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A NEW MULTIPLEXED ADC UNIT

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Summary

A new multiplexed ADC unit was designed and constructed in the lab in order to replace old units which were used around the accelerator. This was the first attempt to replace the old units, which had had discrete components, with a new unit, which had IC's and subsystems. The author concludes that the new unit is reliable and easily repairable, and that it converts faster.

Introduction

A new multiplexed ADC unit was designed and constructed. The author will describe in this report (1) Background - why a new multiplexed ADC was needed to be designed in the lab, (2) Design Details - components, circuit arrangements, and packaging, and (3) Specifications.

More than 100 multiplexed ADC (will be referred to as MADC) units were being used throughout the accelerator areas in order to monitor the vital signs of the accelerator. Those MADC units were getting old. They had been designed and constructed perhaps more than eight years earlier than the date. The old units had discrete components on the p.c. boards. It was difficult and time-consuming to repair p.c. boards with discrete components. In the meantime, new facility expansions demanded more units. Therefore, the spare units and parts situation was very bad.

First, we looked for a commercial unit. However, it was impossible to find any commercial unit that had similar physical size, similar input and output signals, and similar connectors to the ones that the old units had. Dynamic System Electronics, who delivered the old MADC units, could have duplicated their old design. However, their quote on their new design was much higher than what we had expected.

Our design goal was first to duplicate the physical size, input and output signals, and connectors of the old DSE units. Furthermore, we wanted to make the conversion speed faster, the repair work easier, the reliability better, and the life longer. We used IC's and packaged subsystems throughout our design. We first tried an instrumentation amplifier, which was not fast enough. We then formed an instrumentation amplifier with three high speed operational amplifiers, which had a fast settling time, a good temperature stability and a high common mode rejection at high frequencies. By virtue of IC's, the p.c. boards in the new MADC were simpler and less complicated, and therefore the repair work became easier and faster. The number of parts used on the p.c. boards was smaller, and therefore the reliability and life of the unit became better and longer.

In the following sections, the author will describe which components were selected, how circuits were arranged, what were unique features, how the unit was packaged and what were the specifications of the unit.

Design Details

Overall

Two stages of multiplexers were employed in order to multiplex

64 differential analog inputs. Following the multiplexer stages, there were an amplifier, a sample and hold, and an analog to digital converter. The amplifier was constructed with three high speed operational amplifiers. The sample and hold, and the analog to digital converter were module packages. For displaying the data, a decimal display was incorporated w: a binary display. The overall block diagram is shown in Figure 2.1.

Analog Multiplexers

Harris Semiconductor's HI-507A differential 8-channel multiplexers were selected over Burr Brown's MPC8Ds and Datel's MXD-807s. The last two manufacturers had a very poor quality assurance on their product, 60% of which were defective. In the first stage, 64 differential channels were multiplexed with 8 multiplexers, yielding 8 differential outputs. Further, in the second stage, the 8 differential outputs were multiplexed with a multiplexer to produce one differential output. With the two stage arrangement mentioned above, parallel loading or leakage effects upon the on channel from the off channels can be theoretically reduced from 63X to 14X.[1]

Amplifiers

First, an instrumentation amplifier, Analog Devices' AD521, was tried. However, the device was not fast enough to settle for the overall conversion time of 10 μsec. An instrumentation amplifier was constructed with 3 high speed operational amplifiers, Analog Devices' AD509. The thus constructed instrumentation amplifier had a gain of ½, a good temperature coefficient of better than 0.01%/°C, a good temperature coefficient of better than 0.01%/°C, a good common mode rejection of greater than 74dB at 60 Hz, and a fast settling time of 6 μs to 0.01%. The input common mode voltage range was ± 12 V. The circuit arrangement of the amplifier is shown in Figure 2.2.

Sample - Hold and ADC

A very high speed sample/hold, Burr Brown's SHM60, and a very high speed ADC, Burr Brown's ADC60-12, were selected. The reader should be aware of the fact that the selection was made around May, 1978, and that much more v eties of devices (with faster speeds, smaller sizes, etc.) are now available. The ADC60-12 is a successive approximation ADC and its conversion speed is 3.5 μsec. Therefore, if the input is a 1 KHz sine wave, the maximum conversion error with changing input is[2]

$$\frac{\Delta V}{V} \times 100 = 2\pi f \Delta t \times 100$$

$$= 2(3.14) \times 10^{3} \times (3.5 \times 10^{-6}) \times 100$$

$$= 2.20\ (\%).$$

This can be improved with a sample/hold such as SHM60, which has an aperture time of 12 nsec typical, as follows:

$$\frac{\Delta V}{V} \times 100 = 2\pi \Delta t \times 100$$

$$= 2(3.14) \times 10^{3} \times (12 \times 10^{-9}) \times 100$$

$$= 0.00754\ (\%)$$

Displays and Controls

The front panel controls and displays are shown in Photo 2.1. When CONTROL is selected to LOCAL and when LOCAL TRIGGER is switched to INT, internal trigger pulses are generated. They digitize an analog signal and display it in decimal and binary. Whenever a new data is displayed, UPDATE is flashed to indicate that the display is updated. The channel address is selected with the thumbwheel switches. If channels beyond 63 are attempted to be chosen, OVERFLOW is lit indicating that the channel is out of range. When CONTROL is selected to LOCAL and when LOCAL TRIGGER is switched to EXT, an analog signal is digitized with external trigger pulses, and it can be examined in synchronization with the external pulses. When CONTROL is selected to REMOTE, a remote controller sends DIGITIZE pulses to the MADC. When the digitized data is ready, the MADC flags to the controller with DATA VA, and the controller latches the data. When DISPLAY is switched to MULT, CHANNEL and VOLTAGE may change whenever they are updated. However, when DISPLAY is switched to SING, only the thumbwheel selected channel and its data are displayed. In this way, a particular channel can be examined while a number of channels are scanned along with the channel in question. When the remote controller needs to control the MADC even if the front panel CONTROL is selected to LOCAL, the controller sends $\overline{\text{RMTOVR}}$ and can override the local control. When the MADC is in this mode, OVERRIDE is lit.

A timing diagram is shown in Figure 2.3 for a remote control. A remote controller sends a DIGITIZE pulse along with a channel address to the MADC. Inside the MADC, ASTROBE latches the channel address immediately after receiving the DIGITIZE pulse. Six μs later, $\overline{\text{HOLD}}$ pulse is applied to the sample/hold. CNVCMD pulse is applied to the ADC 200 ns later than the sample to hold transient. The ADC does the conversion within 3.5 μs, and its $\overline{\text{STATUS}}$ changes from low to high when the data is ready. When the control sees this transient, it sends the data and DATA VA to the remote controller. At the same time, the control latches the data with STRD for local displays. BUSY signal indicates the entire period from the beginning of DIGITIZE to the end of STRD.

A block diagram on the displays and controls is shown in Fig. 2.4. The figure shows the general flows of major signals from one block to another. "Address Select" selects one of the two groups of address lines, i.e., LA<0:5> and RA<0:5>. "Address Latch A" latches the selected group of address lines. These address lines are used to select an input channel for the a to d conversion. After the conversion, the address lines are latched in "Address Latch B" for displays at the same time as the data is latched. When CONTROL is selected to REMOTE, and when DISPLAY is switched to SIN, a thumbwheel-selected address and channel addresses are compared in "Compare". When there is a match, "AMTCH" is generated. "AMTCH" is used to generate "STRD" in "CONTROL & TIMING", only when there is a match. In this way, one channel is continuously displayed and examined even when a number of channels are being scanned.

<u>Packaging</u>

The front panel is 7 inches high and 19 inches wide. The main body of the chassis, which is attached to the rear side of the front panel, is approximately 5¼ inches high, 16 inches wide and 13½ inches deep. The front panel is hinged, and therefore the pc boards can be easily taken in and out of the card cage, which is placed behind it. The right and left ends of the rear panel are bent 90° to form mounting brackets. Therefore, when it is mounted onto the side panels, it can be easily swung open for wiring purposes. The top and bottom covers are perforated with small holes, which provide an adequate ventilation, and which still keep small animals away from the unit. The card cage consists of Scanbe's card file components, which are quickly and easily assembled, and which are versatile to provide infinite variations in forming card files. The size of the pc boards in the card cage is 4.5 inches wide and 6.4 inches long.

Specifications

The prototype unit of the MADC was tested. The test results constitute the following tentative specifications:

Throughput rate	100 KHz
Resolution	12 Bits
Number of channels	64 Differential
Input voltage range	+10.235V to -10.240V
Input voltage protection	±35V
Input impedance	50 MΩ min
Input common mode voltage range	±12 V
System accuracy at 25°C	±0.049% of FS ±½ LSB
System temperature coefficient	±65 ppm/°C max of reading
Sample and hold aperture time	12 nsec
Channel cross talk	70 dB down min. at 6 KHz, from OFF channel to ON channel
System CMRR	74 dB at 60 Hz
Output coding	Two's complement
Front panel dimension	19"W x 7"H
Main chassis dimension	16"W x 5-3/8"H x 13/5"D

Conclusion

We heard some people say, "Why don't you buy commercial units?" We had definite reasons. First, the new MADC had to be able to replace the old DSE units, which had been used. Therefore, it had to have similar physical size, similar input and output s als, and similar connectors to the ones that were associated with the DSE units. It was impossible to find any unit that had such similarities except DSE units themselves. Secondly, a recent quote from Dynamic System Electronics was $7,799 - $8,219 per unit, which was much higher than our cost estimate on our unit. Our estimated cost was $3,500 including parts and labor.

By virtue of IC's, the pc boards in the new MADC were turned out to be much simpler, less complicated than the ones in the old DSE units. The reliability and life of the new MADC are therefore better and longer. The troubleshooting and repair work on the new MADC are easier and faster.

As I mentioned earlier, our work was the first attempt to design and construct a multiplexed ADC unit with IC's and packaged subsystems. We heard various suggestions like (1) expansion to 128 channels, (2) analog view output, (3) three state control on input/output signals, etc. There may be many other suggestions and possibilities. However, it was very important for us to get the job done fast. We therefore had to pass on those suggestions to a second attempt, and constructed basic units. We still believe that these basic units will be used for some time as a unit with a medium accuracy and with a reasonable number of channels.

Acknowledgment

I am grateful to David Von Ohlen for his efforts on the prototype unit construction and the pilot production. Without his close supervision, the first five units might not have been properly assembled. Thanks are also due Robert Gorge for his mechanical design and drafting of the new MADC.

References

1. Analog-Digital Conversion Notes, Analog Devices, Inc., p. 18, 1977.

2. Burr Brown 1979 General Catalog, pp. 5-177.

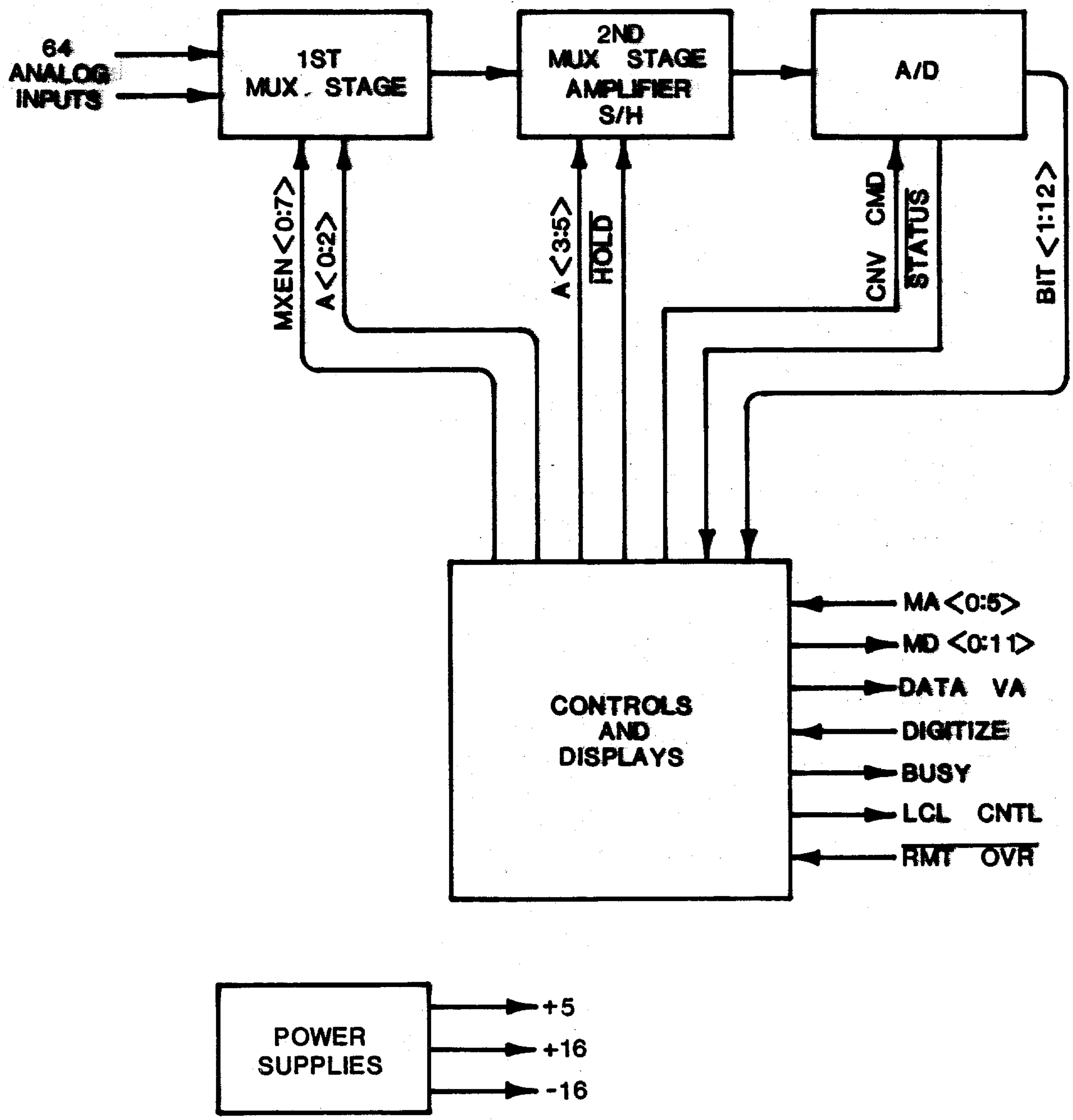
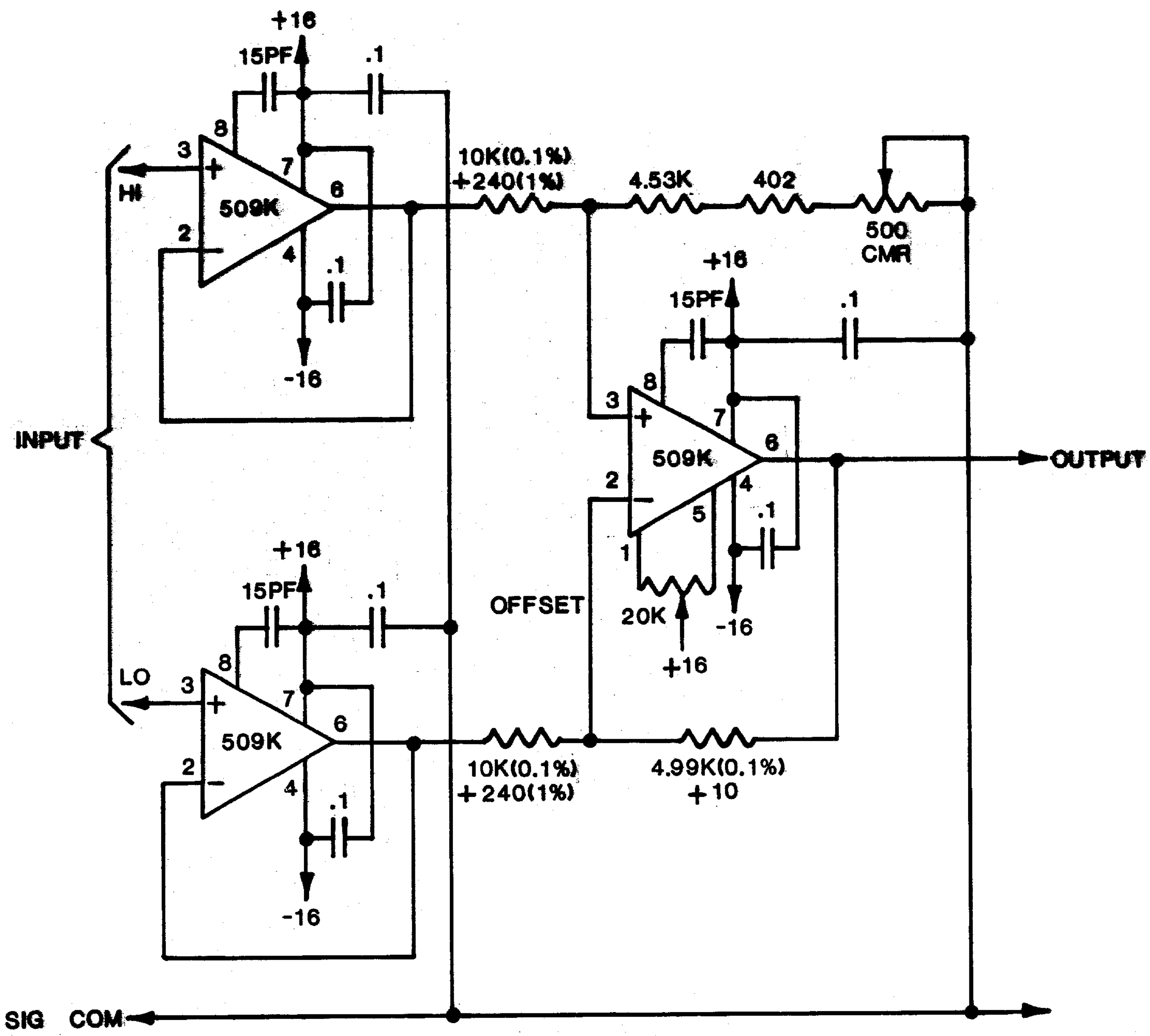


FIG. 2.1 MADC OVERALL BLOCK DIAGRAM

FIG. 2.2 HIGH SPEED INSTRUMENTATION AMPLIFIER FOR MADC



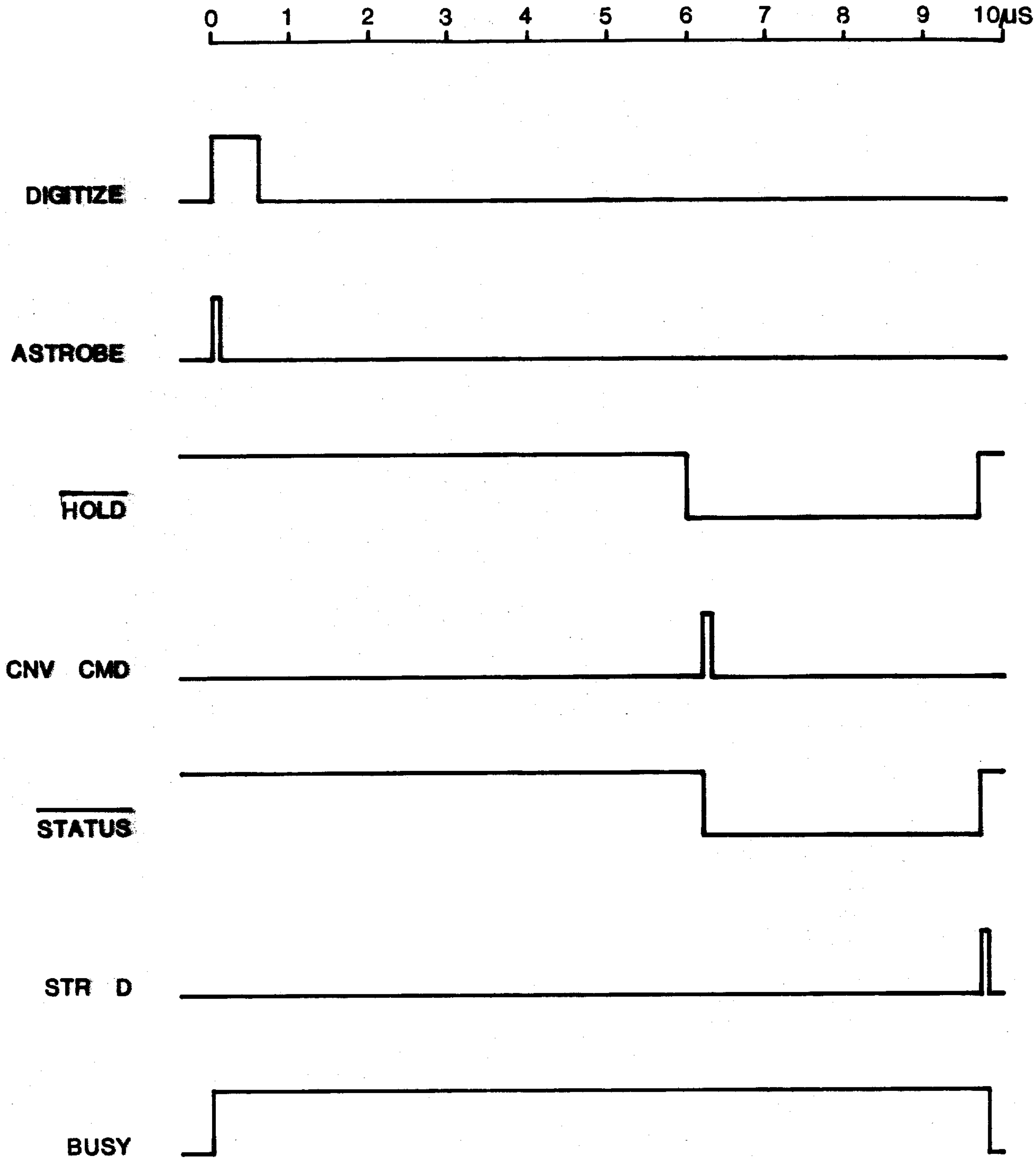


FIG. 2.3 MADC TIMING DIAGRAM FOR REMOTE CONTROL

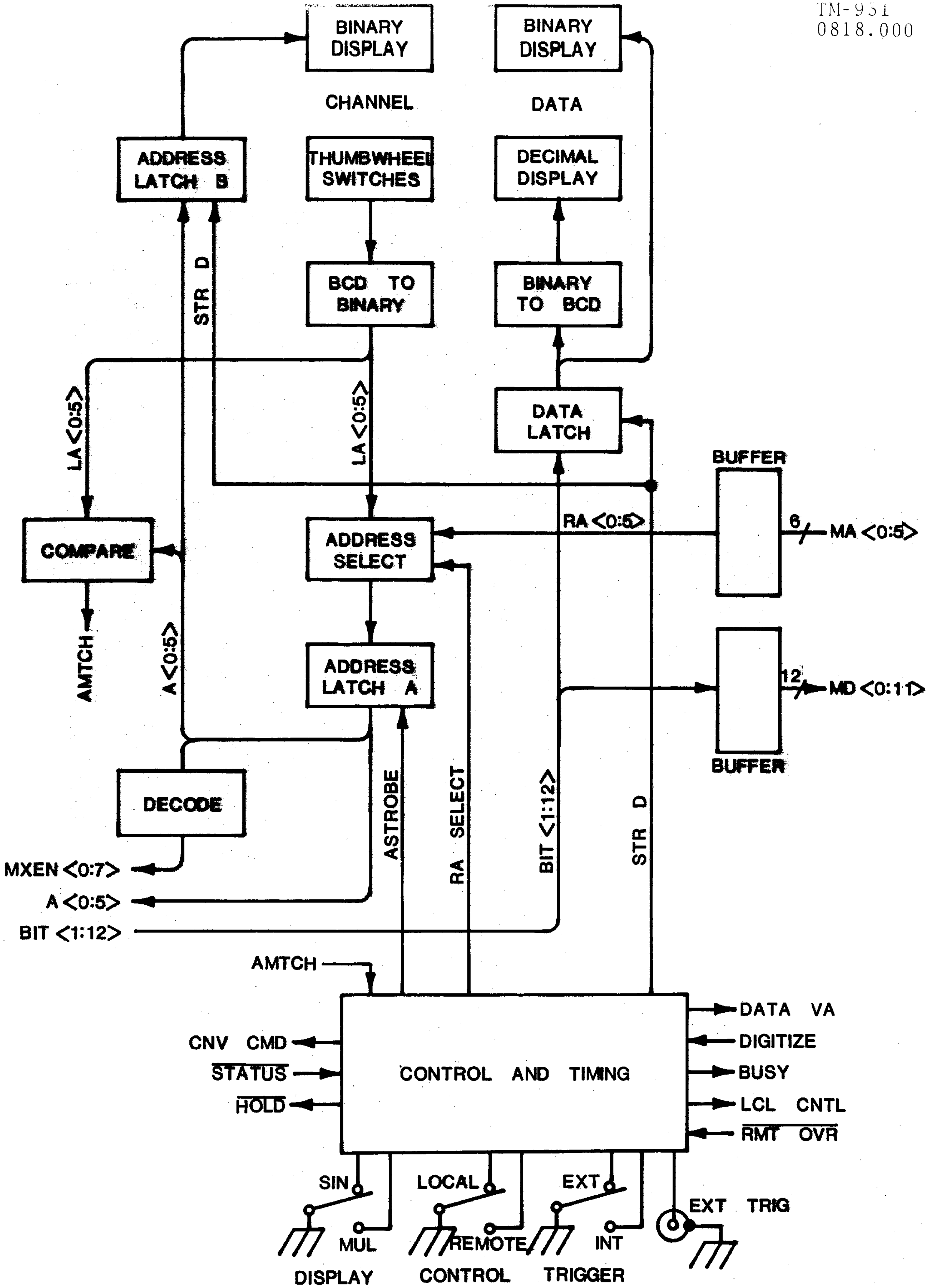


FIG. 2.4 MADC BLOCK DIAGRAM ON CONTROLS AND DISPLAYS

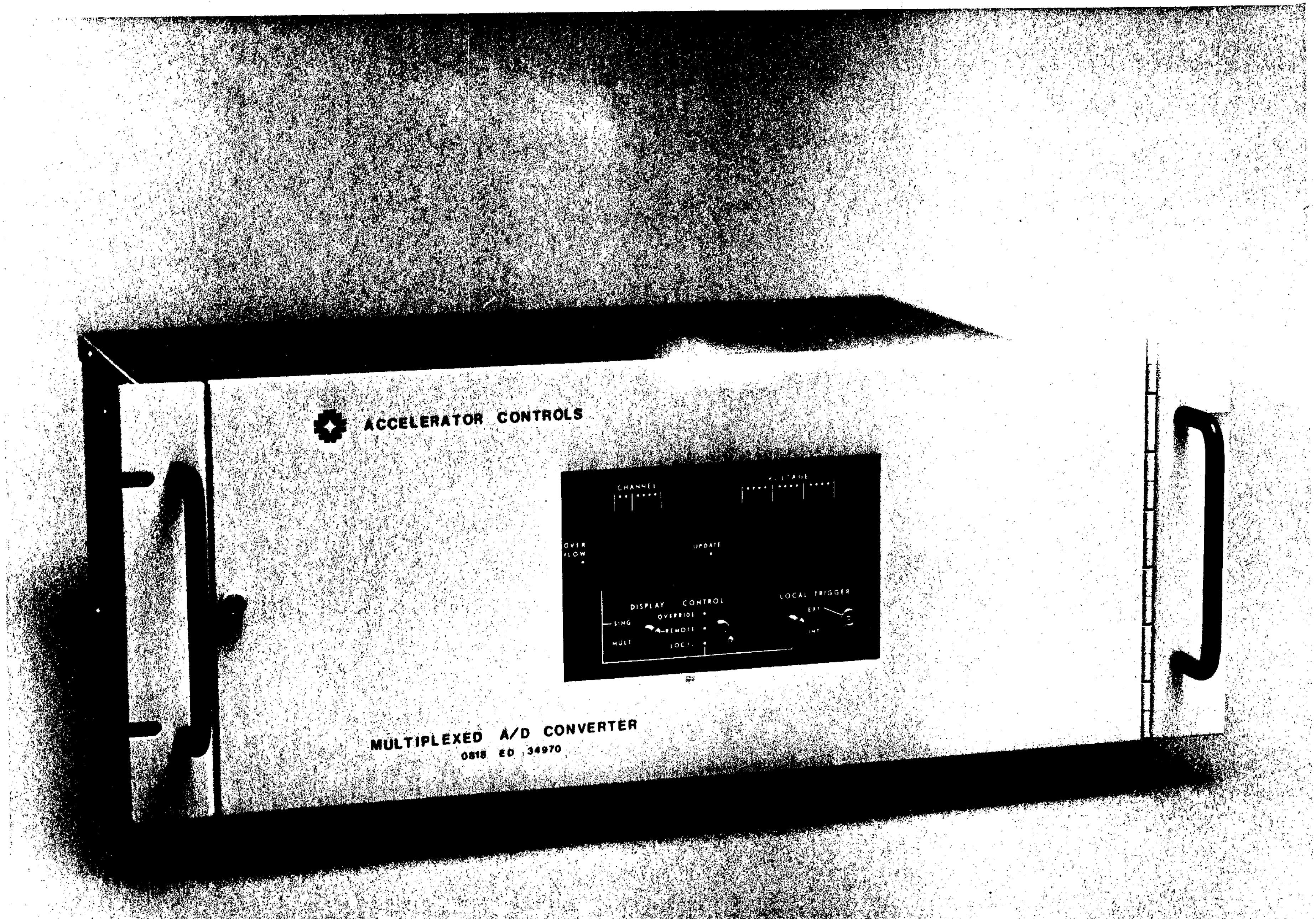


PHOTO 2.1 MADC FRONT PANEL CONTROLS AND DISPLAYS