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ABSTRACT

A seismic signal processor has been developed and tested for use with the NOAA-GOES satellite data collection system. Performance tests on recorded, as well as real time, short period signals indicate that the event recognition technique used (formulated by Rex Allen) is nearly perfect in its rejection of cultural signals and that data can be acquired in many swarm situations with the use of solid state buffer memories. Detailed circuit diagrams are provided. The design of a complete field data collection platform is discussed and the employment of data collection platforms in seismic networks is reviewed.

CONTENTS

ACKNOWLEDGMENT

The authors wish to thank the many people who have worked on the development of the Seismic Detector system. In particular, the Fabrication and checkout performed by T. Clemons, the controller and simulater designed by C. Ferenc. In addition, the authors would like to acknowledge the helpful discussions with J. Yogelowich and G. Mead during the early design phases.

APPLICATIONS OF SATELLITE DATA RELAY

TO PROBLEMS OF FIELD SEISMOLOGY

INTRODUCTION

In 1975, The Geophysics Branch of Goddard Space Flight Center decided that developing a data collection platform (DCP) to transmit seismic information by satellite relay would be an excellent way of using space techniques to benefit scientific research. For the next several years, a cooperative program was maintained with Rex Allen at the U.S. Geological Survey's Branch of Earthquake Mechanics and Prediction at Menlo Park, California, with Goddard furnishing partial financial support for the development of a seismic-event detector algorithm. In 1977, a breadboard event detector, using a first version of Allen's algorithm, was designed, built and tested by Rovert Novas (1977)* at Goddard. This was preliminary to the present effort.

The design goal was a system with maximum reliability and scientific return at minimum unit cost and complexity. Scientific requirements were established by a survey of potential users in universities and federal agencies.

Upon completion of the initial design in mid-1977, it was decided to construct a breadboard engineering model to demonstrate the viability of the concept. The purpose of this effort was to show that a satellite seismic DCP can be constructed with no technical risk. All of the elements of the DCP that might represent a risk were breadboarded and the results were used to refine the final design of the DCP. The breadboard was completed in early 1979 and was initially tested using

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*Novas, R. G., 1977, An Application of Microprocessor Technology to Remote Station Analysis of Seismic Signals, unpublished Master of Science Thesis, Lehigh University, Bethlehem, Pennsylvania.

magnetic tapes of Alaskan seismic events, furnished by the University of Alaska. Since then the breadboard has been undergoing operational tests using a seismic signal transmitted by telephone lines to Goddard from a vertical axis, short-period seismic installation near Baltimore, Maryland.

The stated goal of proving the feasibility of the concept has been accomplished. Programmatic considerations have precluded further efforts to use the existing unit or develop a field-hardened unit. The purpose of this report is to describe and evaluate the breadboard design and operational characteristics. Additional information may be furnished to any group desirous of continuing this development.

HISTORY AND JUSTIFICATION

The collection of data by satellite is a relatively new technique first demonstrated in 1967 using NASA's ATS-1 (Applications Technology Satellite). The first demonstration was the NASA Omega Position Location Equipment System which proved that accurate positions could be obtained from platforms in remote locations and that satellite relay did not degrade the data. This experiment was followed in 1969 by the Interrogation, Recording and Location System flown on Nimbus-3 and Nimbus-4. This was the first global satellite system to demonstrate the worldwide capabilities of data collection by satellite.

Because they were designed to respond to interrogations from the satellites, these ground systems were relatively large and expensive and required considerable power. This was overcome in the Landsat series of satellites, initiated in 1972, by designing the ground platforms to transmit at random times, thus eliminating the requirement for having a receiving system in the DCP. In 1974, NOAA introduced the GOES (Geostationary Operational Environmental Satellite) system that employs either a scheduled or satellite interrogated transmission system.

Figure 1 is a block diagram of typical satellite relaying systems currently being used to return information from low-data-rate geophysical instruments such as tide gauges, strain meters and tiltmeters. However, because of the high-data-rate requirements, no practical cost-effective system presently exists for returning high-data-rate seismic information. For example, continuously recording seismic data, using a 12-bit word for signal resolution and sampling at 50 hertz (Hz), requires almost 52 megabits per day per component.

Off-the-shelf availability of such a field system would have many advantages. Currently, most unmanned seismic field stations either have to be visited every day or two, to replace recording paper, or the information has to be transmitted to a central location by expensive and sometimes noisy phone lines and/or radio relays. Phone lines, almost nonexistent in remote, inhospitable or underdeveloped areas such as Alaska, are often unreliable, even in populated areas. Furthermore, ground communcations often become inoperative before, during, and after a major earthquake. When geophysical systems are operated in extremely inaccessible regions, data are usually preserved on low-powered, slow-speed recording systems which may run unattended for months; the data are then collected several times a year. Such systems require sacrifices in timing accuracy and information content, and since data analysis is often delayed for months after the events, earthquake prediction capability is lost. Also, there can be no assurance that the instrument is performing as planned. In addition, it is often desirable to rapidly augment a seismic network to collect earthquake precursor signals or monitor aftershocks, and the dependence upon phone lines or radio relays might impede the mobility of instrument siting and increase installation time. Finally, for earthquake disaster relief, it would be of inestimable value to have available worldwide seismic data in real time. The primary disadvantages are the increased cost and complexity of the collection system and, depending

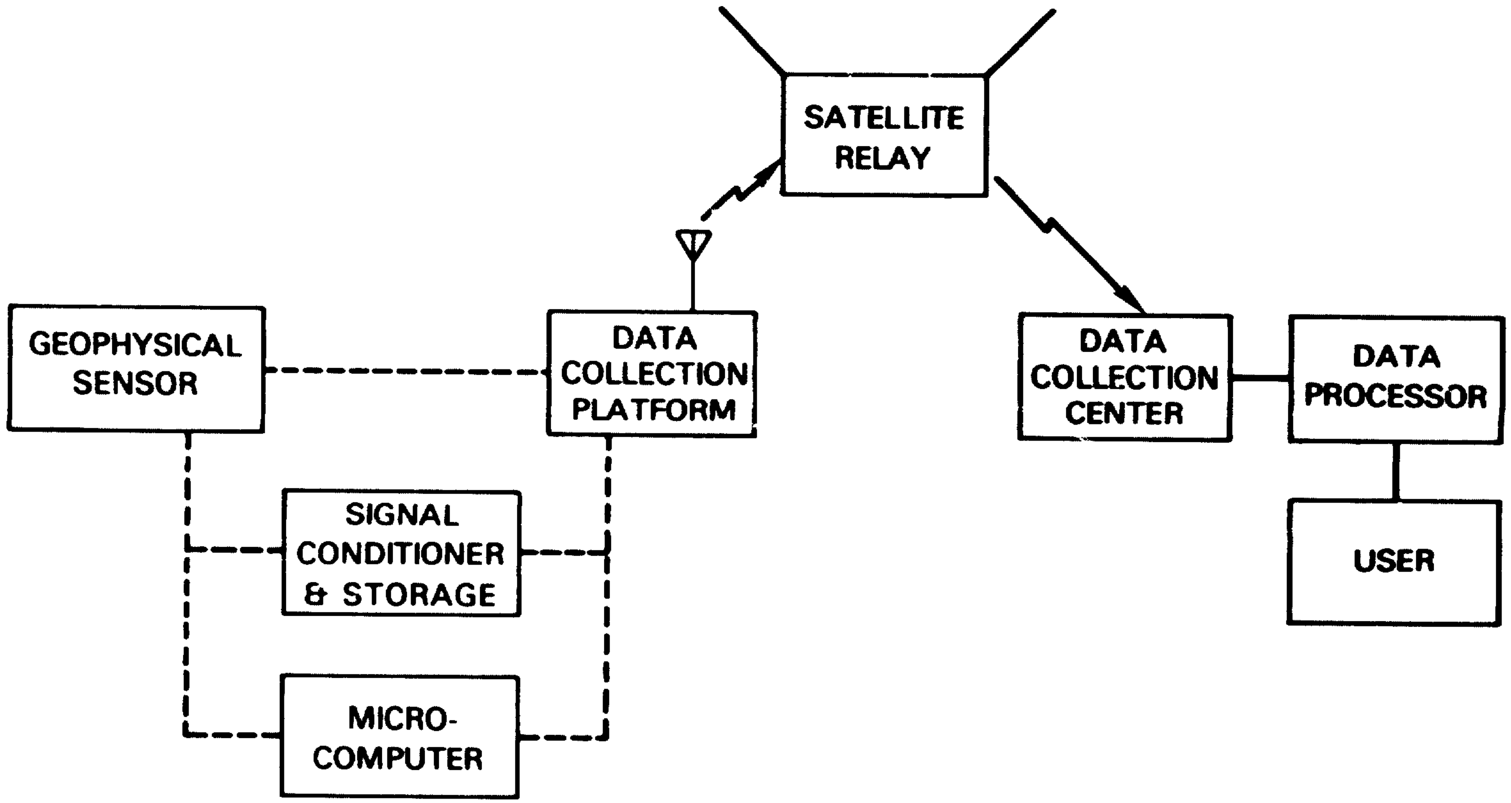

Figure 1. Block diagram of a typical satellite data relay system.

on the requirements of the investigator, the possible necessity of working with simplified or degraded data.

DESIGN PHILOSOPHY AND USER REQUIREMENTS

To be most widely applicable, a seismic DCP should possess the following characteristics:

1. Provide, in near real time, significant scientific data for a broad spectrum of investigators
2. Have a reasonable price; i.e., be affordable by most investigators
3. Operate with existing satellites
4. Operate on a one-to-one basis with a single seismic system; i.e., not be dependent on cross-correlation schemes between multiple systems
5. Be battery operated with at least a six-months life between battery changes
6. Be field hardened; i.e., reliable, capable of unattended operation, environmentally sealed, wide thermal operating range, minimal moving parts such as tape recorders, etc.
7. Be relatively small and lightweight.

The obvious key to a practical field system is an "event detector" device that reliably differentiates signals from background noise. Once this is done, the noise periods can be discarded and the event signals can be operated on by the system. If desirable, further data compression can be performed on the stored events before transmission. igure 2 schematically illustrates such a system.

The majority of event detecting devices have generally depended on a manually-set threshold for comparing short-term energy (signal) with long-term energy (noise). The reliability of such a device is considerably increased when cross-correlation between multiple seismic stations is possible, but such correlation is obviously not feasible when a single seismometer/DCP system is under

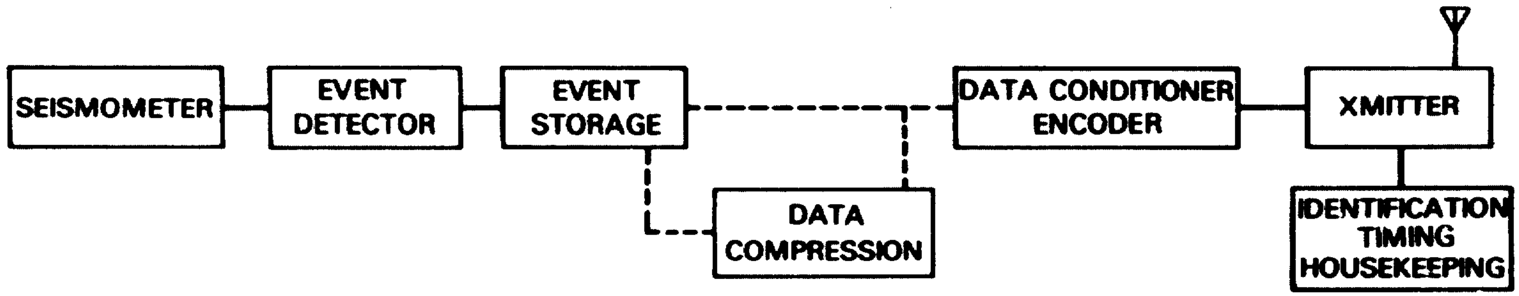

Figure 2. Block diagram of a seismic data collection platform (DCP).

consideration. Allenby et al. (1977), detailed the development of seismic event detectors. The algorithm used for Goddard's breadboard was developed by Rex Allen (1978) of the U.S. Geological Survey in Menlo Park, California, and was based on an earlier design by Stewart (1977).

In considering the scientific data provided by the system, it was decided that the DCP should be applicable mainly to research presently associated with remote, untended, short-period seismic installations. This would generally restrict the use of the system to local and regional data studies and would avoid data requirements associated with relatively complex analyses of very distant events or surface waves. The DCP should then be useful for studies related to:

1. Crustal Hazard Reductions
   a. Earthquake mechanisms
   b. Earthquake prediction
   c. Interplate and intraplate stress and tectonism
   d. Volcanic eruption prediction
   e. Seismicity of reservoir filling.
2. Crustal and Mantle Composition and Structure
3. Mine and Quarry Blast Monitoring
4. Tsunami Prediction.

The next scientific design consideration was what components of the individual seismic signal are needed for the various studies. In order of increasing data complexity these are:

1. Number of events per day	Volcano monitoring Earthquake swarm studies

2. "P" (compressional wave) arrival time	Location and magnitude of earthquakes (tectonic and volcanic)
Direction first motion	Tsunami prediction
Duration and/or maximum amplitude and frequency	Blast monitoring
	Fault plane solutions
3. All of "2" plus "S" (shear wave) arrival time	Earthquake prediction (V_p/V_s anomalies)
	Regional seismicity

The challenge, then, was to design a practical field DCP system that would provide as much as possible of the above information. To help us in this, university and government scientists were consulted regarding their data preferences. Initially, some consideration was given to processing the data in the field and relaying back only numbers representative of the values of times of the desired features. However, developing an algorithm to identify the "S" phase would be a very difficult, if not impossible, task. In addition, we found almost no application in which the users were willing to accept the loss of the actual trace, primarily because of a natural unwillingness to depend on a field computer to analyze the signal. For these reasons it was decided to reconstruct the returned signal into analog form. The general requirements for such a signal were a bandwidth of 0.5 to 25 Hz, a maximum-event length of around 180 seconds, and a digital resolution of 12 bits (72-dB signal-to-noise ratio). Considerable interest was also expressed in using 16-bit word lengths for signal level (96-dB signal-to-noise ratio), but, at that time 16-bit analog-to-digital converters lacked stability and reliability. For these reasons the final system was designed for a 12-bit word at a sampling rate of 50 times per second. Thus, a 180-second recording involves a total of 108 kilobit (kb) (not including any overhead due to housekeeping, timing, magnitude and quality data).

In addition to these primary requirements, other factors arose. First, because the S arrival from nearby events is often stronger than the P on short-period vertical sensors, it is desirable to return a portion of the trace preceding the selected event to verify that the event was picked on the P and not the S phase. For regional earthquakes, the headwave P_n is weak in comparison with P and P*. It is therefore desirable to have, perhaps, 5 seconds of pre-event detect signal so that those phases can be properly identified. It would then be possible to put tight constraints on depth and distance and provide detailed information on regional structure.

A short pre-event strip is also useful for indicating the background noise level and hence the operating reliability of the event detector. For these reasons, a 10 second pre-event strip precedes the recording of the actual event. As mentioned previously, the maximum total recording time per event is 180 seconds (including the 10 seconds pre-event time). However, this total time is adjustable because, for many applications, an event time of 90 seconds is sufficient.

Several users expressed concern about the possible saturation of the system in the event of swarms. A number of schemes were considered. A procedure of buffer swapping to be described below was adopted. Three such buffers or memories would allow an efficiency of 43 percent in the event of swarms. The system would saturate the available output data stream but would be able to record 43 percent of the time for transmission.

Magnetic tape was eliminated for event storage because of mechanical complexities. Reliable bubble memories are not yet available, and power requirements are high. Solid-state memories proved to be quite satisfactory. The breadboard contains two memories. When an event is identified, number one memory records 10 seconds of pre-event noise and, depending on the setting, 80 seconds of the event at a high-data rate. The stored event is then "dumped" at a lower-data rate through the satellite. It requires about 9 minutes for a 1½-minute event to be transmitted to the satellite.

The design was dependent on the choice of satellites. A dedicated channel on a synchronous satellite would permit continuous transmission (depending on the power budget of the DCP). In contrast, nonsynchronous satellites require satellite callup, random or timed data dumps. In both cases maximum data rates vary depending on antenna sizes, power, etc. While there are numerous communication satellites that are technically suitable, ground unit costs are related to the operating frequencies of the satellite. Thus, our requirement for low DCP unit costs eliminated many satellites from contention at the present. Most of the high volume satellites operate in the 1-GHz (gigahertz) or 5-GHz satellite allocations. Technology is not yet up to producing inexpensive and efficient transmitters at these frequencies. A typical 20-watt transmitter at 2 GHz is about 10 times as expensive and half as efficient as its 400-MHz (megahertz) counterpart. In addition, because frequency slots are assigned within satellite transponders to a high percentage accuracy, the frequency control is much more expensive at the microwave frequency than at uhf (ultra-high frequency).

Accordingly, satellites with uplink frequencies in the uhf range are preferred. As an example of the maturity of the uhf technology, a single-module power amplifier capable of generating a 15-watt output signal from 150 mW (milliwatt) of drive at 400 MHz costs about $80. A similar microwave power amplifier costs $1000 and is half as efficient.

The most extensive network of satellites using a uhf data collection system (DCS) is the GOES system. In addition to its prime function as an imaging meteorological satellite, GOES has a

400-MHz uplink DCS. A simplified block diagram of the DCS system is given in Figure 3. Note that there are 200 DCP uplink channels between 401.2 and 401.7 MHz. Each of these channels is 15-kHz (kilohertz) wide and is intended to accommodate ASCII code at 100 bps (bits per second). The satellite, being synchronous, allows random dumping by the DCP whenever an event is identified and stored. Also, since the United Nations' World Meteorological Organization (WMO) protocol provides for a worldwide GOES system, it seems likely that a GOES type DCS will be available for at least the near future.

Therefore, the design and demonstration work was conducted, assuming the GOES DCS characteristics as the design driver. However, because the 100 bps restriction is relatively severe (and, in fact, represents a "worst-case" situation for all practical purposes), and since microwave transmitter technology is fast becoming mature, a modular approach was adopted which would allow an easy change of output data rate and transmitter frequency.

BASIC OPERATING PRINCIPLES OF SYSTEM

The output of a single-axis, high frequency (1 to 2 Hz) seismometer is continuously monitored by an automatic event detector ("P" picker). When an event is identified, up to 180 seconds of signal (10 seconds pre-event noise and 170 seconds of event) is recorded and stored in a solid-state memory at a sampling rate of 50 times per second and a 12-bit word for signal resolution. A delay line allows the system to recover 10 seconds of pre-event signal after the event picker decides it has an event.

Upon completion of recording, the first memory system goes off the line and begins transmitting to the GOES satellite at 100 bps. During the 18 minutes required for the first memory to dump a

GOES DATA COLLECTION SYSTEM

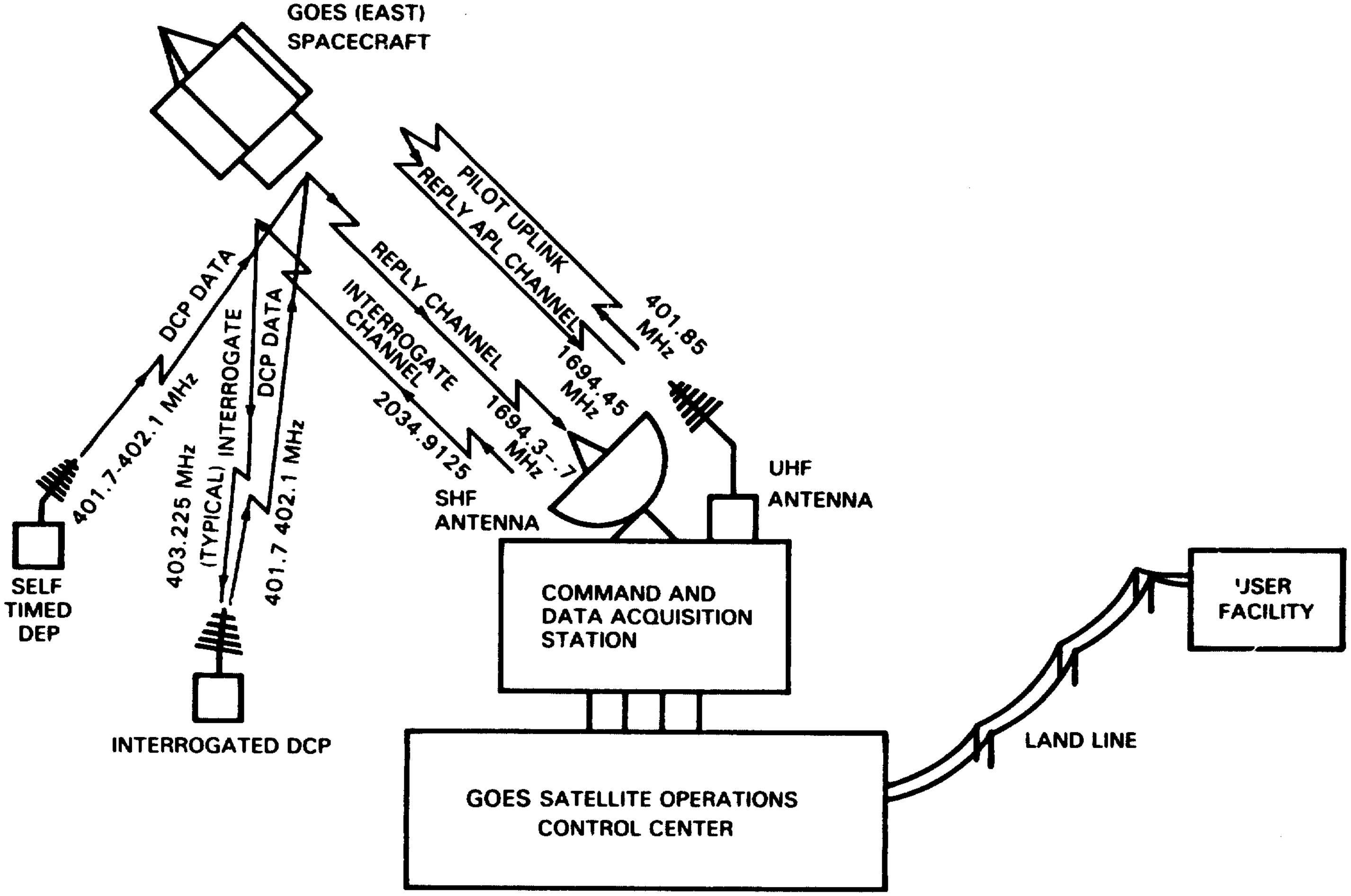

Figure 3. GOES data collection system data flow.

3-minute signal to the satellite, a second memory is on the line to record the next detected event. For field use, particularly if swarms are expected, at least three memories would be required.

DEMONSTRATION HARDWARE

The demonstration breadboard was designed and constructed according to the following criteria:

Input signal	Analog
Bandwidth	25 Hz
Event length	180 seconds (maximum)
Resolution	12 bits
Output signal	Compatible with GOES (100 bps bi-phase)
Operating mode	GOES emergency event triggered
Power	Battery pack
Battery life	Six months (average 12 events per day)
Cost per field unit	Less than $10,000, including DCP and radio set

A block diagram is given in Figure 4 and contains all the subunits of the breadboard. In what follows, the design of the demonstration unit on a subunit basis will be discussed.

The breadboard receives signals from an event simulator, a tape recorder, or a conventional discriminator. The prerecorded analog tapes were provided by the University of Alaska. The event simulator generates a damped harmonic signal electronically. The breadboard output is a serial-digital signal at the GOES rate of 100 bps. This signal is passed to a digital-to-analog converter for comparison with the input signal.

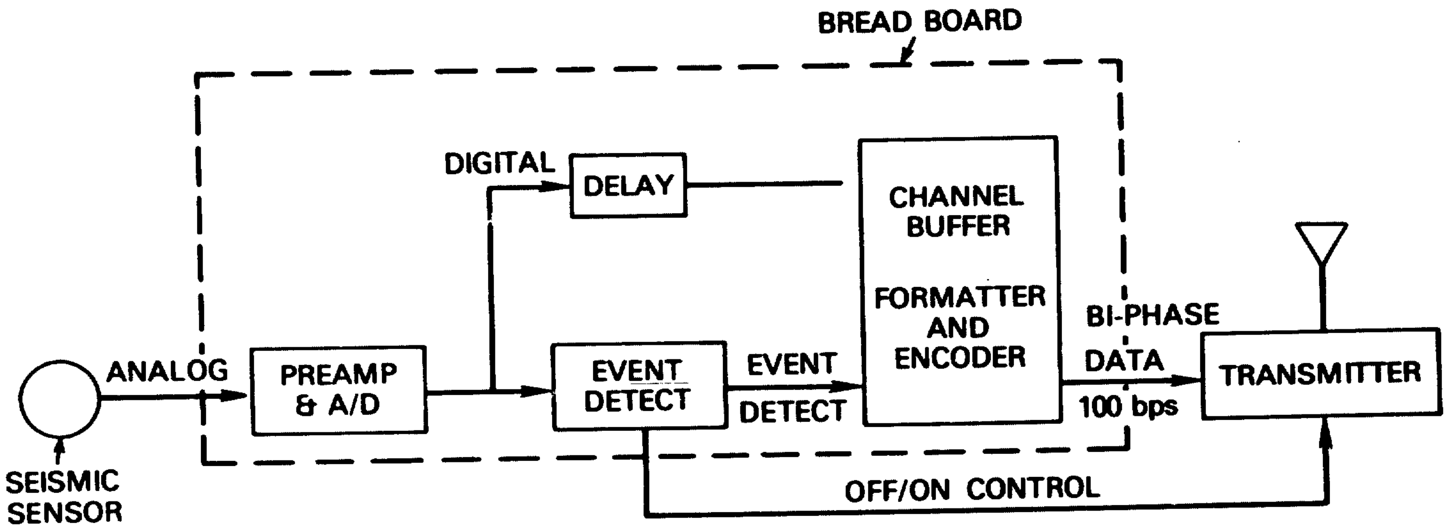

Figure 4. Block diagram of seismic DCP showing portion constructed in breadboard.

ANALOG CIRCUITS

Figure 5 shows the analog circuit block diagram, a detailed circuit diagram is shown in Sheet 2*. The instrumentation preamplifier has a bandwidth of 50 Hz and a gain of two. This amplifier gain can be increased to 2000 by a component change. The high gain was not required for the breadboard because the tape recorded signal was already preamplified. The wide bandwidth of 50 Hz enables the event detector to determine event-occurrence time to within 10 milliseconds. With a 50-Hz information bandwidth, the Nyquist sampling theorem dictates at least a 100 sample-per-second rate. The 12-bit analog/digital (A/D) converter has additional filtering (25-Hz low pass) to minimize signal aliasing.

The demonstration breadboard could have been designed with one 12-bit A/D converter followed by a digital filter and a divide-by-16 circuit. This approach was not used because: (1) using the digital divider and filter would have required more modules, and (2) this approach also allows an easy change of microprocessors since the entire event detector is isolated from the main data stream.

Digital Delay

A delay is required before buffer storage to:

1. Provide the experimenter with some pre-event noise for signal analysis.
2. Provide time for the microprocessor to calculate whether an event has occurred.
3. Provide pre-event time for the base station receiving system to obtain synchronization.
4. Provide time for the DCP transmitter to stabilize prior to sending an event signal.

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*There are 11 engineering blueprints referred to as sheets. (See back cover.)

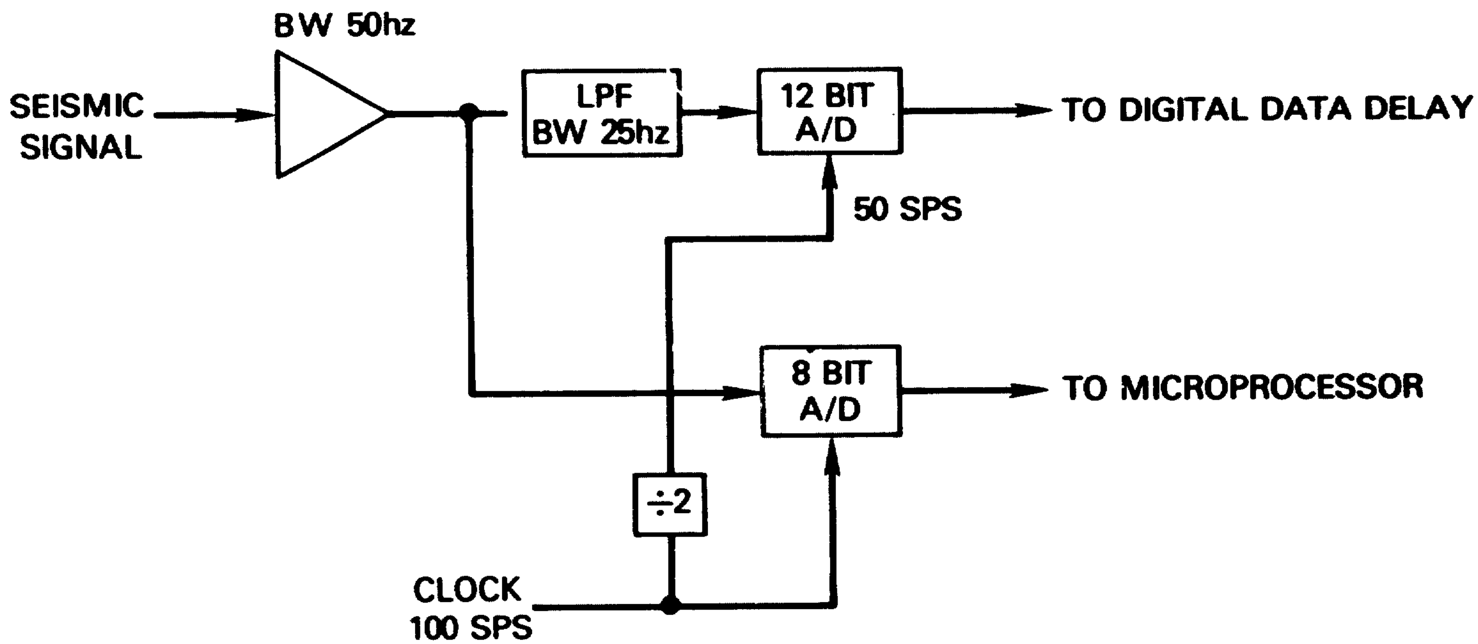


Figure 5. Analog circuit block diagram for breadboard.

A delay of 10 seconds appears to be adequate to perform these functions. A delay of 10 seconds is obtained by a 1024 word, 12-bit-per-word CMOS RAM used as a first in-first out memory. If more delay is necessary, the delay time can be changed to a maximum 81.92 seconds by a wiring modification that changes the decoder input signals (Sheet 3, module E3). The decoded output resets the 12-stage ripple counter module E1 at the required time. The output of the ripple counter also provides the addressing signals to RAM devices with address-state changes every 20 milliseconds.

Data delayed by the delay time is always being sent to the buffer memory module for possible storage. Recording in the buffer storage depends on the buffer storage control and gating signals that are under control of the microcomputer.

100 kb Buffer Memory

There are several solid state technologies that can be used for a memory size of 100 kb; i.e., core, plated wire, CMOS, NMOS, MNOS and magnetic bubble. Because of reliability considerations, mechanical devices (i.e., tape recorders) were not considered. Charge coupled devices (CCD) were not a candidate because of our need for a low operating rate of 100 bps. The operating rate has to be greater than 50 kbps for most CCD chips containing 4096 bits or greater because of "dark current" limitations. Plated wire is too expensive; core dissipates too much power compared to the other solid-state devices. Metal-nitrate-oxide semiconductor (MNOS) devices are too expensive, ease of manufacture is poor, and the availability of second sources is also poor. A list of the candidate components and their characteristics for a 100-kb buffer memory is given in Table 1.

The static CMOS RAM memory device was selected over the other candidates primarily because of the very low average power dissipation. Rejection of the magnetic bubble device was not primarily

Table 1
Memory Components Characteristics for Mass Memory Application

	CMOS	DYNAMIC NMOS	MAGNETIC BUBBLE	STATIC NMOS
Manufacturer's Number	1M6508	Intel 2116	TBM 0100	EMM 4044
Chip Density (bits)	1024	16384	92000	4096
Chip Organization	RAM	RAM	FIFO	RAM
Number of Different Voltages Required	1	3	4	1
Operating Temperature (°C)	-55+125	-55+125	+15+35	-55+125
Module Cap., kilobits	110.6	114.7	92	110.6
Average Power, watts	0.054	1.7	1.1	6.4
Module Component Cost ($)	540	390	470	416

due to power requirements. The magnetic bubble device has the advantage that storage is nonvolatile and the device can be power switched. We did not use the device because its availability is poor at present and the ease of use in the design is difficult. A re-evaluation of the magnetic bubble should be conducted in a few years, when the device's performance, availability, and adaptability are improved.

A detailed schematic for each of the two 110-kb buffers is given in Sheet 7. Note, that the buffer is parallel organized (12 bits X 9216 words). The storage elements are CMOS RAMS (1024 X 1). Operating length of each buffer can be changed by eight switches from 2048 to 9216 words in steps of 1024 words. This corresponds to event lengths of 41 to 184 seconds. (S-P range circles of about 250 kilometers (km) to 1700 km.)

Event Detector

The event detection function is performed by a microprocessor that is programmed to process digitized seismic signals in real time. Interface to the rest of the system is particularly simple. Figure 6 shows the event detector interface signals. The only output interface signal used by the remaining modules is the event-detect signal; the event-status data, which would be used in a field unit, is not used here; this signal can be obtained via the data terminal. The control signals and program constants are on front-panel switches and are read only during program initialization.

There are several microprocessor systems that could have been used. A list of candidate microprocessors is given in Table 2. The CMOS CDP1802 was selected based on the following criteria:

1. Low power
2. Add time
3. Support chips available
4. Reliability (only microprocessor on GSFC preferred parts list).

The CDP1802 microprocessor is a single-chip, 8-bit, static microprocessor fabricated in CMOS technology. The CDP1802 thus has all the advantages of CMOS technology; i.e., low power dissipation, single wide-range power supply, full operating temperature range and a single-phase clock. Our system uses a 5-volt power supply and a 2-MHz clock. (With a 2-MHz clock, the machine-cycle time is 4 microseconds and the instruction cycle time is 8 microseconds.)

Refer to Sheets 4, 5, and 6 for the event detector module details. Note that Sheet 4 shows the interface and control circuits and the connections to the CDP1802 microprocessor. Sheet 5 diagrams the 4K words of RAM (used as working storage) (32, CDP1822's). Sheet 6 shows the 4K

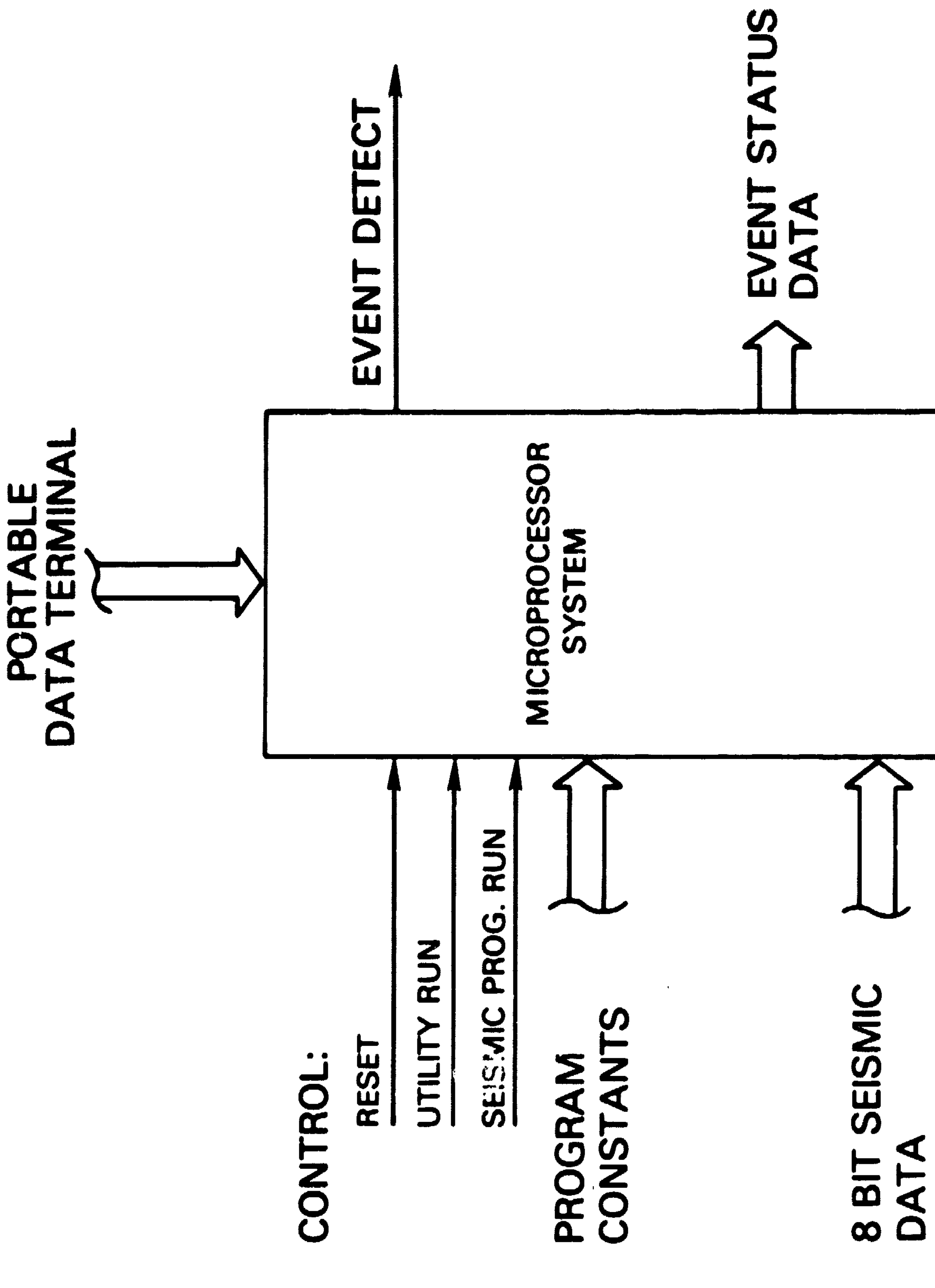


Figure 6. Event detect interface signals.

Table 2
Candidate Microprocessors Characterization
With a 2-MHz Clock

Part Number	Process	Power (Milliwatts)	Data Bus Width	Add Time (Microseconds)
SBP 9900	I^2L	500	16	9
TMS 9900	NMOS	1000	16	15
CDP 1802	CMOS	4	8	8
I M 6100	CMOS	5	12	10

words of ROM (4, M 2700) and 32 words of RAM used for program and register storage). Only 2K words of ROM are actually needed; 1K words for a standard utility program and 1K words for the seismic processor program. The utility program is used to communicate with the data terminal.

Control Circuitry

The control circuitry is used to generate:

1. Analog-to-digital conversion sample pulses
2. Buffer-control signals
3. Multiplexer-control signals.

All of these signals are derived from combinations of the 2-MHz clock; the event-detect signal and the buffer full/empty signal.

The 2-MHz clock is divided down to generate all the sampling and timing pulses (modules C1, C10, Sheet 8). Also derived are the analog-to-digital converter (ADC) sampling pulses which are continuous at either 50 cps (12-bit ADC) or 100 cps (8-bit ADC).

Figure 7 shows the buffer timing sequences that are generated on the control circuit board. Until an event-detect signal occurs, both buffers are in standby. When the event detector declares a valid event, the event-detect signal triggers buffer 1 into operation. Buffer 2 remains in standby. Soon after the event-detect signal occurs, the buffer-1 clock starts operating at its high rate (50 cps) and the MWR-1 signal enables a write operation. Buffer-1 initialization occurs when the first clock pulse causes memory location one to be written into. After buffer 1 is full, the "1 full" signal is generated. The buffer-full signal starts a read operation clocked at the GOES rate (100 bps). This is done through the MWR signal that places the memory into a read state. The memory addressing is organized so that the first-clock pulse after full signal enables reading from memory location one (the memory is a first-in/first-out type). After all memory cells are read, a (1 empty) signal is generated which places buffer 1 into standby. However, if another event occurs between the buffer-full and the buffer-empty signal, buffer 2 begins a write operation. Buffer 2 will not perform a read operation until buffer 1 has received an empty signal, and a buffer-2 full signal is generated.

The data-ready signals, diagramed in Figure 7, control the multiplexing of the two buffer output signals into one signal during buffer read times (Sheet 9). In a field DCP, this signal would be biphase modulated and then sent to the transmitter. In our unit, this signal is sent to a digital-to-analog converter, then to a visual recorder. The recorder used is a standard Sprengnether three channel drum recorder. The three signals recorded during unit-performance testing are: (1) the analog signal after the preamplifer, (2) the event-detect signal, and (3) the delayed processed data from the buffers read out at the equivalent of 100 bps.

The unit was constructed of CMOS DIP integrated circuits mounted on Augat circuit boards with connections by wirewrap. These boards are mounted into a standard 48-cm (19-inch) rack chassis,

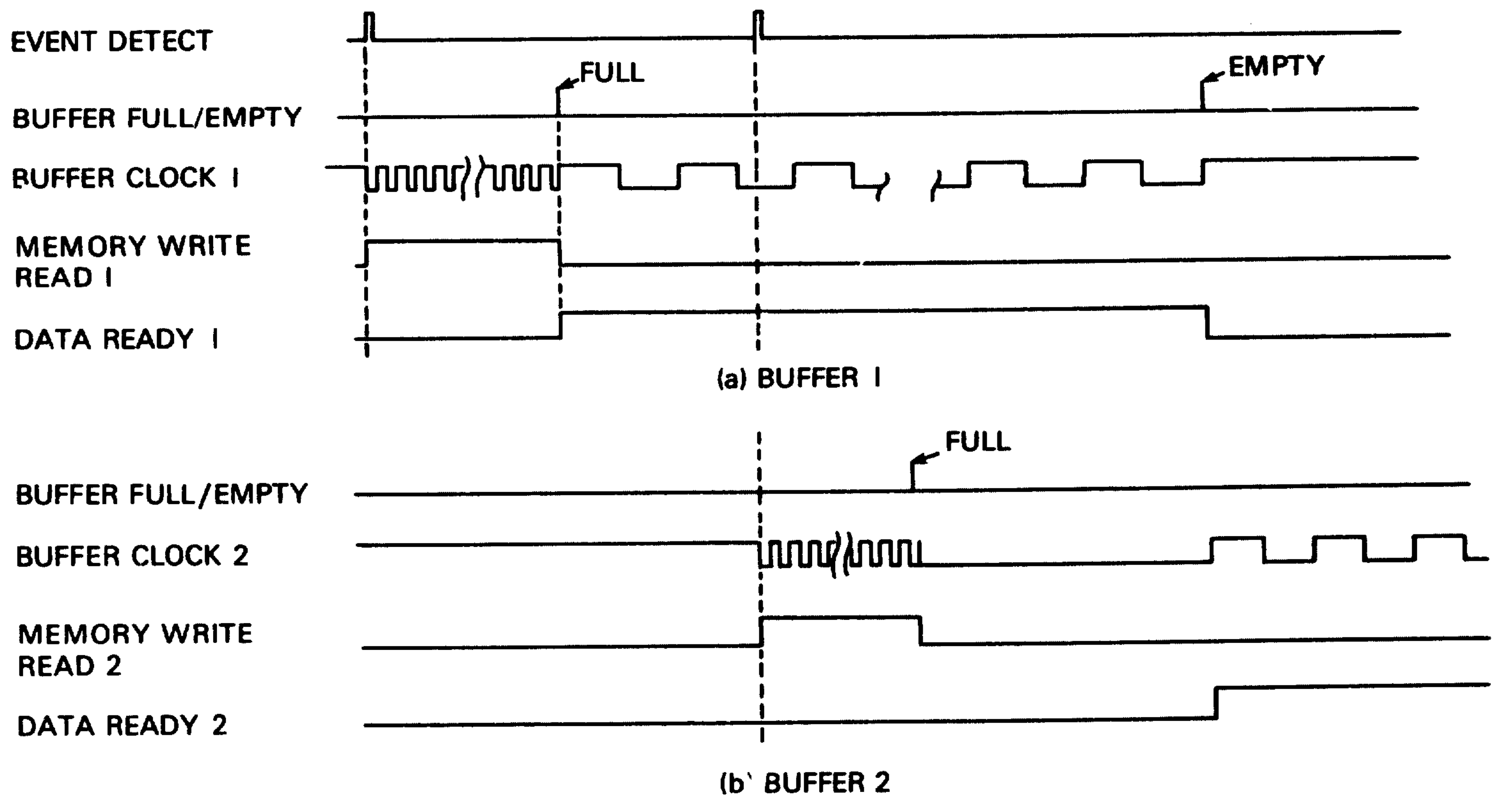


Figure 7. Buffer timing diagram.

8.5 cm (3½ inches) high. Power supplies are mounted separately. The unit was partitioned into boards as follows:

Board	Function
1	Analog circuitry, control logic and multiplexing
2	Microprocessor, associated random access memory and read only memory
3	Buffer memory #1
4	Buffer memory #2

The system was partitioned so that: (1) a different type microprocessor module could easily be added for additional evaluation, and (2) buffer memory could easily be expanded if necessary. All controls are front-panel mounted with exception of the buffer-length switch.

EVENT-DETECTOR ALGORITHM AND ITS IMPLEMENTION

The event-detection program, used on the 1802, is based on an algorithm developed by Rex Allen (1978) for the automatic detection and timing of seismic events from a single seismometer; however, modifications were necessary to run the program on the 8-bit RCA 1802 microprocessor. The program is an interrupt-driven (real-time) task that identifies events to within 10 milliseconds. The program also evaluates the accuracy of its picks, thus eliminating the recording of events generated from noise sources such as vehicle traffic.

Appendix 3 contains the 1802 assembly code, a memory map, and the tables for conversion of control constant values to switch settings. Appendix 2 contains a running description of the Allen (1978) algorithm as implemented for the 1802.

Data from the 8-bit analog/digital converter is searched for the possibility of an event according to Allen's criteria. The characteristic-function calculation is the primary time consumer of this event-search mode operation. Ideally, the whole event-search process for one sample should not take more than 10 milliseconds. In practice, the average time was calculated as 9.64 milliseconds, and in the worst case, 16.4 milliseconds. In actual use, we found that most samples (85 percent) could be handled in 10 milliseconds. When the program requires more than 10 milliseconds to process the sample, the next sample is ignored. The consequences of this time constraint are discussed in the engineering tests section.

Once a potential event is registered, the program enters the event-validation mode to test whether the suspected event passes duration, frequency, and amplitude criteria. On the average, this process should take 6.52 minutes, and in the worst case 13.28 milliseconds. In practice, we have not observed undersampling during the event-validation mode.

The current formulation of the algorithm will store up to 256 event initiation times in the form of clock cycles since initialization. Interpolation to a fractional clock cycle is not done. In addition to the event times, the zero crossings and peak amplitudes used in the analysis (up to 128) are also available. The memory lap in Appendix 3 shows that of the available 4K words of RAM, only about 1.5K words are used. Of the 4K words of PROM, 1K words are required for the event-detection program, while 1K words are used for the utility. This small RAM/ROM requirement indicates a possibility of sharing the memory resources between two processors to decrease the apparent cycle time. Although this alternative might permit faster processing of individual samples, multiprocessors have not been explored here.

The expected time requirements during each of the processor modes could be improved by using high-speed multiply/divide chips as peripheral devices to the 1802 processor. Although 1802 processor compatible forms of these chips are not yet available, it seems likely that such devices will appear in the immediate future.

Engineering Evaluation

The completed unit was subjected to several tests designed to evaluate the system's ability to detect events over a wide range of input-signal parameters. These measurements were then used to calculate: (1) the probability of false detection on broadband noise, (2) the probability of under sampling and, (3) the time to detect and verify an event.

The sensitivity to noise was measured with a "white" gaussian noise signal (i.e., no impulse noise). The probability of a false detection and the ability to complete the search and validate tasks in the prescribed time were measured. The statistical behavior of this type of noise exceeds, within the design bandwidth, the current implementation of the program's validation test (20 zero crossings in 2 seconds). Theoretically, additive gaussian noise in a 50-Hz bandwidth should have 38 maxima per second and 50 zero crossings.

A graph of the probability of false detection as a function of noise and gain is given as Figure 8. The noise levels are in millivolts per square root hertz measured after the preamplifier (bandwidth 50 Hz). Also plotted along the abscissa are the analog/digital converter quantization levels. With the program gain set to maximum, the figure shows that the probability of a false trigger increases significantly as the noise level rises above one quantization interval. For this reason, the noise level should be adjusted to less than 5 millivolts.

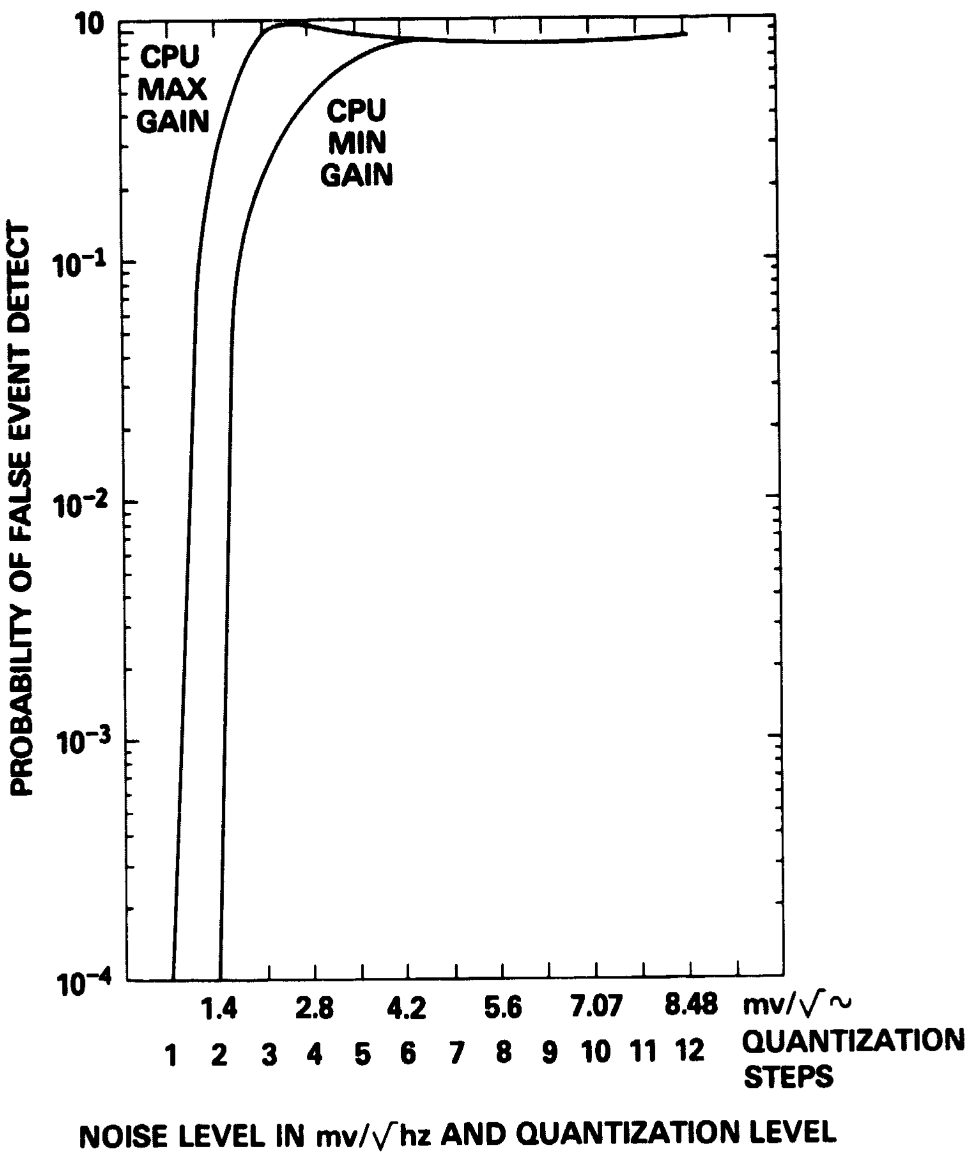


Figure 8. Probability of false detection as a function of noise and CPU gain.

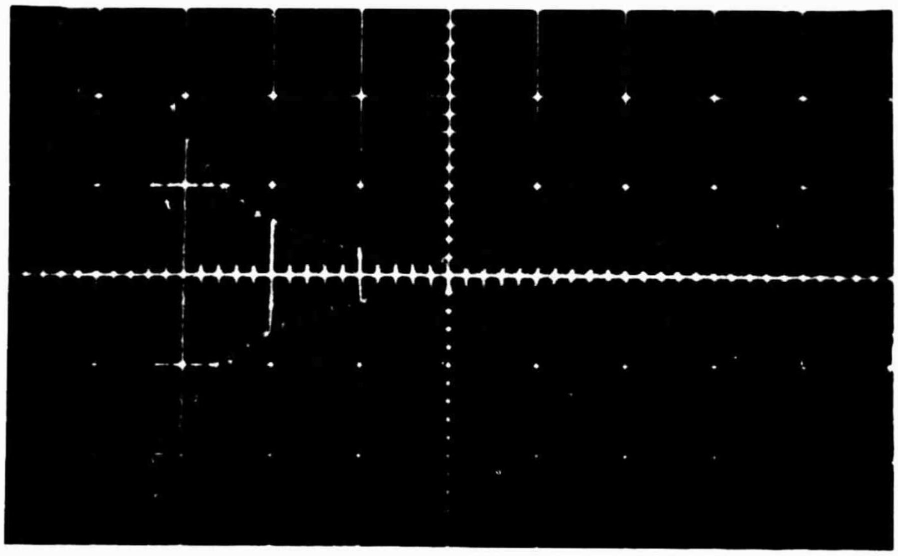
The predicted number of instructions for the program to process one sample in the search and validate modes, with a full scale signal of 127, is as follows:

Mode	Worst Case	Average	At Best
Search	2050	1205	795
Validate	1650	815	705

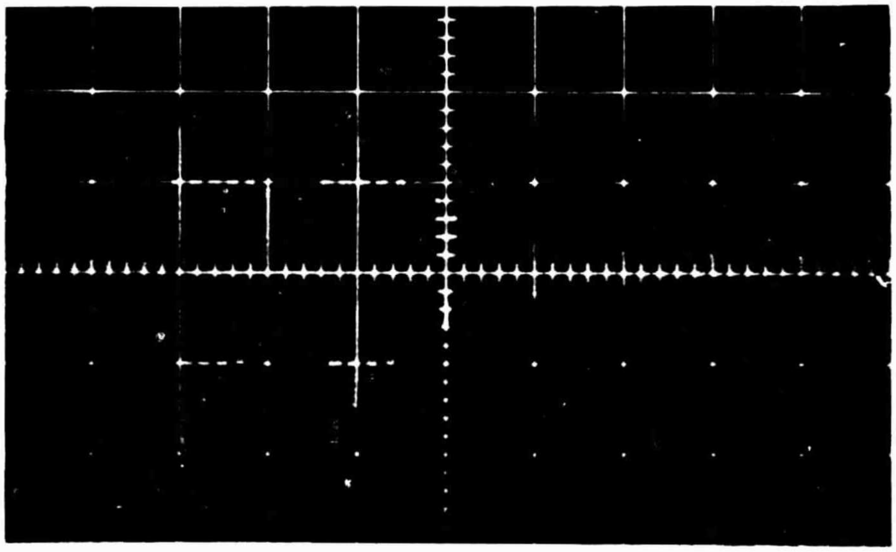
For a 2-MHz clocking rate (which yields 8 microseconds per instruction time) there will be 1250 instructions within the 10 millisecond data sampling interval. It appears that under worse case conditions the central processing unit (CPU) data input could be under sampled, since the maximum number of instructions per sampling interval is 1250. Measurements were made to check the efficiency on real-time data. The algorithm efficiency was measured by counting the CPU external flags (EF) that request transfer of data into the CPU. EF pulses were counted over a 10-second period for various input noise and signal levels. Over a 10-second period there should be 1000 transfers.

The following results were obtained:

1. No under sampling was detected with noise levels of 5, 10, 20, and 30 millivolts. With the CPU programmed for maximum gain, the number of instructions to process these noise levels varied from 2 to 75 per EF sample time. The number of instructions was directly related to the noise level. As expected, the maximum gain setting yielded the largest running time.
2. No under sampling was detected when a simulated event was used as a signal. The simulated event is an electronically generated damped harmonic sinewave with a natural frequency of 10 Hz and a decay time of about 3.0 seconds (Figure 9). Under sampling was checked with various peak signal levels (4, 2 and 1 volt) and the CPU gain.



(a) SINGLE EVENT



(b) COMPOUND EVENT

Figure 9. Electronically generated event signals, vertical axis 2.0 v/cm, horizontal axis 0.5 sec/cm; a. single arrival; b. double arrival (P,S).

3. Under sampling was detected when a compound signal was used. A compound signal is two simulated events that occur within one second of each other; i.e., double arrivals or P and S phases (see Figure 9b). Under sampling was detected when the CPU was operating at maximum gain and the peak-input signal was 4 volts. Under these conditions the probability of missing a data transfer into the CPU was calculated to be 0.011.

4. Figure 10 shows the relationship between the start of an event and the event-detect signal. Measurements obtained from over 200 trials, with both simulated and compound signals, show a variation from 0.1 to 3.0 seconds from the start of an event to the leading edge of the event-detect signal, t_D. Figure 11 is a plot of the mean time to detect and verify a simulated signal t_D, as a function of peak-signal level and the CPU gain. These tests showed that a 10 second delay is sufficient to provide the computational time needed to determine that a noncultural event has occurred.

PERFORMANCE TESTS

As part of the evaluation, the processor unit was connected to a realtime analog signal from an auxilliary short-period vertical seismometer (SPZ) at the Geophysics Branch, Ellicott City, Maryland, seismic station (identification code ECM). This signal is unfiltered and has a bandpass appropriate to the seismometer and voltage-controlled oscillator responses (0.1 to 30 Hz). The ECM station is located just east of the intersection of I-40 and I-70 west of Baltimore, Maryland. The instrument package is on a poured concrete slab in contact with the banded member of the Baltimore Gneiss. Because of its location, unfiltered signals from ECM contain large numbers of heavy and light vehicle signatures. I-70 is, in fact, one of the main truck routes into Baltimore. Local earthquakes and close mine blasts are not frequent enough to provide the kind of detailed evaluation of the event

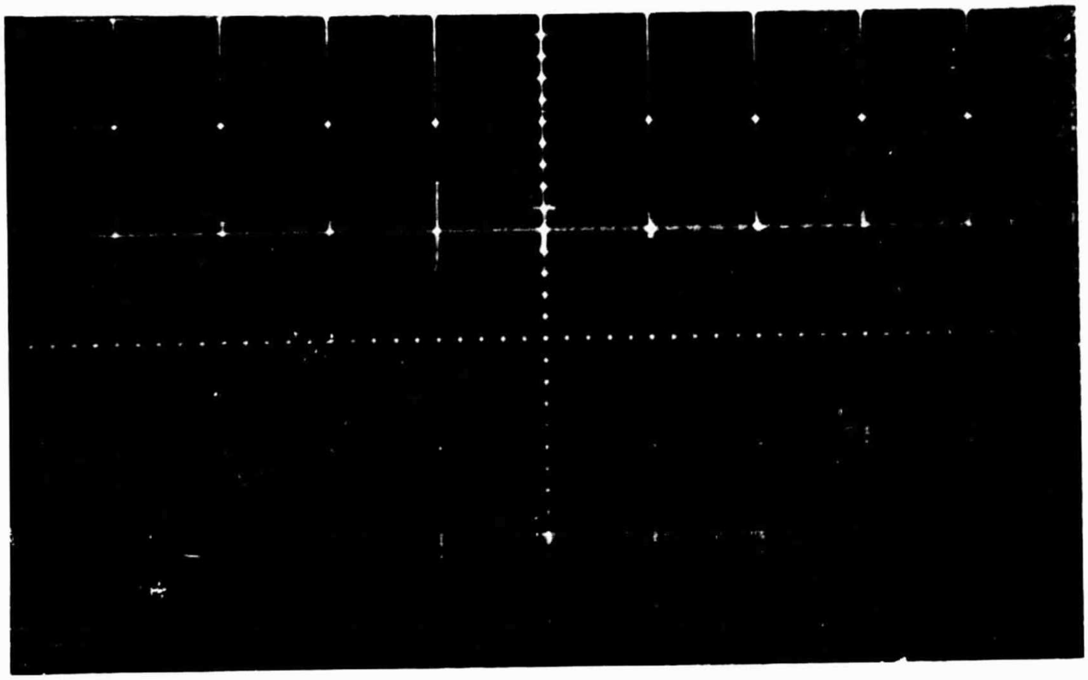


Figure 10. Timing relationship between the start of a simulated event (a) and the event-detect signal (b). Vertical scale 5 v/cm, horizontal scale 0.5 s/cm.

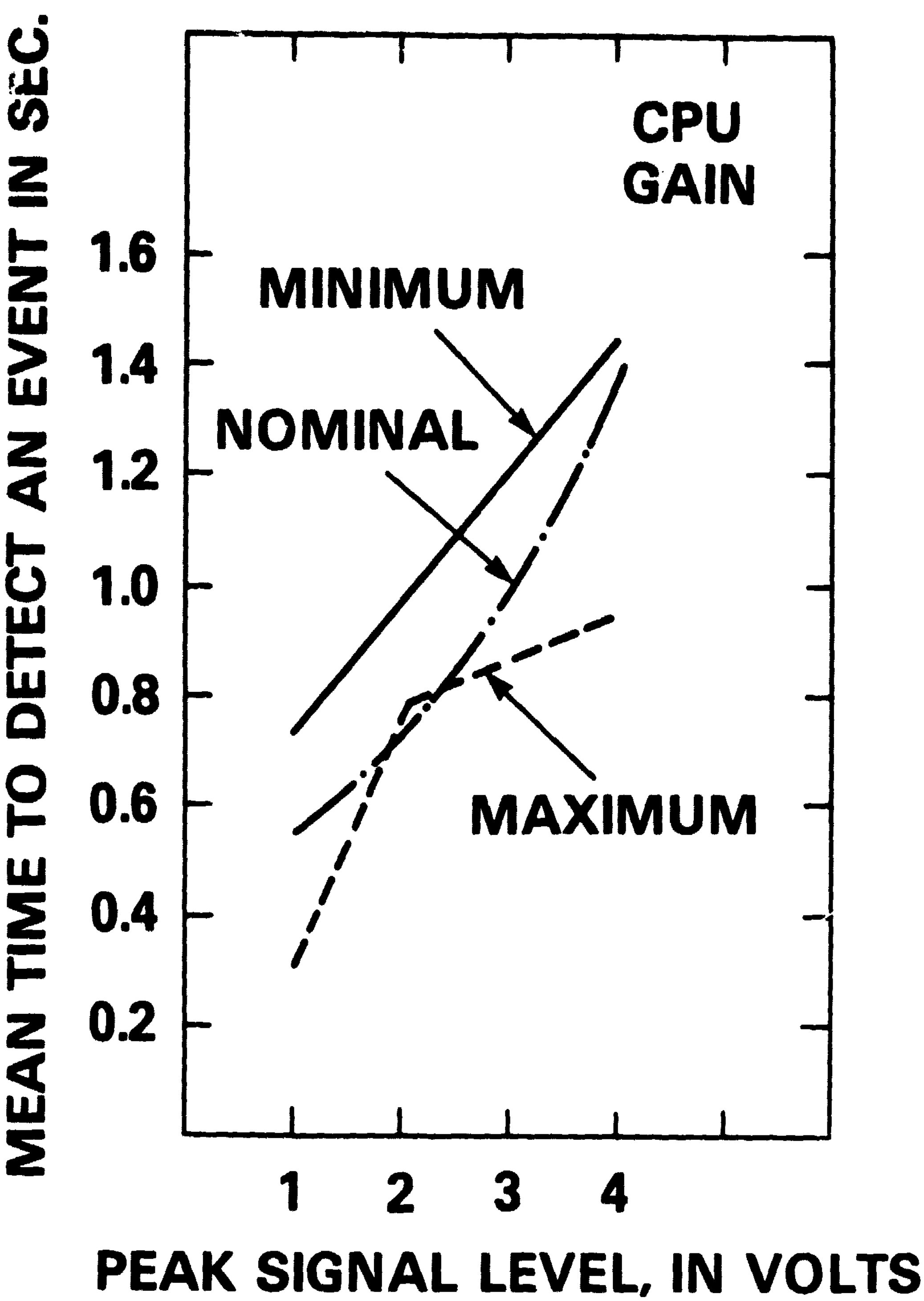


Figure 11. Mean time to detect an event as a function of signal level and CPU gain.

recognition algorithm on seismic signals as reported by Allen (1978). The relatively low frequency of such events only allows us to show that the Allen algorithm performs on such blasts and earthquakes in a manner consistent with Allen's observations in a much more active seismic environment. An example of the performance on noncultural signals is given in Figure 12.

Within a typical seven day period, four mine blasts closer than 200 km are detected at ECM. Also, there are two known areas of low-level seismicity within 600 km of ECM (see Bollinger, 1973 and Sbar and Sykes, 1973, for example). The Lancaster, Pennsylvania, area has been responsible for about three events per year and the magnitudes are typically well under mb = 3.0. The second zone is in west central Virginia and has averaged two events per year, also with magnitudes well under 3.0.

Although the low number of close noncultural signals does not permit the quick acquisition of meaningful performance statistics on such signals, the extensive vehicular traffic near ECM allows a definitive analysis of the Allen algorithm's ability to discriminate between cultural signals and real seismic events. To illustrate: the unfiltered SPZ output contains about 40 truck and 20 automobile signatures in a typical 4-hour period centered around one of the "rush hours." There is also a clear diurnal cycle in the high-frequency background noise with peaks during the rush hours. As would be expected, there is a strong decrease in the high-frequency background and in the number of high-frequency signatures on weekends and holidays.

Following is a summary of the performance of the system on noncultural signals. The results are presented as the probability that the algorithm will fail to detect an event in a particular

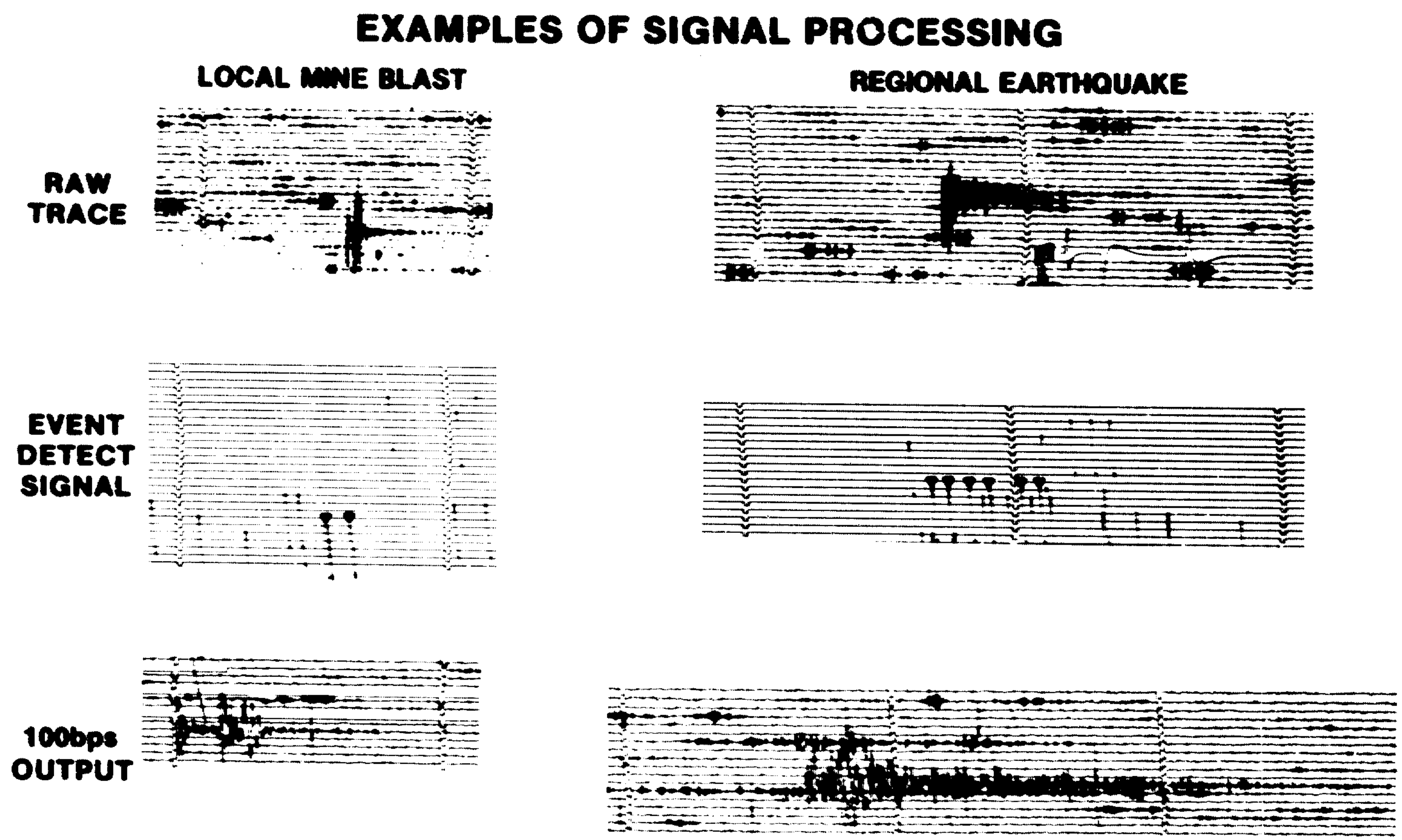


Figure 12. Examples of signal processing by the breadboard unit. The event-detect pulses corresponding to the events displayed are marked with triangles.

distance range are based on a total of 80 events.

• False hits/possible false hits		10 to 25 percent
• Activity level of 100 bps channel		20 to 40 percent
• Event miss probability	$D \geq 600$ km	0 percent
	$1000\text{ km} \geq D \geq 600$ km	25 percent
	$D > 1000$ km	100 percent

In our formulations, Allen's (1978) algorithm has a soft cutoff at around 1000 km due to our choice of averaging technique and the accentuation of the high frequency sensitivity by the form of Allen's characteristic function. Since the characteristic frequency of seismic signals decreases with increasing distance, the algorithm will not respond to distant signals unless they are stronger than normal.

The best indication of the performance of the system on cultural signals is to measure the percentage of time that the 100 bps output is active. In general, the activity level is a measure of the rate of false triggering. Also, the truck signature is of characteristic frequency greater than 10 Hz and shows two short duration spikes of about twice the amplitude of the rest of the signature. This signature provides all the necessary elements for a severe test of the rejection of cultural signals and occurs often enough to yield good statistics in a reasonable time.

Activity on the 100 bps channel is, of course, heavily dependent on the choice of operating constants input to the microcomputer. With an optimum set of constants, the activity level is between 10 and 20 percent. The same set of constants was used to generate the performance statistics on noncultural signals reported above. Since the noise environment was intentionally made more severe (no filtering) than would normally be the case, the rejection of cultural signals should be nearly perfect in most applications.

Since the number of noncultural signals is so small, we tested the buffer swapping procedure with cultural signals. A set of constants was selected to give a pick on each vehicle signature with a signal-to-noise ratio greater than two. The buffer lengths were set for 90 seconds and the system was operated through a complete rush-hour peak (150 minutes). The number of vehicle signatures with suitable signal-to-noise ratio was compared to the number of event-detect signals and the number of vehicle signatures in the 100 bps output. Since there are about five signatures per minute at the peak of the rush hour, the system was operating at the saturation level for two buffers. The predicted efficiency is 28 percent and the observed efficiency was 29 percent. The difference is probably due to the nonrandomness of the time of occurrence of the signatures.

Design of a Complete Seismic DCP

Figure 13 shows five remote data collection platforms and a central data collection station. This is a basic form of a GOES-based seismic data collection system. Each DCP is event triggered and uses a single DCS channel. The DCP radio sets are small 402-MHz transmitters which have a signal bandwidth corresponding to 100 bits per second.

The DCP required EIRP is 48 dBm to communicate at a bit-error rate of 10^{-6}. A 10-watt transmitter with an antenna gain of 8 dB is adequate. Figure 14 shows the central station's received signal processing line. This is a low technical risk area since there is nothing unique at the receiver as all components have been proven under operating conditions.

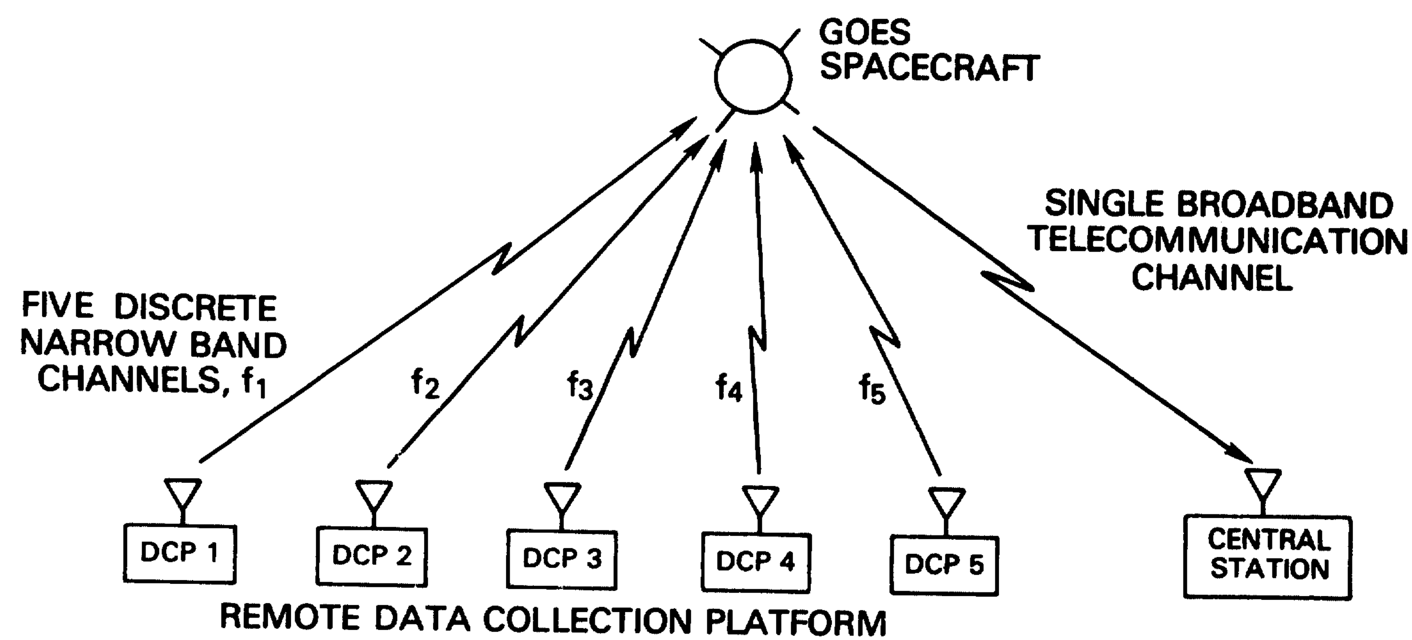


Figure 13. System diagram showing a five DCP network with a central station.

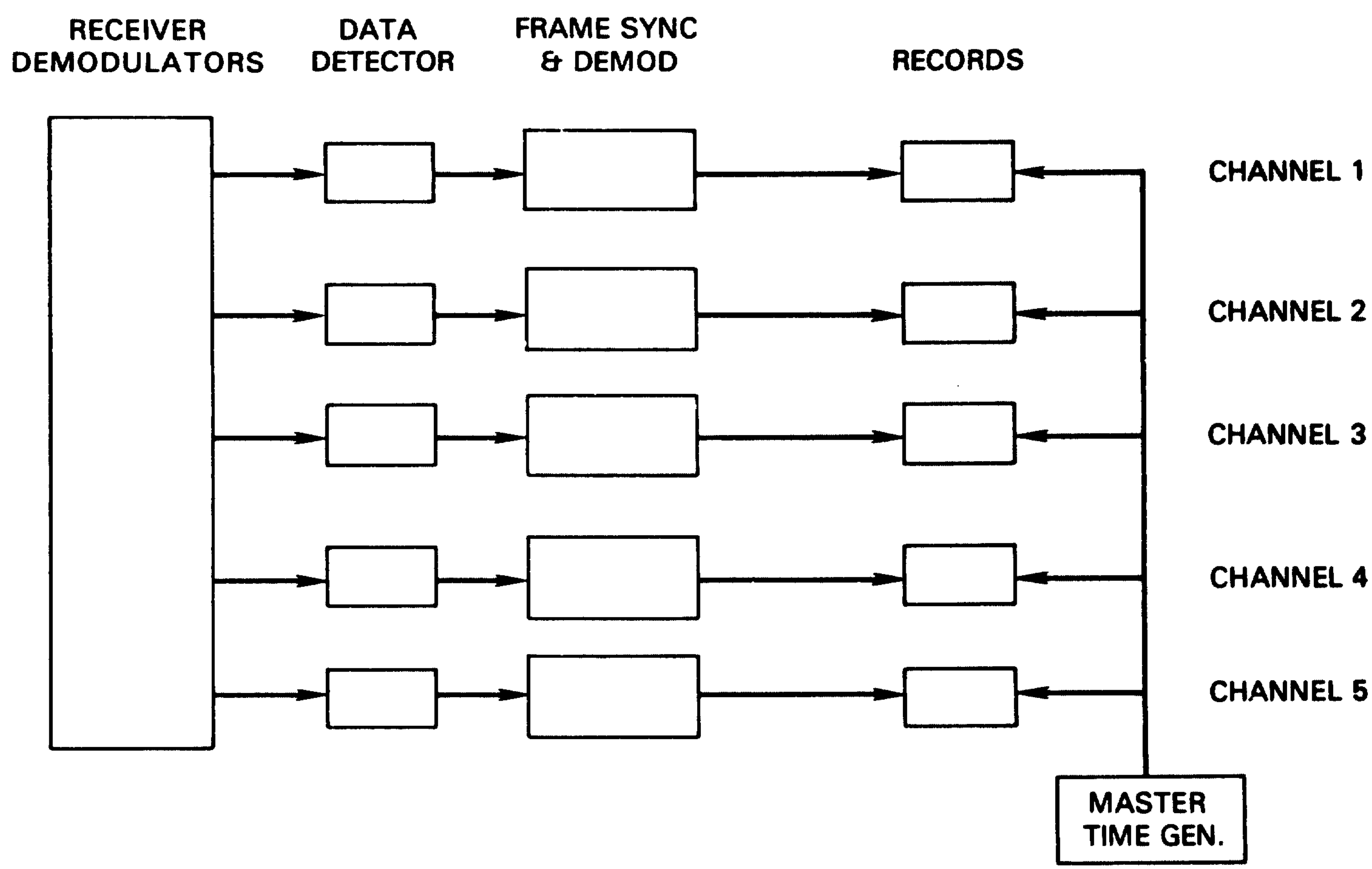


Figure 14. Received signal processing at the central station.

Figure 4 is a block diagram of the full DCP. The event-detector output signals to be telemetered along with event waveform are the event-detect signal, direction of first motion, event confidence measure, and number of timing pulses from event first zero crossing until the event-detect signal acknowledges an event has occurred. The DCP transmitter will be power switched under control of the microprocessor to increase the battery life time.

A complete data collection platform unit would consist of:

1. Seismometer
2. Event detector with dual buffering
3. Transmitter (GOES compatible, 10 watts)
4. Cross-yagi antenna
5. Battery power pack.

A power profile was calculated for six months operation. This profile assumes an average of 12 events per day with the DCP/transmitter operating for 1260 seconds per event (180 seconds record and 1080 seconds playback). Also included in the power calculation are the following voltage and current requirements:

Transmitter (10 watts)	12.5 volts at 5 mA (milliampere) idle, 2.5 A trans.
Event detector	12.0 volts at 5 mA
	5.0 volts at 12 mA
	-5.0 volts at 2 mA.

Power profile dictates that the battery power pack should have the following capacity:

12 volts at 1900 ampere-hours

5 volts at 430 ampere-hours.

It would be possible to derive the 5 volts from a 12-volt pack. The estimated cost for a DCP, excluding the seismometer, is:

Event detector and dual buffers	$13,500
Transmitter and antenna	3,300
Battery pack	500
Total	$17,300.

The cost is based on using:

1. Ceramic CMOS integrated circuit packages
2. Dual 108-kilobit buffers
3. Single unit cost (i.e., no quantity discount)
4. Wirewrap construction.

The cost of the processor could decrease by as much as $6,000 in large quantities. This cost savings would appear as lower costs for the CMOS parts, testing, and packaging. Also, printed circuit packaging techniques could be used instead of the more costly wirewrap boards.

The cost of the transmitter and antenna assumes using a HANDAR 524A SMS/GOES data collection platform and a high gain crossed yagi. The HANDAR unit contains a GOES compatible formatter, 10-watt transmitter, and power conditioning circuitry. The cost shown above is for a single unit procurement. For a large procurement (greater than 10 units) the total cost of a DCP should drop to $11,000.

OPERATION OF AN EVENT LOCATION NETWORK USING THE SEISMIC DCPs

To illustrate the use of the seismic DCP, we examine the implementation of a location network for large events in South America. The purpose of this section is to show how a small network of DCPs will allow the location of potentially damaging earthquakes with sufficient dispatch to allow mobilization of civil disaster forces should the circumstances warrant. This is perhaps the most elementary application of the seismic DCP concept.

The following goals are assigned to the network: locate any earthquake within the Andean region of South America whose body wave magnitude is ≥ 5.0 within two hours. The hypocenter must be located to ±0.1 degree in latitude and longitude and characterized as shallow, intermediate, or deep focus.

The stations to be implemented were selected from the list of World Wide Standard Seismograph Network (WWSN) and array stations on the South American mainland. For the eight stations shown in Figure 15, a three minute P-S time circle will permit at least three stations to transmit P and S arrivals for events in the populous part of the western active area. Coverage is not so complete for the less populated areas of western South America (i.e., Tierra del Fuego) and the relatively inactive eastern area of Brazil.

According to a study by Berrocal (1976), stations in continental South America observed 113 events during 1973 with mb ≥ 5.0 in the region bounded by latitudes 14°N and 56°S and longitudes 30°W and 90°W. Although fluctuations in this number occur on a yearly basis, the distribution of stations and the quality of data used by Berrocal make it extremely unlikely that any

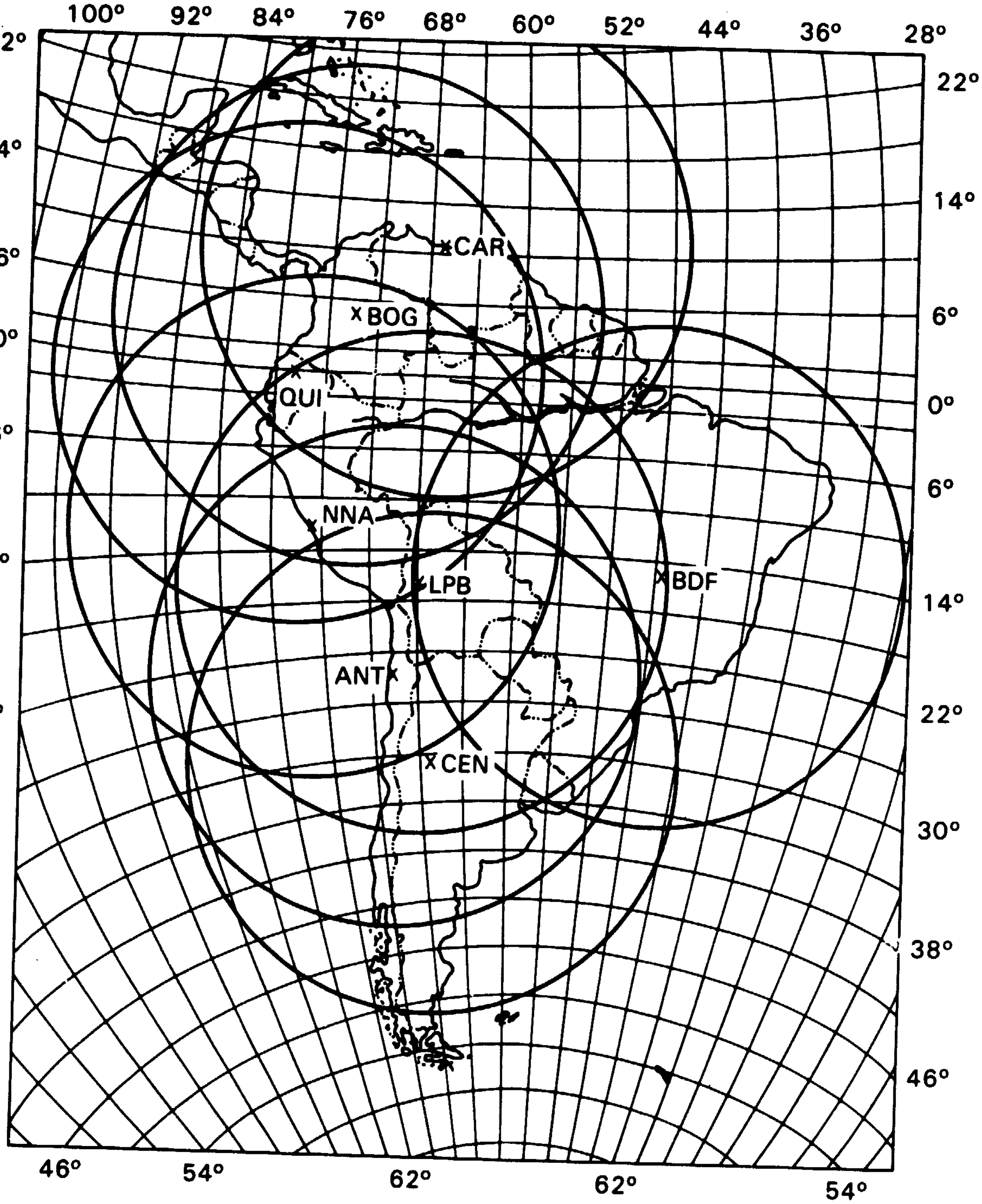


Figure 15. Eight station network in South America showing three minute P and S range circles.

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events with mb $\geq$ 5.0 were missed. Accordingly, the expected data load is about 905 station events per year. This will not tax the capability of any individual seismic DCP.

To avoid transmitting unneeded events, each DCP would calculate a magnitude based on the usual log (A/T) (amplitude/period) calibrations to decide whether the event should be transmitted. Since the event buffer would have to be held during the calculation, the buffer swapping technique would be needed to avoid mssing an event.

The GOES platform radio sets transmissions may be initiated in three ways: (1) The DCP may be polled by using interrogate channels; (2) the DCP may be activated by an internal timer on a regular basis, one or more times a day; and (3) the DCP may begin transmitting when a sensor threshold has been exceeded. These different modes are called: interrogate, self-timed, or emergency.

After considering the objectives, the "emergency mode" was selected for the system baseline design. Advantages of the emergency mode over the other operation modes are:

1. Requires a smaller DCP storage capacity. The emergency mode requires 108 kilobits, whereas the other modes require 324 kilobits for transmission on a 6-hour schedule.
2. Requires a shorter playback time and dissipates lower power because the memory is smaller.
3. Central station has near real-time monitoring of events.
4. Requires only one master clock which is located at the central station. This is possible because the DCP delay can be measured during deployment; the transmission time through the GOES satellite system can be accountable, and the time from the event's first zero crossing to event trigger pulse can be determined by the microprocessor and transmitted from the DCP with the event record.

The major disadvantage of the emergency mode is that eight dedicated GOES channels are required versus one channel for the other modes. Also, an inoperative DCP could go unnoticed for several days. A combination mode, in which the DCP returns housekeeping data once every six hours and operates in the emergency mode as well, may be the most desirable.

The receive site requirements are modest. The DCS downlink from GOES is in the 1.7-GHz region. Microwave receiver technology for this kind of application is mature and the antennas are not very costly. Since the GOES spacecraft are in synchronous orbit, the ground antenna need only be positioned one time. Baseband signal processing is simple in the emergency mode since the exact baseband frequency for each DCP is known. A squelched discriminator can be used for each baseband signal with the squelch signal used to alert the data processing equipment.

The data processing requirements are also modest. The basic analysis consists of two phases. In the first phase, the individual bit streams are converted to analog traces, timing information inserted and the traces are displayed for an analyst's evaluation. At the same time, a preliminary hypocenter can be computed from the first arrival times reported by the DCP's and the expected arrival times for other than main P can be marked. S arrivals, where present, would be selected. In the second phase, the analyst's modifications would be used to calculate the final hypocenter and the individual traces would be output in final form. Neither of these tasks requires a particularly sophisticated or expensive computer. A microcomputer with video display, disk pack and hard copy plotter would be sufficient. Purchased now, the required hardware should cost much less than $20,000.

The DCPs are intended to operate unattended in the field. The only anticipated need for regular interventions would be the battery changes. This can not be avoided since the high power requirements (10 W rf output for 18 minutes per buffer transmission) require high capacity batteries. Such batteries normally can not be recharged by solar panels.

Field setup would include:

a. Seismometer implacement and calibration. The DCP will need the necessary constants for a log (A/T) magnitude calculation.

b. Processor activation and checkout. The noise characteristics of the site will determine the digital and analog constants. Since this will vary from site to site a certain amount of "cut and try" will be necessary.

c. Transmitter activation, antenna pointing, and delay measurement. Antenna pointing angles can be calculated beforehand. The individual delay measurements can be made by initiating a transmission at a carefully measured time. The DCP clock, the delay transmission initiation time, and the location of the DCP (to a few meters) can be set by observations of the Global Positioning System satellites during installation and activation.

SUMMARY

Our development effort has shown that there is no technical risk in building a field worthy seismic DCP. Because of the advent of low power digital and analog electronics (in our case CMOS), a field processor would require only a modest fraction of the total power budget. The power requirements of the DCP are dominated by the transmitter.

The major improvement over previous seismic signal processors is the use of the Allen (1978) event-recognition scheme. In the presence of severe cultural noise, Allen's algorithm proved to be nearly perfect in its rejection of cultural signals. Our implementation on the CDP1802 microprocessor required only modest amounts of ROM and RAM.

The processor could be added to an existing GOES DCP with little difficulty. The digital format and bit rate costs nothing in terms of information content but does require a relatively long period of transmitter activation. The physical size of a field processor would most likely be about one quarter the size of an automobile battery.

Operated in a dedicated network, through GOES, eight seismic DCPs would allow the location of large events (mb $\geq$ 5.0) in South America within an hour of the event onset. Such a network would not tax the capabilities of the DCP design and would represent no technical risk in its implementation.

REFERENCES

Allen, R. V., 1978, Automatic Earthquake Recognition and Timing from Single Traces, BSSA, 68, pp. 1521-1532.

Allenby, R. J., W. J. Webster, Jr., and J. E. Painter, 1977, Satellite Relaying of Geophysical Data, NASA/GSFC X-922-77-273.

Berrocal, J., 1976, *in* Programa Sismo Unificado CERESIS-AID-NASA-USGS, CERESIS, Lima, Peru.

Bollinger, G. A., 1973, Seismicity of the Southeastern United States, BSSA, 63, pp. 1785-1808.

Sbar, M. L. and L. R. Sykes, 1973, Contemporary Compressive Stress and Seismicity in Eastern North America; An Example of Intra-Plate Tectonics, Bul. G.S.A., 84, pp. 1861-1882.

Stewart, S. W., 1977, Real-Time Detection and Location of Local Seismic Events in Central California, BSSA, 67, pp. 433-452.

APPENDIX A
OPERATING INSTRUCTIONS

Operational Procedure

The following describes the operational procedure for the seismic detector and the procedure to communicate with the system microprocessor via a silent 700-data terminal.

Power

1. Press power-on switch, located on power chassis, to apply power to seismic detector. Power lamp indicates power is applied to detector.
2. Switch silent 700-terminal power on.
3. Switch helical-recorder power on.

Reset

Press reset switch on seismic detector front panel. This places the microprocessor into initialization state and clears buffer memory. Event detect, record, and playback indicators are in off state.

Run Utility Program

1. Press utility program switch.
2. Depress silent 700-terminal keyboard carriage return key, print head returns to left margin and types an asterisk. The asterisk acknowledges that the microprocessor address pointer is at memory location 0000. For programming instructions refer to "User Manual for the CDP1802 Cosmac Microprocessor," RCA-MPM-201-B.

Run Seismic Program

1. Place unit into utility program state.

2. Enter master program start address into memory location 0000 by typing keys

   !M0000 C01000

3. To verify, start address is stored into microprocessor memory type.

   ?M000 3.

4. Terminal response is to type

   0000 C010 00.

5. Press micro reset switch to ensure microprocessor is in initialization state.

6. Press program start switch to initiate Rex Allen's seismic program.

Seismic program will operate between two states (test and verify) without additional controlling. When an event is verified, the event indicator is turned "on" for approximately one second and the record indicator is turned "on" and remains on until memory buffer number one is filled.

Buffer filling timing is predetermined by the status of switch E28 which is located on memory board (see Sheet 7). Filling time can be set from 10.2 to 153.6 seconds. (See Table A-1 for available record times.) After the buffer is filled, the record indicator goes out and the playback indicator is turned on. Playback time is six times record time. If a second event occurs while buffer one is in playback state, the event is stored in buffer two and both the record and playback indicators are energized; buffer two will play back after buffer one has completed its playback.

Table A-1
Buffer Memory Record and Playback
Times and Switch Position

Switch Position	Time, Seconds	
	Record	Playback
1	10.24	61.44
2	30.72	184.32
3	51.2	307.2
4	71.68	430.08
5	92.16	552.96
6	112.64	675.84
7	133.12	798.72
8	153.6	921.6

Program Constants

Constants C_1 through C_5 are entered into program when microprocessor is in initialization state (reset). The programmed constants remain unchanged until the constant switch position is altered and the unit is reset. Table A-2 relates the constant switch positions to program value.

Event Statistics

Event peak values and time of occurrence referenced to first zero crossing are stored in the RAM memory. Memory location 0035 stores the number of peaks. Memory location starting at 0100 stores the time and peak values. There are three paired hexidecimal words per detected peak with the following format:

3 paired hex words

$$t^1_{(i)}\, t^2_{(i)} P_{(i)} \quad \ldots . t^1_{(n)}\, t^2_{(n)}\, P_{(n)}$$

Table A-2
Binary Switch Settings vs. Value

Gain, C_1		Weight, C_2		Short Ave, C_3		Long Ave, C_4	
Code	Value	Code	Value	Code	Value	Code	Value
0000	0.5	0000	0	00000	0.2	00000	0.005
0001	0.6	0001	0.15	00001	0.225	00001	0.0075
0010	0.7	0010	0.3	00010	0.25	00010	0.01
0011	0.8	0011	0.45	00011	0.275	00011	0.0125
0100	0.9	0100	0.6	00100	0.3	00100	0.0175
0101	1.0	0101	0.75	00101	0.325	00101	0.02
0110	1.1	0110	0.9	00110	0.35	00110	0.0225
0111	1.2	0111	1.0	00111	0.375	00111	0.025
1000	1.3	1000	1.05	01000	0.4	01000	0.0275
1001	1.4	1001	1.20	01001	0.425	01001	0.03
1010	1.5	1010	1.35	01010	0.45	01010	0.0325
		1011	1.50	01011	0.475	01011	0.035
		1100	1.65	01100	0.5	01100	0.0375
		1101	1.80	01101	0.525	01101	0.04
		1110	1.95	01110	0.55	01110	0.0425
Threshold, C_5				01111	0.575	01111	0.045
Code	Value			10000	0.6	10000	0.0475
00	4			10001	0.625	10001	0.05
01	5			10010	0.65		
10	6			10011	0.675		
11	7			10100	0.7		
				10101	0.725		
				10110	0.75		
				10111	0.775		
				11000	0.8		

where n is the value recorded in location 0035, and i references i peak and runs from 0 to n. The event statistics can be obtained without disturbing the contents in the buffer. The procedures to be used to enter into utility run is made by using the micro reset switch. Events statistics have to be obtained from memory before the program goes into another test sequence.

Helical Recorder

Refer to Sprengnether VR-60 helical recorder operation manual for operation, calibration, and maintenance procedures.

This is a three-channel recorder. Channel one records the real-time signal that has been amplified and filters to 50 hertz. Channel two records the event-detect signal which is binary. Channel three records the delayed playback signal, which is 1/6 the rate of channel one signal. Channel three signal has been digitized, stored, and played back at the GOES channel rate of 100 bits per second. This signal is converted back to an analog signal before it is sent to the helical recorder.

APPENDIX B
COMMENTARY ON THE CDP1802
IMPLEMENTATION OF THE ALLEN ALGORITHM

Event Detection Program Flow

1. Initialize and reset flags

   Read constants (C_1 - C_5)

   $i = 1$

2. Input digital data R_i, $i = i + 1$

   (1) convert to 2's complement

   (2) $R_i = C_1 * R_i$

   (3) Calculations:

   $R_i = C_2 * (R_i - R_{i-1})$

   $E_i = R_i^2 + \Delta R_i^2$

   $\alpha_i = \alpha_{i=1} + C_3 * (E_i - \alpha_{i-1})$

   $\beta_i = \beta_{i-1} + C_4 * (E_i - \beta_{i-1})$

3. Completed 2 second average?

   (i.e., $i \geqslant 200$)

   0.1t Go to 4

   0.2f Go to 2

4. Compute reference level (γ_i)

   $\gamma_i = C_5 * \beta_i$

5. Short term average abruptly increased?

   (i.e., $\alpha_i > \beta_1$)

   0.1t Go to 6

   0.2f Go to 2

6. Save potential hit onset values

   0.1 $T_o = i$

   0.2 $A_o = R_i$

   0.3 $D = R_i - R_{i-1}$

   0.4 $M = 1$

   0.5 $S = 0$

7. Save provisional peak

   $P = | R_i |$

8. Input digital data, $i = i + 1$

   0.1 Convert to 2's complement

   0.2 $R_i = C_1 * R_i$

   0.3 Calculations:

   $R_i = C_2 * (R_i - R_{i-1})$

   $E_i = R_i^2 + \Delta R_i^2$

   $\alpha_i = \alpha_{i-1} + C_3 * (E_i - \alpha_{i-1})$

9. Zero crossing?

   (i.e., $R_i = 0$)

   0.1t Go to 11

   0.2f Go to 10

10. $| R_i | > P$?

0.1t To to 7

0.2f Go to 8

11. 128 zero crossings recorded?

(i.e., $M \geq 128$)

0.1t Go to 13

0.2f Go to 12

12. Record zero crossing

0.1 $T_M = i - T_o$

0.2 $A_M = P$

0.3 $M = M + 1$

13. Has 2 seconds passed since potential hit?

(i.e., $i - T_o \geq 200$)

0.1t Go to 14

0.2f Go to 8

14. More than 40 zero crossings?

(i.e., $M > A0$)

0.1t Go to 15

0.2f Go to 2

15. Declare significant event (set Q), and compute continuation criterion

$\sigma = f(G, T_m, M)$

16. $\alpha_i > \sigma$?

0.1t S = 0, reset small count counter

0.2f S = S + 1

0.3 L = 4 + M/4, value of S at which event is over

17. Is the event over?

(i.e., S > L)

0.1t Go to 18

0.2f Go to 8

18. Declare event over (reset Q)

0.1 i = 0

0.2 Go to 2

APPENDIX C
1802 ASSEMBLY CODE, MEMORY MAP, PROGRAM CONSTANT SPECIFICATIONS AND TIMING SUMMARY

```
!M
0000 ;                 ..
0000 ;                 ..
0000 ;                 ..
0000 ;                 ..
0000 ;                 ..   ** GFSC EARTHQUAKE RECOGNITION MONITOR  **
0000 ;                 ..
0000 ;                 ..
0000 ;                 ..      THIS MONITOR IS DESIGNED TO RECOGNIZE AND
0000 ;                 ..      TO TIME SEISMIC EVENTS ON A SINGLE TRACE.
0000 ;                 ..      THE MONITOR EXECUTES AS A REAL-TIME PROGRAM
0000 ;                 ..      IN CONJUNCTION WITH SEISMIC PLATFORM HARDWARE.
.
0000 ;                 ..      IT IS WRITTEN IN RCA COSMAC 1802 ASSEMBLY
0000 ;                 ..      LANGUAGE AND REPRESENTS A PROTOTYPE FOR 8-BIT
0000 ;                 ..      PROCESSING OF SEISMIC DATA......
0000 ;                 ..
0000 ;                 ..
0000 ;                 ..
0000 ;                 ..
0000 ;                 ..
0000 ;                 ..
0000 ;                         ORG     0             ..
0000 C01000;                   LBR     GERM          .. START ADDRESS
0003 ;                 ..
0003 ;                 S=#04                         ..
0003 ;                 L=#05                        ..
0003 ;                 ..
0003 ;                 LR=06                         ..
0003 ;                 R=#07                         ..
0003 ;                 C1X=#08
0003 ;                 C1=#09                        .. TIME CONSTANT H. P.F.
0003 ;                 C2X=#0B                       ..
0003 ;                 C2=#0C                        .. WEIGHTING CONSTANT
0003 ;                 C3X=#0E                       ..
0003 ;                 C3=#0F                        ..
0003 ;                 C4X=#11                       ..
0003 ;                 C4=#12                        ..
0003 ;                 C5X=#14                       ..
0003 ;                 C5=#15                        .. THRESHOLD CONSTANT
0003 ;                 ..
0003 ;                 ..
0003 ;                 ALFA=#19                      .. SHORT TERM AVG.
0003 ;                 BETA=#1D
0003 ;                 GAMMA=#21
0003 ;                 DELTA=#25
0003 ;                 CHAR=#29
0003 ;                 DELTAH=#2D
0003 ;                 PP=#31
0003 ;                 M=#35
```

```
0003 ;       TEMP=#39
0003 ;       TEMP2=#3D
0003 ;       CONT=#41
0003 ;       GOF=#45
0003 ;       HITS=#47
0003 ;       TIMES=#0100
0003 ;       HTIMES=#0400
0003 ;       READ=#12A0                      .. READ SUBROUTINE
0003 ;       MPLY=#12C0                      .. MPLY SUBROUTINE
0003 ;       MEAT=#1340
0003 ;       ..
0003 ;       ..
0003 ;       ..
0003 ;       ..   ** GERM **   MAIN PROGRAM
0003 ;       ..
0003 ;       ..
0003 ;       ..
0003 ;                 ORG   #1000        .. START ADDRESS
1000 F807;   GERM:      LDI   GERMA          ..
1002 AF;                PLO   RF        ..
1003 F810;              LDI   A.1(GERMA)     ..
1005 BF;                PHI   RF             ..
1006 DF;                SEP   RF             ..
1007 F808;   GERMA:     LDI   C1X
1009 A7;                PLO   R7             ..
100A F800;              LDI   0
100C B7;                PHI   R7             ..
100D E7;                SEX   R7             ..
100E 6F;                INP   7              .. READ C1X
100F FA0F;              ANI   #0F            ..
1011 57;                STR   R7       ..
1012 FE;                SHL
1013 FC00;              ADI   C1T      .. LOOK UP
1015 A8;                PLO   R8       ..
1016 F812;              LDI   A.1(C1T)
1018 B8;                PHI   R8       ..
1019 48;                LDA   R8       .. SAVE C1
101A 60;                IRX            ..
101B 57;                STR   R7       ..
101C 08;                LDN   R8       ..
101D 60;                IRX                  ..
101E 57;                STR   R7       ..
101F F814;              LDI   C5X            .. WANT C5H
1021 A7;                PLO   R7       ..
1022 6C;                INP   4        .. READ C5X
1023 FA0F;              ANI   #0F            ..
1025 A9;                PLO   R9       ..
1026 57;                STR   R7       ..
1027 FA03;              ANI   3        ..
1029 FC8E;              ADI   C5T
```

```
102B A8;        PLO  R8     ..
102C 08;        LDN  R8       ..
102D 60;        IRX         ..
102E 57;        STR  R7     .. SAVE C5
102F 60;        IRX
1030 F800;      LDI  0
1032 57;        STR  R7     ..
1033 F80B;      LDI  C2X    ..
1035 A7;        PLO  R7     ..
1036 69;        INP  1         .. READ C2X
1037 FA0F;      ANI  #0F        ..
1039 57;        STR  R7         ..
103A FE;        SHL
103B FC16;      ADI  C2T        ..
103D A8;        PLO  R8         ..
103E 48;        LDA  R8         .. SAVE C2
103F 60;        IRX             ..
1040 57;        STR  R7         ..
1041 60;        IRX             ..
1042 08;        LDN  R8         ..
1043 57;        STR  R7         ..
1044 60;        IRX             ..
1045 6A;        INP  2          .. READ C3X
1046 FA0F;      ANI  #0F        ..
1048 57;        STR  R7         ..
1049 89;        GLO  R9         ..
104A FA04;      ANI  4          ..
104C FE;        SHL             ..
104D FE;        SHL             ..
104E F1;        OR              ..
104F FE;        SHL
1050 FC36;      ADI  C3T        ..
1052 A8;        PLO  R8         ..
1053 48;        LDA  R8         .. SAVE C3
1054 60;        IRX             ..
1055 57;        STR  R7         ..
1056 08;        LDN  R8         ..
1057 60;        IRX
1058 57;        STR  R7         ..
1059 60;        IRX             .. R7= ADD(C4X)
105A 6B;        INP  3          ..
105B FA0F;      ANI  #0F        .. READING C4X
105D 57;        STR  R7         ..
105E 89;        GLO  R9         ..
105F FA08;      ANI  8          ..
1061 FE;        SHL             ..
1062 F1;        OR              ..
1063 FE;        SHL
1064 FC68;      ADI  C4T        ..
1066 A8;        PLO  R8
```

```
1067 48;    LDA  R8        .. SAVE C4
1068 60;    IRX            ..
1069 57;    STR  R7        ..
106A 08;    LDN  R8
106B 60;    IRX            ..
106C 57;    STR  R7        ..
106D F806;  LDI  LR        ..
106F A4;    PLO  R4        ..
1070 F819;  LDI  ALFA      ..
1072 A5;    PLO  R5        ..
1073 F81D;  LDI  BETA      ..
1075 A6;    PLO  R6        ..
1076 F839;  LDI  TEMP      ..
1078 A7;    PLO  R7       ..
1079 F800;  LDI  0         ..
107B B4;    PHI  R4        ..
107C B5;    PHI  R5        ..
107D B6;    PHI  R6        ..
107E B7;    PHI  R7        ..
107F B8;    PHI  R8        ..
1080 B9;    PHI  R9
1081 B3;    PHI  R3        ..
1082 A3;    PLO  R3        .. I= 0
1083 55;    STR  R5
1084 56;    STR  R6
1085 25;    DEC  R5        ..
1086 26;    DEC  R6
1087 55;    STR  R5        ..
1088 56;    STR  R6
1089 15;    INC  R5        ..
108A 16;    INC  R6
108B F8A0;  LDI  READ      ..
108D AB;    PLO  RB        ..
108E F812;  LDI  A.1(READ) ..
1090 BB;    PHI  RB        ..
1091 F8C0;  LDI  MPLY      ..
1093 AC;    PLO  RC        ..
1094 F812;  LDI  A.1(MPLY) ..
1096 BC;    PHI  RC        ..
1097 F840;  LDI  MEAT      ..
1099 AE;    PLO  RE        ..
109A F813;  LDI  A.1(MEAT) ..
109C BE;    PHI  RE        ..
109D F845;  LDI  GDF       ..
109F A9;    PLO  R9        ..
10A0 F800;  LDI  0         ..
10A2 59;    STR  R9        .. GO FLAG= 0
10A3 7A;    REQ            .. RESET EVENT DETECT
10A4 E4;    SEX  R4        .. X= R4= ADD(LR)
10A5 DB;    SEP  RB        .. CALL READ(LR)
```

```
10A6 60;                IRX              .. R4= ADD(R)
10A7 E4;         LOOPA: SEX    R4        ..
10A8 DB;                SEP    RB        .. CALL READ(R)
10A9 DE;                SEP    RE        .. CALL MEAT
10AA DC;                SEP    RC        ..
10AB DE;                SEP    RE        ..
10AC DC;                SEP    RC
10AD DE;                SEP    RE
10AE DC;                SEP    RC        ..
10AF DE;                SEP    RE        ..
10B0 DC;                SEP    RC
10B1 DE;                SEP    RE
10B2 DC;                SEP    RC        ..
10B3 DE;                SEP    RE        ..
10B4 F829;              LDI    CHAR      .. COMPUTE BETA
10B6 A8;                PLO    R8        ..
10B7 06;                LDN    R6        ..
10B8 F5;                SD               ..
10B9 57;                STR    R7        ..
10BA 27;                DEC    R7        ..
10BB 28;                DEC    R8        ..
10BC 26;                DEC    R6        ..
10BD 46;                LDA    R6        ..
10BE FBFF;              XRI    #FF       ..
10C0 74;                ADC              ..
10C1 57;                STR    R7        ..
10C2 17;                INC    R7        ..
10C3 F812;              LDI    C4        ..
10C5 A9;                PLO    R9        ..
10C6 49;                LDA    R9        ..
10C7 BA;                PHI    RA        ..
10C8 09;                LDN    R9        ..
10C9 AA;                PLO    RA        ..
10CA F83D;              LDI    TEMP2     ..
10CC A8;                PLO    R8        ..
10CD DC;                SEP    RC        .. CALL MPL(TEMP2)
10CE 06;                LDN    R6        ..
10CF F4;                ADD              ..
10D0 56;                STR    R6        ..
10D1 26;                DEC    R6        ..
10D2 28;                DEC    R8        ..
10D3 06;                LDN    R6        ..
10D4 74;                ADC              ..
10D5 56;                STR    R6        .. BETA= BETA +
10D6 16;                INC    R6        .. C4*(CHAR-BETA)
10D7 04;                LDN    R4        ..
10D8 24;                DEC    R4
10D9 54;                STR    R4        .. LR=R
10DA 14;                INC    R4        .. R4= ADD(R)
10DB F845;              LDI    SOF       ..
```

```
10DD A9;                PLO  R9         ..
10DE 09;                LDN  R9         ..
10DF 3AE9;              BNZ  LOOK
10E1 83;                GLO  R3         ..
10E2 FDC8;              SDI  200        ..
10E4 3AA7;              BNZ  LOOPA      ..
10E6 F801;              LDI  1          .. I= 200, SO GO
10E8 59;                STR  R9         .. GOF= 1
10E9 ;             ..
10E9 ;             ..
10E9 F821;         LOOK: LDI  GAMMA      .. CALCULATE GAMMA
10EB A8;                PLO  R8         ..
10EC F815;              LDI  C5         ..
10EE A9;                PLO  R9         ..
10EF 09;                LDN  R9
10F0 BA;                PHI  RA         ..
10F1 F800;              LDI  0
10F3 AA;                PLO  RA         ..
10F4 06;                LDN  R6         ..
10F5 57;                STR  R7         ..
10F6 27;                DEC  R7         ..
10F7 26;                DEC  R6         ..
10F8 46;                LDA  R6         ..
10F9 57;                STR  R7         ..
10FA 17;                INC  R7         ..
10FB DC;                SEP  RC         .. CALL MPLY(C5*BETA)
10FC 05;                LDN  R5         .. CALC GAMMA-ALFA
10FD F5;                SD              ..
10FE 25;                DEC  R5          ..
10FF 28;                DEC  R8         ..
1100 45;                LDA  R5
1101 FBFF;              XRI  #FF        ..
1103 74;                ADC             ..
1104 FE;                SHL             .. GET SIGN
1105 CB10A7;            LBNF  LOOPA     .. ALFA>=GAMMA ? NO
1108 F835;              LDI  M          .. YES, HAVE POSS. HIT
110A A9;                PLO  R9         ..
110B F804;              LDI  I          ..
110D A8;                PLO  R8         ..
110E F800;              LDI  0          ..
1110 AD;                PLO  RD
1111 BD;                PHI  RD         ..
1112 B1;                PHI  R1         ..
1113 B2;                PHI  R2         ..
1114 59;                STR  R9         ..
1115 58;                STR  R8         .. I= 0
1116 F800;              LDI  TIMES      .. SAVE HIT TIME
1118 A1;                PLO  R1         ..
1119 F801;          LDI   A.1(TIMES)
111B B1;            PHI   R1
```

```
111C 93;                 GHI   R3       ..
111D 51;                 STR   R1       ..
111E 11;                 INC   R1       ..
111F 83;                 GLO   R3       ..
1120 51;                 STR   R1       .. TIMES(0)= I
1121 11;         INC   R1
1122 04;          LDN   R4
1123 51;          STR   R1
1124 F825;               LDI   DELTA    .. SAVE HIT SLOPE
1126 A8;                 PLO   R8       ..
1127 F82D;               LDI   DELTAH   ..
1129 A9;                 PLO   R9       ..
112A F0;                 LDX            ..
112B 59;                 STR   R9       ..
112C 28;                 DEC   R8       ..
112D 29;                 DEC   R9       ..
112E F0;                 LDX            ..
112F 59;                 STR   R9       .. DELTAH= DELTA
1130 F831;               LDI   PP       .. SAVE PROV. PEAK
1132 A8;                 PLO   R8       ..
1133 04;                 LDN   R4       .. SAVE PROV. PEAJ
1134 FE;                 SHL            ..
1135 333A;               BDF   NEGB     ..
1137 76;                 SHRC           ..
1138 303D;               BR    POSC     ..
113A 76;         NEGB:   SHRC           ..
113B FD00;               SDI   0        ..
113D 58;         POSC:   STR   R8       .. PP= ABS(R)
113E E4;         LOOPB:  SEX   R4       ..
113F DB;                 SEP   RB       .. CALL READ(R)
1140 DE;                 SEP   RE       .. CALL MEAT
1141 DC;                 SEP   RC
1142 DE;                 SEP   RE
1143 DC;                 SEP   RC       ..
1144 DE;                 SEP   RE       ..
1145 DC;                 SEP   RC       ..
1146 DE;                 SEP   BE       ..
1147 DC;                 SEP   RC       ..
1148 DE;                 SEP   RE       ..
1149 DC;                 SEP   RC       ..
114A DE;                 SEP   RE       ..
114B 04;                 LDN   R4       ..
114C 3261;               BZ    ZEROX    .. 0 CROSS ? YES
114E FE;                 SHL            .. NO, GET ABS(R)
114F 3354;               BDF   NEGC     ..
1151 76;                 SHRC           ..
1152 3057;               BR    POSD     ..
1154 76;         NEGC:   SHRC           ..
1155 FD00;               SDI   0        ..
1157 A9;         POSD:   PLO   R9       ..
```

```
1158 F831;                LDI   PP          ..
115A A8;                  PLO   R8
115B 89;                  GLO   R9          ..
115C F7;                  SM                ..
115D 333D;                BPZ   POSC        .. ABS(R) > PP ? YES
115F 303E;                BR   LOOPB        .. NO, GET NEXT R
1161 ;               ..
1161 ;               ..
1161 ;               ..
1161 ;               ..
1161 9D;             ZEROX:   GHI   RD      .. ZERO CROSSING
1162 3A7E;                BNZ   ZEROA       .. SAVED ENOUGH ? YES
1164 93;                  GHI   R3          .. NO
1165 11;               INC   R1
1166 51;                  STR   R1          ..
1167 11;                  INC   R1          ..
1168 83;                  GLO   R3          ..
1169 51;                  STR   R1          .. TIMES(M)= I
116A 11;                  INC   R1          ..
116B F831;                LDI   PP          ..
116D A8;                  PLO   R8          ..
116E 08;                  LDN   R8          ..
116F 51;               STR   R1
1170 F835;                LDI   M           ..
1172 A9;                  PLO   R9          ..
1173 09;                  LDN   R9          ..
1174 FC01;                ADI   1           ..
1176 59;                  STR   R9          .. M= M+1
1177 FD7F;                SDI   127         ..
1179 3A7E;             BNZ   ZEROA
117B F801;                LDI   1           ..
117D BD;                  PHI   RD          ..
117E 31AB;           ZEROA:   BQ   ENDCK    ..
1180 1D;                  INC   RD
1181 8D;                  GLO   RD          ..
1182 FDC8;                SDI   200         ..
1184 3B3E;                BM   LOOPB        .. 200 SEC PASSED ? NO
1186 F835;                LDI   M           .. YES
1188 A9;                  PLO   R9          ..
1189 09;                  LDN   R9
118A FD28;                SDI   40
118C FE;               SHL
118D C310A7;           LBDF   LOOPA
1190 7B;                  SEQ               .. YDS, SET FLAG
1191 F847;                LDI   HITS        .. SAVE HIT TIME
1193 A9;                  PLO   R9
1194 09;                  LDN   R9          ..
1195 FE;                  SHL
1196 FC00;                ADI   HTIMES      ..
1198 A2;               PLO   R2
```

```
1199 F804;          LDI  A.1(HTIMES)
119B B2;            PHI  R2
119C F800;                 LDI  TIMES        ..
119E A9;                   PLO  R9
119F 49;                   LDA  R9           ..
11A0 52;            STR  R2
11A1 12;            INC  R2
11A2 09;                   LDN  R9
11A3 52;            STR  R2
11A4 F847;                 LDI  HITS
11A6 A9;                   PLO  R9
11A7 09;                   LDN  R9
11A8 FC01;                 ADI  1
11AA 59;                   STR  R9           .. HITS= HITS+1
11AB F841;     ENDCK:      LDI  CONT         .. COMPUTE M**2
11AD A8;                   PLO  R8
11AE F835;                 LDI  M            ..
11B0 A9;                   PLO  R9
11B1 09;                   LDN  R9           ..
11B2 BA;                   PHI  RA
11B3 57;                   STR  R7           ..
11B4 27;                   DEC  R7
11B5 F800;                 LDI  0            ..
11B7 AA;                   PLO  RA
11B8 57;                   STR  R7           ..
11B9 17;                   INC  R7
11BA DC;                   SEP  RC           ..
11BB F821;                 LDI  GAMMA
11BD A9;                   PLO  R9           ..
11BE 09;                   LDN  R9
11BF F4;                   ADD               ..
11C0 73;                   STXD
11C1 29;                   DEC  R9           ..
11C2 74;                   ADC
11C3 58;                   STR  R8           .. CONT= GAMMA+M**2
11C4 60;                   IRX
11C5 F804;                 LDI  S            ..
11C7 A9;                   PLO  R9            ..
11C8 05;                   LDN  R5
11C9 F5;                   SD                 ..
11CA 25;                   DEC  R5
11CB 28;                   DEC  R8            ..
11CC 45;                   LDA  R5
11CD FBFF;                 XRI  #FF           ..
11CF 74;                   ADC
11D0 FE;                   SHL                ..
11D1 33F0;                 BDF  SSET
11D3 09;                   LDN  R9            ..
11D4 FC01;                 ADI  1
11D6 59;                   STR  R9            .. S= S+1
```

```
11D7 F835;          0449            LDI  M
11D9 A8;            0450            PLO  R8                 ..
11DA 08;            0451            LDN  R8
11DB F6;            0452            SHR                     ..
11DC F6;            0453            SHR
11DD FC04;          0454            ADI  4                  ..
11DF E9;            0455            SEX  R9
11E0 F5;            0456            SD                      ..
11E1 E8;            0457            SEX  R8
11E2 FE;            0458            SHL                     ..
11E3 C3113E;        0459            LBDF  LOOPB
11E6 F845;          0460            LDI  GOF
11E8 A9;            0461            PLO  R9
11E9 F800;          0462            LDI  0
11EB 59;            0463            STR  R9
11EC 7A;            0464   REQ
11ED C010A7;        0465            LBR  LOOPA              .. RE-ENTER SEARCH
11F0 F800;          0466 SSET:      LDI  0                  ..
11F2 59;            0467            STR  R9
11F3 C0113E;        0468            LBR  LOOPB              ..
11F6 ;              0469 ..
11F6 ;              0470 ..
11F6 ;              0471 ..
11F6 ;              0472            ORG  #1200              ..
1200 0101;          0473 C1T:       DC   #0101              .. .5
1202 0503;          0474            DC   #0503              .. .6
1204 0B04;          0475            DC   #0B04              .. .7
1206 0D04;          0476            DC   #0D04              .. .8
1208 1D05;          0477            DC   #1D05              .. .9
120A 0100;          0478            DC   #0100              .. 1.0
120C 4706;          0479            DC   #4706              .. 1.1
120E 1304;          0480            DC   #1304              .. 1.2
1210 1504;          0481            DC   #1504              .. 1.3
1212 2D05;          0482            DC   #2D05              .. 1.4
1214 0301;          0483            DC   #0301              .. 1.5
1216 ;              0484 ..
1216 ;              0485 ..
1216 ;              0486 ..
1216 0000;          0487 C2T:       DC   #0000              .. 0.0
1218 0906;          0488            DC   #0906              .. 0.15
121A 0905;          0489            DC   #0905              .. 0.30
121C 0704;          0490            DC   #0704              .. 0.45
121E 0503;          0491            DC   #0503              .. 0.60
1220 0302;          0492            DC   #0302              .. 0.75
1222 1D05;          0493            DC   #1D05              .. 0.90
1224 0100;          0494            DC   #0100              .. 1.00
1226 1104;          0495            DC   #1104              .. 1.05
1228 1304;          0496            DC   #1304              .. 1.20
122A 0B03;          0497            DC   #0B03              .. 1.35
122C 0301;          0498            DC   #0301              .. 1.50
```

```
122E 0D03;          0499            DC   #0D03         .. 1.65
1230 1D04;          0500            DC   #1D04         .. 1.80
1232 1F04;          0501            DC   #1F04         .. 1.95
1234 0200;          0502            DC   #0200         .. 2.00
1236 ;              0503 ..
1236 ;              0504 ..
1236 ;              0505 ..
1236 0D06;          0506 C3T:       DC   #0D06         ..
1238 0705;          0507            DC   #0705         .. .225
123A 0102;          0508            DC   #0102         .. .25
123C 2307;          0509            DC   #2307         .. .275
123E 1306;          0510            DC   #1306         .. .3
1240 1506;          0511            DC   #1506         .. .325
1242 0B05;          0512            DC   #0B05         .. .35
1244 0303;          0513            DC   #0303         .. .375
1246 0D05;          0514            DC   #0D05         .. .4
1248 1B06;          0515            DC   #1B06         .. .425
124A 1D06;          0516            DC   #1D06         .. .45
124C 0F05;          0517            DC   #0F05         .. .475
124E 0101;          0518            DC   #0101         .. .5
1250 4307;          0519            DC   #4307         .. .525
1252 2306;          0520            DC   #2306         .. .55
1254 2506;          0521            DC   #2506         .. .575
1256 2706;          0522            DC   #2706         .. 0.6
1258 0503;          0523            DC   #0503         .. 0.625
125A 1505;          0524            DC   #1505         .. 0>>5
125C 2B06;          0525            DC   #2B06         .. 0.675
125E 2D06;          0526            DC   #2D06         .. 0.7
1260 1705;          0527            DC   #1705         .. 0.725
1262 0302;          0528            DC   #0302         .. 0.75
1264 2F06;          0529            DC   #2F06         .. 0.775
1266 0D04;          0530            DC   #0D04         .. .8
1268 ;              0531 ..
1268 ;              0532 ..
1268 ;              0533 ..
1268 050A;          0534 C4T:       DC   #050A         .. .005
126A 0107;          0535            DC   #0107         .. .0075
126C 0509;          0536            DC   #0509         .. .01
126E 0D0A;          0537            DC   #0D0A         .. .0125
1270 0106;          0538            DC   #0106         .. .015
1272 0909;          0539            DC   #0909         .. .0175
1274 0508;          0540            DC   #0508         .. .02
1276 0307;          0541            DC   #0307         .. .0225
1278 0D09;          0542            DC   #0D09         .. .025
127A 0708;          0543            DC   #0708         .. .0275
127C 0105;          0544            DC   #0105         .. .03
127E 1109;          0545            DC   #1109         .. .0325
1280 0908;          0546            DC   #0908         .. .035
1282 1309;          0547            DC #1309         .. .0375
1284 0507;          0548            DC #0507           .. .04
```

```
1286 0B08;                     DC   #0B08          .. .0425
1288 1709;                     DC   #1709          .. .045
128A 0306;                     DC   #0306          .. .0475
128C 0D08;                     DC   #0D08          .. .05
128E ;                ....
128E ;                ..
128E 04;              C5T:     DC   #04            .. 4.0
128F 05;                       DC #05              .. 5.0
1290 06;                       DC   #06            .. 6.0
1291 07;                       DC   #07            .. 7.0
1292 ;                ..
1292 ;                ..
1292 ;                ..
1292 ;                         END                 ..
0000

->EOF!Q$$
```

```
!M
0000 ;          ..
0000 ;          ..
0000 ;          ..
0000 ;          ..      SUBROUTINE READ         ..
0000 ;          ..        CALLING SEQ:          ..
0000 ;          ..              SEX  R4         .. INPUT BUFFER ADD.
0000 ;          ..              SEP  RB          ..
0000 ;          ..
0000 ;          ..
0000 ;          ..
0000 ;                          ORG  #12A0     ..
12A0 3EA0;         READ:        BN3  *         .. WAIT FOR DATA
12A2 6E;                        INP  6          .. READ IT !!
12A3 FC80;                      ADI  #80        .. CONVERT TO 2'S C
12A5 54;                        STR  R4         .. SAVE IT
12A6 FE;                        SHL             .. GET SIGN BIT
12A7 3BAE;                      BNF  READA      .. NON '-' ?? YES
12A9 3AAE;                      BNZ  READA      .. BAD CASE ? NO
12AB F881;                      LDI  #81        .. FORCE TO -127
12AD 54;                        STR  R4         .. SAVE IT
12AE 13;           READA:       INC  R3         .. I= I+1
12AF DF;                        SEP  RF         .. RETURN TO GERM
12B0 30A0;                      BR  READ        ..
12B2 ;          ..
12B2 ;          ..
12B2 ;          ..
12B2 ;          ..      SUBROUTINE MPLY        ..
12B2 ;          ..         CALLING SEQ:        ..
12B2 ;          ..           R7= 16 BIT MULTIPLICAND ADD. ..
12B2 ;          ..           R8=  "   "  PRODUCT ADD. ..
12B2 ;          ..           RA.0= RIGHT SHIFT COUNT ..
12B2 ;          ..           RA.1= LEFT SHIFT COUNT ..
12B2 ;          ..
12B2 ;          ..           SEX  R8  ..
12B2 ;          ..           SEP  RC  ..
12B2 ;          ..
12B2 ;          ..
12B2 ;          ..
12B2 ;                          ORG  #12C0      ..
12C0 F800;         MPLY:        LDI  0          .. CLEAR PRODUCT
12C2 73;                        STXD
12C3 73;                        STXD
12C4 58;                        STR  R8
12C5 60;                        IRX
12C6 60;                        IRX
12C7 27;                    DEC  R7
12C8 27;                    DEC  R7
12C9 57;                    STR  R7
12CA 17;                    INC  R7
```

```
12CB 07;              LDN   R7
12CC 27;              DEC   R7
12CD FE;              SHL
12CE 3BD3;            BNF   *+5
12D0 F8FF;            LDI   #FF
12D2 57;              STR   R7
12D3 17;              INC   R7
12D4 17;              INC   R7
12D5 F808;                     LDI   8
12D7 A9;                       PLO   R9         .. R9.0= MAX L. SHIFT COUNT
.
12D8 9A;        MPLYA:         GHI   RA         ..
12D9 F6;                       SHR              .. RHIFT MULTIPLIER
12DA BA;                       PHI   RA         .. SAVE IT
12DB 3BEB;                     BNF   LHIFT      .. ADD ON ?  NO!
12DD 07;                       LDN   R7
12DE F4;                       ADD
12DF 73;                       STXD             .. SAVE IT
12E0 27;                       DEC   R7         .. ADD ON HIGH ORDER
12E1 07;              LDN   R7
12E2 74;                       ADC              .. WITH CARRY
12E3 73;              STXD
12E4 27;              DEC   R7
12E5 47;              LDA   R7
12E6 17;              INC   R7
12E7 74;              ADC
12E8 58;                       STR   R8         .. SAVE IT
12E9 60;                       IRX              ..
12EA 60;              IRX
12EB 9A;        LHIFT:         GHI   RA         ..
12EC C21304;          LBZ   RHIFT
12EF 29;                       DEC   R9         .. LSC= LSC-1
12F0 89;                       GLO   R9         .. GET LSC
12F1 C21304;          LBZ   RHIFT
12F4 07;                       LDN   R7         .. NO, SO SHIFT L
12F5 FE;                       SHL              .. DO IT, LOW BITS
12F6 57;                       STR   R7         ..
12F7 27;                       DEC   R7         ..
12F8 07;                       LDN   R7         ..
12F9 7E;                       SHLC             .. HIGH ORDER BITS
12FA 57;                       STR   R7         .. SAVE THEM
12FB 27;              DEC   B7
12FC 07;              LDN   R7
12FD 7E;              SHLC
12FE 57;              STR   R7
12FF 17;              INC   R7
1300 17;                       INC   R7         ..
1301 C012D8;          LBR   MPLYA
1304 ;          ..
1304 ;          ..
```

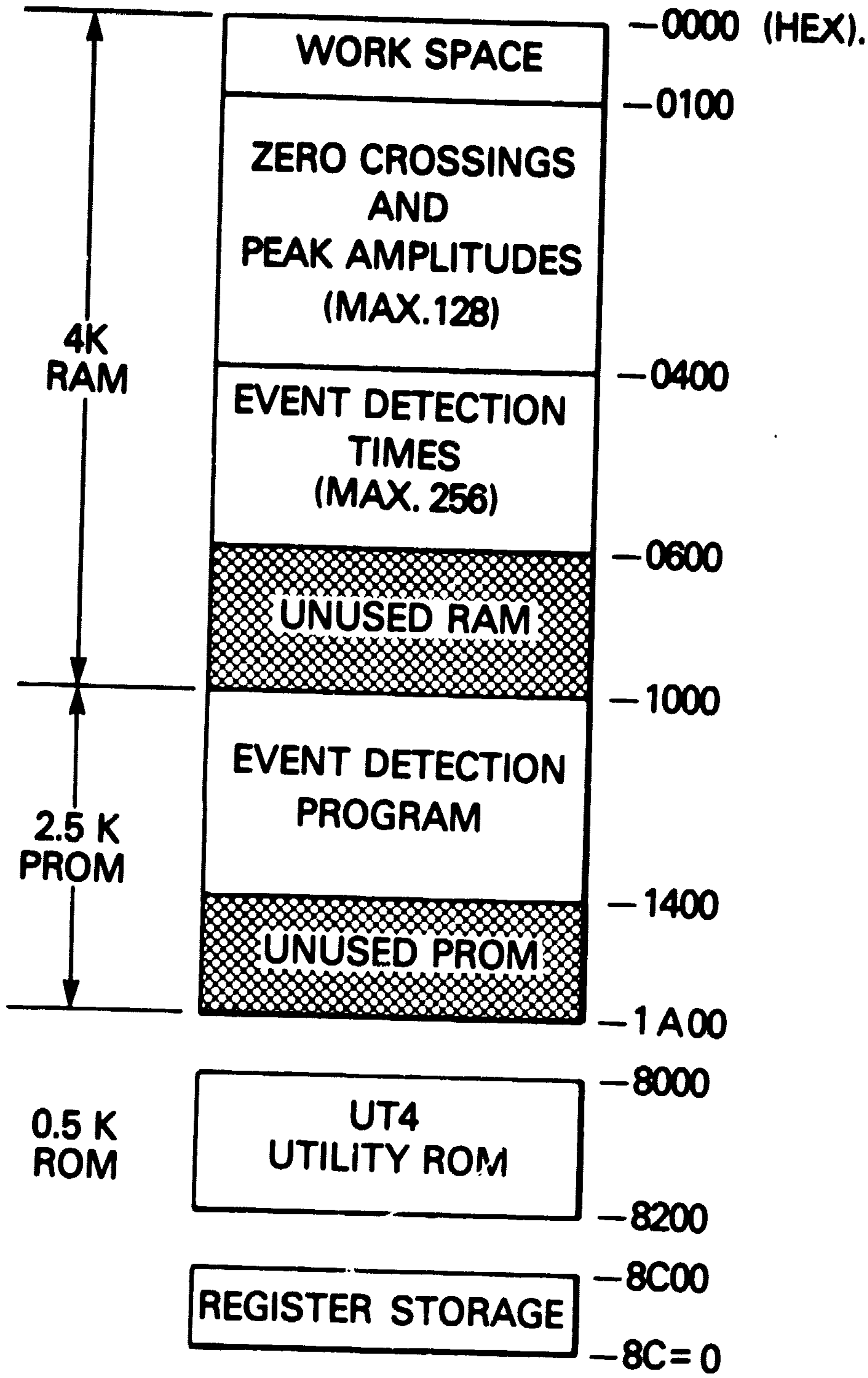
```
1304 8A;              RHIFT:   GLO  RA
1305 3221;                     BZ   EXITA      ..
1307 2A;                       DEC  RA         ..
1308 28;                       DEC  R8         ..
1309 28;                DEC  R8
130A F0;                       LDX             ..
130B F6;                       SHR             ..
130C A9;                       PLO  R9
130D FA40;                     ANI  #40        .. GET PREV. SIGN
130F 3215;                     BZ   RH1        .. SIGN "+" ?  YES!
1311 89;                       GLO  R9         .. NO, IT'S "-"
1312 F980;                     ORI  #80        .. RESTORE "-"
1314 A9;                       PLO  R9
1315 89;              RH1:     GLO  R9       .. GET IT
1316 58;                       STR  R8         .. SAVE HIGH ORDER BITS
1317 60;                       IRX
1318 F0;                       LDX
1319 76;                       SHRC            ..
131A 58;                       STR  R8
131B 60;                IRX
131C F0;                LDX
131D 76;                SHRC
131E 58;                STR  R8
131F 3004;                     BR   RHIFT      ..
1321 DF;              EXITA:   SEP  RF         .. RETURN
1322 C012C0;                   LBR  MPLY
1325 ;                ..
1325 ;                ..
1325 ;                ..
1325 ;                ..     SUBROUTINE MEAT     ..
1325 ;                ..        CALLING SEQ. :   ..
1325 ;                ..           SEX  R4  .. R4= ADD(R)
1325 ;                ..                    .. R7= A.0(TEMP)
1325 ;                ..        SEP  RE  ..
1325 ;                ..
1325 ;                ..
1325 ;                ..
1325 ;                LR=#06
1325 ;                C1=#09
1325 ;                C2=#0C
1325 ;                C3=#0F
1325 ;                DELTA=#25
1325 ;                CHAR=#29
1325 ;                TEMP2=#3D
1325 ;                ..
1325 ;                ..
1325 ;                ..
1325 ;                  ORG  #1340
1340 F0;              MEAT:    LDX              ..
1341 57;                       STR  R7          .. R7= R
1342 27;                       DEC  R7
1343 FE;                       SHL             .. GET SIGN
1344 334A;                     BDF  NEGAA      .. NEG ?? YES
1346 F800;                     LDI  0          .. NO, EXT ZEROES
1348 304C;                     BR   MEATA      ..
134A F8FF;            NEGAA:   LDI  #FF        .. EXT ONES
134C 57;              MEATA:   STR  R7         .. SAVE IT
134D ;                ..                       .. TEMP= R , 16 BITS
134D 17;                       INC  R7
134E F83D;                     LDI  A.0(TEMP2)   ..
1350 A8;                       PLO  R8
1351 F809;                     LDI  C1           ..
1353 A9;                       PLO  R9
1354 49;                       LDA  R9           ..
```

```
1355 BA;        PHI   RA
1356 09;        LDN   R9      ..
1357 AA;        PLO   RA
1358 E8;        SEX   R8      ..
1359 DF;        SEP   RF
135A 08;        LDN   R8      ..
135B E4;        SEX   R4
135C 73;        STXD          .. X= R4= ADD(LR)
135D F800;      LDI   0       ..
135F A9;        PLO   R9      .. SIGN OF LR
1360 AA;        PLO   RA      .. SIGN OF R
1361 72;        LDXA          .. A= LR
1362 FE;        SHL           .. GET SIGN
1363 3368;      BDF   *+5     ..
1365 F8FF;      LDI   #FF
1367 A9;        PLO   R9      ..
1368 F0;        LDX           .. A= R
1369 FE;        SHL           ..
136A 3B6F;      BNF   *+5
136C F8FF;      LDI   #FF     ..
136E AA;        PLO   RA
136F 24;        DEC   R4      ..
1370 72;        LDXA          .. A= LR, H= R4= ADD(R(
1371 F5;        SD
1372 57;        STR   R7      ..
1373 27;        DEC   R7
1374 89;        GLO   R9      .. ADD EXTENSIONS
1375 57;        STR   R7
1376 E7;        SEX   R7      .. R7=X= A.1(TEMP)
1377 8A;        GLO   RA
1378 74;        ADC           ..
1379 57;        STR   R7      .. TEMP= R-LR, 16 BITS
137A 17;        INC   R7
137B F825;      LDI   DELTA
137D A8;        PLO   R8      ..
137E F80C;      LDI   C2
```

```
1380 A9;              PLO  R9
1381 49;              LDA  R9
1382 BA;              PHI  RA          .. RA.1= LSC "C2"
1383 09;              LDN  R9
1384 AA;              PLO  RA
1385 E8;              SEX  R8
1386 DF;              SEP  RF          .. CALL MPLY(DELTA)
1387 04;              LDN  R4          .. A= R(7-0)
1388 FE;              SHL              .. GET SIGN
1389 338E;            BDF  NEGA
138B 76;              SHRC
138C 3091;            BR  POSA
138E 76;        NEGA: SHRC
138F FD00;            SDI  0
1391 BA;        POSA: PHI  RA          .. RA.1= ABS(R)
1392 57;              STR  R7          .. TEMP.0= ABS(R)
1393 F829;            LDI  CHAR
1395 A8;              PLO  R8          ..
1396 F800;            LDI  0
1398 AA;              PLO  RA          ..
1399 27;              DEC  R7
139A 57;              STR  R7          ..
139B 17;              INC  R7          .. R7= ADD. OF MULTIPLICAND
139C DF;              SEP  RF          .. CALL MPLY(CHAR=R*R)
139D F824;            LDI  A.0(DELTA-1) ..
139F A9;              PLO  R9          ..
13A0 49;              LDA  R9
13A1 FE;              SHL              ..
13A2 09;              LDN  R9
13A3 3BA7;            BNF  POSB        ..
13A5 FD00;            SDI  0
13A7 BA;        POSB: PHI  RA
13A8 57;              STR  R7          ..
13A9 27;              DEC  R7          .. TEMP= ABS(DELTA)
13AA F800;            LDI  0
13AC 57;              STR  R7           ..
13AD 17;              INC  R7
13AE AA;              PLO  RA           ..
13AF F83D;            LDI  DEMP2
13B1 A8;              PLO  R8
13B2 DF;              SEP  RF          .. CALL MPLY(TEMP2)
13B3 ;          ..                     ..    = DELTA**2
13B3 F829;            LDI  CHAR
13B5 A9;              PLO  R9
13B6 09;              LDN  R9
13B7 F4;              ADD
13B8 59;              STR  R9
13B9 29;              DEC  R9
13BA 28;              DEC  R8
```

```
13BB 09;          LDN  R9
13BC 74;          ADC
13BD 59;          STR  R9          .. CHAR= R**2+DELTA**2
13BE F829;        LDI  CHAR
13C0 A8;          PLO  R8
13C1 05;          LDN  R5            .. A= ALFA(7,0)
13C2 F5;          SD                .. A=CHAR-ALFA, LO ORDER
13C3 57;          STR  R7
13C4 27;          DEC  R7            ..
13C5 25;          DEC  R5
13C6 28;          DEC  R8
13C7 45;          LDA  R5            ..
13C8 FBFF;        XRI  #FF
13CA 74;          ADC                .. HIGH ORDER BITS
13CB 57;          STR  R7
13CC 17;          INC  R7            ..
13CD F80F;        LDI  C3
13CF A9;          PLO  R9            ..
13D0 49;          LDA  R9
13D1 BA;          PHI  RA            ..
13D2 09;          LDN  R9
13D3 AA;          PLO  RA            ..
13D4 F83D;        LDI  TEMP2
13D6 A8;          PLO  R8            ..
13D7 DF;          SEP  RF          .. CALL MPLY
13D8 05;          LDN  R5
13D9 F4;          ADD              ..
13DA 55;          STR  R5
13DB 25;          DEC  R5          ..
13DC 28;          DEC  R8
13DD 05;          LDN  R5          ..
13DE 74;          ADC
13DF 55;          STR  R5          ..
13E0 15;          INC  R5          .. R5= A.0(ALFA)
13E1 DF;          SEP  RF          .. RETURN
13E2 3040;        BR  MEAT
13E4 ;            END
0000
```

MEMORY MAP


—0000 (HEX).
WORK SPACE
—0100
ZERO CROSSINGS
AND
PEAK AMPLITUDES
(MAX.128)
4K
RAM
—0400
EVENT DETECTION
TIMES
(MAX. 256)
—0600
UNUSED RAM
—1000
EVENT DETECTION
PROGRAM
2.5 K
PROM
—1400
UNUSED PROM
—1A00
—8000
0.5 K
ROM
UT4
UTILITY ROM
—8200
—8C00
REGISTER STORAGE
—8C=0

High Pass Filter (C1)

Range: 0.5 to 1.5

Resolution: 0.1

Mean: 0.995

Steps: 11

Index	Value	Real Value	Index	Value	Real Value
0	0.5	0.5000	6	1.1	1.1093
1	0.6	0.6250	7	1.2	1.1875
2	0.7	0.6875	8	1.3	1.3125
3	0.8	0.8125	9	1.4	1.4062
4	0.9	0.9060	10	1.5	1.5000
5	1.0	1.000	11-15	"NOT USED"	

Weighting Constant (C2)

Range: 0.0 to 2.0

Resolution: 0.15

Mean: 0.65

Steps: 14

Index	Value	Real Value	Index	Value	Real Value
0	0.00	0.0000	8	1.05	1.0625
1	0.15	0.1406	9	1.20	1.1875
2	0.30	0.2812	10	1.35	1.3750
3	0.45	0.4375	11	1.50	1.5000
4	0.60	0.6250	12	1.65	1.6250
5	0.75	0.7500	13	1.80	1.8125
6	0.90	0.9060	14	1.95	1.9375
7*	1.00	1.0000	15*	2.00	2.0000

*Not required in original specification

(C3)

Range: 0.2 to 0.8

Resolution: 0.1

Mean: 0.5

Steps: 7

Index	Value	Real Value	Index	Value	Real Value
0	0.200	0.2030	13*	0.525	0.5234
1*	0.225	0.2187	14*	0.550	0.5468
2*	0.250	0.2500	15*	0.5750	0.5781
3*	0.275	0.2730	16	0.6000	0.6093
4	0.300	0.2960	17*	0.6250	0.6250
5*	0.325	0.3280	18*	0.6500	0.6562
6*	0.350	0.3437	19*	0.6750	0.6718
7*	0.375	0.3750	20	0.7000	0.7031
8	0.400	0.4062	21*	0.7250	0.7187
9*	0.425	0.4218	22*	0.7500	0.7500
10*	0.450	0.4531	23*	0.7750	0.7656
11*	0.475	0.4687	24	0.8125	0.8125
12	0.500	0.5000	25-31	"NOT USED"	

(C4)

Range: 0.005 to 0.05

Resolution: 0.005

Mean: 0.025

Steps: 10

Index	Value	Real Value	Index	Value	Real Value
0	0.0050	0.0048	10	0.0300	0.0312
1*	0.0075	0.0078	11*	0.0325	0.0332
2	0.0100	0.0097	12	0.0350	0.0351
3*	0.0125	0.0126	13*	0.0375	0.0371
4	0.0150	0.0156	14	0.0400	0.0390
5*	0.0175	0.0175	15*	0.0425	0.0429
6	0.0200	0.0195	16	0.0450	0.0449
7*	0.0225	0.0234	17*	0.0475	0.0468
8	0.0250	0.0253	18	0.0500	0.0507
9*	0.0275	0.0273	19-31	"NOT USED"	

Threshold Constant (C5)

Range: 4.0 to 6.0

Resolution: 1.0

Mean: 5.0

Steps: 3

Index	Value	Real Value
0	4.0	4.0
1	5.0	5.0
2	6.0	6.0
3	7.0	7.0

Expected Time Consumption
(Search Mode)

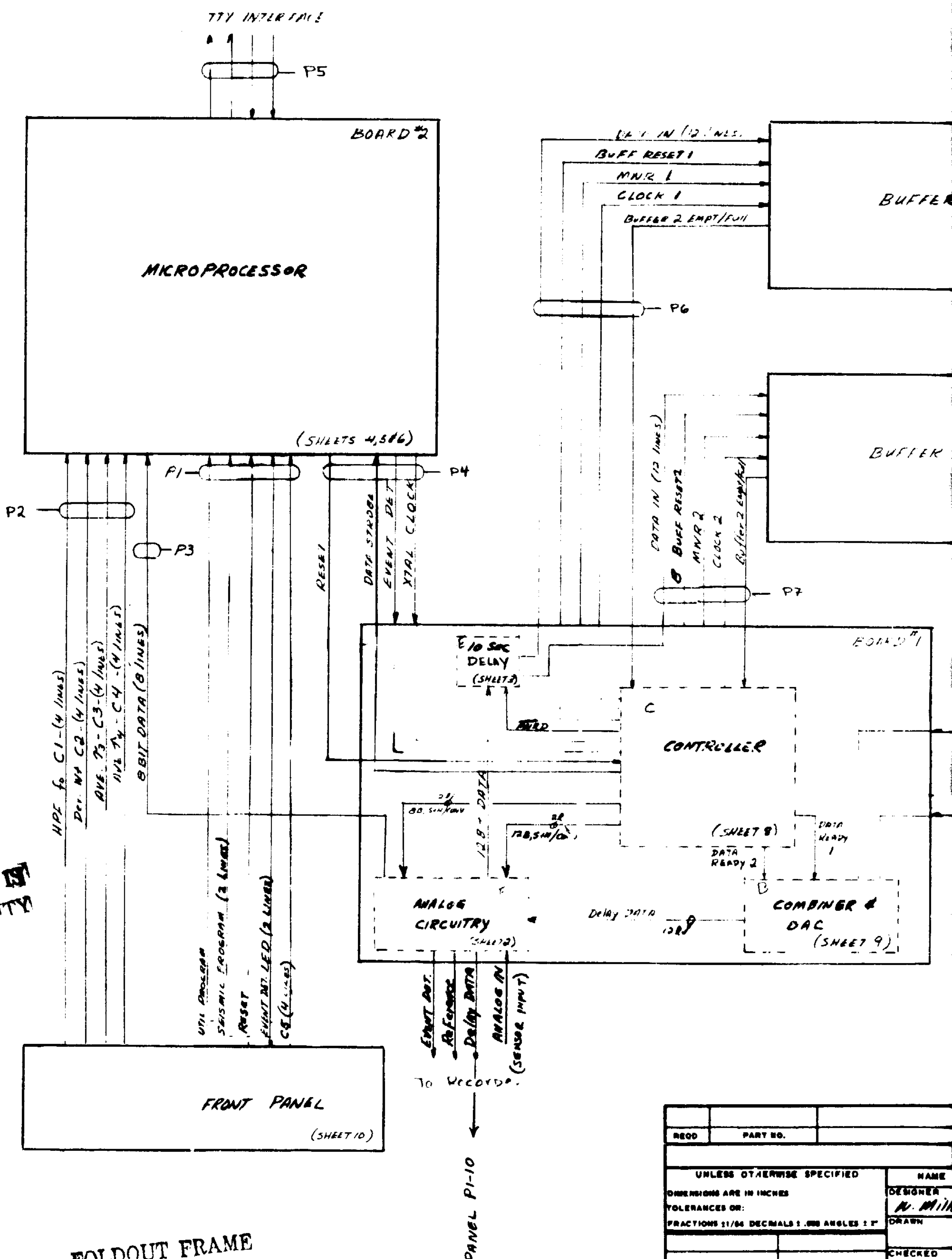
| R | = 127   1250 inst. = 10 ms)

Program Seq. or Function	At Average Values	Worst Case	At Best Values
Germ Main	130	130	130
Sub Read	20	20	20
Sub Meat	125	125	125
Sub Mply (C1)	30	320	
Sub Mply (C2)	30	245	
Sub Mply (R^2)	200	200	200
Sub Mply (ΔR^2)	230	230	230
Sub Mply (C3)	50	340	
Sub Mply (C4)	300	320	
Sub Mply (C5)	90	90	90
Totals	1205	2050	

Expected Time Consumption
(Validation Mode)

|R| = 127 (1250 inst. = 10 ms)

Program Seq. or Function	At Average Values	Worst Case	At Best Values
Germ Main	100	100	100
Sub Read	20	20	20
Sub Meat	125	125	125
Sub Mply (C1)	30	320	
Sub Mply (C2)	30	245	
Sub Mply (R^2)	200	200	200
Sub Mply (ΔR^2)	230	230	230
Sub Mply (C3)	50	340	
Totals	815	1660	



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FOLDOUT FRAME

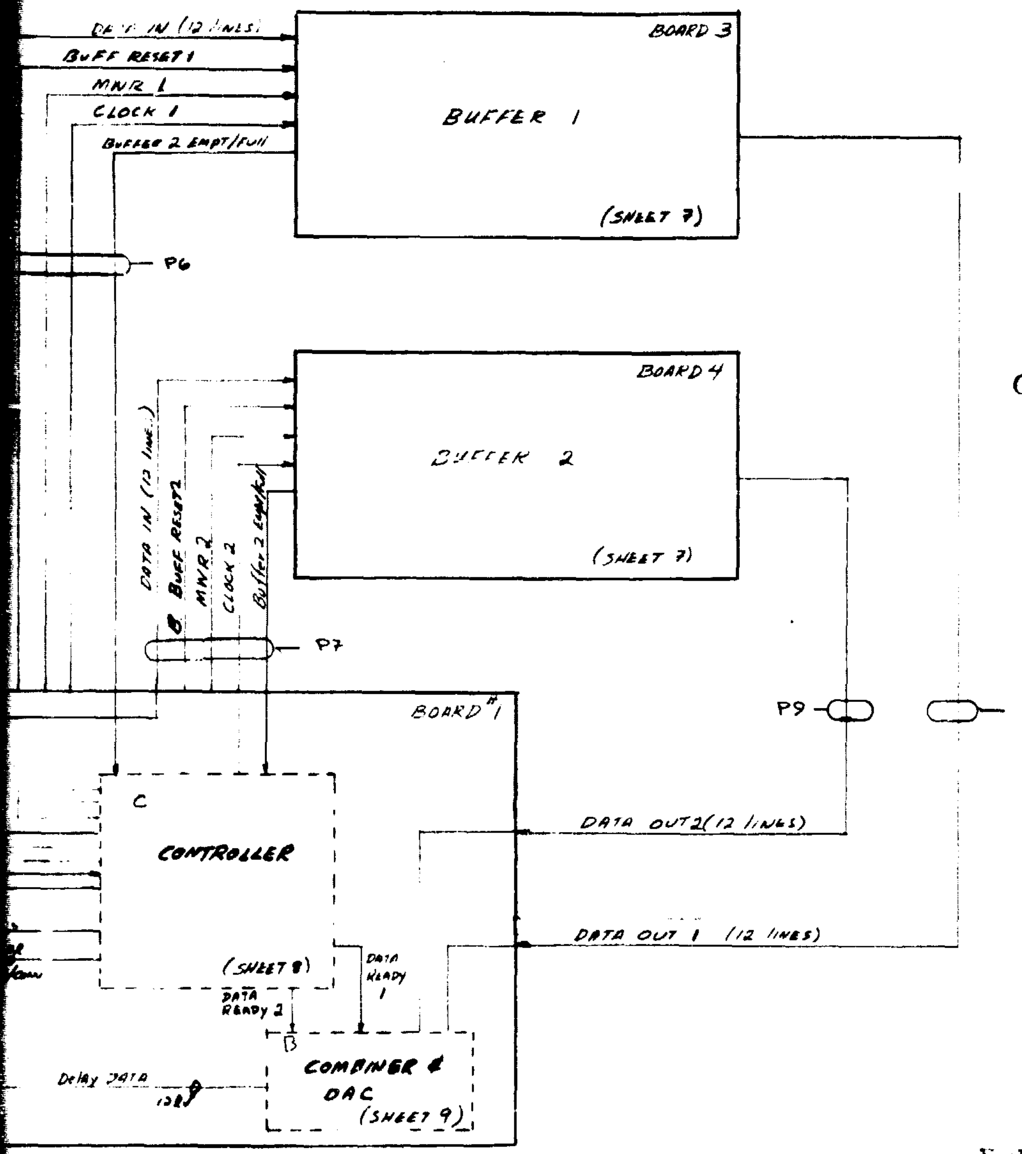
REQD	PART NO.	

UNLESS OTHERWISE SPECIFIED		NAME
DIMENSIONS ARE IN INCHES		DESIGNER
TOLERANCES ON:		W. Mill
FRACTIONS ±1/64 DECIMALS ± .005 ANGLES ± 2°		DRAWN
		CHECKED
		APPROVED
		APPROVED
NEXT ASSY	USED ON	

DRAWING FORMAT GSFC-G-104 (9/8)

REVISIONS

SYM	DESCRIPTION	DATE	APPROVAL



GC

FOLDOUT FRAME

REQD	PART NO.	DESCRIPTION	MATL	MATL SPEC	UNIT WT.

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON:
FRACTIONS ±1/64 DECIMALS ±.005 ANGLES ± 2°

	NAME	INIT	DATE
DESIGNER	N. Miller		
DRAWN			
CHECKED			
APPROVED			
APPROVED			

NEXT ASSY | USED ON

SEISMIC EVENT DETECTOR BLOCK DIAGRAM

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

GC

SCALE | UNIT WT | CODE | SHEET 1 OF 11

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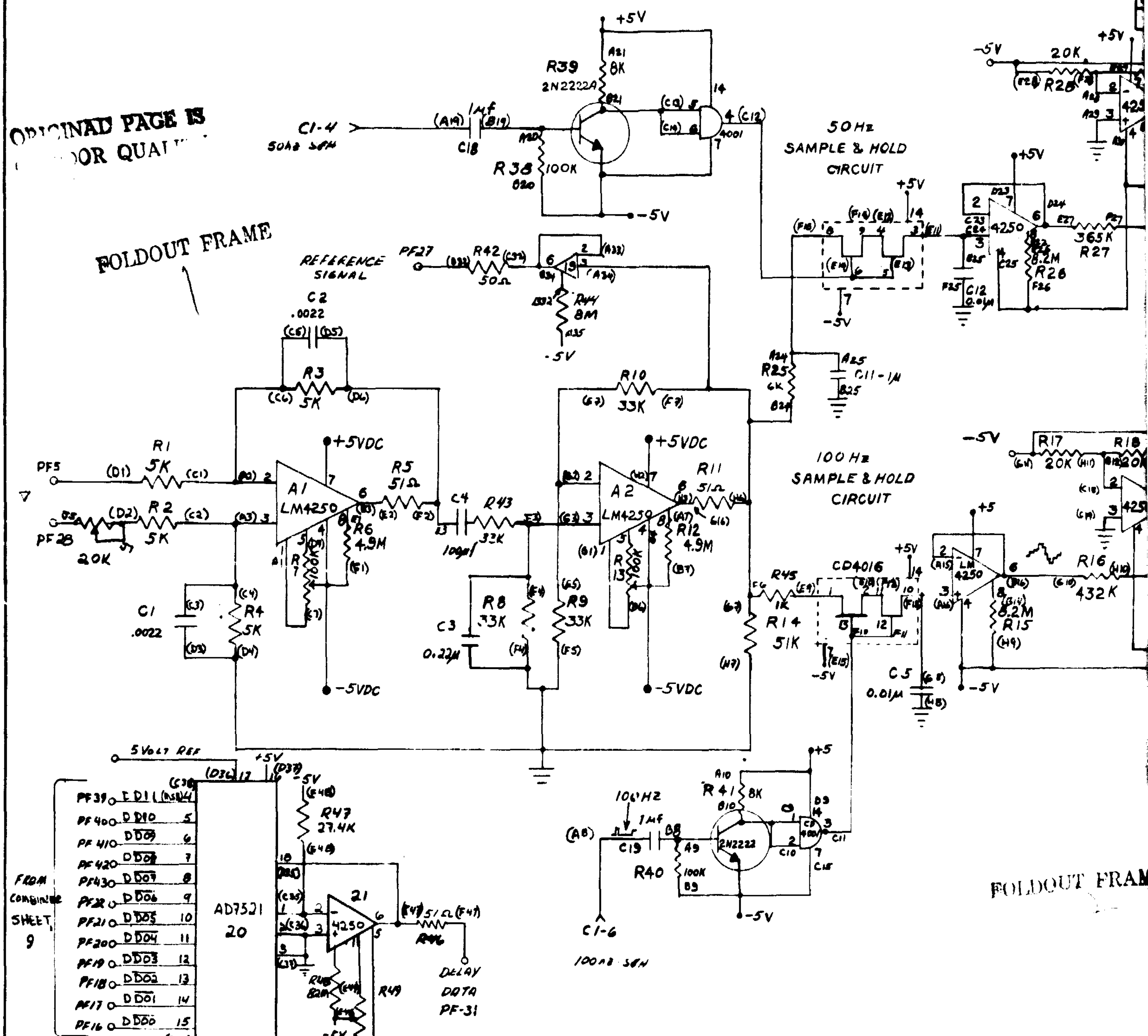

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CONTRACT NO

NEXT ASSY | USED ON

APPLICATION

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MATERIAL

NAME

DRAWN

DESIGNER T CLEMO

CHECKED W Mille

APPROVED

APPROVED

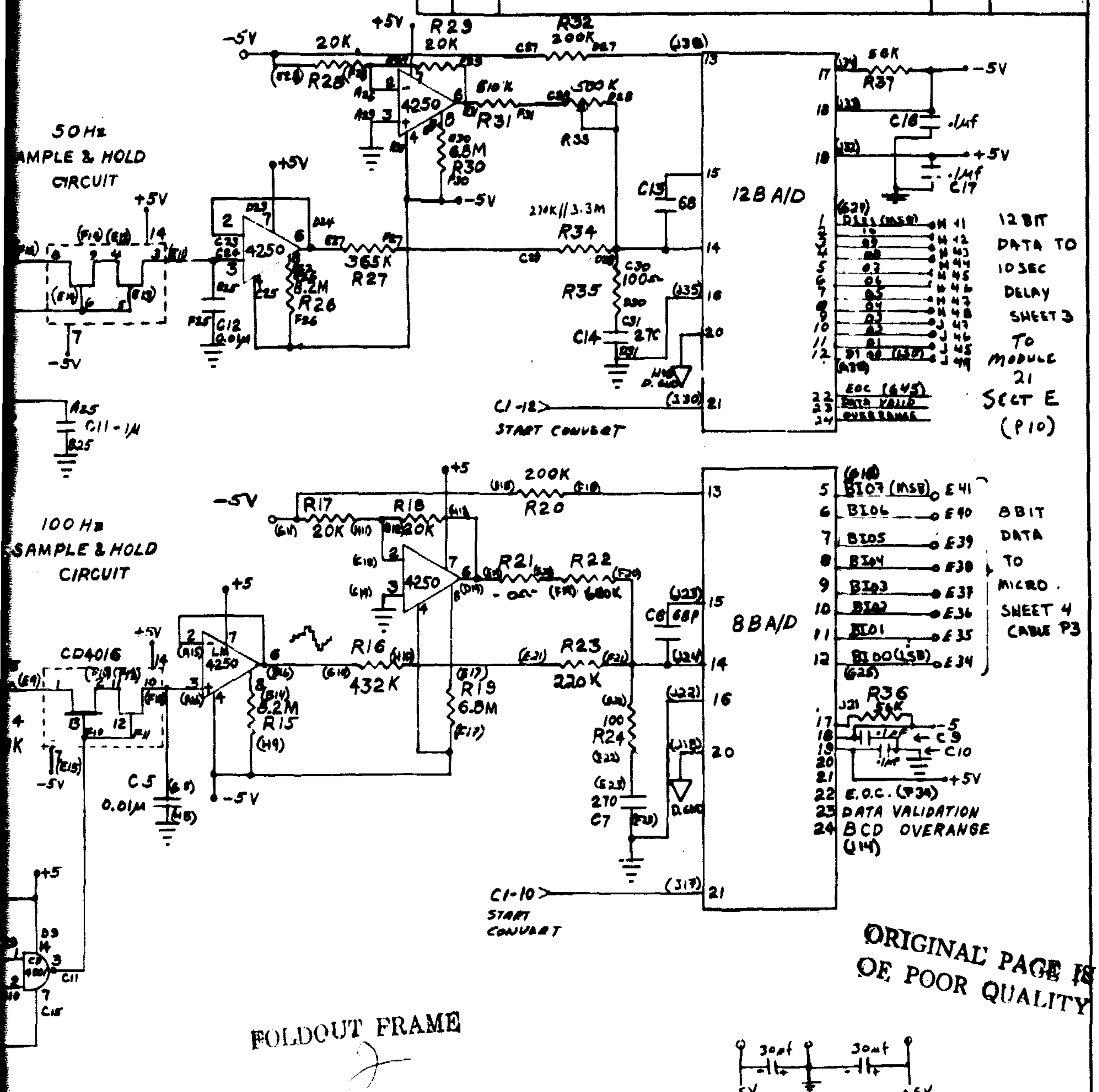
APPROVED

GSFC APPROVAL

BY ORDER OF THE

GSFC 6-18A (8/69)

FOLDOUT FRAME



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DO NOT SCALE THIS DRAWING	DRAWN			
MATERIAL:	DESIGNER	T. CLEMONS		
	CHECKED	W. Miller	1/18/79	
	APPROVED			
	APPROVED			
	APPROVED			
	GSFC APPROVAL		19	
	BY ORDER OF THE DIRECTOR			

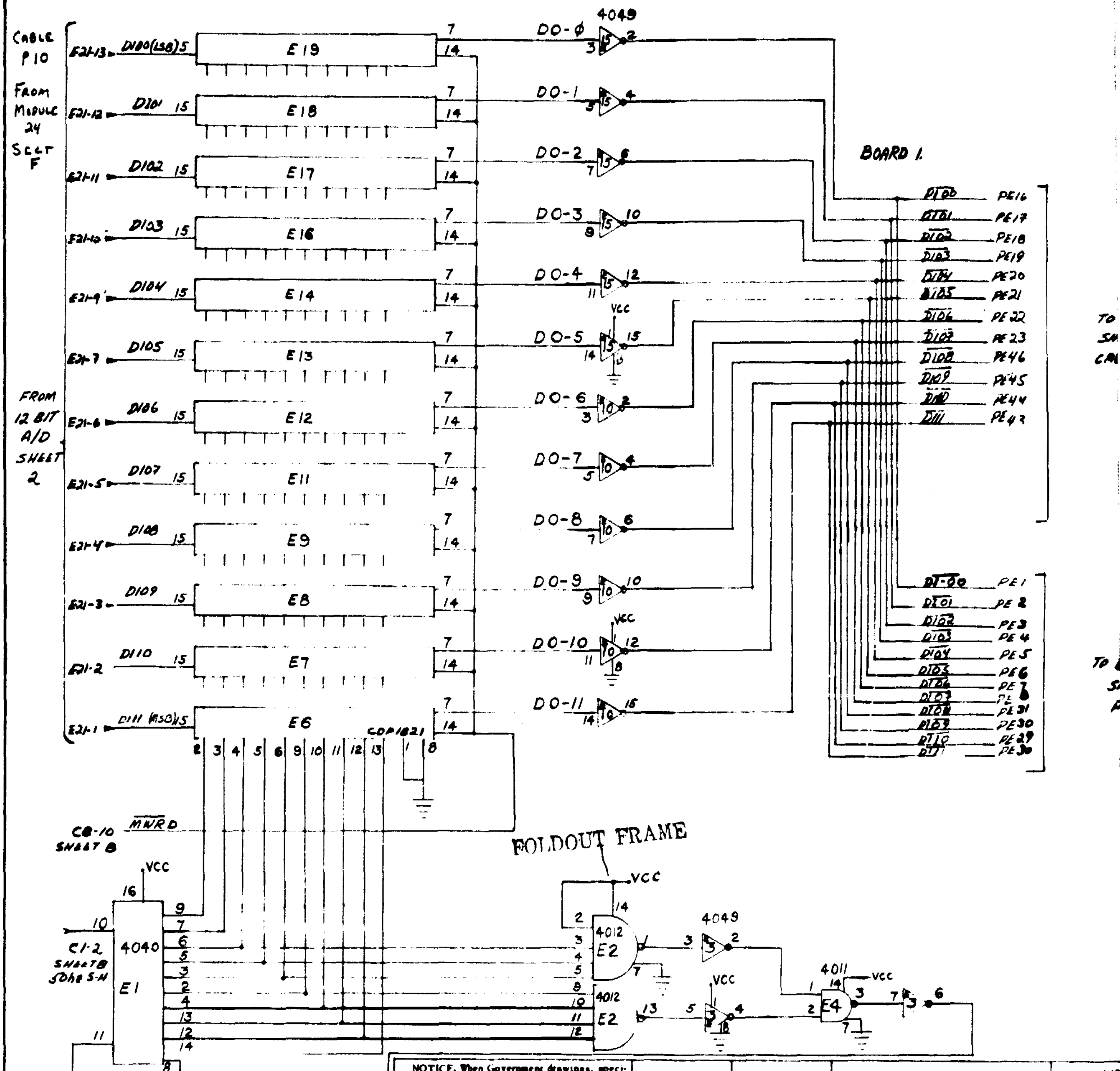
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND 20771
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SEISMIC PLATFORM

ANALOG CIRCUIT (BOARD 1 SECTION F)

CODE IDENT NO: G

SCALE | UNIT WT | SHEET 2 OF 11



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TOLERANCES ON DECIMALS ±
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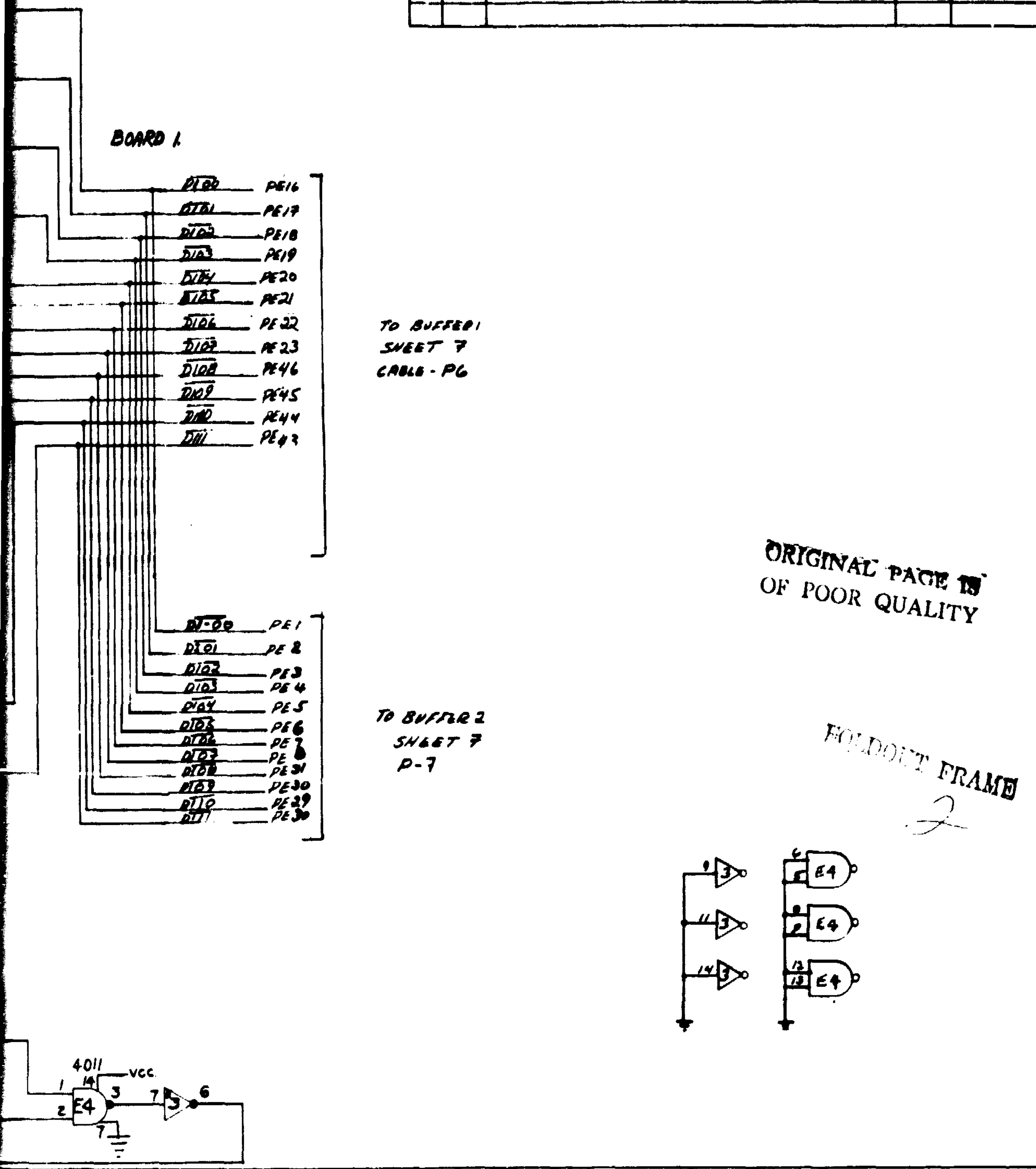

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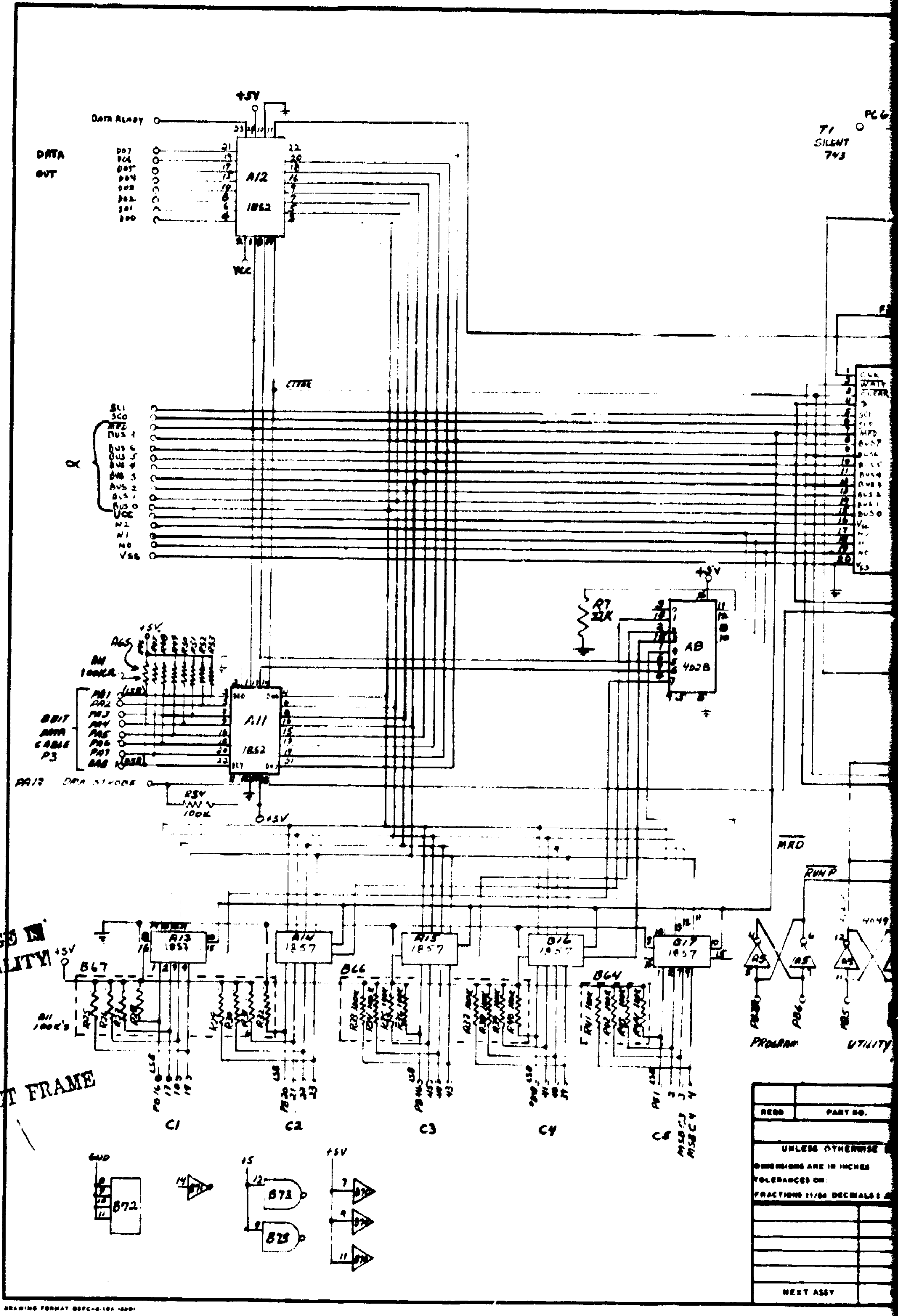

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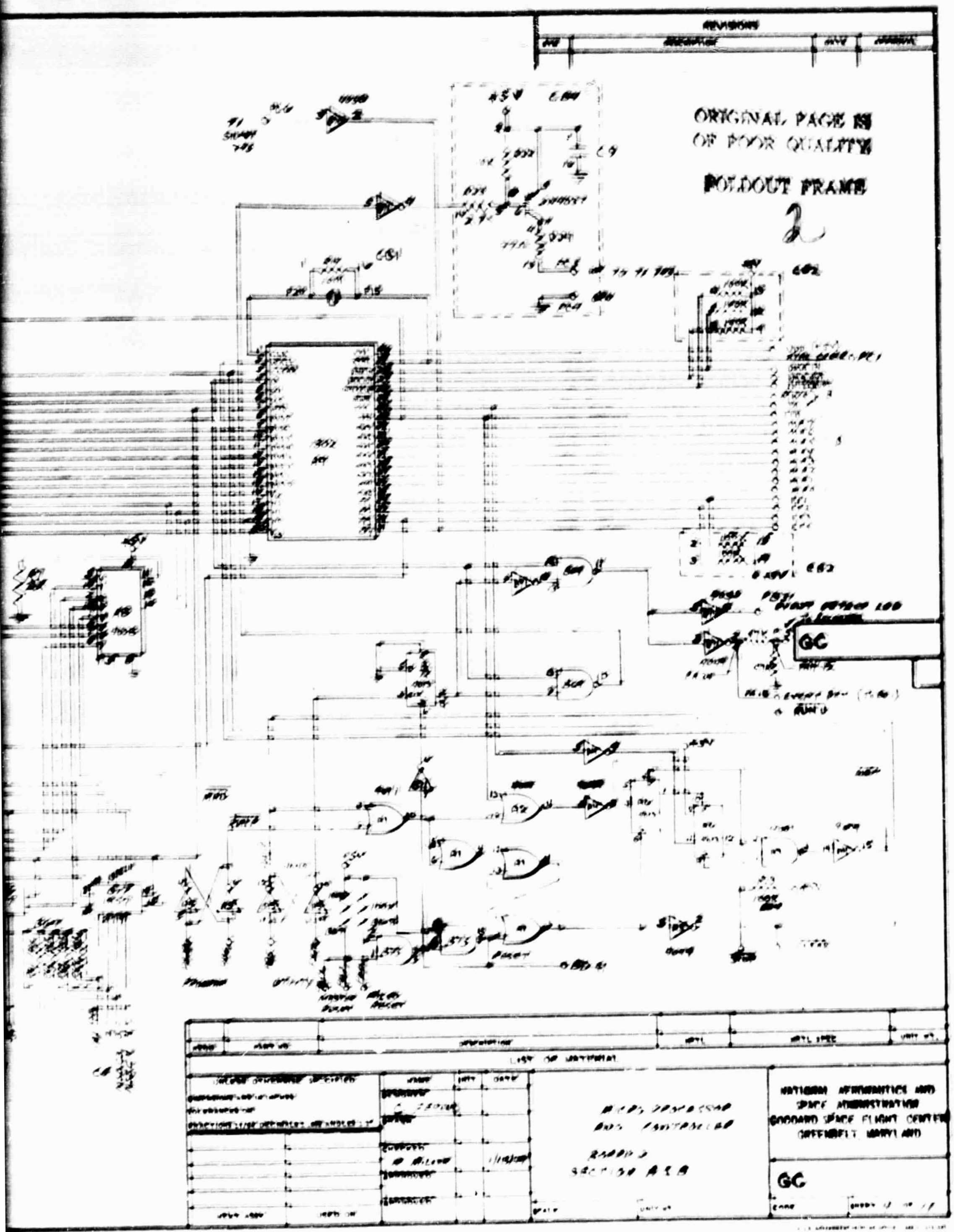

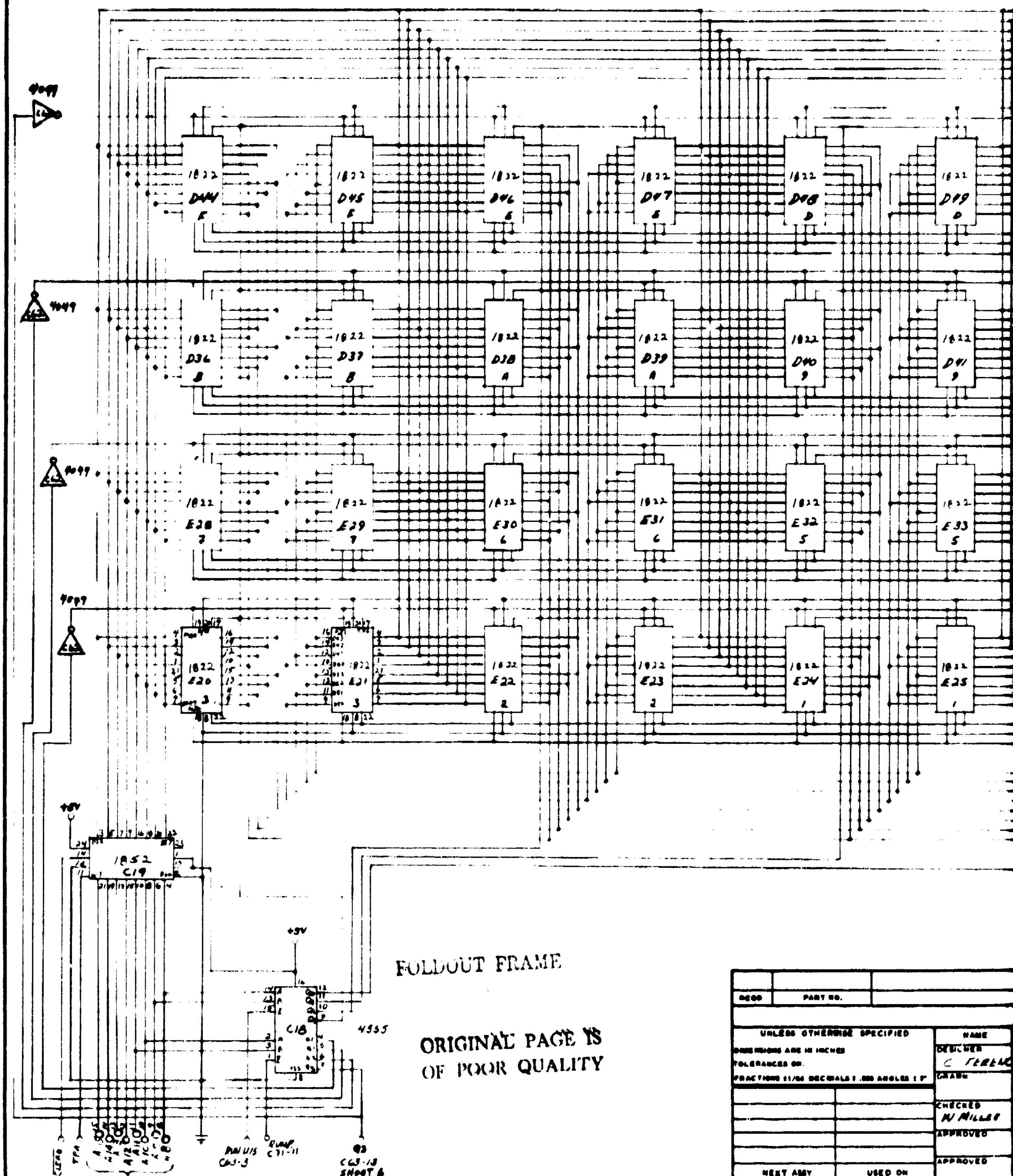

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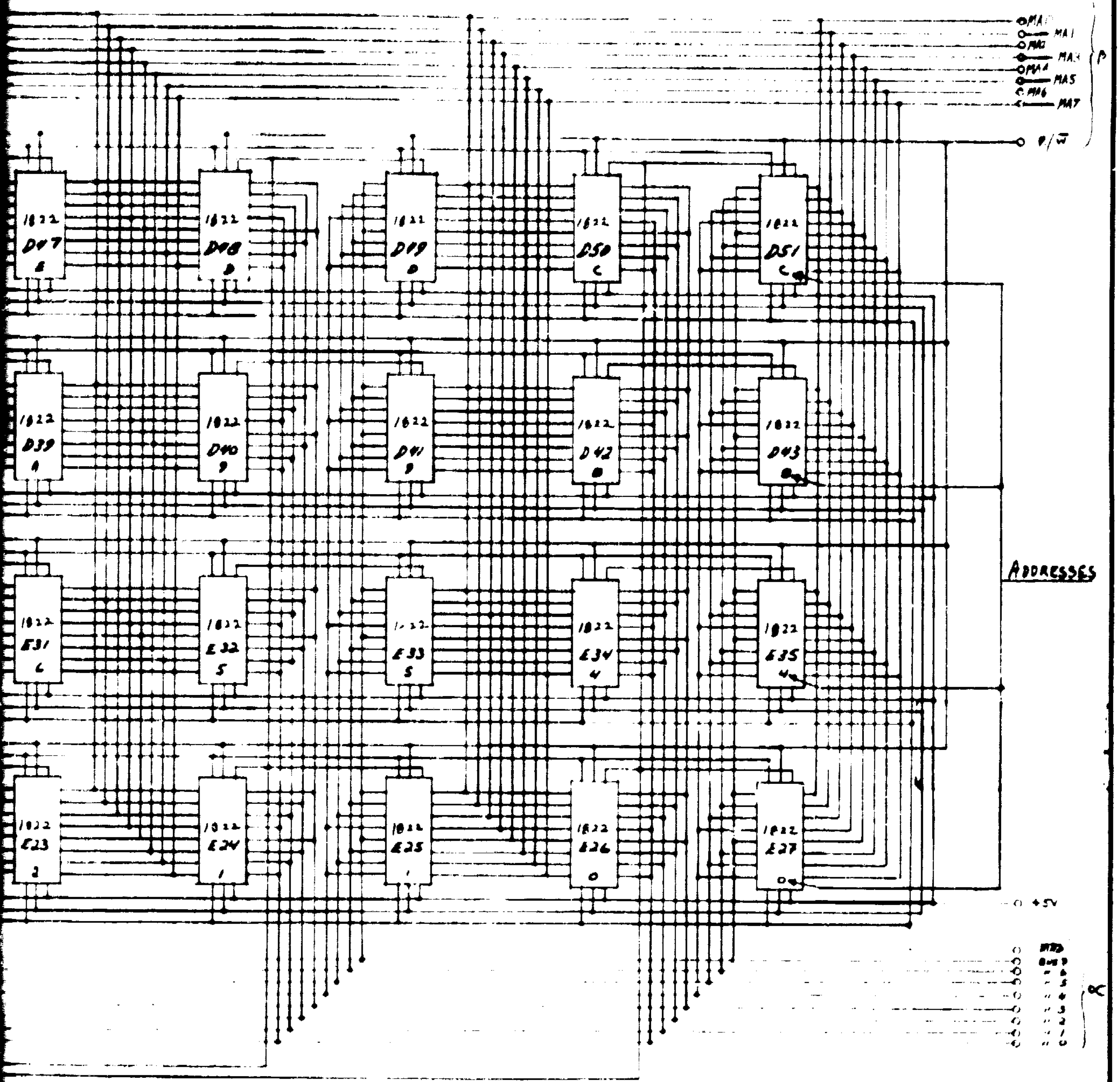

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MICRO PROCESSOR
RAM
BOARD 2
SECTION C D + E

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GREENBELT, MARYLAND

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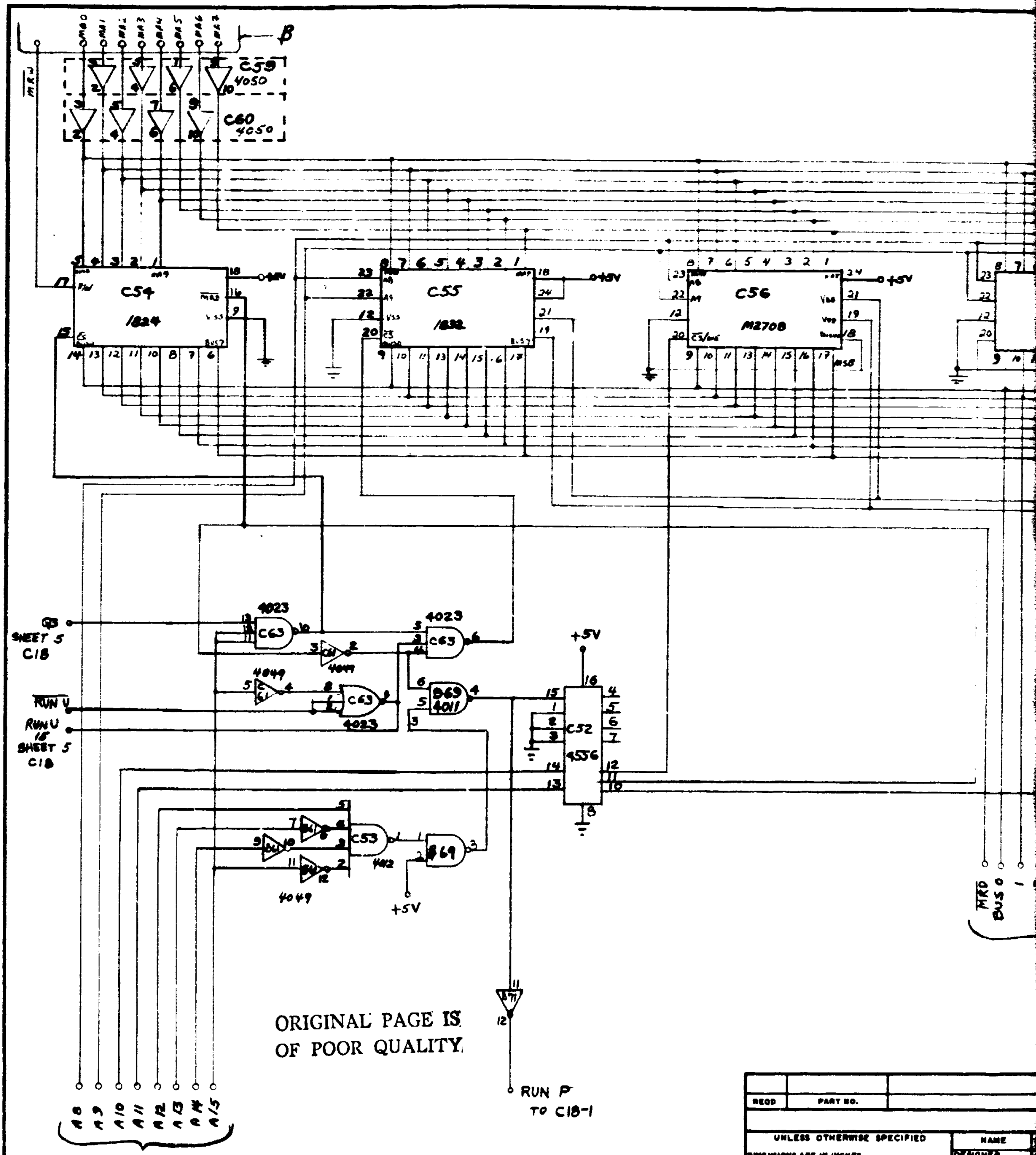

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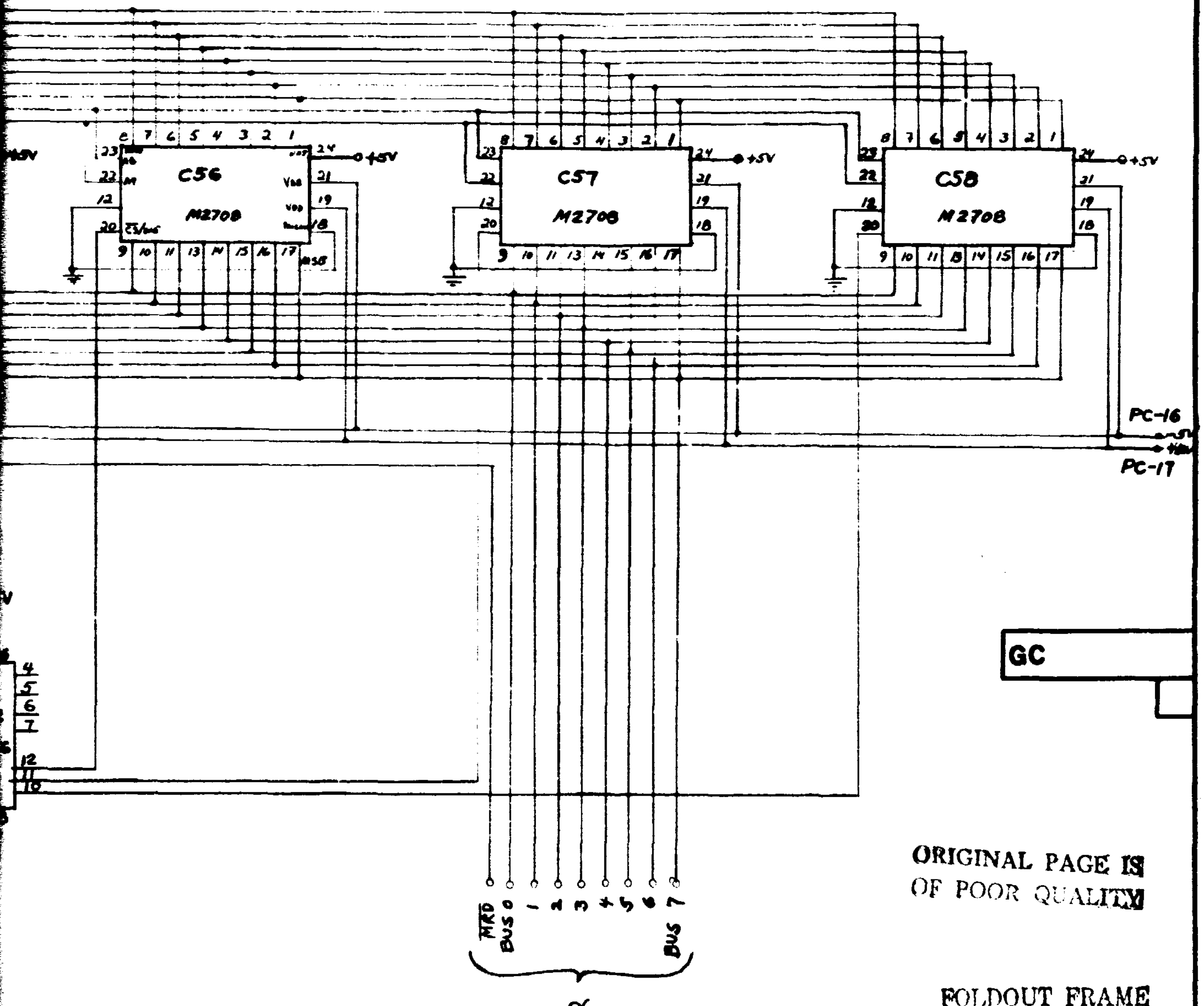

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SECTION B+C

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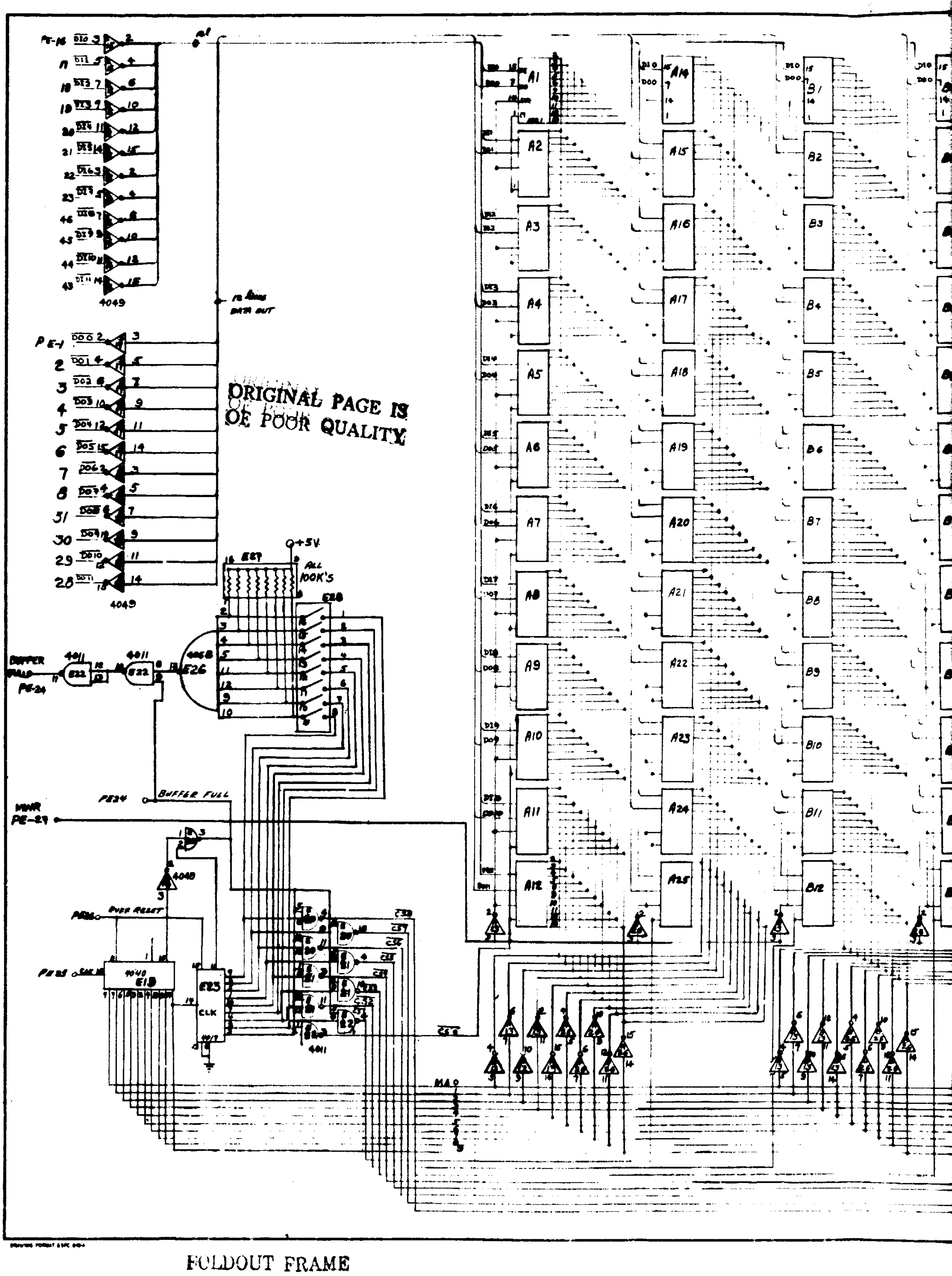

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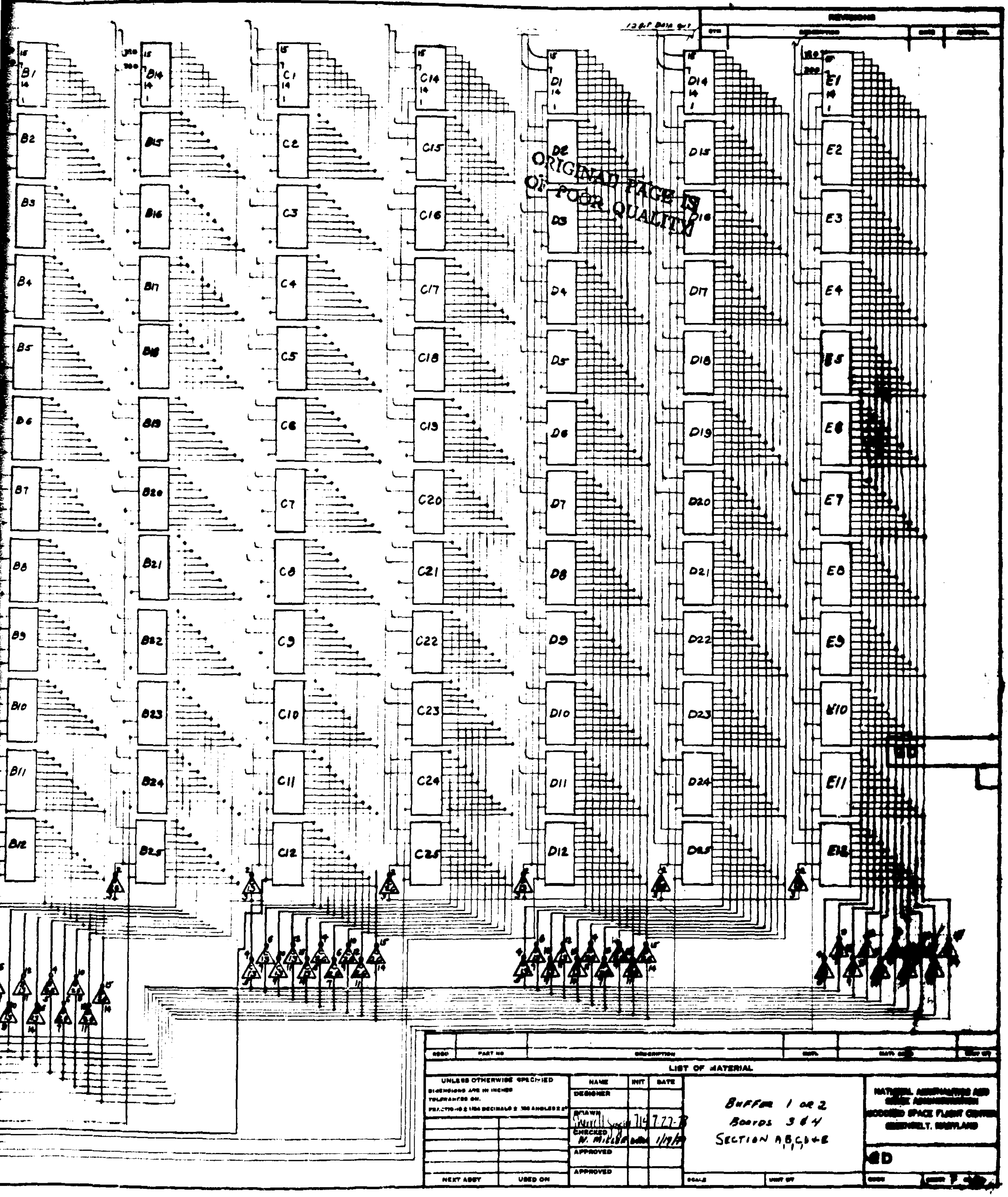

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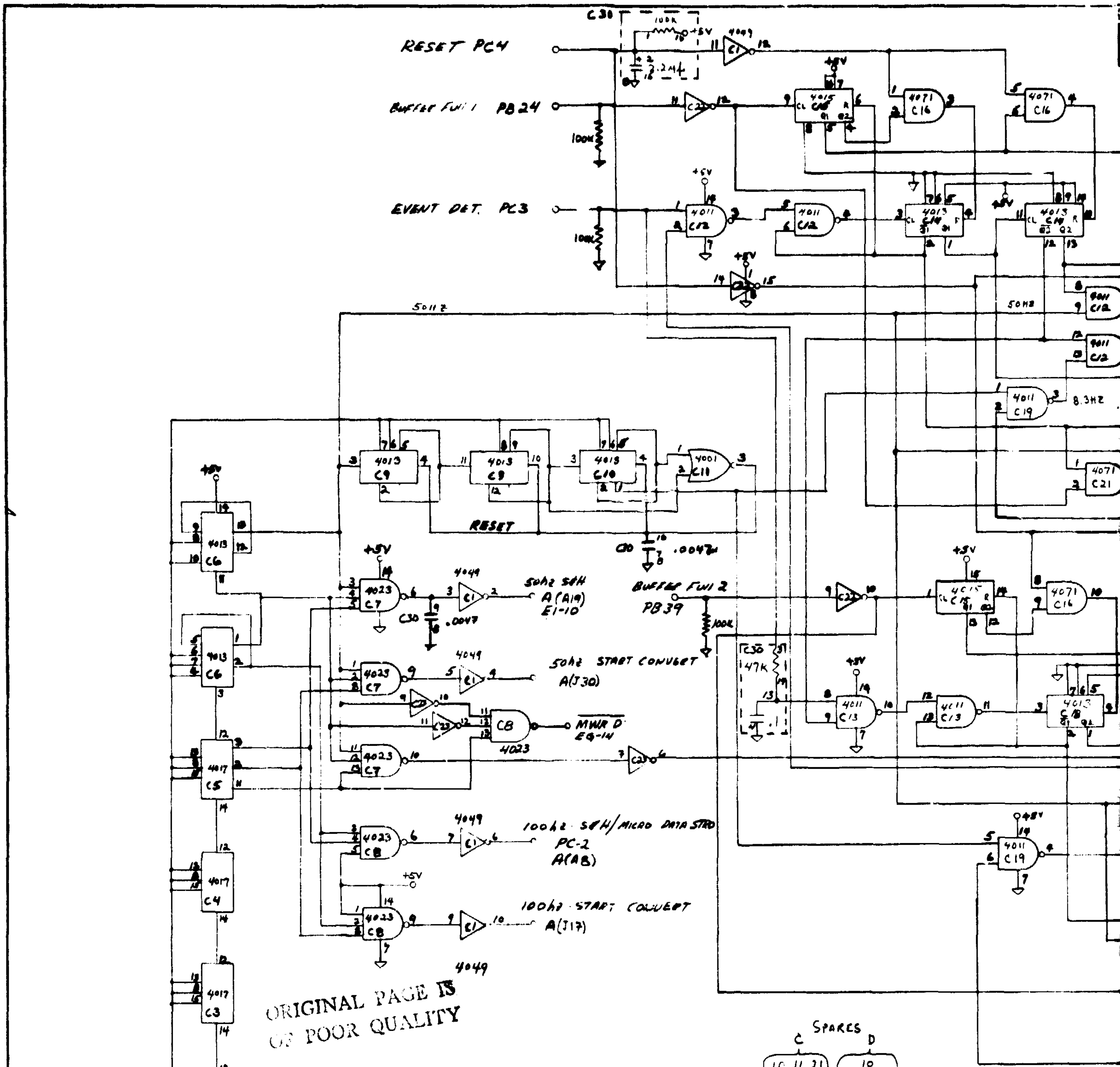

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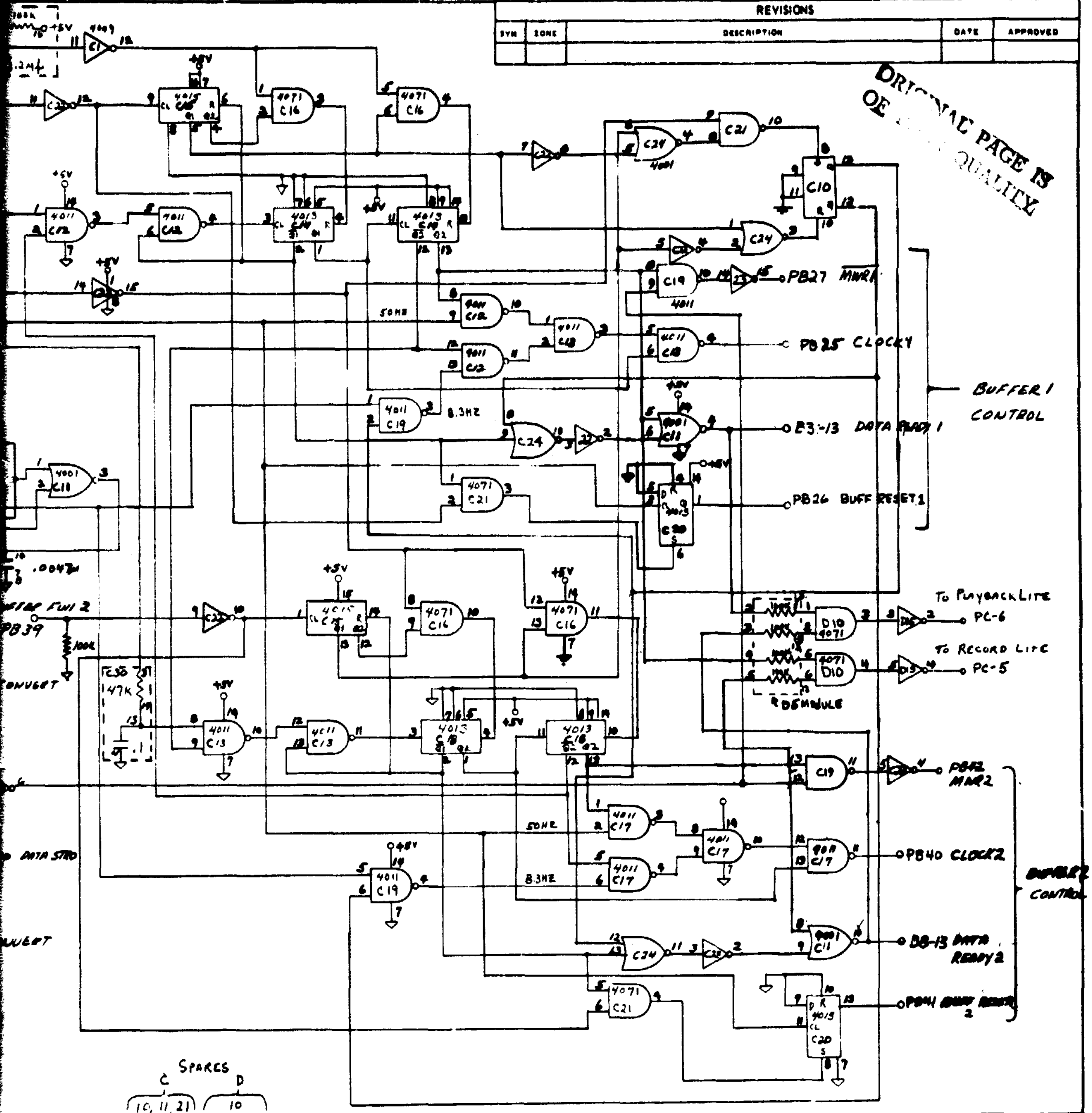

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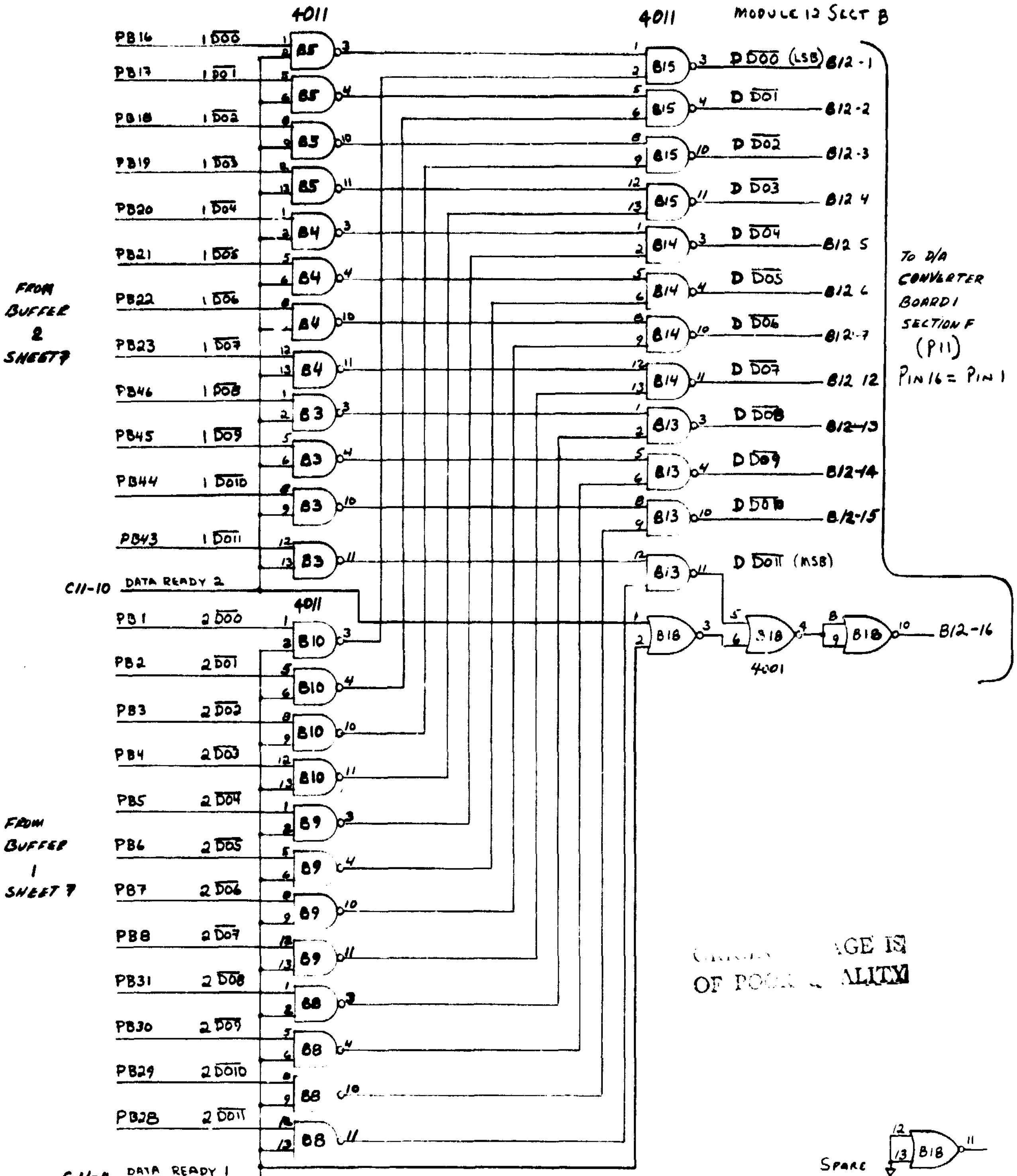

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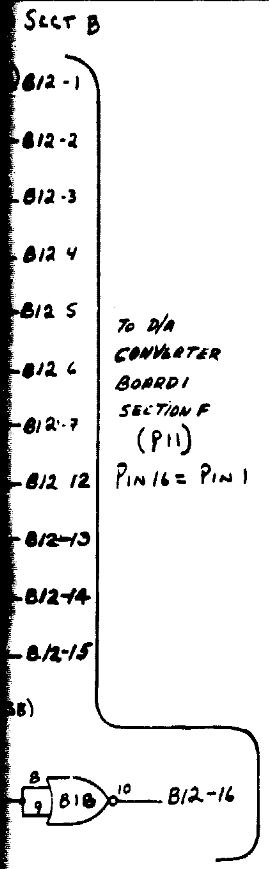

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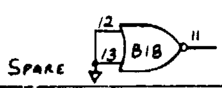

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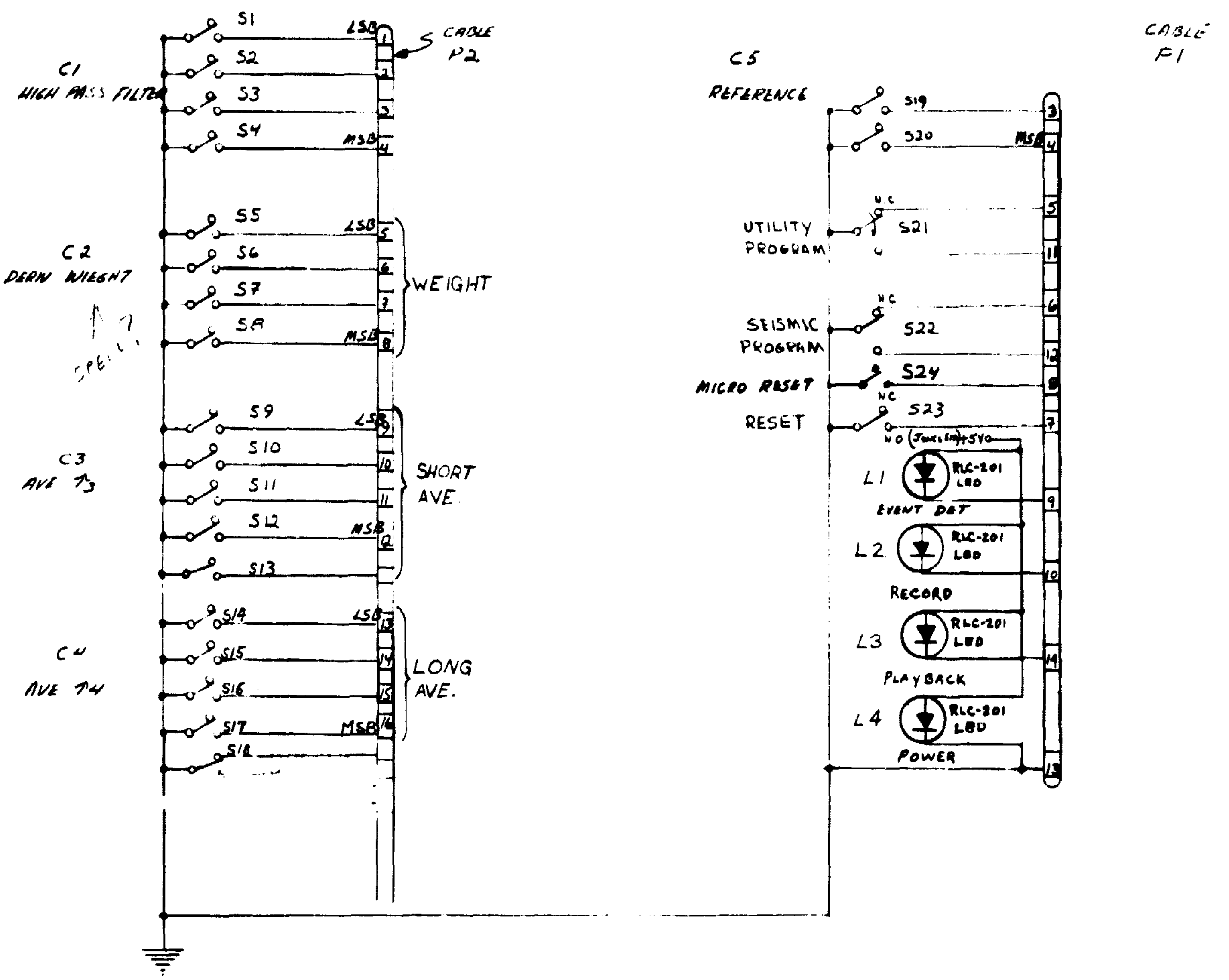

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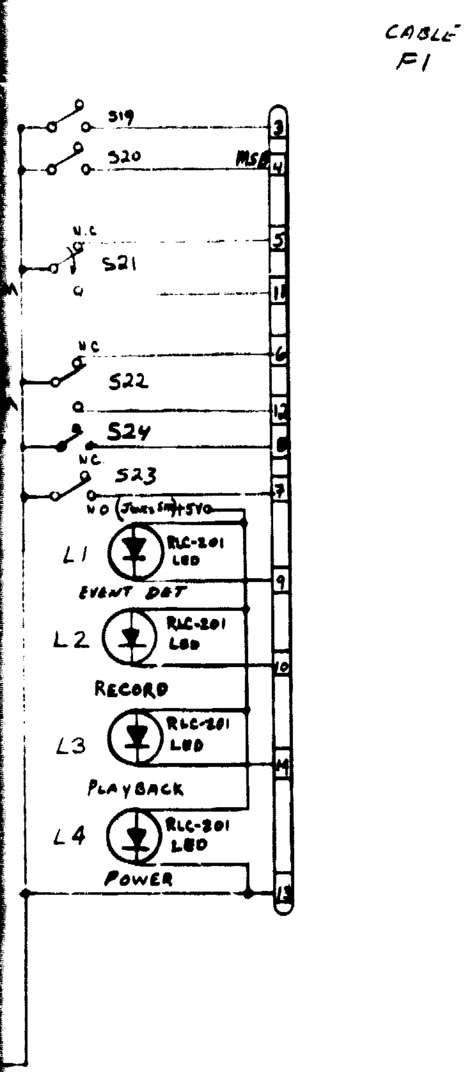

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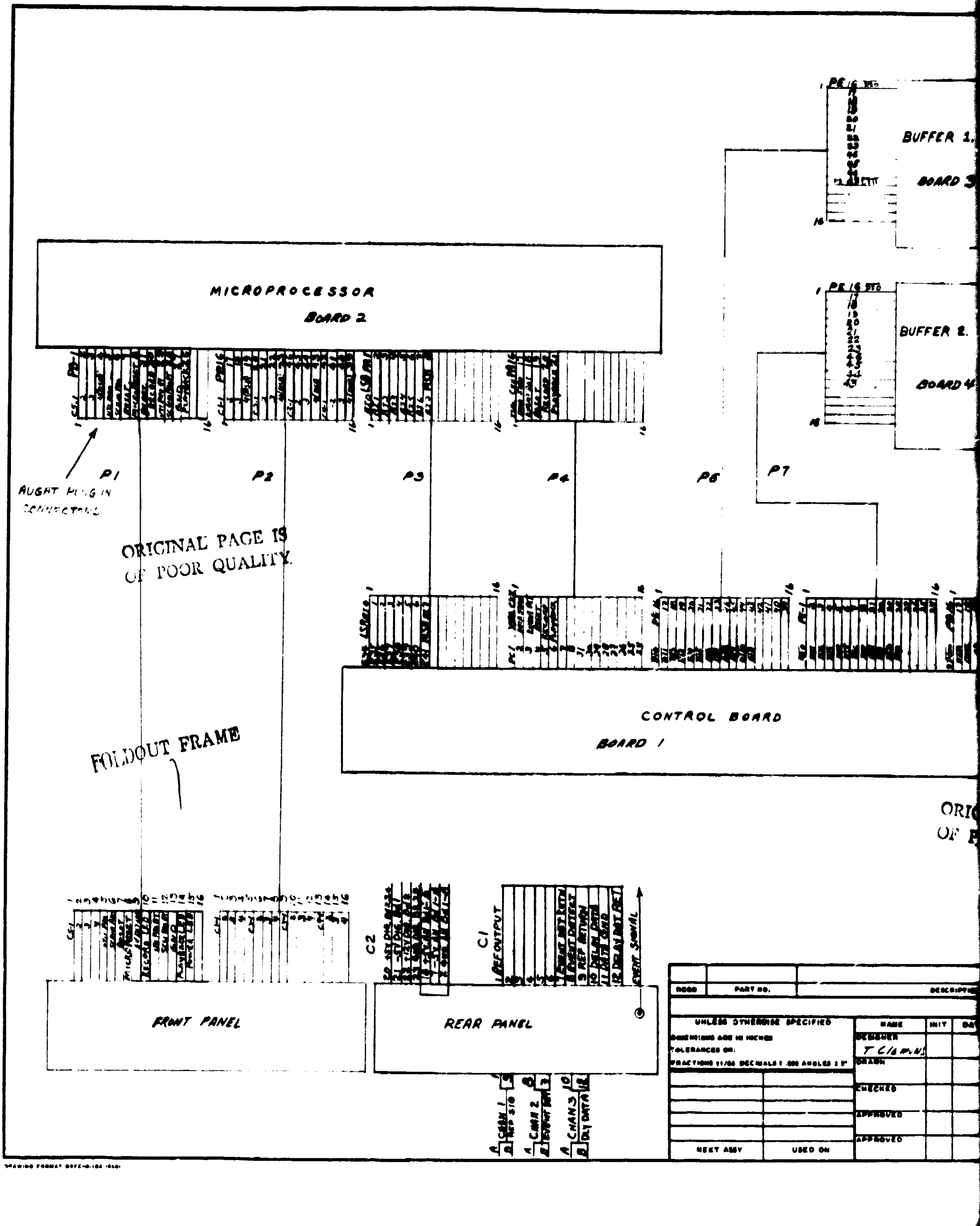
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BOARD 3
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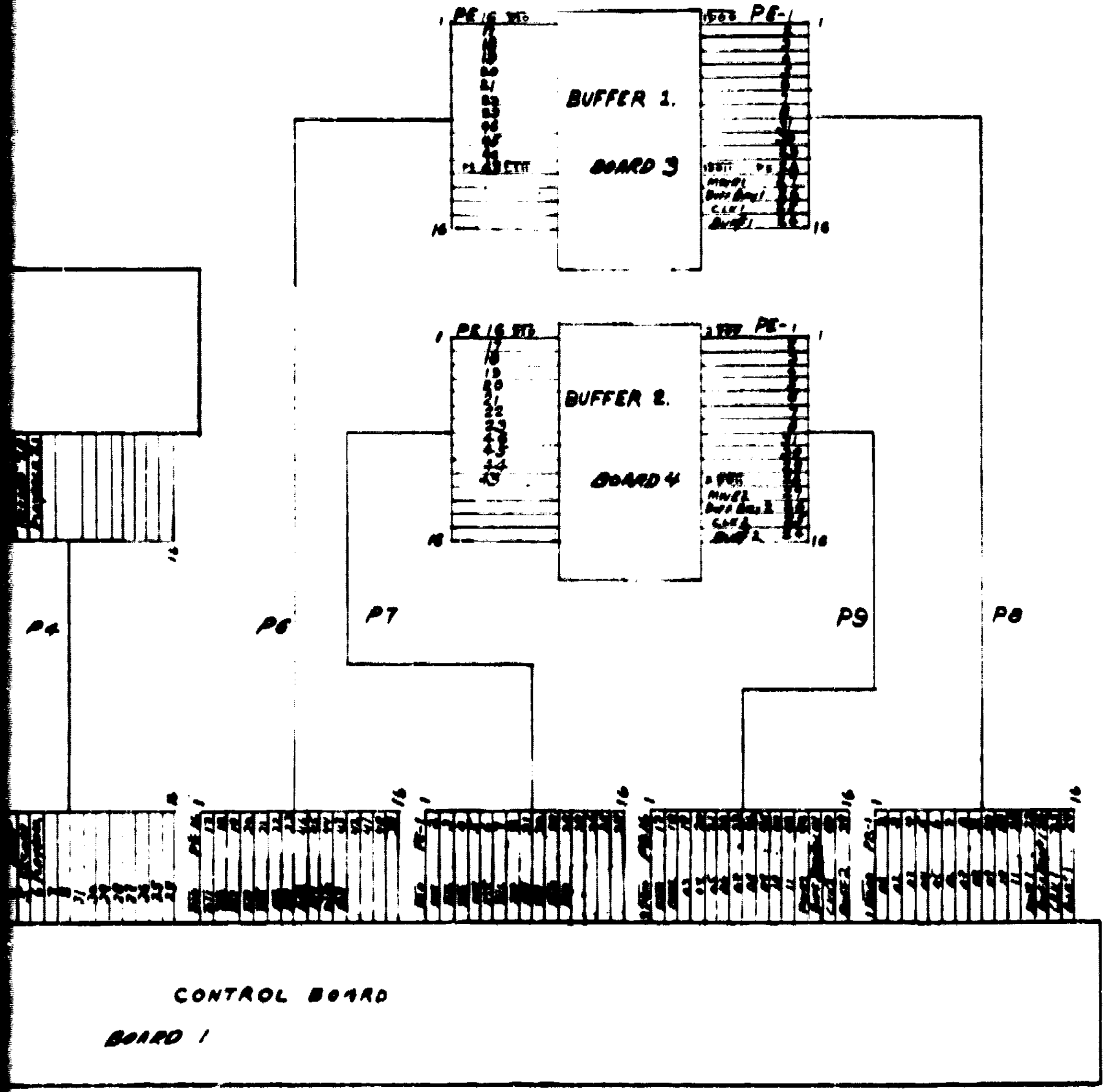

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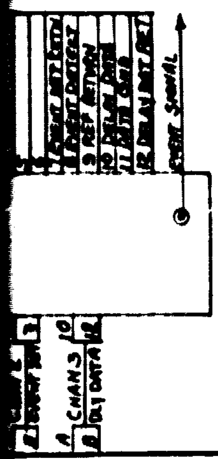

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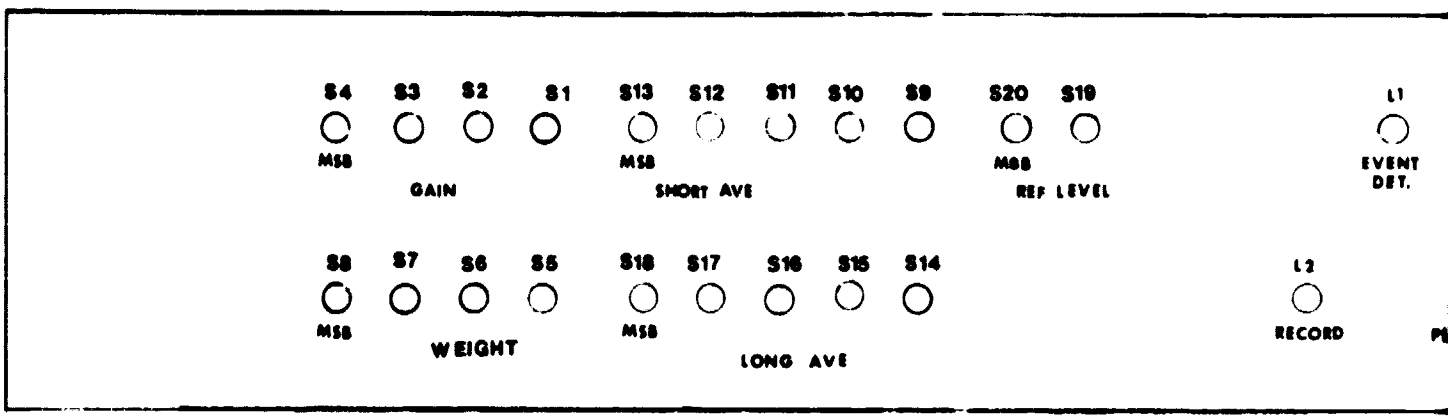

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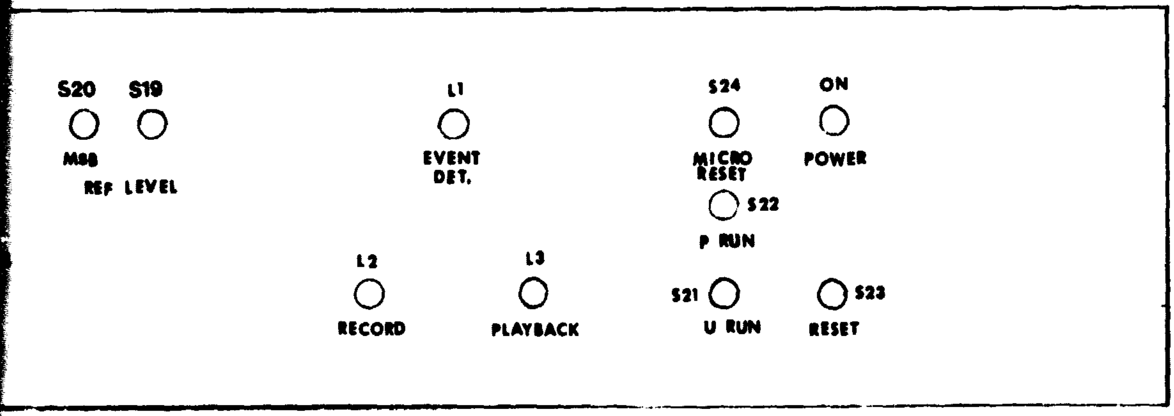

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		6. Performing Organization Code
7. Author(s) W. J. Webster, Jr., W. H. Miller, R. Whitley, R. J. Allenby and R. T. Dennison		8. Performing Organization Report No.
9. Performing Organization Name and Address Geophysics Branch, Code 922 Goddard Space Flight Center Greenbelt, Maryland 20771		10. Work Unit No.
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		13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address NASA/Goddard Space Flight Center Greenbelt, Maryland 20771		
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15. Supplementary Notes		

16. Abstract

A seismic signal processor has been developed and tested for use with the NOAA-GOES satellite data collection system. Performance tests on recorded, as well as real time, short period signals indicate that the event recognition technique used (formulated by Rex Allen) is nearly perfect in its rejection of cultural signals and that data can be acquired in many swarm situations with the use of solid state buffer memories. Detailed circuit diagrams are provided. The design of a complete field data collection platform is discussed and the employment of data collection platforms in seismic networks is reviewed.

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