UNIPOLAR PULSE AND BIPOLAR NOISE TESTING
OF WIDEBAND SIGNAL CONDITIONER (MC476-0132-0034)

NASA CR-151569

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ACRONYMS AND ABBREVIATIONS

cm	centimeter
dB	decibel
dc	direct current
DFI	Development Flight Instrumentation
EMI	Electromagnetic Interference
g	acceleration, gain
Hz	Hertz
kHz	kilohertz
MΩ	megohm
ms	millsecond
mV	millivolt
PTT	Push-to-Talk
RC	Resistor-Capacitor
rms	root mean square
uhf	ultrahigh frequency
V	volt
WBSC	Wideband Signal Conditioner

1. SUMMARY

This report presents information on performance characteristics of the Shuttle Orbiter Wideband Signal Conditioner when subjected to special types of input signals. Design analysis of the signal flow path through the signal conditioning amplifier was first performed followed by actual testing of the amplifier with various signal inputs. The results indicate that the signal conditioner should perform acceptably if the Shuttle Orbiter flight vibration signal levels are in accord with preflight predictions. No electromagnetic interference (EMI) testing was performed as a part of this report.

Subsequent to the preparation of this report, flight results on OV 101 showed EMI sensitivity of the signal conditioner to keying of the ultrahigh frequency (UHF) voice transmitter. During the short interval that the crew pressed or released their push-to-talk (PTT) switch that energized or de-energized, respectively, the transmitter carrier (RF power), the long coaxial input signal cable to the signal conditioner was subject to a relatively high level of pulsed electromagnetic energy that caused a transient unipolar output pulse to appear at the signal conditioner output. This problem is under separate investigation and will probably be solved by grounding the signal input shield at the amplifier's input.

2. INTRODUCTION

Johnson Space Center's structural and instrumentation personnel have wanted information concerning performance of the DFI Wideband Signal Conditioner (WBSC) when subjected to special types of input signals. In particular, the amplifier's output characteristic with a unipolar input signal was needed to determine if it could respond accurately to a pressure pulse, for example from booster ignition. Information on the effects of large overscale pulses, (e.g., shock pulses) was desired to determine if the amplifier's response would be distorted for a certain time period following the large unipolar input. And finally, data were needed on the effect of high vibration signal inputs beyond the intended frequency range of the measurement. For example, some of the pogo acceleration measurements have a low measurement range (±2 g, 2 to 50 Hz); but since the piezoelectric transducer will respond to high level vibration stimuli and over a very high frequency range, testing was performed to ensure that potentially high g-levels beyond 50 Hz would not saturate the amplifier.

Section 3 provides a design analysis of the signal flow path through the amplifier and also reports on actual test results. A summary of the overall results is given in section 4.

3. DISCUSSION

This section presents information on the signal path design of the Wideband Signal Conditioner, P/N MC476-0132-0039, and associated test results when special types of signal inputs are processed (i.e. square-wave unipolar pulse, half sinewave pulse, over-range unipolar and bipolar signals, and "white noise" signal inputs beyond the amplifier's designated output bandwidth).

3.1 AMPLIFIER DESIGN CHARACTERISTICS

3.1.1 FIRST STAGE

Figure 1 is the general equivalent circuit of a typical "charge amplifier" system. The charge converter uses negative capacitance feedback (C_f) which gives a very large effective input capacitance (e.g., 10^7 P_f) to the amplifier. Therefore, the signal shunting effects of the transducer (C_t) or cable capacitance (C_c) are negligible in comparison to the amplifier's very high input capacitance. Different transducer cable lengths therefore have no practical effect on the input charge. "Voltage-type amplifier" accuracy would, however, be very dependent on the transducer and cable capacitances.

Figure 2 shows the elemental signal circuit of the K-West signal conditioner (Reference K-West Schematic No. 100149). The first stage acts as a "charge converter" because it effectively converts the charge which a piezoelectric accelerometer generates into a voltage at its output. The transfer function "charge gain" for this first stage is

$$\frac{E_o}{Q_1} = \frac{(-5 \times 10^8)(s)(s + 1/11)}{s^2 + 6.85s + 23.3} \qquad (1)$$

In deriving equation 1, it has been assumed that the input impedance of the first stage is virtually infinite. Analytical results

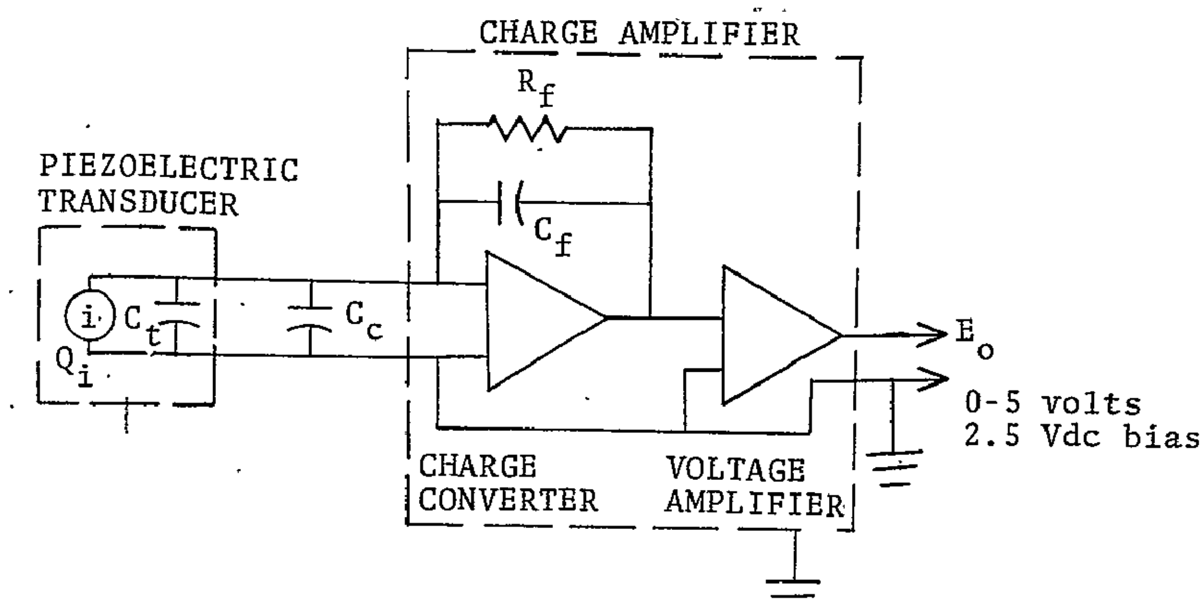
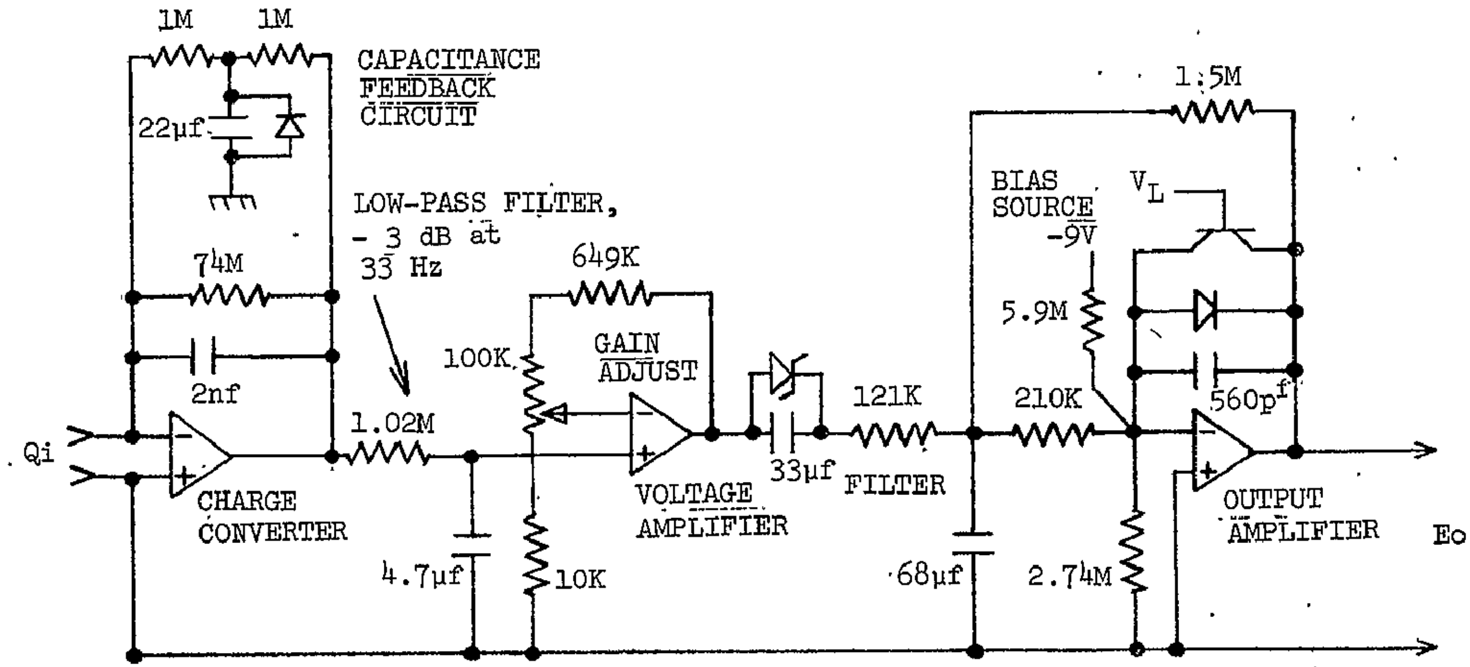


Figure 1.– Simplified diagram of charge amplifier measurement system.



*Second stage gain is variable from 7 to 76, nominally 18.

*$V_L \approx 5$ volts.

Figure 2.— AC equivalent schematic of K-West Signal Conditioner (P/N MC476-0132-0034) (± 2g output range, 0.75 - 50 Hz response, -3 dB)

agree well with test results, therefore, this assumption seems valid. (Design specification requires input impedance greater than 25 MΩ.)

It is to be noted from equation 1 that the response is in terms of voltage-out for charge-in. This is shown in figure 1 as a charge source driving the first stage.

The value Q_i is the charge generated by the transducing element. That charge is held on the total capacitance which is the sum of the transducer and cable capacitances. Using the relationship

$$E = \frac{Q}{C} \qquad (2)$$

the charge model can be converted to a voltage model (voltage-in/voltage-out) as shown in figure 3.

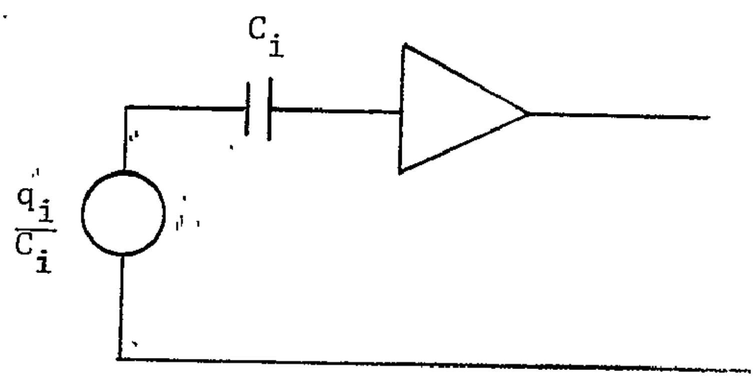


Figure 3.— A voltage equivalent model of charge measurement system.

Then equation 1 becomes

$$\frac{E_o}{Q_1} = \frac{E_o}{E_i C_i} \tag{3}$$

$$\frac{E_o}{E_i} = \frac{C_i(-5 \times 10^8)(s)(s + 1/11)}{s^2 + 6.85s + 23.3} \tag{4}$$

For the bipolar noise testing which was performed to substantiate the analysis, the input capacitance was 1000 pF. Consequently, for the test data

$$\frac{E_o}{E_i} = \frac{-.5(s)(s + 1/11)}{s^2 + 6.85s + 23.3} \tag{5}$$

By examining equation 5, it can be noted that the first stage acts as a highpass filter; it has no response at direct current (dc). The low frequency response is primarily fixed by the $R_f C_f$ time constant (figure 1). The 3-decibel (dB) rolloff point for the first stage can be calculated from equation 5 to be 0.75 Hz.

It can also be observed that the denominator introduces a damped sinusoid in any transient response which occurs. That transient is of the form

$$e^{-3.43t} \cos(3.4t + \phi) \tag{6}$$

The effect of this transient is noticeable only for about 1200 milliseconds (ms) after which the exponential decay causes this term's contribution to the output signal to be less than 2 percent of its peak valve.

It can be demonstrated that "short" pulses have little effect on the WBSC output while "long" pulses are more harmful. A short pulse in this analysis is considered to be any pulse which is less than 30 ms in duration. For the input form shown in figure 4, the first stage response is given by equation 7.

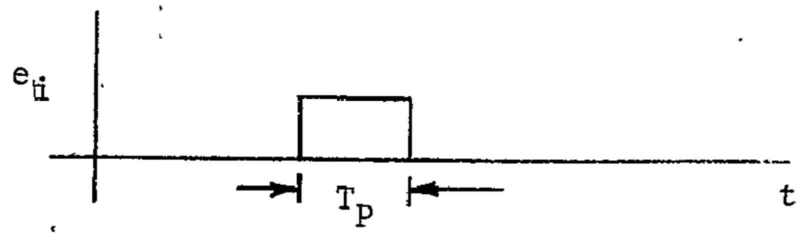


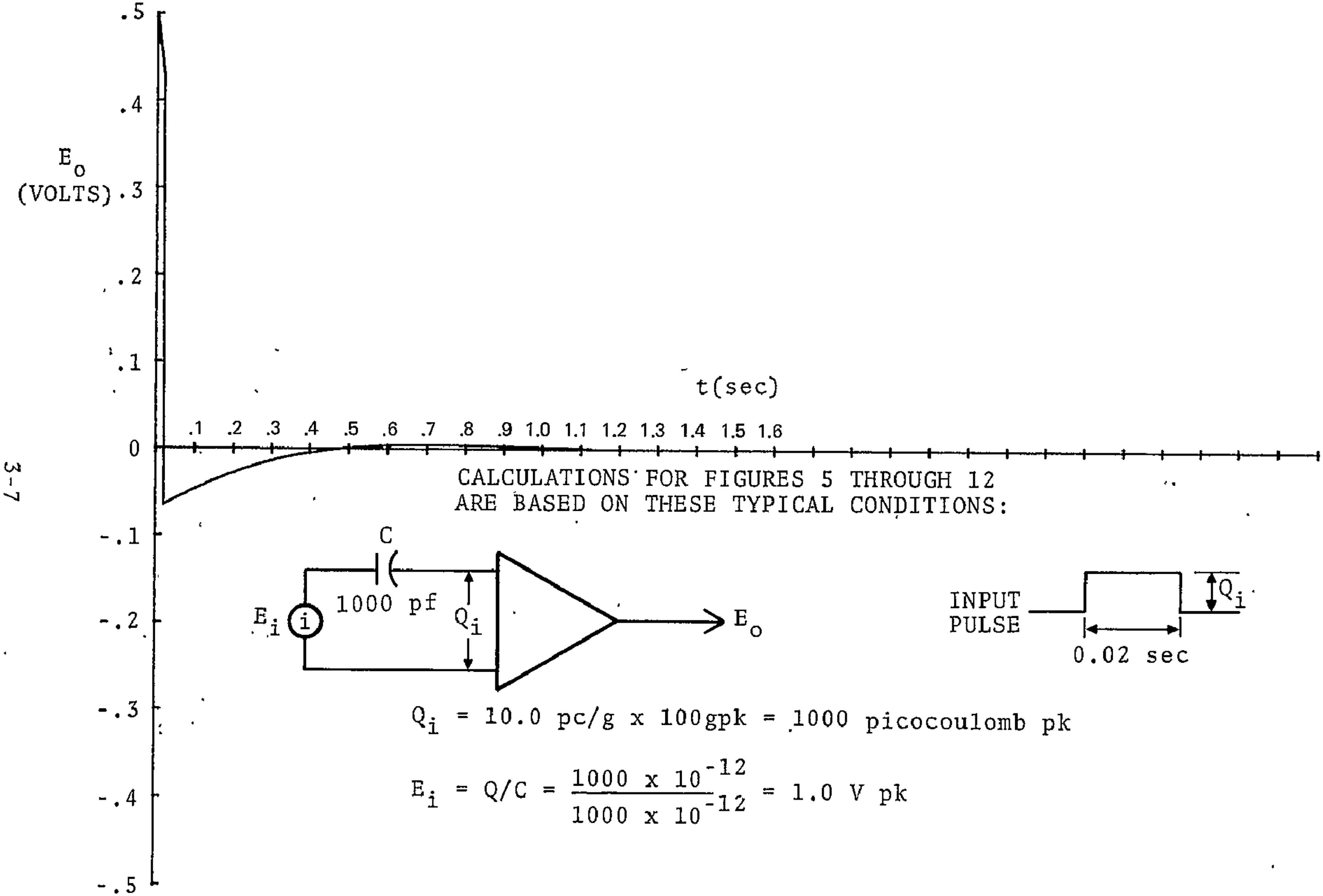
Figure 4.— Input to first stage.

$$\frac{e_{o1}(t)}{|e_i|} = .707e^{-3.43t}\cos(3.4t + 45°)$$

$$-.707e^{-3.43(t - T_p)}\cos[3.4(t - T_p) + 45°]U(t - T_p) \quad (7)$$

If the delayed term of equation 7 occurs before the first exponential has undergone substantial decay, then the delayed term will effectively cancel the first term. If $e^{-.1}$ is assumed to be the maximum decay tolerable, then $T_p \leq 29$ ms.

The figures which follow (figures 5 through 11) are plots of the first stage output as given by equation 7 for several values of pulse duration, T_p. The input is assumed to be 1 volt peak which for the signal conditioner tested (S/N 661) corresponds to an approximate 100 g peak input. The first stage calculated output therefore ranges between ±.5 V. Figure 12 applies the gain factors of the second and third stages (but not their filtering effect) to the first stage output shown in figure 6 and performs the overscale limiting function of the third stage. This response can be compared with the actual output response of the amplifier (plot 7A).



$$Q_i = 10.0 \text{ pc/g} \times 100 \text{gpk} = 1000 \text{ picocoulomb pk}$$

$$E_i = Q/C = \frac{1000 \times 10^{-12}}{1000 \times 10^{-12}} = 1.0 \text{ V pk}$$

Figure 5.– The first stage response to a <u>20 ms</u>, 100g pulse calculated from equation 7. Vertical scale is 100mV/division, horizontal scale is 100 ms/div. Notice on the figures which follow the height of the positive going overshoot and the length of time before the horizontal axis is finally reached.

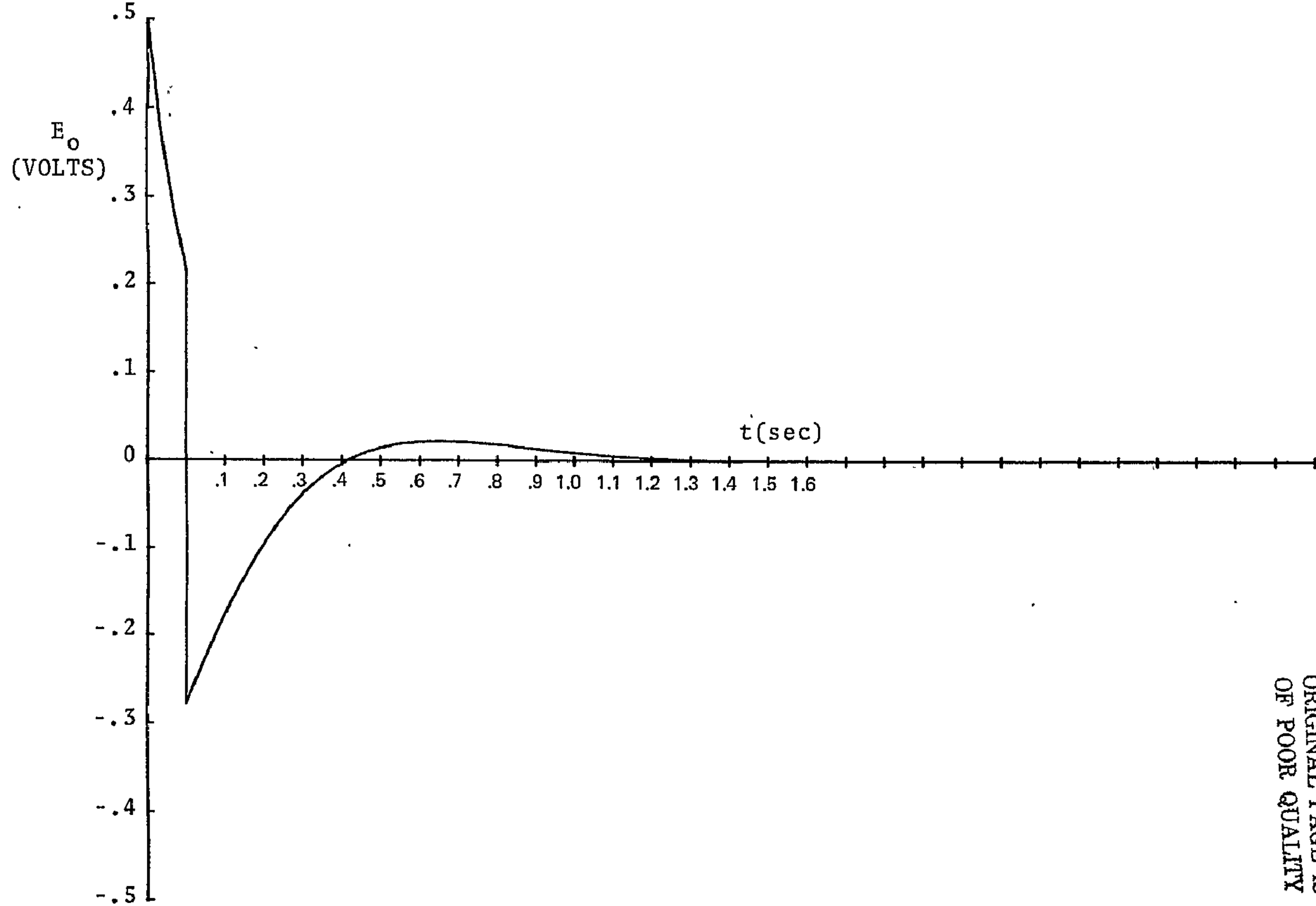


Figure 6.– The first stage response to a 100 ms, 100g pulse calculated from equation 7. Vertical scale is 100 mV/division, horizontal scale is 100 ms/division.

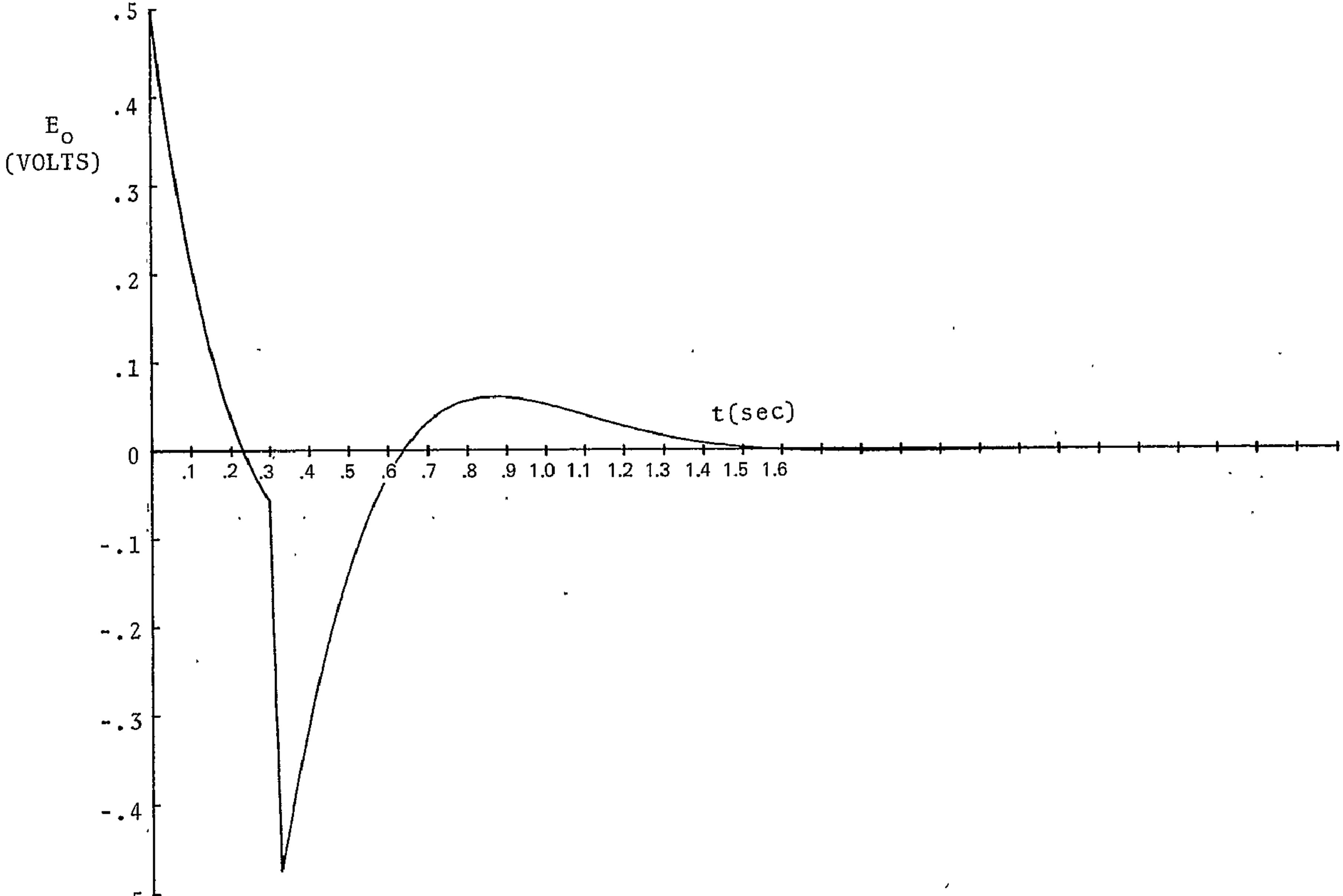


Figure 7.– The first stage response to a 300 ms, 100g pulse calculated from equation 7. Vertical scale is 100 mV/division, horizontal scale is 100 ms/division. Note the similarity with the test pulse of figure 15.

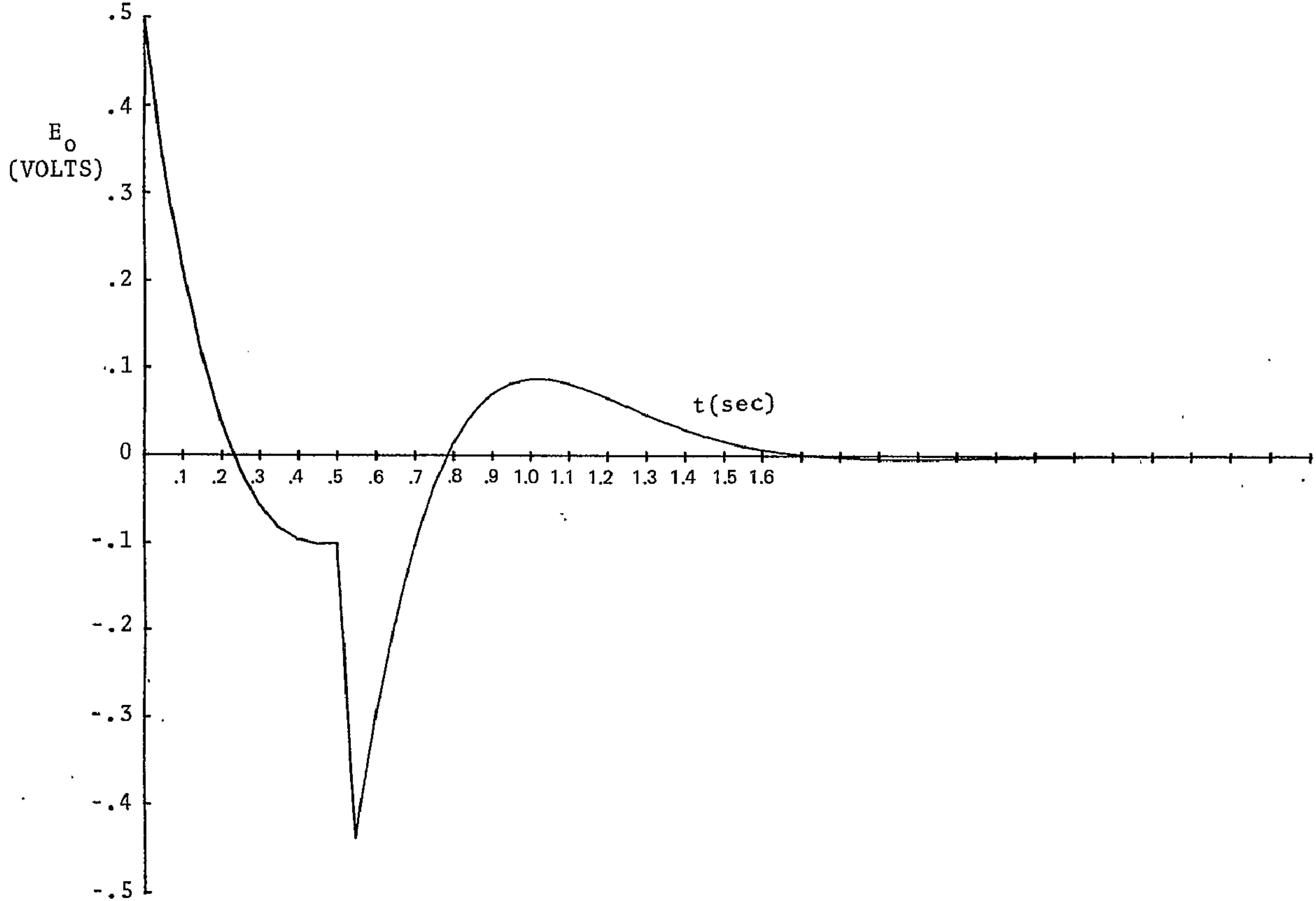


Figure 8.— The first stage response to a 500 ms, 100g pulse calculated from equation 7. Vertical scale is 100 mV/division, horizontal is 100 ms/division.

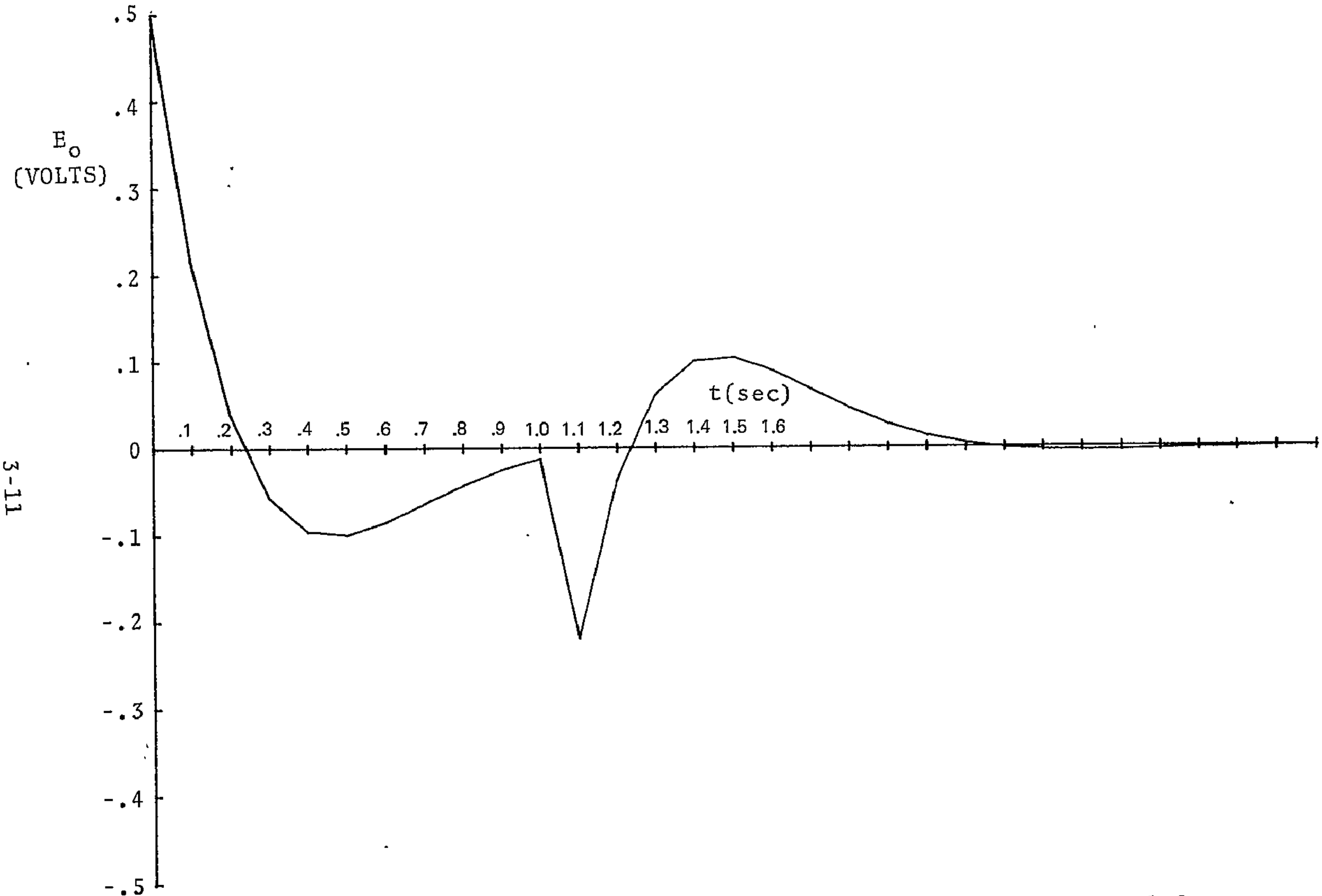


Figure 9.– The first stage response to a 1 sec, 100g pulse calculated from equation 7. Vertical scale is 100 mV/division, horizontal is 100 ms/division.

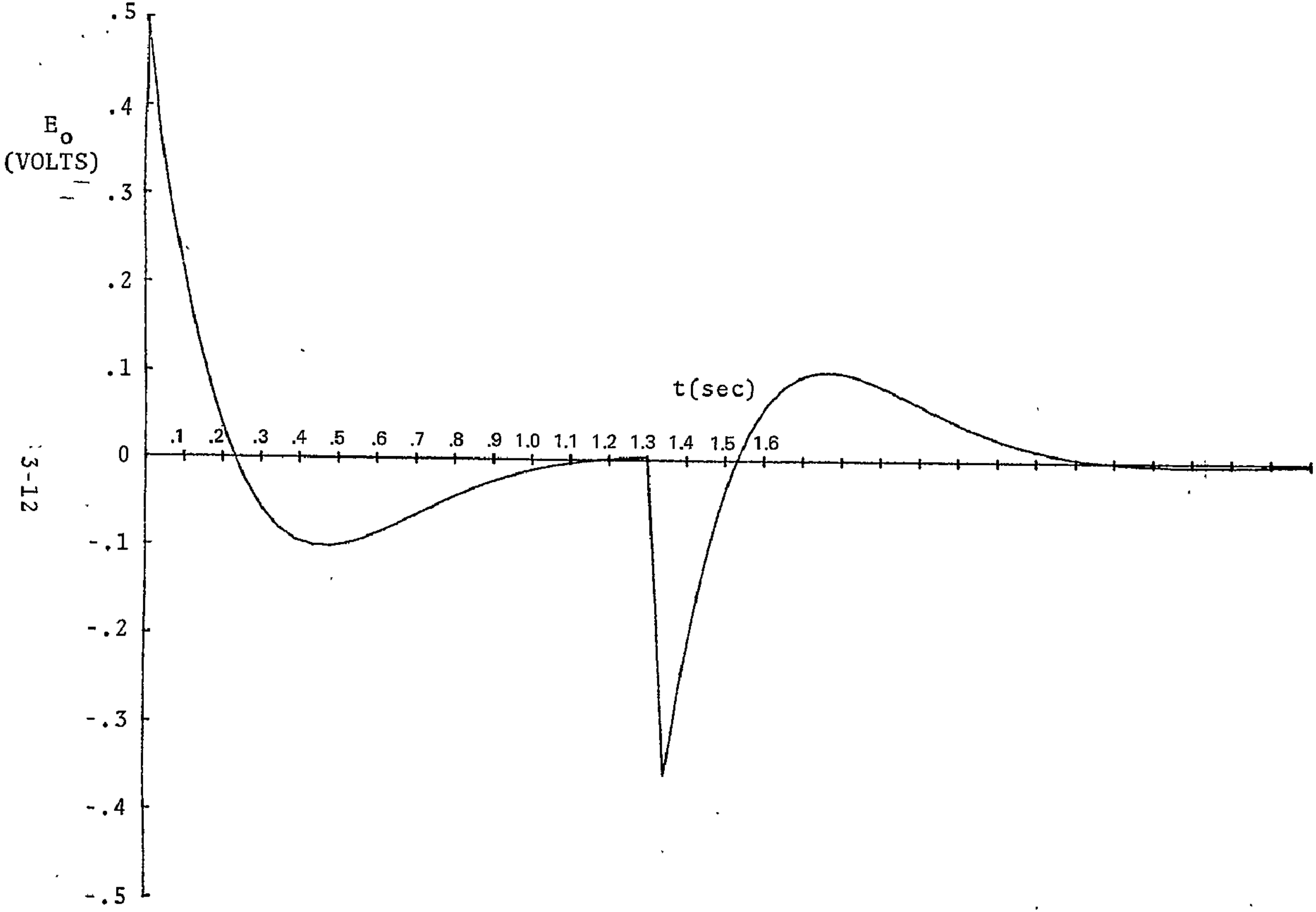


Figure 10.– The first stage response to a 1.3 sec, 100g pulse calculated from equation 7. Vertical scale is 100 mV/division, horizontal is 100 ms/division.

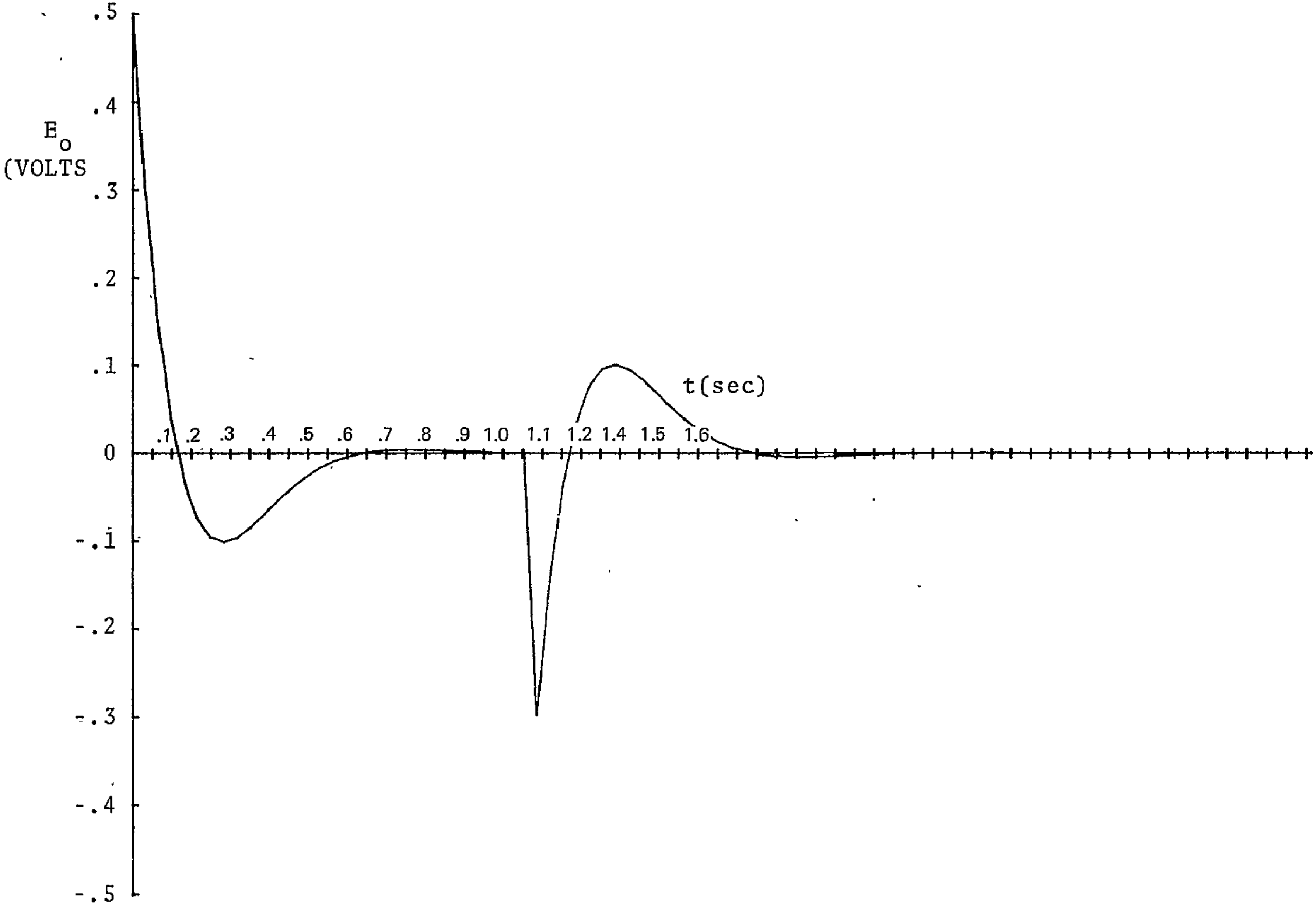


Figure 11.– The first stage response to a 2 sec, 100g pulse calculated from equation 7. Vertical scale is 100 mV/division, horizontal is 100 ms/division. Total scale length is now 6 seconds:

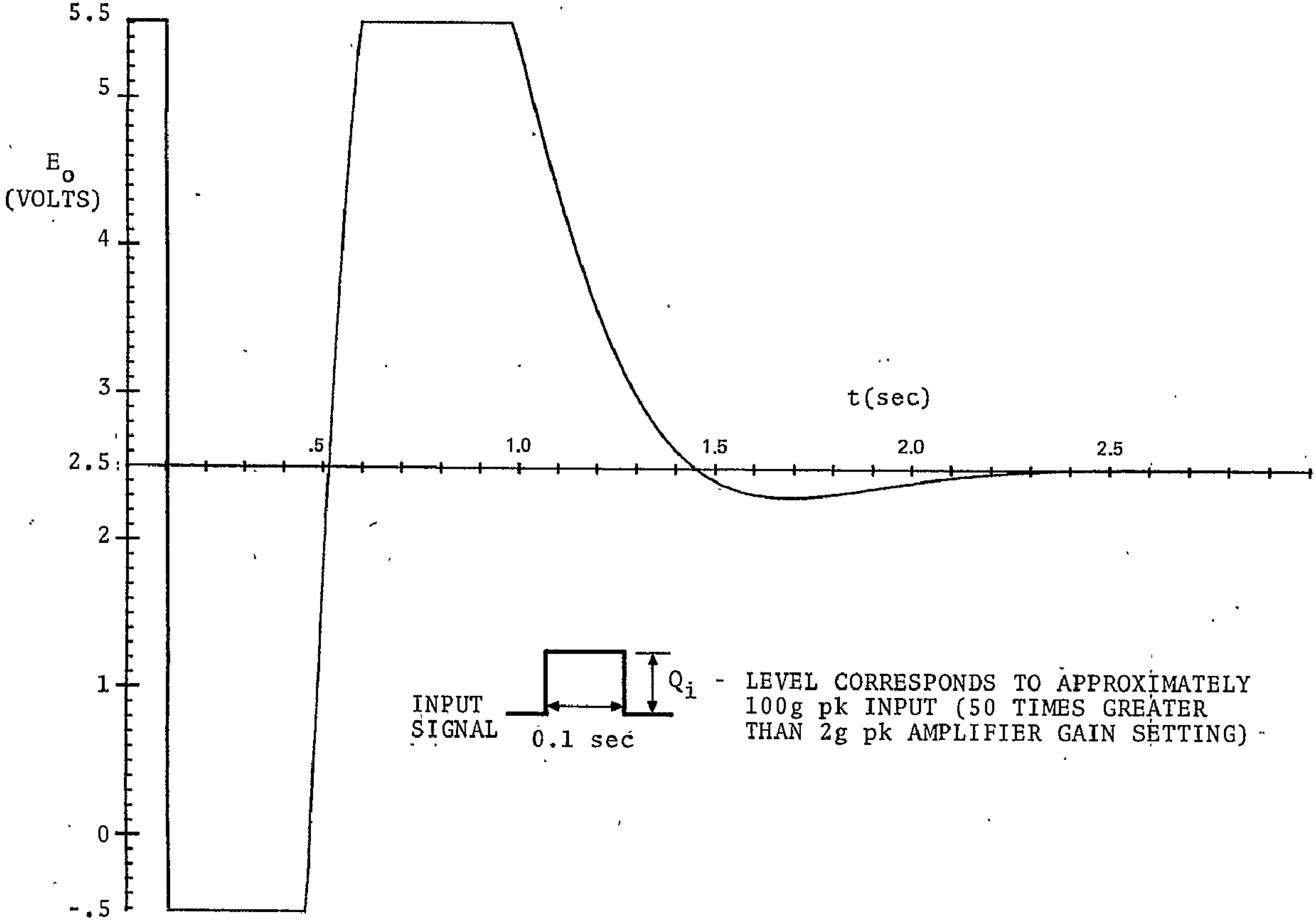


Figure 12.— The result of applying the second and third stage gain and clipping to the waveform of figure 6. The vertical scale ranges from -.5 volts to 5.5 volts in .1 volt increments. The horizontal scale is in 100ms/division. Note the agreement between this calculated result and the test result of plot 7A.

For input pulses which exceed the amplitude range of the signal conditioner, any other signal which is present is lost to the output during the duration of the pulse. The signal can also be blocked if the "bounce" following the pulse drives the amplifier to its output limits. In any case, the signal following the pulse will be offset by the residual response caused by the pulse.

In concluding the first stage analysis, it is noted that the WBSC is designed to work in conjunction with a transducer of a given sensitivity (S). For the transducer assumed in this analysis, the nominal sensitivity is 10 $\frac{pc}{g}$.

The output of the first stage in terms of acceleration can be derived from equations 1 and 2. It is

$$E_o = -(g_{in})(S)(5 \times 10^8)\frac{s(s + 1/11)}{s^2 + 6.85s + 23.3} \qquad (8)$$

The power supply limits of all three stages are ±9 V. Consequently, if the transducer sensitivity (S) were 10 $\frac{pc}{g}$, then theoretically the signal output of the first stage definitely would not become nonlinear until the input acceleration reached 1800 g (the signal equals the power supply voltage at this g-level).

3.1.2 SECOND STAGE

The second stage of the amplifier is a single pole, RC lowpass filter followed by a gain element. The 3 dB point for this stage is 33 Hz. The transfer function for the second stage for the particular amplifier tested is

$$\frac{E_{o2}}{E_{o1}} = \frac{k(208)}{S + 208}; \; 7 \le k \le 76 \qquad (9)$$

For the ±2 g amplifier tested, k (gain) has a nominal value of 18. The input to the second stage cannot exceed .5 V (at near dc frequencies) if the second stage is to remain linear in operation, due to the same power supply limits discussed above. This is equivalent to an input g level of 100 g, based on the analyses made for the first stage.

3.1.3 THIRD STAGE

The third stage of the WBSC is effectively a two-pole active low-pass filter. The second and third stages are capacitively coupled, therefore, the dc response is zero. The gain of the third stage ranges from 12 at low frequencies to approximately 18 at 40 Hz. This peaked gain compensates the RC rolloff of the second stage to give a flatter gain curve for the second and third stage combinations (figure 13).

Included in the third stage is circuitry which limits the output to a level between -.5 and +5.5 volts by varying the gain of the third stage. Linearity of the third stage is assumed only for signals which produce an output between 0 and 5 volts. The transfer function for the third stage is

$$\frac{E_{o3}}{E_{02}} = \frac{(-1.03 \times 10^6)(s)}{s^3 + 202s^2 + 83400s + 20900} \tag{10}$$

In summary, the WBSC employs a highpass first stage (with 0.75 Hz, -3 dB low frequency rolloff) of very high input impedance which converts the charge generated by the transducing element into a voltage essentially independent of the specific shunting capacitance of the transducer and cable. The second stage filters and amplifies the signal. The final stage provides additional filtering and gain and limits the output to a maximum range of -0.5 to 5.5 volts (0 to 5 V nominal full scale range).

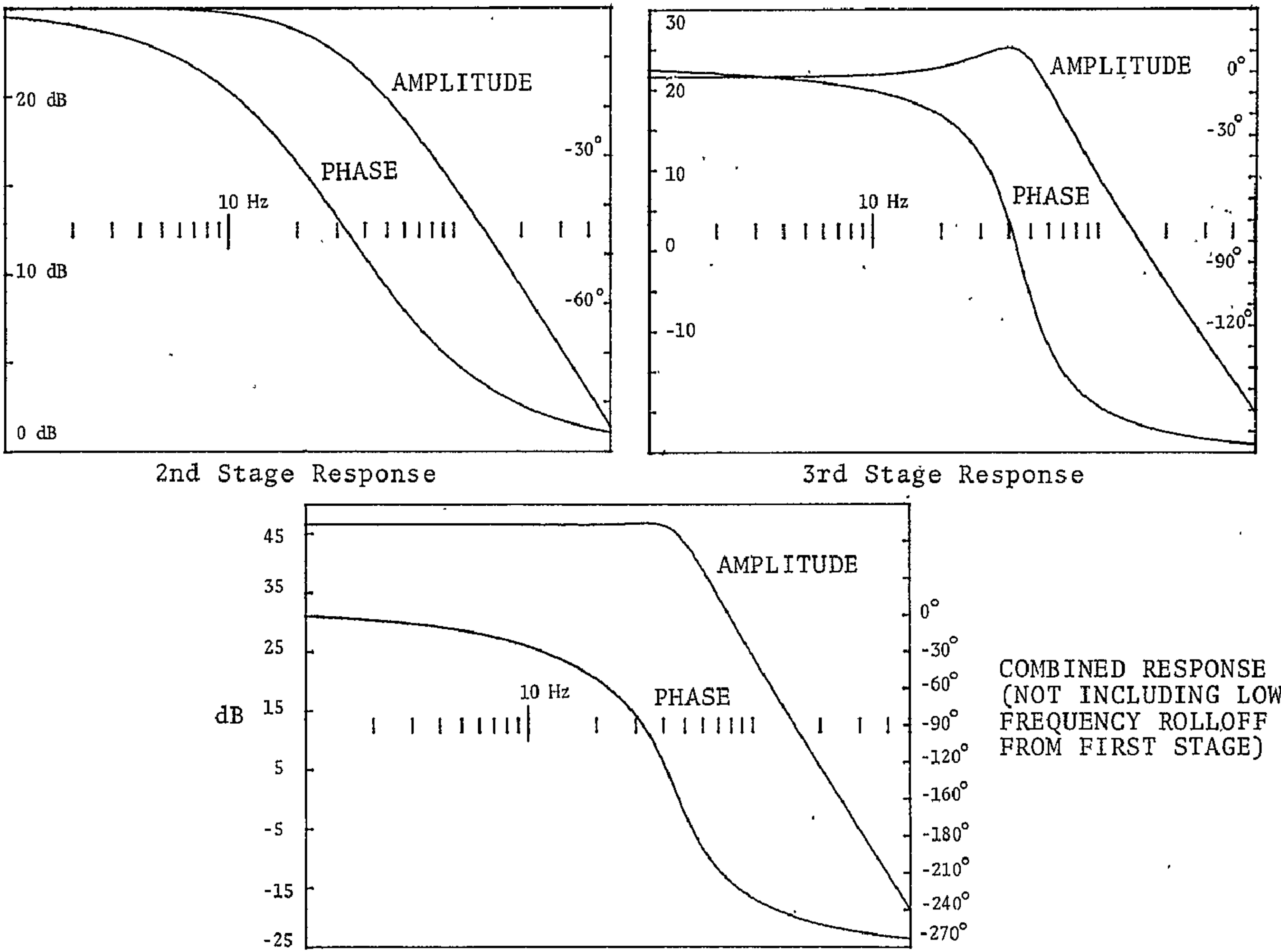


Figure 13A.— Gain characteristics of the second and third stages.

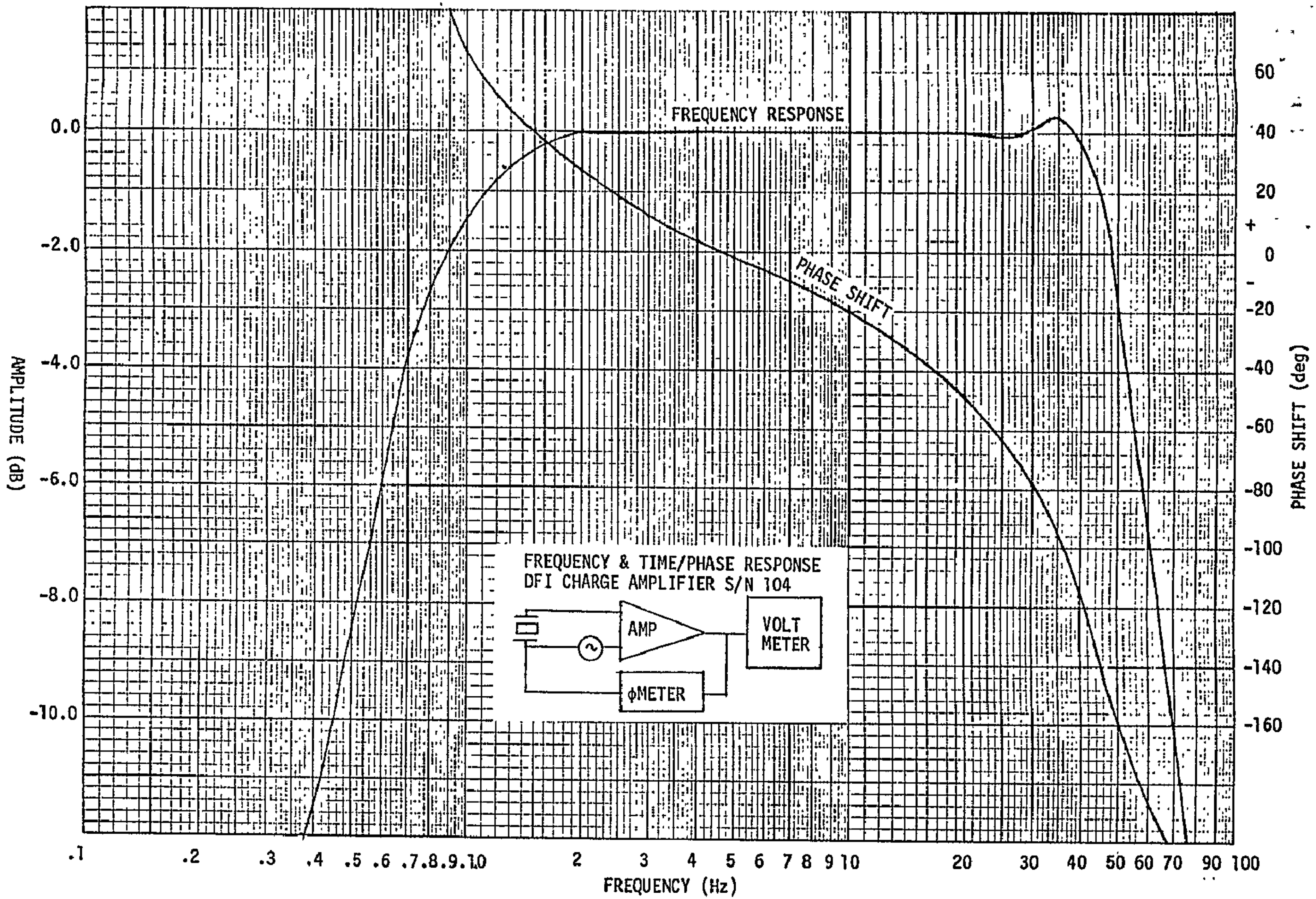


Figure 13B.-Measured Frequency and Phase Response.

3.2 PULSE AND BURST SIGNAL RESPONSE

The first stage response to a square pulse has been discussed in the preceding section. Since the second stage is a dc coupled lowpass filter with the filtering action occurring relatively far from the characteristic frequency of the first stage (3.4 radians), its primary effect is to add gain to the output of the first stage. The inclusion of the third stage, for pulse considerations, results primarily in the additional term, $e^{-.25t}$. The end-to-end significant response of the signal conditioner is given in the following:

$$e_o \approx |e_i| \Big[740e^{-3.4t} \cos(3.4t) + .8e^{-.25t} + (-740e^{-3.4(t - T_p)} - .8e^{-.25(t - T_p)})U(t - T_p) \Big] \qquad (11)$$

The contribution by the third stage term is small in comparison to the term generated by the first stage and its time constant is long relative to that of the first stage. Therefore, the third stage can be considered essentially as a gain stage and the response of the signal conditioner will have approximately the same waveform as the output of the first stage except that limiting will occur to clip the top and bottom portions of the waveform.

The response of the WBSC to a burst of signal can be deduced from the knowledge of the response to a pulse. Consider a burst as shown in figure 14.

Figure 14.— A burst input signal.

If the frequency of the sine wave in the burst is high, then the two lowpass filters of the second and third stages will greatly limit the signal reaching the output. The only question then is what will the response be to the first and last cycles of the waveform? The response to the first cycle of a sine wave will be less drastic than the response to a pulse. If the frequency of the sinusoidal burst is greater than the range of the WBSC (50 Hz for the device tested) then the exponential sinusoid response associated with the first stage transfer function is less than 1 percent of the response due to the input sine wave, (i.e., at the output of the first stage).

$$100[e^{-3.4t} \cos(3.4t + \phi)\text{term}] < \sin wt \text{ term } \frac{w}{2\Pi} > 50 \text{ Hz} \quad (12)$$

Consequently, a perfectly symmetrical burst of 2 kilohertz (kHz) will have considerably less effect on the output than the amplitude of the pulse would lead one to believe. If, however, the burst has a dc offset, then the response may be considered to be the super-position of the response to a symmetrical burst plus the response to a pulse of duration equal to the burst. Hence, asymmetrical bursts have the same effect as pulses and can result in a loss of signal during or following the burst period.

Shown on the following pages are photographs of oscilloscope traces comparing input burst signals with the amplifier's output response (figures 15 through 21). It should be noted that the amplifier tested is a ±2 g, 2- to 50-Hz unit; therefore, the input 2 kHz bursts of ±10 g, ±100 g, ±200 g, and ±500 g greatly exceed the output range setting. When the input burst has no dc offset, the amplifier's output is distorted only at the beginning and end of the burst (figures 16 and 20). A burst with dc offset will result in an output transient response also during the burst period (figures 15, 17, 18, and 19). Compare figures 18 and 20 to see the comparison of same burst signal with and without dc offset. For the ±200 g signal case, a 1 percent offset equals the 2 g peak range of the amplifier being tested. The offsets in the test signal occurred due to difficulty in adjusting the signal generator output to produce equal amplitude swings on both sides of zero volts.

3.3 BIPOLAR NOISE SIGNAL RESPONSE

Testing was performed on the WBSC to determine its behavior in a "noise" environment (i.e., with input vibration signals outside the amplifier's output bandwidth). The equipment was configured as shown in figure 22.

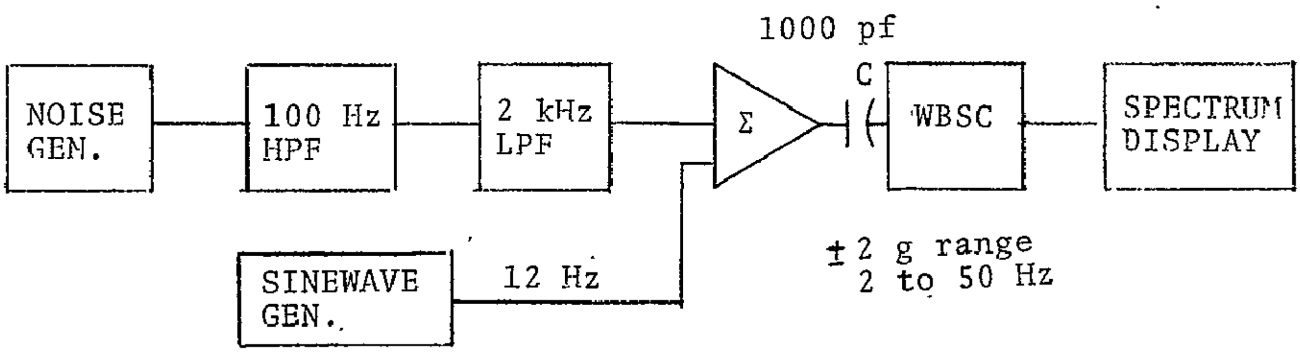


Figure 22.— Equipment configuration for bipolar noise signal response.

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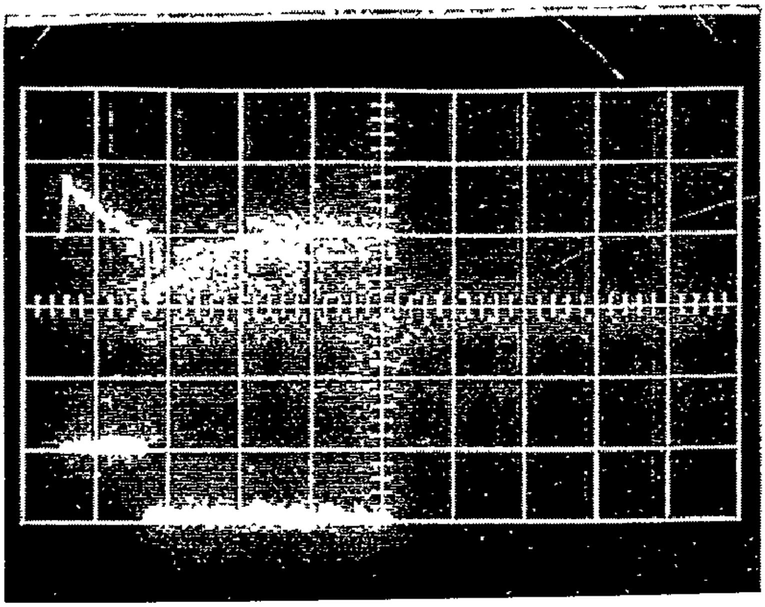

Figure 15.— A 2g reference pulse. Input - bottom 20 mV/cm. Output - top 2 V/cm. Time = 200 ms/cm.

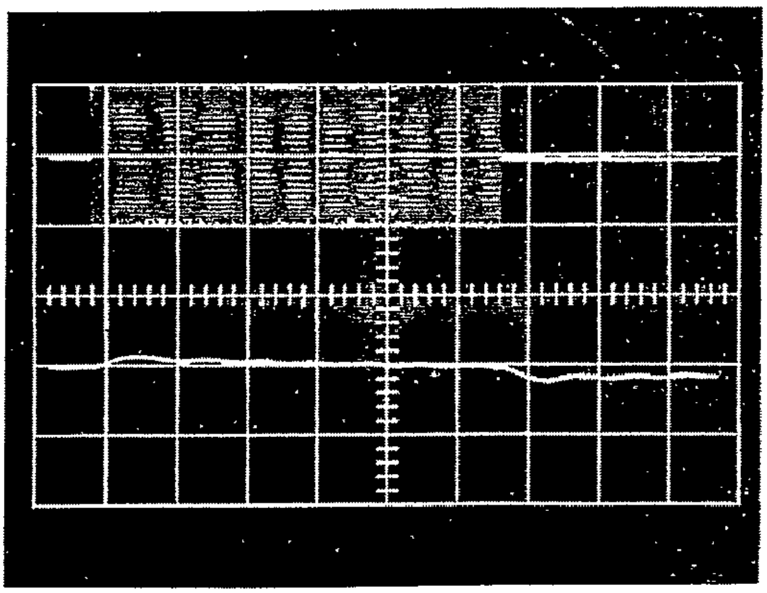

Figure 16.— A ±10 g, 2 kHz burst. Input - top 100 mV/cm. Output - bottom 2 V/cm. Time - 20 ms/cm.

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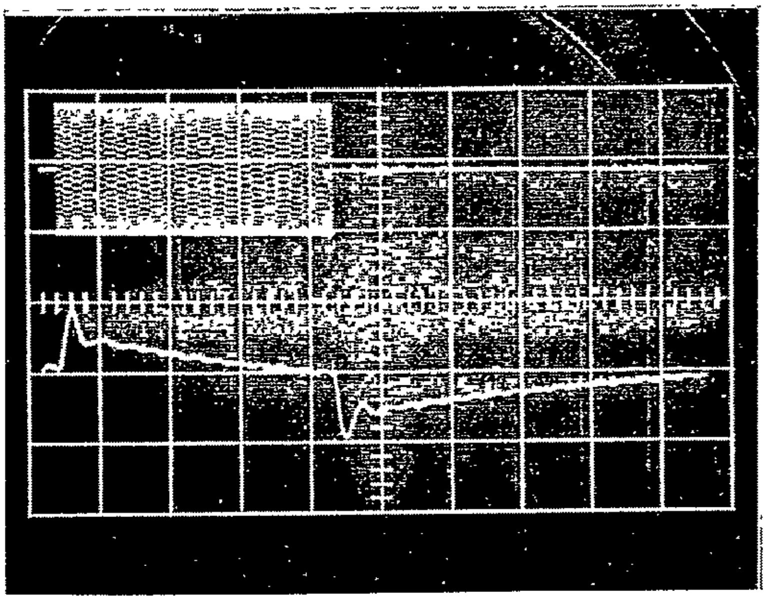

Figure 17.— A ±100 g, 2 kHz burst. Input - top 1 V/cm
Output - bottom 2 V/cm. Time - 50 ms/cm (burst slightly asymmetrical).

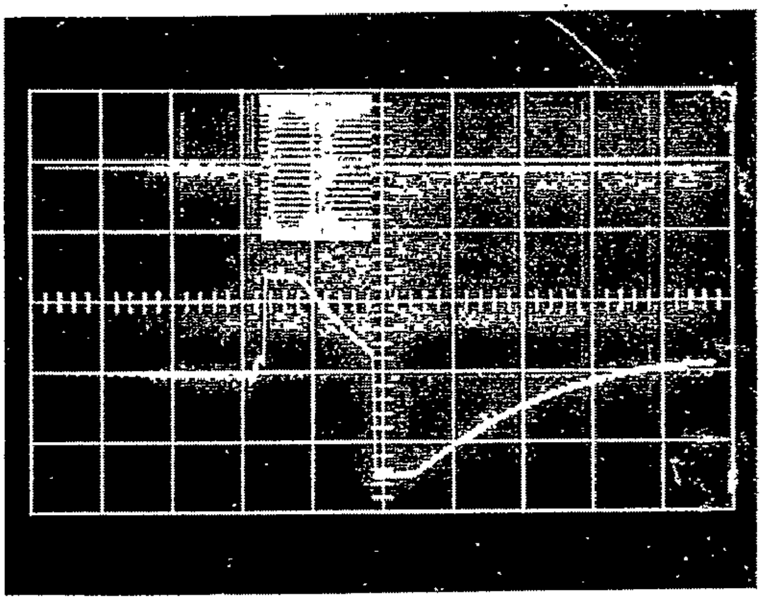

Figure 18.— Slightly asymmetrical ±200 g, 2 kHz burst. (See figure 20.)
Input - top 2 V/cm. Output - bottom 2 V/cm. Time - 100 ms/cm.

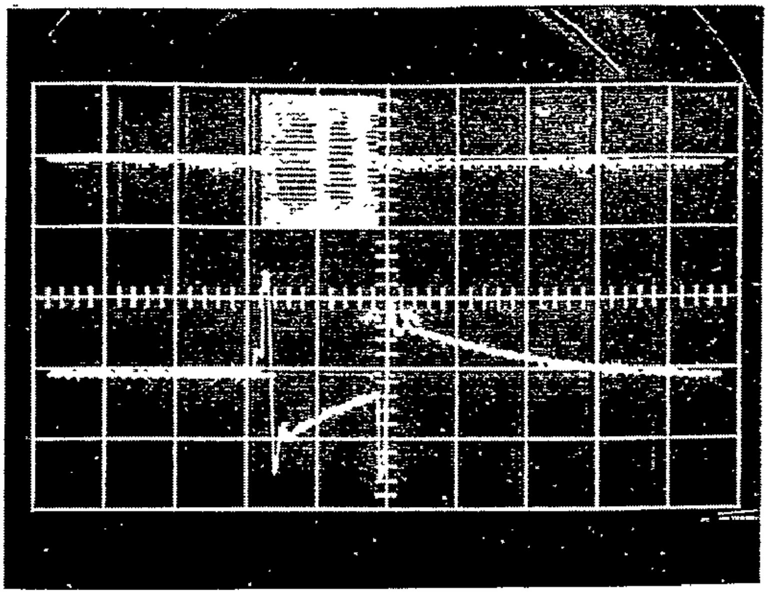

Figure 19.— ±500 g, 2 kHz burst. Input - top 5 V/cm. Output - bottom 2 V/cm. Time - 100 ms/cm (burst slightly asymmetrical).

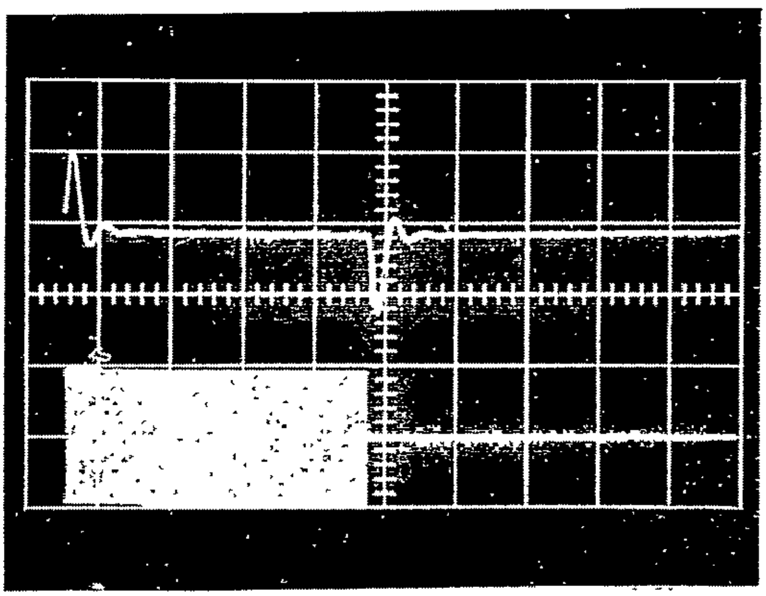

Figure 20.— ±200 g, 2 kHz burst. Input - bottom 2 V/cm. Output - top 2 V/cm. Time - 50 ms/cm. This pulse was adjusted for symmetry to produce only the start and stop spikes.

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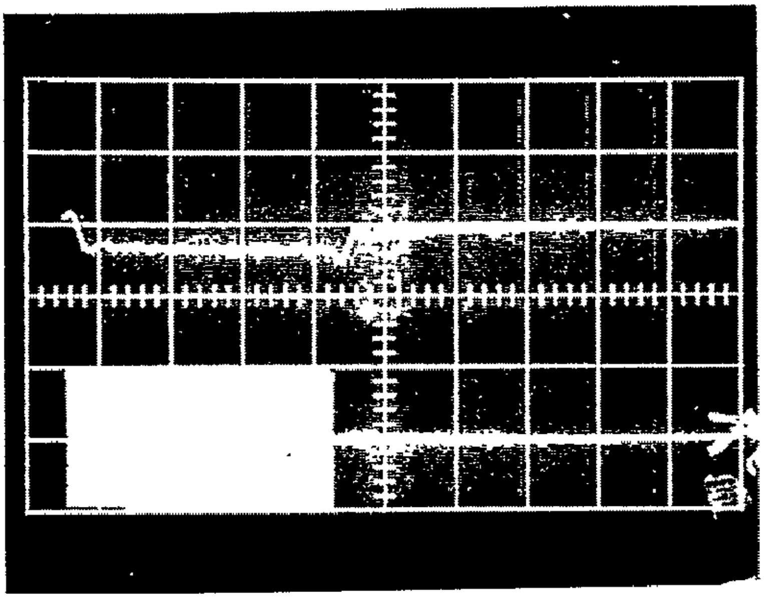


Figure 21.— ±200 g, 8 kHz burst. Input - bottom 2 V/cm. Output - top 2 V/cm. Time 50 ms/cm.

The equipment used were:

- El Genco Model 610A Noise Generator
- Khron-Hite Model 3202R 4-pole Butterworth Filters
- EMR1510 Spectrum Analyzer
- K-West WBSC MC476-0132-0034
- Khron-Hite Model 5000 Function Generator

The input capacitance to the WBSC was 1000 pF. Nominal input signal level was 1 g = 10.9 mV = 7.7 mV rms. The outputs shown are the result of ensemble averaging in the spectrum analyzer.

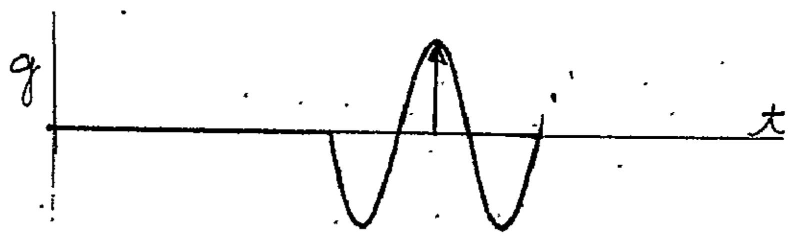
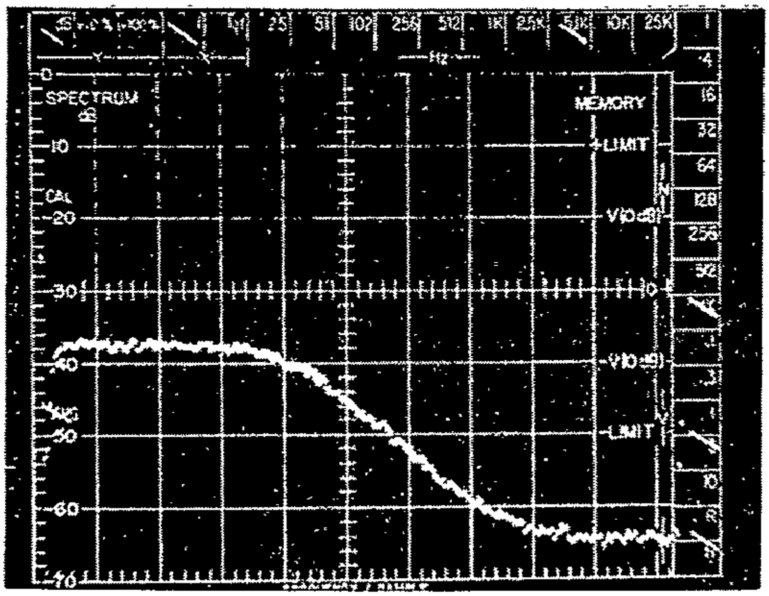


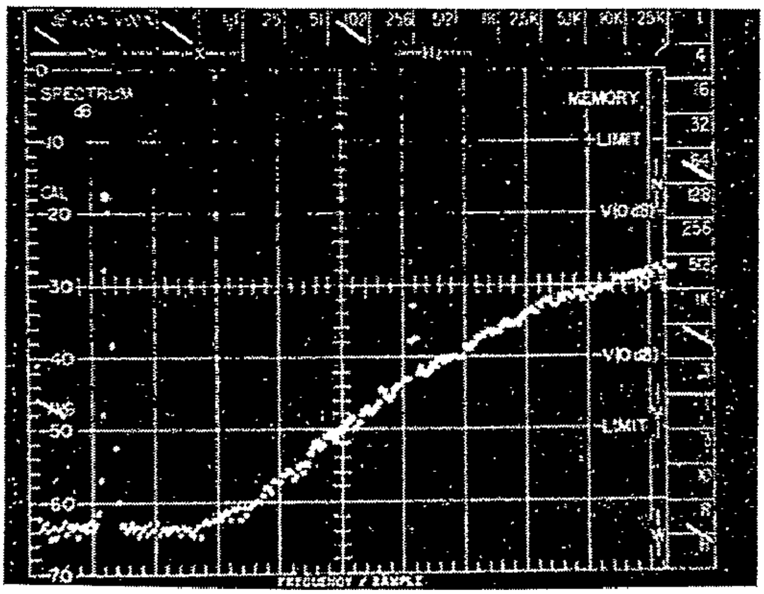
Figure 23.— Nominal signal input.

A review of the test results (examples shown in figures 24 through 30) shows that the 2- to 50-Hz (-3 dB points) amplifier is relatively immune to "noise" (unwanted vibration signals) above 100 Hz. Noise densities up to approximately 5 g^2/Hz from 100 Hz to 2 kHz have virtually no effect on the signal within the band. Above that level, random noise peaks cause the third stage to clip the output by reducing the third stage gain (figure 30). For example, testing showed that a signal drop of 5 percent occurred when the noise density was about 9.0 g^2/Hz over the noise bandwidth of 100 Hz to 2 kHz.



A

Figure 24.— The unfiltered spectrum of the noise source. Vertical scale, 0 dB referenced to 3 Vrms. Horizontal scale linear to 5.1 kHz.



B

Figure 25.— Input to the WBSC. (Portion below 100 Hz shown only.) Noise level is .24 g^2/Hz from 100 Hz to 2 kHz. Scale is uncalibrated but relative level of signal and noise can be noted. Horizontal scale linear to 102 Hz.

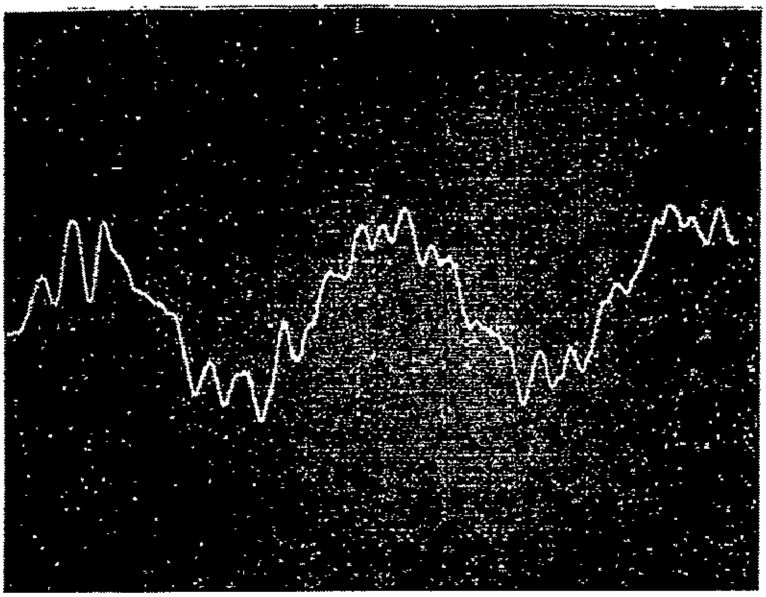
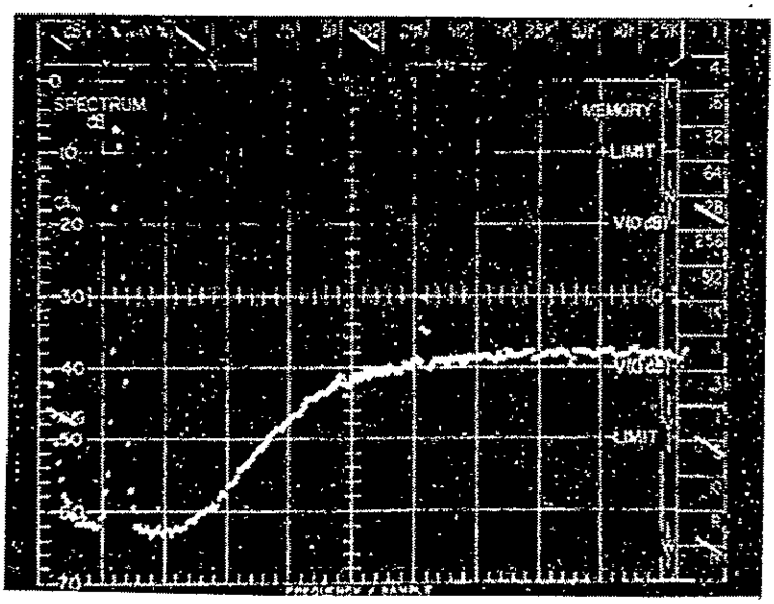
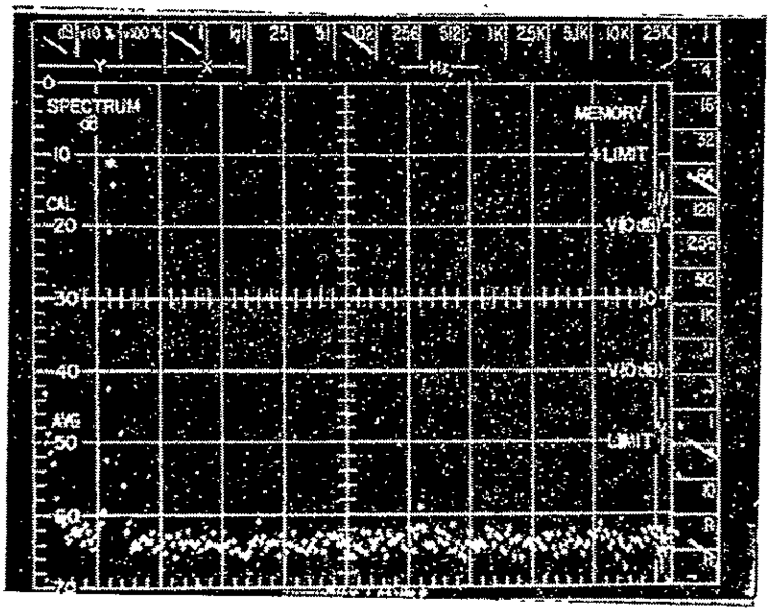


Figure 26.— Output of WBSC. Vertical scale is 1V/cm. Horizontal is 20 ms/cm.



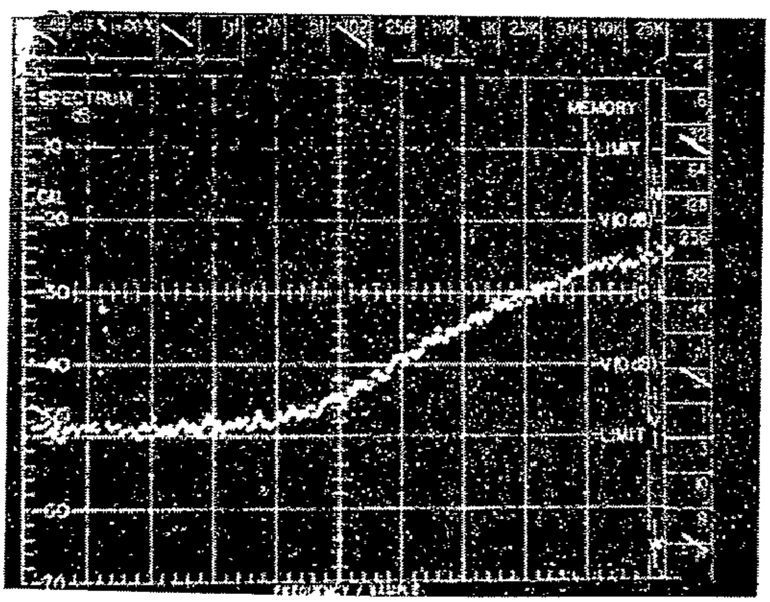
C

Figure 27.— PSD of the WBSC output for input spectrum of figure 25. Vertical scale, 0 dB ref. to 3 Vrms. Horizontal scale linear to 102 Hz.



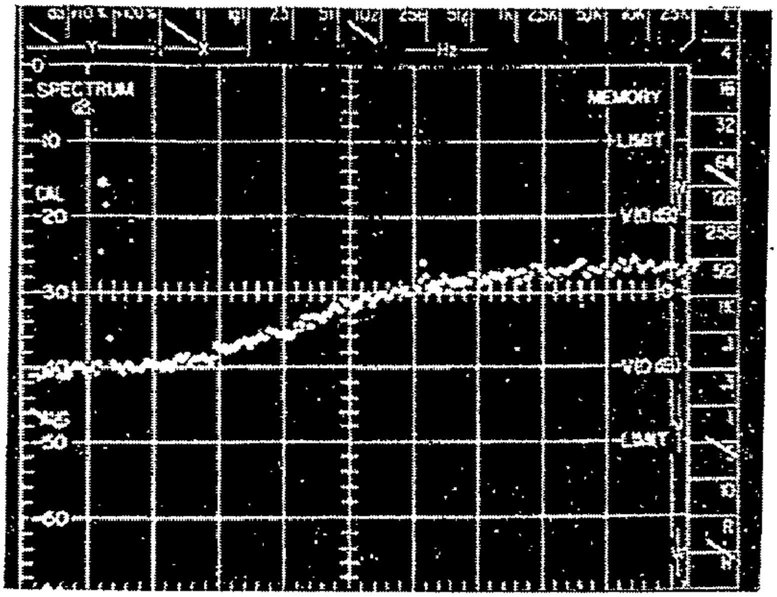
D

Figure 28.— PSD of the output of the WBSC, without noise input. This particular trace is calibrated and shows the signal to be down 10.6 dB relative to 3V (same scaling as figure 27).



E

Figure 29.— PSD of the input to WBSC, signal plus noise. Noise density is $24g^2$/Hz, 100 Hz to 2 kHz (same scaling as figure 27).



F

Figure 30.- Output of WBSC for input of figure 29.
Signal (12 Hz) level down 5 dB from level in figure 28.
(Same scaling as figure 28.)

The lowpass filter characteristics of the second and third stages are seen to be quite effective in eliminating unwanted signals outside the bandwidth of the amplifier. For pogo measurements at least, no problem with amplifier saturation should occur due to out-of-band noise since the anticipated flight levels are less than 5 g^2/Hz.

3.4 UNIPOLAR SIGNAL RESPONSE

Testing was performed on the WBSC to determine its behavior with unipolar input signals (i.e., square wave and half sine-wave pulses) both separately and in combination with random vibration signals, 1 g^2/Hz, 20 to 2000 Hz. Table I correlates the plot number (pages 3-34 through 3-58) with the signal input conditions. The equipment was configured as shown in figure 31.

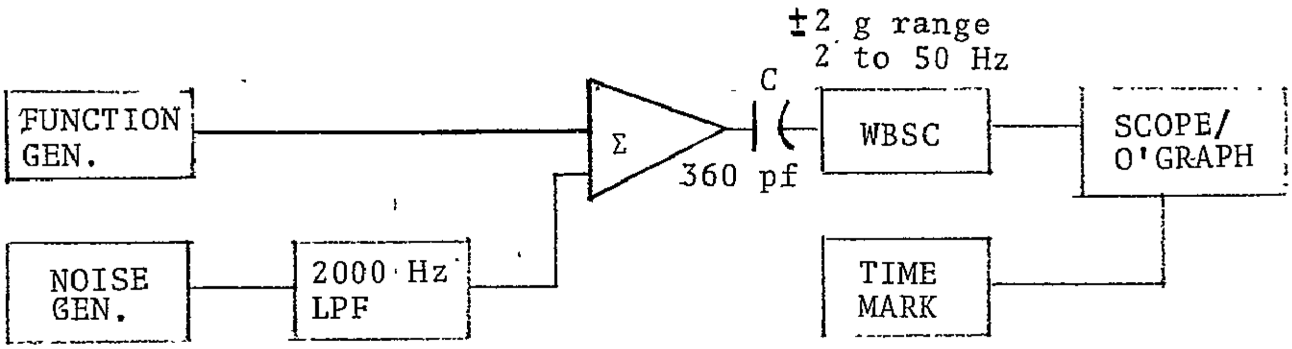


Figure 31.— Equipment configuration for unipolar signal response.

The equipment used were:

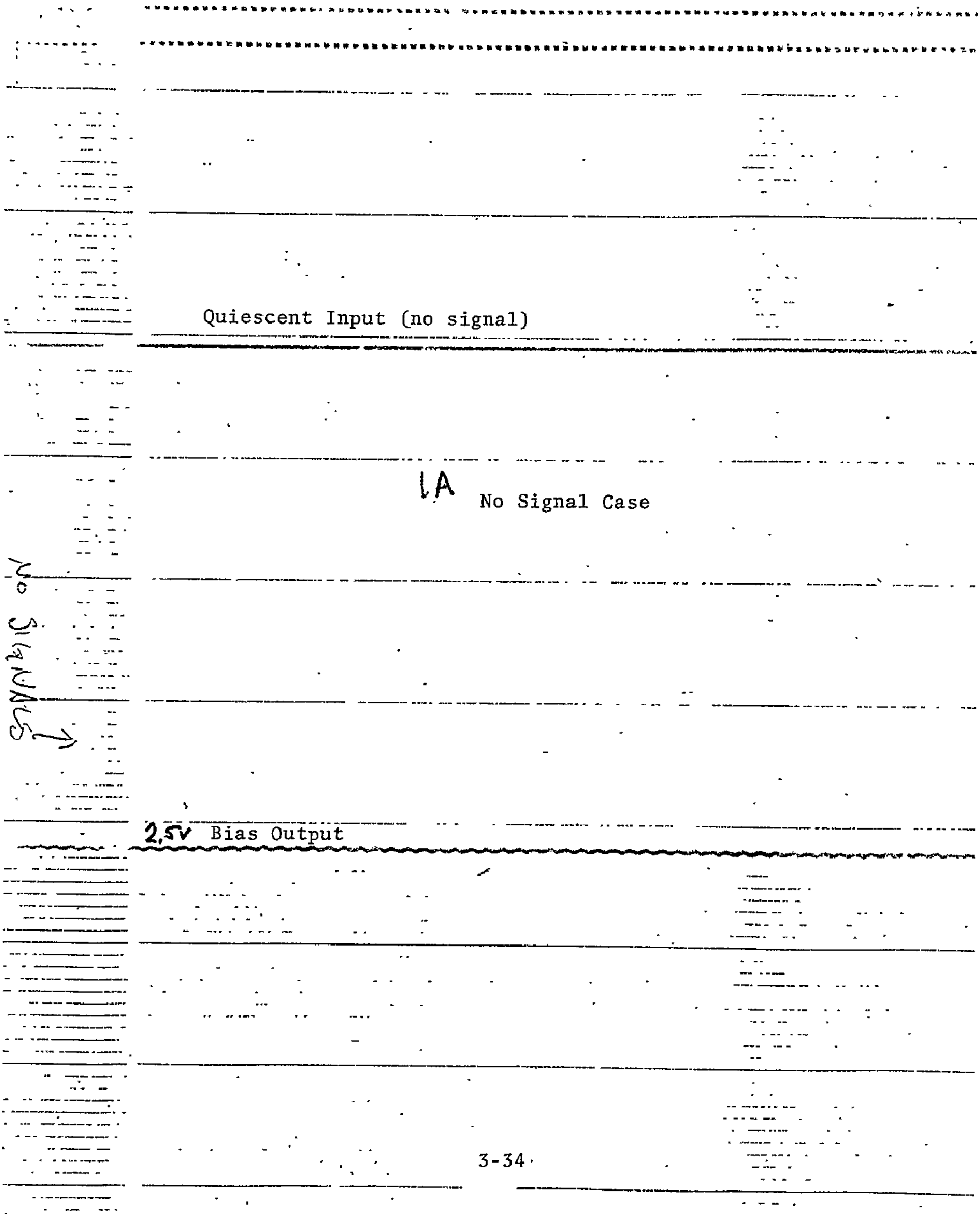
- HP 3300A Function Generator
- Data Graph Model 5-133 oscilloscope
- K-West WBSC MC476-0132-0034

TABLE I.— CORRELATION BETWEEN PLOT NUMBERS AND INPUT CONDITIONS USED IN UNIPOLAR PULSE TESTING

Primary Input Type	Freq. Hz	Amplitude 0 - Peak (Approx.)	Primary Input/ Output Plot Designation	Primary + $1g^2$/Hz 20-2000 Hz White Noise Plot Designation
No Signal	-	0V (2.5 V Bias)	1A	1C
Sine	5	1g 10g 100g	2A 3A 4A	
Square Pulse	100 ms	1g 10g 100g	5A 6A 7A	
1/2-cycle Sine wave	2.5	1g 10g 75g	8A 9A 10A	8C 9C 10C
1/2-cycle Sine wave	12.5	1g 10g 75g	11A 12A 13A	
1/2-cycle Sine wave	50	1g 10g 75g	14A 15A 16A	

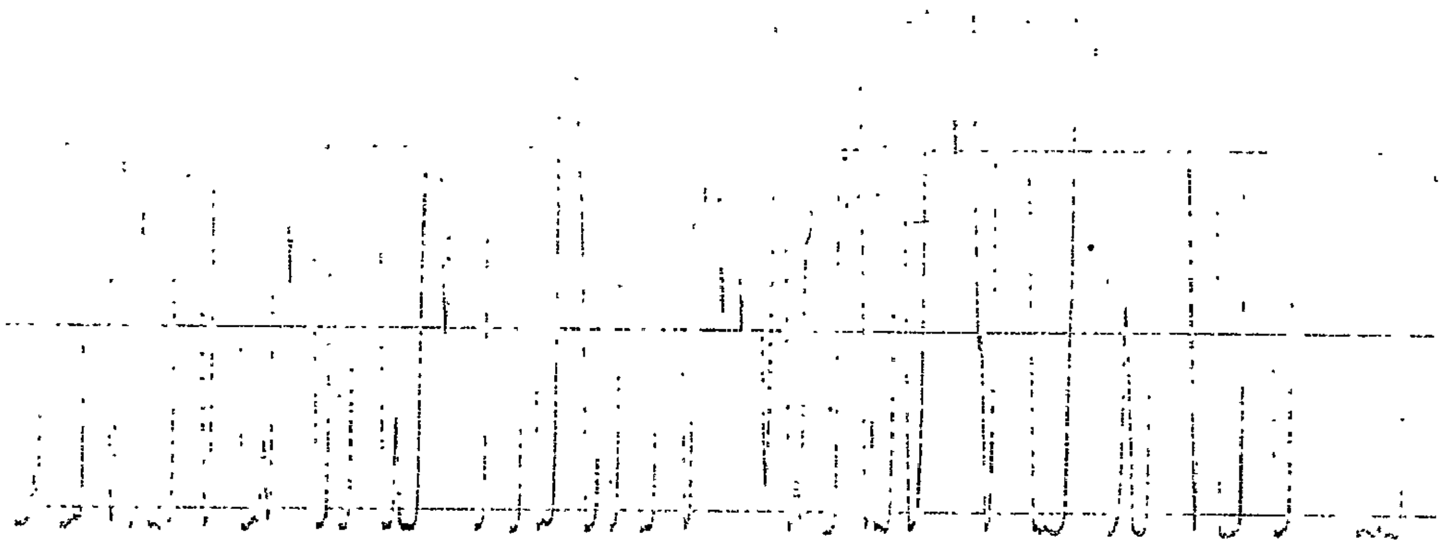
- Krohn-Hite Model 5000 Function Generator
- El Genco Model 610A Noise Generator
- Krohn-Hite Model 3202R Active Filter

By observing the resulting output waveforms to the various input signals, several conclusions are evident: (1) The amplifier responds to an over-range bipolar sine wave (e.g., 100 g sine wave, 50 times full scale range), in a clipped manner (-.5 to 5.5 V) but will return immediately to a linear (undistorted) output as soon as the input signal is within the preset full scale range of the amplifier; (2) The amplifier responds to an over-range unipolar signal (e.g., 100 g square wave pulse, 50 times full scale range) in both a clipped and saturated manner – The saturated condition is typified by figures 7A and 10A which show that the output is severely distorted for almost 1.5 seconds after the end of the input signal pulse. The response to a single half sine wave within the amplifier's range is not a faithful reproduction (figure 8A); (3) The signal output is delayed, has a slower rising and falling waveform, and has an appreciable undershoot below the quiescent bias; and (4) Fourier analysis of a single half sine wave shows high amplitude frequency content beginning at dc. Since the WBSC has a low frequency rolloff (-3 dB at 0.7 Hz), it cannot respond accurately to a half sine wave.

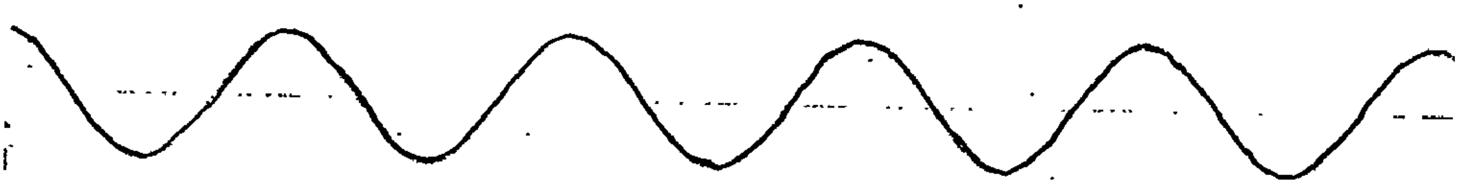

Quiescent Input (no signal)
1A No Signal Case
2.5v Bias Output
No Signals

1C Output with Random Noise Signal Input

$1 g^2/Hz$, 20 to 2000 Hz

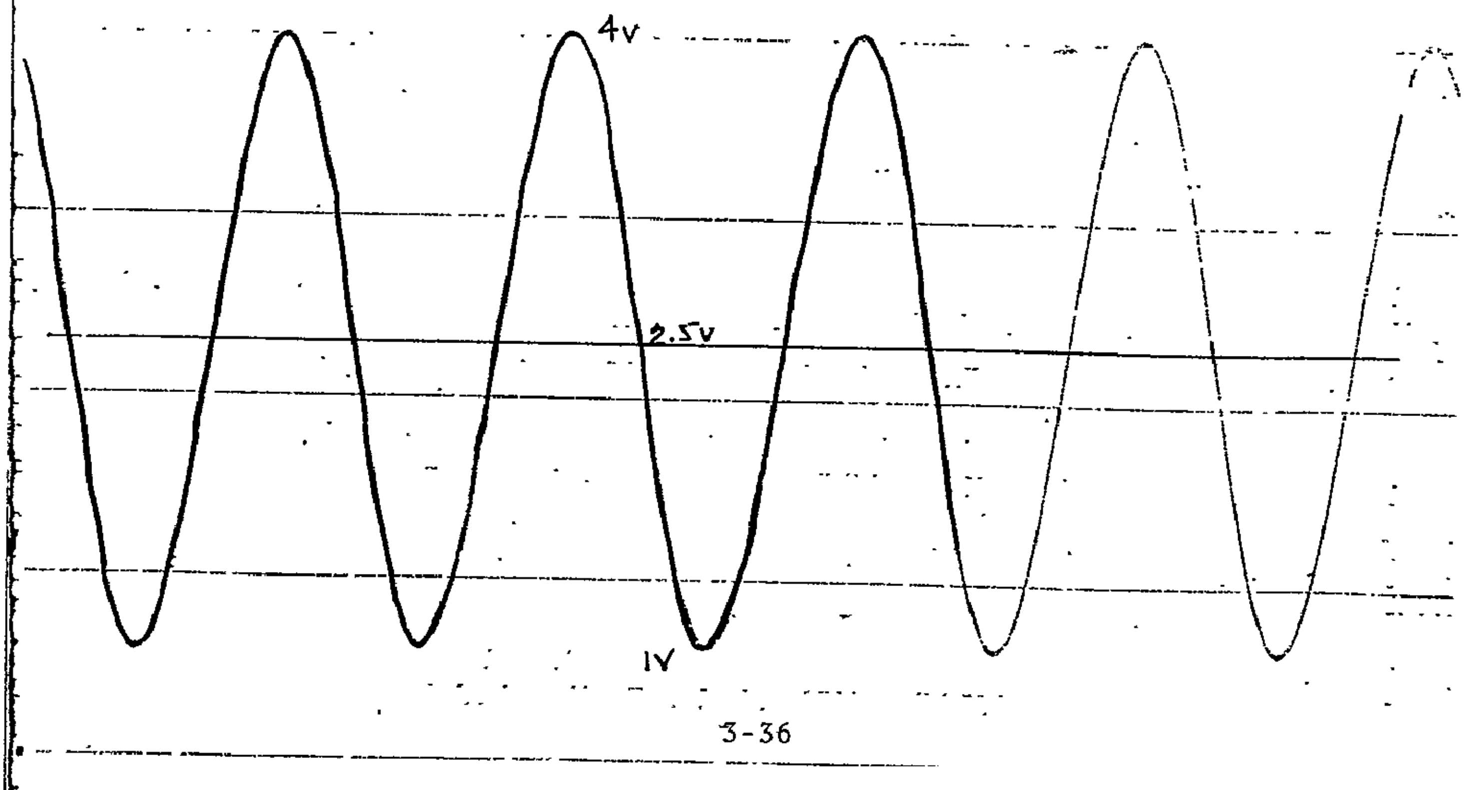


Signal Input

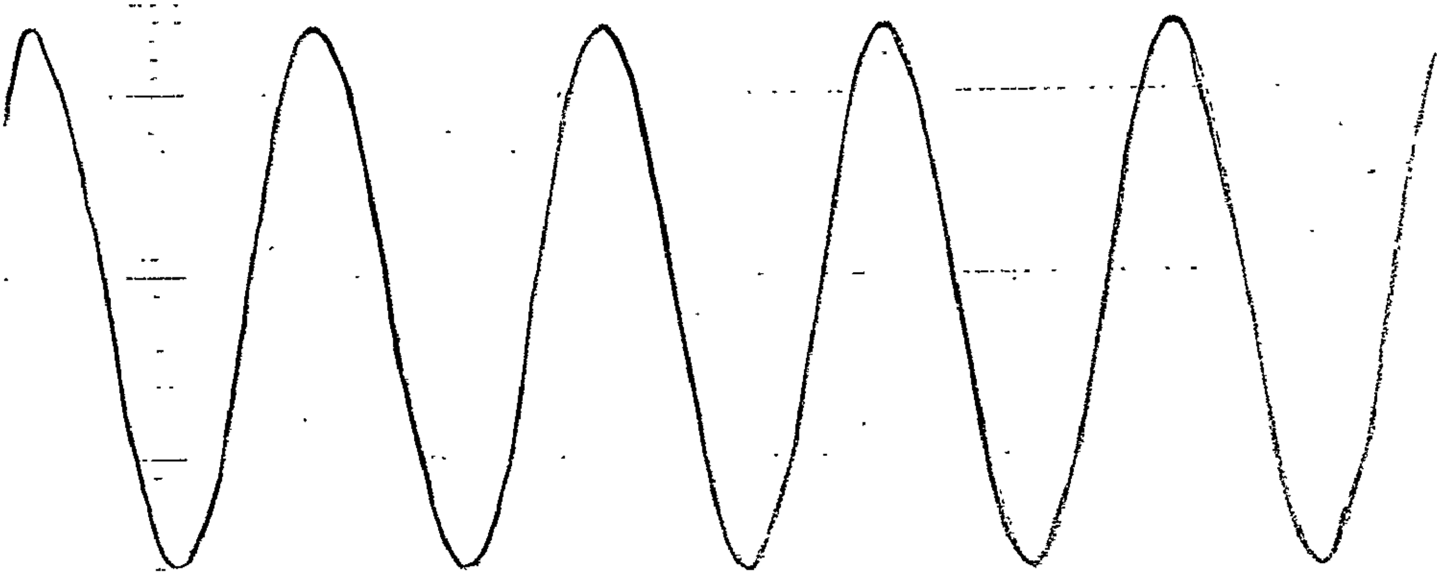


PLOT 2A 1 g Sine Wave

Signal Output

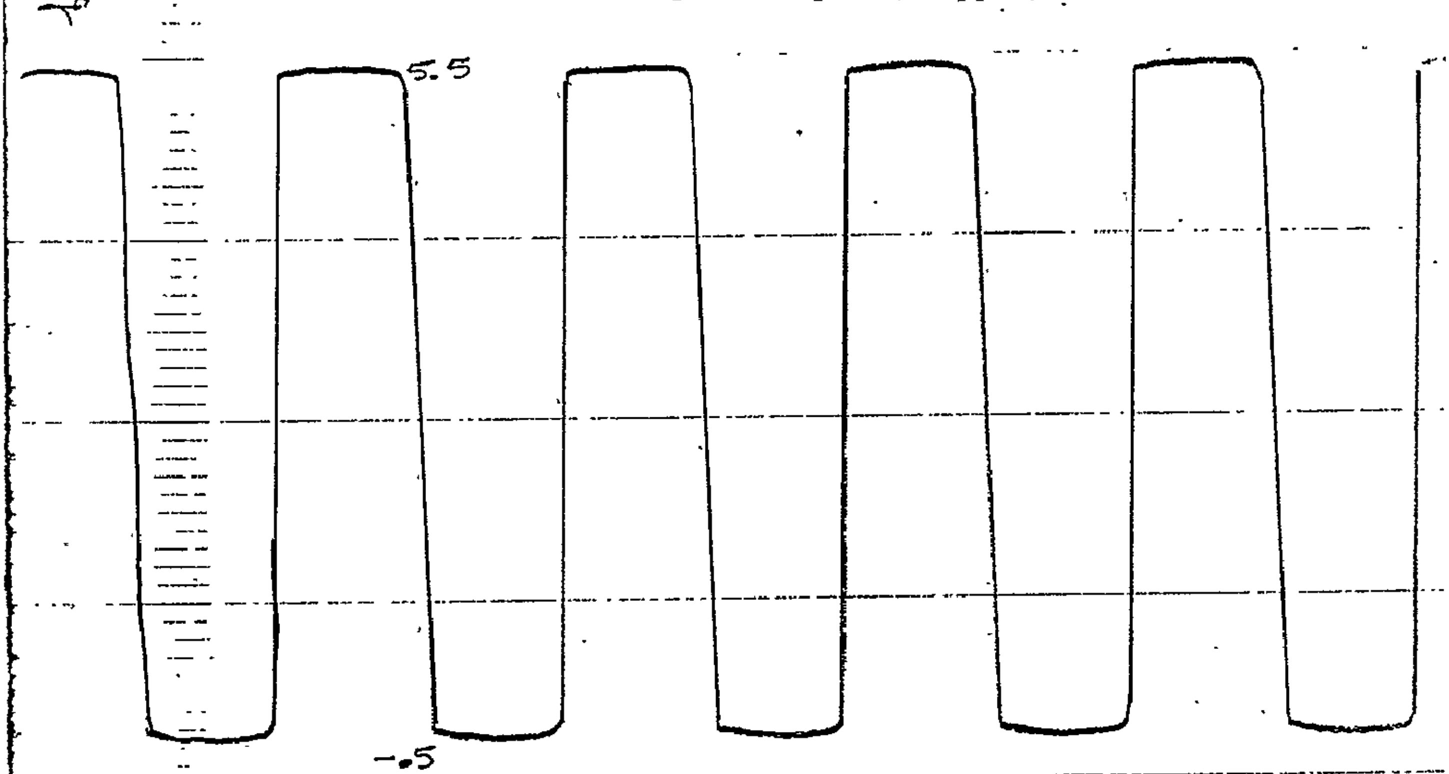


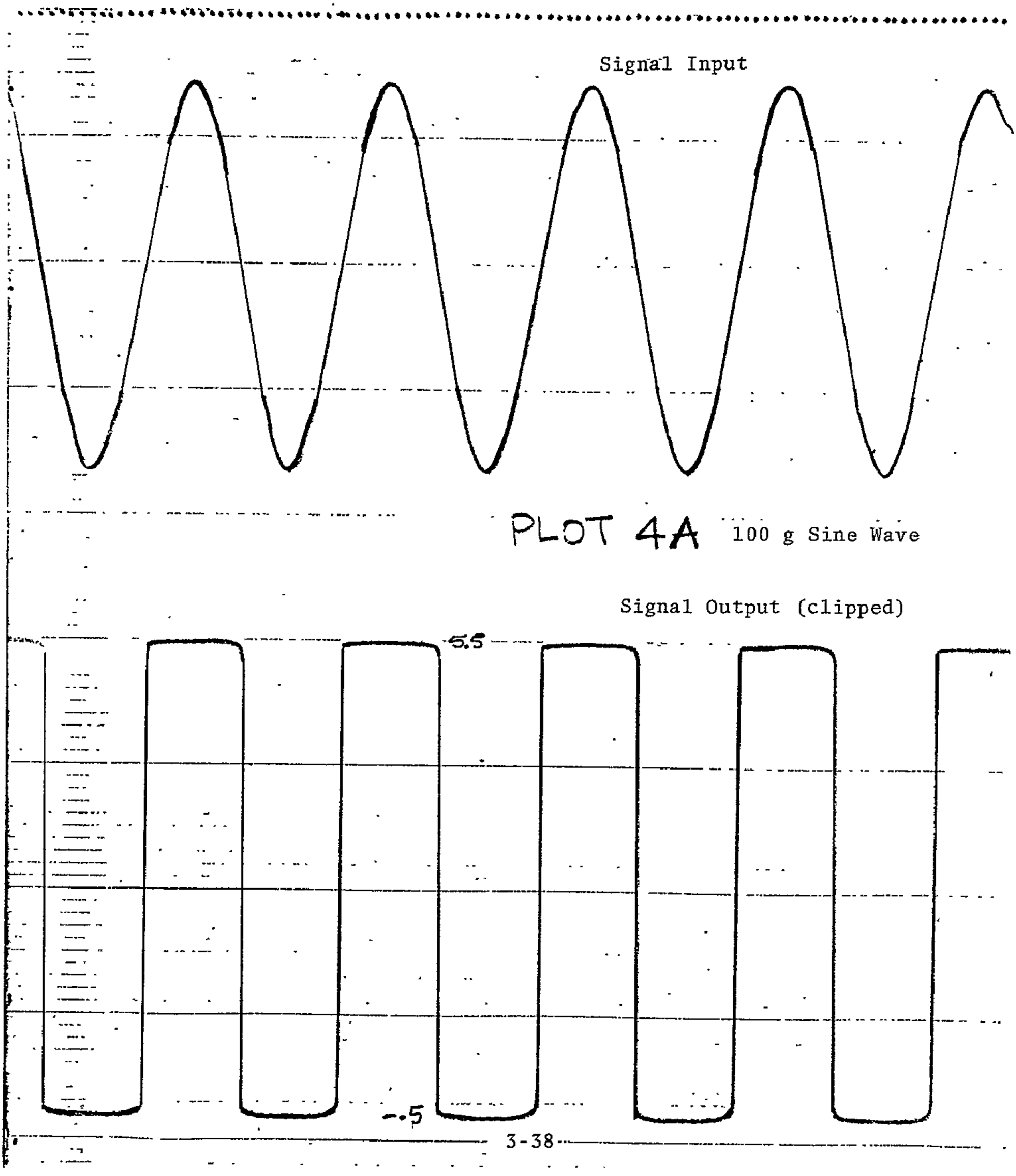
Signal Input

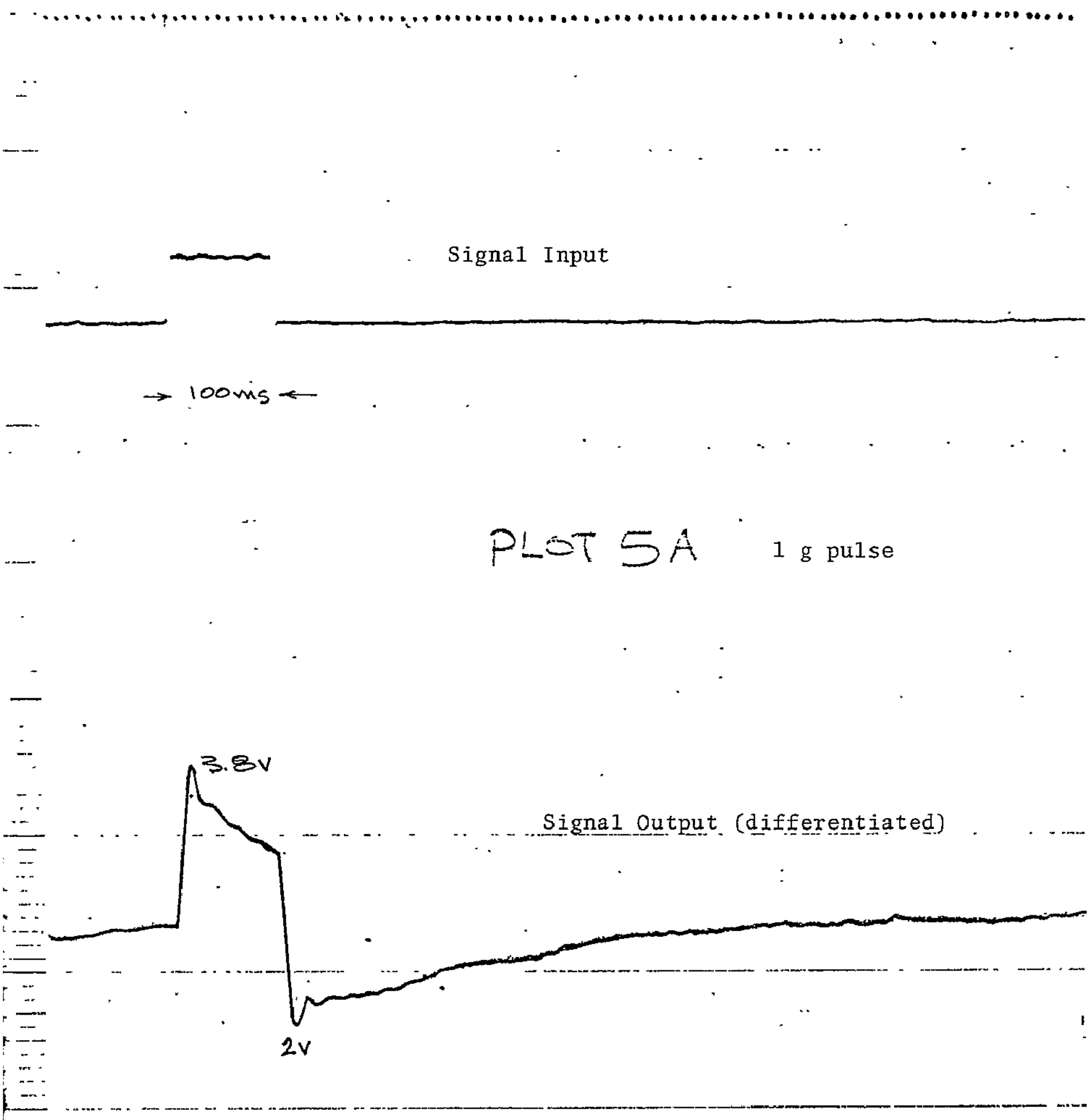


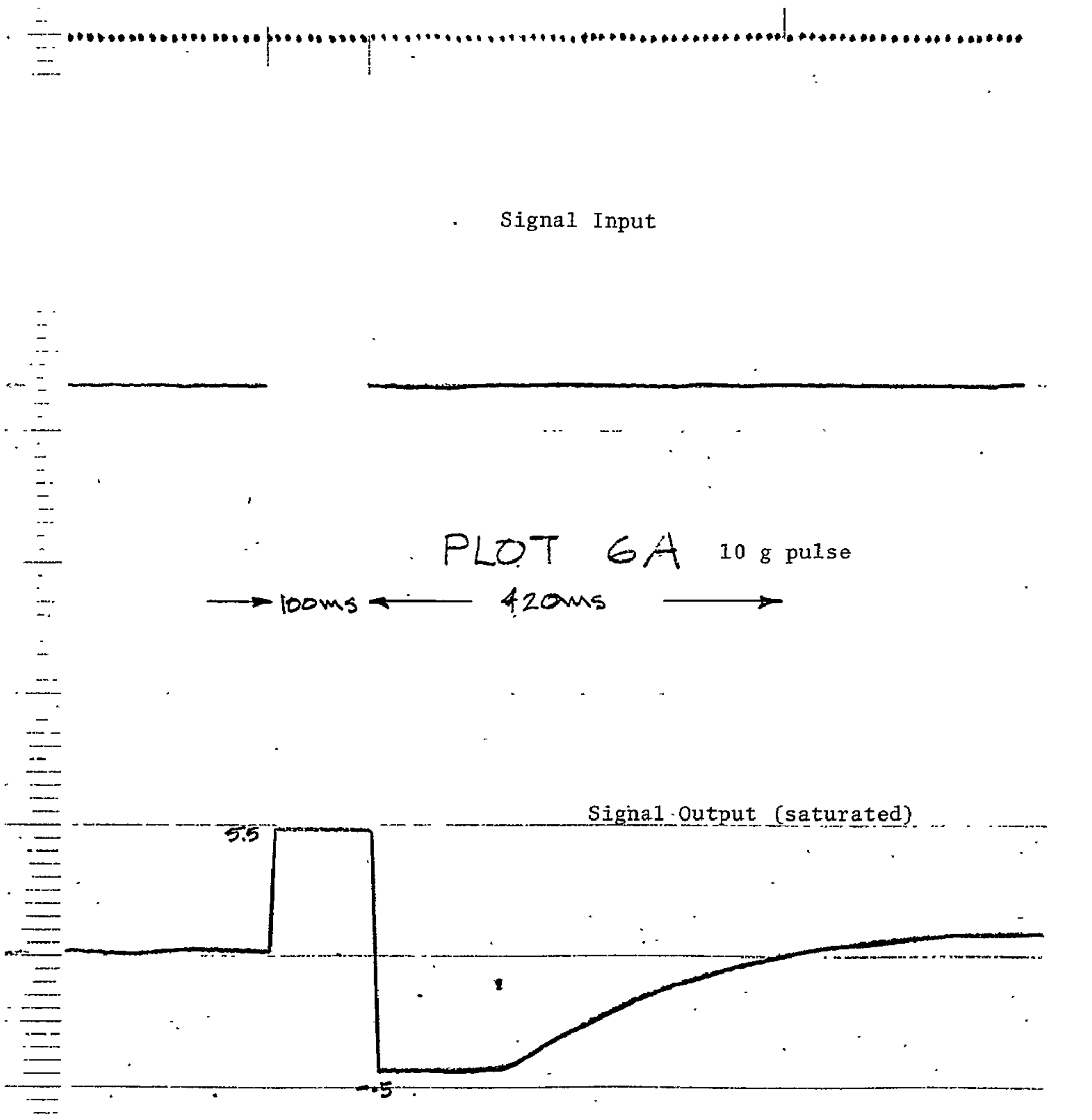
PLOT 3A 10 g Sine Wave

Signal Output (clipped)

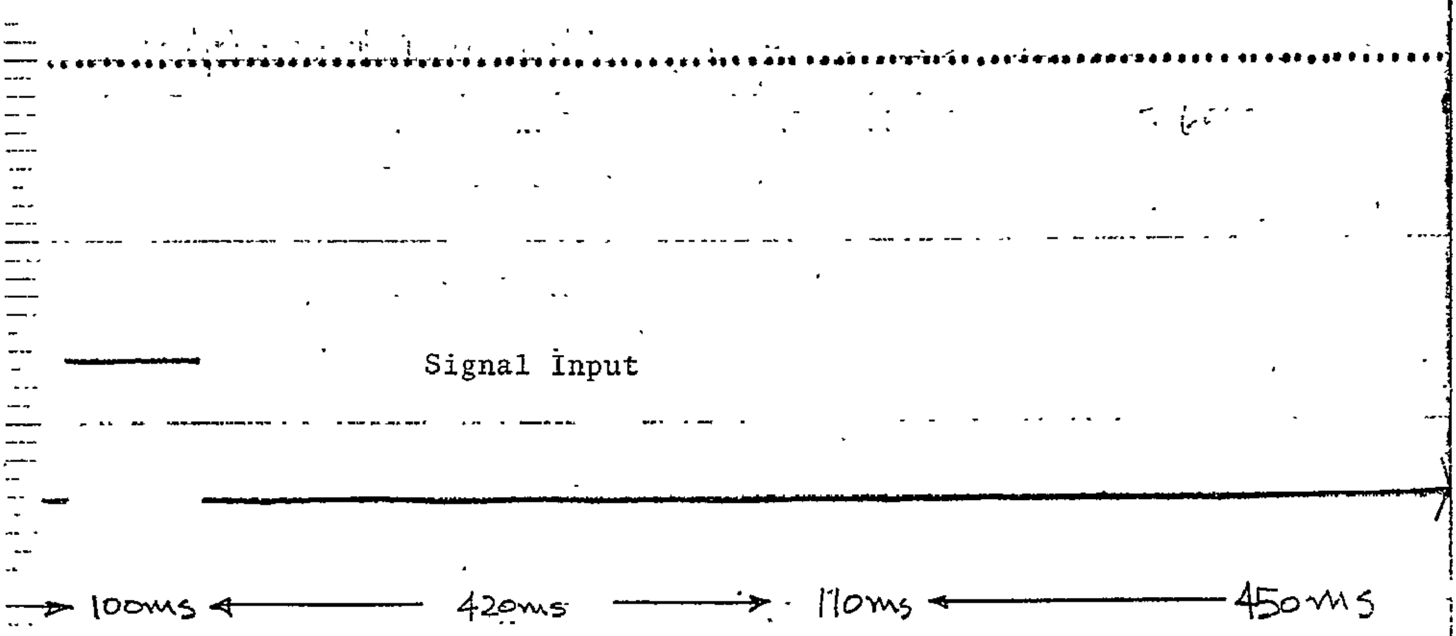



Signal Input
PLOT 4A
100 g Sine Wave
Signal Output (clipped)
5.5
-.5


Signal Input
→ 100ms ←
PLOT 5A
1 g pulse
3.8V
Signal Output (differentiated)
2V



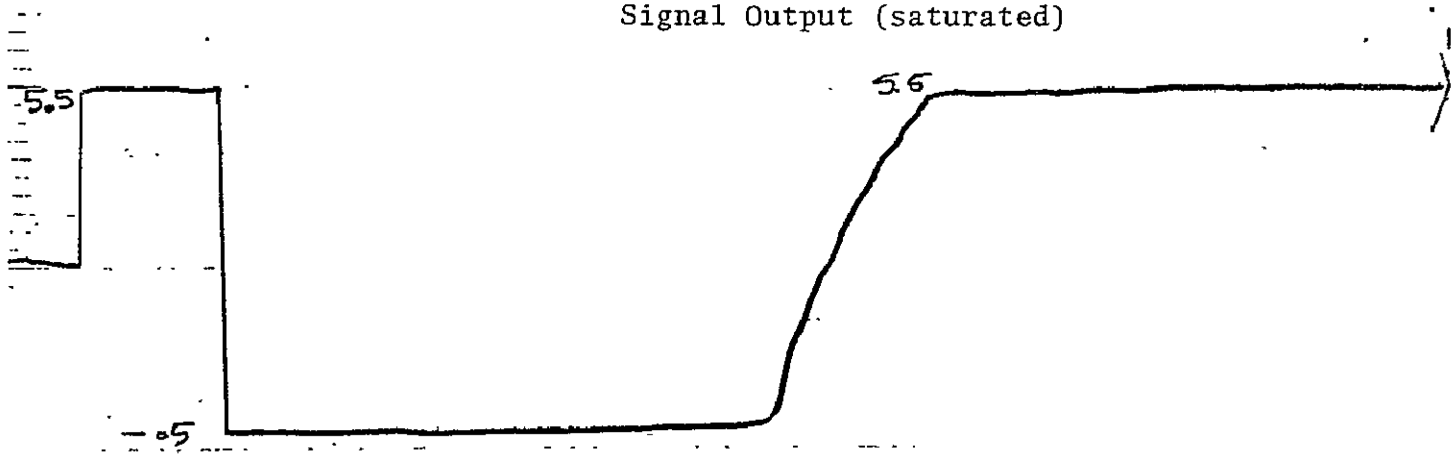
Signal Input
PLOT 6A 10 g pulse
100ms
420ms
Signal Output (saturated)
5.5
-5

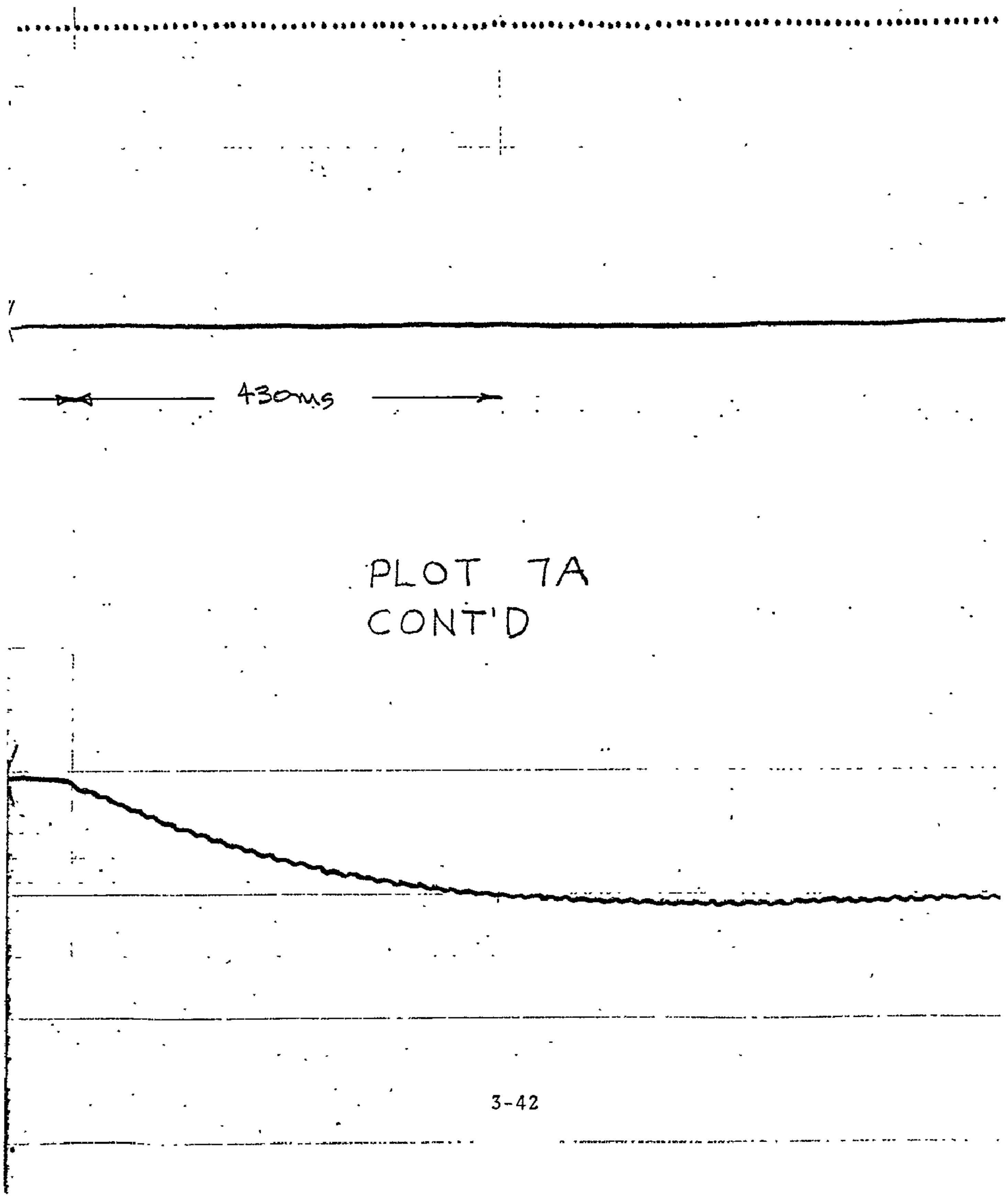


PLOT 7A 100 g Pulse

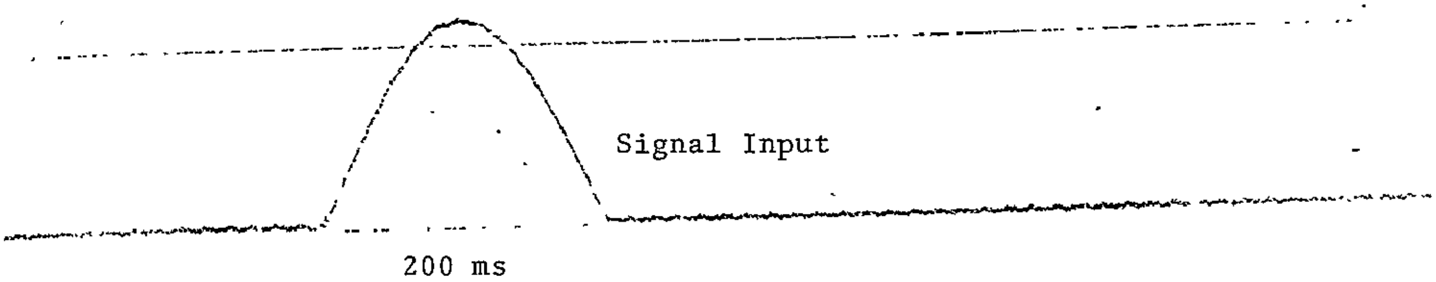
(continued on next page)

Signal Output (saturated)

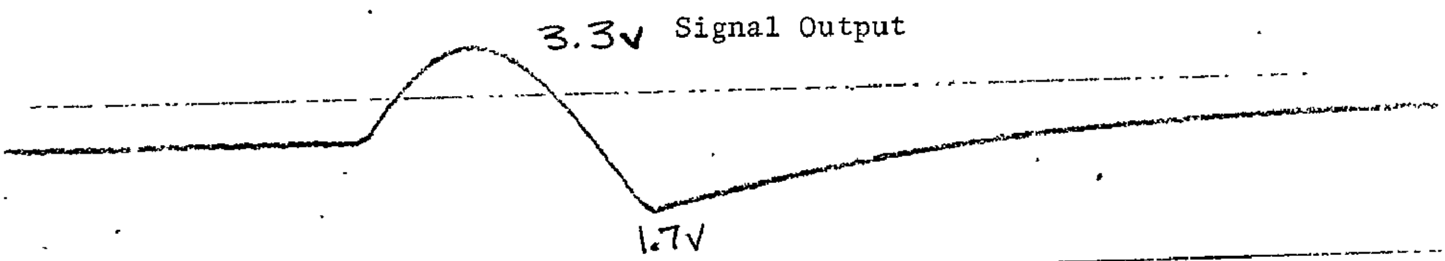




PLOT 7A
CONT'D

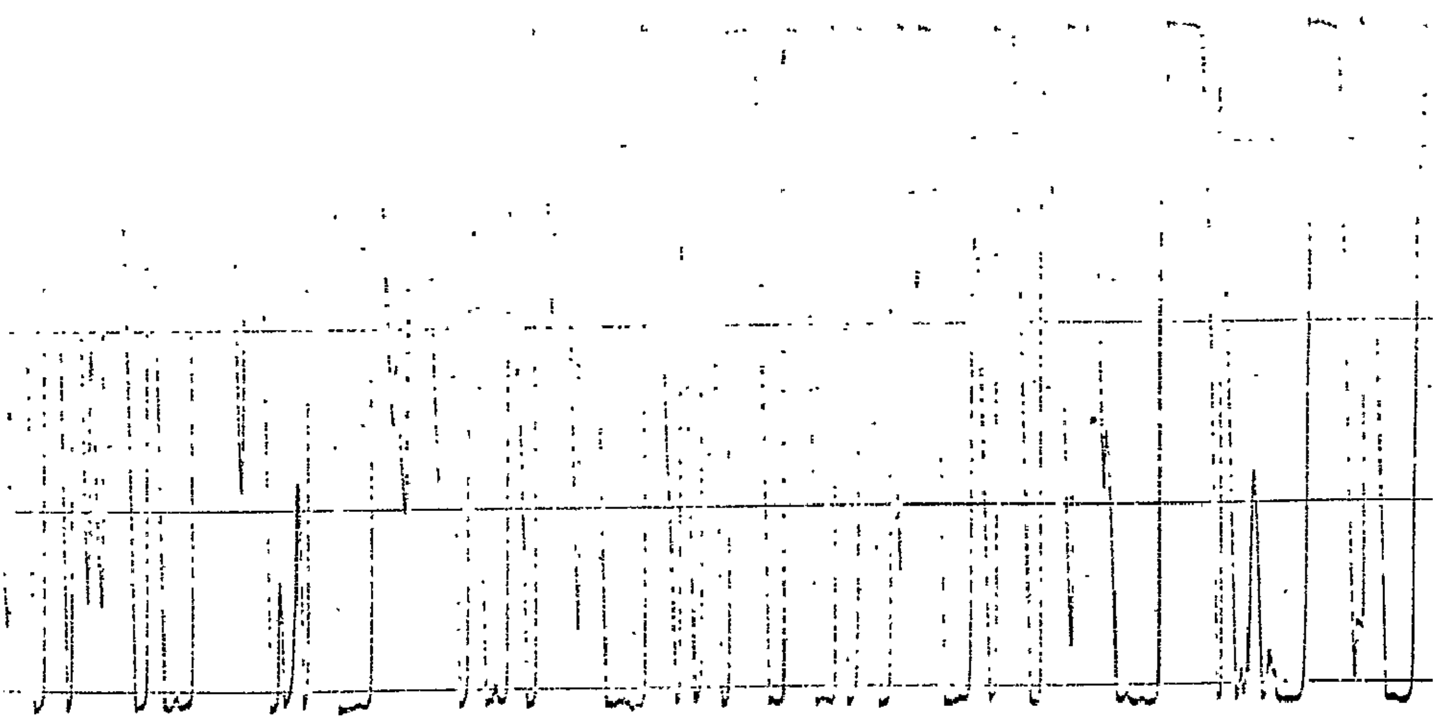


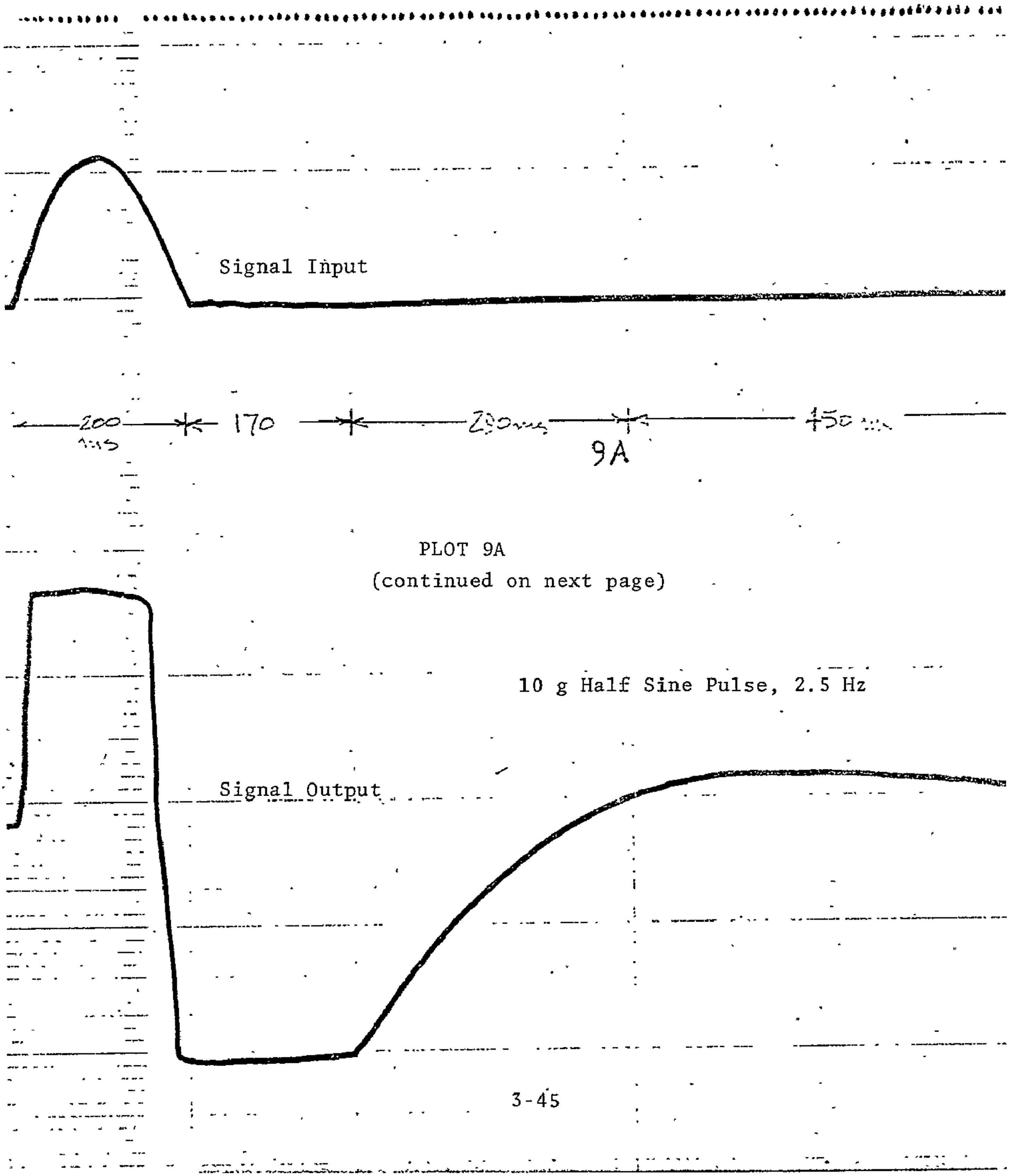
8A 1 g Half Sine Pulse, 2.5 Hz



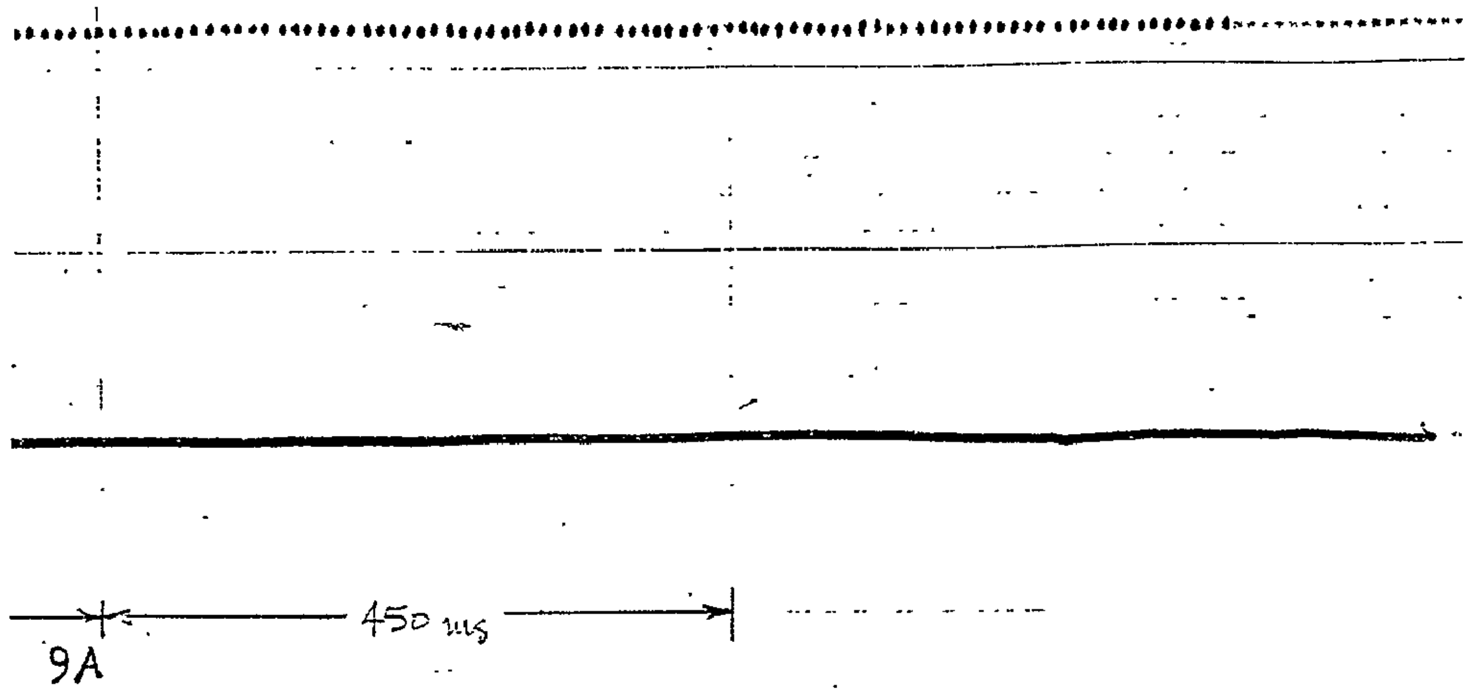
Signal Output

8C 1 g Half Sine Pulse, 2.5 Hz
(with superimposed noise, 1 g^2/Hz)

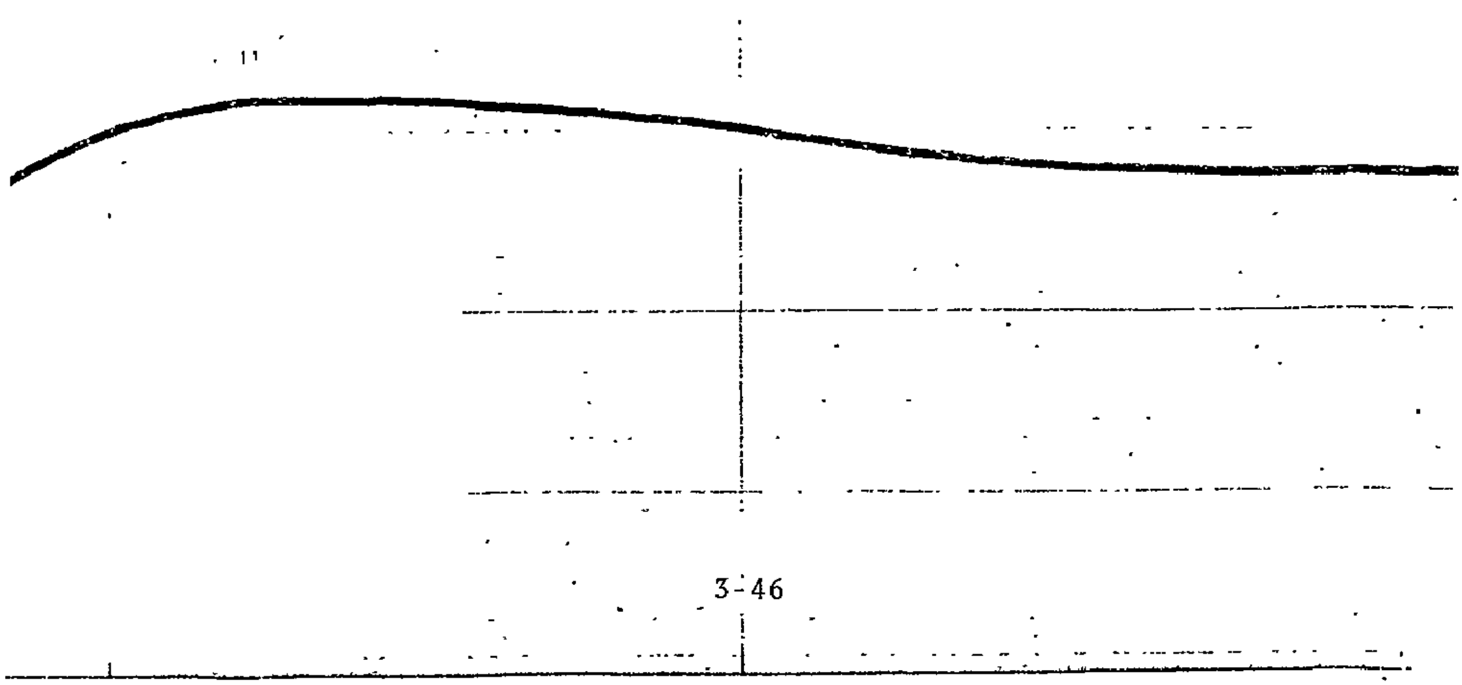




PLOT 9A
(continued on next page)

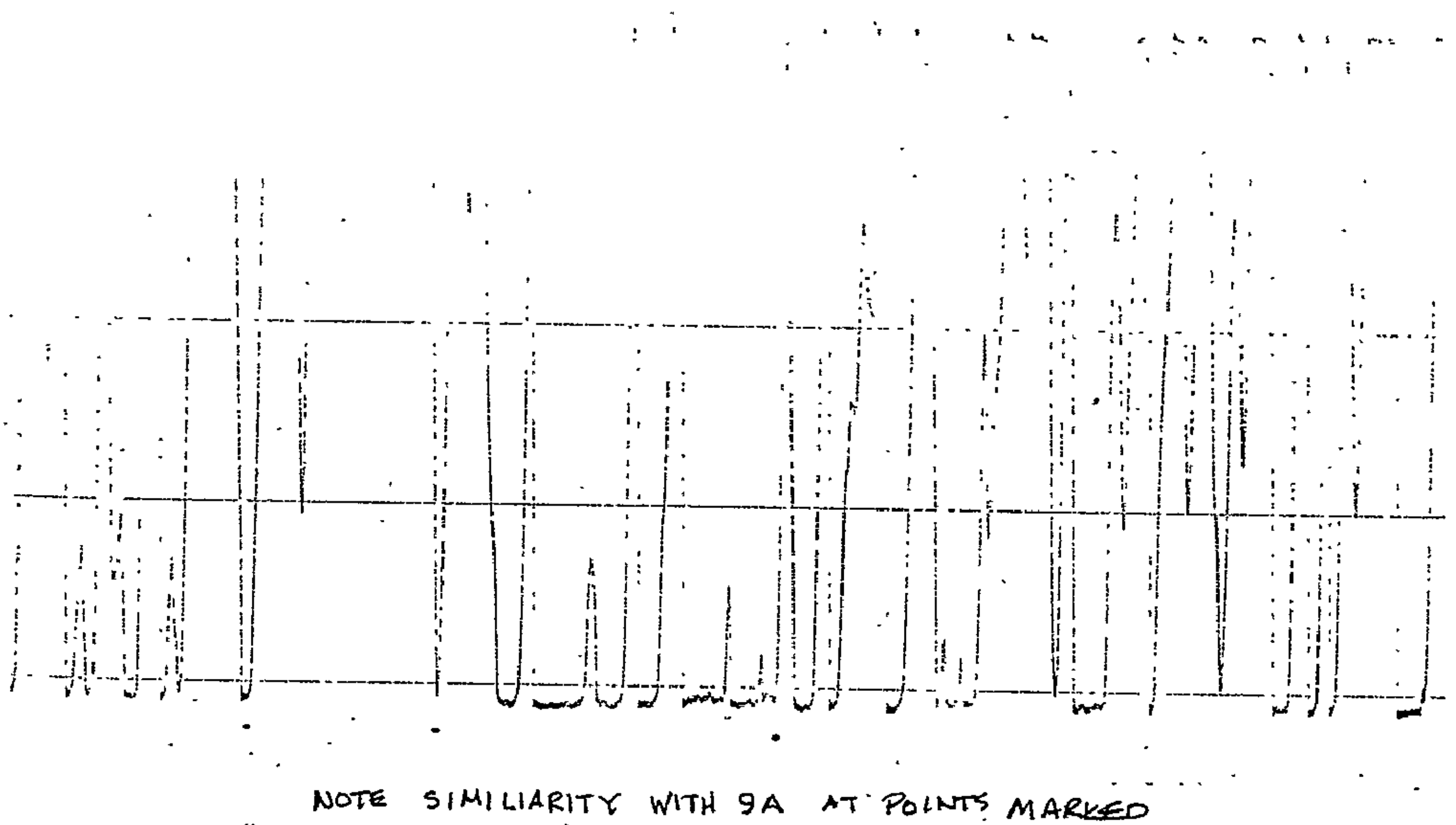


(PLOT 9A concluded)

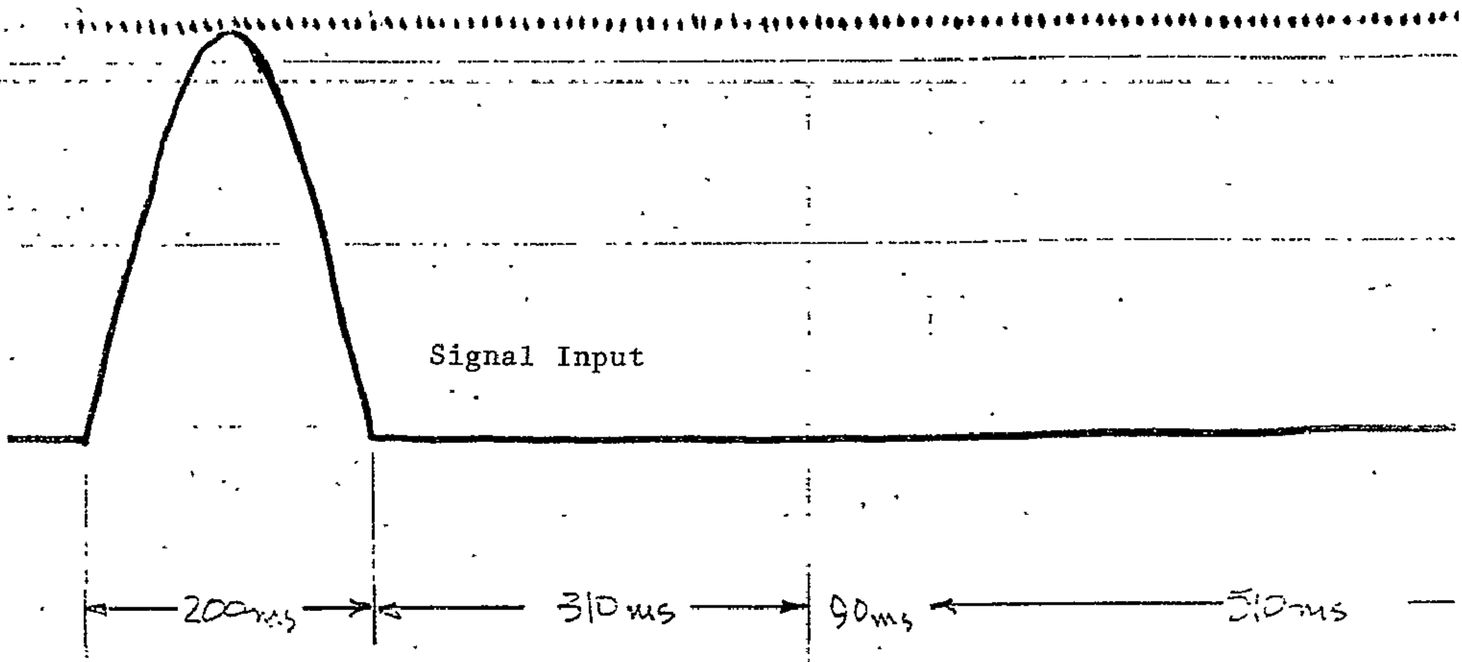


Signal Output

9C 10 g Half Sine Pulse, 2.5 Hz, (with superimposed noise $1g^2/Hz$)



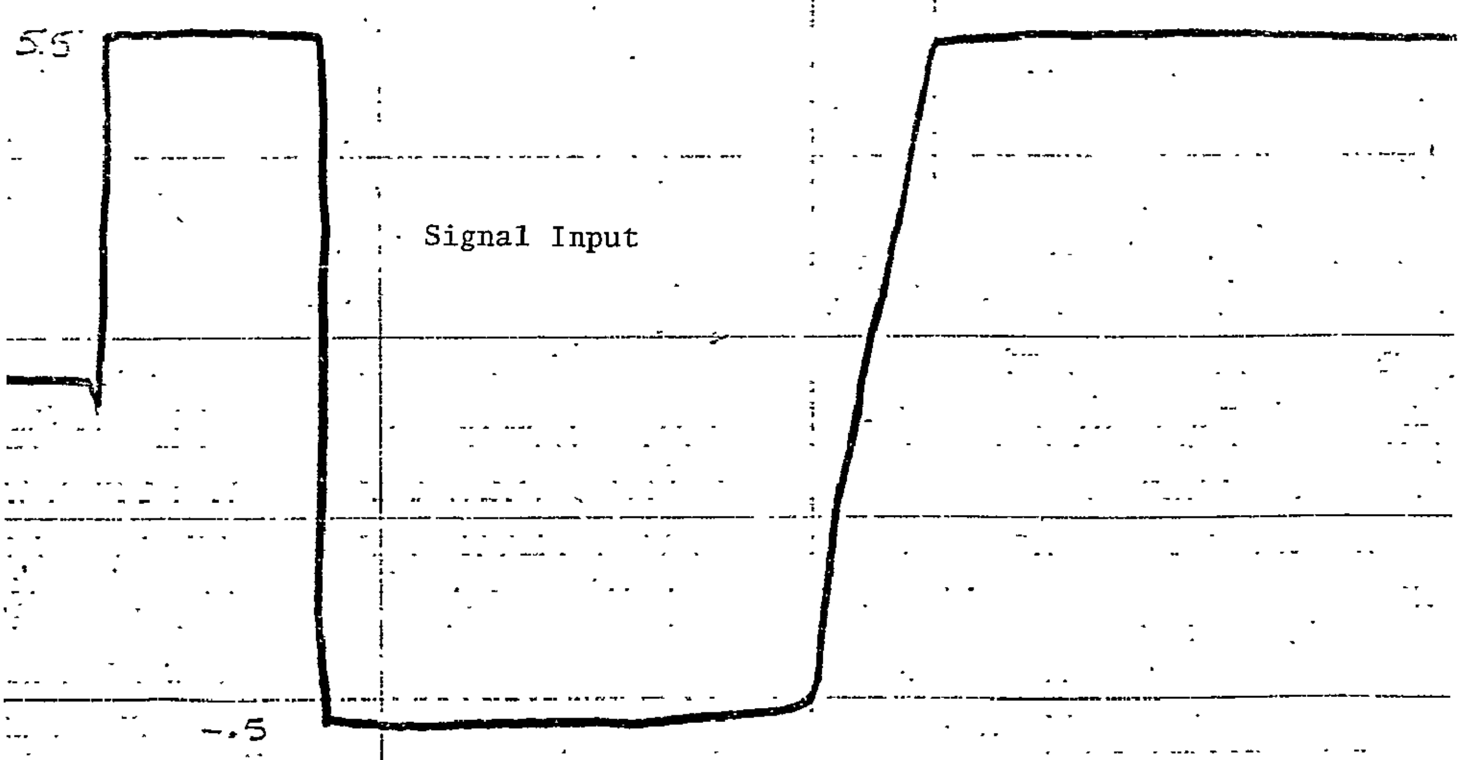
NOTE SIMILIARITY WITH 9A AT POINTS MARKED

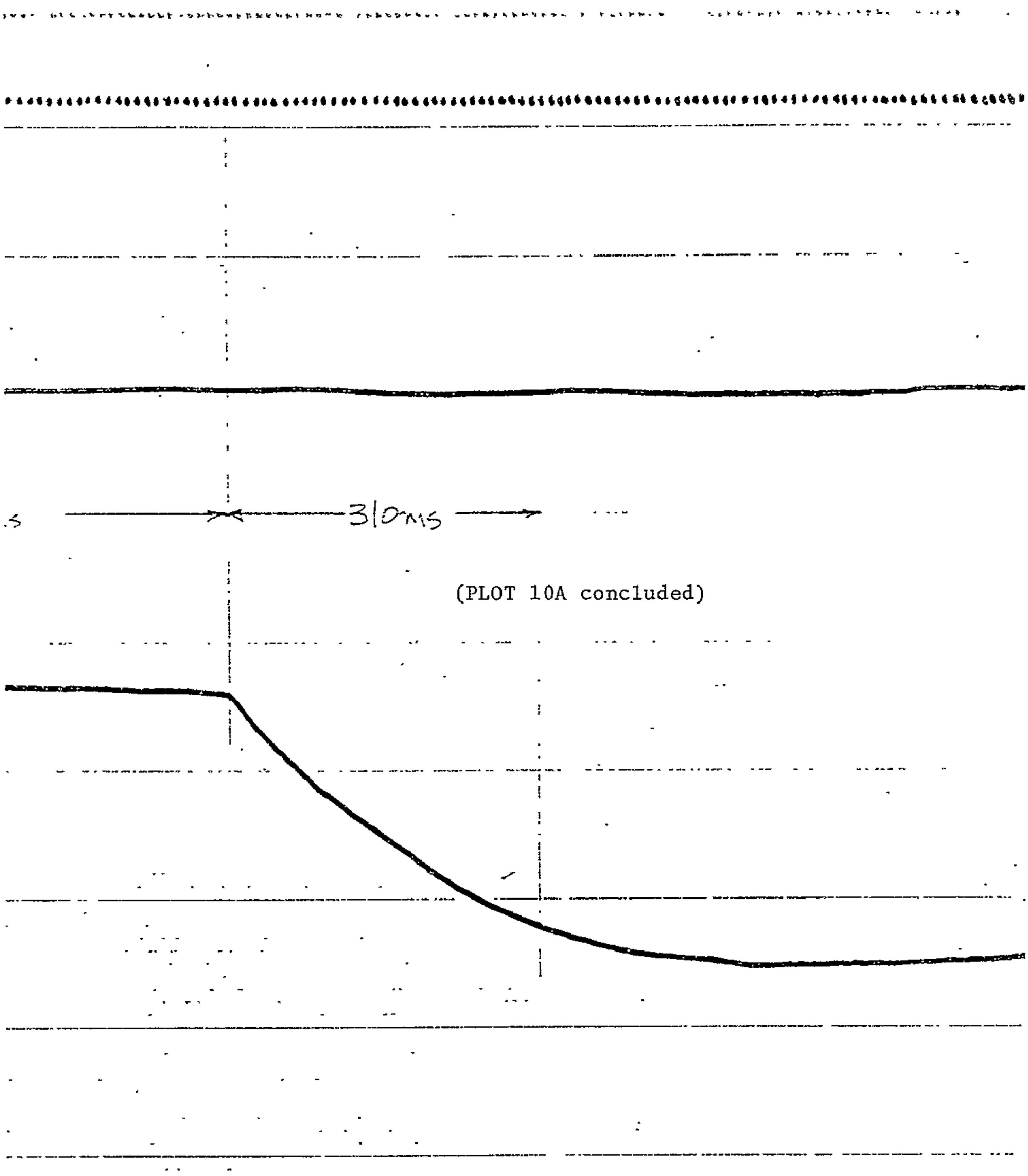


75 g Half Sine Pulse, 2.5 Hz

PLOT 10A

(continued on next page)

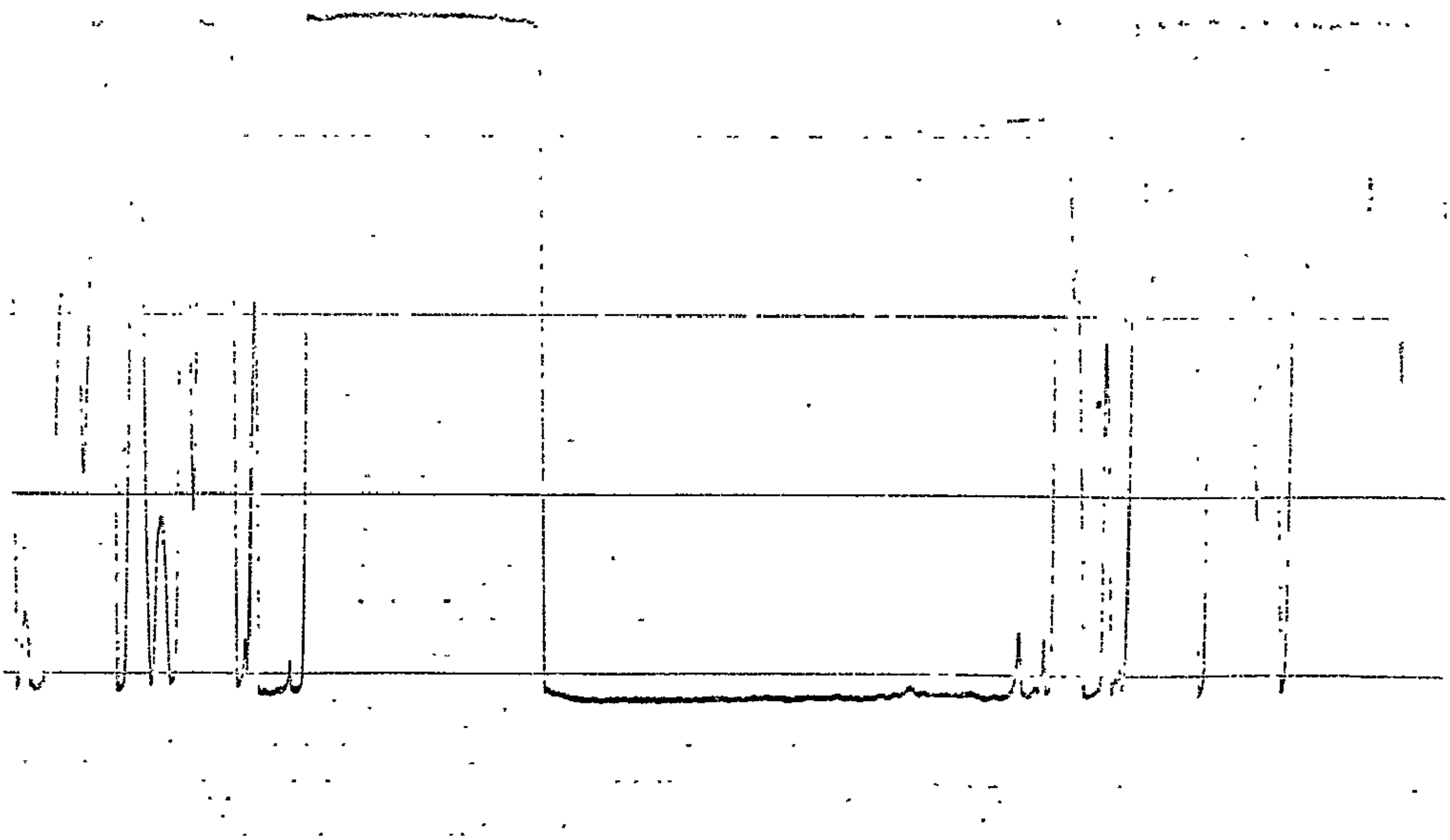


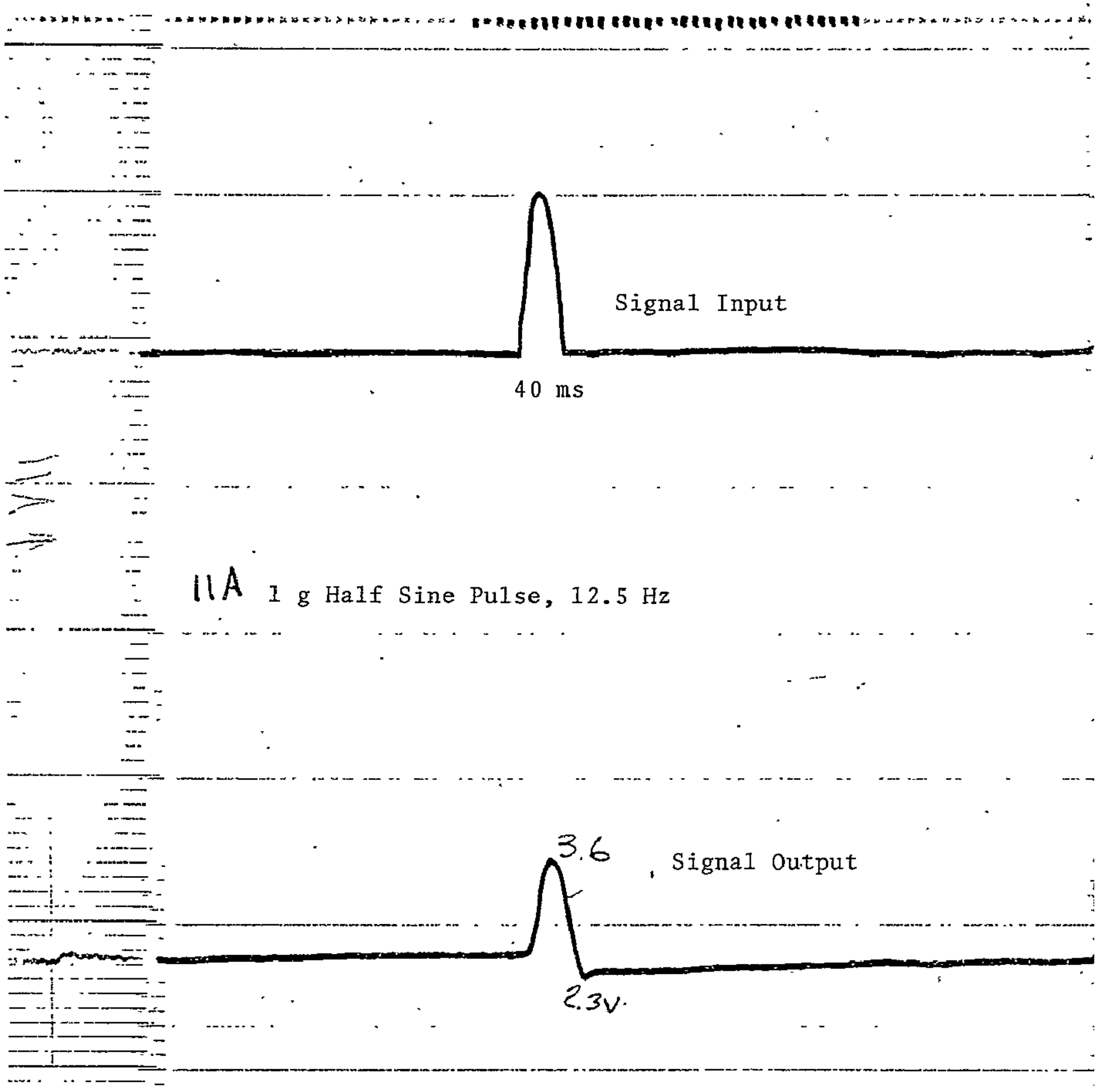


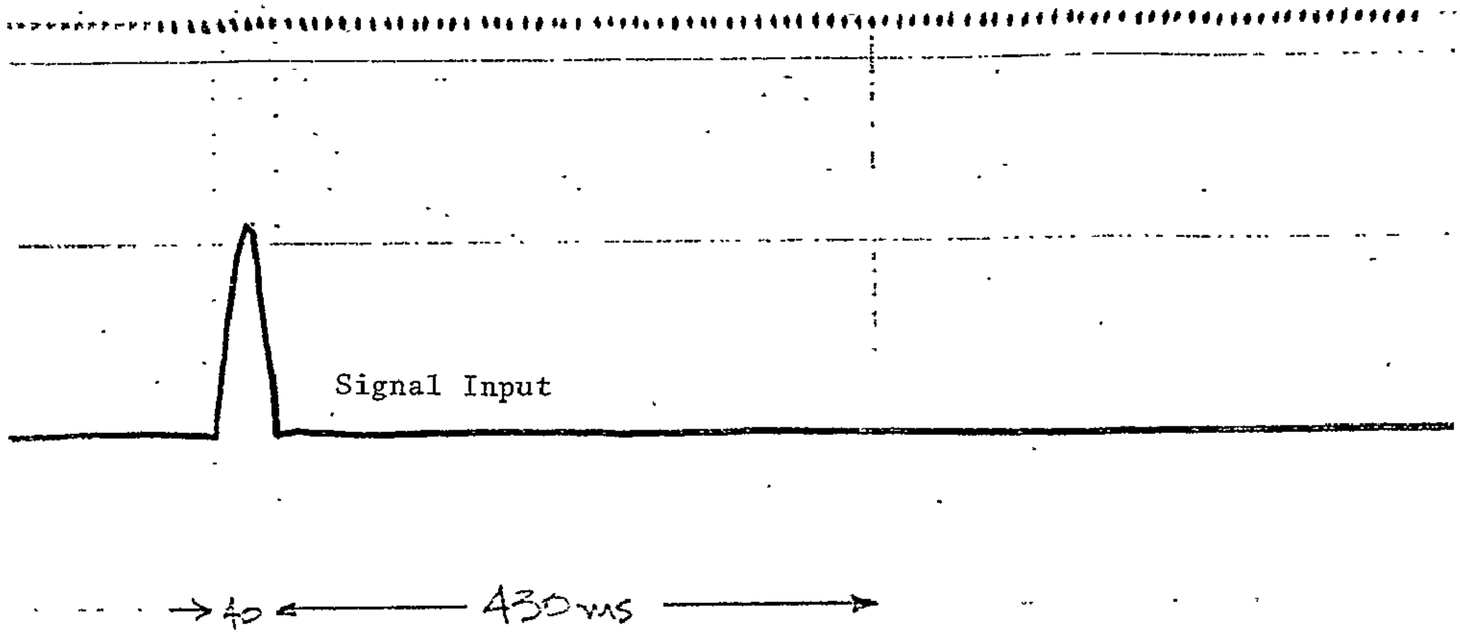
(PLOT 10A concluded)

Signal Output

10C 75 g Half Sine Pulse, 2.5 Hz
~~(with superimposed noise $1g^2/Hz$)~~

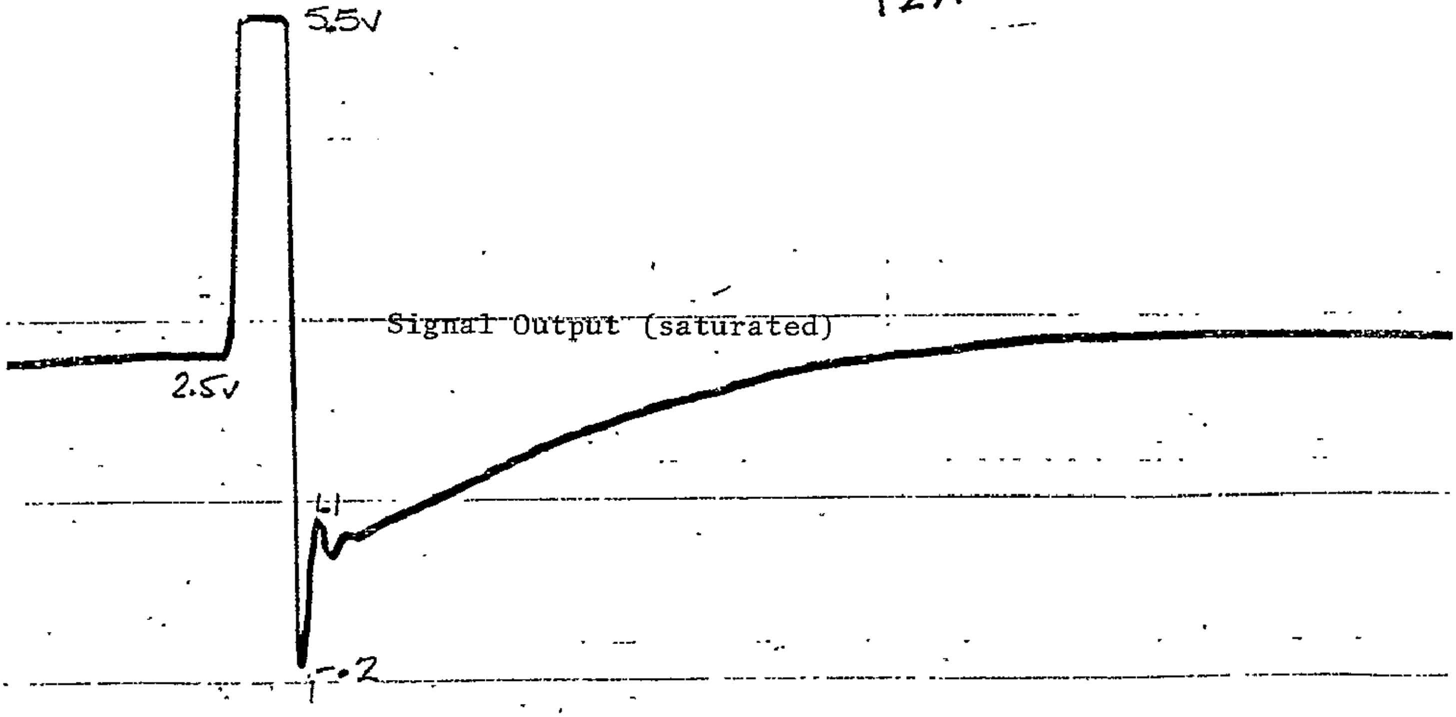


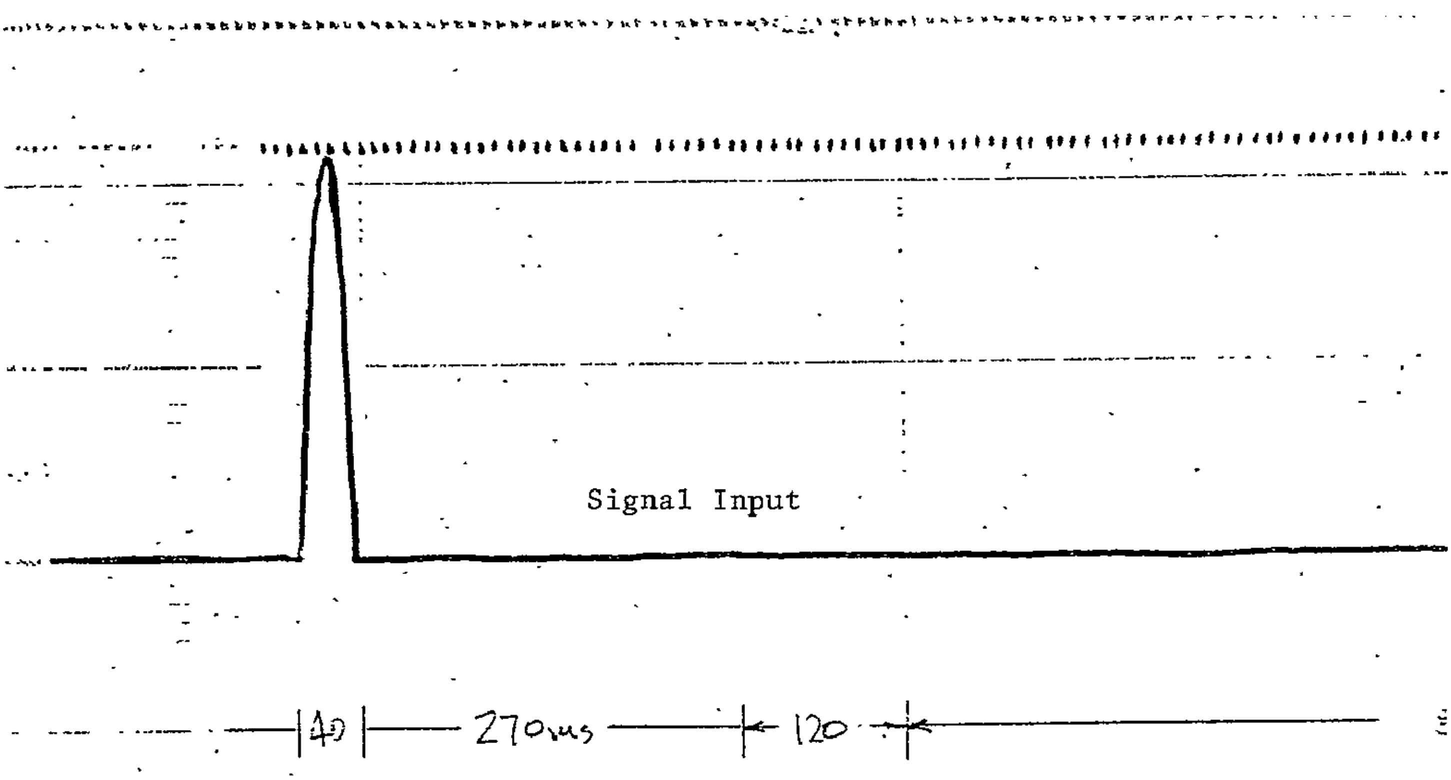

Signal Input
40 ms
11A 1 g Half Sine Pulse, 12.5 Hz
3.6
Signal Output
2.3V.



10 g Half-Sine Pulse, 12.5 Hz

12A

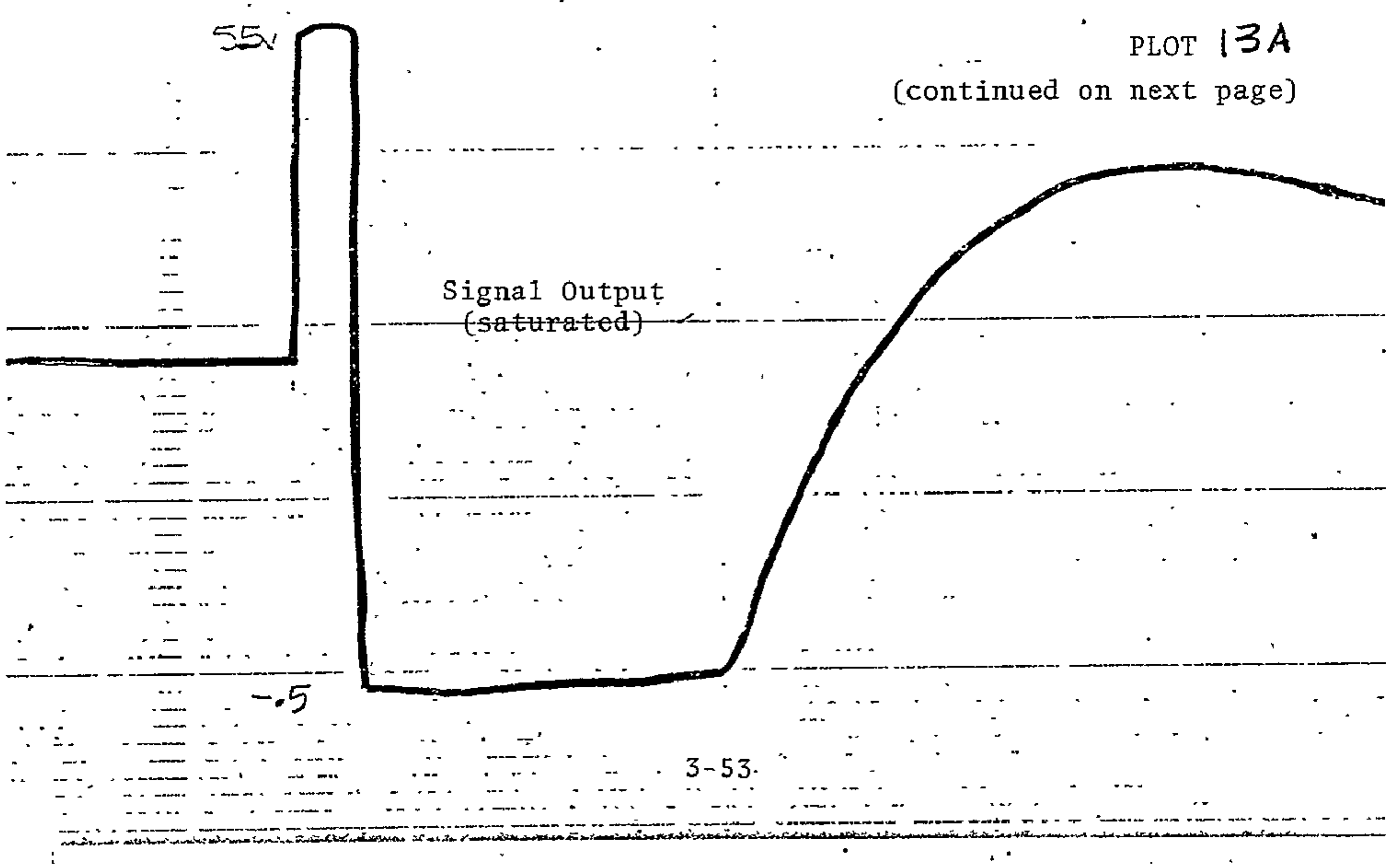


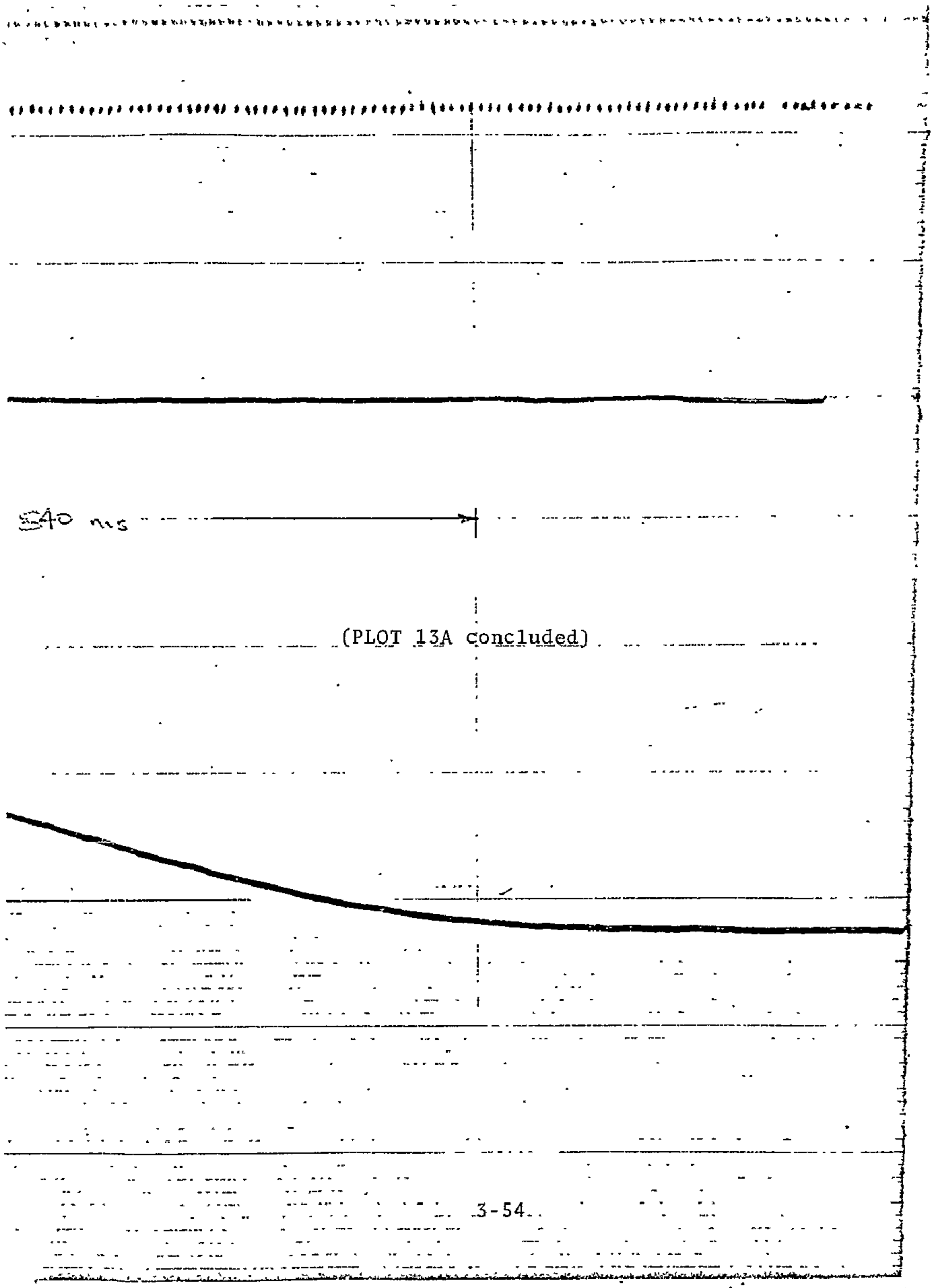


75 g Half Sine Pulse, 12.5 Hz

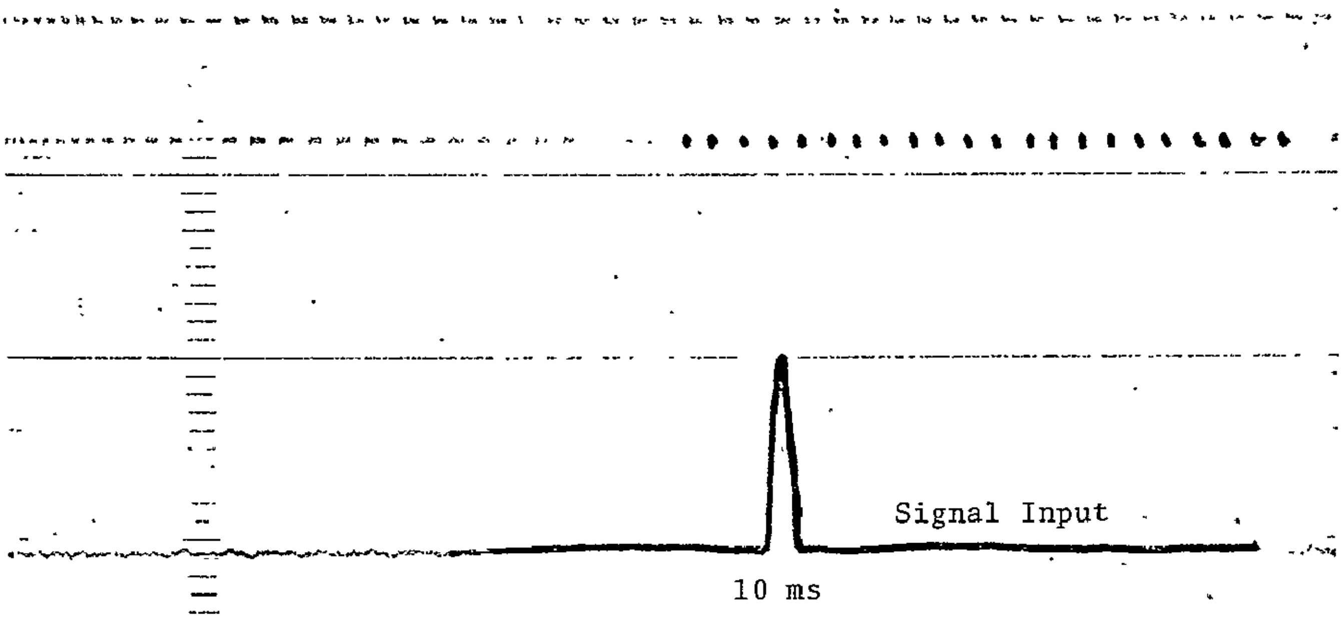
PLOT 13A

(continued on next page)

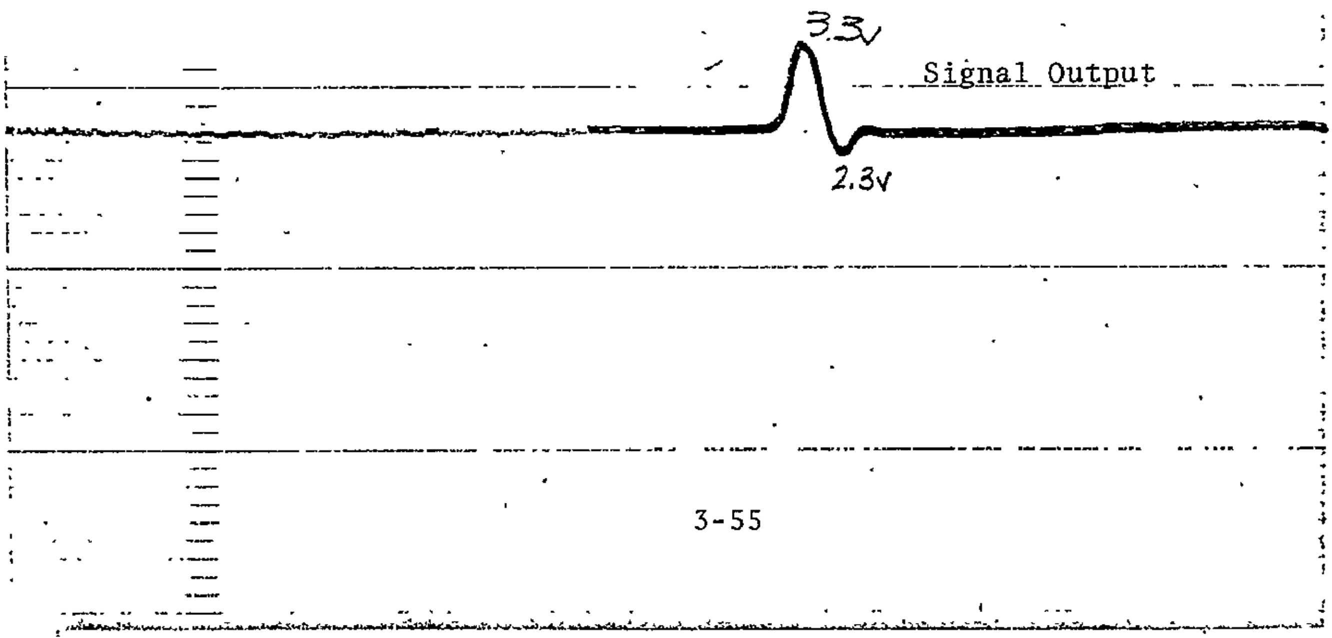


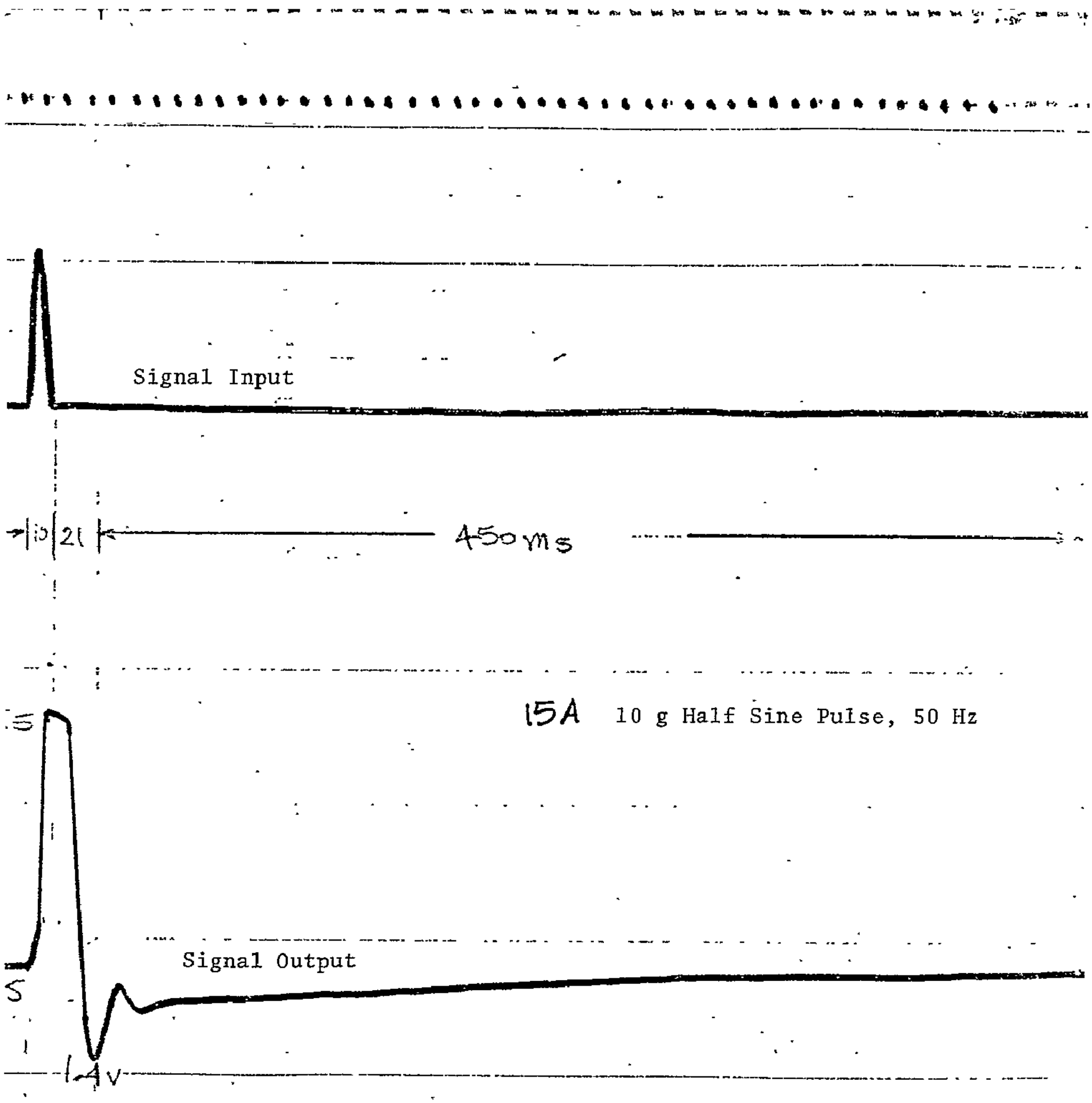


(PLOT 13A concluded)

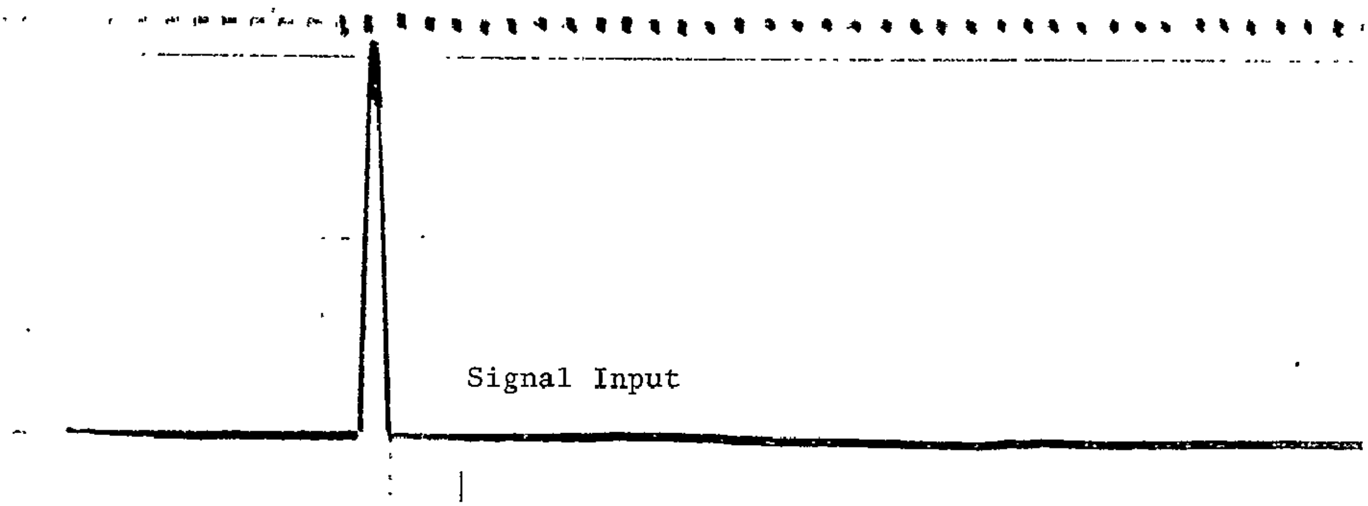


14A 1 g Half Sine·Pulse, 50 Hz



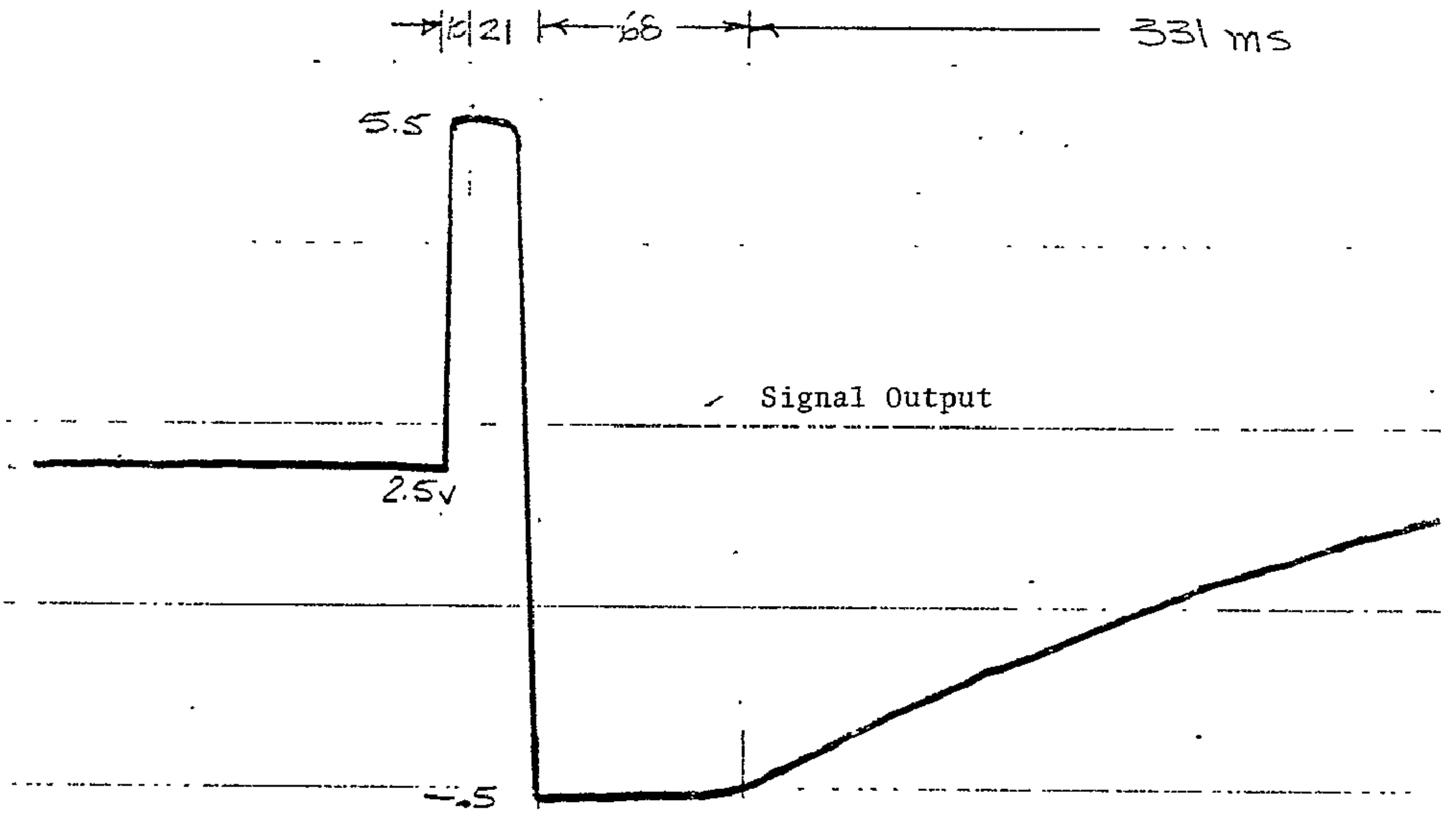


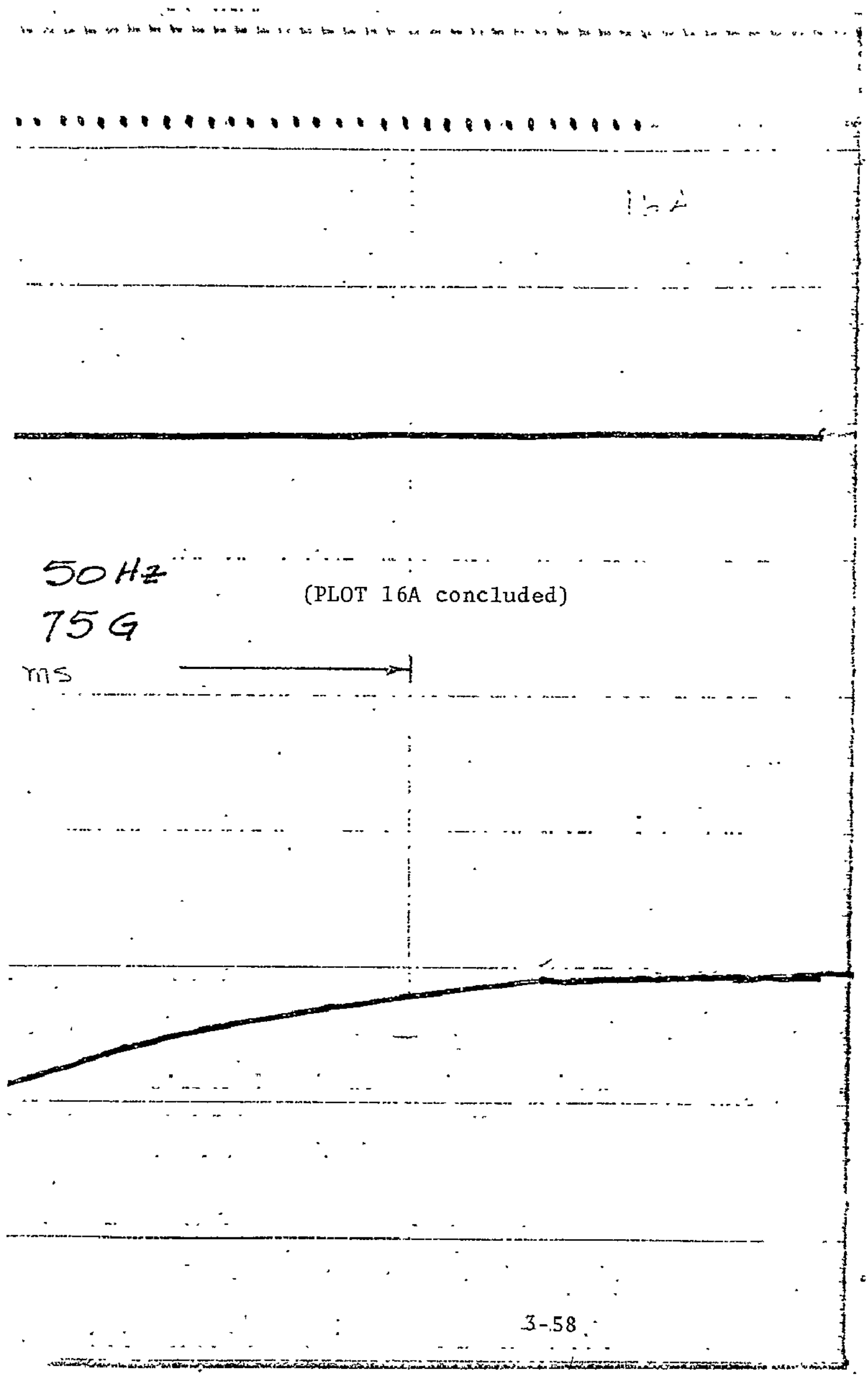
15A 10 g Half Sine Pulse, 50 Hz



75 g Half Sine Pulse, 50 Hz Plot 16A

(continued on next page)





(PLOT 16A concluded)

4. CONCLUSION

The theoretical analysis and actual testing performed to acquire amplifier output response information were done in response to general requirements presented by the Structures Branch/Structures and Mechanics Division (ES2). The initial requirement for pulse testing was to define the amplifier's response to a single half sine-wave input of various levels. This information was desired for two reasons: (1) for determining how accurately the amplifier could respond to the pressure shock pulse from Shuttle booster ignition and (2) to determine if a unipolar shock pulse could saturate the amplifier for a lengthy time period.

Initial bipolar noise requirements were to obtain the amplifier's response in a random vibration "noise signal" environment of 1 g^2/Hz from 20 to 2000 Hertz (Hz). This information was needed to demonstrate that the acquisition of pogo signal data would not be degraded due to high-level random vibration signal inputs beyond 50 Hz.

Overall results of the analysis and testing are provided in the following paragraphs. Refer to section 3 for further details.

Unipolar pulses which exceed the preset full scale gain range of the signal conditioner will cause its output to be driven to a limit value of +5.5 or -0.5 volts, depending on input pulse polarity, and will block out a signal which might accompany the pulse. The degree of saturated degradation depends on the pulse width and amplitude. Pulses of short duration have less of an undesirable effect than do long pulses since they do not obstruct data at their trailing edge. Long pulses can obstruct data at both the leading and trailing edges of the pulse. (Refer to plots summarized in table I.)

olar noise which is three octaves above the lowpass cutoff of WBSC and is greater than the full-scale range has virtually effect on the output. The charge converter does not saturate the amplifier lowpass filter does not allow the noise signal pass to the output (figures 25 and 27).

se which occurs in the passband of the WBSC produces ampli- e errors in the frequency domain analysis of the data whenever noise amplitude is 10 percent or more over full-scale level. rd stage gain reduction occurs, thereby degrading "wanted nal" accuracy (figures 29 and 30).

rall, the signal conditioner responded in a way character- ic of a charge amplifier. Considering its measurement appli- ions on the Shuttle Orbiter, no special problems are foreseen.

5. REFERENCES

1. Rhodes, James E.: "Piezoelectric Transducer Calibration Simulation Method Using Series Voltage Insertion." Endevco Corporation Publication, April 1962.

2. Harris, C. M., and Crede, C. E., eds.: Shock and Vibration Handbook, vol. I; Basic Theory and Measurements. McGraw-Hill, 1961.

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