UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

A Seismic Electronic System With Automatic Calibration and Crystal Reference

by

John A. Rogers

Sam Maslak

John C. Lahr

Open-File Report #80 -324

Menlo Park, California

1980

This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature. Any use of trade names and trademarks in this publication is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey

TABLE OF CONTENTS

TABLE OF APPENDICES

ILLUSTRATIONS

TABLES

ACKNOWLEDGMENTS

John Van Schaack, Jack Healy and Jerry Eaton have contributed substantially to the development of this electronics system by their many discussions of past and future instrumentation. In addition, William Wong helped in editing the parts lists and gathering data for the A1VCO performance graphs.

ABSTRACT

A low cost seismic field station with crystal reference and self calibration features has been designed and deployed by the U.S. Geological Survey in southern Alaska. The unit consists of an amplifier, calibrator and voltage controlled oscillator. Power consumption is less than 500 microamperes at 7 volts so long-term operation from batteries is possible. The crystal reference insures a stable frequency and calibration cycle, with each calibration containing information on gain settings, geophone parameters, overall system response, battery voltage and temperature. Various operational modes are selectable by means of jumper wires and rotary digital switches. An automatic gain ranging mode increases the normal system dynamic range of 40 dB by an additional 20 dB. The unit is packaged in a water-tight box which allows operation in wet climates. Output is an analog modulated FM carrier suitable for transmission over phone circuits or radio.

INTRODUCTION

The desire to monitor seismic activity in southern Alaska for the purpose of earthquake hazard evaluation led the Office of Earthquake Studies to establish the Southern Alaskan Seismic Network. The geographical extent of this network is from Cook Inlet to Yakutat, extending from the coast to as much as 200 km inland as indicated in the station map of Appendix 9. The electronic equipment used in California by the U.S.G.S. (model J202 VCO-Preamplifier) was originally installed in Alaska without modification. This equipment, however, did not operate well under Alaska's severe weather conditions. Instead of attempting to modify these electronics, it was decided to redesign the unit completely so that several new features could be incorporated, in addition to eliminating the electronic problems which had hampered earthquake analysis in the past.

Data from each seismic station are transmitted over analog phone circuits using FM modulation of audio carriers. Eight channels are frequency multiplexed onto a single 3000 Hz phone line so frequency stability of the carriers is important. Adequate stability is difficult to obtain in the midst of large temperature fluctuations when the carrier frequency is generated by an unstabilized R-C oscillator. With previous VCO designs drifts of tens of Hertz was common and even with compensation, the drift problem remained unsolved. The new voltage controlled oscillator electronics (A1VCO)1 deployed during the summer of 1978 uses a crystal reference to obtain a stable frequency. Since crystal oscillators are not very sensitive to supply voltage variation, operation from ultra stable but very expensive batteries is no longer necessary. In addition, the A1VCO uses digital techniques to synthesize and shape the carrier wave form; this eliminates lengthy tuning procedures as well as allowing for easy selection of channels.

An automatic calibration cycle periodically transmits station information in place of the normal seismic signal. This information includes geophone response, system (geophone and amplifier combined) response, gain setting, station identification, temperature, reference voltage (see below) and battery voltage. The system has a gain range feature which allows signals ten times larger than normal to be transmitted on scale. An indication of whether the system is in gain range is also part of the calibration.

A detailed description of system operation is provided in the next section. The three sections following it contain circuit level descriptions of the electronics of the three printed circuit boards. The Appendices at the report's end contain information of a very detailed nature which, if presented in the text, would probably risk obscuring the main features of operation. It is for this reason that they are included at the end. Appendices 10-14 contain parts lists for all boards and hardware, while Appendix 8 gives the test procedure used in screening the A1VCO, with Appendix 15 containing pinout information.

The time span from conceptualization of the VCO through actual deployment in Alaska was about 3 years. Initially John Lahr and Sam Maslak came up with a list of operational features and specifications they considered desirable in a new VCO. Sam Maslak then designed a unit which met these specifications and produced a prototype. The special test equipment (except for the discriminator) used in evaluating the prototype was designed by John Rogers. The tests of the prototype resulted in several design changes which were incorporated in the production runs.* In addition to these modifications, other features are currently being considered. For example, John Rogers designed an EPROM-based calibrator board which will be introduced in place of the present hardwired calibrator. Also a fourth printed circuit card which would automatically switch sensors is being designed. For example, at those sites where a strong motion event recorder is present, an event of sufficient magnitude could be used to transmit data from the strong motion accelerometer instead of the geophone which is normally transmitted. These features may be incorporated in 1980, at least in a portion of the network.

*Cost estimates from the 1980 production run are given in Appendix 18.

OPERATION

The A1VCO consists of three printed circuit boards with a fourth slot available for future multi-channel applications. The three cards now in service are the preamplifier, calibrator and voltage controlled oscillator (VCO).

Power

The A1VCO requires a single-voltage power source of 6 - 8.5 volts. The unit generates its own centered ground so only 2 wires for power are needed. The ground wire (zero volts) is an output and may be used externally for a reference. Current drain varies directly with frequency and supply voltage. Typically, the unit will draw less than 600 microamperes at 7.2 volts and 3060 Hz center frequency. High current diodes provide some degree of protection to the circuitry against reverse polarity connections.

Sensory Input

The intended input source is from a seismometer with a 5500 ohm coil resistance and 1 Hz natural frequency. The seismometer is connected to a differential low noise input stage with a 9.28 KΩ impedance for 0.7 of critical damping. This differential input also provides about 60 dB common mode noise rejection. For additional noise immunity the input signal shield can be connected to system ground. The frequency response of the system is from 0.1 Hz to 30 Hz at which points the amplitude is down 3dB from its amplitude at 5 Hz.

Audio Output

The output is a digitally synthesized sine wave whose frequency is selectable by means of a digital rotary switch on the VCO board. Frequencies from 340 Hz to 5100 Hz in steps of 340 Hertz can be obtained, but only the lowest 9 channels (340 Hz-3060 Hz) are suitable for transmission on phone circuits and most radios used by the USGS.

Normally this output (4 volts peak-to-peak, fixed) is not suited for direct connection to phone lines without a resistive divider or active summing-attenuation network. The circuit diagram of a low power summing amplifier attenuator currently in use in Alaska is given in Appendix 6.

The amplitude spectrum of the signal output has been optimized via Fourier analysis techniques for minimum harmonic distortion. All harmonics inside the passband of phone circuits or radios are down at least 60 dB from the fundamental. The Fourier and experimental results of the spectral analysis are given in Appendix 1.

Calibration

The A1VCO calibrator produces a complete system calibration every 24 or 12 hours. The interval between calibrations is selectable by means of a jumper wire on the calibrator card. The calibration lasts about 144 seconds during which time the sequence of events as shown in Figure 1 occurs. Figure 1 is an actual calibration of the station Harlequin (HQN) located about 25 miles east of Yakutat, Alaska. The station has a VHF radio which transmits to a receiver located in Yakutat. The signal is transmitted via satellite to the Tsunami Warning Center in Palmer, Alaska, where it is recorded on magnetic tape. The tape was digitized on the Data General Eclipse computer at Menlo Park, California using ISDS (unpublished computer program, P. R. Stevenson) and then written onto a digital tape. The digital tape was written to a file on the USGS Multics computer and plotted (using Geolab Manual; J. Herriot; P. Ward, Preprint). These plots, along with explanations, comprise Figure 1. Table 1 annotates this calibration sequence. Also, since the calibration starts at t = 28 seconds, the table can be used to locate the various portions of the calibration cycle in the figure.

The calibration consists of two parts: chopped and unchopped. Chopping is a periodic 180o phase reversal of the input signal. Chopping is necessary to pass low frequency or d.c. signals.

The first 24 seconds of each calibration is the reference voltage chopped at 21 Hz. Later in the calibration cycle the same signal is chopped at 5.3 Hz. Because the 21 Hz signal is nearer the high frequency cut off of the system response, its amplitude is attenuated compared to the 5.3 Hz signal. The amplitudes of these two signals provide two points on the frequency response curve of the A1VCO system. This reference voltage (stable to 1 mv) also is used to calculate parameters such as deviation sensitivity, temperature and battery level.

The next 12 seconds consists of the chopped calibration bits. The 180o phase change which occurs when a calibration bit goes from logic level "0" to "1" (or vice versa) indicates the changes in logic levels.

The first four bits of the calibration code are hard wired to a set code (0011) to allow for syncronization with the timing of the entire bit stream. The next three bits indicate the system gain setting. A gain range bit follows which is high only if the system is in gain range at the time of calibration. The remaining 8 bits give the station (identification) ID expressed in two hexidecimal digits (0-F).

The next six seconds are chopped ground voltage. This portion allows determination of the system (nonseismic) noise level, since ideally this signal would be zero if no noise other than seismic were present. The amplitude of the signal indicates how much nonseismic noise is present in the actual data.

For the next 9 seconds the reference, battery and temperature indicator voltages respectively are chopped. The chopped battery voltage signal can be used to monitor battery life. The temperature signal (see section on "Preamplifier") is derived from the preamplifier board. It follows the relation:

$$V_{Temp} = \frac{138mV}{300°K} \times Temp\ (°K)$$

During the next 15 seconds the chopped geophone response is looked at. First, for three seconds the geophone signal at minimum gain is passed through the system. At the three-second point a positive step of approximately 1 microampere is fed into the geophone. The magnitude of this current step is determined by resistors on the preamplifier board and by the battery voltage. This current step displaces the geophone mass, causing a response which allows

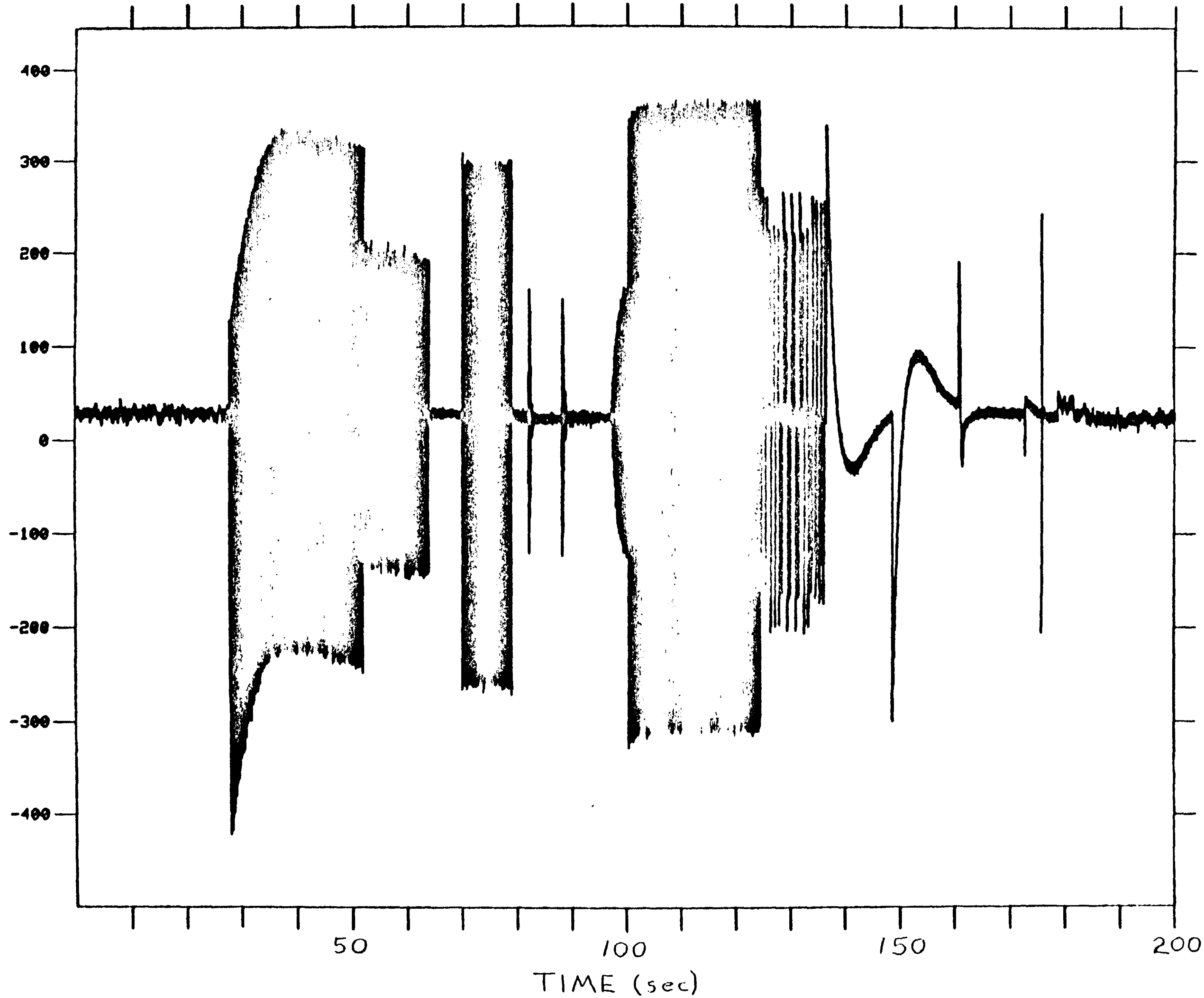


Fig. 1a A1VCO Calibration

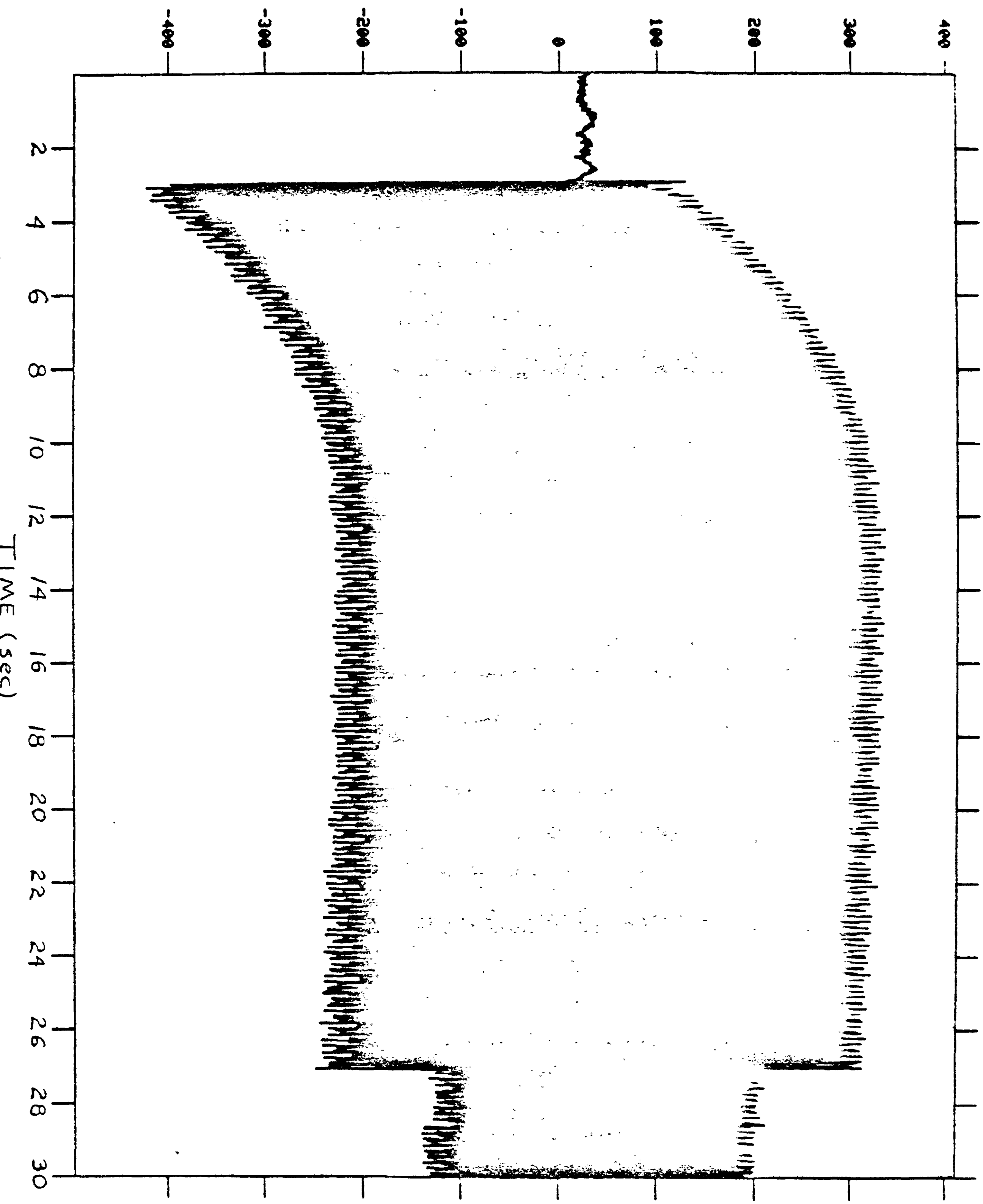


Fig. 1b Chopped reference

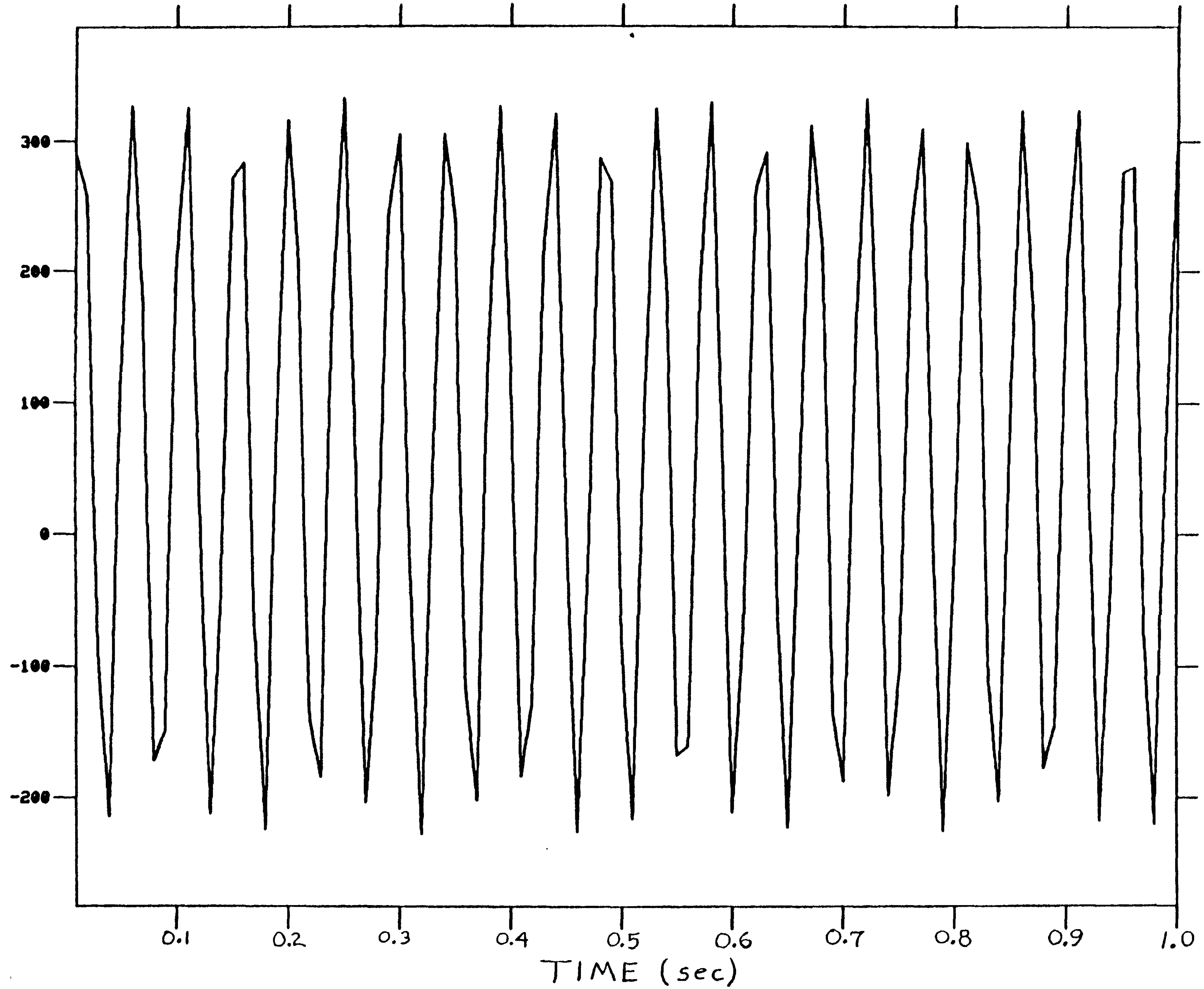


Fig. 1c Chopped reference

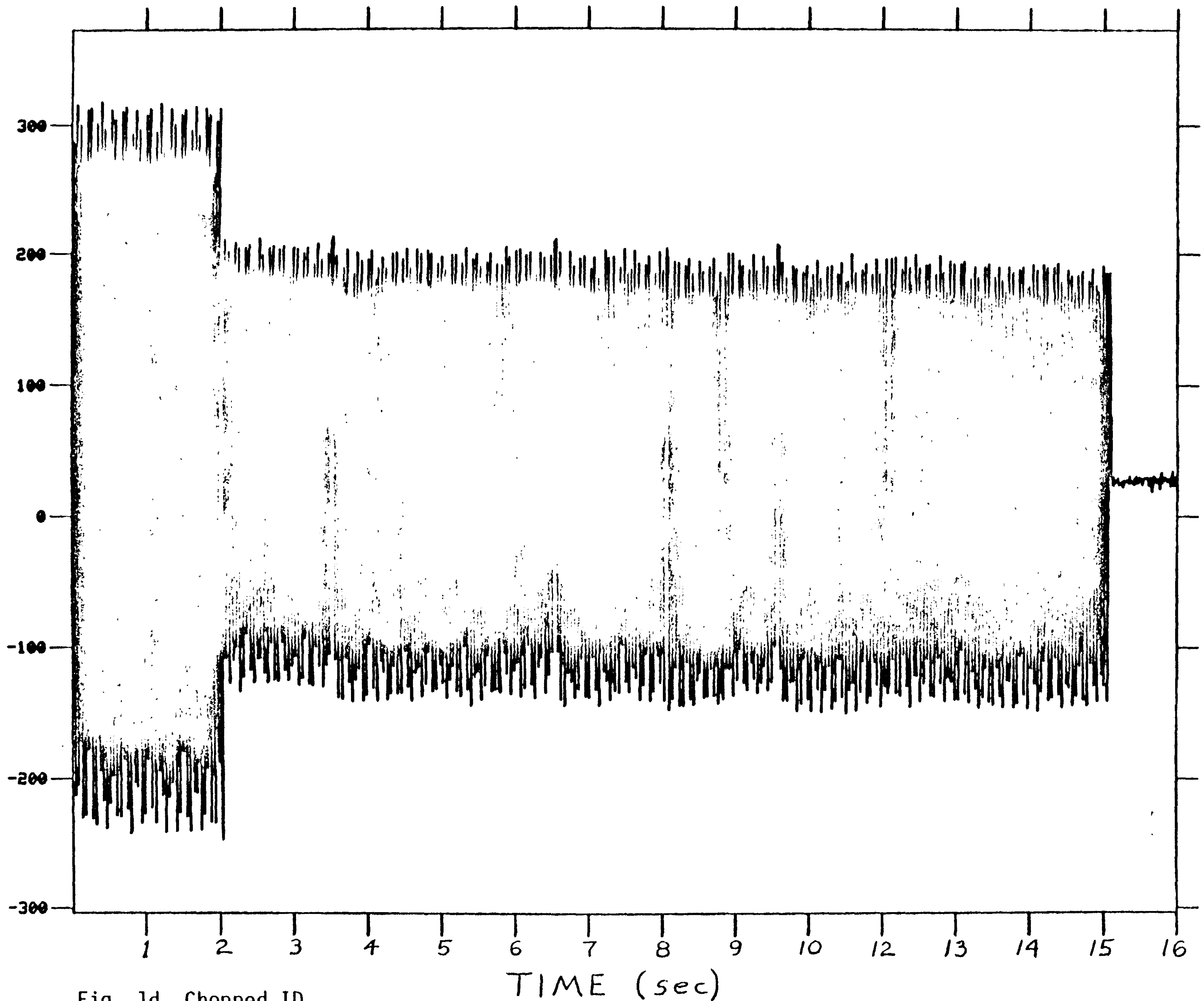


Fig. 1d Chopped ID

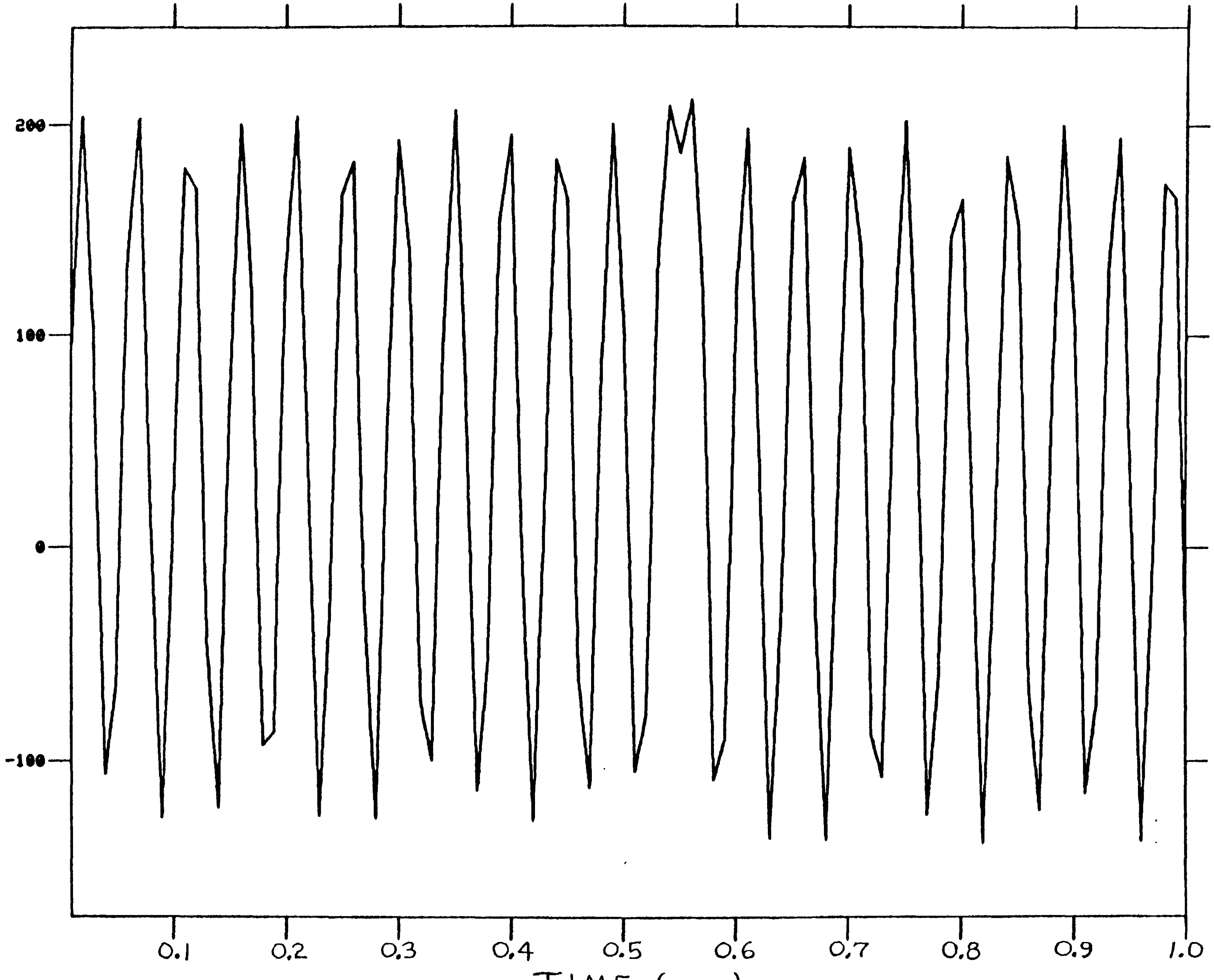


Fig. 1e Chopped ID

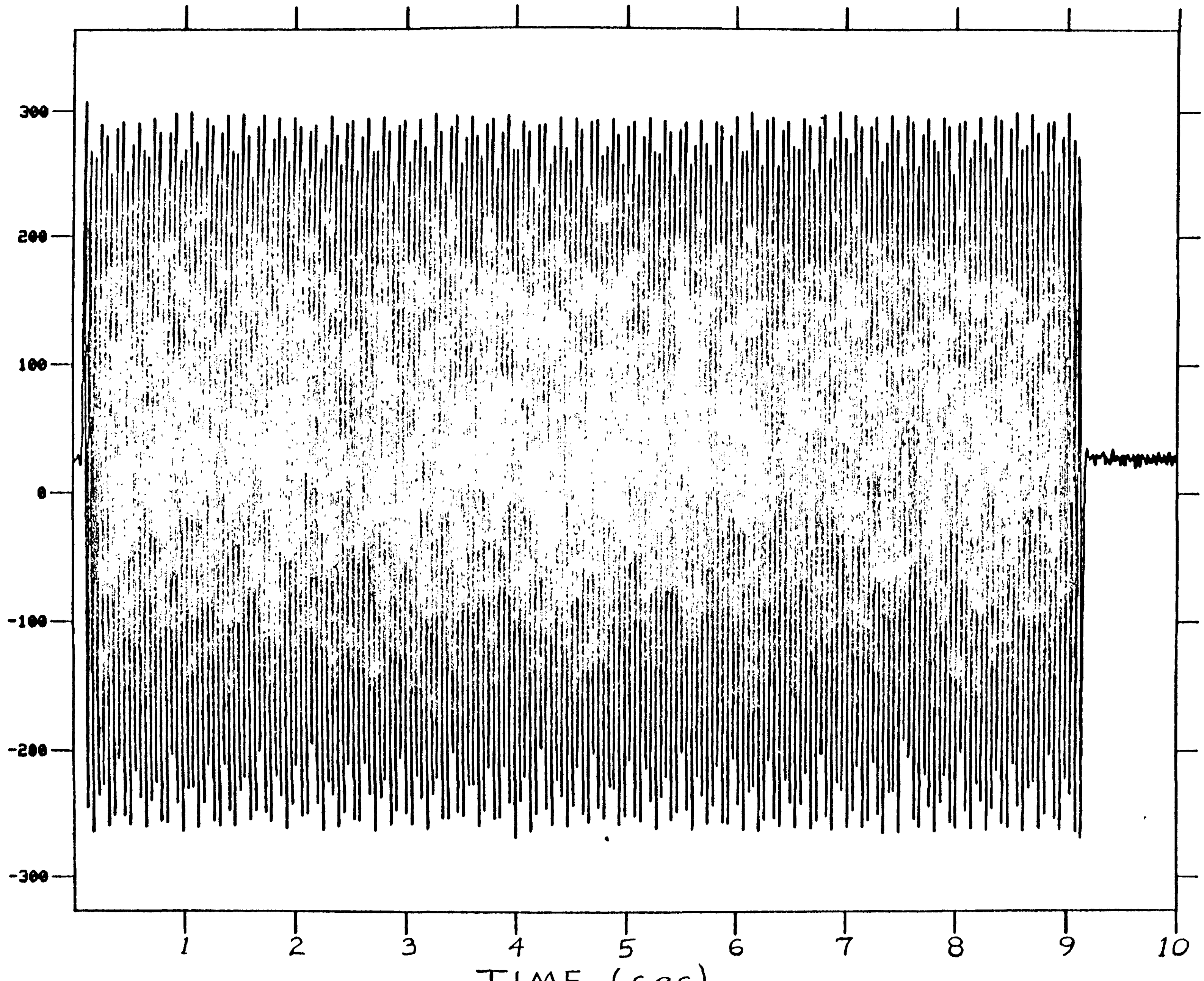


Fig. 1f Chopped Voltages

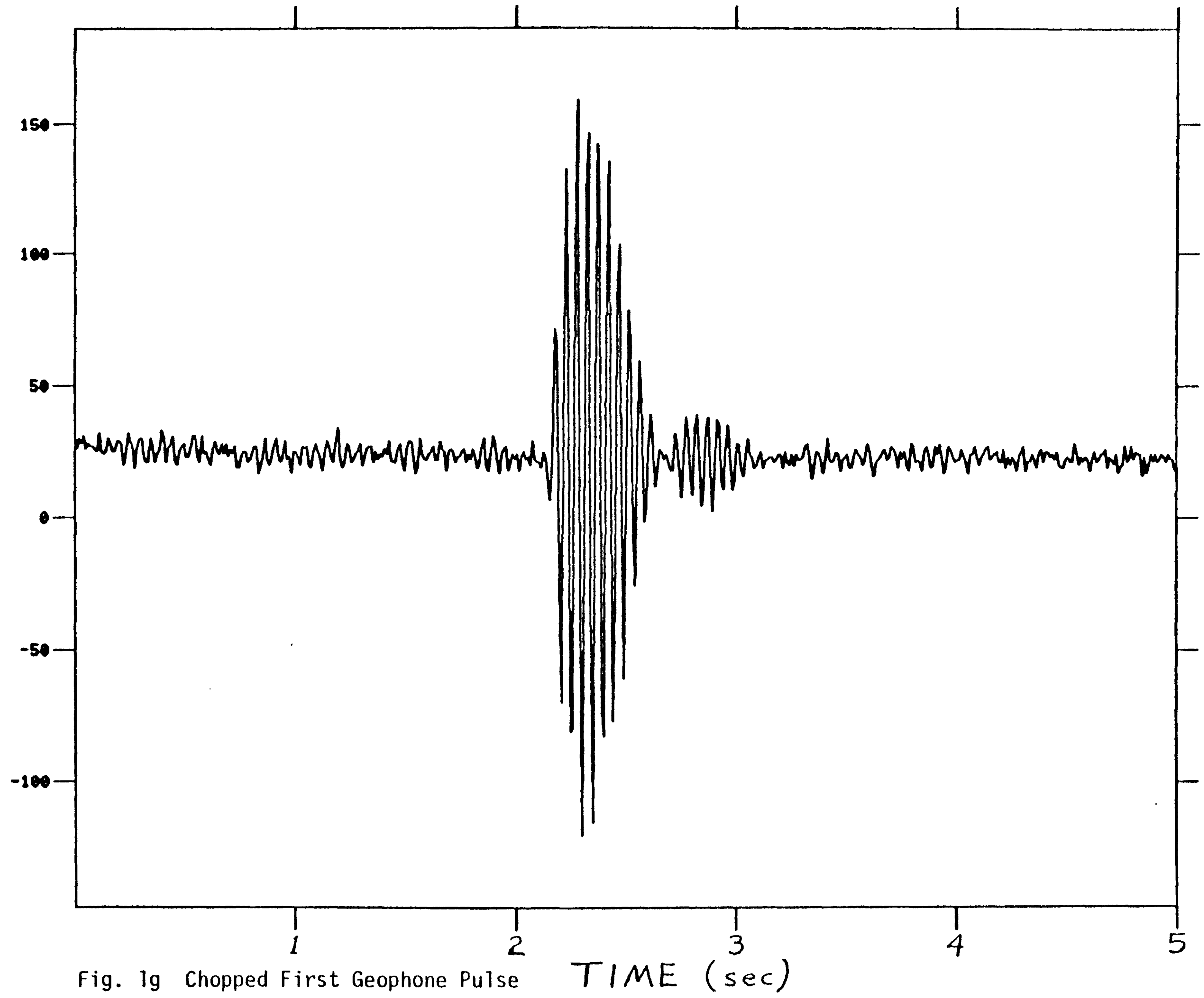


Fig. 1g Chopped First Geophone Pulse

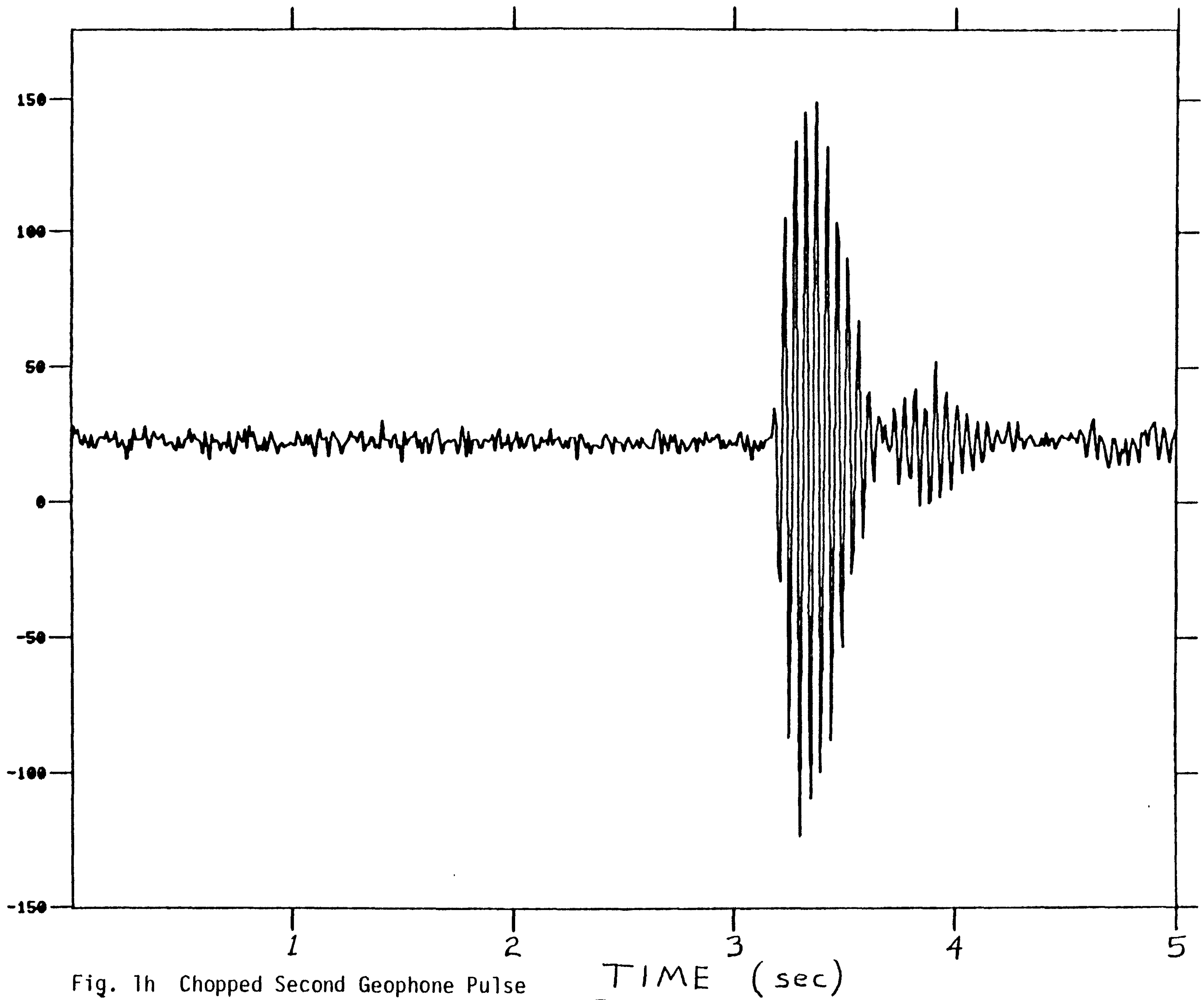


Fig. 1h Chopped Second Geophone Pulse

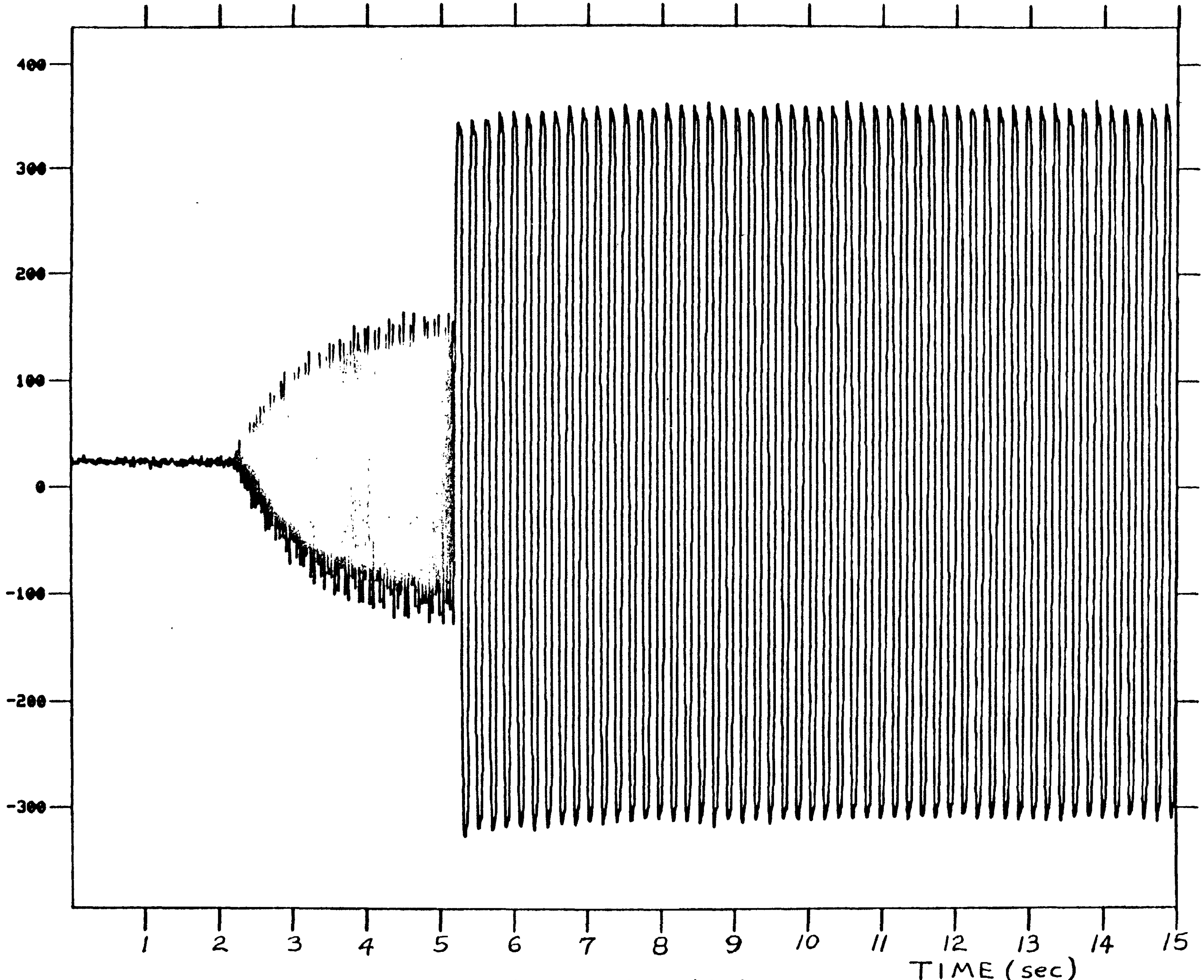


Fig. 1i Chopped Auxiliary Inputs and 5.3 Hz Chopped Reference

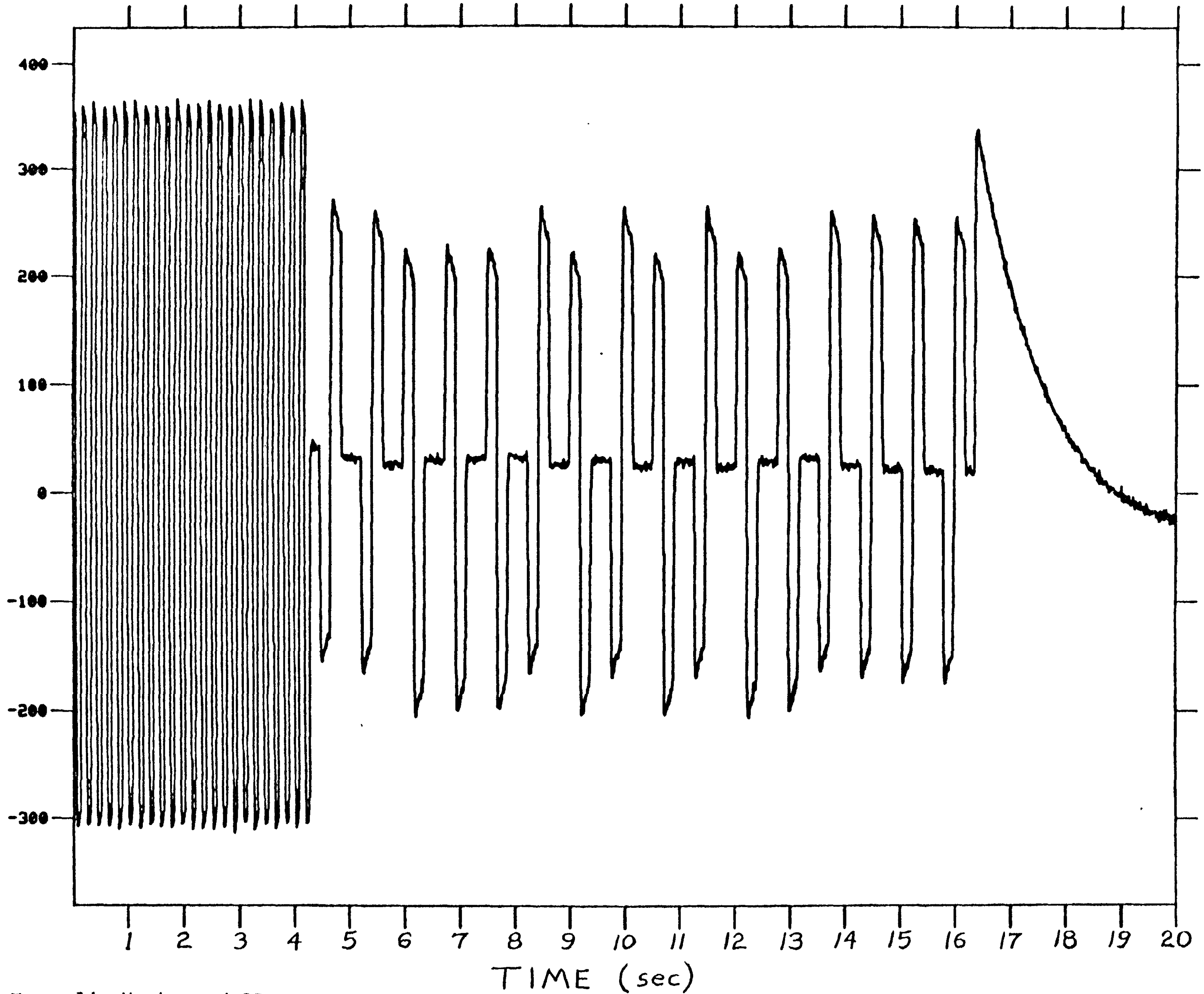


Fig. 1j Unchopped ID

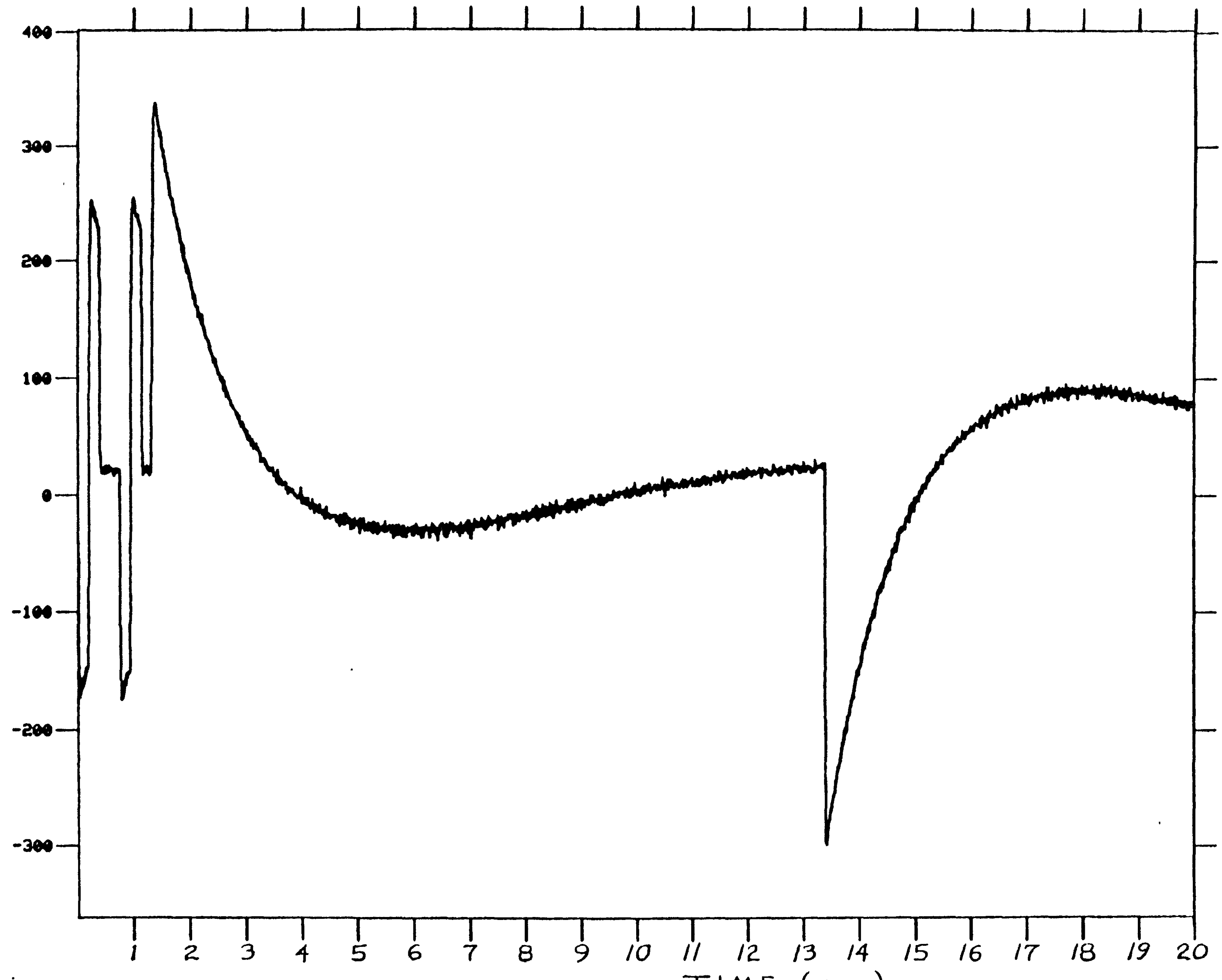


Fig. 1k Positive Amplifier Reference Step

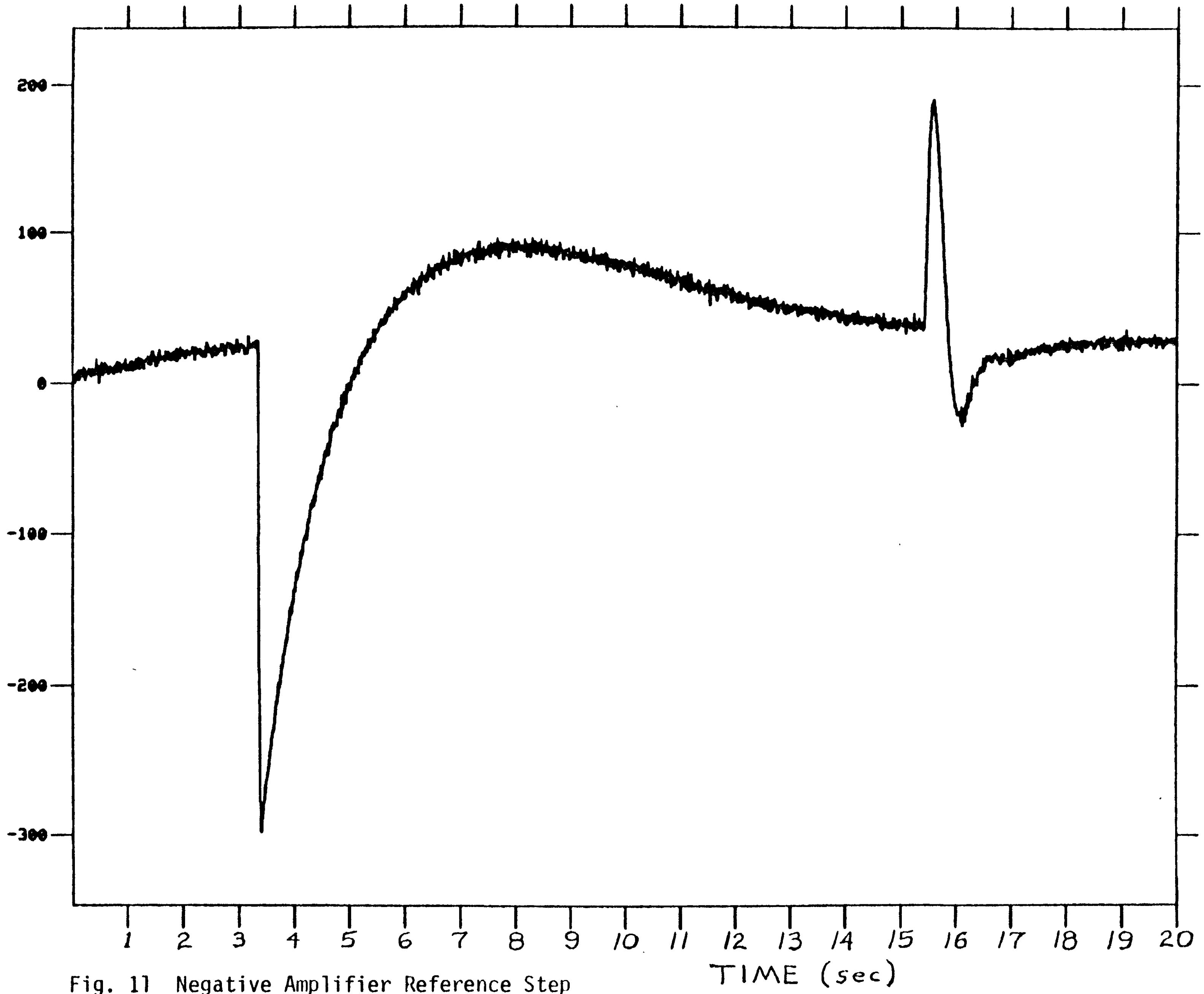


Fig. 11 Negative Amplifier Reference Step

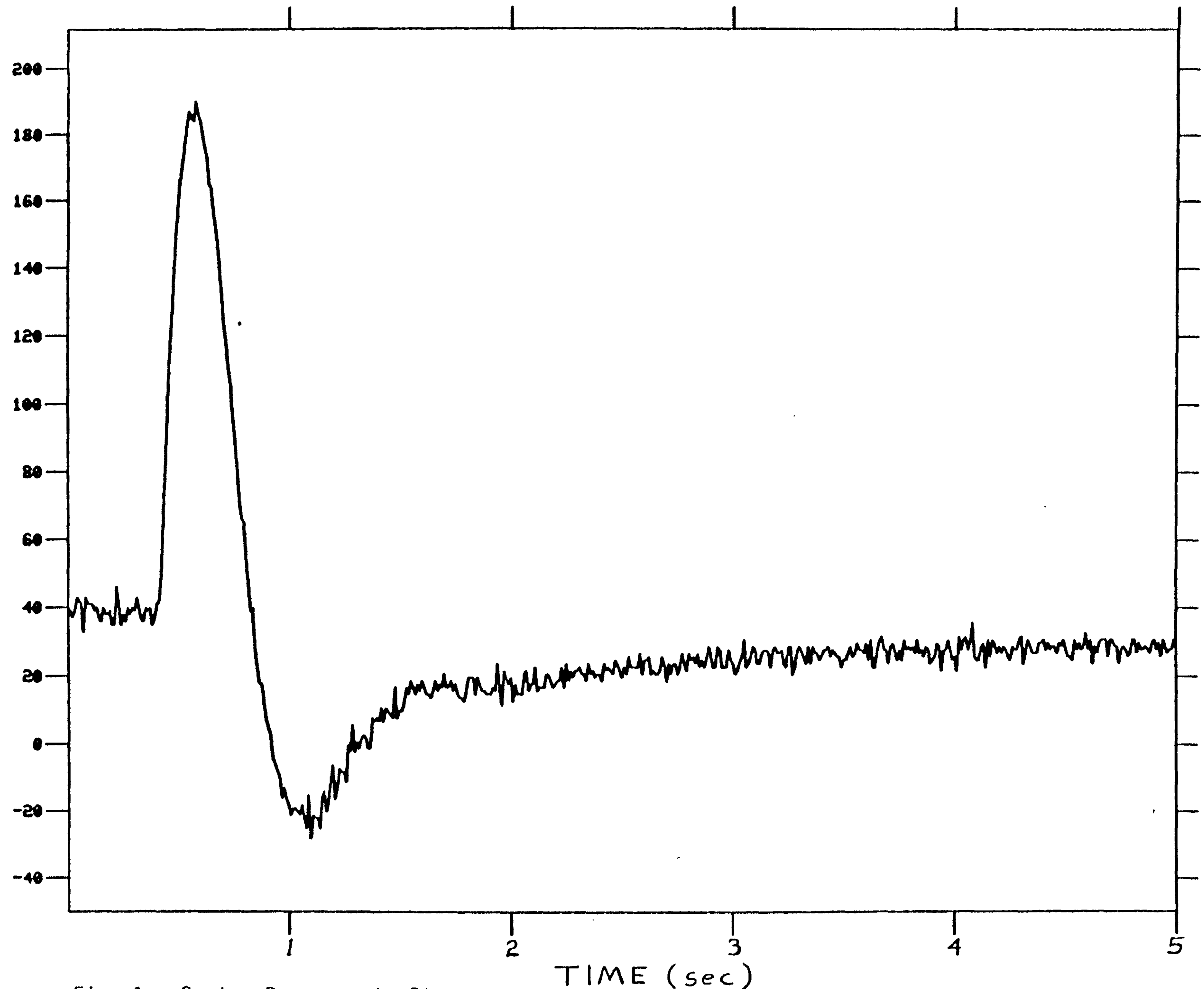


Fig. 1m System Response to Step

CALIBRATION EVENT SEQUENCE

Event	Start (m/sec)	End (m/sec)
	21.25 Hz Chopped Portion	
Reference	0	24094
ID	24094	36141
Ground	36141	42165
Reference	42165	451776
Battery	45176	48188
Temperature	48188	51200
Geophone	51200	66259
Geophone + step	54212	--
Geophone - step	60235	--
Auxiliary Input H	66259	69270
Auxiliary Input L	69270	72282
	5.31 Hz Chopped Portion	
Reference	72282	96376
	Unchopped Portion	
ID	96376	108423
Reference	108423	120470
Ground	120470	132517
Geophone	132517	144564
Geophone-step	132517	

Table 1

Calibration Event Sequence

calculation of geophone parameters, such as natural frequency, damping and motor constant. After six seconds the step of current is removed, causing a similar signal, but of revised polarity as the geophone mass returns to rest. Finally during the last 6 seconds of the 21 Hz chopped phase, two auxiliary inputs are run through the system. A fourth card slot is provided to interface and select any of six input sensors to be part of this section of the calibration cycle if multi-channel operation is desired. Of course, since calibrations occur only once or twice per day, only very low frequency data can be meaningfully transmitted.

After 24 seconds of reference chopped at 5.3 Hz, the calibration cycle enters the unchopped phase. First the ID signal is generated. This contains the same information as the chopped ID but uses a bipolar return-to-zero* format so the 16 bits can be easily read. Next, the amplifier response is examined by applying positive step of reference voltage and subsequently a negative step back to ground.

Finally, a one microampere positive step of current is applied to the geophone and then removed after six seconds. This current is identical to that introduced during the chopped mode. This portion gives the overall system response to a step in acceleration. After 6 more seconds the calibration cycle is terminated and the gain is restored to its original value.

* A return to zero code format precedes each bit with a zero volt signal.

A1VCO-202 VCO Gain and Sensitivity

Specification

A1VCO Specifications

AMPLIFIER

Minimum Gain: 344

Sensitivity: ±8 mV input for ±2.75 Volt output

Maximum Gain: 44000

Sensitivity: ±62.5 μV input for ±2.75 Volt output

VOLTAGE CONTROLLED OSCILLATOR

Sensitivity: 45.5 Hz/Volt* (nominal)

AMPLIFIER - VCO

Minimum Sensitivity: ±8 mV input for ± 125 Hz output

Maximum Sensitivity: ±62.5 μV input for ± 125 Hz output

Sensitivity at any Gain Setting: $2^{(G-6)}$ MHz/Volt

TEST DISCRIMINATOR

± 125 Hz input for ±10 Volt output

TEST DISCRIMINATOR - VCO

3.636 V output for each 1 V input to VCO

TEST DISC-VCO-AMPLIFIER

Minimum 1,250 volts per volt

* VCO sensitivity changes with battery voltage and center frequency. See Appendix 15 for experimental results.

J202 VCO SPECIFICATIONS

Voltage Controlled Oscillator

Sensitivity: 36.9 Hz/Volt

TABLE 2

A1VCO-202VCO Specifications

Signal Amplification and Dynamic Range

The dynamic range of the A1VCO at maximum gain is about 62 dB with gain ranging and 42 dB without. This represents a worst case noise figure referred to the input (at maximum gain) of 1 μV with a full scale input signal (at maximum gain) of 125 μV. The gain is selectable via a rotary digital switch; there are seven switch positions, each increasing the gain by 6dB (i.e., by a factor of two) from switch position "0", the minimum gain position.

Table 2 contains information on the gain specifications and system sensitivity for the A1VCO, and additionally for the older, but still operational J202 VCO. The discriminator mentioned in this table was built as a calibration standard for the A1VCO's.

The system gain is currently set in the field after noting the background seismic noise. This setting can vary widely from site to site due to differences in the seismic background. Weather also can affect gain setting, as wind and waves impart substantial vibrations into the ground. Field personnel currently set the gain in such a way that about 2-3 Hz of deviation on the FM modulated carrier is produced.

The A1VCO also provides a gain range feature so that larger events can be recorded without clipping. Gain range reduces the amplifier gain by a factor of 10 within one millisecond after the input signal exceeds a threshold level. This threshold level is twice the signal level required for clipping. Hysteresis is applied so the system remains gain-ranged until the seismic signal falls below the chip level. Hysteresis prevents excessive switching into and out of gain range. Table 3 shows an example of a gain range sequence for a gain setting of 0. Notice that the signal clips until the gain range threshold of 32 mV is reached, at which point the gain is reduced by a factor of 10 and the amplifier is once again in its linear region.

When the system goes into gain range a pulse is produced 3.01 seconds later. This pulse lasts about 200 msec during which time the seismic data is interrupted. This pulse has the same polarity as the signal which caused gain ranging. Jumper J2 on the Preamp board allows the disabling of the pulse while J1 disables both the pulse and gain range feature. Figure 2 illustrates how data is affected by this pulse and also displays the polarity feature.

Input Signal (mV peak-to-peak	Pre-amp Output (volts peak-to-peak	Gain Range
160	5.5	1
16	5.5	0
31	Clipped	0
35	1.2	1
18	0.65	1
16	5.5	0

Time increases in the downward direction. Initially the system is in GR (GR = 1) with the input at 160 mV p-p. The threshold in this direction is 16 mV p-p. As the signal increases again, the other threshold is reached (32 mV p-p). Any signal between 16 and 32 mV p-p is clipped. For each additional 6dB of gain, the thresholds are reduced by 6dB.

Table 3

Input Signal Sequence to Demonstrate

Gain Range Thresholds (G = 0)

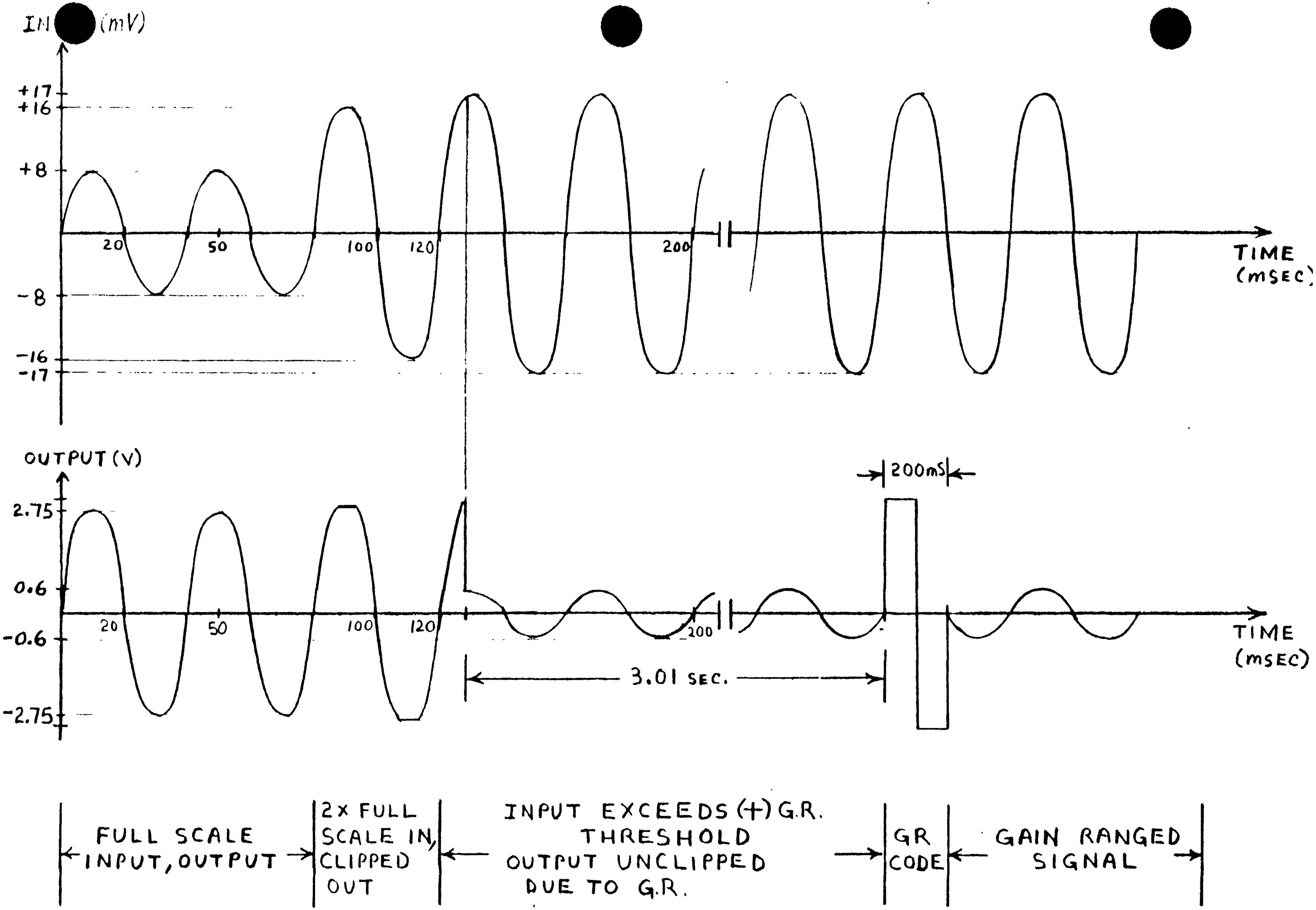


FIG 2a
WAVEFORMS DEMONSTRATING GAIN RANGE AND GAIN RANGE CODE FOR POSITIVE EXCURSION (G=0)

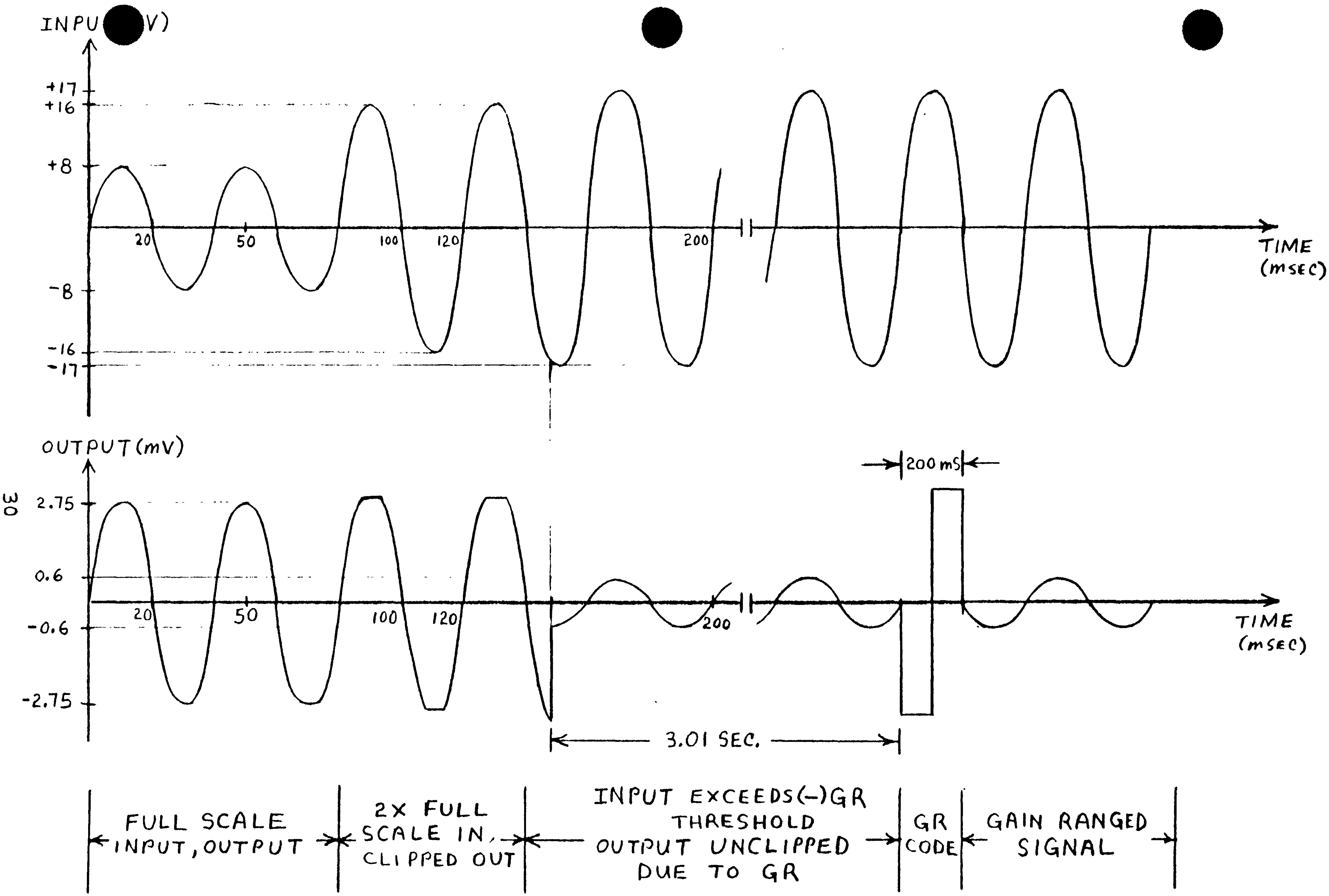


FIG 2b
WAVEFORMS DEMONSTRATNG GAIN RANGE AND GAIN RANGE CODE FOR NEGATIVE EXCURSION (G=0)

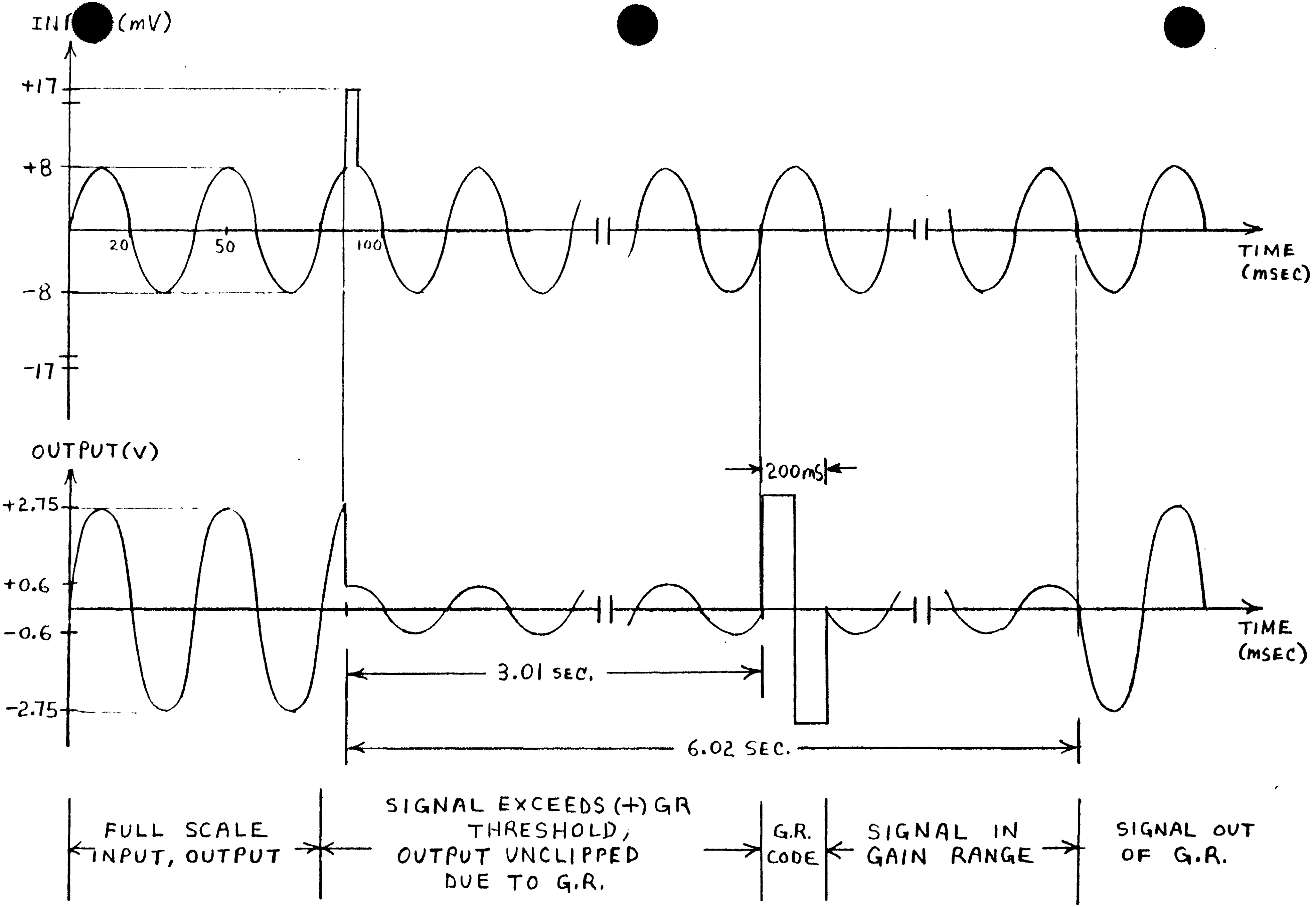


FIG 2C
WAVEFORMS DEMONSTRATING MINIMUM GAIN RANGE TIME

CALIBRATOR ELECTRONICS

The calibrator board is all digital using solely CMOS integrated circuit (IC) packages. Its two main functions are as a timer to initiate calibrations at proper intervals in time and as a sequencer to control the calibration cycle itself.

The circuit diagram of the hard-wired calibrater board is shown in Figure 3 with its timing diagram in Appendix 2. A later version of this circuit replaces a section of the board with a CMOS Erasable Programmable Read Only Memory (EPROM). This circuit is included in Appendix 4 with a brief description. The advantage of using the EPROM-based calibrator is that any portion of the calibration cycle can be changed merely by changing the data stored in memory. Four programs are stored in memory with program "0" producing the same calibration cycle as the hard-wired calibrator.

The operation of the hard-wired calibrator begins with an 85 Hz clock derived from the crystal oscillator on the VCO board which is input to two "D" type flip flops wired as dividers. Their output is input to a 12 stage binary counter, the outputs of which serve to sequence the calibration through its various states.

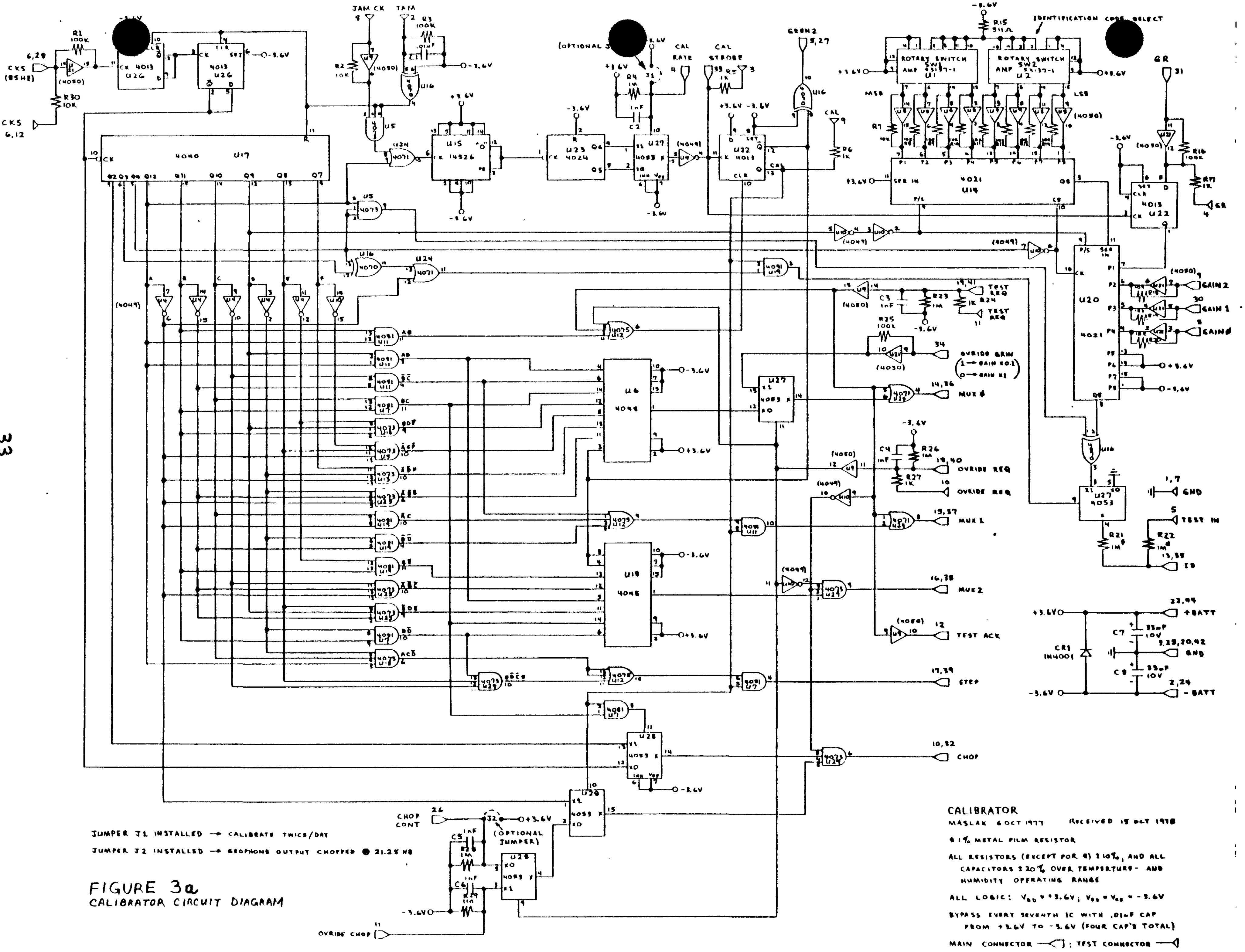
Continuing with the division of the clock signal, Q12 of U17 is input into a programmable divider wired for division by 7. U23 is another binary divider whose two outputs are fed to a CMOS switch. Jumper wire J1 determines which output is passed on to the calibration flip-flop (U22). The two outputs differ in frequency by a factor of two, thus calibrations can be made to occur every 12 hours when J1 is in place and every 24 hours otherwise. The accuracy of the time interval depends on the stability and accuracy of the crystal oscillator. For the type of crystal specified for Alaska, calibration intervals drift several tens of seconds per day, and no synchronization of calibrations between stations is attempted.

When enough pulses are accumulated in the counters discussed above, the output of U22 (Q) goes high, which initiates the calibration. This output, together with the sequence of states from U17 results in a sequence of MUX codes. This sequence (as can be seen in the timing diagram in Appendix 4) will produce the series of events described above under calibrator operation.

Note that latched digital information is present at the shift registers inputs (U14 and U20). The first four bits to be shifted out are hard wired for 0011. The next 3 bits are the gain code followed by a gain range bit which is latched at the time of calibration. The other 8 bits comprise an ID code which comes from the settings on two rotary hexidecimal switches on the calibrator board.

These calibration bits are clocked through twice during a calibration cycle. The second time through the control input on U27 (a CMOS switch) causes the interspersion of ground potential at the beginning of each clocked ID bit. This produces the Return-to-Zero code format described above. The timing diagram of this operation is shown in Appendix 2.

The calibrator board has several inputs from the fourth card which may be used in the future. The OVRIDE REQ line changes the MUX code to one of the two auxiliary inputs and also clears the calibration flip-flop if the system



JUMPER J1 INSTALLED → CALIBRATE TWICE/DAY

JUMPER J2 INSTALLED → GEOPHONE OUTPUT CHOPPED @ 21.25 HZ

FIGURE 3a
CALIBRATOR CIRCUIT DIAGRAM

CALIBRATOR

MASLAK 6 OCT 1977 RECEIVED 15 OCT 1978

* 1% METAL FILM RESISTOR

ALL RESISTORS (EXCEPT FOR *) ±10%, AND ALL CAPACITORS ±20% OVER TEMPERATURE- AND HUMIDITY OPERATING RANGE

ALL LOGIC: V_{DD} = +3.6V; V_{SS} = V_{EE} = -3.6V

BYPASS EVERY SEVENTH IC WITH .01μF CAP FROM +3.6V TO -3.6V (FOUR CAP'S TOTAL)

MAIN CONNECTOR ; TEST CONNECTOR

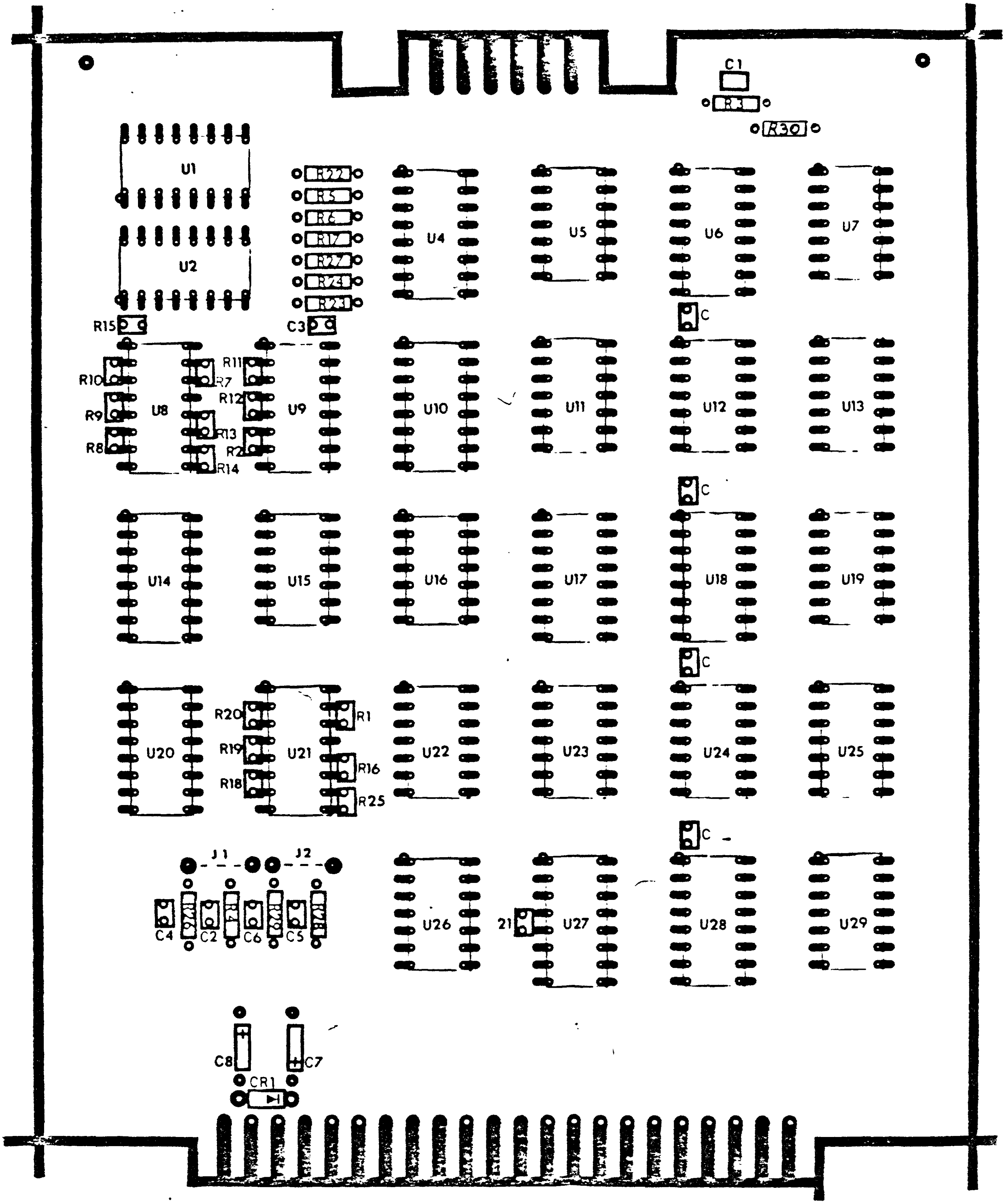


Fig. 3b CALIBRATOR LOADING DIAGRAM

happens to be in calibration at the time the OVRIDE REQ becomes active. The OVRIDE GAIN level determines which of the two input signals is routed through the multiplexer on the preamplifier board. If this level is high, AUX H is chosen, and the input signal is attenuated by 20 db. The other input, AUXL is not attenuated.

The TEST REQ input allows an external signal to be fed through the system via the test connector on the calibrator board. TEST REQ changes the MUX code to binary 3, which is the ID input in the multiplexer. This signal (test in) then goes through the preamplifier and VCO and could be used for externally programmed system calibrations.

The calibration cycle has a chopped and unchopped section. When J2 is not installed the geophone signal (when not in calibration) is unchopped. If J2is installed, then the chopping mode is enabled and the output is always chopped at 21.25 Hz. Thus the system could be used to telemeter low frequency data since once the d.c. data is chopped it is in the passband of the system.

Two other test connector inputs allow for manually initiating a calibration. The JAM input clears the 12 stage counter and opens gate U5 to the jam pulses from JAM CK. A special "Calibration Decoder" field unit was built to initiate these calibrations and then display the digital calibration data. This unit is described in Appendix 3.

Finally the GREN 2 output goes low with the start of calibration. This signal ensures that the system is not in gain range during calibration. In addition, this signal causes the gain of the Preamp to be set to zero for calibration. Thus, the system gain during calibration is automatically set to its minimum value regardless of the switch-selected gain setting and state of gain range.

VOLTAGE CONTROLLED OSCILLATOR ELECTRONICS

The VCO board takes as an input the signal from the preamplifier and outputs a modulated audio carrier. In addition, the board contains the ground reference circuit and a crystal reference oscillator. The circuit diagram for this board is shown in Figure 4.

Ground Reference

Since the A1VCO does not use a bi-polar power supply, an internal reference (i.e., a stable voltage midway between the supply voltage leads) must be supplied for use by the operational amplifiers (op-amps) on the preamplifier board. This reference is produced using feedback to an op amp (U2) whose input is from a symmetrical voltage divider. The divider is across the battery and uses 1% resistors to guarantee a reference within 1% of the actual electrical center. Thus, if the internal ground were connected to the external ground (of the source powering the VCO), a large current could flow and possibly damage this ground reference op amp.

Crystal Reference Oscillator

All timing for the calibrator and audio output signals is derived from the crystal oscillator on this board. The IC (RCA CD4060) contains an oscillator section and a 14 stage counter. The output from the last stage is used as the frequency stabilizing signal in the Phase Lock Loop (PLL). Two other outputs are pulled off of this divider: an 85 Hz signal for calibration timing and a 1360 Hz signal for gain range timing.

Phase Lock Loop (PLL)

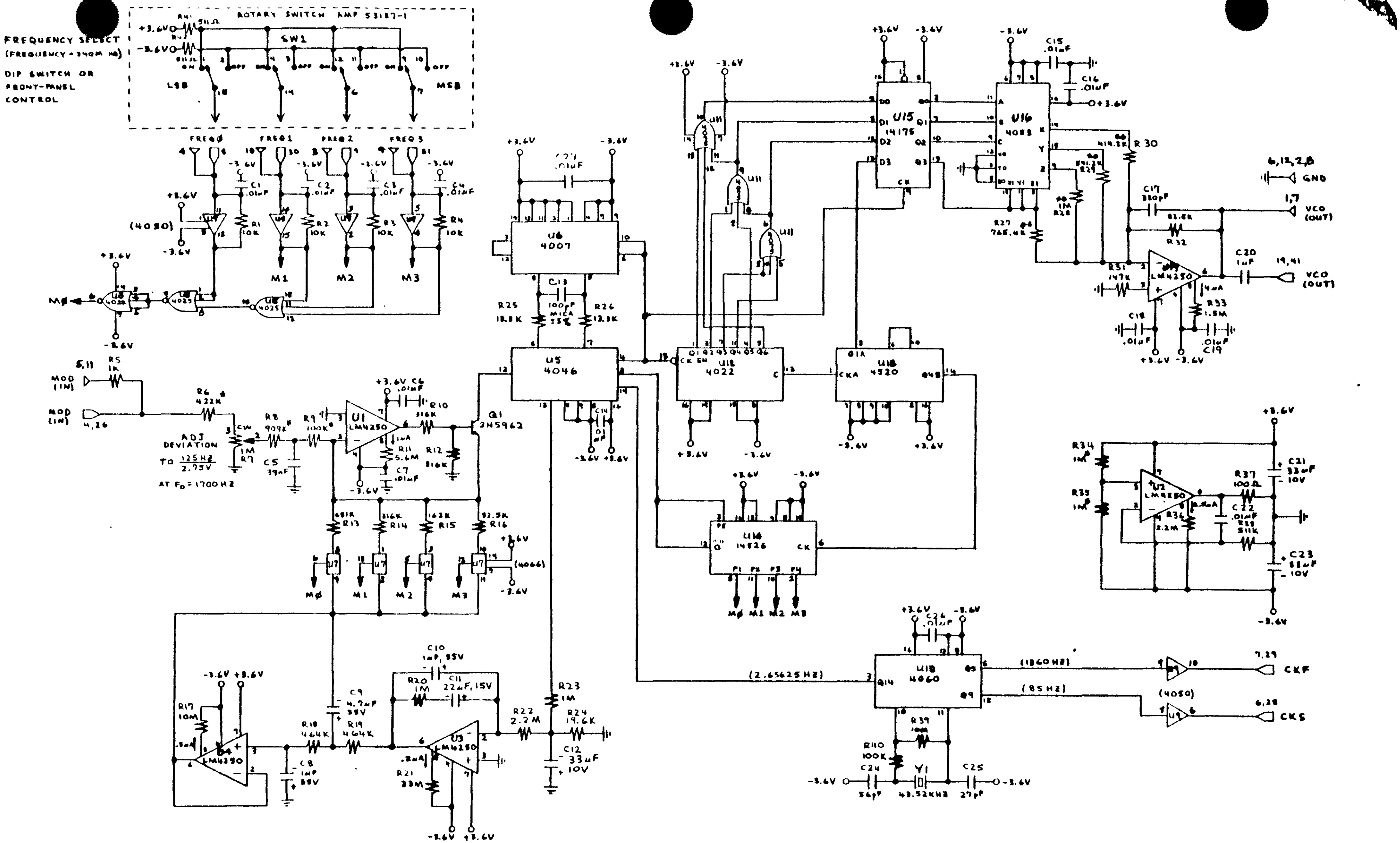
A PLL is used to produce the FM modulated carrier with the output of U10, a 2.65625 Hz signal, serving as the reference input. The loop forces the average VCO output frequency to equal an integral multiple of the reference frequency. The integral multiple is determined by U12, U13 and U14 which divide the VCO output frequency. The first divider is octal, the second is comprised of two cascaded 4-bit binary counters and the last counter is a programmable 4-bit binary divider. Thus the VCO output will be:

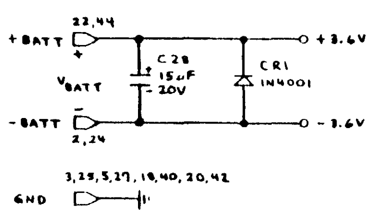
$$8 \times 16 \times 16 \times N \times 2.65625 \text{ Hz} = \text{average VCO frequency at U5, pin 4}$$

Here "N" is the value of a 16 position switch which can assume values from 0 to 15. Note the code conversion logic for the code N = 0 performed by U8. This logic has the effect of causing switch position "0" and "1" to have the same output codes. Thus, the first two switch positions result in the same center frequency (340 Hz). Each succeeding switch position increases the center frequency by 340 Hz.

Sine-Wave Synthesis

The VCO produces a sine wave of high spectral purity using digital synthesis techniques (Kregszig, 1962). Basically the outputs of the divider chain are used as digital inputs to a 4-bit digital to analog converter. The converter has the affect of dividing the average VCO frequency of U5 by 16. The timing diagram for the process is given in Appendix 1. The sine wave has been optimized for minimum harmonic distortion by selecting 4 resistor





12127-20001

CRYSTAL-STABILIZED VCO

MASLAK 25 JUN 1977 RECEIVED 13 OCT 1978

* 1% METAL FILM RESISTOR

ALL RESISTORS (EXCEPT FOR *) ±10% OVER TEMPERATURE-AND HUMIDITY-OPERATING RANGE

ALL CAPACITORS ±20% OVER TEMPERATURE-AND HUMIDITY-OPERATING RANGE (I.E. X7R OR BETTER FOR CERAMICS)

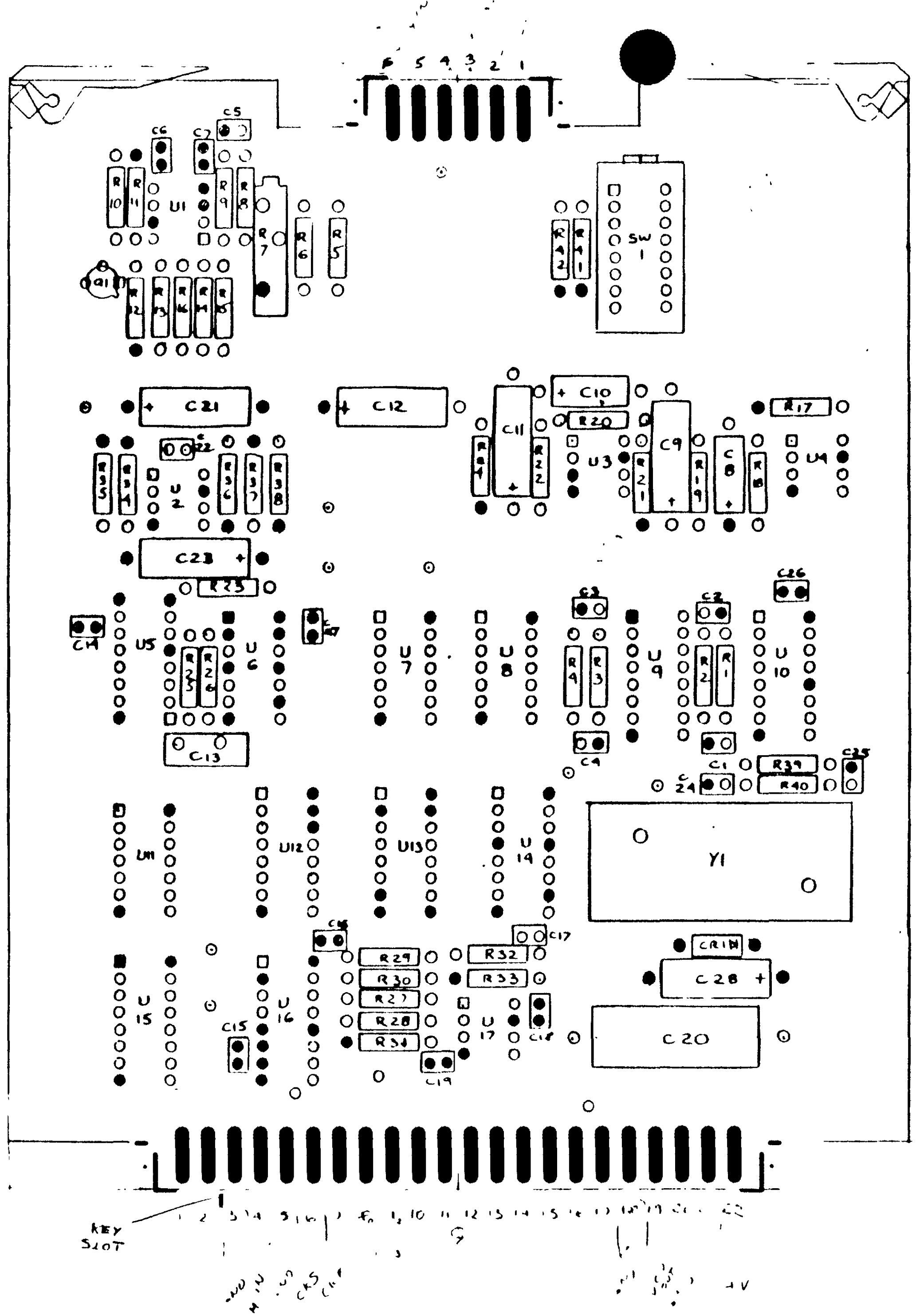
ALL POLAR CAPACITORS SOLID TANTALUM

BATTERY VOLTAGE MUST SATISFY 6V < V_{BATT} < 8V

** SPURIOUS HARMONIC COMPONENTS ≤ ¼ RESISTOR TOLERANCE

MAIN CONNECTOR —◁ ; TEST CONNECTOR —◁

FIGURE 4a VOLTAGE CONTROLLED OSCILLATOR CIRCUIT DIAGRAM



CRYSTAL STABILIZED
VCO

Fig. 4b VOLTAGE CONTROLLED OSCILLATOR LOADING DIAGRAM values. Fortunately these can be selected so that that all the harmonics up to the 14th are down at least 60 dB relative to the fundamental. The harmonics higher than the 14th are far beyond the pass band of the phone line and therefore do not present a problem. This has been verified experimentally in Alaska by spectrum analysis*. The derivation of the resistor values using Fourier-analysis techniques is given in Appendix 1.

The synthesized sinewave output above is passed through a single pole low pass filter with a cut off frequency of 5900 Hz. This filter smooths out the sharp edges of the synthesized sinewave and provides an output drive capability through a coupling capacitor of about 1 ma. This can be increased by reducing the value of R33.

Modulation Circuitry

The VCO frequency is modulated by bias- current changes at pin 12 of U5. The relation between changes in bias current and changes in frequency is linear. A change in current is brought about by a change in the biasing of transistor Q1. Two factors can lead to a bias shift:

a) Input signal changes at MOD(IN). When the input signal from the preamp changes in value the voltage on the base of Q1 will increase or decrease. This in turn increases or decreases the current which modulates the VCO frequency. The sensitivity is set by a potentiometer to 125 Hz per 2.75 volts of input signal. A 5.5 volt peak-to-peak sine wave produces a $\pm$125 Hz modulation of the carrier. This sensitivity (45.5 Hz/Volt) changes slightly with supply voltage and center frequency as shown in Appendix 17.

b) Frequency offset between desired frequency and VCO frequency. The VCO output is divided down and compared to the reference frequency via a phase comparator inside U5. If these two signals do not agree in frequency, the comparator will produce a series of positive or negative going pulses depending on the sense of the frequency disparity. The pulse repetition rate increases with increasing offset. These pulses cause a current input to the integrator (U3), either charging or discharging its capacitor. The integrated output, in turn, is buffered and filtered by U4 whose output changes the bias point of the emitter of Q1. The resistor network R13-R16 provides a higher gain at higher switch-selected center frequencies to keep PLL lock-in time relatively constant over the entire frequency range.

The time constant of this loop (100 seconds) is long enough so that no significant correction of frequency will occur over the bandwidth of the system. In other words, a signal at the lower bandedge of the system, 0.1 Hz, will not be corrected for as a frequency offset. Frequencies lower than this would tend, however, to be corrected for as described in b) above.

When the VCO is initially powered up, the output frequency takes about 10 minutes toreach the desired center frequency and stabilize. This settling time is due to the long time constant associated with the loop. A quantative description of this loop can be found in Appendix 5.

* For radio transmitters, the low pass output filtering results in a -30 dB value of the 15th and 17th harmonic relative to the fundamental. No problems have been observed in directly modulating the radio transmitter with the A1VCO.

PREAMPLIFIER ELECTRONICS

The main function of the preamplifier board (Figure 5) is to provide gain for a differential input signal in the microvolt range. In addition to amplification several other features of the A1VCO unit are derived on this board. Below is an explanation of these functions.

Amplification

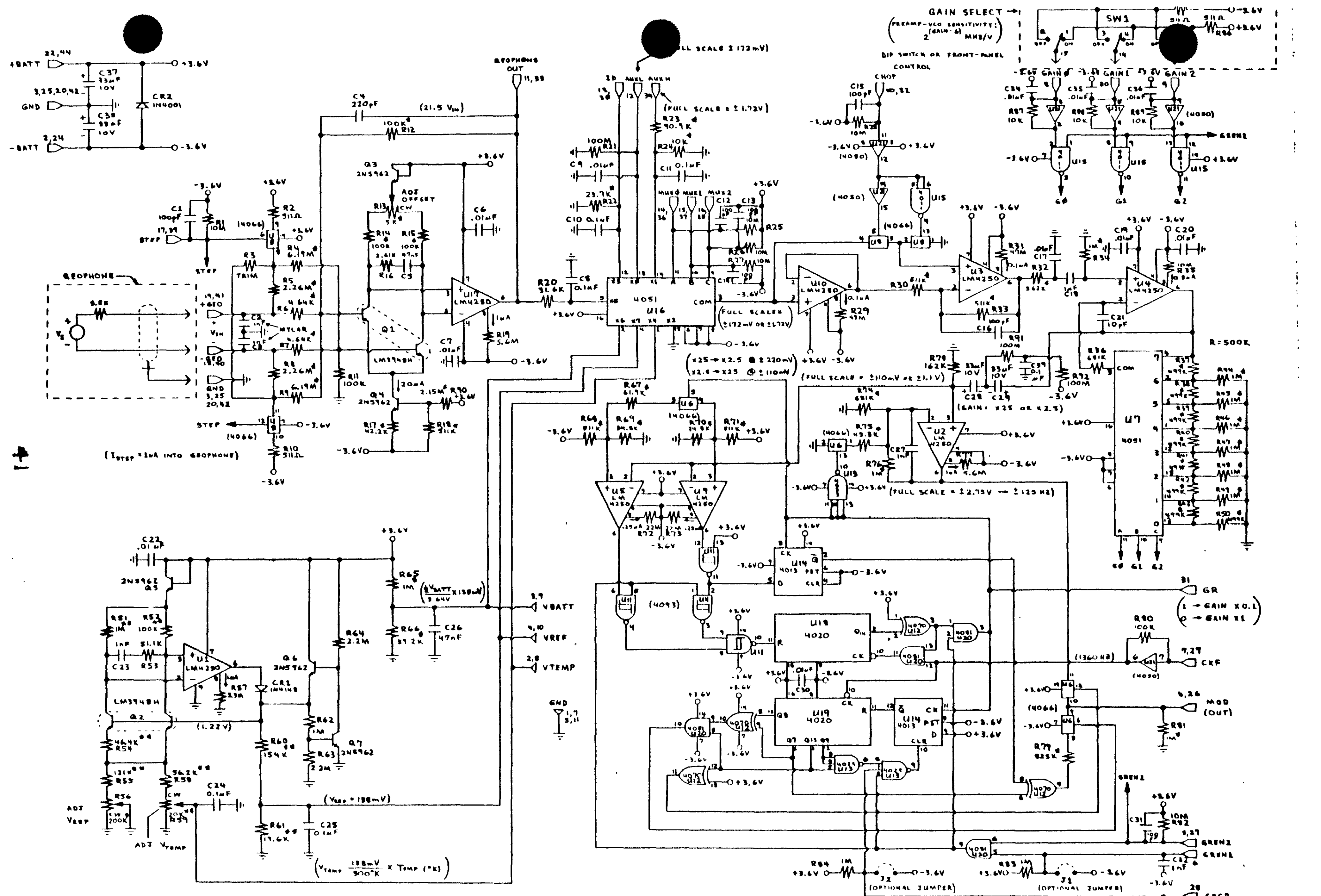
The differential input signal from the seismic sensor is applied to a low noise differential amplifier composed of a matched pair of transistors. The input impedance of 9.28KΩ produces a critical damping factor of about 0.7 in the Mark Products L4-Z geophone. The gain of this stage is fixed at 21.5. The single ended output is then fed to a multiplexer IC whose output is selectable from the various inputs via a code derived from the calibrator board (see description of calibrator, above). The seismic signal is passed through the multiplexer except during calibration or when an auxiliary input is selected. The full scale non-gain-ranged signal level at this point corresponds to 344 mV p-p as indicated in Fig. 5. After passing through the chopping circuitry (discussed below), the signal is input to another multiplexer which provides solid state switchable gain control. This gain control is accomplished with a resistive ladder network where the rotary switch-selected gain code determines how many sections of the ladder are fed back to the op amp input. Latches are provided on the rotary switch outputs to latch the gain code and prevent gain changes in case of switch failure. During calibration the GREN 2 signal forces the gain code to 000 which is the minimum gain setting. A code of 111 is the maximum gain setting and causes an amplification of 2^7 relative to the minimum gain setting.

This signal with a full scale voltage of ± 110 mv volts is then ac coupled to a final amplifier (gain = 25) which raises the full scale signal to ± 2.75 volts. AC coupling is necessary in spite of the offset adjust in the differential amplifier stage in order to prevent any dc voltage offset from being input to the VCO. The output of the final amplifier is then fed through a solid state switch to the VCO. This switch does not affect the signal except after gain range (GR) has occurred (see below).

Chopping Circuitry

The A1VCO has a low frequency cut off of 0.1 Hz. It is therefore not possible to pass any dc signal through this system. However, since deviation sensitivity is proportional to battery voltage it is desirable to be able to pass dc information such as battery level. This information can be obtained by converting the dc signal to a chopped or ac signal, the chop frequency being within the passband of the A1VCO. The CHOP input from the calibrator determines when the signal is chopped.

Normally the signal at the CHOP input is low. This causes the section of U8 between pins 4 and 3 to be open and the section between pins 2 and 1 to be shorted to ground. Thus, U10 is a buffer and U3 an inverter. When CHOP is active a digital signal at 21.25 Hz (or 5.31 Hz) appears at the chop input. When this signal is low, the input is inverted. When the signal is high, the signal is fed to the non-inverting input of U3 and is therefore not inverted.



JUMPER J1 INSTALLED → GAIN RANGER AND GAIN RANGE CODE DISABLED

JUMPER J2 INSTALLED → GAIN RANGE CODE DISABLED; GAIN RANGER ENABLED

MAIN CONNECTOR —◁ ; TEST CONNECTOR —◁

PREAMPLIFIER, CHOPPER, GAIN RANGER, AND REFERENCE

MASLAK 5SEP1977 RECEIVED 15 OCT 1978

- ♦ 1% METAL FILM RESISTOR
- ♦♦ 1% METAL FILM RESISTOR; TEMPCO'S TRACK WITHIN ±25ppm/°C FOR BEST PERFORMANCE

ALL RESISTORS (EXCEPT FOR ♦) ±10%, AND ALL CAPACITORS ±20% OVER TEMPERATURE- AND HUMIDITY-OPERATING RANGE

ALL POLAR CAPACITORS: SOLID TANTALUM

BATTERY VOLTAGE MUST SATISFY 6V ≤ V_{BATT} ≤ 8V

FIGURE 5a PREAMPLIFIER CIRCUIT DIAGRAM

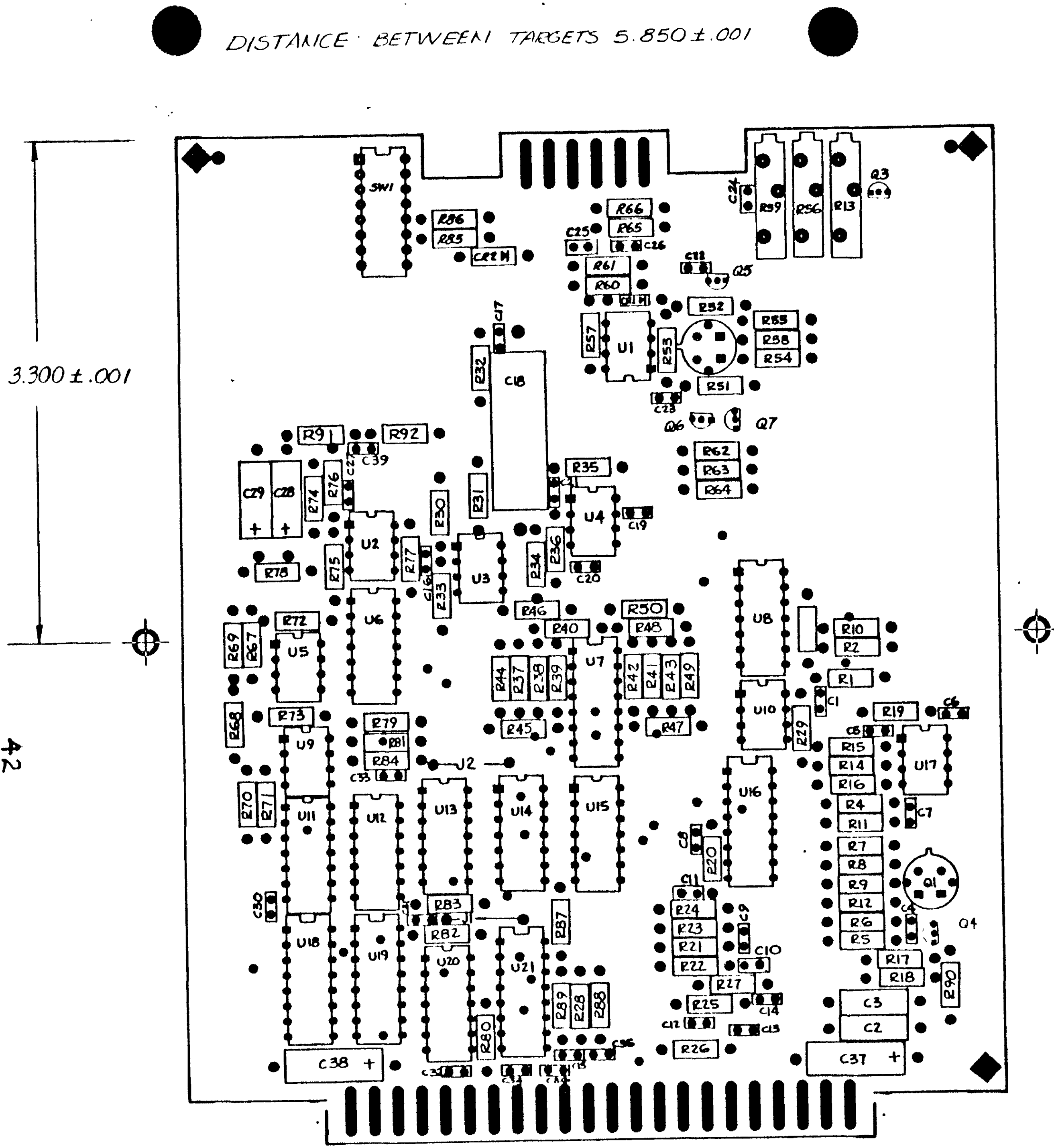


Fig. 5b PREAMPLIFIER LOADING DIAGRAM

UNLESS OTHERWISE SPECIFIED:
1 ... DIAMETERS ARE FINISHED SIZE
2 ... TOP FINGERS MARKED X
3 HOLE ... PLATED ... UNPLATED E EITHER
4 P HOLE DESIGN ... ATES N C DRILLED PILOT HOLE
5 FINISH NICKEL ... GOLD TIN NICKEL TIN LEAD
6 SOLDER MASK CIRCUIT SIDE
7 DISTANCE BETWEEN TARGET REG... ±.001

SYMBOL	PASS	HOLE DESIG	FINISHED DIA ±.002	HOLE FINISH	QTY

ASSEMBLY

ARTWORK SHT 1 OF 3

PREAMPLIFIER, CHOPPER, GAIN RANGER & REFERENCE

checked 5/26/78 JCC

Thus, the signal undergoes 180° phase shifts at the chop frequency. The signal appears at the preamp output to be bipolar, symmetric about zero volts.

Gain Range Circuitry

The A1VCO provides an extra 20db of dynamic range through an automatic gain ranging circuit as illustrated by the strip chart recording of Figure 6. The circuit is activated by two op amp threshold detectors (U5, U9) when the input signal exceeds an absolute threshold level. Gain ranging occurs instantly (relative to the seismic data) as soon as either threshold is exceeded. This threshold is determined by 2 resistive dividers in such a way that the system enters gain range (GR = 1) for any signal exceeding twice the nominal full-scale level (±220 mV at U2, pin 3).

When a signal exceeds this threshold U5 or U9 changes state, which in turn, resets U18, a binary counter. Normally (when GR = 0) Q14 of this counter is high, which means that the switch between pins 1 and 2 of U6 is closed. Thus amplifier U2 has a gain of 25. However, when GR is high, U18 has been cleared, resulting in this switch being opened, reducing the gain by a factor of 10. In addition, R67 is switched into the circuit, which reduces the threshold for GR, resulting in the hysteresis described by Table 2.

In addition to these events, a flip flop U14 is set if the signal causing GR was positive. This level will be used later as an indication in the output data of the polarity of the signal causing the gain range.

The system is now in GR and will remain there so long as the threshold is exceeded. If the signal stays strictly below the threshold for a predetermined interval of time, the system will come out of GR. That is, when the analog signal drops below the threshold, the reset signal to U18 is removed, allowing the 1360 Hz clock signal to be counted. After 2^{13} clock pulses (6.02 sec) the system comes out of GR. Thus, it takes 6 seconds for the system to come out of gain range after the signal drops below the threshold.

Before GR times out, however, the high generated by U20, pin 3, clocks U14, Q from high to low, enabling the counter, U19. When Q13 goes high, a high on Q7 closes the lower portion of switch U6 while the upper portion is opened. This interrupts the signal for as long as Q13 is high. Q13 remains high until Q9 goes high (0.2 sec) which is the length of the GR code. The reset of U14 in turn resets U19. While this occurs a high on Q7 allows the polarity pulse stored in U14 to be output via U6 in place of the normal seismic signal. This happens 3 seconds after the system enters GR. Figure 6 is a strip chart recording displaying a gain range pulse.

If the signal causing GR were positive then U14 holds a low. The high from Q7 is then converted to a high by U12, an exclusive OR gate. When Q7 goes low and Q8 goes high, the low stored in U14 is then output. Thus, for a positive signal causing GR, the gain range signal would be a positive followed by a negative pulse. The opposite would occur if the signal which caused GR were negative. After this code is output, the normal seismic signal resumes.

Two jumper wires allow the user to disable GR if desired. If J2 is installed then U14 is always reset effectively disabling the gain range code generating circuit. In this case, gain ranging will operate but no output

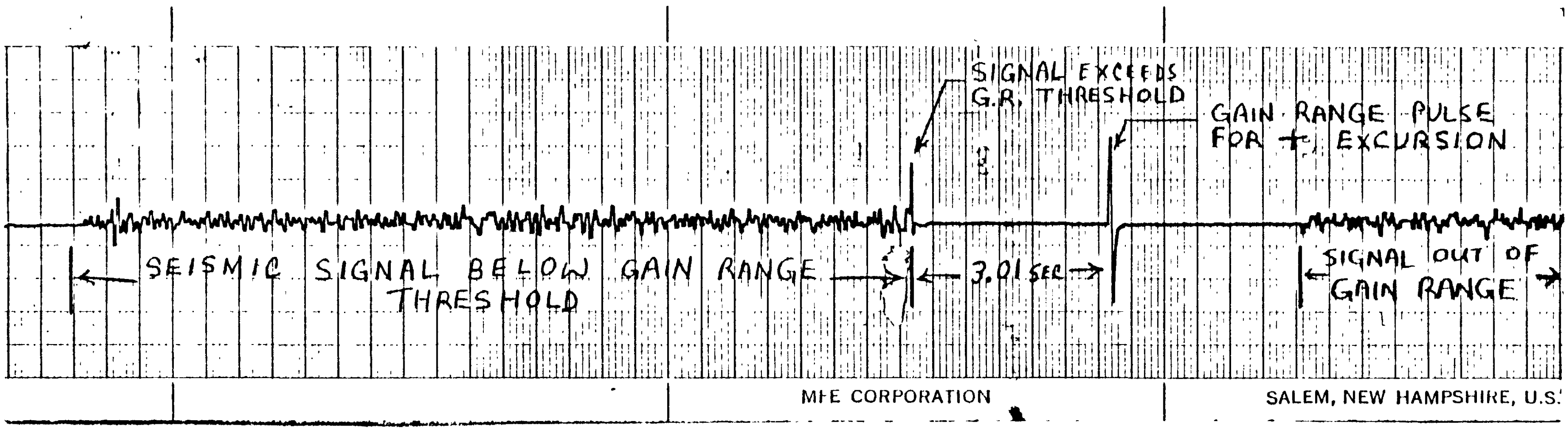


Fig. 6 Strip-chart recording with gain-range pulse

code pulse will be generated. If J1 is installed then the section of switch U6 between pins 1 and 2 is always closed causing the changes in state of U5 and U9 to be ignored. In this case the system will never enter GR.

Voltage Reference, Temperature and Battery

In order to calculate parameters such as deviation sensitivity, GR thresholds and battery voltage, a reference voltage of 138 mV with $\pm$ 1 mV stability over -30°F to +100° F is provided. Test data on this and other aspects of the A1VCO is provided in Appendix 16. This reference signal is produced by feedback in U1 which requires that the current in R51 be one-tenth that in R52. The base current required in Q2 to produce these currents generates a 1.22 volt level on the bases of Q2 which is divided by R60 and R61 to the required 138mV. R56 allows this level to be adjusted by changing the magnitude of the currents in R51 and R52.

Transistor Q5 is used to generate the temperature voltage since for every 1°C increase in temperature its base-emitter voltage decreases by 2.5 mv. This changes the currents flowing in Q2 in a direct relation. R59 is used to adjust the temperature voltage to 138mv at 300° K.

The battery voltage is obtained via a voltage divider whose ratio is 0.03791, which is the same as 138mV/3.64V. Thus, if a 3.64 volt battery is used, the battery reference signal is 138 mv.

Geophone Calibration Steps

During calibration the current steps are produced when the STEP input goes high. This causes a current of magnitude

$$I = \frac{7.2}{2 \times 2.26} \times \frac{9.28}{R + 9.28} \text{ microamperes}$$

to flow in the geophone. In this equation R is the coil resistance of the geophone and 9.28 is the input impedance of the preamp, both in kiloohms. The first factor in this equation is the total battery current drawn during calibration while the second gives the proportion flowing in the geophone.

For R = 5.4

KΩohms, the current is one microampere. For a current of one microampere, 5.4 mV is generated by the geophone coil resistance which would also be input along with the electromechanical transient produced by the STEP. To compensate for the voltage step produced by the coil resistance, a voltage of the same magnitude but opposite in polarity is introduced at the input to the differential amplifier. Since different geophones have different coil resistances and this resistance is also a function of temperature, a "standard" impedance geophone sensor of 5.4 KΩohms is assumed.

One interesting by-product of this compensation procedure is the ability to determine the geophone resistance from this portion of the calibration. Basically the dc offset after the application of the step current is proportional to the amount of deviation in coil resistance the actual geophone has from the ideal of 5.4 KΩ . This dc offset voltage can be measured during the chopped portion of the calibration. The calculations are given in Appendix 7.

Data Filtering

The preamplifier acts as a bandpass filter to prevent transmission of frequencies higher than 30 Hz or lower than 0.1 Hz. The higher frequencies tend to be nonseismic and are of little interest. Voltage offsets in the preamplifier make a low frequency cutoff necessary. Table 4 gives the locations of all poles associated with this filtering.

Filter Type	R-C Combination	Cut Off Frequency (Hz)
LP*	R12-C4	7234
LP	R20-C8	50
LP*	R33-C16	3114
LP	R32-R34-C17	44
HP	R32-C18-R34	0.10
HP	R78-C28-C29	0.06

*Negligable affect in overall response

Table 4

Preamplifier Filter Poles

REFERENCES

1. Lahr, J. C., 1977, Crystal Controlled Seismic Amplifier-Calibrator-VCO, U. S. Geological Survey Open-File Report 77-116, 6. p. This report describes the basic features of the A1VCO which are expanded on in this report.

2. Kreyszig, E. Advanced Angineering Mathematics, 1962, John Wiley & Sons, Inc.

3. RCA COSMOS Integrated Circuits (1975) ICAN-6101, RCA Solid State Data Books, Somerville, N. J.

APPENDIX 1

VCO SINEWAVE SHAPING AND ANALYSIS

The following is a calculation of the values of the four summing resistors used in the VCO sinewave synthesizer based on Fourier analysis. Performance expectations are also derived.

Consider the four normalized square waves shown in Figure 1. We desire the amplitude values for each wave so that the first harmonic will be unity and as many harmonics as possible after that will be zero. First we calculate the Fourier coefficients corresponding to the Fourier series for each of the square waves. Then we equate the first harmonic to unity. All cosine coefficients will turn out to be zero since the waves have odd symmetry, so evaluation of the coefficients involves only a sine integration. The general form for the sine coefficients is:

$$b_n = \frac{2}{T}\int_{-T/2}^{T/2} f(x)\,\sin 2\,\frac{n\pi t}{T}\,dt$$

We will evaluate these coefficients for f(t), g(t), h(t) and j(t). Then the desired sine wave will be:

$$m(t) = f(t) + g(t) + h(t) + j(t)$$

Coefficients of the same harmonic add since they all have the same period.

We evaluate bn's for f(t):

$$b_n = \frac{2}{T}\int_0^{T} f(t)\,\sin\frac{2n\pi t}{T}\,dt$$

$$b_n = \frac{2}{T}\left[\int_0^{T/2}\sin\frac{2n\pi t}{T}\,dt - \int_{T/2}^{T}\sin\frac{2n\pi t}{T}\,dt\right]$$

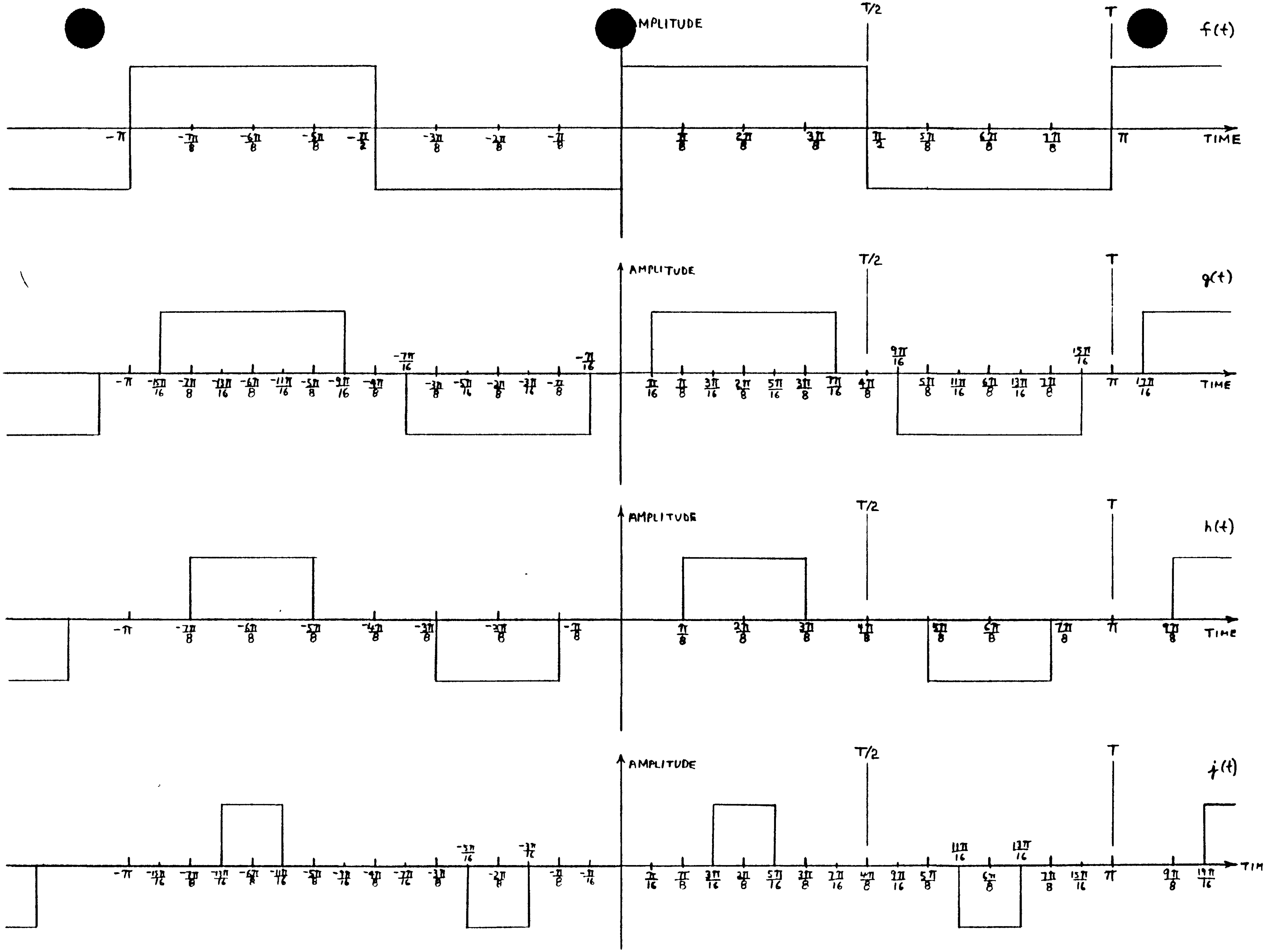


FIGURE AI-I NORMALIZED SQUARE WAVES

$$b_n = \frac{2}{T}\left[-\cos\frac{2n\pi t}{T}\,\frac{T}{2n\pi}\,\Bigg|_{o}^{T/2} + \cos\frac{2n\pi t}{T}\,\frac{T}{2n\pi}\,\Bigg|_{T/2}^{T}\right]$$

$$b_n = \frac{2}{T}\,\frac{T}{2n\pi}\left[-\left(\cos\frac{2n\pi T}{2T} - 1\right) + \left(\cos\frac{2n\pi T}{T} - \cos\frac{2n\pi}{2T}T\right)\right]$$

$$b_n = \frac{1}{n\pi}\left[-2\cos n\pi + 2\right]$$

$$b_n = \frac{2}{n\pi}\left[1 - \cos n\pi\right] = \frac{4}{n\pi} \quad n \text{ odd}$$

Similarly for g(t)

$$b_n = \frac{2}{T}\int_{-T/2}^{T/2} g(t)\,\sin\frac{2n\pi t}{T}\,dt$$

$$b_n = \frac{2}{T}\left[\int_{\frac{-7}{16}}^{-1/16} (-1)\,\sin\frac{2n\pi t}{T}\,dt + \int_{\frac{1}{16}}^{\frac{7}{16}} 1\,\sin\frac{2n\pi t}{T}\,dt\right]$$

$$b_n = \frac{2}{T}\quad \frac{T}{2n\pi}\left[\cos\frac{2n\pi t}{T}\,\Bigg|_{\frac{-17T}{16}}^{\frac{1}{16}} - \cos\frac{2n\pi t}{T}\,\Bigg|_{1/16T}^{7/16T}\right]$$

$$b_n = \frac{2}{n\pi}\left[\cos\frac{n\pi}{8} - \cos\frac{7n\pi}{8}\right]$$

$$b_n = \frac{4}{n\pi}\cos\frac{n\pi}{8}$$

for h(t): $b_n = \frac{4}{n\pi} \cos \frac{n\pi}{4}$

and j(t): $b_n = \frac{4}{n\pi} \cos \frac{3n\pi}{8}$

We evaluate the first four coefficients for each series:

f(X):

$$b_1 = \frac{4}{\pi} = 1.273$$

$$b_3 = \frac{4}{3\pi} = 0.424$$

$$b_5 = \frac{4}{5\pi} = 0.255$$

$$b_7 = \frac{4}{7\pi} = 0.182$$

$$b_9 = \frac{4}{9\pi} = 0.141$$

$$b_{15} = \frac{4}{15\pi} = 0.085$$

g(x):

$$b_1 = \frac{4}{\pi} \cos \frac{\pi}{8} = 1.273 \times 0.924 = 1.176$$

$$b_3 = \frac{4}{3\pi} \cos \frac{3\pi}{8} = 0.424 \times 0.383 = 0.162$$

$$b_5 = \frac{4}{5\pi} \cos \frac{5\pi}{8} = 0.255 \times -0.383 = -0.098$$

$$b_7 = \frac{4}{7\pi} \cos \frac{7\pi}{8} = 0.182 \times -0.924 = -0.168$$

$$b_9 = \frac{4}{9\pi} \cos \frac{9\pi}{8} = 0.141 \times (-924) = -0.130$$

$$b_{15} = \frac{4}{15\pi} \cos \frac{15\pi}{8} = .085 \times .924 = .079$$

h(x):

$$b_1 = \frac{4}{\pi} \cos \frac{\pi}{4} = 1.273 \times 0.707 = 0.900$$

$$b_3 = \frac{4}{3\pi} \cos \frac{3\pi}{4} = 0.424 \times -0.707 = -0.300$$

$$b_5 = \frac{4}{5\pi} \cos \frac{5\pi}{4} = 0.255 \times -0.707 = -0.180$$

$$b_7 = \frac{4}{7\pi} \cos \frac{7\pi}{4} = 0.182 \times 0.707 = 0.129$$

$$b_9 = \frac{4}{9\pi} \cos \frac{9\pi}{4} = .141 \times .707 = .100$$

$$b_{15} = \frac{4}{15\pi} \cos \frac{15\pi}{4} = .085 \times .707 = .060$$

g(x):

$$b_1 = \frac{4}{\pi}\cos\frac{3\pi}{8} = 1.273 \times 0.383 = 0.488$$

$$b_3 = \frac{4}{3\pi}\cos\frac{3(3)\pi}{8} = 0.424 \times -0.924 = -0.392$$

$$b_5 = \frac{4}{5\pi}\cos\frac{3(5)\pi}{8} = 0.255 \times 0.924 = 0.236$$

$$b_7 = \frac{4}{7\pi}\cos\frac{3(7)\pi}{8} = 0.182 \times -0.383 = -0.070$$

$$b_9 = \frac{4}{9\pi}\cos\frac{3(9)\pi}{8} = .141 \times (-)(.383) = -.054$$

$$b_{15} = \frac{4}{15\pi}\cos\frac{3(15)\pi}{8} = .085 = .033$$

We then apply the four conditions:

$$1.273a + 1.176b + .900C + .488d = 1$$

$$.424a + .162b - .300c - .392d = 0$$

$$.255a - .098b - .180c + .236d = 0$$

$$.182a - .168b + .129c - .07d = 0$$

which yield the solutions:

$a = .1963$

$b = .3628$

$c = .2777$

$d = .1503$

The level of the 9th harmonic, for example is:

$$(.197)(.141) + .363(-.130) + (.278)(.1) + (.151)(-054) = 2.33 \times 10^{-4}$$

This harmonic is very small, and would ideally use zero if more significant digits were used in the numerical calculation. It turns out that the first 14 harmonics are all virtually zero, excluding the first harmonic which is unity.

For the 15th harmonic:

$$.197(.085) + (.363)(.079) + (.278)(.060) + (.151)(.033) = .067$$

So the 15th harmonic is down 20 log (0.067) = -23.4 dB

This harmonic falls outside the frequency band passed by the phone lines. We can use the amplitude values a, b, c and d to find the four summing resistors. If we let b = .3628 correspond to 1 m , then

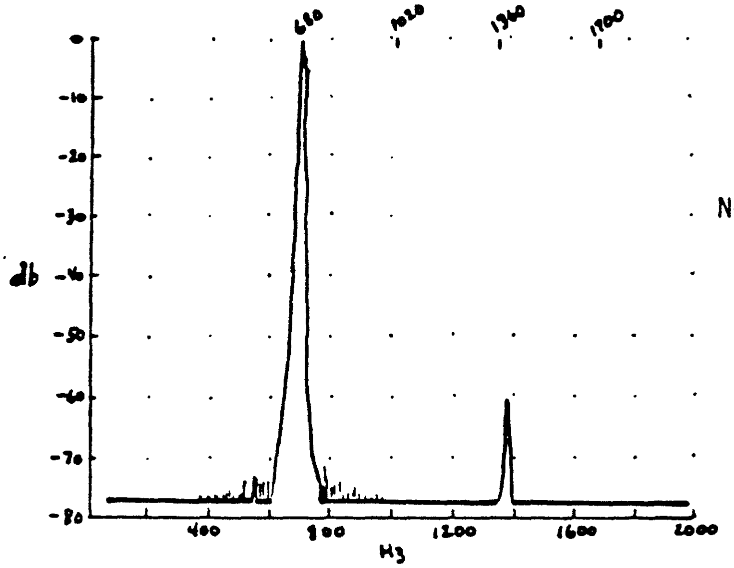
$$b \longrightarrow 1m\Omega \times \frac{.363}{.363} = 1\ m\Omega$$

$$a \longrightarrow 1\ m\Omega \times \frac{.197}{.363} = 541.2K\Omega$$

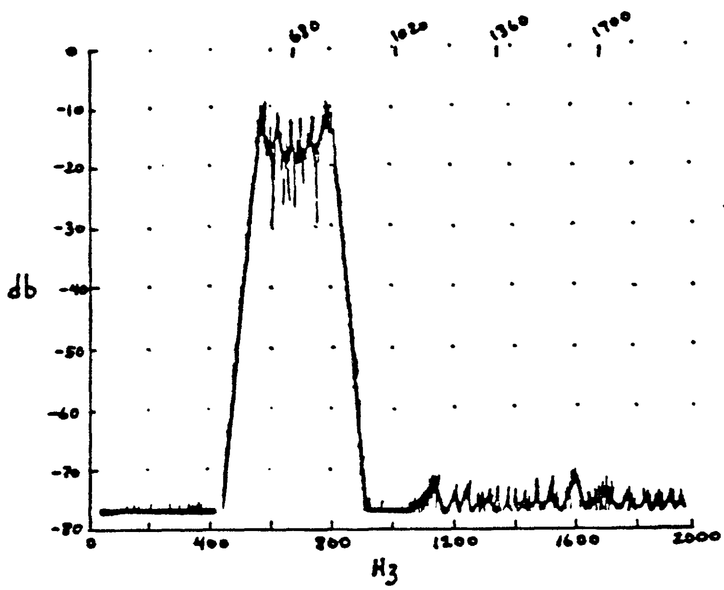
$$c = 1\ m\Omega \times \frac{.278}{.363} = 765.4K\Omega$$

$$d = 1\ m\Omega \times \frac{.151}{.363} = 414.4K\Omega$$

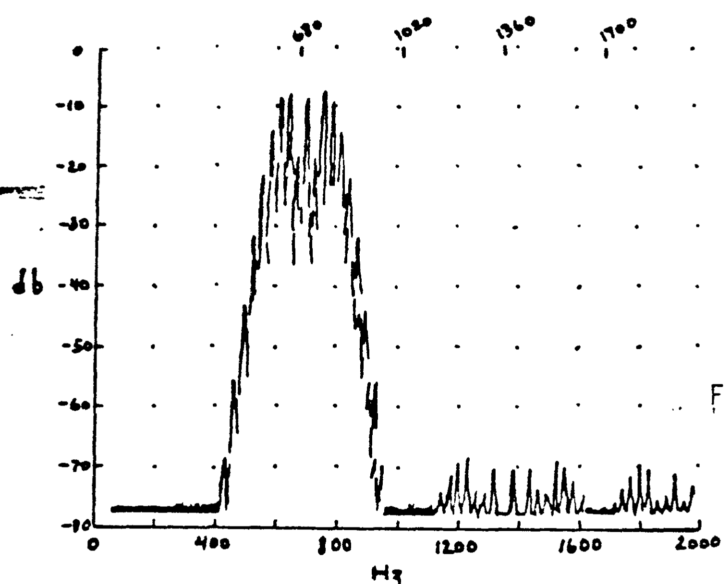
Figures A 1-2 and A1-3 present experimentally measured spectra from the A1VCO output. Note that all in-band harmonics are down nearly 60dB relative to the fundamental. Figures A1-4 and A1-5 are the timing diagrams for the sine wave shaping



NO MODULATION



±125 Hz MODULATION
@ 15 Hz



±125 Hz MODULATION
@ 30 Hz

Figure A1 -2 Spectral analysis of VCO output at various modulation levels.

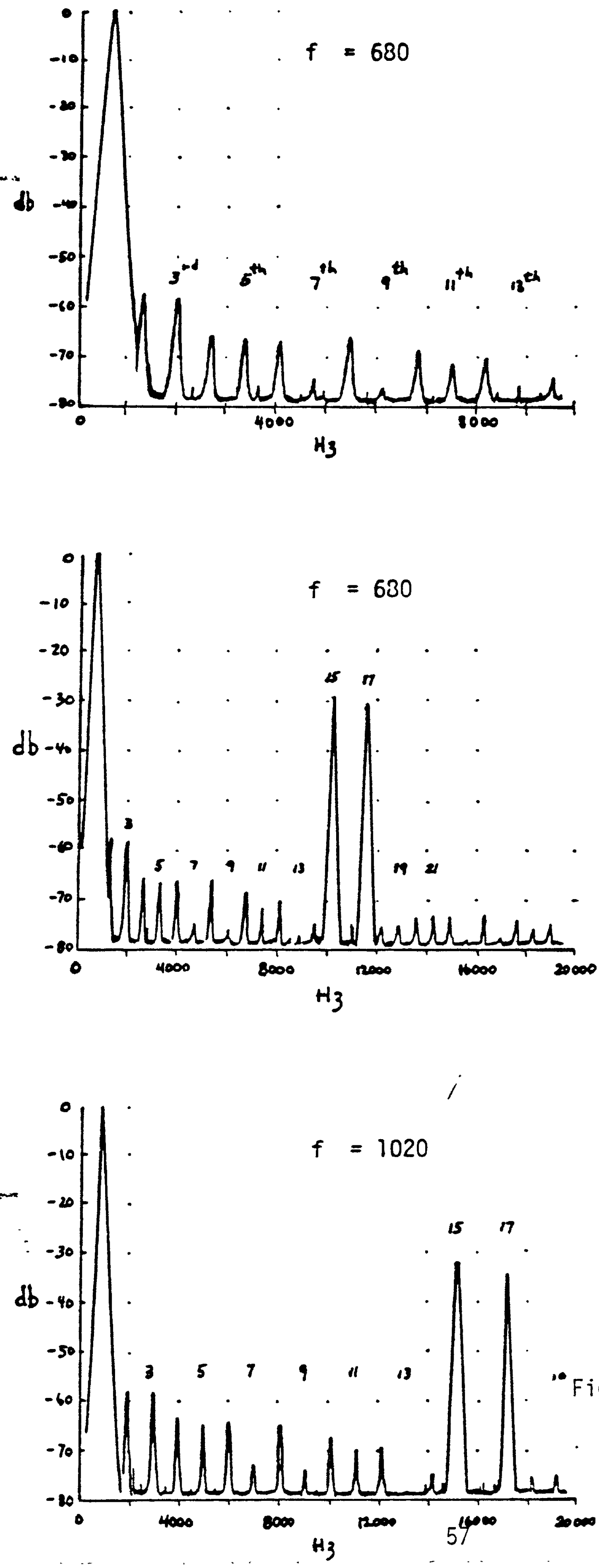


Figure A1 - 3 Spectral analysis of unmodulated VCO output.

VCO SINE WAVE SHAPING

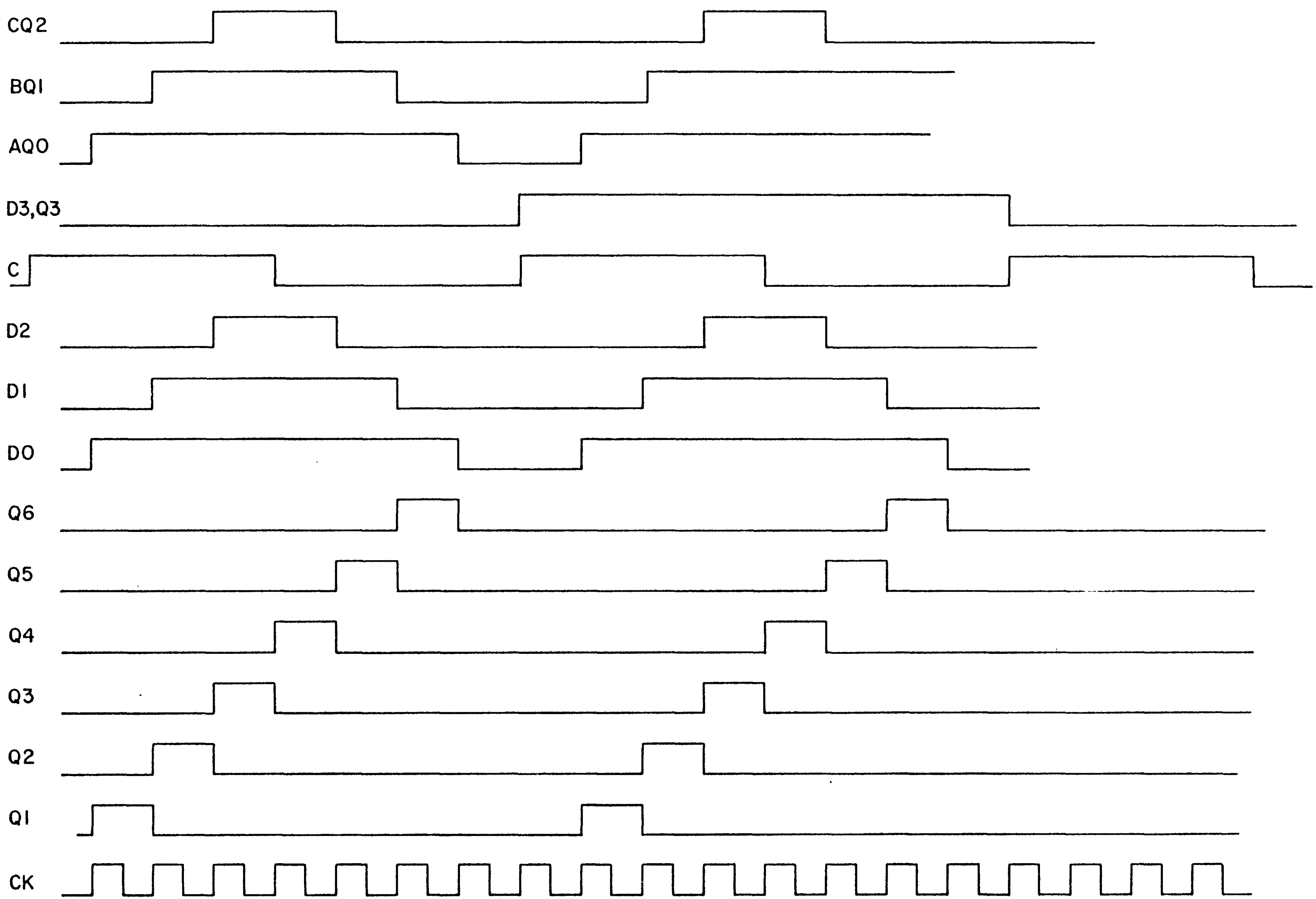


Figure A 1-4 VCO ... ne wave shaping

VCO SINE WAVE SHAPING

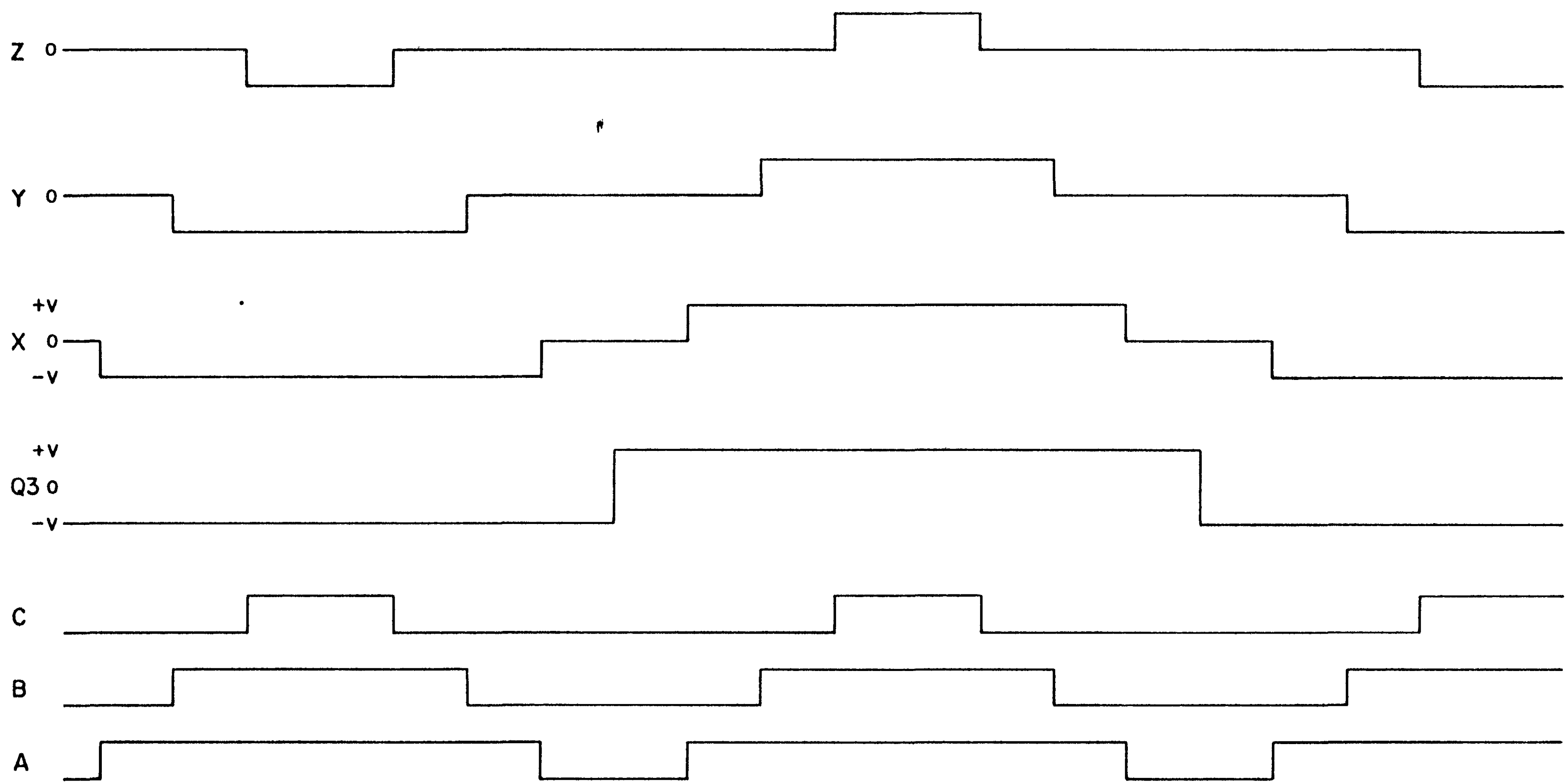


Figure A 1-5 O[illegible]ine wave shaping

CALIBRATOR

ID - TIMING - CALIBRATION (SECOND ID STREAM)

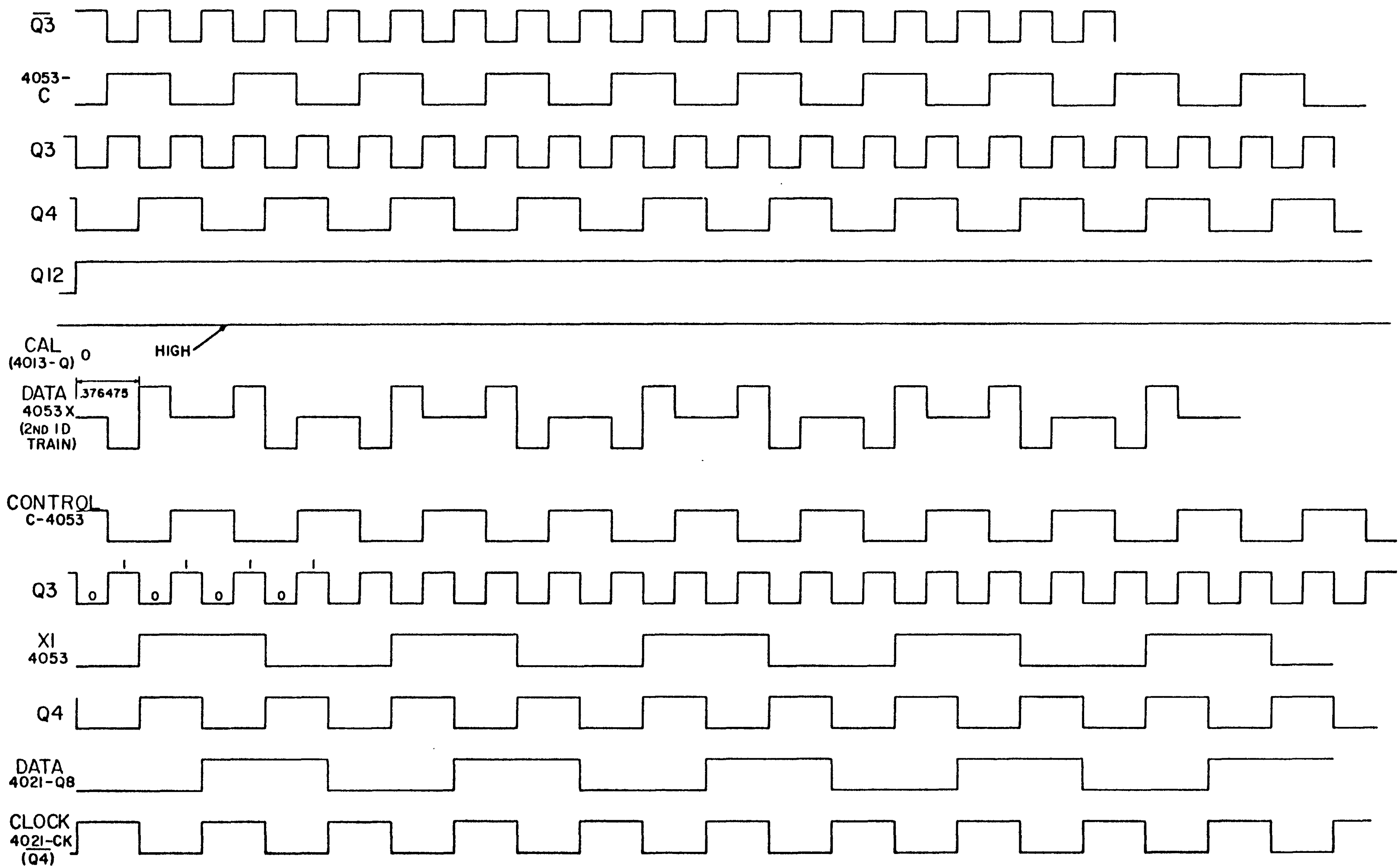


Figure A2 -1 Timing Diagram for ID code

CALIBRATOR
(Ist ID STREAM)

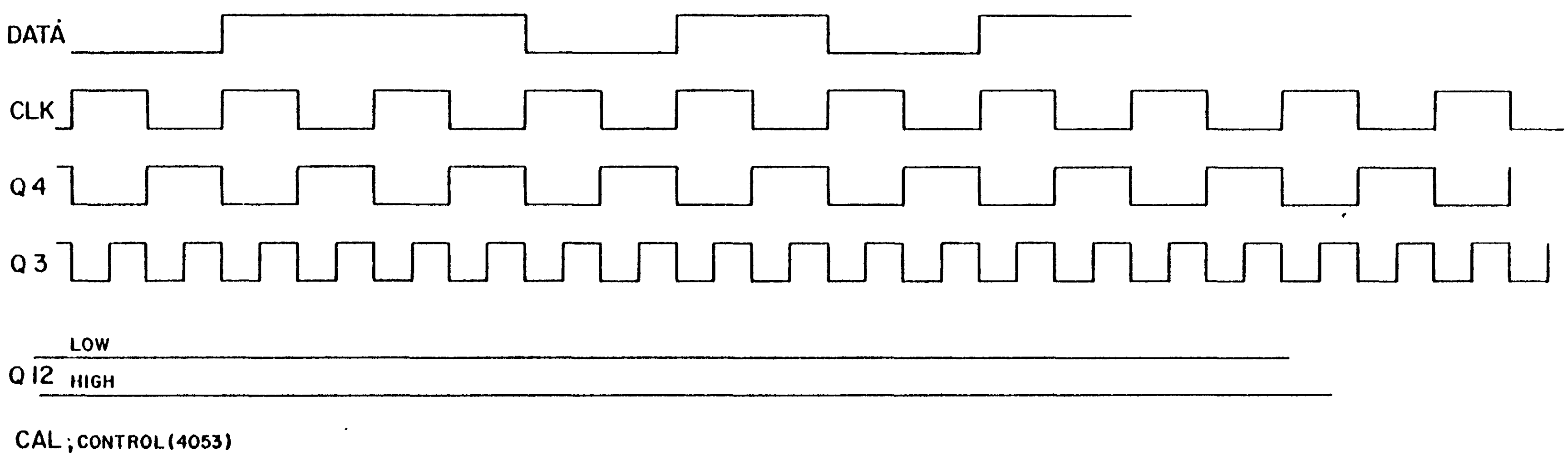


Figure A 2-2 Tuni[illegible] Diagram for ID code

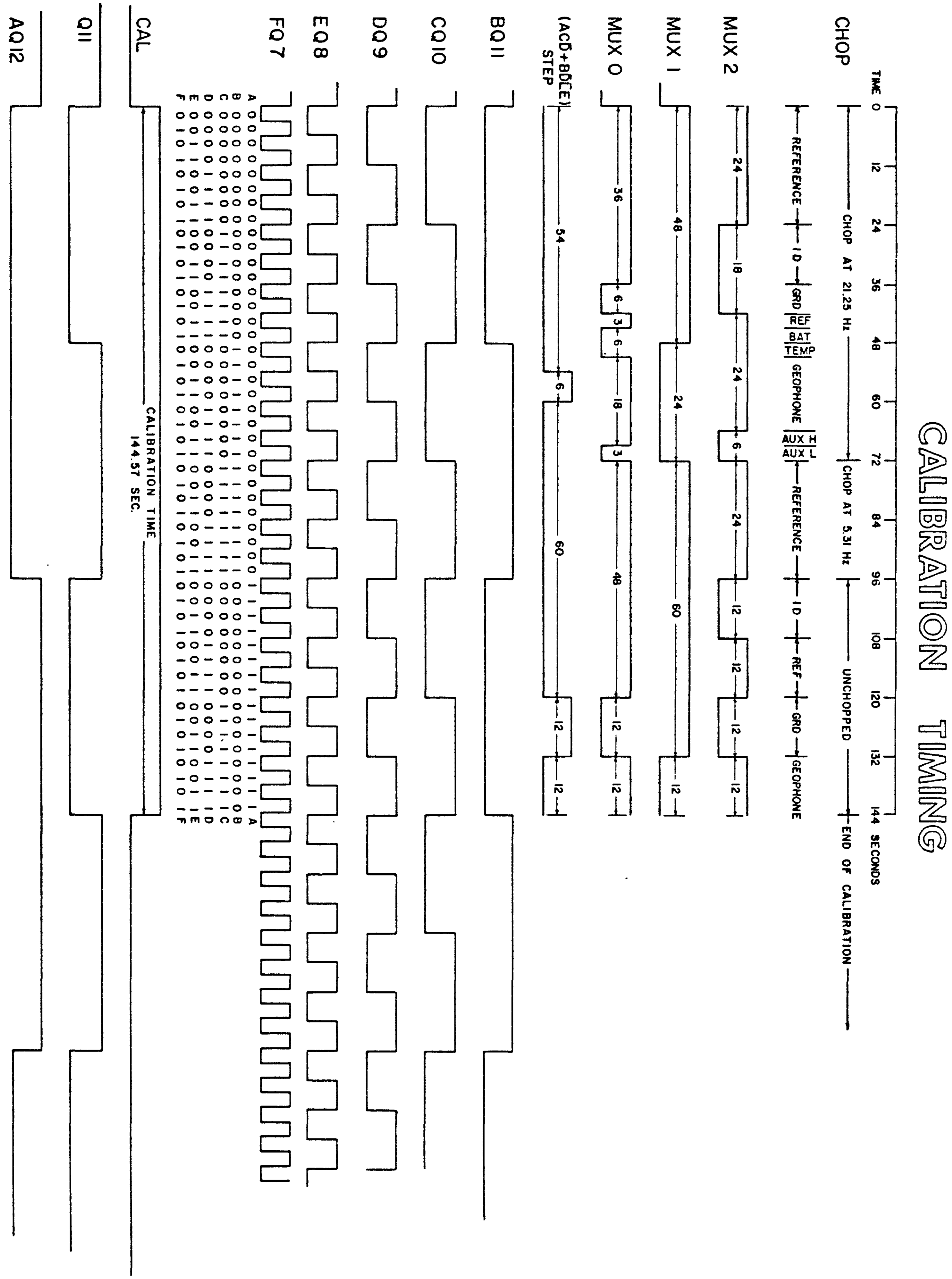


Figure A-2 -3 Timing Diagram for Calibrator

APPENDIX 3

CIRCUIT FOR CALIBRATION DECODER

The ID Decoder is a separate test box which enables the user to check the gain setting, station ID and gain range (both as part of the calibration and before calibration). When the switch is depressed, the system is forced into a calibration with the serial data being stored in shift registers U4 and U5. These data are then latched and presented via the two hex and one decimal display. In addition, the state of GR at the time of calibration is presented by LED 2. LED 1 is used for error detection and is only lit when correct data is present in the shift registers. Correct data is detected when the first four bits are 0011. LED 3 gives the momentary state of GR. The circuit diagram is shown in Figure A3-1.

This unit is useful for two purposes:

1) To check if gain setting and ID code correspond to the values set by the switches.

2) To ensure that station is not in GR during initial setup.

A high quality 9-volt transistor radio battery will run the decoder continuously for at least 2 days.

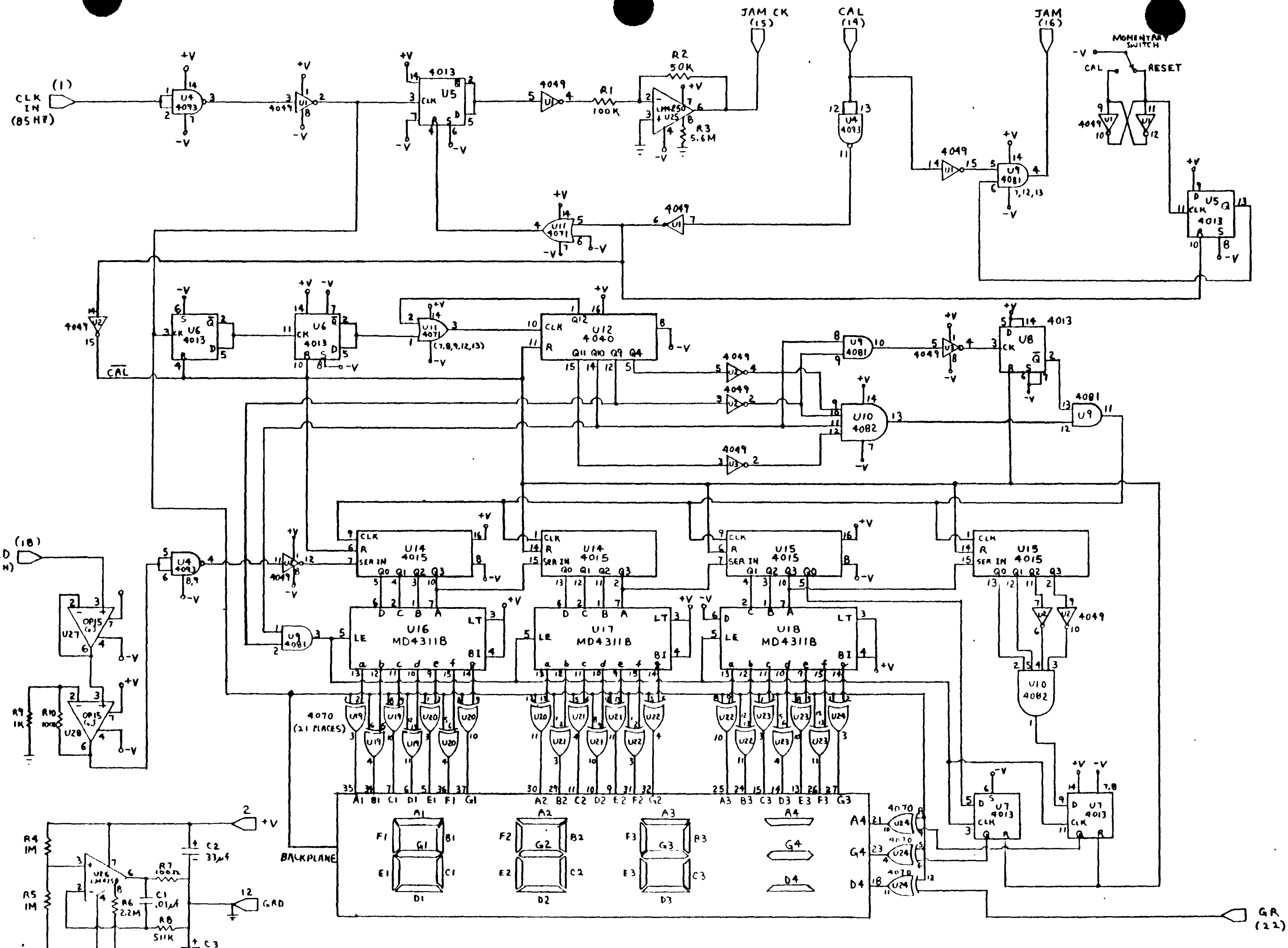
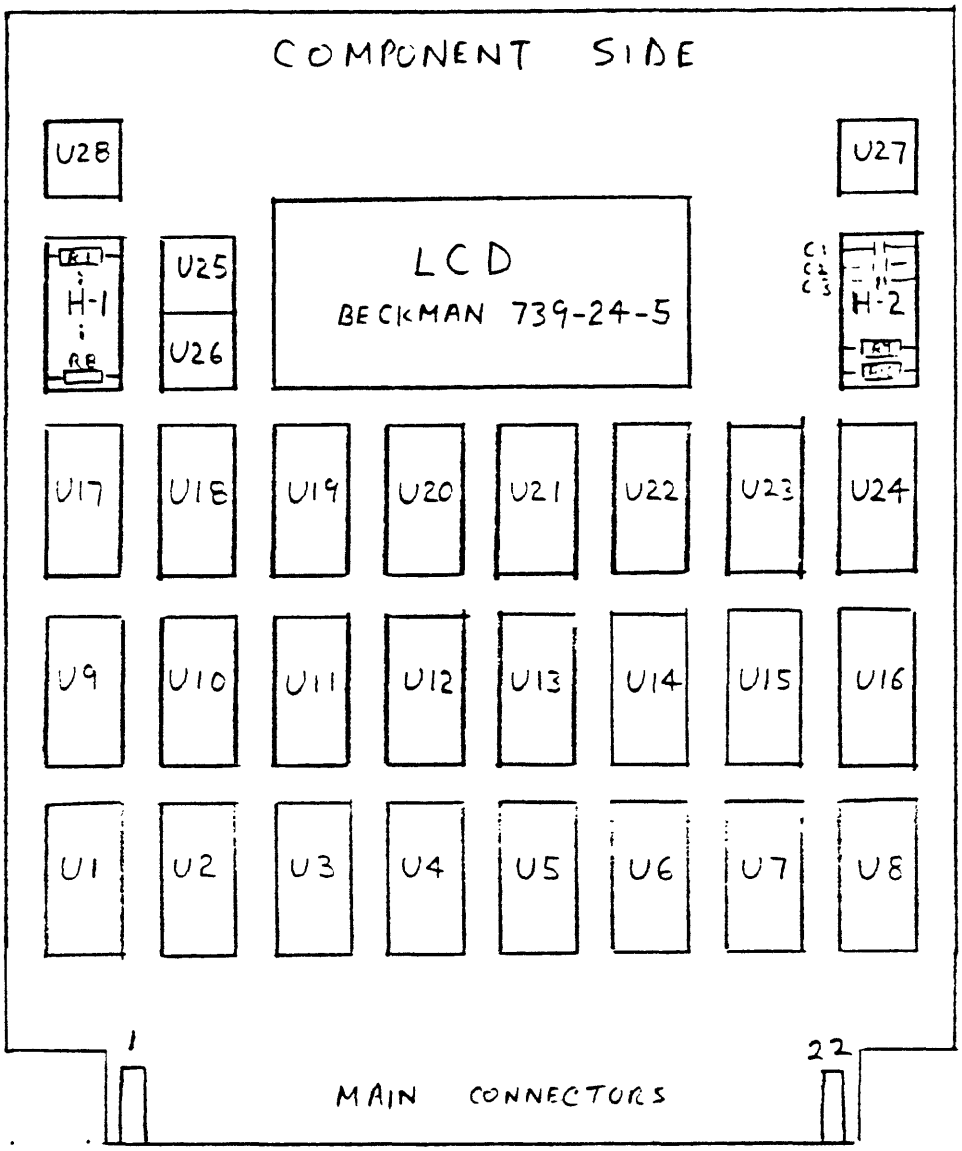


FIGURE A3-1 LCD CALIBRATOR ID DECODER

Fig A3-2 CALIBRATION ID DECODER LOADING DIAGRAM



INTEGRATED CIRCUITS

U1 - 4049
U2 - 4049
U3 - 4049
U4 - 4093
U5 - 4013
U6 - 4013
U7 - 4013
U8 - 4013

U9 - 4081
U10 - 4082
U11 - 4071
U12 - 4040
U13 - EMPTY
U14 - 4015
U15 - 4015
U16 - MD4311B

U17 - MD4311B
U18 - MD4311B
U19 - 4070
U20 - 4070
U21 - 4070
U22 - 4070
U23 - 4070
U24 - 4070

U25 - LM4250
U26 - LM4250
U27 - PMI OP-15GJ
U28 - PMI OP-15GJ

HEADER 1 (H-1)

R1 - 100K
R2 - 50K
R3 - 5.6M
R4 - 1.0M
R5 - 1.0M
R6 - 2.2M
R7 - 100Ω
R8 - 511K

HEADER 2 (H-2)

C1 - .01 µf
C2 - 33 µf
C3 - 33 µf

R9 - 1K
R10 - 100K

MAIN CONNECTORS

1 = IN (85 HZ)
2 = +V
12 = GRD
14 = CAL
15 = JAM CK
16 = JAM
20,21 = -V
22 = GAIN RANGE

APPENDIX 4

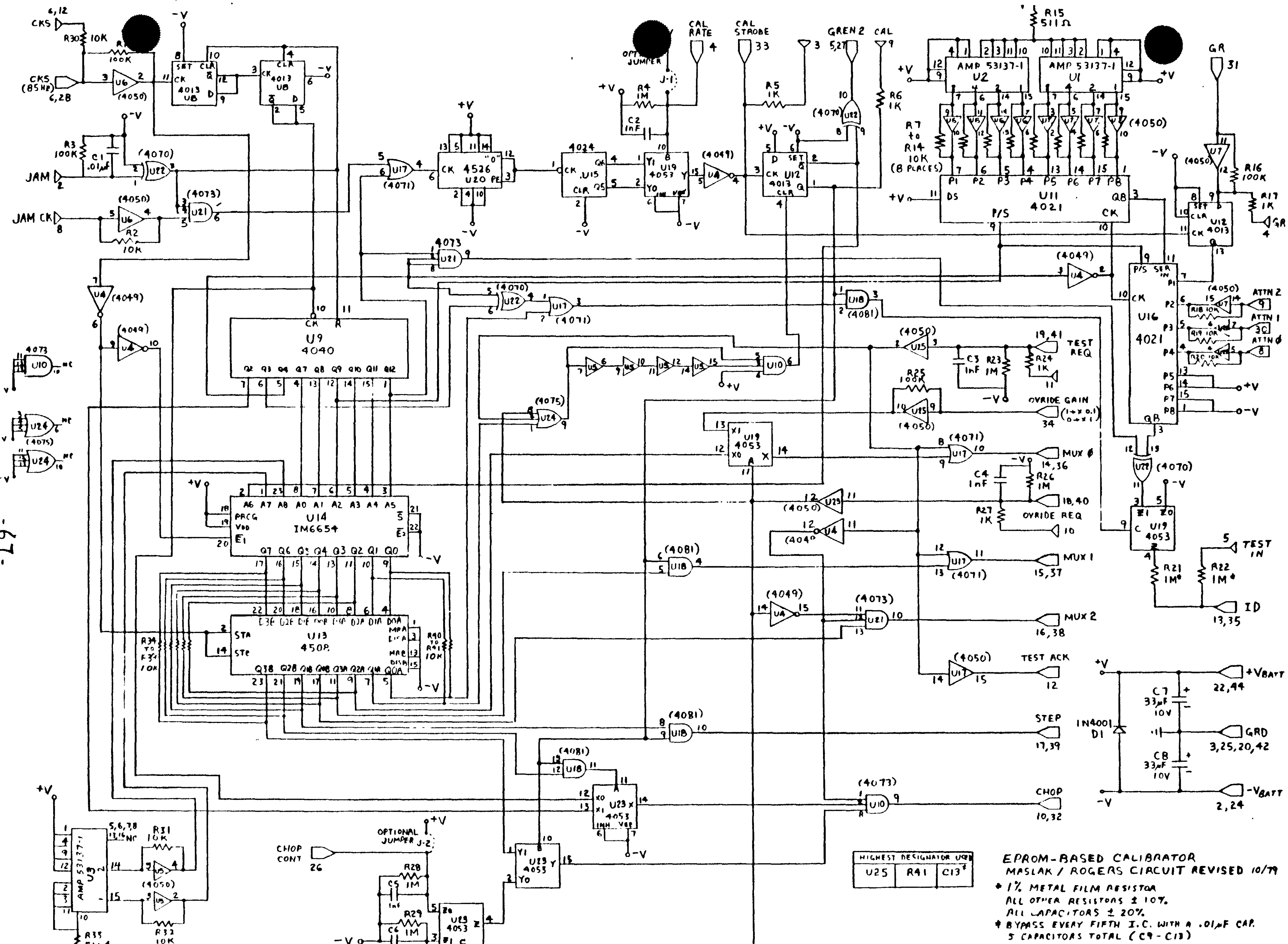
EPROM - Based Calibrator

The EPROM based calibrator of Figure A4-1 gives the user a large degree of flexibility in choosing the calibration cycle. This is accomplished through the use of an Intersil IM6654 COMOS erasable programmable read only memory (EPROM). This memory IC is organized in 512 x 8 bit fashion.

The calibrator divides the 512 x 8 bit words into four 128 word pages, each representing an independent calibration cycle. The user can select any of the four pages via a digital rotary switch. Switch position "0" selects page "0" which contains a calbiration program identical to that presently used in the hard-wired calibrator version. The other three pages are used for special purpose calibration cycles. A program whose output is the same as the hard-wired calibrator is shown in Table A4-1.

As can be seen from this table, the EPROM data output byte (8 bits) controls the MUX code, STEP, CHOP, the CHOP frequency, the return to zero ID code and the end of calibration pulse. Table A4-2 summarizes the control function of each output. The "normal condition" mentioned in the table refers to the bit state when not in calibration.

Referring again to Table A4-1 it is seen that states 49-127 have the same code. This represents room for possible expansion (in time) of the calibration cycle. The maximum duration allowable is 6.37 minutes.



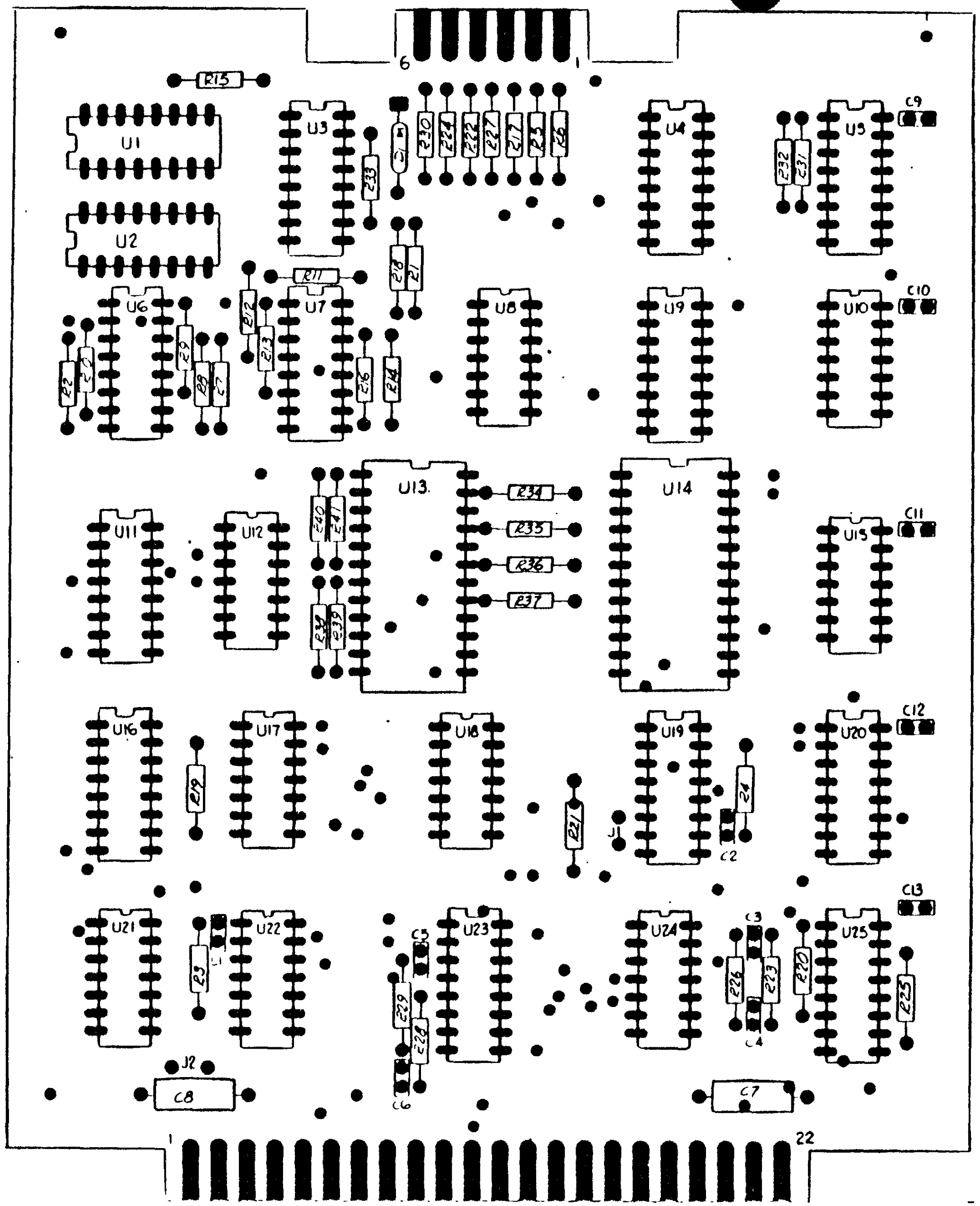
HIGHEST DESIGNATOR USED		
U25	R41	C13*

EPROM-BASED CALIBRATOR
MASLAK / ROGERS CIRCUIT REVISED 10/79

* 1% METAL FILM RESISTOR
ALL OTHER RESISTORS ± 10%
ALL CAPACITORS ± 20%
* BYPASS EVERY FIFTH I.C. WITH A .01μF CAP.
5 CAPACITORS TOTAL (C9 - C13)
MAIN CONNECTOR
TEST CONNECTOR

FIGURE A4-1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



PAD MASTER

REDUCE TO 7.000 ± .005

CONTRACT NO.		
APPROVALS		DATE
DR	McS	11-'79
CHK		
APPD		
APPD		
APPD		

USGS CALIBRATOR
PROM VERSION

SIZE	CODE IDENT NO
C	-

SCALE | SHEET | OF

NEXT ASSY	USED ON
APPLICATION	

DO NOT SCALE DRAWING

Fig A4-2 EPROM-BASED CALIBRATOR LOADING DIAGRAM

NOTES: UNLESS OTHERWISE SPECIFIED

ADR STATES	CHOP FREQ.	OUT	B7	B6	B5	B4	B3	B2	B1	B0
0-7	21.25	Ref	1	0	0	1	1	1	0	1
8-11	21.25	ID	1	0	0	0	1	1	0	1
12-13	21.25	Grd	1	0	0	0	1	0	0	1
14	21.25	Ref	1	0	0	1	1	1	0	1
15	21.25	Bat	1	0	0	1	1	0	0	1
16	21.25	Temp	1	0	0	1	0	0	0	1
17-21	21.25	Geo	1	0	*	1	0	1	0	1
22	21.25	Aux H	1	0	0	0	0	1	0	1
23	21.25	Aux L	1	0	0	0	0	0	0	1
24-31	5.31	Ref	1	1	0	1	1	1	0	1
32-35	0	ID	0	0	0	0	1	1	0	0
36-39	0	Ref	0	0	0	1	1	1	0	0
40-43	0	Grd	0	0	1	0	1	0	0	0
44-47	0	Geo Stp	0	0	0	1	0	1	0	0
48+	-	Geo	0	0	0	1	0	1	1	0
49-127	-	Geo	0	0	0	1	0	1	0	0

* B5 causes + step (state 18) and then - step (state 20) into geophone

+State 48 clears calibration when B2 goes high state.

Table A4-1

Calibration Code Sequence

CODE NAME	EPROM BIT	NORMAL CONDITION
MUX 0	B2	1
MUX 1	B3	*
MUX 2	B4	1
STEP	B5	*
CHOP	B7	*
CHOP (frequency select)	B6	*
ID (ground select)	B0	*
CALIBRATION CLR	B1	0

*don't care

Table A4-2

EPROM Code - Output Table

Appendix 5

VCO PLL ANALYSIS

As indicated in the VCO electronics section, the PLL circuitry synthesizes a clock frequency sixteen times that of the desired output carrier. This carrier is modulated in three different ways: at power on, by the seismic input signal and during center frequency selection, e.g., from 680 Hz to 1360 Hz.

a) Power On

Initially, when power is applied to the VCO, the VCO frequency is offset from the final VCO frequency by hundreds of Hertz. In response, the phase comparator outputs a series of comparator output pulses whose average value is approximately VCC/2 or 3.2 V as measured at pin 13 of U5. The charging current available to the integrator (U3) is $3.2 \times \frac{R24}{R23 \times R22}$ or

about 3.0×10^{-8} amperes. Since U3 in the settled state has an output voltage of about 1 volt, the time required to charge C11 to 1v is:

$$T \times 3.0 \times 10^{-8} = Q = 1 \text{ volt} \times C11$$

or T = 750 sec. = 12.5 minutes.

Thus the settling time for the loop is limited by the current delivery capacity from U13.

b) Seismic Modulation - Normal Operation

As noted in the VCO circuit section, the seismic signals will not cause any frequency correction. This fact can be seen by writing the expression for the open loop gain G(s) x F(s). Here F(s) is the gain from pin 13 to the integrator output and G(s) is the gain from the integrator output back to pin 13. The relation for F(s) is:

(1) $$F(s) = \frac{\dfrac{\dfrac{(R_{24})\left(\dfrac{1}{SC_{12}}\right)}{R_{24} + \dfrac{1}{SC_{12}}}}{R_{23} + \dfrac{R_{24}\left(\dfrac{1}{SC_{12}}\right)}{R_{24} + \dfrac{1}{SC_{12}}}}}{} \times \frac{\dfrac{1}{SC_{10}}\left(R_{20} + \dfrac{1}{SC_{11}}\right)}{\left(\dfrac{1}{SC_{10}} + \dfrac{1}{SC_{10}} + R_{20}\right) R_{22}}$$

$$F(s) = \frac{1}{R_{22}} \frac{\dfrac{R_{24}}{1 + R_{24} SC_{12}}}{R_{23} + \dfrac{R_{24}}{1 + R_{24} SC_{12}}} \times \frac{R_{20} + \dfrac{1}{SC_{11}}}{1 + \dfrac{C_{10}}{C_{11}} + SC_{10} R_{20}}$$

$$F(s) = \frac{1}{R_{22}} \frac{R_{24}}{R_{23}(1 + R_{24} SC_{12}) + R_{24}} \times \frac{1 + SR_{20} C_{11}}{S(C_{10} + C_{11}) + S^2 C_{10} C_{11} R_{20}}$$

$$F(s) = \frac{1}{R_{22}} \times \frac{R_{24}}{SR_{23} R_{24} C_{12} + R_{23} + R_{24}} \times \frac{1}{S} \times \frac{1 + SR_{20} C_{11}}{C_{10} + C_{11} + S C_{10} C_{11} R_{20}}$$

(2) $C_{10} R_{20} = 1 \quad C_{11} >> C_{10} \quad R_{23} >> R_{27}$

$$F(s) = \frac{1}{C_{11} R_{22}} \times \frac{R_{24}}{R_{23} + SR_{23} R_{24} C_{12}} \times \frac{1}{S} \frac{1 + SR_{20} C_{11}}{1 + S}$$

$$(3) \ (F(s) = \frac{1}{R_{22} R_{23} C_{11}} \times \frac{1}{S} \times \frac{R_{24} (1 + S R_{20} C_{11})}{(1 + S) (1 + R_{24} C_{12} S)})$$

The first term in expression 1) represents the action of the low pass filter-divider R23-R24-C12 while the second term is the transfer function for the integrator U3. Equation 2) is derived using the simplifying assumptions in equation 2).

The relation for G(s) is:

$$G(s) = \frac{K_{vco} \times \frac{1}{MN} \times \frac{1}{R_{18} R_{19} C_8 C_9} \times \frac{2\pi}{5} \times \frac{Vcc}{4\pi} \times \frac{1}{R_{13} C_T}}{S^2 + \left[\frac{1}{R_{18} C_9} + \frac{1}{R_{19} C_8}\right] S + \frac{1}{R_{18} R_{19} C_8 C_9}}$$

Transfer function G(s) includes a low-pass filter which smooths the pulse output of the phase comparator and the factor $\frac{Vcc}{4\pi}$ accounts for the conversion of frequency to phase by the phase comparator. Kvco represents the sensitivity of the VCO and is about 0.3 Hz per nanoampere. The VCO frequency is divided down in the loop by M x N.

The product of G(s) H(s) is the open loop gain. The closed loop transfer function is then given by

$$K(s) = \frac{H(s)\,G(s)}{1 + H(s)\,G(s)} \qquad (5)$$

for $\omega \ll 1$ Hz $K(s) \cong 1$, since the open loop gain at very low frequencies is large, and in particular, $K(s) \approx 1$ for $f < 0.01$ Hz.* The high loop gain is caused by a double pole at the origin in the open loop transfer function. The open loop gain could have following break points on a Bode plot.

1) $f_1 = 1/2\pi = 0.159$ Hz.
2) $f_2 = 0.25$ Hz (caused by R24-C12).
3) $f_3 = 0.007$ Hz (caused by R20-C11).
4) $f_4 = 0$ Hz (integrator pole at the origin).

The unity gain crossover frequency (the point at which the open loop gain could have a magnitude of one) occurs at about 0.01 Hz. Thus for frequencies greater than about 0.01 Hz the open loop gain function is rapidly decreasing, or

$$1 \gg |H(s)\,G(s)|$$

and using this inequality in equation (5) $K(s) \approx 0$ for $s > .0628$ rad/sec. This means that frequencies above 0.01 Hz will be too fast for the loop to follow. Since the band of frequencies the A1VCO can pass starts at 0.1 Hz, the loop will not affect frequencies in the seismic band.

* 0.0628 rad/sec

c) <u>Center Frequency Switching</u>

When the center frequency is switched after the VCO has been powered up for a long period of time (in comparison to the warm-up time) the integrating capacitor is already charged up. Thus the time required to switch to the new frequency is determined by the loop time constant which is about 16 seconds*. The time required to get within 5% of the new center frequency is approximately:

$$2\pi f_c t = 3 \text{ (three time constants)}$$

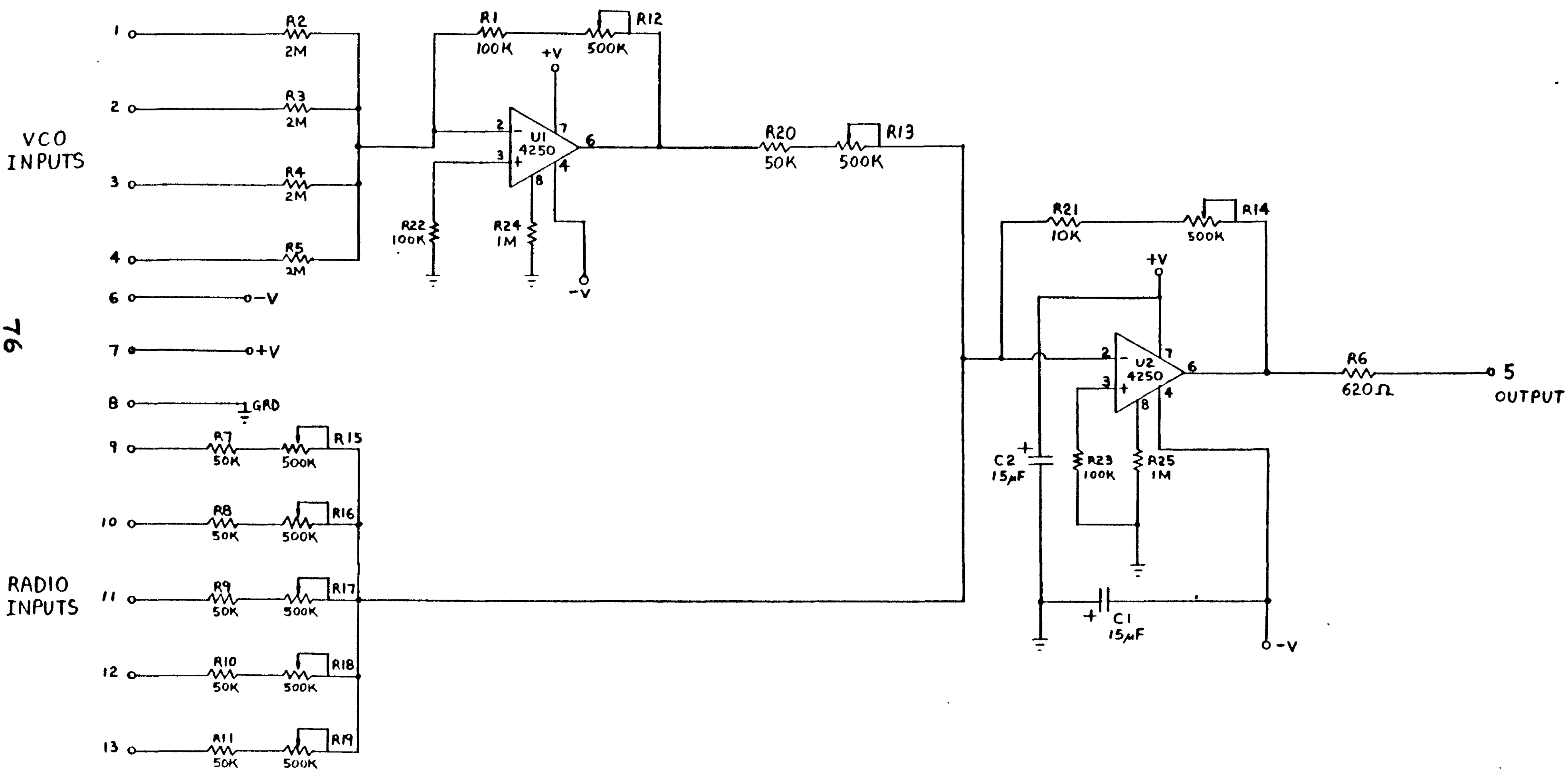
$$(2\pi)(.01)\, t = 3$$

$$t = \frac{\quad}{(.01)(2\pi)} = 45 \text{ seconds}$$

Thus we can see that the loop changes center frequencies much faster than it warms up.

* Loop time constant = $\frac{1}{\omega C} = \frac{1}{2\pi f_c}$, where ω_c is the unity gain loop crossover frequency in radians/second.

ALASKA SUMMING AMPLIFIER



ALL RESISTORS 5% 1/4 WATTS
ALL POTS. : 64W504

FIGURE A6-1 AIVCO SUMMING AMPLIFIER

5/78

APPENDIX 7

GEOPHONE RESISTANCE CALCULATION

The current flowing into the preamp during the step is given by:

$$I_p = \frac{R_G \times V_{cc}}{2.26\ (R_G + 9.28)}$$

where R_G is in kilohms and Vcc is the absolute value of the battery voltage, nominally 3.6 volts.

The compensating current injected to cancel this current is Vcc/6.19 microamperes. The absolute value of the difference of these two currents is a function of the mismatch of the geophone d.c. resistance from its ideal value of 5.34 kΩ. If the geophone had this ideal resistance, then of course the mismatch current would be zero.

Feedback in the preamp forces any mismatch current to flow through the 100 kΩ feedback resistor. The mismatch voltage can then be expressed as:

$$Vm = 10^5\,\Omega \times Im\ \mu V$$

where Im is a mismatch current or

Vm = 100 Im millivolts, where Im is expressed in microamperes.
An equation can now be set up to relate the amplitudes of the mismatch voltage to the amplitude of the battery during the chopped part of the calibration:

$$138\ \frac{A_Z}{A_R} = 2 \times 100 \times \left(\frac{1}{6.19} - \frac{R_G}{2.26\ (R_G + 9.28}\right) \times 3.64\ \frac{A_B}{A_R}$$

Here A_R is the amplitude of the chopped reference voltage and A_Z/A_B is the ratio of the amplitude of the chopped mismatch voltage to the amplitude of the chopped battery voltage. If $A_Z = 0$, then there is no imbalance or mismatch. The factor of two enters the equation due to chopping

When the above equation is evaluated for R_G the following relation results:

$$R_G = \frac{5.34 + 6.26\ \frac{A_Z}{A_B}}{1 \pm 0.675\ \frac{A_Z}{A_B}}$$

The plus or minus sign is necessary since the mismatch can be in either direction. In order to determine from the calibration which sign to use, the phase of the chopped reference is compared to the phase of the chopped mismatch voltage. If these two signals are in phase, then both are chopping a positive signal and the balancing current is too large, implying that the geophone resistance is too small and the negative sign in the numerator and positive sign in the denominator in the equation for R_G should be used.

Table A 7-1 gives R_G for several A_Z/A_B ratios.

A_Z/A_B	R_G (Kilohms)
0	5.34
+0.1	4.42
-0.1	6.40
+0.2	3.60
-0.2	7.62

TABLE A7-1

Table of Geophone Resistance for several values of A_Z/A_B

Appendix 8

A1VCO TEST PROCEDURE

BOARD SCREENING

In screening all boards are run through a detailed series of tests. Each board has a number, e.g., VCO-017, which corresponds to a section in a log book. After the boards have been tested, there are 2 groups: those that have passed and those which have one or more problems. Test results are recorded on special forms and all problems corresponding to a board are kept for reference during repair. All boards are given an initial room temperature screening before any are temperature cycled. Finally the entire unit is assembled and then tested at room temperature and in the environmental chamber. If any specification is not met during a test the board or unit is flagged by circling the test failed in red ink on the test form.

VCO SCREENING

VCO screening is aided by using a specially designed VCO testing circuit. This circuit (see Fig. A8-1 and A8-2) contains decoding, channel select logic and switching which allows 5 VCO's to be tested together. The results of all tests are recorded on the sample form shown in Figure A10-3.

As can be seen from the test form there are ten items which require test data. These will now be described in order. The first 7 items are done with MODIN grounded.

1) A subjective evaluation of the FM carrier quality while VCO is shifting frequency on its way to 1700 Hz. It should stabilize in less than 15 minutes. If not, a "special comment" should be made.

VCO TESTING CIRCUIT

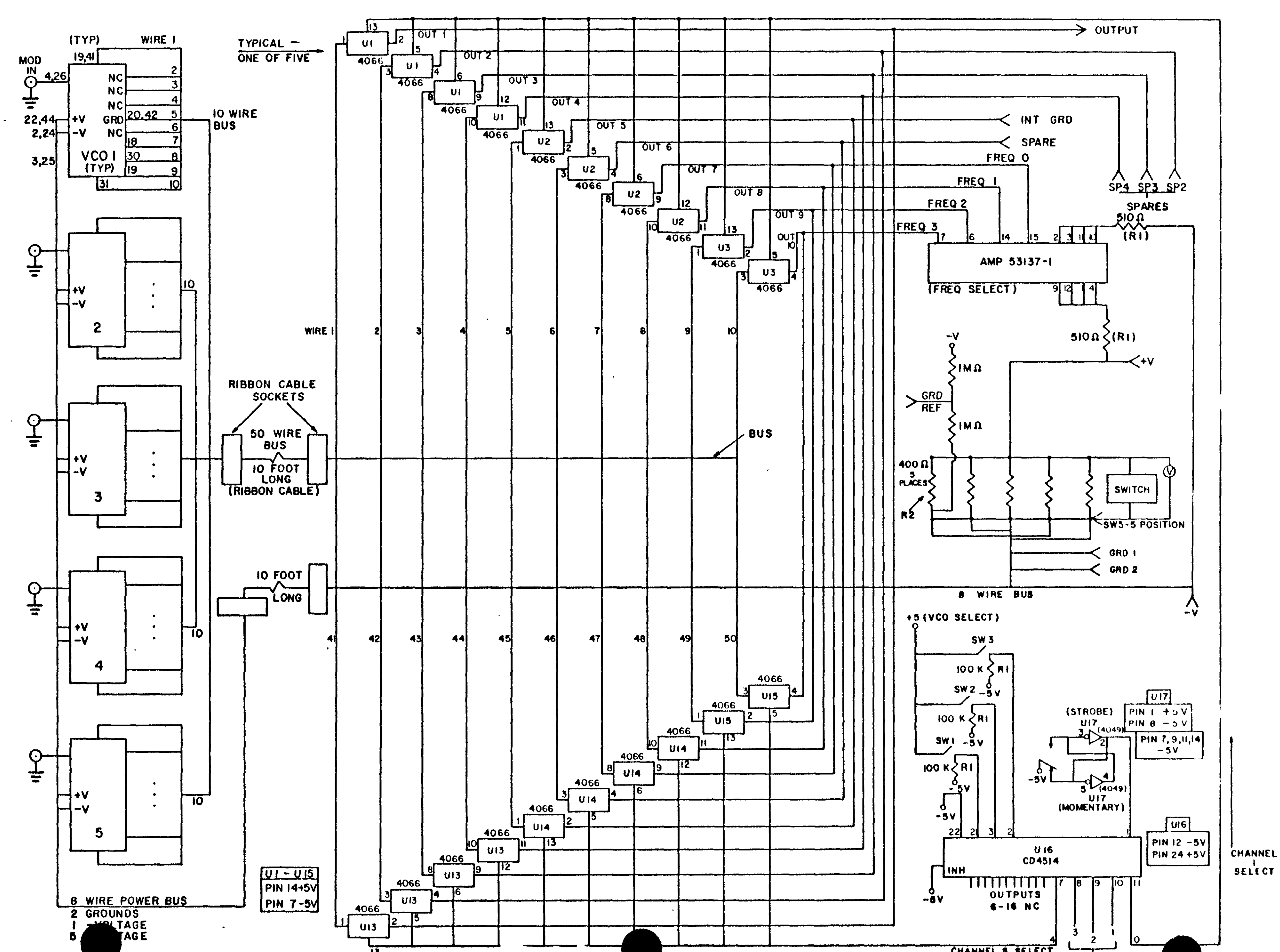


Figure A 8 -1 VCO Test Procedure

VCO PART LOCATION DIAGRAM

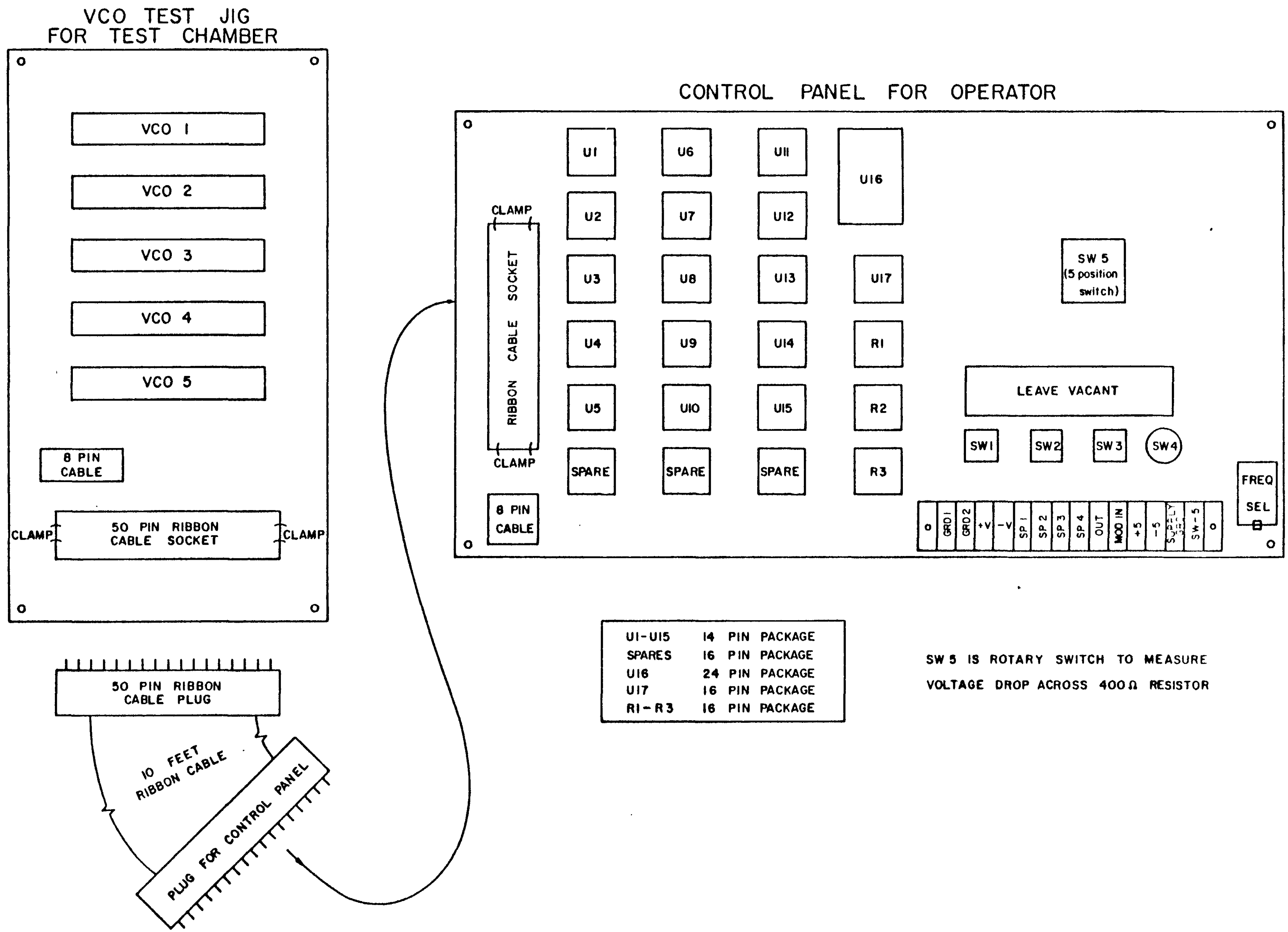


Figure A 8 -2[illegible]0 Test Procedure

Date:

BOARD NO:

FIGURE A8-3

VCO BOARD TEST SHEET

Test Item	25°C	+40°C	-40°C	Normal Result
1. Output quality				Good
2. Second harmonic		--	--	-50db
3. Third harmonic		--	--	-50db
4. Highest harmonics		--	--	-30db
5. Current drain				
340 Hz				260 A
680				280
1020		--	--	300
1360		--	--	320
1700				340
2040		--	--	360
2380		--	--	380
2720		--	--	400
3060				420
6. Ground assymetry				35 mV
7. FM noise (@1700)				40 mV
8. % Dev. change/1700 Hz Ref.				10%
9. Output level				
340				4v p-p
680				4v p-p
1700				4v p-p
3060				3.6 $\pm$ 0.1 v p-p
10. Recovery	--		--	OK

Special Comments:

2, 3, 4) Use spectrum analyzer to quantify harmonic distortion. If a Tectonix 5L4N plug-in is used the following will be applicable:

a) Input attenuator (external).

b) Frequency select dial set to lowest value.

c) "Display": on.

"CTR": out, for starting display at left 10 dB/div.

d) Input termination: 1 M-ohm

e) Log scale: 10 dB/div.

f) Input: single ended.

g) Span/div: 10 k

h) Sec/div: 10 msec.

i) Chop, video filter 300 and 10 Hz; freq. mode; 5kHz comb; Trig GEN-all out.

Frequency is set to 1700 Hz. Record levels in dB of second, third and highest harmonic (after VCO has stabilized to 1700 Hz). This test is only done at room temperature, which is about 25° C.

5) Current drain is noted for all 9 channels at room temperature, but only for a subset in the environmental chamber (as indicated on test sheet). Check that frequency will stabilize at assigned values.

6) Ground asymmetry is calculated by taking the absolute value of the positive battery voltage referenced to ground and then subtracting the ground voltage referenced to the negative voltage.

7) FM noise is measured from the test discriminator output.

8) Place MODIN switch in grounded position. Input a 5.5 volt p-p sinewave at MODIN at 10 Hz. This should be accurate to ±1% so a DMM will be necessary to properly set signal generator as resolution of an oscilloscope would only be about 0.2 volts p-p, (about 5%). Since most DMM's have rolloffs near 10 Hz, the DMM must be calibrated first at 10 Hz on its AC scale. For

the Data Precision DMM 3500 the signal read on the a.c. scale should have the same value as at 100 Hz. If not, adjust the DMM to 5.5 vp-p (1.94 v rms) at 100 Hz and then turn frequency back down to 10 Hz. Note this voltage in volts rms. All tests requiring a 5.5 v p-p sinewave at 10 Hz should now produce this value. Periodically check the signal generator output to verify correct output level. On the test discriminator a 20 v p-p sinewave corresponds to 6.17 volts rms on the Data Precision 3500 due to DMM rolloff (a 20 v p-p sinewave is actually 7.07 v rms).

The VCO is then set to deviate so that 6.17 volts rms is produced at DISC output when the 5.5v p-p is applied at MODIN. Switch the frequency to 340 Hz andk then 3060 Hz. Note the DISC output for both cases. Then readjust the deviation at 1700 Hz according to:

$$\Delta \text{DEV} = \frac{\text{LARGER (A, B) - 6.17}}{2}$$

where A and B are DISC output in volts, rms and the larger function selects the larger of A and B. Both A and B should be greater than 6.17 V rms. The term Δ DEV is the amount the deviation at 1700 Hz is to be reduced by. Once this is done, recheck the DISC output at 340 and 3060 Hz. The percent change is given by:

$$\text{percent change} = \frac{\text{Larger deviation at (340, 3060 Hz) - deviation at 1700 Hz}}{\text{deviation at 1700 Hz}}$$

In all cases check the DISC output for distortion. If any distortion appears, make a special comment.

9. Check output level at indicated frequencies on oscilloscope.

10. At 100°F turn off power for two minutes, then turn power back on and check that each board comes back up to correct frequency.

CALIBRATOR SCREENING

A special semi-automatic calibrator board tester is used to compare the various logic level outputs of the boards under test to that of a known working board. If any logic level differs at any time during the 144 second calibration cycle, this information is latched and an LED is illuminated. The diagram for this tester is shown in Figures A8-4 and A8-5. A reset switch is used to clear all flip-flops. The "External Input Circuit" automatically toggles in sequence the inputs from the fourth board illuminating an LED if operation is correct.

An external signal generator is used as a fast clock and is set to 2700 Hz so the cycling of the boards takes only about 5 seconds. Current is measured in the quiescent mode and during calibration. Figure A8-6 is the test sheet used for these boards.

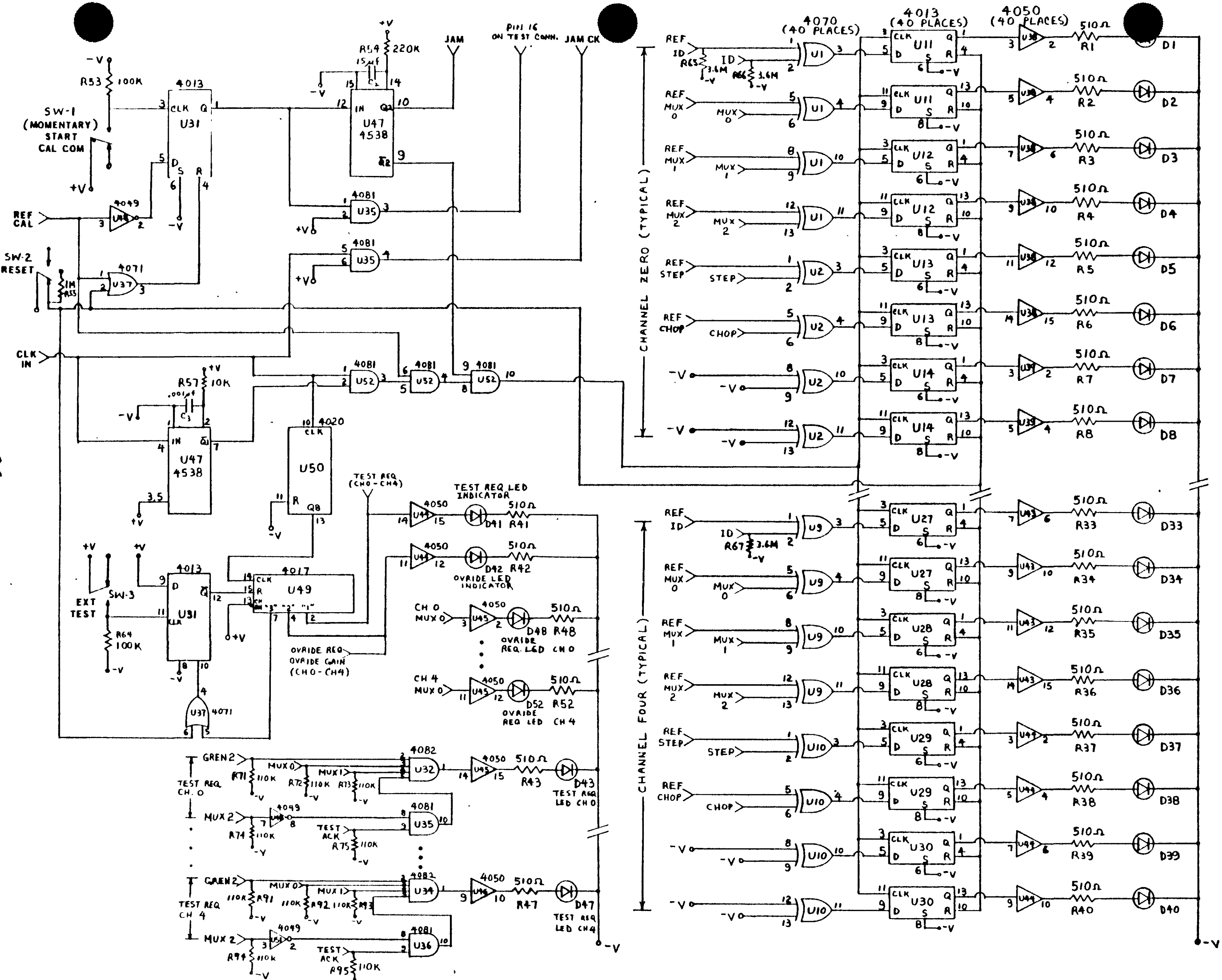


FIGURE A8-4 CALIBRATION COMPARATOR CIRCUIT

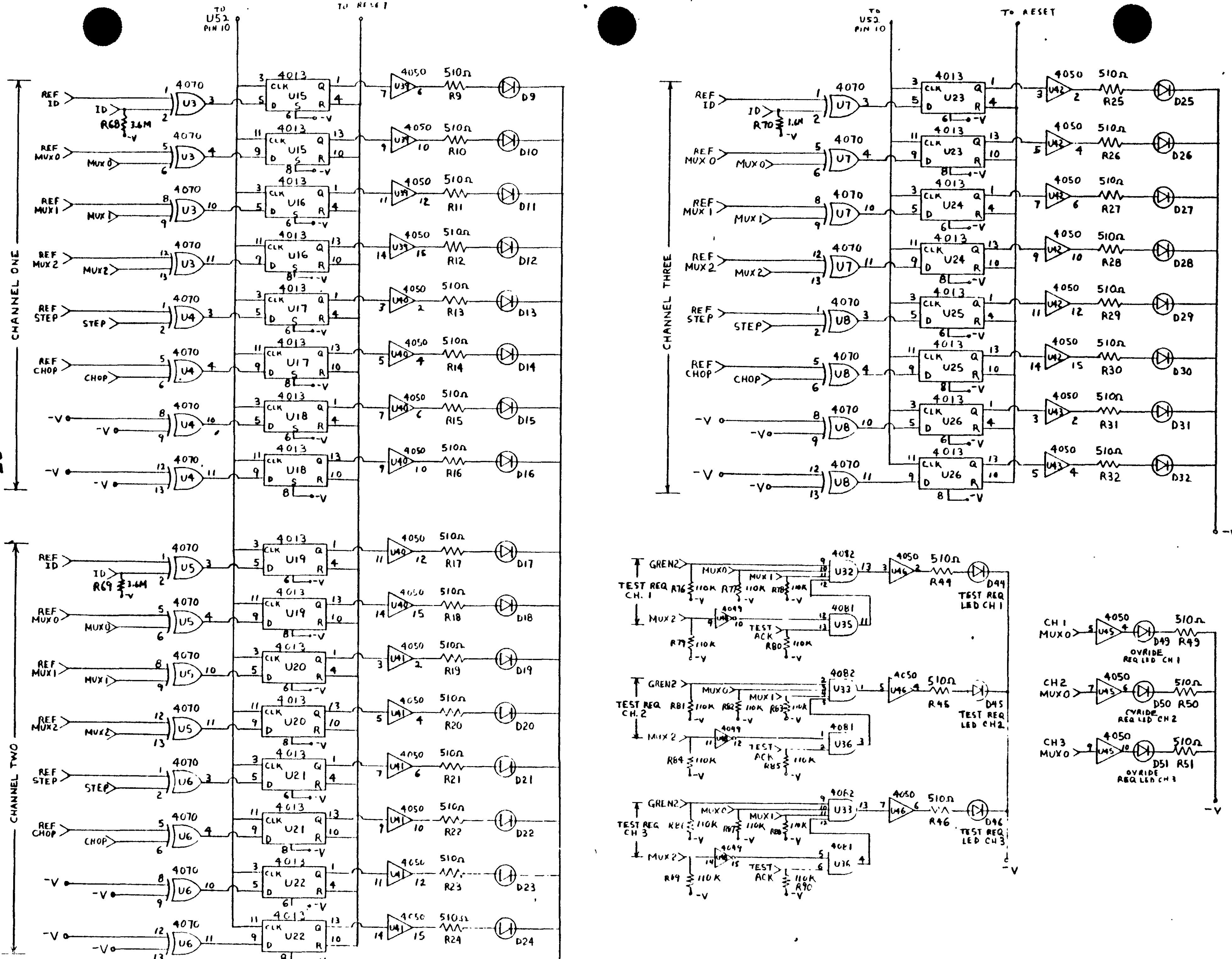
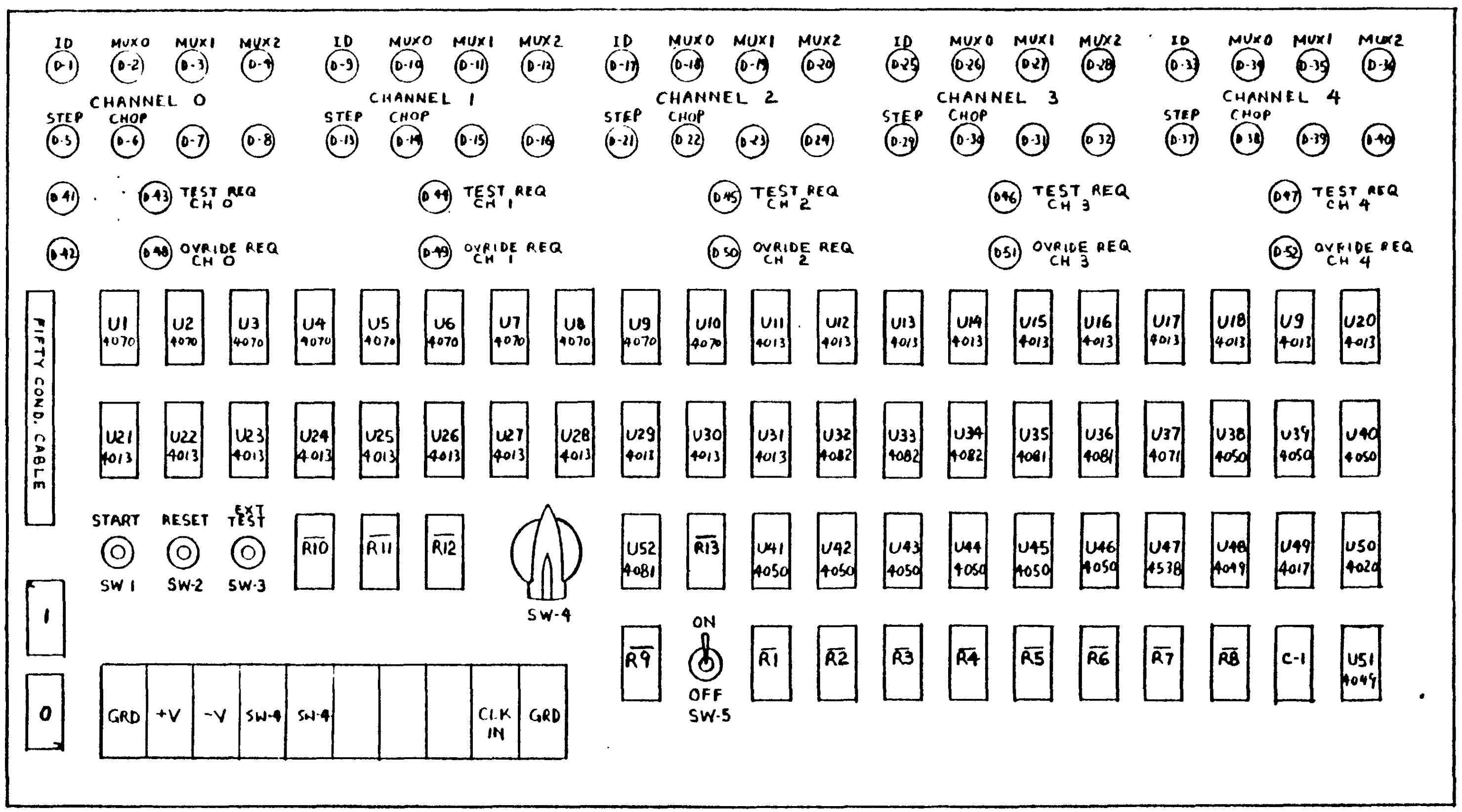


FIGURE A8-5 CALIBRATION COMPARATOR CIRCUIT



R1 : R1-R8 · 510Ω
R2 : R9-R16 · 510Ω
R3 : R17-R24 · 510Ω
R4 : R25-R32 = 510Ω
R5 : R33-R40 : 510Ω
R6 : R41-R48 · 510Ω
R7 : R49-R52 · 510Ω
R53 = 100K
R54 = 220K
R55 = 1M
R56 = TRIM

R8 : R57 = 10K
R58-R61 = TRIM
R64 = 100K

R9 : R65-R70 = 3.6M
R10 : R71-R78 = 110K
R11 : R79-R86 = 110K
R12 : R87-R95 = 110K

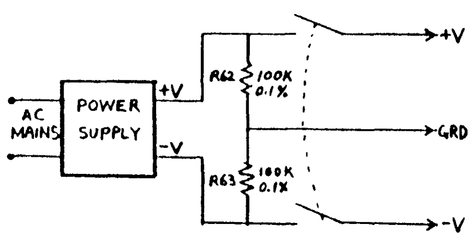


FIGURE A8-5a LOADING DIAGRAM FOR CALIBRATION COMPARATOR CIRCUIT

DATE:

BOARD NO:

FIGURE A8-6

CALIBRATOR BOARD TEST SHEET

Test Item	25° C	+ 40°C	- 40°C	Normal Result
MUX 0				OK
MUX 1				OK
MUX 2				OK
Step				OK
Chop				OK
ID				OK
TEST REQ.				OK
OVRIDE REQ.				OK
Quiescent current				Less than 10 Microamperes
Calibration current				Less than 20 microamperes

Special comment:

PRE-AMP SCREENING

The preamplifiers are tested using a special jig which contains one LED per channel as an indication of the state of GR. VREF and VTEMP are brought out to allow for monitoring of these voltages remotely. The test sheet (Fig. A 8-7) contains 19 items which will now be described.

1, 2) +VBATT and -VBATT refer to the batteries powering the preamps.

3) Set switch to chop cont, gain to 7 and adjust R13, the offset potentiometer to minimum output at MOD out. Record GEOOUT. Inputs should be terminated in 5.34 KΩ resistors. Disable CHOP CONT mode.

4a) Measure p-p input noise (still with 5.34 K source resistors) with an oscilloscope set to sweep at 0.5 sec/cm. Noise referred to input is peak-to-peak reading divided by 44000.

4b) Remove source resistors and input a 200 mV p-p 60 Hz sinewave as a common mode signal referred to ground.

Calculate CMRR using:

$$CMRR = \frac{200}{GEOOUT}$$

where GEOOUT is in millivolts, p-p.

5) Adjust VREF potentiometer to $\pm$ 0.1%.

6) Check accuracy of battery voltage according to formula:

$$VBATT = \frac{VALUE}{3.64} \times 138 \text{ mV}$$

where value is the plus voltage of the battery measured in part 1).

7) Set VTEMP using accurate thermometer at room temperature. The temperature voltage should be compared to the ideal using:

$VTEMP = \frac{138}{300} (^{o}C + 273)$ where ^{o}C is the temperature in degrees Centigrade inside the chamber.

8, 9) During the temperature tests record the actual temperature using a thermometer and a precision temperature probe.

10) Set MODIN to 16mV p-p at 10 Hz. Note MODOUT and then raise input by 20 dB and note MODOUT again. Calculate the ratio of the two above outputs.

11, 12) Find the high threshold for GR by increasing the signal from 16 mV to 38 mV. GR occurs when the LED is illuminated. The low threshold is obtained by lowering the voltage back down to 16 mV.

13) Measure linearity of the amplifier by applying a signal through attenuators with the gain set as indicated. The signal is set to 16 mV p-p at 10Hz. Measure the output on the DMM and convert to p-p values.

14) Measure current drain and convert to microamperes.

15, 16) Set input signal level to 16 mV p-p. Monitor output on oscilloscope. Go up and then down in frequency until output is 0.707 times 5.5 volts p-p (3 db points). Note the two corner (3 db) frequencies.

17, 18, 19) Toggle GRCD, GRENL and GREN 2 and check to see that the GR code is disabled and for GREN1 and GREN 2 that GR is disabled.

DATE:

BOARD NO:

FIGURE A8-7

PREAMP BOARD TEST SHEET

Test Item	25°C	+ 40°C	- 40°C	Normal Result
1. +VBATT		--	--	+3.64 ± 0.04
2. -VBATT		--	--	-3.64 ± 0.04
3. GEOOUT		--	--	Less than 10 V
4a. Input Noise				Less than 5 V
4b. CMRR				100 or more
5. VREF				138 ± 0.5%
6. VBATT		--	--	Value ± 1%
7. V TEMP				Value ± 2%
8. Probe resistance				
9. Actual temperature (°C)				
10. Gain range attn.		--	--	Ratio = 10± 1%
11. Gain range HI thresh.				35 mV ± 3 mV
12. Gain range LO thresh.				17 mV ± 2 mV
13. Linearity				

Gain (db)	Attn. (db)	Normal Result
0	0	5.5 v p-p ± 1%
6	6	5.5 v p-p ± 1%
12	12	5.5 v p-p ± 1%
18	18	5.5 v p-p ± 1%
24	24	5.5 v p-p ± 1%
30	30	5.5 v p-p ± 1%
36	36	5.5 v p-p ± 1%
42	42	5.5 v p-p ± 1%

DATE:

BOARD NO:

FIGURE A8-7 (Continued)

PREAMP BOARD TEST SHEET

Test Item	25°C	+ 40°C	- 40°C	Normal Result
14. Current drain				Less than 100 A
15. Hi freq. cutoff		--	--	30 Hz ± 2 Hz
16. Lo freq. cutoff		--	--	0.1 Hz ± 0.2 Hz
17. GRCD		--	--	No
18. GREN1		--	--	No
19. GREN2		--	--	No

Special comments::

A1VCO UNIT SCREENING

The assembled A1VCO is now tested as a unit, first at room temperature and then in the environmental chamber. A special test jig allows up to 6 A1VCO units to be tested during one temperature run. The ID switch should be set to the proper code.

The unit screening consists of 6 parts which will now be described. The form used is shown in Figure A8-8.

1) The current drain is measured at the four indicated frequencies. Make a special note of any distortion on FM output. The seismic input is shorted.

2) Using the ID decoder check to see that ID code and gain code are correct.

3) Using attenuators and 16 mV signal to verify that output remains fixed as the gain switch position is increased from 0 to 7. The correct level is 20 v p-p ± 0.2 v p-p.

4) Using seismometer as an input signal source verify on chart recorder that calibration is normal.

5) Check for normal sesimic signal before and after calibration.

6) Tap seismometer and verify that unit goes into GR, produces the GR code at proper time, and comes out of GR.

7) Replace input signal with 5.34 K-ohm resistor and measure p-p output on oscilloscope.

FIGURE A 8-8

Date:

UNIT NO:

A1VCO UNIT SCREENING

TEST ITEM	25°C	+40°C	-40°C	NORMAL RESULT
1) Current drain				
340		---	---	350 A
1020		---	---	390 A
1700		---	---	450 A
3060		---	---	510 A
2) ID Code		---	---	Correct ID
3) GAIN				
0		---	---	Correct level
1		---	---	Correct level
2		---	---	Correct level
3		---	---	Correct level
4		---	---	Correct level
5		---	---	Correct level
6		---	---	Correct level
7		---	---	Correct level
4) Calibration	---			OK
5) Seis Output	---			OK
6) Gain range	---			OK
7) Noise		---	---	Less than 40 mV p-p

Figure A 8-8

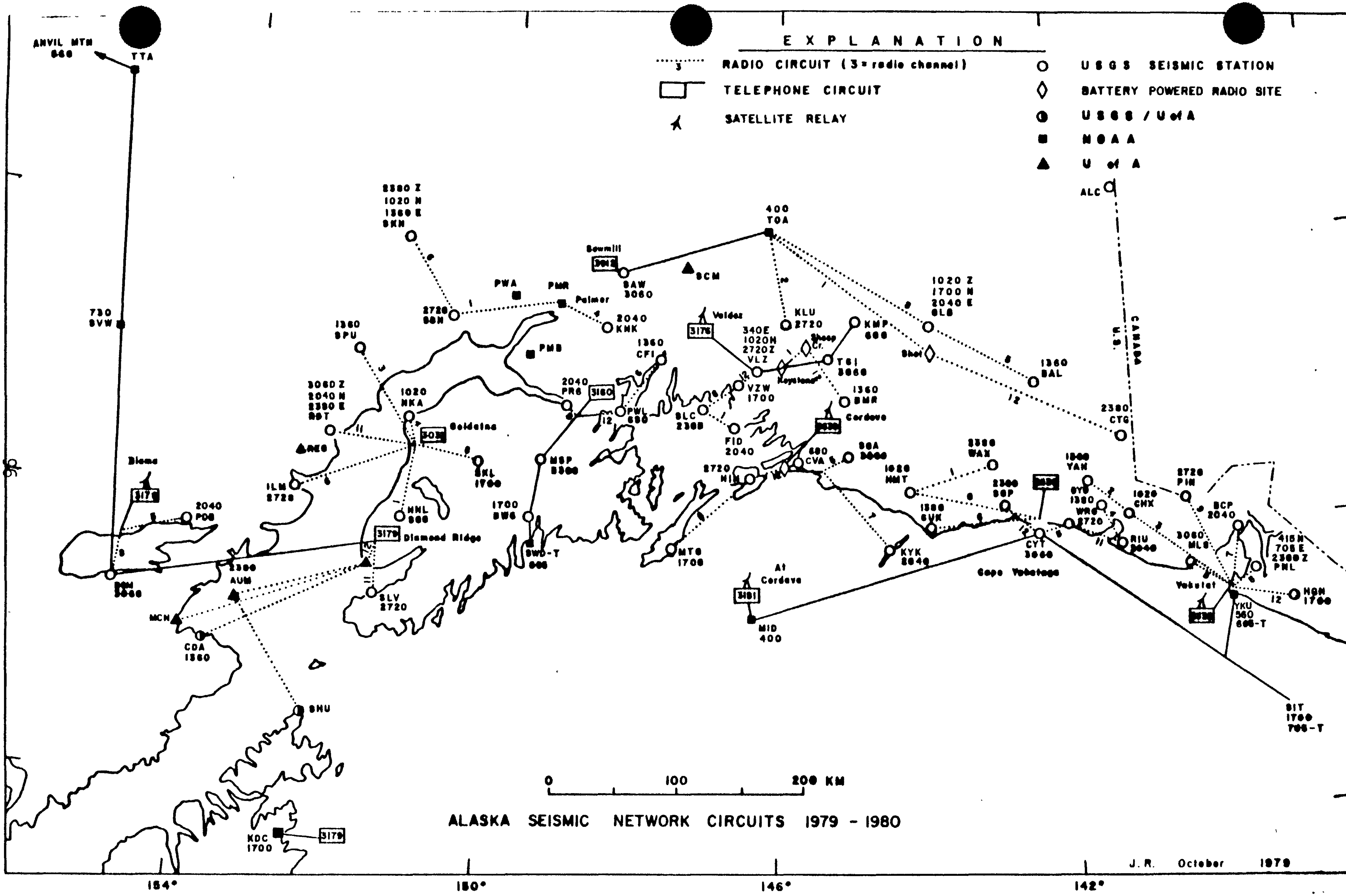


Figure A9-1 Alaska Seismic Stations with A1VCO

SEISMIC STATIONS

CODE	Map 250K 63K	LOCATION LAT N	LONG W	ELEV (ft.)	TX RF	TX AZM	RX RF	RX AZM	TX ANT POL	TX ANT VAR	RX ANT POL	RX ANT VAR	COMP	POWER OTHER	(CODE)
ALC	NABS (C1)	62 37.35	141 00.50	1910	-	-	Helicorder at site				-	-	Z	AC+B	ALC
BAL	MCTY (B7)	61 02.17	142 20.67	4266	5	N59W	-	-	H	YAG	-	-	Z	B/SMA	BAL
BCP	YAKU (D5)	59 57.22	139 38.07	1300	7	S05W	-	-	V	YAG	-	-	Z	B	BCP
BGM	ILIAM (B6)	59 23.62	155 13.50	2010	9	N24E	-	-	H	LOG	-	-	Z	B	BGM
BMR	CORD (D2)	60 57.51	144 34.98	4150	12	N74W	-	-	H	LOG	-	-	Z	B	BMR
CFI	ANCH (A3)	61 10.96	147 45.99	10	6	S40W	-	-	H	YAG	-	-	Z	B	CFI
CHX	BERING GL	60 03.75	141 07.10	3600	3	S55E	2	N45W	V	LOG	H	LOG	Z	B	CHX
CTG	BERING GL	60 57.99	141 19.86	5080	12	N73W	-	-	H	YAG	-	-	Z	B	CTG
CVA	CORD (C5)	60 32.85	145 44.8	295	-	-	Land Line -			-	-	-	Z	B	CVA
CYT	BERGL (A4)	60 04.47	142 24.68	1060	-	-	Land Line -			-	-	-	Z	B	CYT
FID	CORD (C7)	60 43.73	146 35.63	1600	1	N55W	-	-	H	YAG	-	-	Z	B	FID
GLB	MCTY (B8)	61 26.50	143 48.66	2772	8	N58W	5	S60E	H	YAG	H	YAG	NZE	B	GLB
GLC	SEWRD (D1)	60 53.44	147 04.38	10	8	N56E	1	S55E	H	YAG	H	YAG	Z	B	GLC
GYO	BERGL (A2)	60 08.78	141 28.29	600	4	S24E	-	-	H	YAG	-	-	Z	B/SMA	GYO
HIN	CORD (B7)	60 23.81	146 30.10	2005	12	N67E	B	S45W	V	YAG	H	LOG	Z	B	HIN
HMT	CORD (B1)	60 20.19	144 15.64	2034	8	S73E	1	N81E	H	LOG	H	LOG	Z	B	HMT
HQN	YAKU (B3)	59 27.15	138 52.58	1220	12	N78W	-	-	V	YAG	-	-	Z	B	HQN
ILM	KENAI (A8)	60 10.92	152 48.97	1804	6	N69E	-	-	H	LOG	-	-	Z	B	ILM
KLU	VALDZ (B6)	61 29.57	145 55.27	3350	2	N81W	-	-	H	YAG	-	-	Z	B	KLU
KMP	VALDZ (C3)	61 30.78	145 01.08	3750	-	-	Land Line -			-	-	-	Z	B	KMP
KNK	ANCH (B4)	61 24.75	148 27.34	1952	4	N60W	-	-	H	YAG	-	-	Z	B	KNK
KYK	MID (OID2)	59 52.09	144 31.39	1230	7	N37W	-	-	H	LOG	-	-	Z	B	KYK
MLS	YAKUTAT	59 46.07	140 08.88	10	5	S43E	-	-	V	YAG	-	-	Z	B	MLS
MSP	SEWARD (B7)	60 29.35	149 21.64	492	-	-	Land Line -			-	-	-	Z	B	MSP
MTG	BLY (OID2)	59 54.71	147 29.87	102	8	N45E	-	-	H	YAG	-	-	Z	B	• MTG
NKA	KENAI (C4)	60 44.52	151 14.23	328	4	S19E	-	-	H	YAG	-	-	Z	B	NKA
NNL	KENAI (A4)	60 02.53	151 17.78	1201	1	N12E	-	-	H	YAG	-	-	Z	B	NNL
PDB	ILIAM (D4)	59 47.27	154 11.57	1000	5	S85W	-	-	H	LOG	-	-	Z	B	PDB
PIN	M+S+ELIAS	60 05.85	140 15.30	3199	9	S26E	-	-	V	YAG	-	-	Z	B	PIN
PNL	YAKU (C4)	59 40.06	139 23.82	1920	8	S52W	-	-	V	YAG	-	-	NZE	B	PNL
PRG	SEWRD (D6)	60 51.83	149 01.27	100	8	S42E	-	-	V	YAG	-	-	Z	B	PRG
PWL	SEWRD (D4)	60 51.56	148 20.02	1801	12	S65W	6	N40E	V	YAG	H	LOG	Z	B	PWL
RDT	KENAI (C7)	60 34.43	152 24.37	3051	11	S86E	-	-	H	LOG	-	-	NZE	B	RDT
RIU	ICY BAY	59 52.70	141 13.71	49	11	N68W	4	N24W	H	YAG	H	YAG	Z	B	RIU
SAW	ANCH (D4)	61 48.49	148 19.98	2428	-	-	Land Line -			-	-	-	Z	B	SAW
SGA	CORD (C4)	60 32.04	145 12.39	1391	5	S73W	-	-	H	YAG	-	-	Z	B	SGA
SKL	KENAI (C1)	60 30.85	150 12.96	2130	8	N87W	-	-	H	LOG	-	-	Z	B	SKL
SKN	TYONK (D5)	61 58.82	151 31.78	1850	6	S36E	-	-	H	YAG	-	-	NZE	B	SKN
SLV	SELDV (B5)	59 28.28	151 34.83	300	11	N01W	-	-	H	YAG	-	-	Z	AC	SLV
SPU	TYDNK (A6)	61 10.90	152 03.27	2625	3	S55E	-	-	H	LOG	-	-	Z	B	SPU
SSN	TYO (B2B3)	61 27.83	150 44.60	4255	1	N81E	6	N36W	H	LOG	H	LOG	Z	B	SSN
SSP	BERING GL	60 10.80	142 50.30	1500	12	S61E	-	-	H	YAG	-	-	Z	B/SMA	SSP
SUK	BERING GL	60 03.32	143 47.31	980	6	N89E	-	-	H	YAG	-	-	Z	B	SUK
SWD	SEWRD (A7)	60 06.22	149 26.93	300	-	-	Land Line -			-	-	-	Z	B	SWD
TSI	VALDZ (A4)	61 13.57	145 20.24	3652	-	-	Land Line -			-	-	-	Z	B/SMA	TSI
VLZ	VALDZ (A7)	61 07.89	146 19.92	33	-	-	Land Line -			-	-	-	NZE	B	VLZ
VZW	VALDZ (A7)	61 03.54	146 03.24	2612	12	N55E	8	S56W	H	LOG	H	LOG	Z	B	VZW
WAX	BERING GL	60 26.91	142 51.06	3199	1	S81W	-	-	H	YAG	-	-	Z	B	WAX
WRG	BERGL (A3)	60 02.27	142 01.90	1804	5	N82W	11	S68E	H	YAG	H	LOG	Z	B	WRG
YAH	BERING GL	60 21.32	141 43.89	7300	2	S45E	-	-	H	YAG	-	-	Z	B	YAH

RELAYS

NAME	MAP 250K 63K	LOCATION LAT N	LONG W	ELEV ft.	TX RF	TX AZM deg.	RX RF	RX AZM deg.	TX ANT POL-VAR	RX ANT POL-VAR	PW / OT
SHEEP CREEK	VALZ (A6)	61 08.66	145 55.00	5700	01	S33E	12	S74E	H - LOG	H - LOG	B
SHOT	MCTY (B7)	61 17.12	143 23.21	5611	01	N59W	12	S73E	H - YAG	H - YAG	B
U of A Trailer	SEL (C5)	59 39.48	151 39.07	600	12	N57E			H - YAG		AC
YAKUTAT FAA	YAKU (C5)	59 32.59	139 43.66	BO	11	S62W			H - YAG		AC

RECEIVE SITES

NAME	MAP 250K 63K	LOCATION LAT N	LONG W	ELEV (ft.)	RX RF	AZM	RX ANT POL	RX ANT VAR	POWER / OTHER	SIGNAL FROM
CAPE YAGATAGA	BERGL (A4)	60 04.13	142 25.85	75	12	N61W	H	YAG	AC	SSP
					5	S82E	H	YAG		WRG
					6	S89W	H	YAG		SUK
					8	N73W	H	YAG		HMT
CORDOVA ES	CORD (C5)	60 32.85	145 44.80	295	12	S67W	V	YAG	B	HIN
CORDOVA 13 Mile	CORD (B4)	60 29.68	145 28.18	65	5	N73E	H	YAG	AC	SGA
					7	S37E	H	YAG		KYK
DIAMOND RIDGE	SELDV (C5)	59 40.63	151 35.62	1080	12	S57W	H	YAG	AC	U of A Trlr
					11	S01E	H	YAG		SLV
ILIAMNA	ILIAM (D6)	59 45.22	154 54.51	183	5	N85E	H	YAG	AC	PDB
					9	S24W	H	YAG		BGM
KEYSTONE	VALDZ (A5)	61 03.66	145 48.42	4060	1	N33W	H	LOG	B	Sheep Ck
PALMER	ANCH (C6)	61 35.92	149 07.98	250	1	S81W	H	YAG	AC	SSN
					4	S60E	H	YAG		KNK
PORTAGE	SEWRD (D6)	60 50.44	148 58.68	25	8	N42W	H	YAG	AC	PRG
SOLDOTNA	KENAI (C3)	60 31.88	151 04.95	230	8	S87E	H	YAG	AC	SKL
					11	N86W	H	YAG		RDT
					1	S12W	H	YAG		NNL
					6	S69W	H	YAG		ILM
					4	N19W	H	YAG		NKA
					3	N55W	H	YAG		SPU
TOLSONA	GULKA (A5)	62 06.31	146 10.17	3024	8	S58E	H	YAG	AC	GLB
					1	S59E	H	YAG		SHOT
					2	S81E	H	YAG		KLU
VALDEZ ES	VALDZ (A7)	61 07.89	146 20.17	50	12	S55W	H	YAG	AC	VZW
WHITTIER	SEWRD (D5)	60 46.67	148 41.47	50	12	N65E	V	YAG	AC	PWL
YAKUTAT	YAKU (C5)	59 32.59	139 43.66	150	3	N55W	H	YAG	AC	CHX
					5	N43W	H	YAG		MLS
					9	N26W	H	YAG		PIN
					7	N05E	H	YAG		BCP
					8	N52E	H	YAG		PNL
					12	S78E	H	YAG		HQN
YAKUTAT ES	YAKU (C5)	59 32.50	139 43.95	80	11	N62E	H	YAG	AC	YAKU-FAA

KEY

250K 1:250000 scale
63K 1:63360 scale
TX Transmitter
RX Receiver
AZM Azimuth from station
ANT Antenna
POL Polarization
V Vertical
H Horizontal
VAR Variety (antenna)
YAG Yagi
LOG Log--periodic

COMP Component(s)
Z Vertical
N North-South
E East-West

AC Standard Power Line
B Battery
SMA Strong Motion
Accelerograph Station

Figure A9-2 Alaska Seismic Stations with A1VCO - list

APPENDIX 10
PREAMP

Component	Position	Quan	Value Tolerance	Voltage/ Temp.Spec.	Manufacturer/ Part #	Type
Resistor	R1,25,26, 28,82,35, 27	7	10 M 5%		R-OHM	
Resistor	R2,10,85, 86	4	511OHM 1%		Corning RN55D	
Resistor	R3 (TRIM)	1	261 K 1%	100 PPM/Co	Allen Bradley RN55D	
Resistor	R4, 9	2	6.19 M 1%	100 PPM/Co		
Resistor	R5, 8	2	2.26 M 1%	100 PPM/Co		
Resistor	R6, 7	2	4.64K 1%	100 PPM/Co	Corning RN55D	
Resistor	R11,12, 14,15,80	5	100K 1%	100 PPM/Co	Corning RN55D	
POT	R13	1	5K		Spectrol 43W502	
Resistor	R16	1	2.61K 1%	100 PPM/Co	Corning RN55D	
Resistor	R17	1	42.2K 1%	100 PPM/Co	Corning RN55D	
Resistor	R18,30,33, 68, 71	5	511K 1%	100 PPM/Co	Allen Bradley RN55CC	
Resistor	R19, 77	2	5.6M 5%		R-ohm	
Resistor	R20	1	31.6K 1%	100 PPM/Co	Allen Bradley RN55CC	
Resistor	R21,91,92	3	100M 5%		Allen Bradley RN55CC	
Resistor	R22	1	23.7K 1%	100 PPM/Co	Corning RN55D	
Resistor	R23	1	90.9K 1%	100 PPM/Co	Corning RN55D	
Resistor	R24,87-89	1	10K 1%	100 PPM/Co	Corning RN55D	

APPENDIX 10 (continued)
PREAMP

Component	Position	Quan.	Value Tolerance	Voltage/ Temp.Spec.	Manufacturer/ Part #	Type
Resistor	R29,31	2	47M 5%			
Resistor	R32	1	562K 1%	100 PPM/Co	Allen Bradley RN55CC	
Resistor	R34,44,-49, 62,65,76, 81,83,84	13	1M 1%	100 PPM/Co	Allen Bradley RN55CC	
Resistor	R36, 74	2	681K 1%	100 PPM/Co	Allen Bradley RN55CC	
Resistor	R37-R43, R50	8	499K 1%	100 PPM/Co	Allen Bradley RN55CC	
Resistor	R51	1	1M 0.1%	25 PPM/Co	TRW RN55E	
Resistor	R52	1	100K 0.1%	25 PPM/Co	TRW RN55E	
Resistor	R53	1	51.1K 1%	100 PPM/Co	TRW RN55E	
Resistor	R54	1	46.4K 0.1%	25 PPM/Co	TRW RN55E	
Resistor	R55	1	121K 0.1%	25 PPM/Co	TRW RN55E	
POT	R56	1	200K		Spectrol 43 W 204	
Resistor	R57	1	3.3M 5%			
Resistor	R58	1	56.2K0.1%	25 PPM/Co	TRW RN55E	
POT	R59	1	20K		Spectrol 43 W 203	
Resistor	R60	1	154K 0.1%	25 PPM/Co	TRW RN 55E	
Resistor	R61	1	19.6K0.1%	25 PPM/Co	TRW RN55E	
Resistor	R63,64	2	2.2M 5%		R-OHM	
Resistor	R66	1	39.2K 1%	100 PPM/Co	Corning RN55D	
Resistor	R67	1	61.9K 1%	100 PPM/Co	Corning RN55D	
Resistor	R69,70	2	34.8K 1%	100 PPM/Co	Corning RN55D	

APPENDIX 10 (continued

PREAMP

Component	Position	Quan.	Value Tolerance	Voltage/ Temp.Spec.	Manufacturer/ Part #	Type
Resistor	R72, 73	2	22M 5%		R-OHM	
Resistor	R75	1	45.3K 1%	100 PPM/Co	Corning RN55D	
Resistor	R78	1	162K 1%	100 PPM/Co	Corning RN55D	
Resistor	R79	1	825K 1%	100 PPM/Co	Allen-Bradley RN55CC	.06
Resistor	R90	1	2.15M 1%	100 PPM/Co	Allen-Bradley RN55D	.14
Capacitor	C1, 12-16, 31	7	100PF	100V ± 10% CN15A 101 K	Central Lab	Ceramic
Capacitor	C-2,3	2	1nF	630V ± 10%	Plessey 50AA102K630	Mylar
Capacitor	C-4	1	220 PF		Erie 8101-100-X7R)-221K	Ceramic
Capacitor	C-5, 26	2	47nF	50V ± 10%	Central Lab CW 20C 473K	Ceramic
Capacitor	C6,7,9,17, 19,20,22, 30,34,35, 36	11	.01 uF	50 ± 10%	Central Lab CW15C 103K	Ceramic
Capacitor	C-8,10,11, 24,25,39	6	0.1uF	50 V ± 10%	Central Lab CW 20C 104K	Ceramic
Capacitor	C-18	1	1uF	50V ± 10%	Cornell-Dublier MMW05W1 ± 10%	Mylar
Capacitor	C-21	1	10PF	100V ± 10%	Central Lab CN15A 100K	Ceramic
Capacitor	C23,27, 32,33	4	1nF	50VB	Erie 8121-100-COGO-102-J	Ceramic
Capacitor	C28,29, 37,38	4	33uF	10V ± 10%	Sprague 150D 336 x 9010 B2	Electro- litic

APPENDIX 10 (continued)

PREAMP

Component	Position	Quan.	Value Tolerance	Voltage/ Temp. Spec.	Manufacturer/ Part #	Type
1C	U-1,2,3, 4,5,9,10,17	8	LM 4250		National LM 4250CN	
1C	U6, 8	2	4066		Motorola MC 14066CP	
1C	U7, 16	2	4051		Motorola MC1 4051CP	
1C	U11	1	4093		Motorola MC 14093 CP	
1C	U12	1	4070		Motorola MC 14070 CP	
1C	U13	1	4023		Motorola MC1 4023 CP	
1C	U14	1	4013		Motorola MC1 4013CP	
1C	U15	1	4011		Motorola MC 14011CP	
1C	U18, 19	2	4020		Motorola MC14020CP	
1C	U20	1	4081		Motorola MC 14081CP	
1C	U21	1	4050		Motorola MC 14050CP	
Transistor	Q1, Q2	2	LM 394CH		National LM 394 CH	
Transistor	Q 3,4,5, 6, 7	5	2N5962		Fairchild 2N5962	
DIODE	CR1	1	1N4148		1N 4148	
DIODE	CR2	1	1N4001		Fairchild 1N 4001	
Switch	SW1	1			AMP53137-1	

APPENDIX 11

VCO 1/4

Component	Position	Quan.	Value Tolerance	Voltage/ Temp. Spec.	Manufacturer/ Part #	Type	Unit Price
Resistor	R1,2,3,4	4	10K 1%		Corning RN55D		.06
Resistor	R5	1	1 K 1%		Corning RN55D		.06
Resistor	R6	1	422K 1%	100PPM/Co	Allen-Bradley RN55CC		.09
POT	R7	1	1M		Spectral 43W105		1.01
Resistor	R8	1	909K 1%	100PPM/Co	Allen-Bradley RN55CC		.09
Resistor	R9, 40	2	100K 1%	100PPM/Co	Corning RN55D		.06
Resistor	R10,12, 14	3	316K		Allen-Bradley RN55 CC		.09
Resistor	R11	1	5.6M 5%		R-OHM		.04
Resistor	R13	1	681K 1%		Allen-Bradley RN55CC		.09
Resistor	R15	1	162K 1%		Corning RN55D		.06
Resistor	R16, 32	2	82.5K 1%		Corning RN55D		.06
Resistor	R17, 39	2	10M 5%		R-OHM		.04
Resistor	R18, 19	2	464K 1%		Allen-Bradley RN55CC		.09
Resistor	R20,23, 34, 35	4	1M 1%	100 PPM/Co	Allen-Bradley RN55CC		.09
Resistor	R21	1	33M 5%		Allen-Bradley CB-3365		.16

APPENDIX 11

VCO 2/4

Component	Position	Quan.	Value Tolerance	Voltage/ Temp. Spec.	Manufacturer/ Part #	Type	Unit Price
Resistor	R22, 36	2	2.2M 5%		R-OHM		.02
Resistor	R24	1	19.6K 1%		Corning RN55D		.06
Resistor	R25, 26	2	13.3K 1%		Corning RN55D		.25
Resistor	R27	1	765.4K1 %	25PPM/Co	TRW RN55E-765.4-B		.57
Resistor	R28	1	1M .1%	25PPM/Co	TRW RN55E		1.14
Resistor	R29	1	541.2K.1%	25PPM/Co	TRW RN55E		.57
Resistor	R30	1	414.2K.1%	25PPM/Co	TRW RN55E		.57
Resistor	R31	1	147 K 1%		Corning RN55D		.06
Resistor	R33	1	1.5M 5%		R-OHM		.02
Resistor	R37	1	100 1%		Corning RN55D		.06
Resistor	R38	1	511K 1%		Allen-Bradley RN55CC		.09
Resistor	R41, 42	2	511 1%		Corning RN55D		.06
Rotary Switch	SW1	1	4P 2T		AMP 53137-1		2.39
Integrated Circuit	U1,2,3 4, 17	5	LM4250		National LM4250CN		1.12
Integrated Circuit	U5	1	4046		Motorola MC14046CP		1.13
Integrated Circuit	U6	1	4007		Motorola MC14007CP		.26

APPENDIX 11

VCO 3/4

Component	Position	Quan.	Value Tolerance	Voltage/ Temp. Spec.	Manufacturer/ Part #	Type	Unit Price
Integrated Circuit	U7	1	4066		Motorola MC14066CP		.53
Integrated Circuit	U8	1	4025		Motorola MC14025CP		.26
Integrated Circuit	U9	1	4050		Motorola		.52
Integrated Circuit	U10	1	4060		RCA CD4060AE		1.42
Integrated Circuit	U11	1	4075		Motorola		.26
Integrated Circuit	U12	1	4022		Motorola MC14022CP		.90
Integrated Circuit	U13	1	4520		Motorola MC14520CP		1.08
Integrated Circuit	U14	1	4526		Motorola MC14526CP		1.08
Integrated Circuit	U15	1	4175		Motorola MC14175CP		.90
Integrated Circuit	U16	1	4053		Motorola MC14053CP		.90
Capacitor	C1,2,3, 4,6,7,14, 15,16,18 19,22,26, 27	14	.01uF	50V DC±10%	Central Lab CWCW15C103K	Ceramic	.16
Capacitor	C5	1	39nF	50VDC±10%	Central Lab CW20C393K	Ceramic	.48
Capacitor	C8, 10	2	1uF	35V 10%	Sprague 150D105X9035A2	Electro-litic	.29
Capacitor	C9	1	4.7uF	35V 10%	Sprague 150D475X9035B2	Electro-litic	.29
Capacitor	C11	1	22uF	15V 10%	Sprague 150D226X9015B2	Electro-litic	.49

APPENDIX 11 (continued)

VCO 4/4

Component	Position	Quan.	Value Tolerance	Voltage/ Temp. Spec.	Manufacturer/ Part #	Type	Unit Price
Capacitor	C12, 21, 23	3	33uF	10V 10%	Sprague 150D336X9010B2	Electro-litic	.30
Capacitor	C13	1	100pf	300V 5%	Sprague CM04FD101J03	Mica	.18
Capacitor	C17	1	330PF	50V	ERIE 8121-100-COGO-331K	Ceramic	.48
Capacitor	C20	1	1uF	50VDCW±10%	Cornell-Dubue MMW 05W1±10%	Mylar	
Capacitor	C24	1	47PF	100V±10%	Central Lab CN15A470K	Ceramic	1.87
Capacitor	C25	1	27PF	50V	Varadyne 2115COG050R270J	Ceramic	.34
Capacitor	C28	1	15uF	20V 10%	Kemet T110B156K20AS	Electro-litic	.40
Transistor	Q1	1			Fairchild 2N5962		.28
Crystal	Y1	1	43.52KHZ		Reeves-Hoffman E2NS20		8.25
DIODE	CR1	1			Fairchild IN4001		.07

APPENDIX 12

CALIBRATOR (Hard-wired)

Component	Position	Quan.	Value Tolerance	Voltage/ Temp. Spec.	Manufacturer/ Part #	Type	Unit Price
Resistor	R1, R3, 16, 25	4	100K 1%		Corning RN55D		.06
Resistor	R2,7-14, 18-20, 30-32	15	100K 1%		Corning RN55D		.06
Resistor	R4,21,22, 23,26,28-29	7	1M 1%		Allen-Bradley		.09
Resistor	R5-R6, 17,24,27	5	1K 1%		Corning RN55D		.06
Resistor	R15, 33	2	511 OHM 1%		Corning RN55D		.06
Capacitor	C1	1	.01uF	50V	Erie 8121-050-X7R0-103K	Ceramic	.60
Capacitor	C2-C6	1NF	50V	Erie	Ceramic 8121-100-C0G0-102J		.40
Capacitor	C7-C8	2	33uF	10V±10%	Sprague 150D-336 X 9010 B2	Electrolitic	.30
Rotary Switch	SW1, SW2, SW3	3	53137-1		Amp 53137-1		2.39
IC	U4, U10	2	4049		Motorola MC 14049 CP		.50
IC	U5,U13, U25,U29	4	4073		Motorola MC 1 4073 CP		.26
IC	U6, U18	2	4048		RCA CD 4048 AE		.71
IC	U7,U11, U19	3	4081		Motorola MC 14081 CP		.26
IC	U8-U9, 21	3	4050		Motorola MC 1 4050 CP		.52
IC	U12	1	4075		Motorola MC 1 4075 CP		.26

APPENDIX 12 (continued)

CALIBRATOR (Hard-wired)

Component	Position	Quan.	Value Tolerance	Voltage/ Temp. Spec.	Manufacturer/ Part #	Type	Unit Price
IC	U14, U20	2	4021		Motorola MC 14021 CP		.90
IC	U15	1	4526		Motorola MC 14526 CP		1.80
IC	U16	1	4070		Motorola MC 14070 CP		.26
IC	U17	1	4040		Motorola MC 14040CP		1.08
IC	U22,26	2	4013		Motorola MC 14013 CP		.42
IC	U23	1	4024		Motorola MC 14024 CP		.75
IC	U24	1	4071		Motorola MC 1 4071 CP		.26
IC	U27-U28	2	4053		Motorola MC 14053CP		.90
DIODE	CR1	1	IN4001		Fairchild IN 4001		.07

APPENDIX 12 (continued)

CALIBRATOR (PROM-BASED)

Component	Position	Quan.	Value Tolerance	Voltage/ Temp. Spec.	Manufacturer/ Part #	Type	Unit Price
Resistor	R1,3,16, 25,34-41	12	100K 1%	± 100 PPM/Co	Corning RN55D		.06
Resistor	R2,7-14, 18-20,30-32	15	10K 1%	100 PPM/Co	Corning RN55D		.06
Resistor	R4,21,22, 23,26,28,29	7	1M 1%	100	Allen Bradley	RN55C	.09
Resistor	R5,R6, R17,R24,R27	5	1K 1%	100	Corning RN55D		.06
Resistor	R15, 33	2	511 1%	100	Corning RN55D		.06
Capacitor	C1	1	.01 f	50V±10%	ERIE 8121-050-X7R0-103K	Ceramic	.60
Capacitor	C2,3,4, 5, 6	5	1nf	50V±10%	ERIE 8121-100-COGO-1025	Ceramic	
Capacitor	C7, C8	2	33 f	10V±10%	Sprague 150D-336 X 9010 B2	Electrolytic	.30
Capacitor	C9,C13	5	.01uf	50V±10%	Central Lab CW15C103K		
IC	U8,U12	2	4013		Motorola MC 14013 CP		.42
IC	U15	1	4024		Motorola MC 14024 CP		.75
IC	U21,U10	2	4073		Motorola MC 14073 CP		.26
IC	U18	1	4081		Motorola MC 1408081 CP		.26
IC	U17	1	4071		Motorola MC 14071 CP		.26
IC	U24	1	4075		Motorola Mc 14075 CP		.26
IC	U22	1	4070		Motorola MC 14070 CP		.26

APPENDIX 12 (continued)

CALIBRATOR (PROM-BASED)

Component	Position	Quan.	Value Tolerance	Voltage/ Temp. Spec.	Manufacturer/ Part #	Type	Unit Price
IC	U19,U23	2	4053		Motorola MC 14053 CP		.90
IC	U11,U16	2	4021		Motorola Mc 14021 CP		.90
IC	U4	1	4049		Motorola MC 14049 CP		.50
IC	U6,U7, U25,U5	4	4050		Motorola MC 14050 CP		.52
IC	U9	1	4040		Motorola MC 14040 CP		1.08
IC	U20	1	4526		Motorola MC 14526 CP		1.08
IC	U14	1	IM6654		Intersil IM 6654		
IC	U13	1	4508		Motorola MC 14508 CP		
DIODE	D1	1	IN4001		Fairchild IN4001		.07
Rotary	U1,U2, U3	3	53137-1		AMP 53137-1		2.39

APPENDIX 13

HARDWARE

COMPONENT	QUANTITY	MANUFACTURER	PART #	UNIT PRICE
Tape Sealant	4 inches	Sigmaform	SFTS	.06
Buck Tubing	2 inches	Sigmaform	BSTS 075	.24
Buck Tubing			BSTS 04	
Chasis Box	1 each	Ken Harper		6.50
Card Guide	8 each	Scanbie	T-309-60	0.19
Spacer .250	16 each	Scanbie	T-101-250	0.06
Spacer .500	4 each	Scanbie	T-101-500	0.06
Spacer .750	4 each	Scanbie	T-101-750	0.06
Spacer .125	4 each	Scanbie	T-101-125	0.05
Mounting Bar	4 each	Scanbie	XTS-802-3.750	0.68
Cord Grip Connector	1 each	T & B	2672	1.20
Locknut	1 each	Midwest	SL-1	.31
Fiberglass Box	1 each	English	A1E2	38.75
Fanning Strip	1 each	TRW	10-160-L	.98
Edge-Connector	4 each	Viking	2VH221AE5	3.47
Mother Board	1 each	Martex		10.00
Cal Board	1 each	Martex		13.00
VCO Board	1 each	Martex		13.00
Pre-Amp Board	1 each	Martex		13.00
Rubber Grommet	1 each	H. H. Smith	91121	.03
Lead-in Cable	3 feet	Belden	8778	1.20
Spacer	8 each	Scanbie	T-101-375	.22
Clamp, Cable	1 each	H. H. Smith	780	.08
Clamp, Cable	1 each	H. H. Smith	775	.05
Card Polarizing Key	4 each	Viking	091-0024-000	.06

APPENDIX 13 (continued)

HARDWARE

COMPONENT	QUANTITY	MANUFACTURER	PART #	UNIT PRICE
Card Extractor	4 each	Hewlett-Packard	4040-0748 (Black)	.10
Card Extractor	4 each	Hewlett-Packard	4040-0749 (Brown)	.10
Seal Rings	1 each			
Card Extractor	4 each	Hewlett-Packard	4040-0/50 (Red)	.10
Card Extractor	4 each	Hewlett-Packard	4040-0751 (Orange)	.10
Card Extractor	4 each	Hewlett-Packard	4040-0752 (Yellow)	.10
Extractor Pin	8 each	Hewlett-Packard	1480-0073	.30
Degreaser	2 cases	Miller Steffansen	MS-180	35.40
Flux Cleaner	2 cases	Miller Steffansen	MS-190HD	36.00
Humiseal	2 cases	Humiseal Division Columbia Technical Corp.	Type 1A27	58.50 Can
Screws ¼" Flat (Phillip)	4 each			

APPENDIX 14

A1VCO TOTAL PARTS LIST (PROM-BASED)

COMPONENT	VALUE	MANUFACTURER	QUANTITY	POSITION*
Resistor	10K 1%	Corning RN55D	(20 ea.)	VR1, 2, 3, 4 PR 24, 87-89 CR 2, 7, 14, 18, 20 19, 30-32
Resistor	100K 1%	Corning RN55D	(1 ea.)	VR 9, 40 PR 11, 12, 14, 15, 80, CR 1, 3, 16, 25
Resistor	1 K 1%	Corning RN55D	(6 ea.)	VR 5 CR 5, 6, 17, 24, 27
Resistor	422K 1%	Allen-Bradley RN55C	(1 ea.)	VR6
Resistor	1 M 1%	Allen Bradley RN55C	(24 ea.)	VR 20, 23, 34, 35 PR 34, 44, -49, 62, 65, 76, 81 PR 83, 84 CR 4, 21, 22, 23, 26, 28, 29
Resistor	909K 1 %	Allen Bradley RN55C	(1 ea.)	V R8
Resistor	316K 1%	Allen Bradley RN55C	(3 ea.)	VR 10, 12, 14
Resistor	5.6 M 5%	R-OHM	(3 ea.)	VR 11 PR 19, 77
Resistor	4.64K 1%	A/B	(2 ea)	PR 6.7
Resistor	2.61K 1%	Corning	(1 ea.)	PR 16
Resistor	42.2K 1%	Corning	(1 ea.)	PR 17
Resistor	31.6K 1%	A/B	(1 ea.)	PR 20
Resistor	100 M 5%	A/B	(3 ea.)	PR 21, 91, 92
Resistor	23.7K 1%	Corning	(2 ea.)	PR22
Resistor	90.9K 1%	Corning	(1 ea.)	PR23
Resistor	47 M 5 %	Corning	(2 ea.)	PR 29.31
Resistor	562K 1%	A/B	(1 ea.)	PR 32

* Location #'s starting with (V) are for VCO board, (P) for preamp, (C) for calibrator.

APPENDIX 14 (continued)
A1VCO TOTAL PARTS LIST

COMPONENT	VALUE	MANUFACTURER	QUANTITY	POSITION
Resistor	499K 1%	Allen-Bradley	(8 ea.)	PR 37-43, 50
Resistor	100K .1%	TRW RN55E	(1 ea.)	PR 52
Resistor	51.1K 1%	TRW RN55E	(1 ea.)	PR 53
Resistor	46.4K .1%	TRW RN55E	(1 ea.)	PR 54
Resistor	681K 1%	Allen-Bradley RN55C	(3 ea.)	VR13 PR 36, 74
Resistor	162K 1%	Corning RN 55D	(2 ea.)	VR 15 PR 78
Resistor	82.5 K 1%	Corning	(2 ea.)	VR 16, 32
Resistor	10 M 5%	R-OHM	(8 ea.)	VR 17, 39 PR 1, 25, 26, 28, 82, 35
Resistor	464 K 1%	Allen-Bradley RN 55C	(2 ea.)	VR 18, 19
Resistor	33 M 5%	Allen-Bradley CB-3365	(1 ea.)	VR 21
Resistor	2.2 M 5%	R-OHM	(4 ea.)	VR 22, 36 PR 63, 64
Resistor	19.6 K 1%	Corning	(1 ea.)	VR 24
Resistor	13.3 K 1%	Corning	(2 ea.)	VR 25, 26
Resistor	765.4 K .1%	TRW RN55E	(1 ea.)	VR27
Resistor	1 M .1%	TRW RN55E	(2 ea.)	VR 28 PR 51
Resistor	541.2 K .1%	TRW RN55E	(1 ea.)	VR 29
Resistor	414.2K .1%	TRW RN55E	(1 ea.)	VR 30
Resistor	147K 1%	Corning	(1 ea.)	VR 31
Resistor	1.5 M 5%	R-OHM	(1 ea.)	VR 33
Resistor	100 1%	Corning	(1 ea.)	VR 37
Resistor	511 K 1%	A/B	(8 ea.)	VR 38, 41, 42 PR 18, 30, 33, 68, 71
POT	1 m	Spectrol 43W105	(1 ea.)	VR 7

APPENDIX 14 (continued)
A1VCO TOTAL PARTS LIST

COMPONENT	VALUE	MANUFACTURER	QUANTITY	POSITION
POT	5K	Spectrol 43W502	(1 ea.)	PR 13
POT	200K	Spectrol 43W204	(1 ea.)	PR 56
POT	20K	Spectrol 43W203	(1 ea.)	PR 59
Resistor	511 1%	Corning	(5 ea.)	VR 41, 42 PR 2, 10, 85, 86 CR 15, 33
Resistor	6.19M 1%	Allen Bradley	(2 ea.)	PR 4, 9
Resistor	2.26 M 1%	Allen Bradley	(2 ea.)	PR 5, 8
Resistor	121K .1%	TRW RN55E	(1 ea.)	PR 55
Resistor	3.3M 5%	R-OHM	(1 ea.)	PR 57
Resistor	56.2K .1%	TRW RN55E	(1 ea.)	PR 58
Resistor	154K .1%	TRW RN55E	(1 ea.)	PR 60
Resistor	19.6K .1%	TRW RN55E	(1 ea.)	PR 61
Resistor	39.2K 1%	Corning	(1 ea.)	PR 66
Resistor	61.9K 1%	Corning	(1 ea.)	PR 67
Resistor	34.8K 1%	Corning	(2 ea.)	PR 69, 70
Resistor	22M 5%	R-OHM	(2 ea.)	PR 72, 73
Resistor	45.3K 1%	Corning	(1 ea.)	PR 75
Resistor	825K 1%	Allen Bradley	(1 ea.)	PR 79
Caps	100pf 100V ± 10%	Central Lab (Cer.) CN15A 101 k	(7 ea.)	PC 1, 12-15, 31
Caps Inf	630V ± 10%	Plessey (Mylar) 50AA192K630	(2 ea.)	PC 2, 3
Caps	220pf	Erie (Ceramic) 8101-100-X7R-221 K	1 ea.)	PC 4

APPENDIX 14
A1VCO TOTAL PARTS LIST (continued)

COMPONENT	VALUE	MANUFACTURER	QUANTITY	POSITION
Caps PC 5, 26	47uf 50V ± 10%	Central Lab (Cer.)		(2 ea.)
Caps	15 uf 20 VDC	Kemet Electro T110B156K20AS	)1 ea.)	VC 28
Caps	.1 uf 50VDC	Central Lab	(6 ea.)	PC 8, 10, 11 24, 25, 39
Caps	10pf 100VDC	Central Lab Ceramic CN 15A100K	(1 ea.)	PC 21
Caps	1 nf 50V ± 10%	Erie Ceramic 8121-100-COGO-102J	(9 ea.)	PC 23, 27, 32, 33 CC 2-6
Caps	33 uf 10V	Sprague Elect. 150D 336 x 9010 B2	(9 ea.)	PC 28, 29, 37, 38 CC 7, 8 VC 12, 21, 23
Caps	.01 uf 50V	Erie Ceramic 8121-050-X7R0-103K	(5 ea.)	CC 1, Bypass
Amp	Switch (SWI)	Amp 53137-1	(5 ea.)	VCO SW1 U1, U2, U3 PREAMP SWI
Caps	.01 uf 50VD	Central Lab CW 15C 103K	(29 ea.)	
	VC1, 1, 3, 4, 6, 7, 14, 15, 16, 18, 19, 22, 26, 27 PC 6, 7, 9, 17, 19, 20, 22, 30, 34, 35, 36, CC 9-13			
Caps	39 nt 50VDC	Central Lab Ceramic CW 20C 393K	(1 ea.)	VC5
Caps	1 uf 35VDC	Sprague Elect.	(2 ea.)	VC 8, 10
Caps	4.78 uf 35VDC	Sprague Elect. 150D475 x 9035B2		VC 9
Caps	22 uf 15V	Sprague Elect. 150D 336 x 9010B2	(2 ea.)	VC 11
Caps	100 pf 300V	Sprague MICA CM04FD101J03	(1 ea.)	VC 13
Caps	330 pf 50V	Erie Ceramic 8121-100-COG10-331K	(1 ea.)	VC 17
Caps	1uf 50 VDC	Cornell-Dubue-Mylar MMW-05W1	(2 ea)	VC 20 PC 18

APPENDIX 14
A1VCO TOTAL PARTS LIST (continued)

COMPONENT	VALUE	MANUFACTURER	QUANTITY	POSITION
Caps	47 pf 100V	Central Lab CN15A470K	(1 ea.)	VC 24
Caps	27pt 50V	Varadyne Ceramic 2115 COGO 50R270J		VC 25
IC's	LM 4250	NATNL LM4250CN	(13 ea.)	VU 1, 2, 3, 4, 17 PU 1, 2, 3, 4, 5, 9, 10, 17
IC	4046	Motorola MC MC 14046 CP	(1 ea)	V U5
IC	4007	Motorola 14007 CP	(1 ea.)	VU 6
IC	4066	Motorola 14066 CP	(3 ea.)	VU 7 PU 6, 8
IC	4025	Motorola MC14025 CP	(1 ea.)	VU 8
IC	4050	Motorola MC4050 CP	(5 ea.)	VU 9 PU 21 CU 5, 6, 7, 25
IC	4060	RCA CD 4046AE	(1 ea.)	VU 10
IC	4075	Motor MC14075CP	(2 ea.)	VU 11 CU 24
IC	4022	Motor MC 4022 CP		VU 12
IC	4520	Motor MC4520CP		VU 13
IC	4526	Motorola MC14526CP	(2 ea.)	VU 14 CU 20
IC	4175	Motorola MC4175CP	(1 ea.)	VU 15
IC	4053	Motorola MC4053CP		VU 16 CU 19, 23
IC	4051	Motorola MC14051CP	(2 ea.)	PU 7, 16
IC	4093	Motorola MC 4093CP	(1 ea.)	PU 11
IC	4070	Motorola MC14070CP	(2 ea.)	PU 12 CU 22
IC	4023	Motorola MC14023CP	(1 ea.)	PU 13

APPENDIX 14
A1VCO TOTAL PARTS LIST (continued)

COMPONENT	VALUE	MANUFACTURER	QUANTITY	POSITION
IC	4013	Motorola MC14013CP	(3 ea.)	PU 14 CU 8, 12
IC	4011	Motorola MC14011CP	(1 ea.)	PU 15
IC	4020	Motorola MC14020CP	(2 ea.)	PU 18, 19
IC	4081	Motorola MC14081CP	(2 ea.)	PU 20 CU 18
IC	4049	Motorola MC14049CP	(1 ea.)	CU 4
IC	4073	MC 14073CP	(2 ea.)	CU 10, 21
IC	4021	MC14021BCP	(2 ea.)	CU 11, 16
IC	4040	MC 14040CP	(1 ea.)	CU 9
IC	4024	MC 14024CP	(1 ea.)	CU 15
IC	4071	MC 14071CP	(1 ea.)	CU 17
IC	4508	Motorola (1 ea) MC 14508BCP	CU 13	Transistor
IC	IM6654	INTERSIL IM6654	(1 ea.)	CU 14
Transistor		Fairchild 2N5962	(3 ea.)	VQ1 PQ 3, 4, 5, 6
	ransistor	National LM 394CH	(2 ea.)	PQ 1, Q2
Diode	IN 4148		(1 ea.)	PCR 1
Diode	IN 4001		(3 ea.)	PCR 2 VCR1 CCR1
Crystal	43.52 KHz	Reeves-Hoffman E 2N520	(1 ea.)	VY1

APPENDIX 15
A1VCO PIN ASSIGNMENTS
OVRIDE

Main Connector

PIN	FUNCTION	PIN	FUNCTION
1	+ AUX PWR	23	+ AUX PWR
2	- BATT	24	- BATT
3	GND	25	GND
4	IN A	26	INB
5	GREN 2	27	GREN 2
6	GREN 1	28	GRCD
7	CKF	29	CKF
8	ATTN	30	ATTN 1
9	ATTN 2	31	GR
10	OVRIDE CHOP	32	CAL STROBE
11	GEO OUT	33	GEO OUT
12	AUX L	34	AUX H
13	TEST ACK	35	OVRIDE GAIN
14	ID	36	MUX
15	INC	37	MUX 1
16	IND	38	MUX 2
17	IN E	39	IN F
18	OVRIDE REQ	40	OVRIDE REQ
19	TEST REQ	41	TEST REQ
20	GND	42	GND
21	-AUX PWR	43	- AUX PWR
22	+ BATT	44	+ BATT

MOTHER BOARD PINOUTS

EDGE CONNECTORS		OVERRIDE	CALIBRATOR	PREAMP	VCO	FANNING STRIP
MOTHER BOARD INPUTS	POS		PIN NUMBERS			
VCO	1				19,41	10 (GRN)
+Batt	2	22, 44	22, 44	22, 44	22, 44	8 RED
AUX	3	21				N/C
+ GEO	4			19		4 (BLK)
GEO	5			18		1 (WHT)
INF	6	39				2 (BLK)
INE	7	17				3 (BLU)
IND BRN	8	16				N/C LOOSE
INC BLK	9	15				N/C LOOSE
INB	10	26				7 (BLK)
INA	11	4				7 (YEL)
-BUTT	12	2, 24	2, 24	2, 24	2,24	6 (BLK)
+ AUX POWER	13	1, 23				
GND						(BLK) 9, 5 (BND)

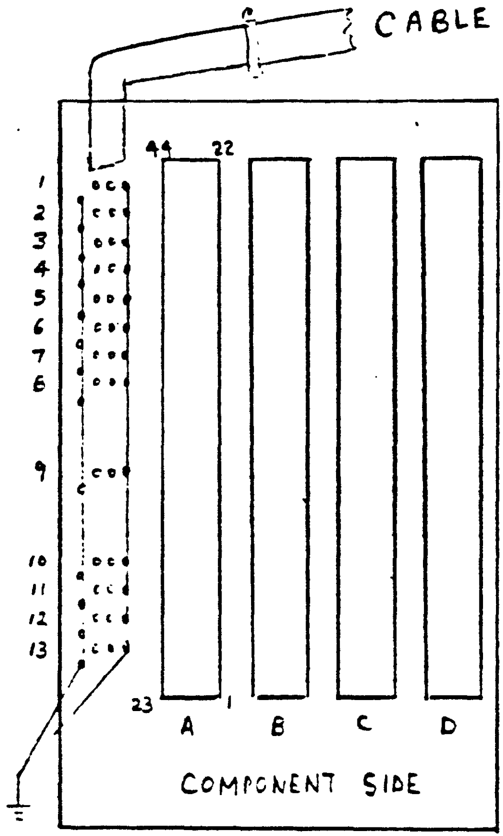
CALIBRATOR

Main Connector

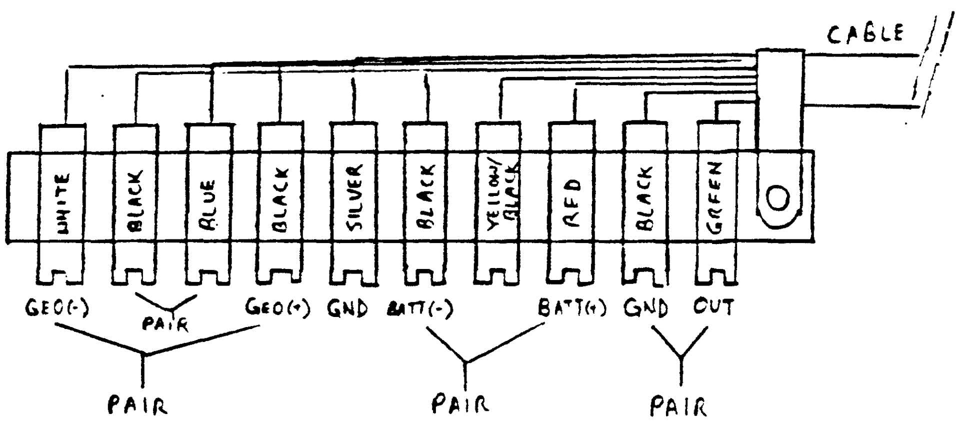
PIN	FUNCTION	PIN	FUNCTION
1	NC	23	NC
2	- BATT	24	- BATT
3	GND	25	GND
4	CAL RATE	26	CHOP CONT
5	GREN 2	27	GREN 2
6	CKS	28	CKS
7		29	
8	ATTN	30	ATTN 1
9	ATTN 2	31	GR
10	CHOP	32	CHOP
11	OVRIDE CHOP	33	CAL STROBE
12	TEST ACK	34	OVRIDE GAIN
13	ID	35	ID
14	MUX	36	MUX
15	MUX 1	37	MUX 1
16	MUX 2	38	MUX 2
17	STEP	39	STEP
18	OVRIDE REQ	40	OVRIDE REQ
19	TEST REQ	41	TEST REQ
20	GND	42	GND
21	NC	43	NC
22	+ BATT	44	+ BATT

PIN	FUNCTION
	+ BATT
12	- BATT
	GND
13	+ AUX PWR
3	- AUX PWR
	GND
10	IN A
11	IN B
	GND
9	INC
8	IND
	GND
7	INE
	INF
	GND
4	+ GEO
5	- GEO
	SHIELD (GND)
1	VCO
	GND

MOTHER BOARD INPUTS



A - OVERRIDE
B - CALIBRATOR
C - PREAMP
D - VCO



FANNING STRIP AND MOTHER BOARD WIRING DIAGRAM

PREAMP

Main Connector

PIN	FUNCTION	PIN	FUNCTION
1	NC	23	NC
2	- BATT	24	- BATT
3	GND	25	GND
4	MOD (OUT)	26	MOD (OUT)
5	GREN 2	27	GREN 2
6	GREN 1	28	GRCD
7	CKF	29	CKF
8	ATTN	30	ATTN 1
9	ATTN 2	31	GR
10	CHOP	32	CHOP
11	GEO OUT	33	GEO OUT
12	AUX L	34	AUX H
13	ID	35	ID
14	MUX	36	MUX
15	MUX 1	37	MUX 1
16	MUX 2	38	MUX 2
17	STEP	39	STEP
18	- GEO	40	- GEO
19	+ GEO	41	+ GEO
20	GND (& SHIELD)	42	GND (& SHIELD)
21	NC	43	NC
22	+ BATT	44	+ BATT

VCO

Main Connector

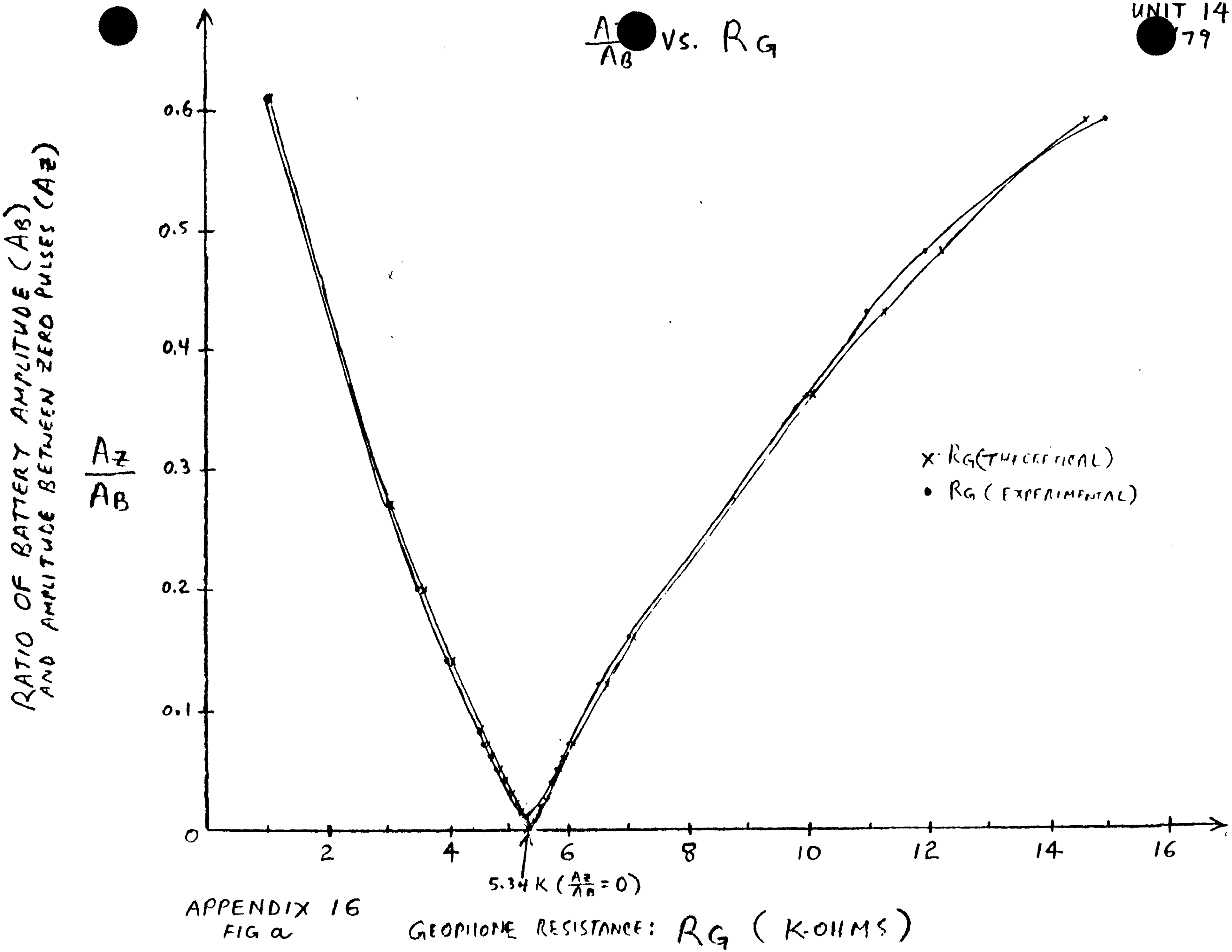
PIN	FUNCTION	PIN	FUNCTION
1	NC	23	NC
2	- BATT	24	- BATT
3	GND	25	GND
4	MOD (IN)	26	MOD (IN)
5	GND	27	GND
6	CKS	28	CKS
7	CKF	29	CKF
8	FREQ	30	FREQ 1
9	FREQ 2	31	FREQ 3
10		32	
11		33	
12		34	
13		35	
14		36	
15		37	
16		38	
17		39	
18	GND	40	GND
19	VCO (OUT)	41	VCO (OUT)
20	GND	42	GND
21	NC	43	NC
22	+ BATT	44	+ BATT

Board No.	REf. (+100 F)	Ref. (-40 F)	Date of Test
003	137.24	137.92	6-22-78
004	137.94	137.94	6-22-78
005	137.94	137.92	6-22-78
006	138.01	137.81	6-22-78
014	138.11	136.70	6-22-78
015	137.95	137.87	6-23-78
017	137.87	137.93	6-23-78
027	137.96	137.18	6-21-78
053	137.8	138.0	--
061	137.96	138.16	4-25-77
064	137.4	138.2	4-4-79

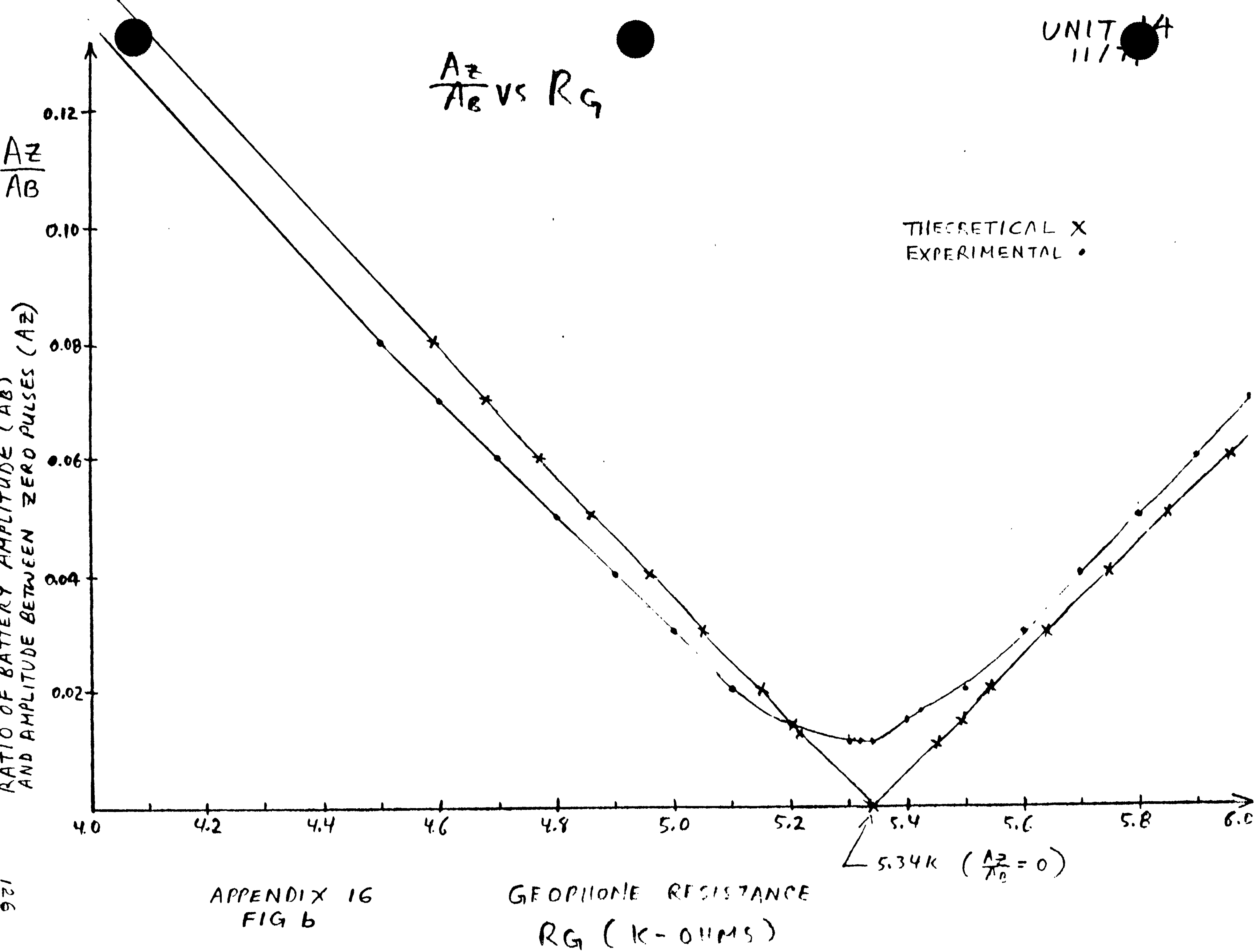
APPENDIX 16

A1VCO Preamplifier Reference Stability

$\frac{A_Z}{A_B}$ vs. R_G

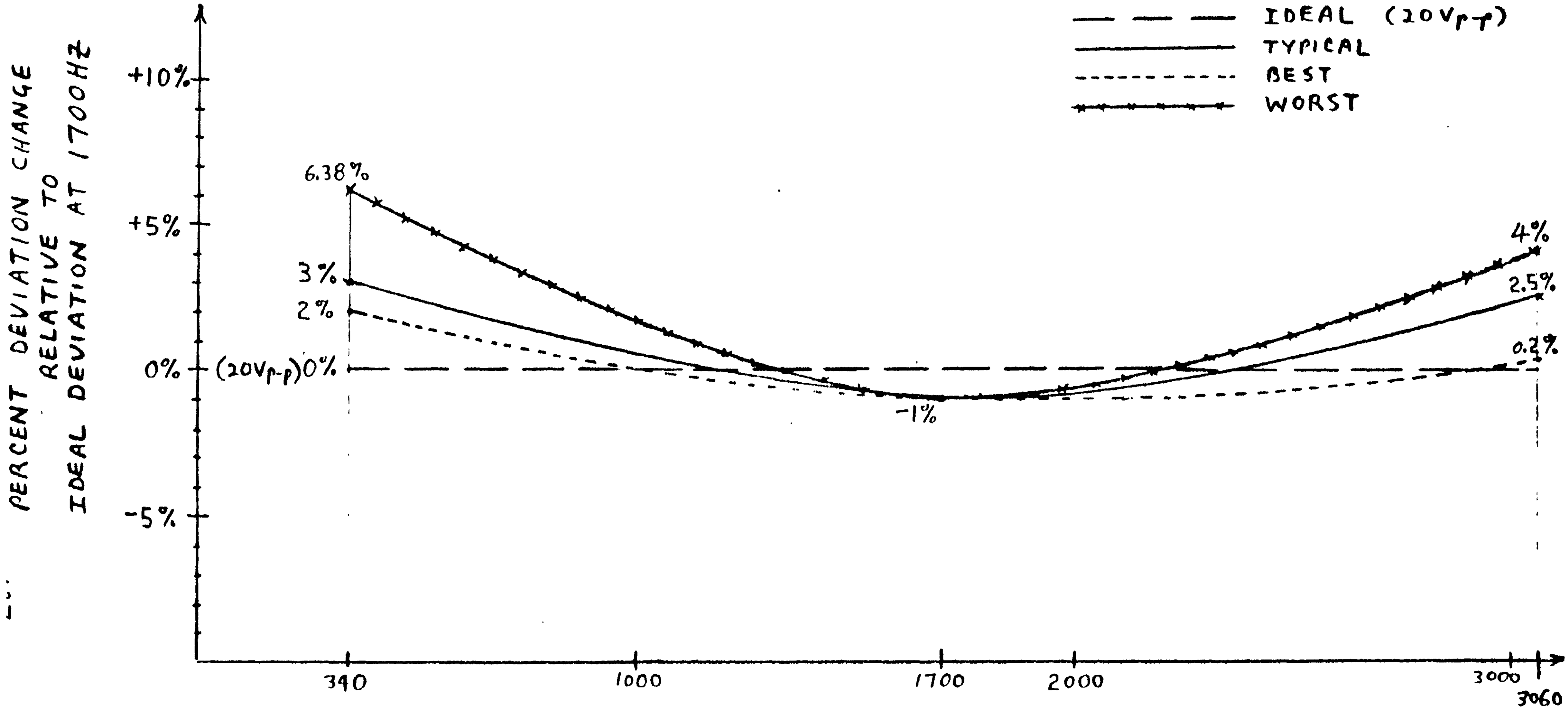


APPENDIX 16
FIG a



APPENDIX 16
FIG 6

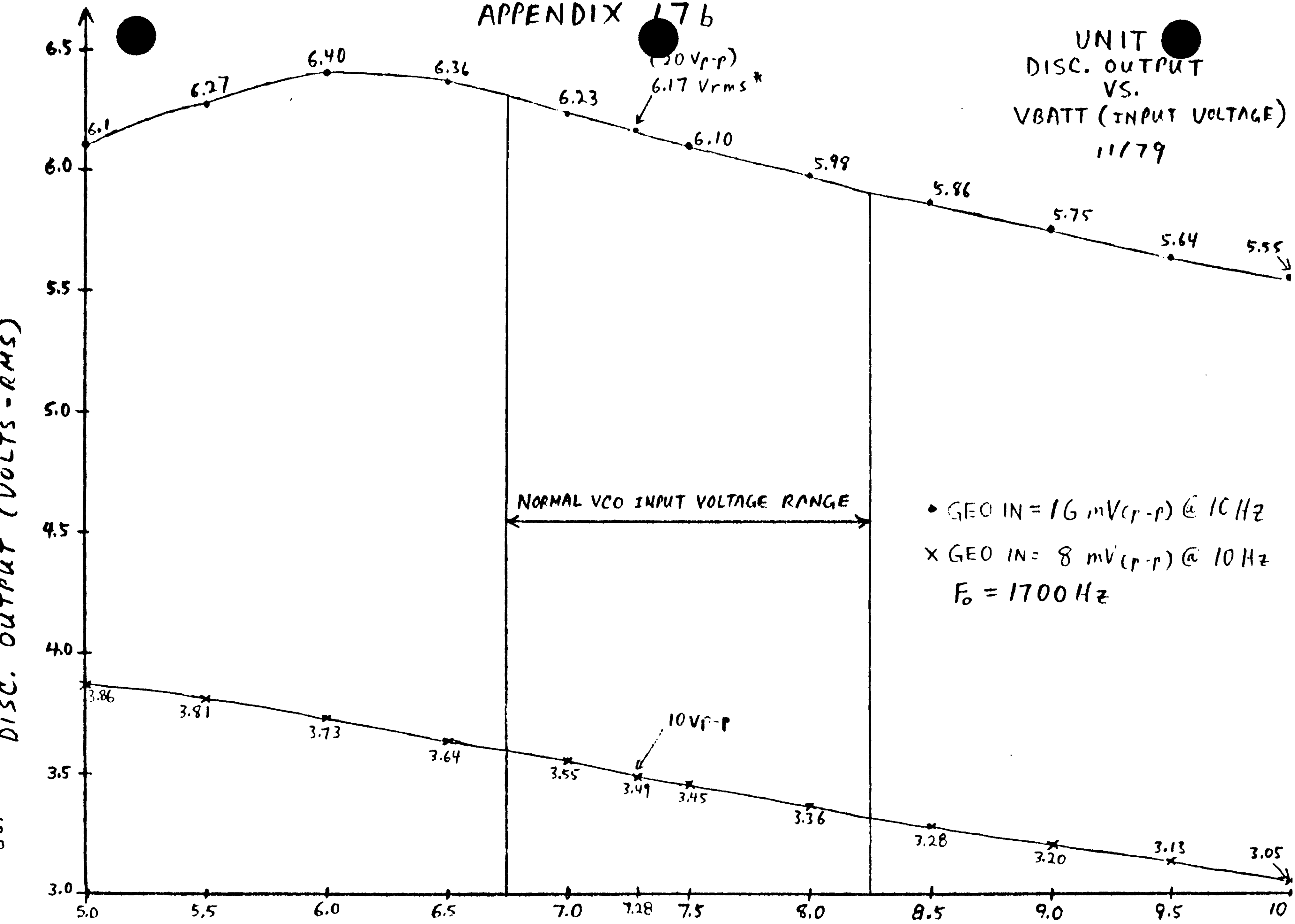
TYPICAL CURVE OF DEVIATION CHANGE VS. CENTER FREQUENCY



APPENDIX 17a

APPENDIX 17b

UNIT
DISC. OUTPUT
VS.
VBATT (INPUT VOLTAGE)
11/79



* 6.17 VOLTS TAKES INTO ACCOUNT DMM ROLLOFF AT 10 HZ

APPENDIX 18

This appendix is intended to give those interested in producing the A1VCO an estimate of the cost and labor involved. The figures cited below are from a production run of 50 units assembled and tested during the winter and spring of 1980.

Labor Costs (Hours Per Unit)

Item	Cost (Hrs)
Inner enclosure & wire harness	5
Environmental testing + burn-in	6
Outer enclosure + cable	2
TOTAL	13

1980 Dollar costs (Per Unit)

Item		Cost (Dollars)
Hardware		80.00
Outer enclosure		38.00
Electronic parts		150.00
Printed circuit boards (PCB)*		
	VCO	11.00
	Preamp	11.00
	Calibrator	15.00
	Mother board	8.00
Assembly of PCB's		
	VCO	8.50
	Preamp	14.50
	Calibrator	9.00
TOTAL		$345.00

*Price is based on gold cost of $600 per ounce