch.s to 0
BR      break setting
AL      enable/disable audible alarm
AS      enable/disable Analog Switch on DAC output
MQ      modify parameters
RE      read set-up from disc file
WR      write set-up to disc file
CA      calibration
DU      dump/no dump mode
HE      help
AB      abort without saving set-up to disc
EX      exit

Command ? DI

Chan   HV Mon HV Ctrl HV Ref HV DAC I(uA) Warnings
 1 PC0  4003. 4000. 4000. 4004.   4.   OK
 2 PC1  4148. 4150. 4150. 4148.  -3.   OK
 3 PC9  4249. 4250. 4250. 4247.  -3.   OK
 4 PC2  4150. 4150. 4150. 4148.  -2.   OK
 6 PC3  3353. 3350. 3350. 3354.  -1.   OK
 7 PC4V 4348. 4350. 4350. 4332.   1.   OK
 8 PC4H 4249. 4250. 4250. 4247.   3.   OK
 9 PC5V 4298. 4300. 4300. 4297.  -0.   OK
10 PC5H 4298. 4300. 4300. 4297.  -2.   OK
11 PC6V 4297. 4300. 4300. 4297.   1.   OK
12 PC6H 4297. 4300. 4300. 4298.   1.   OK
13 PC7V 4202. 4200. 4200. 4199.  -2.   OK
14 PC7H 4295. 4300. 4300. 4300.   4.   OK
15 PC8V 4350. 4350. 4350. 4350.   2.   OK
16 PC8H 4251. 4250. 4250. 4247.   0.   OK

Command ? EX
File STAND.DAT written
CONTR end

```

Fig. 4 - Example listing of program start-up, help command and status display