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DETECTING GROUP, SUBMARINE ANOMALY

AN/ASA-64 (U)

"INDICATOR, MAGNETIC VARIATION

ID-1559/ASA-64 (U)"

Final Report

(8 March 1967 to 1 September 1968)

December 1968

By

A. Zanella

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for

Naval Air Systems Command
Department of the Navy

by

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PART I

1. PURPOSE

a. General - The Detecting Group, Submarine Anomaly (SAD)AN/ASA-64 covered by MIL-D-81465(AS) automatically recognizes and marks submarine type signals in the presence of geologic, geomagnetic and equipment noise as detected by Magnetic Anomaly Detection (MAD) equipment. The equipment is designed to operate in all types of aircraft designated for anti-submarine warfare, which are equipped with MAD equipment. The output signal from the end item is a voltage pulse whose amplitude is proportional to the strength of the detected signal and which can be applied to a computer, coordinate plotter, strip chart recorder, audio oscillator or any other such equipment. Aircraft maneuvers exceeding preset rates are electronically correlated within the end item, preventing for a preset time, any output mark from being generated while providing a visual indication of the inhibition period. Self testing features are incorporated to provide the operator, while airborne and on the ground, with a GO-NO-GO indication of end item readiness and a means of isolating faults. Figures 1 and 2 show the physical configuration of the end item.

(1) Approach of Action - In the sections that follow, a detailed description of the circuits and self testing features used within the end item is given, including the derivation of transfer functions unique to the problem. Sample calculations and graphs of transfer functions are included for comparison with test results obtained from bench testing a production version of the end item.

b. Contents - The end item consists in part of a Recognition Channel, Multiple Mark Suppressor Circuit, Maneuver Channel and two front panel test switches designated as MARK and INHIBIT respectively. A block diagram is shown in Figure 3.

(1) Recognition Channel - The detected MAD signal is the input to this channel which consists of the following circuits.

(a) Signal Reference Converter - This circuit is a differential input bandpass amplifier having a passband from 0.006 Hz to 8 Hz which DC isolates and converts the floating MAD input signal to a single ended output. The output signal is then routed through normally closed contacts of the MARK switch to the Noise Rejection Filters.

(b) Noise Rejection Filters - There are two noise rejection filters connected in a cascaded configuration. These filters reject quasi-sinusoidal geologic and background noise. Both filters are passive parallel twin-T, each having a Q of 0.5. The output of each filter is isolated by an operational amplifier with one filter providing 45 db attenuation at 0.023 Hz and the other 30 db attenuation at 0.9 Hz.

(c) Active Full-Wave Rectifier - This circuit accepts the signal from the Noise Rejection Filters and full-wave rectify it. The gain of this circuit is adjustable between one and ten and its output signal is impressed upon the Active Sampling Integrator.

(d) Active Sampling Integrator - The Active Sampling Integrator integrates the output of the Active Full-Wave Rectifier for a 2.5 second period. The Sampling Integrator output is then returned to zero volts and under no inhibition condition integrates again for 2.5 seconds in a repetitive cycle. The drive circuits for the sampling phase of the integrator consist of a 0.4 Hz Square Wave Master Oscillator, a Passive Differentiator and an "OR" gated Schmitt Trigger driving a solid state Field Effect Transistor (FET) connected in parallel with the integrating capacitor.

(e) Threshold Detector - The Threshold Detector accepts the output voltage from the Active Sampling Integrator and compares it with a preset DC voltage threshold. The output from the Threshold Detector is a voltage pulse which is equal to the difference in amplitude between the Active Sampling Integrator output and the DC threshold voltage. The Threshold Detector generates an output only when the integrator output exceeds the DC threshold voltage. The DC threshold voltage is adjustable in flight by a control on the Selector Control Panel.

(f) Output Amplifier - The output amplifier biases the output signal of the Threshold Detector to a minus 7.5 volts DC level and provides a positive going MARK signal which is supplied to the Multiple Mark Suppressor Circuit and external equipments. The output amplifier is capable of providing a maximum MARK signal of 10 volts into a $5K\Omega$ load.

(2) Multiple Mark Suppressor Circuit - The Multiple Mark Suppressor accepts the output MARK signal from the Recognition Channel Output Amplifier and produces an inhibit pulse, whose period can be preset between 0.5 to 10 seconds, whenever the output MARK signal exceeds 4.5 volts peak. The inhibit pulse is simultaneously introduced:

(a) To an "OR" gated Schmitt Trigger driving the Field Effect Transistor (FET) connected in parallel with the integrating capacitor of the Active Sampling Integrator, resulting in the suppression of additional MARK output signals for the duration of the inhibit pulse, and

(b) To an "OR" gated Relay Driver which enables the Inhibit lamp located on the Selector Control Panel to be illuminated for the duration of the inhibit condition.

(3) Maneuver Channel - The Aircraft Maneuver Signal is the input to this channel which consists of the following circuits.

(a) Differentiator-Lowpass Filter - This circuit accepts the aircraft maneuver signal through normally closed contacts of the INHIBIT switch and differentiates it to a frequency of 0.35 Hz. The lowpass filter attenuates signals having frequencies above 2.0 Hz and adequately suppresses 400 Hz aircraft power interference.

(b) Active Full-Wave Rectifier - The Active Full-Wave Rectifier accepts the signal from the Differentiator Lowpass Filter and full wave rectifies it while providing a constant voltage gain of approximately 5.5.

(c) Maneuver Rate Detector - This circuit accepts the signal from the Active Full-Wave Rectifier and produces an output signal whenever the amplitude of the full-wave rectified signal exceeds an absolute preset DC Voltage.

(d) Inhibit Timing Circuit - The Inhibit Timing Circuit accepts the signal from the Maneuver Rate Detector and produces an inhibit pulse whose period can be preset between 3 to 15 seconds. The inhibit pulse is simultaneously introduced in the same two circuits specified in paragraphs 1. b. (2) (a) and 1. b. (2) (b).

(4) Test Switches - There are two test switches mounted on the front panel of the end item designated as MARK and INHIBIT respectively. These switches which are of the momentary action type are provided as a GO-NO-GO indication of the equipment readiness and a means of isolating faults.

(a) MARK Switch - When operated, this switch disconnects the normal input to the 0.023 Hz Noise Rejection Filter and substitutes the 0.4 Hz Square Wave from Master Oscillator while permitting the front panel test lamp to be illuminated whenever the inhibit relay is energized. The operation of this switch permits the operator to verify and locate malfunctions within the Recognition Channel excluding the Signal Reference Converter.

(b) INHIBIT Switch - When operated, this switch disconnects the Aircraft Maneuver Input Signal to the Maneuver Channel and substitutes the 0.4 Hz Square Wave from the Master Oscillator while permitting the front panel Test lamp to be illuminated whenever the inhibit relay is energized. The operation of this switch permits the operator to verify and locate malfunctions within the Maneuver Channel.

c. Subsidiary Task - A Test Bench Harness (TBH) will be required for the maintenance of the end item at the intermediate and depot level. The TBH should contain identical controls and indicators as located on the Selector Control Panel AN/ASA-71. Its primary functions will be the control of input power and means for connecting standard test equipments for the performance verification and testing of the end item.

2. GENERAL FACTUAL DATA

a. Introduction - This section contains the development of the formulae pertaining to the properties of unique circuits used within the Recognition and Maneuver Channel of the end item. Theoretical results of these formulae are then tabulated and represented graphically. Finally, actual results obtained from bench testing a production version of the end item, are tabulated and represented graphically for comparison with the above theoretical results.

b. Symbols

(1) Graphical symbol systems used for electrical components are as per MIL-STD-15.

(2) Reference symbol system used in equations and on diagrams are as described below.

<u>Symbol</u>	<u>Description</u>	<u>First Used On Page</u>
C	a defined capacity	9
$ E(j\omega) $	magnitude of sinusoidal signal as a function of frequency ω .	9
$ F(j\omega) $	magnitude of $F(s)$ along ω axis	9
$F(s)$	a function of the complex variable s .	16
R	resistance	9
s	complex frequency variable $j\omega$.	16
T	time constant RC and period of sinusoidal waveform	9
$\phi_F(j\omega)$	phase of $F(s)$ along ω axis	9
ω	radian frequency	9

c. Formulae Pertaining to Recognition Channel - Referring to Figure 4, the amplitude and phase response as a function of the individual transfer functions from the input of the Signal Reference Converter to the output of the Noise Rejection Filters 1A4TP2 is

$$|F_T(j\omega)| = \frac{|E_5(j\omega)|}{|E_2(j\omega)| - |E_1(j\omega)|} = |F_1(j\omega)| \cdot |F_2(j\omega)| \cdot |F_3(j\omega)| \quad (2.1)$$

$$\phi_{F_T}(j\omega) = \phi_{F_1}(j\omega) + \phi_{F_2}(j\omega) + \phi_{F_3}(j\omega) \quad (2.2)$$

where $|F_1(j\omega)|$ and $\phi_{F_1}(j\omega)$ are respectively the amplitude and phase response of the Signal Reference Converter. In terms of the actual components we get,

$$|F_1(j\omega)| = \frac{|E_3(j\omega)|}{|E_2(j\omega)| - |E_1(j\omega)|} = \frac{R_2}{R_1} \cdot \frac{|j\omega R_1 C_1|}{|1 + j\omega R_1 C_1| \cdot |1 + j\omega R_2 C_2|}$$

$$= \frac{1}{4} \cdot \frac{|j\omega T_1|}{|1 + j\omega T_1| \cdot |1 + j\omega T_2|} \quad \text{and} \quad (2.3)$$

$$\phi_{F_1}(j\omega) = \tan^{-1} \infty - \tan^{-1} \omega T_1 - \tan^{-1} \omega T_2 \quad (2.4)$$

Similarly, for the 0.023 Hz isolated Notch Filter we get,

$$|F_2(j\omega)| = \frac{|E_4(j\omega)|}{|E_3(j\omega)|} = \frac{2 + j\omega R_4 C_4}{\left| \frac{1 + j\omega R_3 C_3}{1 - \omega^2 R_3^2 C_3^2} \right| \cdot |1 + j\omega R_4 C_4|} = \frac{|2 + j\omega T_4|}{\left| \frac{1 + j\omega T_3}{1 - \omega^2 T_3^2} \right| \cdot |1 + j\omega T_4|} \quad (2.5)$$

and

$$\phi_{F_2}(j\omega) = \frac{\tan^{-1} \omega T_4}{2} - \frac{\tan^{-1} \omega T_3}{1 - \omega^2 T_3^2} - \tan^{-1} \omega T_4 \quad (2.6)$$

Finally, for the 0.9 Hz Notch Filter cascaded with the isolated High Pass Filter, we get,

$$|F_3(j\omega)|^* = \frac{|E_5(j\omega)|}{|E_4(j\omega)|} = \frac{|j\omega R_6 C_6| |2 + j\omega R_7 C_7|}{|1 + j\omega R_5 C_5| |1 + j\omega R_6 C_6| |1 + j\omega R_7 C_7|} = \frac{|j\omega T_6| |2 + j\omega T_7|}{|1 + j\omega T_5| |1 + j\omega T_6| |1 + j\omega T_7|} \quad (2.7)$$

$$\frac{1 - \omega^2 T_5^2}{1 - \omega^2 T_5^2}$$

and

$$\phi_{F_3}(j\omega) = \tan^{-1} \infty + \tan^{-1} \frac{\omega T_7}{2} - \tan^{-1} \frac{\omega T_5}{1 - \omega^2 T_5^2} - \tan^{-1} \omega T_6 - \tan^{-1} \omega T_7 \quad (2.8)$$

Substituting equations (2.3), (2.5) and (2.7) in equation (2.1) and equations (2.4), (2.6) and (2.8) in equation (2.2) letting $\tan^{-1} \infty = 90^\circ$ we get for the total amplitude and phase response as a function of frequency the following equations

$$|F_T(j\omega)| = \frac{|E_5(j\omega)|}{|E_2(j\omega)| - |E_1(j\omega)|}$$

$$= \frac{|j\omega T_1|}{4 |1 + j\omega T_1| |1 + j\omega T_2|} \cdot \frac{|2 + j\omega T_4|}{|1 + j\omega T_3| |1 + j\omega T_4|} \cdot \frac{|j\omega T_6| |2 + j\omega T_7|}{|1 + j\omega T_5| |1 + j\omega T_6| |1 + j\omega T_7|} \quad (2.9)$$

$$\frac{1 - \omega^2 T_3^2}{1 - \omega^2 T_5^2}$$

In terms of decibels we get,

$$20 \log |F_T(j\omega)| = 20 \log \frac{|E_5(j\omega)|}{|E_2(j\omega)| - |E_1(j\omega)|} = 20 \log \frac{|j\omega T_1|}{4 |1 + j\omega T_1| |1 + j\omega T_2|} +$$

$$20 \log \frac{|2 + j\omega T_4|}{|1 + j\omega T_3| |1 + j\omega T_4|} + 20 \log \frac{|j\omega T_6| |2 + j\omega T_7|}{|1 + j\omega T_5| |1 + j\omega T_6| |1 + j\omega T_7|} \quad (2.10)$$

$$\frac{1 - \omega^2 T_3^2}{1 - \omega^2 T_5^2}$$

*This transfer function is valid since the loading effect by the high pass filter on the notch filter output impedance is negligible.

and

$$\phi_{FT}(j\omega) = +180^\circ + \tan^{-1} \frac{\omega T_1}{2} + \tan^{-1} \frac{\omega T_7}{2} - \tan^{-1} \omega T_1 - \tan^{-1} \omega T_2 - \tan^{-1} \frac{\omega T_3}{1 - \omega^2 T_3^2} - \tan^{-1} \omega T_4 - \frac{-\tan^{-1} \omega T_5}{1 - \omega^2 T_5^2} - \tan^{-1} \omega T_6 - \tan^{-1} \omega T_7 \quad (2.11)$$

where

$T_1 = R_1 C_1 = 25$ seconds	$T_5 = R_5 C_5 = 0.177$ seconds
$T_2 = R_2 C_2 = 0.02$ seconds	$T_6 = R_6 C_6 = 25$ seconds
$T_3 = R_3 C_3 = 6.8$ seconds	$T_7 = R_7 C_7 = 0.0015$ seconds
$T_4 = R_4 C_4 = 0.025$ seconds	

Table 1 gives the theoretical results of the normalized magnitude and phase shift for each individual transfer function and the total transfer function. Figure 5 is a graphical representation of the normalized amplitude response in decibels versus frequency for equation (2.10), while Figure 6 shows the phase response versus frequency for equation (2.11).

The output signal represented by equation (2.10) is then full-wave rectified by an Active Full-Wave Rectifier circuit, having an adjustable voltage gain from 1 to 10. The rectified signal is then introduced as input to an Active Sampling Integrator as shown in Figure 7. Under no inhibit conditions the output from the Active Sampling Integrator at 1A3TP2 is reset to zero volts every 2.5 seconds by means of a 0.4Hz Master Oscillator driving a Field Effect Transistor (F.E.T.) connected in parallel with the integrating capacitor. The output pulse amplitude from the Active Sampling Integrator varies between a maximum and minimum value whenever the integrating period (2.5 seconds) divided by the half-cycle period of the input signal does not result in a whole number greater or equal to one. However, as the half-cycle period of the input signal becomes relatively small compared to the integrating period, the maximum and minimum output voltage pulses tend toward the same constant amplitude.

In order to determine the theoretical output of the integrator for sinusoidal input signals, the time integral of $|\sin \omega t|$ were calculated for a band of frequencies which included the MAD passband. The sinusoids were integrated for a period of 2.5 seconds and the maximum and minimum values were found for each frequency.

Referring to Figure 7, each separate rectified half cycle signal to the Active Sampling Integrator can be represented by the following equation

$$|E_6(j\omega)| = K |E_5(j\omega)| \quad (2.12)$$

where K is a constant equal to the preset gain of the Active Full-Wave Rectifier

$|E_5(j\omega)|$ is the peak sinusoidal input signal to the Active Full-Wave rectifier.

$|E_6(j\omega)|$ designates the peak instantaneous amplitude of each half-cycle portion from the output of the Active Full-Wave Rectifier.

Transforming equation (2.12) into the time domain letting $E_5(t) = E_5 \sin \frac{2\pi}{T} t$ where T is the period of the input sinusoidal waveform we get

$$|E_6(t)| = K |E_5(t)| = K \left| E_5 \sin \frac{2\pi}{T} t \right| \quad (2.13)$$

The output voltage from the Active Sampling Integrator is

$$|E_7| = \frac{1}{R_{12}C_8} \int_t^{t+2.5} |E_6(t)| dt \quad (2.14)$$

where $R_{12} C_8 = 2.2$ seconds

Substituting equation (2.13) in (2.14) and letting $K = 1$ for this analysis, we get

$$|E_7| = \frac{|E_5|}{2.2} \int_t^{t+2.5} \left| \sin\left(\frac{2\pi}{T} \cdot t\right) \right| dt \quad (2.15)$$

Let "I" equal $\frac{|E_7|}{|E_5|}$, then

$$I = \frac{1}{2.2} \int_t^{t+2.5} \left| \sin\left(\frac{2\pi}{T} \cdot t\right) \right| dt \quad (2.16)$$

Equation (2.16) designates the normalized output from the Active Sampling Integrator whose limits of integration will depend on the actual period of the full-wave rectified input signal.

The procedure employed for obtaining the actual transfer characteristics of the Active Sampling Integrator is shown by the following examples using Figures 8, 9 and 10.

Illustrative Example 1

This example applies to input signals whose period T is greater than 5 seconds. Referring to Figure 8 it may be seen that a maximum output from the Integrator occurs whenever the input signal is integrated between the following limits:

$$(t+2.5) \text{ seconds} = \left[\frac{T}{4} (2n+1) + 1.25 \right] \text{ seconds} \quad (2.17)$$

and

$$t \text{ seconds} = \left[\frac{T}{4} (2n+1) - 1.25 \right] \text{ seconds} \quad (2.18)$$

where $n = 0, 1, 2, 3, 4 \dots\dots\dots$

Similarly a minimum output from the Integrator occurs whenever the input signal is integrated between the following limits.

$$(t+2.5) \text{ seconds} = \left[\frac{T}{2} (n+1) + 1.25 \right] \text{ seconds} \quad (2.19)$$

and

$$t \text{ seconds} = \left[\frac{T}{2} (n+1) - 1.25 \right] \text{seconds} \quad (2.20)$$

where

$$n = 0, 1, 2, 3, 4, \dots$$

Assuming an input signal whose period $T = 50$ seconds and letting $n = 0$, we get, upon substitution in equations (2.17) to (2.20) inclusive, the following upper and lower limits of integration.

For a maximum output:

$$(t + 2.5) \text{ seconds} = \frac{50}{4} + 1.25 = 13.75 \text{ seconds} \quad (2.21)$$

and

$$t \text{ seconds} = \frac{50}{4} - 1.25 = 11.25 \text{ seconds} \quad (2.22)$$

For a minimum output

$$(t + 2.5) \text{ seconds} = \frac{50}{2} + 1.25 = 26.25 \text{ seconds} \quad (2.23)$$

and

$$t \text{ seconds} = \frac{50}{2} - 1.25 = 23.75 \text{ seconds} \quad (2.24)$$

Applying the above limits to equation (2.16) we get for the maximum output

$$I_{\max} = \frac{1}{2.2} \int_{11.25}^{13.75} \left| \sin \left(\frac{2\pi}{50} t \right) \right| dt \quad (2.25)$$

Since the limits of integration are symmetrical about the $T/4$ or 90° point of the input signal, then equation (2.25) can be expressed as follows

$$\begin{aligned} I_{\max} &= 2 \left[\frac{1}{2.2} \int_{12.5}^{13.75} \left| \sin \left(\frac{2\pi}{50} t \right) \right| dt \right] \quad (2.26) \\ &= 2 \times \frac{50}{4.4\pi} \left[\left| \cos \left(\frac{2\pi}{50} \times 13.75 \right) - \cos \left(\frac{2\pi}{50} \times 12.5 \right) \right| \right] \\ &= \frac{100}{4.4\pi} \left[\left| \cos 99^\circ - 0 \right| \right] = \frac{100}{4.4\pi} \times 0.1564 \end{aligned}$$

$$\text{or } I_{\max} = 1.131 \quad (2.27)$$

Similarly we find for the minimum output

$$I_{\min} = \frac{1}{2.2} \int_{23.75}^{26.25} \left| \sin \left(\frac{2\pi}{50} \cdot t \right) \right| dt \quad (2.28)$$

$$= 2 \left[\frac{1}{2.2} \int_{25.0}^{26.25} \left| \sin \left(\frac{2\pi}{50} \cdot t \right) \right| dt \right] \quad (2.29)$$

$$= 2 \times \frac{50}{4.4\pi} \left[\cos \left(\frac{2\pi}{50} \times 26.25 \right) - \cos \left(\frac{2\pi}{50} \times 25 \right) \right]$$

$$= \frac{100}{4.4\pi} \left[\cos 189^\circ + 1 \right] = \frac{100}{4.4\pi} \times 0.0123$$

$$\text{or } I_{\min} = 0.0889 \quad (2.30)$$

Equations (2.27) and (2.30) show that the maximum and minimum outputs from the Active Sampling Integrator will respectively be 1.311 and 0.0889 times the peak full-wave rectified input signal having a period $T = 50$ seconds.

Illustrative Example 2

This example applies to input signals whose period T is equal to $5/(n+1)$ seconds where $n = 0, 1, 2, 3, 4, \dots$.

Referring to Figure 9 it may be seen that the integrating period of 2.5 seconds divided by the half-cycle period $T/2$ of the input signal always results in a whole number greater or equal to one. Therefore, regardless of which portion of the input signal is being integrated, the output will always be equal to a constant.

Letting " m " equal to the total number of half-cycles obtained from dividing the integrating period of 2.5 seconds by the half-cycle period of the input signals we get

$$m = \frac{2.5}{T/2} = \frac{5}{T} \quad (2.31)$$

$$\text{But } T = 5/(n+1)$$

$$\therefore m = \frac{5}{5/(n+1)} = n+1 \quad (2.32)$$

Using equation (2.16) and integrating over one half-cycle, gives

$$I = \frac{1}{2.2} \int_{kT/2}^{(k+1)T/2} \left| \sin \left(\frac{2\pi}{T} \cdot t \right) \right| dt \quad (2.33)$$

where $k = 0, 1, 2, 3, 4, \dots$

$$\therefore I = \frac{T}{4.4\pi} \left[\left| \cos \left(\frac{2\pi}{T} \times (k+1) \frac{T}{2} \right) - \cos \left(\frac{2\pi}{T} \cdot \frac{kT}{2} \right) \right| \right]$$

or
$$I = \frac{T}{4.4\pi} \left[\left| \cos (k+1)\pi - \cos k\pi \right| \right]$$

But $\left| \cos(k+1)\pi - \cos k\pi \right| = 2$ for all values of k

$$\therefore I = \frac{2T}{4.4\pi} \quad (2.34)$$

Since the integrator output will be proportional to the total number of half-cycles being integrated, equation (2.32) gives

$$I = \frac{2(n+1)T}{4.4\pi} \quad (2.35)$$

But $T = 5/(n+1)$ seconds

$$\therefore I = \frac{2(n+1)}{4.4\pi} \times \frac{5}{(n+1)} = \frac{10}{4.4\pi} = \text{a constant}$$

$$\text{and } I_{\max} = I_{\min} = I = 0.7234, \text{ a constant} \quad (2.36)$$

Equation (2.36) shows that the integrator output will be a constant for all input full-wave rectified signals whose period T is equal to $5/(n+1)$ seconds.

Illustrative Example 3

This example applies to input signals whose period T is less than 5 seconds but not equal to $5/(n+1)$ seconds. Upper and lower limits of integration for both maximum and minimum outputs will be a function of the actual period of the input full-wave rectified signal. Referring to Figure 10 and assuming an input signal whose period T is equal to 2.0 seconds, then both the maximum and minimum output from the integrator will consist of two complete half-cycles plus two identical portions whose upper and lower limits of integrations could be $T/4$ and $T/8$ seconds and $T/2$ and $3T/8$ seconds respectively. Therefore for a maximum output

$$I_{\max} = \frac{2}{2.2} \int_0^{1.0} \left| \sin \left(\frac{2\pi}{T} \cdot t \right) \right| dt + \frac{2}{2.2} \int_{0.25}^{0.5} \left| \sin \left(\frac{2\pi}{T} \cdot t \right) \right| dt \quad (2.37)$$

$$= \frac{8}{4.4\pi} + \frac{4}{4.4\pi} \left[\left| \cos \left(\frac{2\pi}{2} \times 0.5 \right) - \cos \left(\frac{2\pi}{2} \times 0.25 \right) \right| \right]$$

$$= \frac{4}{4.4\pi} \left[2 + \left| 0 - \cos \frac{\pi}{4} \right| \right] = \frac{4}{4.4\pi} \times 2.707$$

$$\therefore I_{\max} = 0.7834 \quad (2.38)$$

Similarly, for a minimum output

$$\begin{aligned}
 I_{\min} &= \frac{2}{2.2} \int_0^{1.0} \left| \sin\left(\frac{2\pi}{T} \cdot t\right) \right| dt + \frac{2}{2.2} \int_{0.75}^{1.0} \left| \sin\left(\frac{2\pi}{T} \cdot t\right) \right| dt \quad (2.39) \\
 &= \frac{8}{4.4\pi} + \frac{4}{4.4\pi} \left[\cos\left(\frac{2\pi}{2} \times 1\right) - \cos\left(\frac{2\pi}{2} \times 0.75\right) \right] \\
 &= \frac{4}{4.4\pi} \left[2 + \left| -1 + \cos 45^\circ \right| \right] = \frac{4}{4.4\pi} \times 2.2929
 \end{aligned}$$

$$I_{\min} = 0.6635 \quad (2.40)$$

Table 2 is a tabulation of the normalized maximum and minimum theoretical outputs from the Active Sampling Integrator versus frequency. Since the peak amplitude of the full-wave rectified input signal to the integrator varies in accordance with the transfer function described by equation (2.10), then the total normalized amplitude response versus frequency from the input of the Recognition Channel to the output of the Active Sampling Integrator is equal to the sum in decibels of equations (2.10) and (2.16). These theoretical results are designated in Table 2 as $I_T(\max)$ and $I_T(\min)$ respectively. Expressed mathematically,

$$I_T(\max) \text{ db} = \frac{|E_7|}{|E_2(j\omega)| - |E_1(j\omega)|} \text{ db} = \left[I_{\max} + |F_T(j\omega)| \right] \text{ db} \quad (2.41)$$

$$\text{and } I_T(\min) \text{ db} = \frac{|E_7|}{|E_2(j\omega)| - |E_1(j\omega)|} \text{ db} = \left[I_{\min} + |F_T(j\omega)| \right] \text{ db} \quad (2.42)$$

Figure 11 is a graphical representation of equations (2.41) and (2.42) versus frequency.

From the Active Sampling Integrator output, the signal is then introduced as input to the Threshold Detector followed by an Output Isolation Amplifier. Under no inhibition condition, the MARK output from the Recognition Channel is therefore directly proportional to the Active Sampling Integrator output.

d. Formulae pertaining to the Maneuver Channel - Referring to Figure 12, the amplitude and phase response as a function of frequency for the Differentiator Lowpass Filter is

$$E_o(s) = \frac{SR_{15}C_9E_1(s)}{(1+SR_{14}C_9)(1+SR_{15}C_{10})(1+SR_{17}C_{11})} \quad (2.43)$$

Since $R_{14}C_9 = R_{15}C_{10} = R_{15}C_9 = T_8$ and $R_{17}C_{11} = T_9$ substituting in equation (2.43) and re-arranging terms, we get,

$$F(s) = \frac{E_o(s)}{E_1(s)} = - \frac{ST_8}{(1+ST_8)^2(1+ST_9)} \quad (2.44)$$

letting

$$S = j\omega$$

$$F(j\omega) = \frac{E_0(j\omega)}{E_1(j\omega)} = - \frac{j\omega T_8}{(1+j\omega T_8)^2(1+j\omega T_9)} \quad (2.45)$$

then

$$|F(j\omega)| = \frac{|E_0(j\omega)|}{|E_1(j\omega)|} = \frac{\omega T_8}{(1+\omega^2 T_8^2)^2 (1+\omega^2 T_9^2)^{\frac{1}{2}}} \quad (2.46)$$

and

$$\phi_F(j\omega) = 90^\circ - 2 \tan^{-1} \omega T_8 - \tan^{-1} \omega T_9 \quad (2.47)$$

where

$$T_8 = 0.2 \text{ seconds}$$

$$T_9 = 0.002 \text{ seconds}$$

Table 3 gives the theoretical results of the normalized output and phase shift versus frequency for the Differentiator Lowpass Filter.

Figure 13 is a graphical representation of the normalized amplitude response in decibels versus frequency for equation (2.46) while Figure 14 shows the phase response versus frequency for equation (2.47).

The output signal represented by equation (2.43) is then full-wave rectified at a constant gain by an Active Full-Wave Rectifier circuit followed by a Maneuver Rate Detector and a Maneuver Inhibit circuit. Whenever the amplitude of the full-wave rectified output signals exceeds a preset DC voltage, the Maneuver Rate Detector generates a pulse which energizes the Maneuver Inhibit circuit resulting in the inhibition of the MARK output from the Recognition Channel.

e. Measurement Procedures

(1) Test Equipment - See Table 4

(2) Diagrams - Figures 15 and 16 describe Special Test Equipment which consists of a Test Panel and interconnecting Test Cables. Figures 17 and 18 show the test set up used for performing the actual tests. Figure 19 is a schematic diagram of the end item.

(3) Procedures - Following is a description of the procedures used for verifying the operational characteristics of unique circuits within the end item. All tests were performed under the following conditions:

Temperature	Room Ambient (25 ± 5°C)
Altitude	Normal Ground
Vibration	None
Humidity	Room Ambient up to 90% Relative Humidity
Input Power	115 ± 1.0 VAC, 400 Hz ± 1%.

(a) Recognition Channel

1. Requirements - The filtering circuits from the input of the Signal Reference Converter to the output of the Noise Rejection Filters shall provide an attenuation of not less than 45 db at 0.023 Hz $\pm$ 10%, not less than 30 db at 0.9 Hz $\pm$ 10% and a low-pass cut-off frequency at approximately 5.0 Hz.

2. Conditions

a. With its top cover removed, the end item was connected as shown in Figure 17.

b. The recorder speed was set to 1 mm/sec and the recorder sensitivity on channels 1 and 2 to 5 V/cm and 5 Mv/mm respectively. The filter was switched on and connected in a cascaded low-pass configuration at a cut-off frequency of 0.031 Hz. The signal generator and recorder were then switched to standby.

c. The end item was switched on and allowed a one minute warm-up time.

d. Prior to the initiation of test, the Threshold Control on the Test Panel was set fully clockwise, gain Control 1A4R1 fully counterclockwise and the following controls adjusted in the specified sequence using the voltmeter as an indicator.

<u>Control</u>	<u>Voltmeter Connected to</u>	<u>Voltage Adjusted to</u>
1A4R3	1A4TP2	Zero VDC
1A4R2	1A4TP1	Zero VDC
1A3R4	1A3TP2	Zero VDC

e. The signal generator was set to 0.01 Hz the recorder started and the voltage at the MAD input adjusted to 10 volts peak-to-peak. Channel 2 of the recorder was then connected to test point 1A4TP2 (See Figure 19).

3. Measurements

a. The output voltage at 1A4TP2 was measured and recorded for all the frequencies specified in Table 5 keeping the input voltage constant while changing the recorder sensitivity on Channel 2 as was required*. The output voltages were then normalized, expressed in decibels and plotted as a function of frequency as shown in Figure 20.

* The use of external filter as a cascaded lowpass filter set to the frequencies specified in Table 5, is to remove the harmonic contents from the sinusoidal waveform of the signal generator in order to obtain the true attenuation characteristics of the notch filters.

b. Channel 2 of the recorder was then removed from test point 1A4TP2 and connected to test point 1A3TP2. The signal generator was reset to 0.01 Hz with the MAD input voltage adjusted to 10 volts peak-to-peak. The maximum and minimum output voltages at 1A3TP2 were measured and recorded for all the frequencies specified in Table 6 keeping the input voltage constant while changing the recorder sensitivity on Channel 2 as was required. Throughout these measurements, the external filter was set to the cut-off frequencies as specified in Table 6. At the end of the measurements all equipments were then switched off. The output voltages were then normalized, expressed in decibels and plotted as a function of frequency as shown in Figure 21.

(b) Maneuver Channel

1. Requirements - The differentiator low-pass filter shall differentiate the input signal up to a frequency of 0.35Hz, attenuate signals with frequencies higher than 1.5 Hz and adequately suppress 400 Hz aircraft power interference.

2. Conditions

a. With its top cover removed, the end item was connected as shown in Figure 18

b. The recorder speed was set to 1 mm/sec and the recorder sensitivity on channels 1 and 2 to 0.5 V/cm and 5 Mv/min respectively. The signal generator and recorder were then switched to standby.

c. Printed circuit board 1A5 was removed, connected to an extender board and re-inserted in the end item.

d. The end item was switched on and allowed a one minute warm-up time.

e. Channel 2 of the recorder was then connected at the junction of 1A5R9 and 1A5C3, (see Figure 19) and the signal generator set to 0.01 Hz and its output to 1 volt peak-to-peak.

3. Measurements

a. The recorder was then started and the voltage measured on channel 2 recorded for all the frequencies specified in Table 7, keeping the input voltage constant. The power to all equipments was then switched off. The measured voltages were then normalized, expressed in decibels and plotted as a function of frequency as shown in Figure 22.

3. DETAIL FACTUAL DATA

a. Relevant Facts - Upon completion of the breadboard version of the end item, the following actions were undertaken.

(1) The end item was first subjected to a thorough operational test under standard conditions of $25 \pm 5^{\circ}\text{C}$ using a sinusoidal signal as input to both the recognition and maneuver channels. The results obtained were analysed and found to meet the Detail Requirements of paragraph 3.5.1.4 of MIL-D-81465(AS).

(2) The end item was then submitted to temperature variations from - 54 to + 72°C. Under these operating conditions, D.C. drift measurements of critical circuits were recorded and the end item's performance as specified in paragraph 3. a. (1) re-verified. Upon advising Naval Air Development Center (NADC) of the performance results obtained, one of their representatives (Marshall C. Bobrin) was sent down with a magnetic tape containing actual recordings of MAD and Maneuver signals.

(3) These recorded signals were introduced as inputs to the end item and upon investigation it was found that the recorded Maneuver signals contained large amounts of spurious noises. Therefore, at this time, only the recognition channel was verified. Satisfied with the performance of the recognition channel, Mr. Bobrin indicated prior to his departure, that he would have available at a later date, another recording of MAD and Maneuver signals.

(4) In the meantime, preproduction versions of the end item were built conforming to the applicable requirements of Specification MIL-E-5400 as to mechanical design, construction and workmanship. Once again, NADC was notified to send a representative to witness any operational tests performed on the end item which they deemed necessary. At this time, Mr. Bruce A. Bollenback was sent as NADC's representative. He brought a magnetic tape* and a feasibility model designated Submarine Anomaly Marker (SAM) which NADC had designed to specification NAVAIRDEVCON AEY-02A dated 2 May 1966. This model was to be used for comparison in performance with a preproduction version of the end item.

* This magnetic tape consisted of:

(a) MAD and aircraft Maneuver signals which had been recorded aboard a P-3 aircraft near Bermuda on August 3, 1965. The submarine signals on the MAD trace were designated as numbers 23 to 25 and 29 to 32 inclusively, and

(b) MAD signals, with no aircraft Maneuver signals, recorded aboard a P-3 aircraft near Nassau on June 21, 1967. These submarine signals were designated as numbers 22 to 26 and 27 to 31 inclusively.

(5) On January 3, 4 and 5, 1968, the comparison tests were performed under standard temperature conditions using, for the preproduction version of the end item, a unit designated as #003. Upon completion of the performance tests, it was concluded that the performance characteristics of unit #003 were superior to those of NADC's feasibility model in the detection and marking of submarine signals with a minimum of false alarms. Original recordings of these results were given to Mr. Bollenback to be taken back to NADC.

(6) The preproduction end items were then submitted to the Preproduction Tests as specified in MIL-D-81465(AS). These tests were completed under the responsibility of the contractor and the supervision of a government inspector. All the Preproduction Tests and Acceptance Test Part II "Qualification Phase of Reliability Assurance" have been completed and approved by a government inspector.

b. Appended Data

(1) Tables

- (a) Table - 1: Calculated amplitude and phase response of individuals and total transfer functions from signal reference converter input to noise rejection filters output.
- (b) Table - 2: Calculated amplitude response of active sampling integrator and total amplitude response from input of signal reference converter to output of active sampling integrator.
- (c) Table - 3: Calculated amplitude and phase response of maneuver channel differential low-pass filter.
- (d) Table - 4: List of test equipments for performance verification of Magnetic Variation Indicator ID-1559/ASA-64.
- (e) Table - 5: Measured output voltage from recognition channel noise rejection filters.
- (f) Table - 6: Measured output voltage from recognition channel sampling integrator.
- (g) Table - 7: Measured output voltage from maneuver channel differentiator low-pass filter.
- (h) Table - 8: Magnetic Variation Indicator ID-1559/ASA-64 physical and functional characteristics.

(2) Figures

- (a) Figure - 1: Magnetic Variation Indicator ID-1559/ASA-64.
- (b) Figure - 2: Top view, Magnetic Variation Indicator ID-1559/ASA-64.
- (c) Figure - 3: Block diagram of AN/ASA-64.
- (d) Figure - 4: Recognition Channel Cascaded signal reference converter, 0.023 Hz and 0.9 Hz isolated notch filters.
- (e) Figure - 5: Graphical representation of normalized theoretical amplitude response versus frequency from input of signal reference converter to output of noise rejection filters.
- (f) Figure - 6: Graphical representation of theoretical phase response versus frequency from input of signal reference converter to output of noise rejection filters.

- (g) Figure - 7: Recognition Channel
Cascaded active full-wave rectifier
and active sampling integrator.
- (h) Figure - 8: Input signal to active sampling integrator.
- (i) Figure - 9: Input signal to active sampling integrator.
- (j) Figure - 10: Input signal to active sampling integrator.
- (k) Figure - 11: Graphical representation of total normalized theoretical amplitude response versus frequency from input of recognition channel to output of active sampling integrator.
- (l) Figure - 12: Maneuver Channel.
Active differentiator low-pass filter.
- (m) Figure - 13: Graphical representation of normalized theoretical amplitude response versus frequency for active differentiator low-pass filter.
- (n) Figure - 14: Graphical representation of theoretical phase response versus frequency for active differentiator low-pass filter.
- (o) Figure - 15: Special Test Equipment Test Panel.
- (p) Figure - 16: Special Test Equipment Test Cables.
- (q) Figure - 17: Test set-up for recognition channel verification.
- (r) Figure - 18: Test set-up for maneuver channel verification.
- (s) Figure - 19: Schematic diagram of Magnetic Variation Indicator ID-1559/ASA-64.
- (t) Figure - 20: Graphical representation of measured amplitude response versus frequency from input of signal reference converter to output of noise rejection filters.
- (u) Figure - 21: Graphical representation of measured amplitude response versus frequency from input of signal reference converter to output of sampling integrator.
- (v) Figure - 22: Graphical representation of measured amplitude response versus frequency for active differentiator low-pass filter.

4. WEIGHT CONTROL

a. General - Figures 1 and 2 show the final version of the end item with its physical and functional characteristics listed in Table 8.

5. CONCLUSIONS

a. Operational Characteristics - An analysis of the data covered in the previous sections reveal that the performance characteristics of the end item do meet the requirements of MIL-D-81465(AS). In addition, a comparison of figures 5 and 20, 11 and 21, 13 and 22, show that the measurements performed on the end item verify the theoretical results.

PART II

6. GENERAL

a. Recommendations - From the data presented in Part I, the contractor considers that the logical outcome of employing the end item in aircrafts designated for anti-submarine warfare equipped with MAD equipment shall:

(1) Increase the probability of detecting and marking MAD submarine type signals in the presence of geologic and equipment background noises, and

(2) Increase the rejection of submarine type signals false alarms due to aircraft maneuvers.

PART III

7. TABLES AND GRAPHS

f_{req} (Hz)	$ F_1(j\omega) $	$ F_1(j\omega) $ (db)	$\phi_1(j\omega)$ (Deg)	$ F_2(j\omega) $	$ F_2(j\omega) $ (db)	$\phi_2(j\omega)$ (Deg)	$ F_3(j\omega) $	$ F_3(j\omega) $ (db)	$\phi_3(j\omega)$ (Deg)	$ F_T(j\omega) $	$ F_T(j\omega) $ (db)	$\phi_{F_T}(j\omega)$ (Deg)
0.010	0.2105	-13.534	+32.5	0.8448	-1.484	-65.0	1.6828	+4.520	+30.2	0.2986	-10.498	-2.30
0.015	0.2299	-12.768	+23.0	0.4305	-7.340	-77.5	1.8358	+5.276	+19.3	0.1813	-14.832	-35.20
0.020	0.2380	-12.468	+17.6	0.1390	-17.142	-85.9	1.8976	+5.564	+12.8	0.0628	-24.046	-55.50
0.023	0.2408	-12.364	+15.3	0	-∞	-89.9	1.9166	+5.650	+9.8	0	-∞	-64.80
0.027	0.2432	-12.281	+13.1	0.1591	-15.990	+85.4	1.9338	+5.727	+6.9	0.0746	-22.544	+115.20
0.030	0.2450	-12.217	+11.8	0.2631	-11.616	+82.4	1.9392	+5.752	+4.4	0.1247	-18.081	+105.40
0.040	0.2468	-12.153	+8.0	0.5597	-5.062	+73.6	1.9438	+5.773	-1.0	0.2679	-11.442	+98.60
0.050	0.2479	-12.114	+7.0	0.7881	-2.088	+66.6	1.9366	+5.740	-5.2	0.3775	-8.462	+80.60
0.060	0.2485	-12.093	+5.7	0.9687	-0.296	+60.7	1.9292	+5.671	-9.0	0.4614	-6.718	+68.40
0.070	0.2489	-12.080	+4.7	1.1220	+0.980	+55.7	1.9012	+5.580	-12.2	0.5297	-5.520	+57.40
0.080	0.2492	-12.071	+4.0	1.2470	+1.900	+51.2	1.8778	+5.472	-15.1	0.5822	-4.699	+48.20
0.090	0.2493	-12.067	+3.4	1.3490	+2.578	+47.1	1.8500	+5.343	-18.0	0.6204	-4.146	+40.10
0.100	0.2494	-12.063	+3.0	1.4330	+3.114	+43.6	1.8176	+5.190	-20.7	0.6487	-3.759	+32.50
0.140	0.2497	-12.052	+2.0	1.6560	+4.374	+33.4	1.6854	+4.533	-29.9	0.6962	-3.145	+25.90
0.200	0.2499	-12.048	+0.4	1.8120	+5.146	+24.1	1.4612	+3.293	-41.5	0.6600	-3.609	+5.50
0.300	0.2498	-12.049	-0.9	1.9110	+5.606	+15.7	1.1104	+0.910	-55.1	0.5288	-5.533	-17.00
0.400	0.2497	-12.052	-2.0	1.9480	+5.774	+11.2	0.8242	-1.681	-64.8	0.3999	-7.959	-40.30
0.500	0.2495	-12.060	-2.8	1.9660	+5.854	+8.3	0.5954	-4.507	-72.0	0.2718	-10.713	-55.60
0.600	0.2493	-12.067	-3.7	1.9760	+5.896	+6.1	0.4090	-7.768	-77.6	0.2009	-13.939	-66.50
0.700	0.2490	-12.076	-4.5	1.9840	+5.928	+4.4	0.2530	-11.939	-82.2	0.1247	-18.087	-75.20
0.800	0.2488	-12.085	-5.3	1.9750	+5.895	+3.0	0.1196	-18.445	-86.0	0.0586	-24.635	-82.30
0.900	0.2484	-12.098	-6.0	1.9750	+5.906	+1.8	0	-∞	-86.6	0	-∞	-88.30
1.000	0.2480	-12.110	-6.8	1.9750	+5.914	+0.8	0.1034	-19.705	+90.4	0.0570	-25.901	-90.80
1.500	0.2457	-12.195	-10.4	1.9560	+5.832	-3.0	0.5136	-5.787	+37.3	0.2469	-12.150	+86.20
3.000	0.2343	-12.605	-20.4	1.8400	+5.296	-10.2	1.2076	+1.637	+75.5	0.5205	-5.672	+81.30
4.000	0.2237	-13.011	-26.5	1.7500	+4.860	-13.3	1.4492	+3.223	+53.0	0.5670	-4.928	+62.10
7.000	0.1894	-14.512	-41.1	1.5400	+3.750	-18.1	1.7718	+4.968	+43.7	0.5133	-5.794	+22.40
10.000	0.1270	-16.129	-51.3	1.3800	+2.800	-18.9	1.8788	+5.477	+27.7	0.5098	-7.852	+3.90
20.000	0.0933	-20.604	-68.2	1.1290	+1.058	-14.6	1.9414	+5.767	+20.0	0.2046	-13.779	-31.50
50.000	0.0397	-28.027	-80.9	1.0280	+0.237	-16.9	1.8544	+5.362	+5.0	0.0756	-22.428	-48.80
100.000	0.0200	-33.996	-85.4	1.0060	+0.051	-3.6	1.6080	+4.129	-8.0	0.0323	-29.816	-77.80
									-18.0			-96.80
												-107.00

TABLE 1 - CALCULATED AMPLITUDE AND PHASE RESPONSE OF INDIVIDUALS AND TOTAL TRANSFER FUNCTIONS
FROM SIGNAL REFERENCE CONVERTER INPUT TO NOISE REJECTION FILTERS OUTPUT

Freq f (Hz)	I _{max}	I _{min}	I _{max} (db)	I _{min} (db)	I _{T(max)} (db)	I _{T(min)} (db)
0.010	1.1358	0.0449	+1.106	-26.956	- 9.392	-37.454
0.015	1.1343	0.0646	+1.094	-23.796	-13.738	-38.628
0.020	1.1310	0.0889	+1.070	-21.022	-22.976	-45.068
0.023	1.1304	0.1000	+1.065	-20.000	-	-
0.027	1.1280	0.1179	+1.046	-18.570	-21.498	-41.114
0.030	1.1257	0.1331	+1.028	-17.516	-17.053	-35.597
0.040	1.1177	0.1769	+0.966	-15.046	-10.476	-26.488
0.050	1.1074	0.2202	+0.886	-13.144	- 7.576	-21.606
0.060	1.0948	0.2628	+0.786	-11.608	- 5.932	-18.326
0.070	1.0800	0.3047	+0.668	-10.322	- 4.852	-15.842
0.080	1.0627	0.3454	+0.528	- 9.234	- 4.171	-13.913
0.090	1.0440	0.3852	+0.374	- 8.286	- 3.772	-12.432
0.100	1.0231	0.4238	+0.198	- 7.458	- 3.561	-11.217
0.140	0.9208	0.5643	-0.716	- 4.970	- 3.861	- 8.115
0.200	0.7234	0.7234	-2.814	- 2.814	- 6.423	- 6.423
0.300	0.8233	0.6260	-1.688	- 4.068	- 7.221	- 9.601
0.400	0.7234	0.7234	-2.814	- 2.814	-10.773	-10.773
0.500	0.7834	0.6635	-2.120	- 3.564	-12.833	-14.277
0.600	0.7234	0.7234	-2.314	- 2.814	-16.753	-16.753
0.700	0.7662	0.6806	-2.314	- 3.342	-20.401	-21.429
0.800	0.7234	0.7234	-2.814	- 2.814	-27.449	-27.449
0.900	0.7381	0.6731	-2.636	- 3.438	-	-
1.000	0.7234	0.7234	-2.814	- 2.814	-28.715	-28.715
1.500	0.7434	0.7035	-2.576	- 3.054	-14.726	-15.204
3.000	0.7234	0.7234	-2.814	- 2.814	- 8.486	- 8.486
4.000	0.7234	0.7234	-2.814	- 2.814	- 7.742	- 7.742
7.000	0.7234	0.7234	-2.814	- 2.814	- 8.608	- 8.608
10.000	0.7234	0.7234	-2.814	- 2.814	-10.666	-10.666
20.000	0.7234	0.7234	-2.814	- 2.814	-16.593	-16.593
50.000	0.7234	0.7234	-2.814	- 2.814	-25.242	-25.242
100.000	0.7234	0.7234	-2.814	- 2.814	-32.630	-32.630

TABLE 2 - CALCULATED AMPLITUDE RESPONSE OF ACTIVE SAMPLING INTEGRATOR AND TOTAL AMPLITUDE RESPONSE FROM INPUT OF SIGNAL REFERENCE CONVERTER TO OUTPUT OF ACTIVE SAMPLING INTEGRATOR

Freq f (Hz)	$ F(j\omega) $	$ F(j\omega) $ (db)	$\phi_F(j\omega)$ (Degrees)
0.02	0.02500	-32.0	+ 87.20
0.04	0.05000	-26.1	+ 84.30
0.06	0.07500	-22.5	+ 81.40
0.08	0.09900	-20.1	+ 78.60
0.10	0.12300	-18.2	+ 75.80
0.20	0.23500	-12.6	+ 61.70
0.40	0.40000	- 8.0	+ 36.20
0.60	0.48000	- 6.2	+ 15.40
0.80	0.50000	- 6.0	- 1.20
1.00	0.48800	- 6.2	- 13.76
2.00	0.34500	- 9.2	- 47.80
4.00	0.19200	-14.3	- 70.30
6.00	0.13100	-17.7	- 79.10
8.00	0.09900	-20.1	- 84.30
10.00	0.07950	-22.0	- 87.93
20.00	0.03880	-28.2	- 99.40
40.00	0.01790	-34.9	-114.26
60.00	0.01065	-39.5	-125.32
80.00	0.00707	-43.0	-133.86
100.00	0.00500	-46.0	-140.41
200.00	0.00151	-56.5	-157.74
300.00	0.00069	-63.3	-164.77
400.00	0.00039	-68.1	-168.46

TABLE 3 - CALCULATED AMPLITUDE AND PHASE RESPONSE
OF MANEUVER CHANNEL DIFFERENTIATOR LOW-
PASS FILTER

TEST EQUIPMENT

CHARACTERISTICS REQUIRED

- | | |
|--|---|
| 1. Voltmeter | Scale: DC
Range: 0 to 500 MV full scale
(AN/PSM-4C or equivalent) |
| 2. Signal Generator | 0.02 to 400 cps sinewave with 2%
or less harmonic distortion.
Output Voltage: 0-20 volts peak-
to-peak
Output impedance: 600 ohms
(SG-321/U or equivalent) |
| 3. *Filter | Cascaded Low-Pass Range 0.04 to 1.5 cps
(Spectrum Type LH-42D or equivalent) |
| 4. Recorder | Dual Channel
Range: Channel 1 - 5 MV/mm to 5V/cm
Channel 2 - 0.5V/cm to 5V/cm
(Sanborn Model 320 or equivalent) |
| 5. Extender Printed Circuit (PC) Board | Dwg. #35181-51683 |
- * Used to remove the harmonic content from the input sinusoidal waveform while verifying the performance characteristics of the 0.023 Hz and 0.9 Hz noise rejection filters.

SPECIAL TEST EQUIPMENT

1. Test Panel - Figure 15
2. Test Cables - Figure 16

TABLE 4 - LIST OF TEST EQUIPMENTS FOR PERFORMANCE
VERIFICATION OF MAGNETIC VARIATION
INDICATOR ID-1559/ASA-64

FREQUENCY f (Hz)	EXTERNAL LOW PASS FILTER SET TO (Hz)	MAD INPUT VOLTS PEAK-TO-PEAK	OUTPUT AT 1A4TP2 VOLTS PEAK-TO-PEAK	NORMALIZED OUTPUT AT 1A4TP2	NORMALIZED OUTPUT AT 1A4TP2(db)
0.0100	0.031	10.0	2.430	0.2430	- 12.3
0.0125	"	"	1.780	0.1780	- 15.0
0.0150	"	"	1.300	0.1300	- 17.7
0.0200	"	"	0.354	0.0354	- 29.0
0.0210	"	"	0.159	0.0159	- 36.0
0.0219	"	"	0.056	0.0056	- 45.0
0.0225	"	"	0.120	0.0120	- 38.4
0.0230	"	"	0.193	0.0193	- 34.3
0.0250	"	"	0.562	0.0562	- 25.0
0.0300	0.050	"	1.240	0.1240	- 18.1
0.0400	"	"	2.450	0.2450	- 12.2
0.0500	0.085	"	3.350	0.3350	- 9.5
0.0600	"	"	4.110	0.4110	- 7.7
0.0700	REMOVED	"	4.730	0.4730	- 6.5
0.0800	"	"	5.230	0.5230	- 5.6
0.0900	"	"	5.520	0.5520	- 5.2
0.1000	"	"	5.730	0.5730	- 4.8
0.1500	"	"	6.240	0.6240	- 4.1
0.2000	"	"	5.810	0.5810	- 4.7
0.3000	"	"	4.660	0.4660	- 6.6
0.4000	"	"	3.510	0.3510	- 9.1
0.5000	"	"	2.500	0.2500	- 12.0
0.6000	"	"	1.820	0.1820	- 14.8
0.7000	"	"	1.140	0.1140	- 18.9
0.8000	1.30	"	0.525	0.0525	- 25.6
0.9000	"	"	0.127	0.0127	- 38.0
1.0000	"	"	0.442	0.0442	- 27.1
2.0000	REMOVED	"	3.180	0.3180	- 10.0
3.0000	"	"	4.420	0.4420	- 7.1
4.0000	"	"	4.780	0.4780	- 6.4
5.0000	"	"	4.700	0.4700	- 6.6
6.0000	"	"	4.490	0.4490	- 7.0
7.0000	"	"	4.220	0.4220	- 7.5
8.0000	"	"	3.870	0.3870	- 8.2
10.0000	"	"	3.320	0.3320	- 9.6
20.0000	"	"	1.810	0.1810	- 14.8
40.0000	"	"	0.885	0.0885	- 21.1
60.0000	"	"	0.511	0.0511	- 25.8
80.0000	"	"	0.393	0.0393	- 28.1
100.0000	"	"	0.296	0.0296	- 30.6

TABLE 5 - MEASURED OUTPUT VOLTAGE FROM RECOGNITION
CHANNEL NOISE REJECTION FILTERS (1A4TP2)

FREQ f (Hz)	EXTERNAL LOW PASS FILTER SET TO (Hz)	MAD IN. UT VOLTS P-P	OUTPUT AT 1A3TP2		NORMALIZED OUTPUT AT 1A3TP2		NORMALIZED OUTPUT AT 1A3TP2	
			I _{MIN} (VOLTS) PEAK	I _{MAX} (VOLTS) PEAK	I _{MIN}	I _{MAX}	I _{MIN} (db)	I _{MAX} (db)
0.0100	0.031	10.0	0.0500	1.3800	0.01000	0.2760	- 40.0	- 11.2
0.0125	"	"	0.0640	1.0500	0.01280	0.2100	- 37.9	- 13.6
0.0150	"	"	0.0500	0.7400	0.01000	0.1480	- 40.0	- 16.6
0.0200	"	"	0.0150	0.2000	0.00300	0.0400	- 50.5	- 28.0
0.0210	"	"	0.0070	0.1050	0.00140	0.0210	- 57.1	- 33.6
0.0219	"	"	0.0018	0.0355	0.00036	0.0071	- 69.1	- 43.0
0.0225	"	"	0.0055	0.0680	0.00110	0.0136	- 59.2	- 37.3
0.0230	"	"	0.0080	0.1090	0.00160	0.0218	- 55.9	- 33.2
0.0250	"	"	0.0280	0.2950	0.00560	0.0590	- 45.0	- 24.6
0.0300	0.050	"	0.0870	0.7000	0.01740	0.1400	- 35.2	- 17.1
0.0400	"	"	0.2300	1.3700	0.04600	0.2740	- 26.7	- 11.2
0.0500	0.085	"	0.3850	1.7500	0.07700	0.3500	- 22.3	- 9.1
0.0600	"	"	0.5650	2.2500	0.11300	0.4500	- 18.9	- 6.9
0.0700	REMOVED	"	0.7000	2.5000	0.14000	0.5000	- 17.1	- 6.0
0.0800	"	"	0.9000	2.7800	0.18000	0.5560	- 14.9	- 5.1
0.0900	"	"	1.0500	2.8800	0.21000	0.5760	- 13.6	- 4.8
0.1000	"	"	1.2000	2.9300	0.24000	0.5860	- 12.4	- 4.6
0.1500	"	"	1.7500	2.6500	0.35000	0.5300	- 9.1	- 5.5
0.2000	"	"	2.1000	2.1000	0.42000	0.4200	- 7.5	- 7.5
0.3000	"	"	1.4200	1.9200	0.28400	0.3840	- 10.9	- 8.3
0.4000	"	"	1.2700	1.2700	0.25400	0.2540	- 11.9	- 11.9
0.5000	"	"	0.8250	0.9800	0.16500	0.1960	- 15.7	- 14.2
0.6000	"	"	0.6600	0.6600	0.13200	0.1320	- 17.6	- 17.6
0.7000	"	"	0.3850	0.4350	0.07700	0.0870	- 22.3	- 21.2
0.8000	1.30	"	0.1900	0.1900	0.03800	0.0380	- 28.4	- 28.4
0.9000	"	"	0.0430	0.0470	0.00860	0.0094	- 41.3	- 40.5
1.0000	"	"	0.1600	0.1600	0.03200	0.0320	- 29.9	- 29.9
2.0000	REMOVED	"	1.1500	1.1500	0.23000	0.2300	- 12.8	- 12.8
3.0000	"	"	1.6000	1.6000	0.32000	0.3200	- 9.9	- 9.9
4.0000	"	"	1.7300	1.7300	0.34600	0.3460	- 9.2	- 9.2
5.0000	"	"	1.7000	1.7000	0.34000	0.3400	- 9.4	- 9.4
6.0000	"	"	1.6250	1.6250	0.32500	0.3250	- 9.8	- 9.8
7.0000	"	"	1.5250	1.5250	0.30500	0.3050	- 10.3	- 10.3
8.0000	"	"	1.4000	1.4000	0.38000	0.2800	- 11.1	- 11.1
10.0000	"	"	1.2000	1.2000	0.24000	0.2400	- 12.4	- 12.4
20.0000	"	"	0.6550	0.6550	0.13100	0.1310	- 17.7	- 17.7
40.0000	"	"	0.3200	0.3200	0.06400	0.0640	- 23.9	- 23.9
60.0000	"	"	0.1850	0.1850	0.03700	0.0370	- 28.6	- 28.6
80.0000	"	"	0.1420	0.1420	0.02840	0.0284	- 30.9	- 30.9
100.0000	"	"	0.1070	0.1070	0.02140	0.0214	- 33.4	- 33.4

TABLE 6 - MEASURED OUTPUT VOLTAGE FROM
RECOGNITION CHANNEL SAMPLING INTEGRATOR

FREQUENCY f (Hz)	OUTPUT VOLTAGE AT JUNCTION OF 1A5R9 and 1A5C3 (volts p-p)	NORMALIZED OUTPUT AT JUNCTION OF 1A5R9 and 1A5C3	NORMALIZED OUTPUT AT JUNCTION OF 1A5R9 and 1A5C3 (db)
0.02	0.0215	0.0215	- 33.4
0.04	0.0425	0.0425	- 27.4
0.06	0.0630	0.0630	- 24.0
0.08	0.0860	0.0860	- 21.3
0.10	0.1000	0.1000	- 20.0
0.20	0.2050	0.2050	- 13.8
0.40	0.3350	0.3350	- 9.5
0.60	0.4050	0.4050	- 7.9
0.80	0.4400	0.4400	- 7.1
1.00	0.4300	0.4300	- 7.3
2.00	0.3200	0.3200	- 9.9
4.00	0.1650	0.1650	- 15.6
6.0	0.1200	0.1200	- 18.2
8.00	0.0900	0.0900	- 20.9
10.00	0.0700	0.0700	- 23.1
20.00	0.0340	0.0340	- 29.4
40.00	0.0160	0.0160	- 35.9
60.00	0.0100	0.0100	- 40.0
80.00	0.0070	0.0070	- 43.1
100.00	0.0050	0.0050	- 46.0
200.00	0.0020	0.0020	- 56.5
300.00	0.0009	0.0009	- 60.9
400.00	0.0006	0.0006	- 64.4

TABLE 7 - MEASURED OUTPUT VOLTAGE FROM
MANEUVER CHANNEL DIFFERENTIATOR
LOW PASS FILTER

<u>ITEM</u>	<u>CHARACTERISTICS</u>
Dimensions (Overall)	Length: 9.0 in. Width: 5.875 in. Height: 6.0 in. Volume: 0.2 cu ft.
Weight	6.5 lbs
Power Supply	115 vac 400 Hz 25 va maximum (as per MIL-STD-704)
Internal Power Supply	± 15 (± 0.6) vdc 75 ma for solid-state circuits
Circuit Breaker	115V 400 Hz 1/2 A
Controls	POWER/OFF switch (on Selector Control Panel C-7693/ASA-71) THRESHOLD ADJUST potentiometer (on Selector Control Panels C-7693/ASA-71) MARK spring-loaded switch INHIBIT spring-loaded switch
Lamps	INHIBIT lamp (on Selector Control Panel) TEST lamp
Inputs	MAD signal from Electronic Control Amplifier Assembly AN-1967B/ASQ-10A Maneuver signal from MAD interface maneuver processor
Outputs	Voltage pulse (MARK) - positive-going ramp on a - 7.5 vdc base, repeated every 2.5 (± 0.25) seconds under no inhibit conditions.

TABLE 8 - MAGNETIC VARIATION INDICATOR ID-1559/ASA-64
PHYSICAL AND FUNCTIONAL CHARACTERISTICS



FIGURE 1 - MAGNETIC VARIATION INDICATOR ID-1559/ASA-64

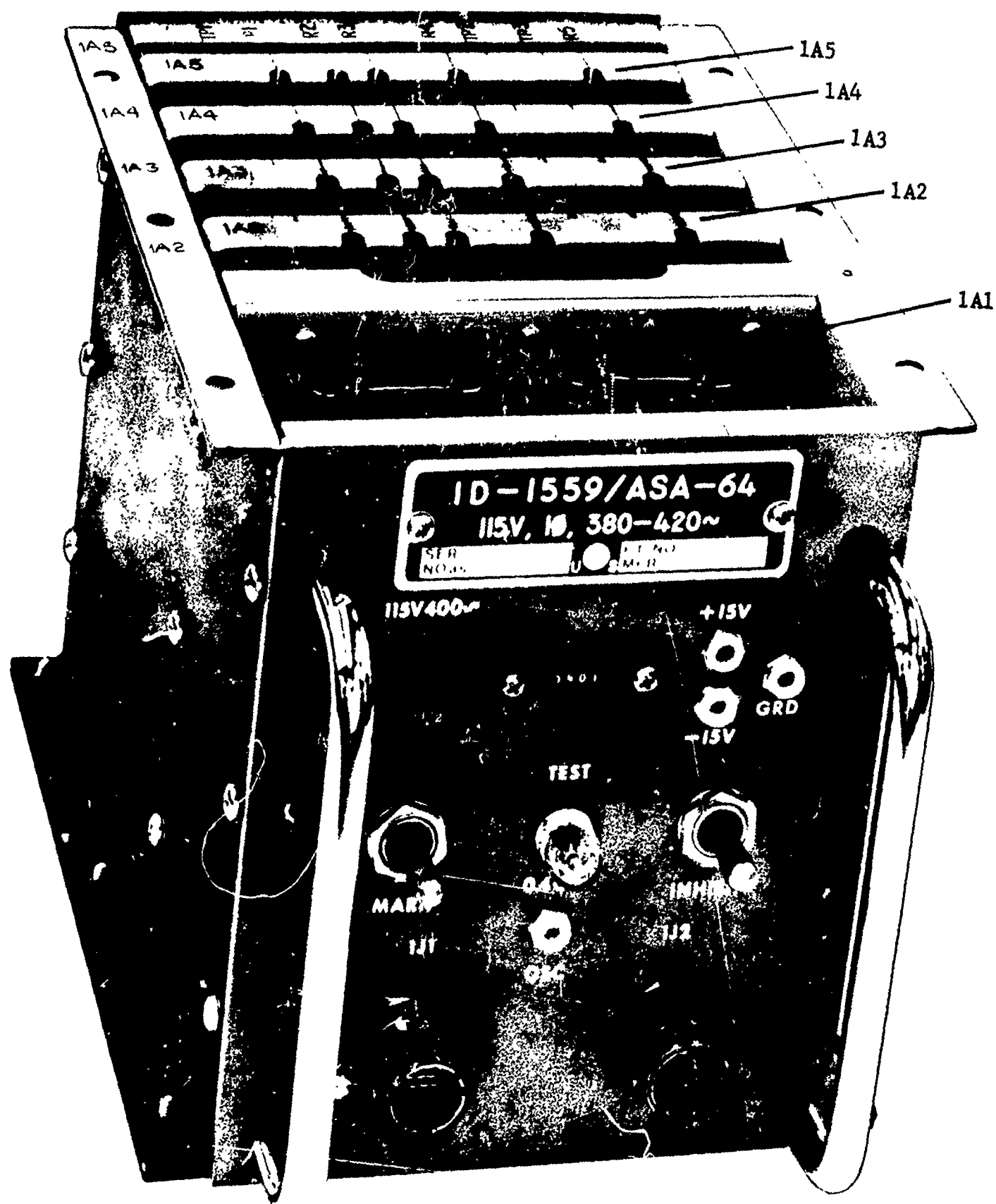
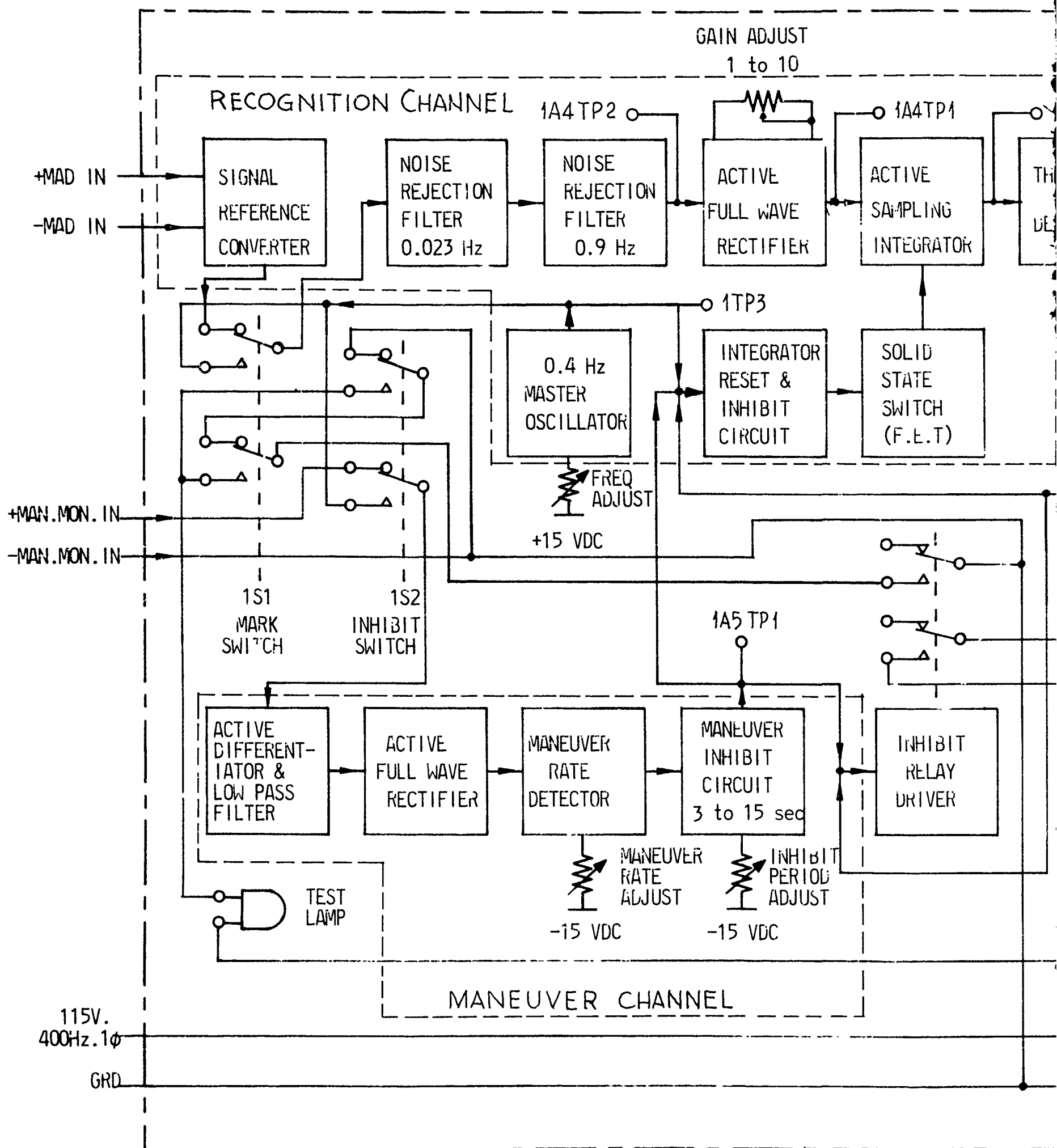
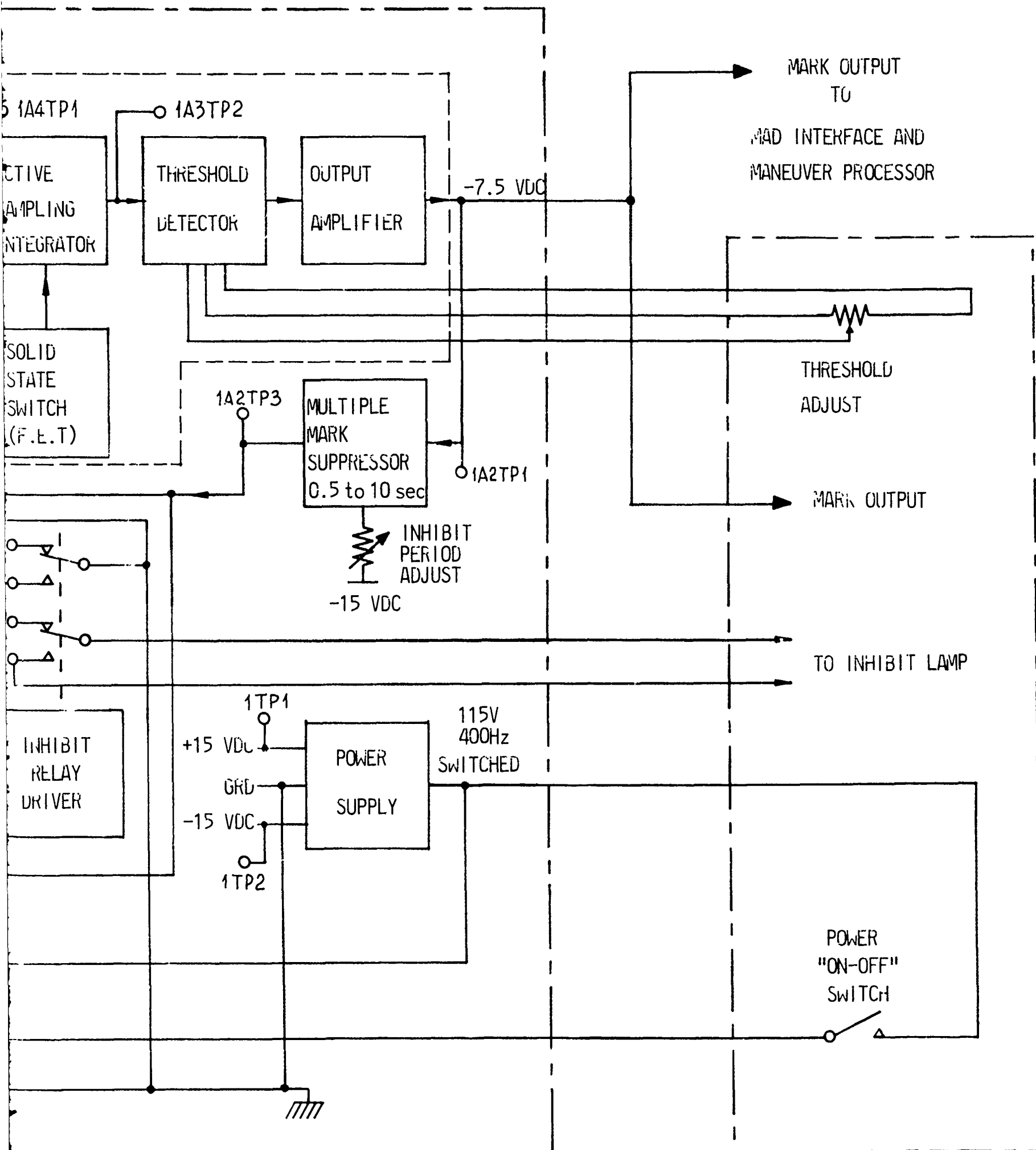


FIGURE 2 - TOP VIEW, MAGNETIC VARIATION INDICATOR ID-1559/ASA-64



MAGNETIC VARIATION INDICATOR MD-1559/ASA-64

FIGURE 3 - BLOCK DIAGRAM



1D-1559/ASA-64

SELECTOR CONTROL PANEL C-7693/ASA-71

LOCK DIAGRAM OF AN/ASA-64

B

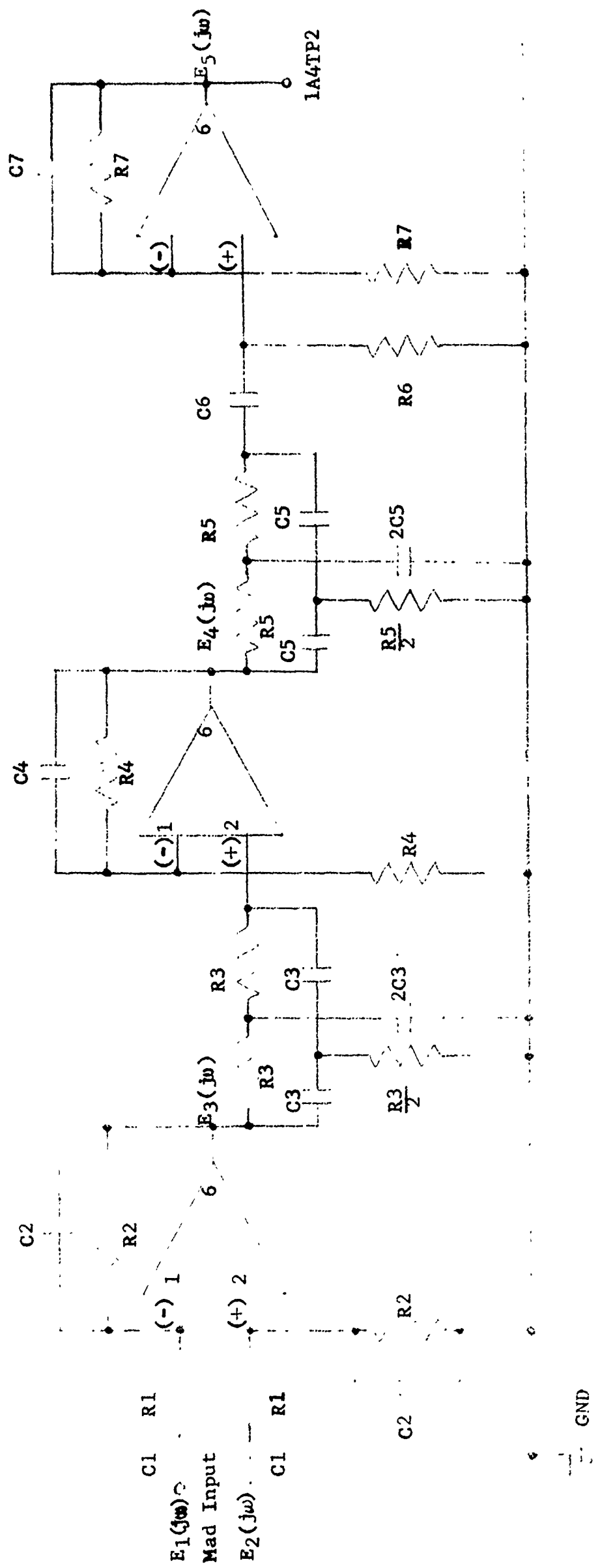


FIGURE 4 - RECOGNITION CHANNEL CASCADED SIGNAL REFERENCE CONVERTER,
0.023 Hz AND 0.9 Hz ISOLATED NOTCH FILTERS

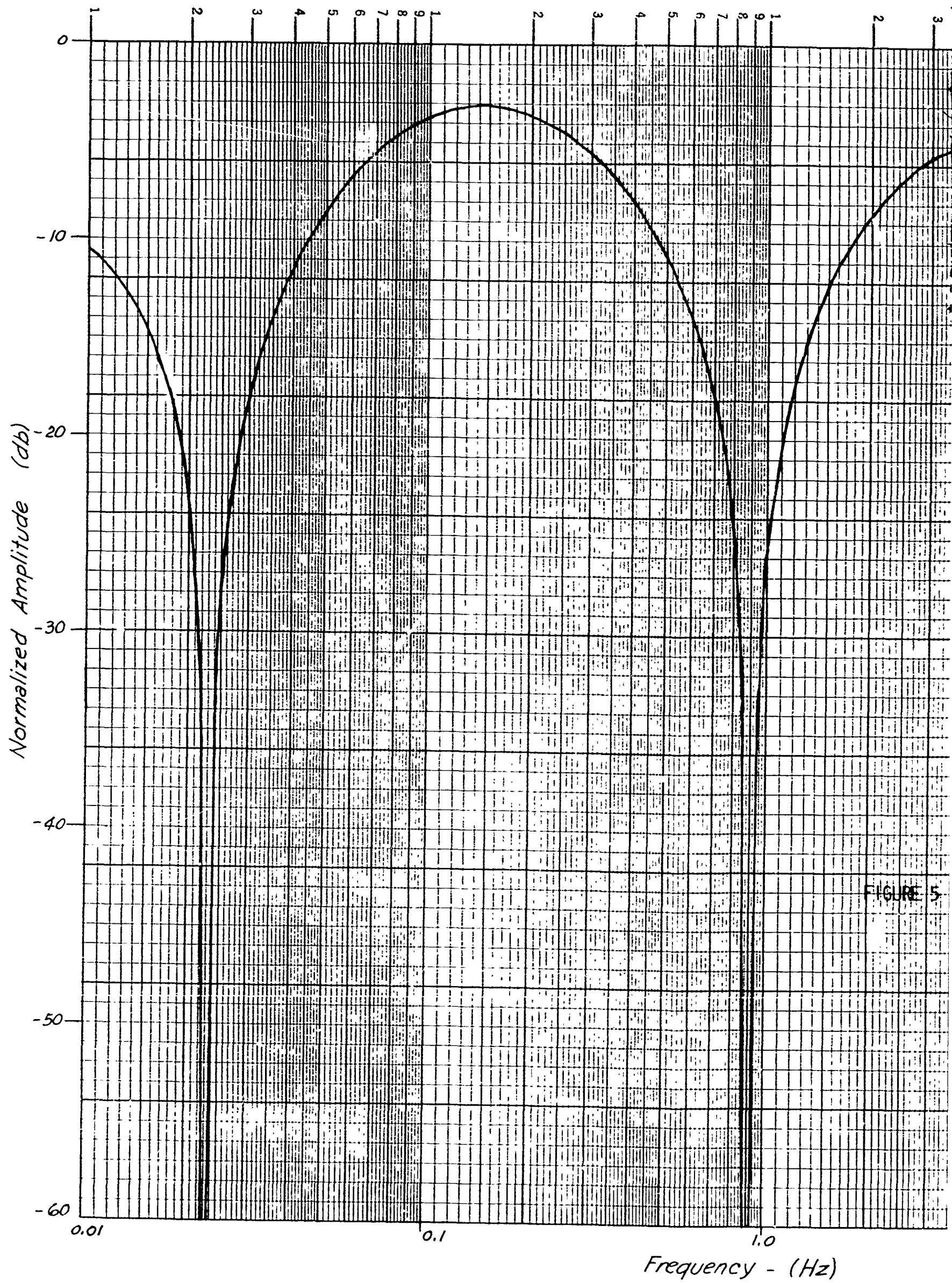


FIGURE 5

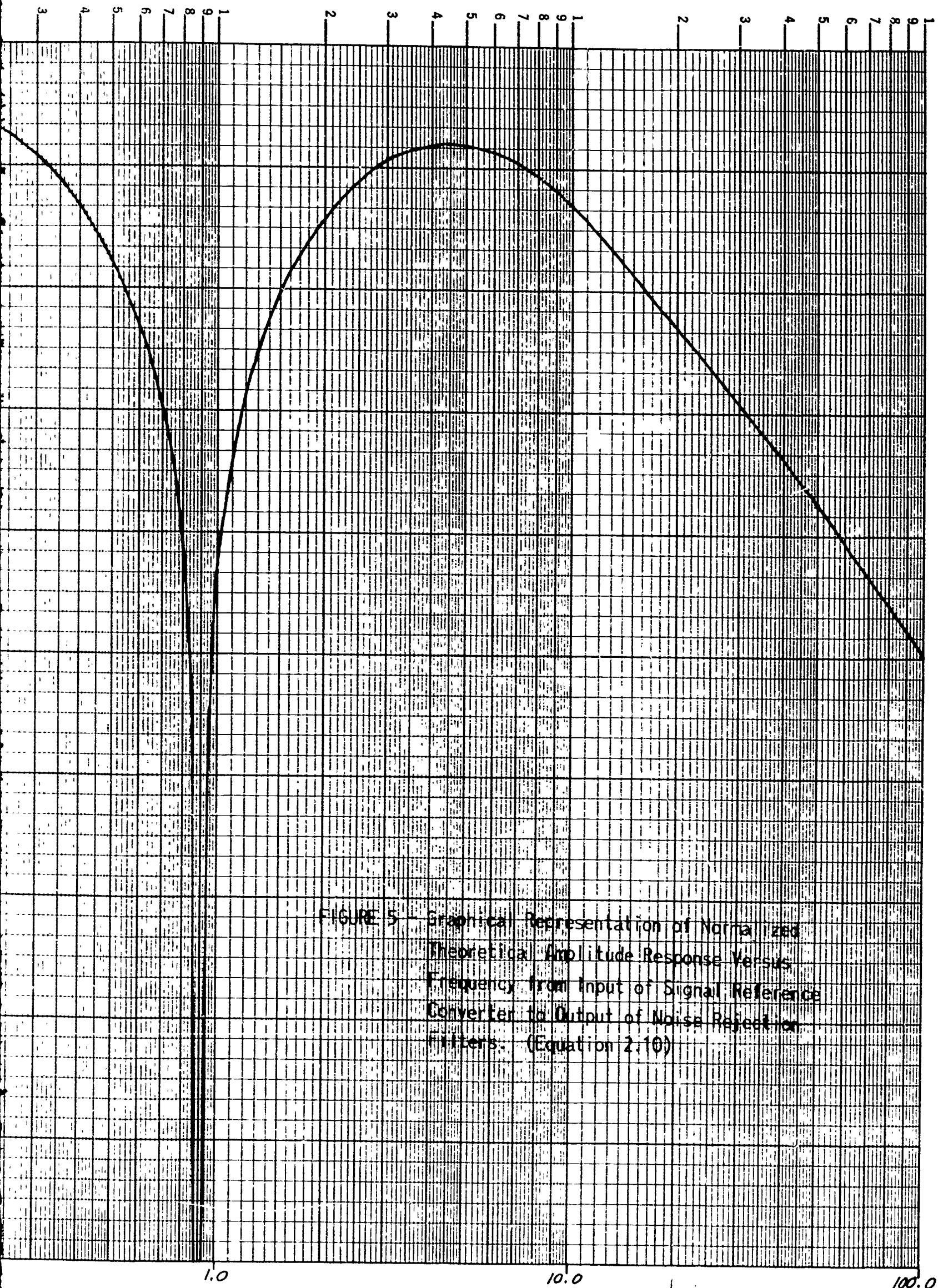
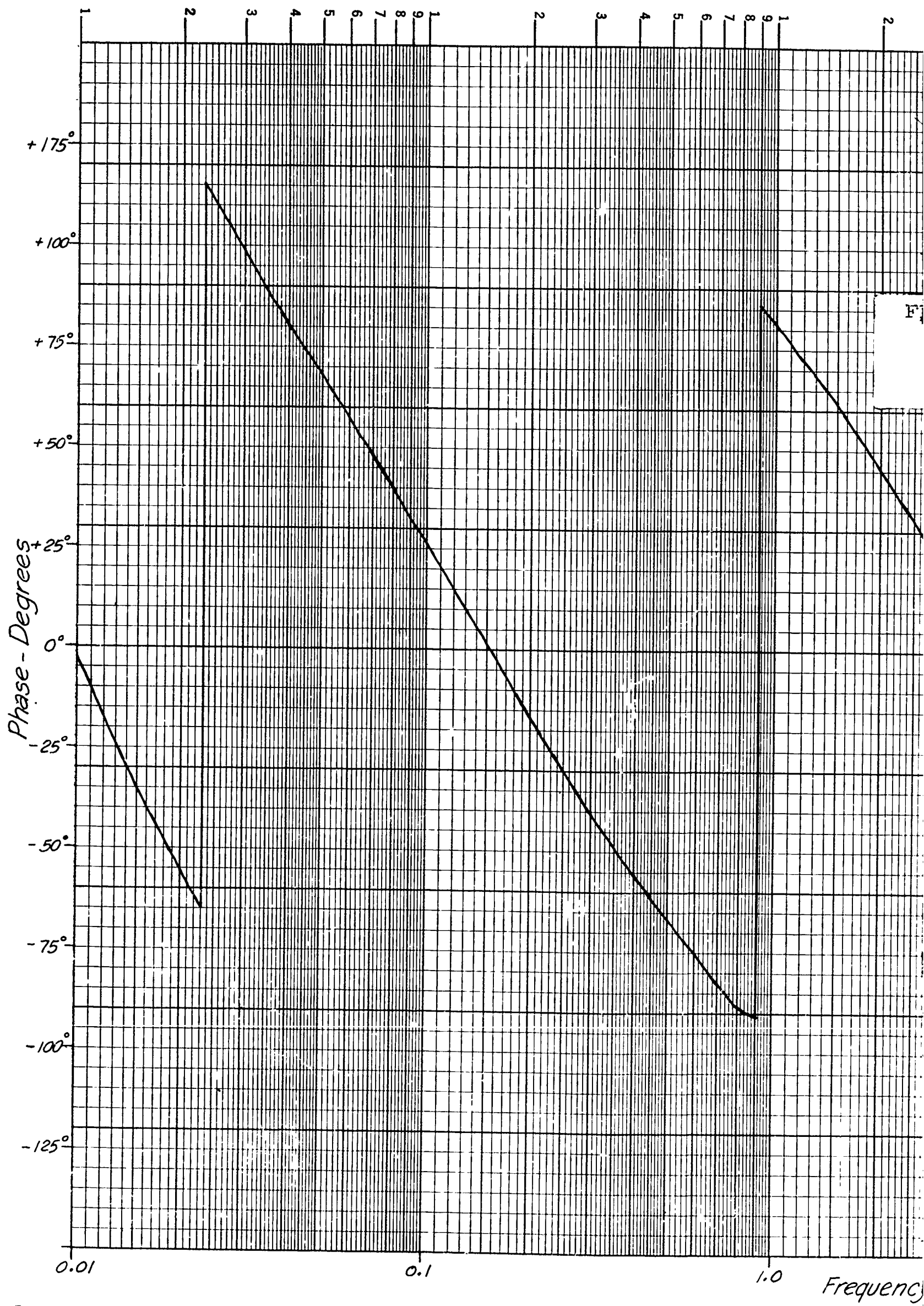


FIGURE 5 - Graphical Representation of Normalized Theoretical Amplitude Response Versus Frequency from Input of Signal Reference Converter to Output of Noise Rejection Filters. (Equation 2.10)



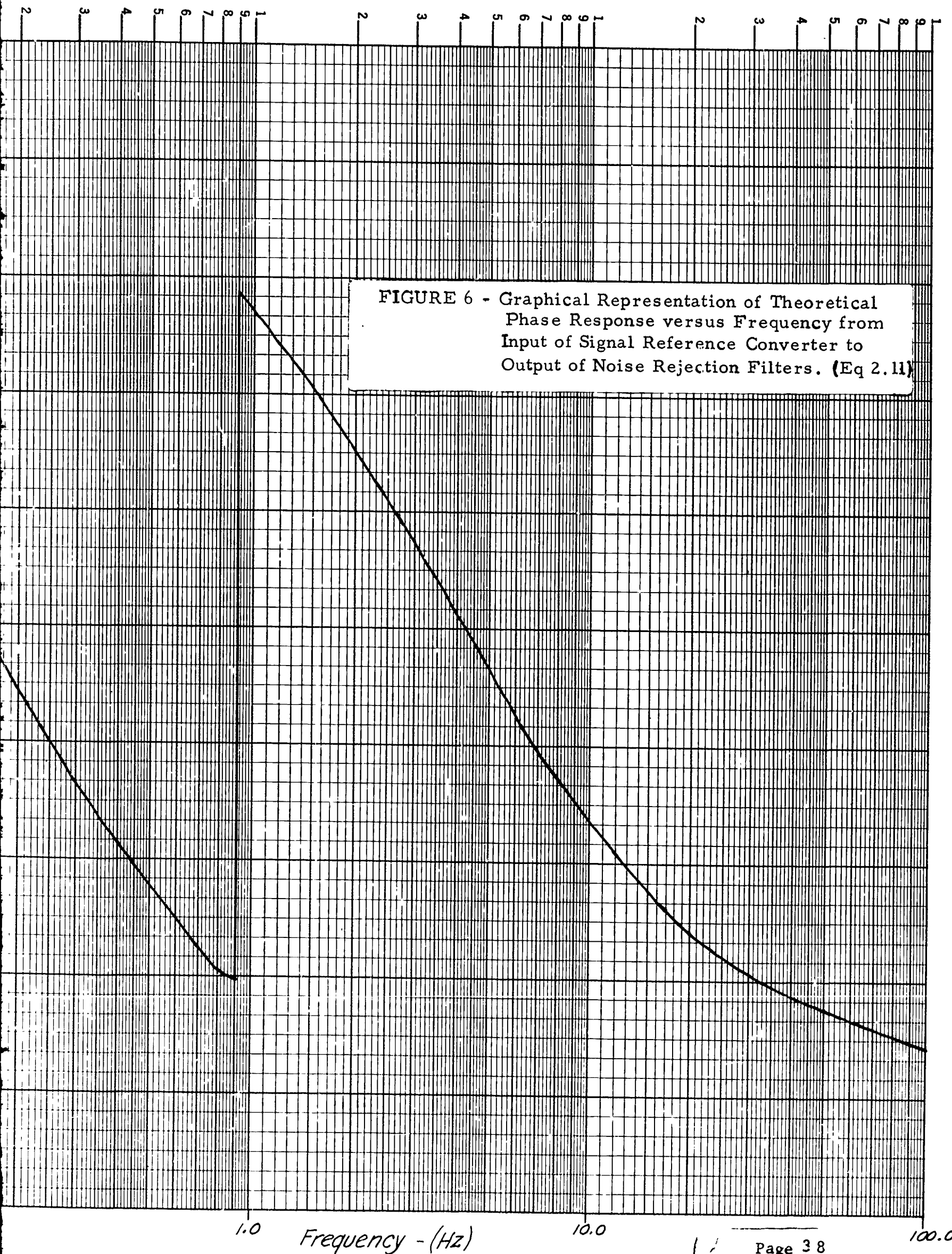


FIGURE 6 - Graphical Representation of Theoretical Phase Response versus Frequency from Input of Signal Reference Converter to Output of Noise Rejection Filters. (Eq 2.11)

Frequency - (Hz)

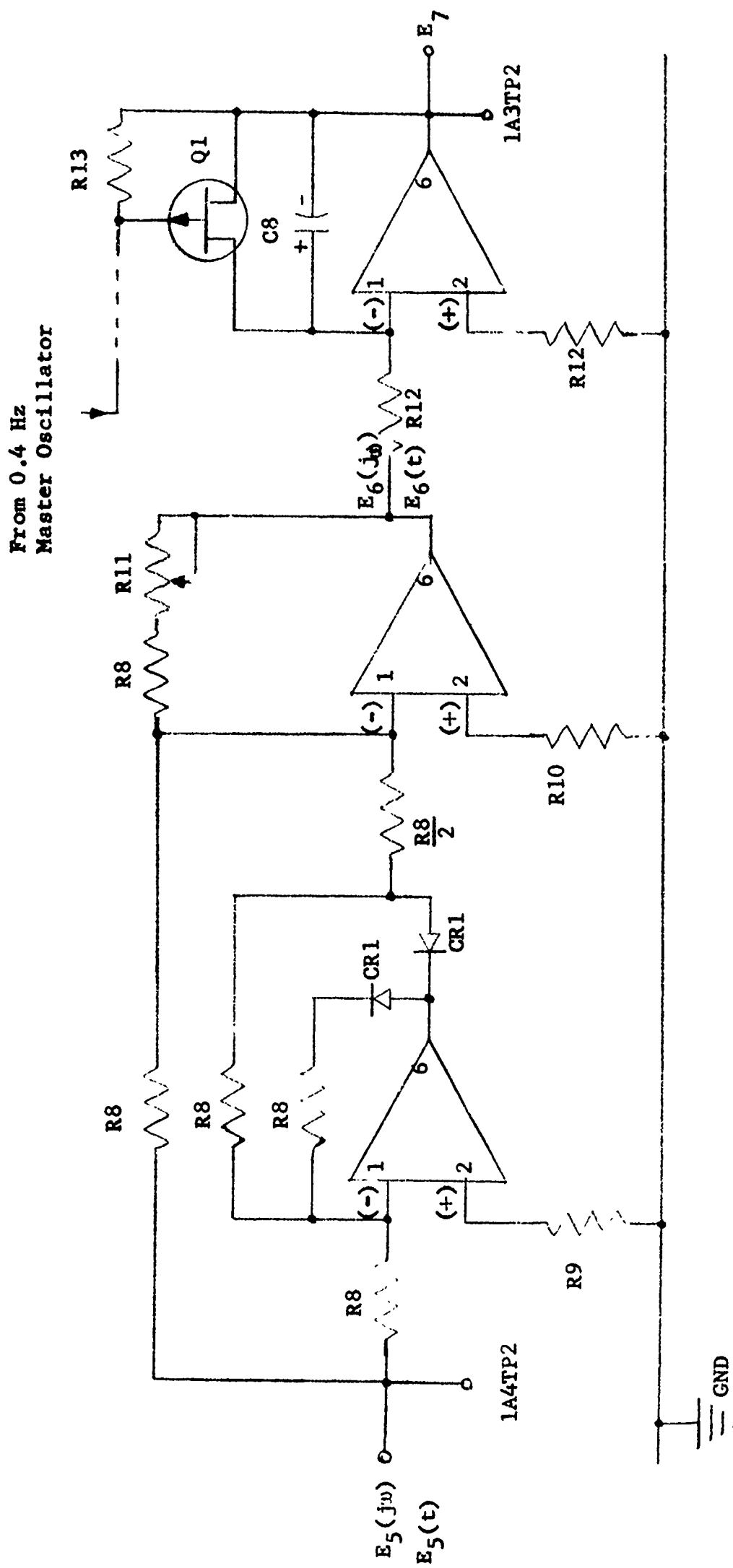
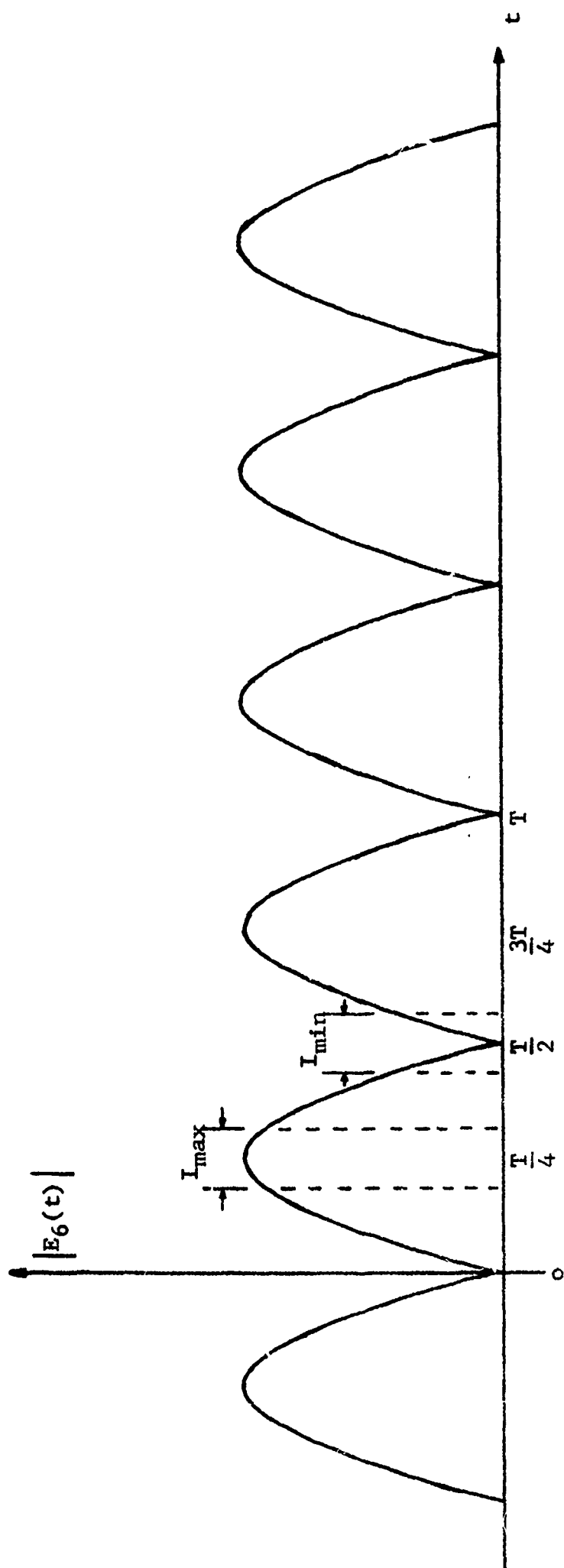


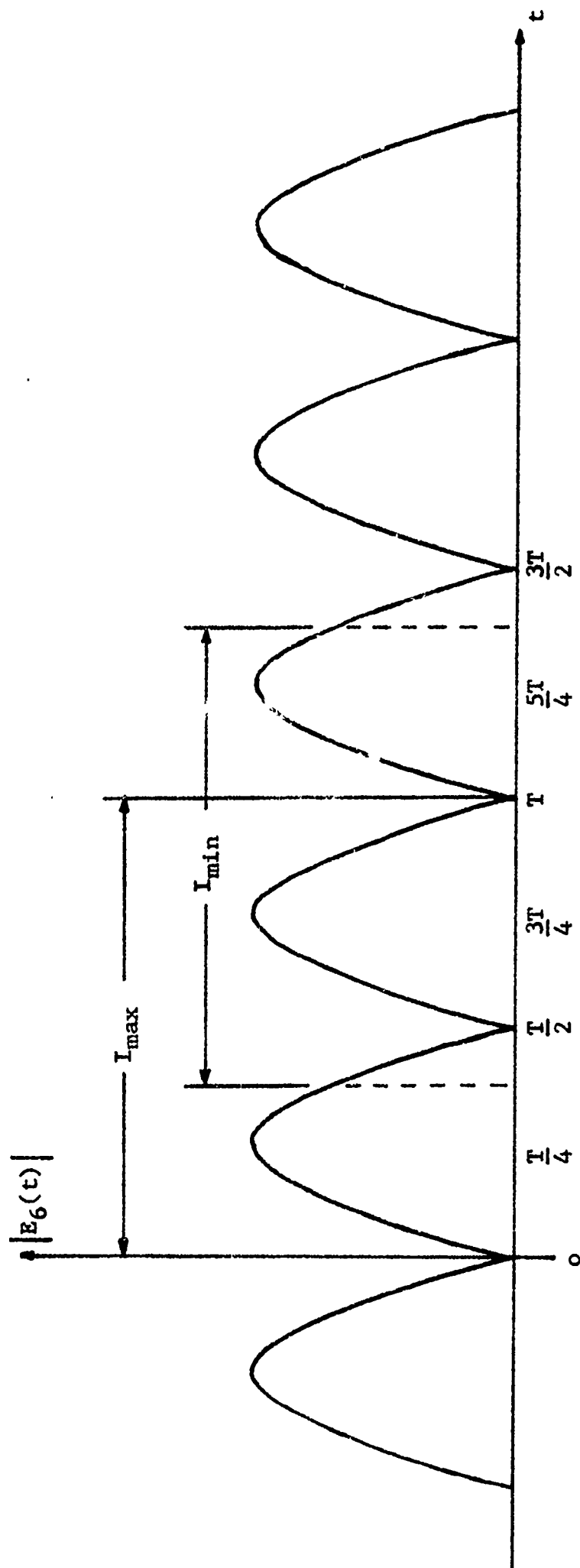
FIGURE 7 - RECOGNITION CHANNEL CASCADED ACTIVE FULL-WAVE RECTIFIER AND ACTIVE SAMPLING INTEGRATOR



EXAMPLE: $T = 50$ SECONDS

CONDITIONS: PERIOD " T " > 5 SECONDS

FIGURE 8 - INPUT SIGNAL TO ACTIVE SAMPLING INTEGRATOR



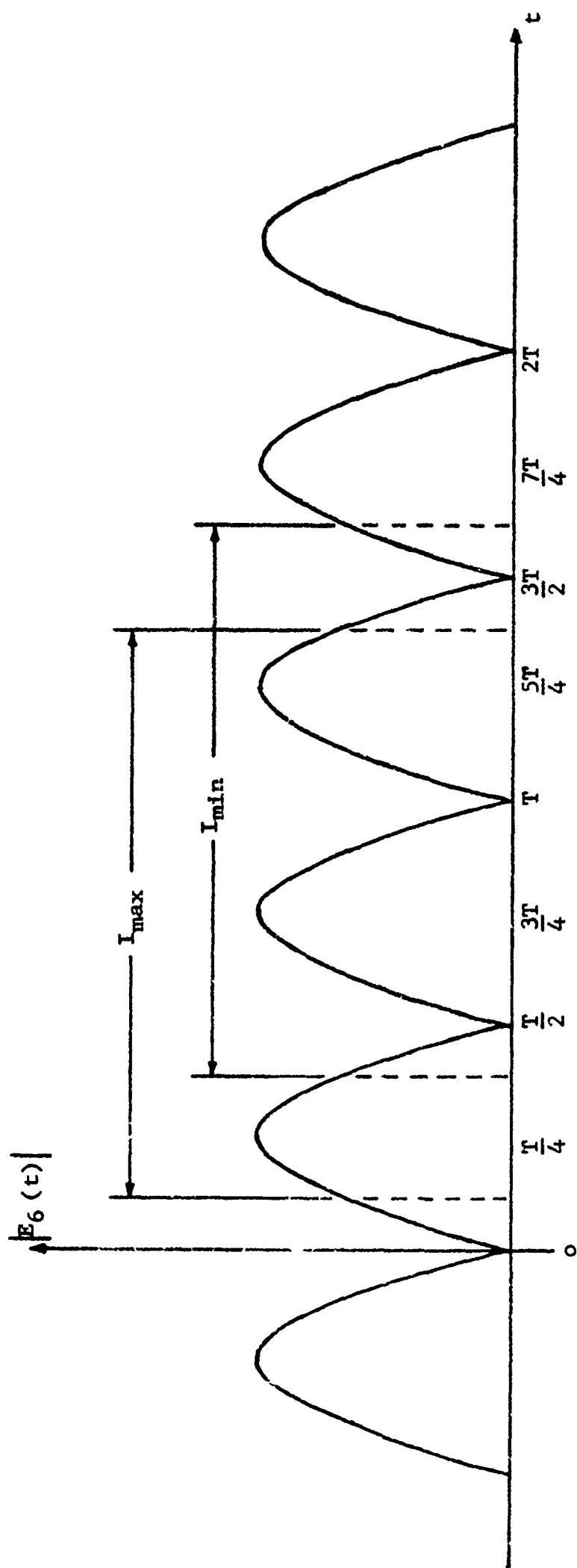
EXAMPLE: $T = 5/(n+1)$ SECONDS

$$I_{\max} = I_{\min} = I \quad A \text{ CONSTANT}$$

CONDITIONS: $T = 5/(n+1)$ SECONDS

$$n = 0, 1, 2, 3, 4 \quad \text{----- } n$$

FIGURE 9 - INPUT SIGNAL TO ACTIVE SAMPLING INTEGRATOR

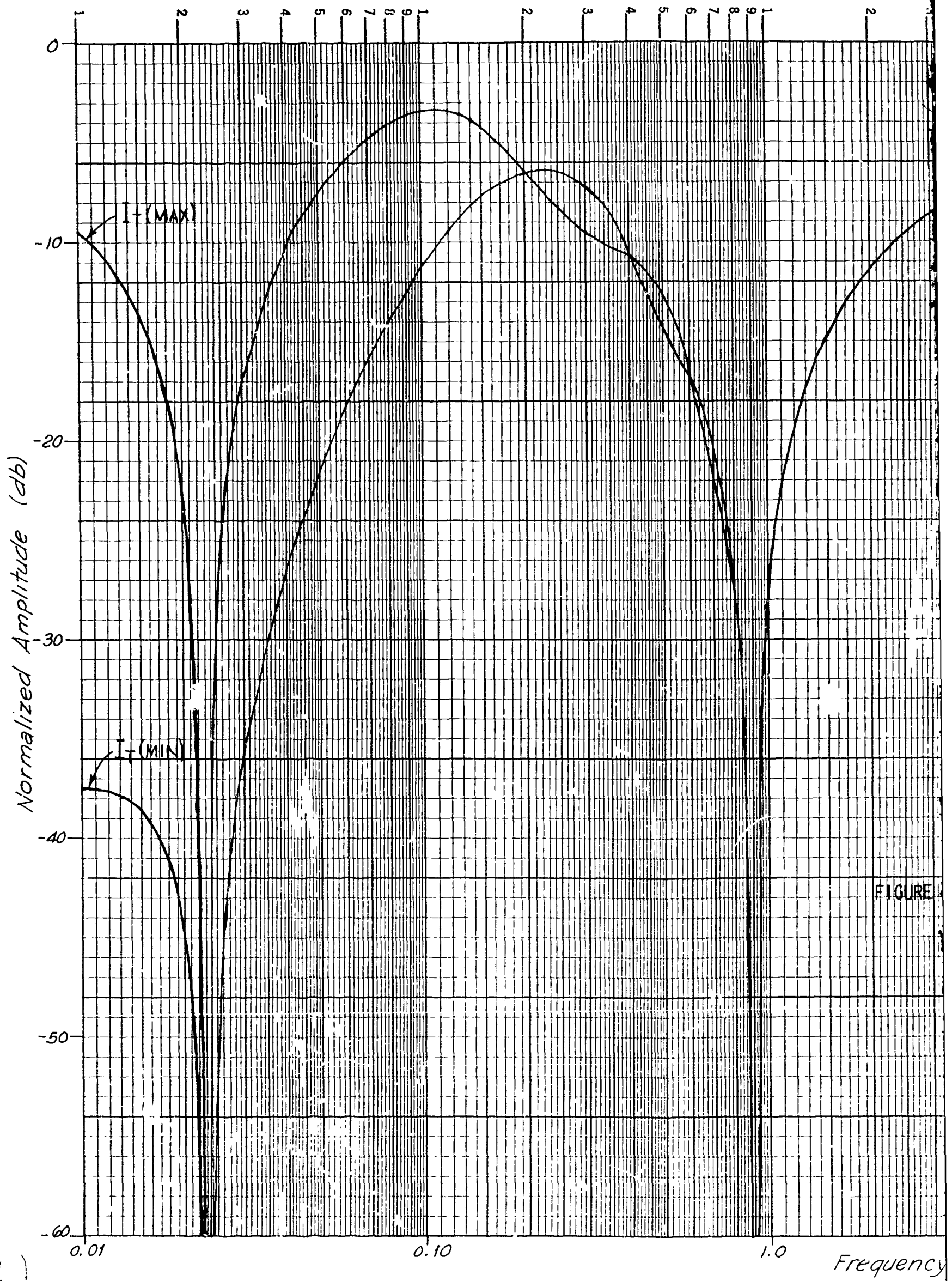


EXAMPLE: $T = 2.0$ SECONDS

CONDITIONS: $T < 5 \neq 5/(n+1)$ SECONDS

$n = 0, 1, 2, 3, 4$ ----- n

FIGURE 10 - INPUT SIGNAL TO ACTIVE SAMPLING INTEGRATOR



FIGURE

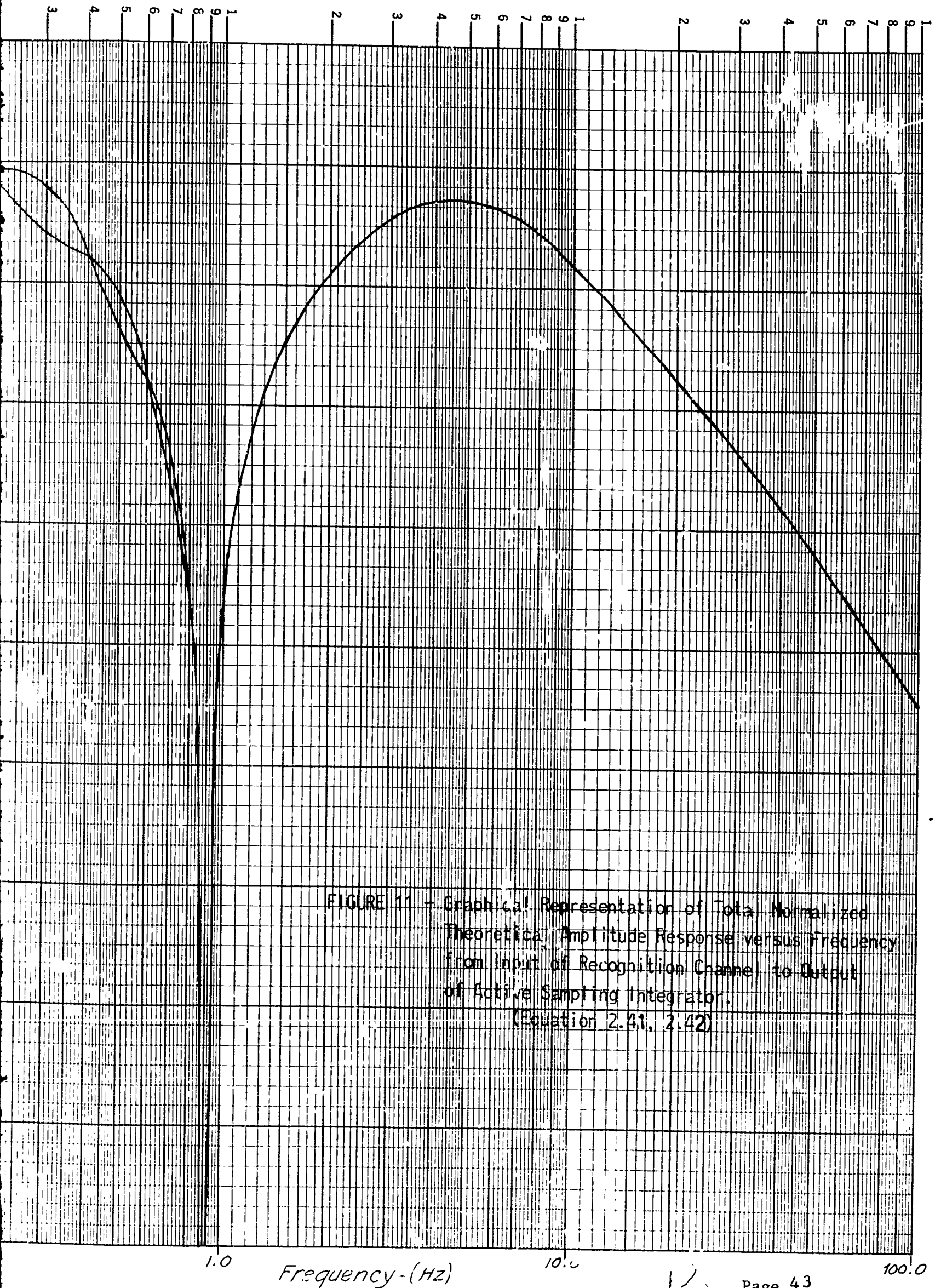


FIGURE 11 - Graphical Representation of Total Normalized Theoretical Amplitude Response versus Frequency from Input of Recognition Channel to Output of Active Sampling Integrator. (Equation 2.41, 2.42)

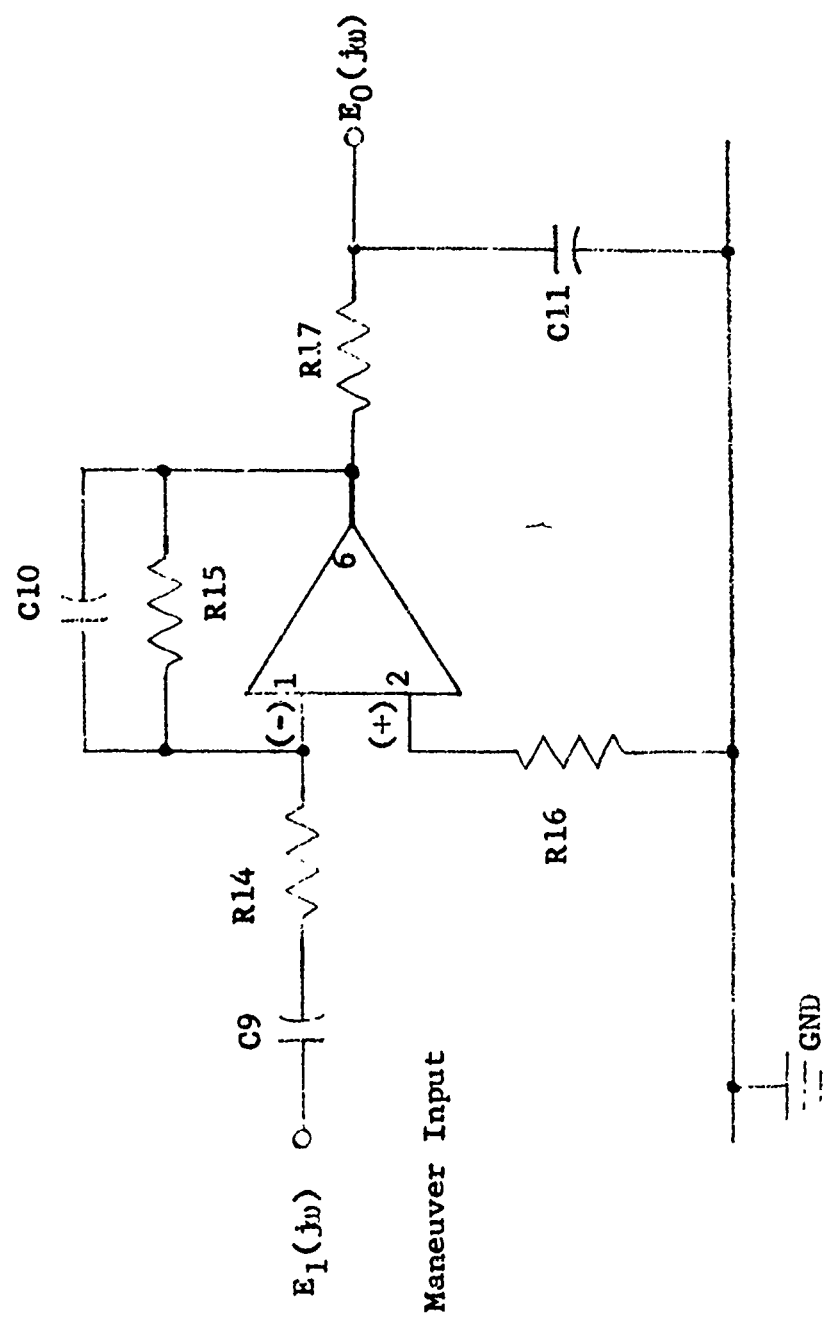
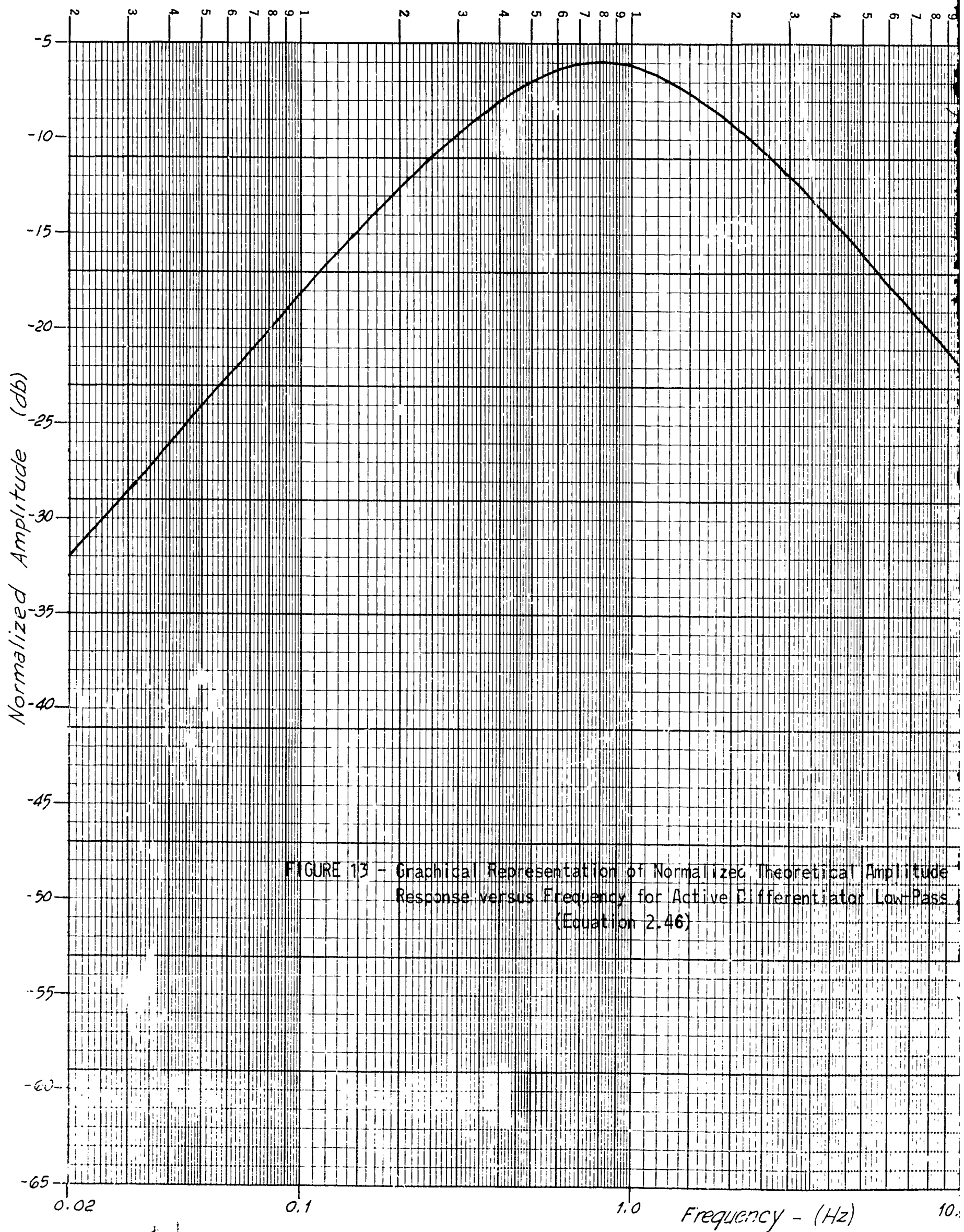
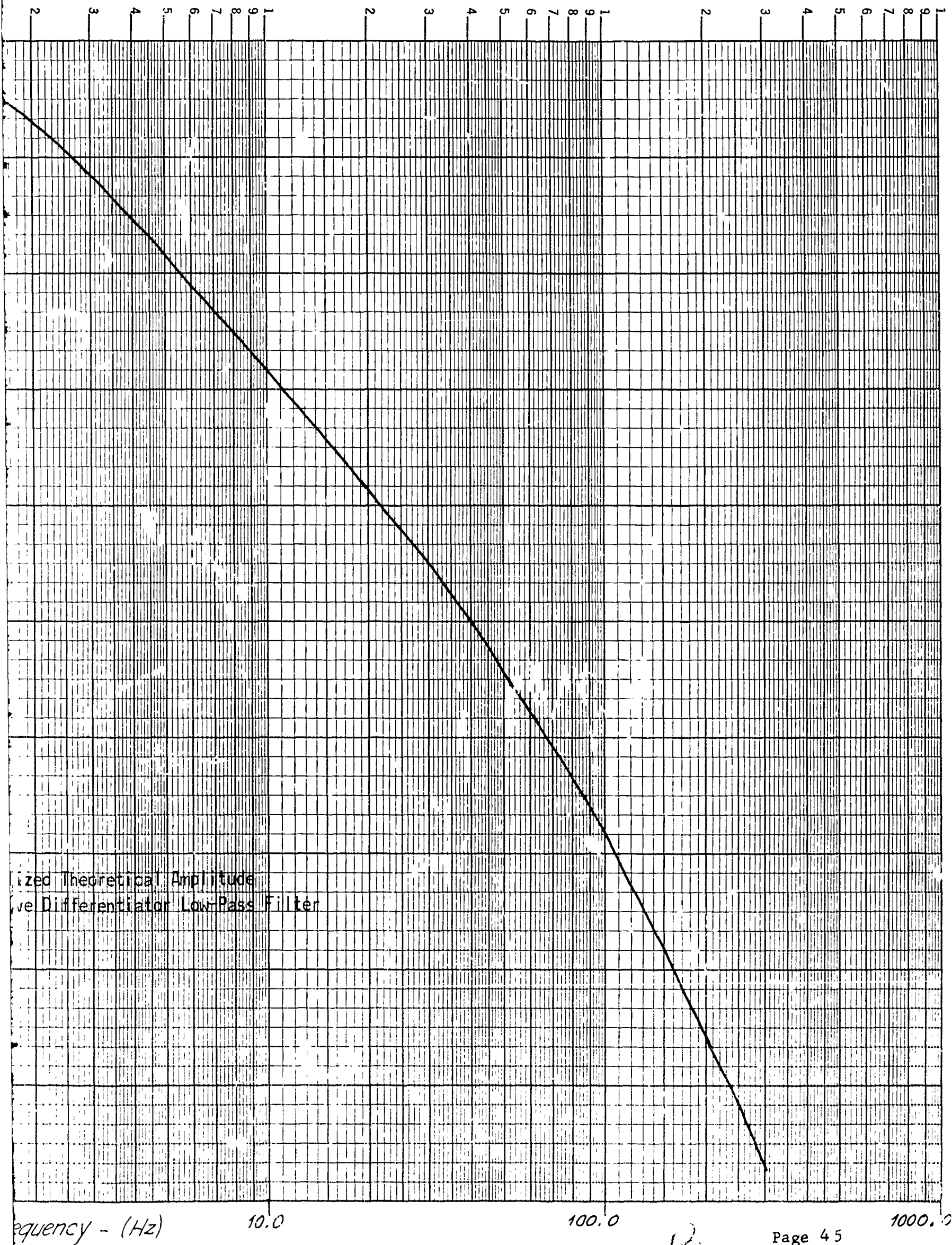


FIGURE 12 - MANEUVER CHANNEL ACTIVE DIFFERENTIATOR LOW-PASS FILTER





Normalized Theoretical Amplitude
Differentiator Low-Pass Filter

Frequency - (Hz)

10.0

100.0

1000.0

B

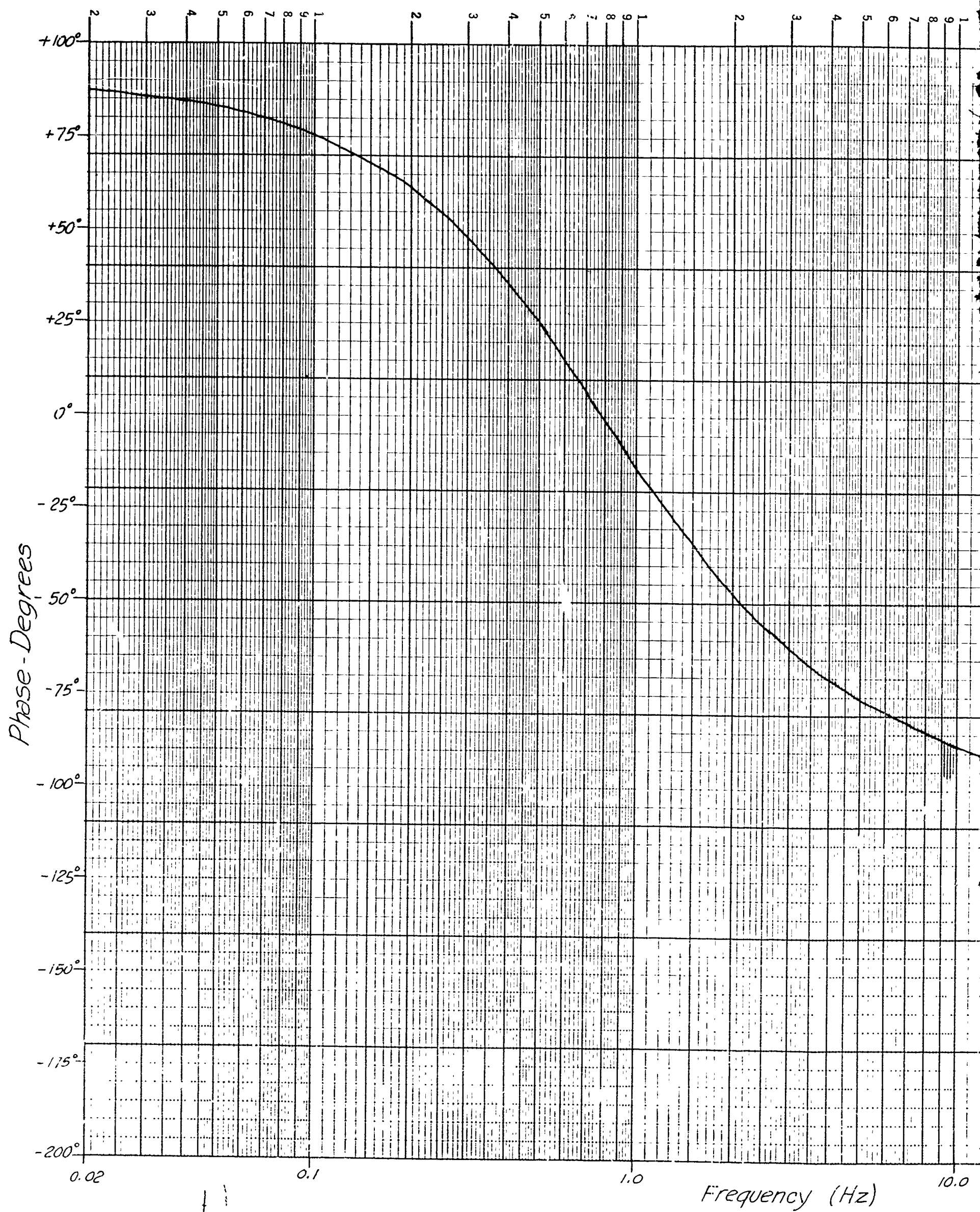
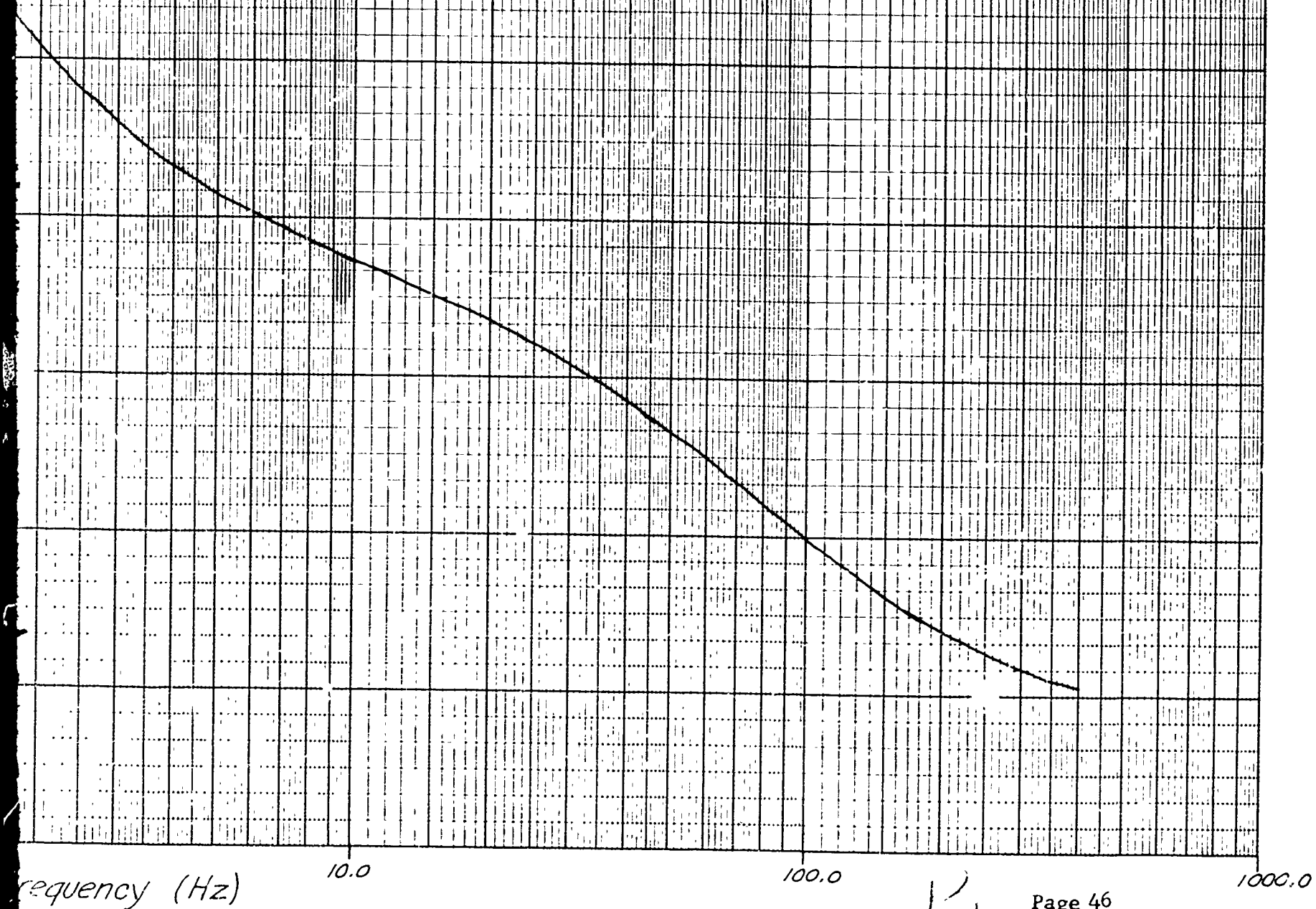


FIGURE 14 - Graphical Representation of Theoretical
Phase Response versus Frequency for
Active Differentiator Low-Pass Filter
(Equation 2.47)



SPECIAL TEST EQUIPMENT

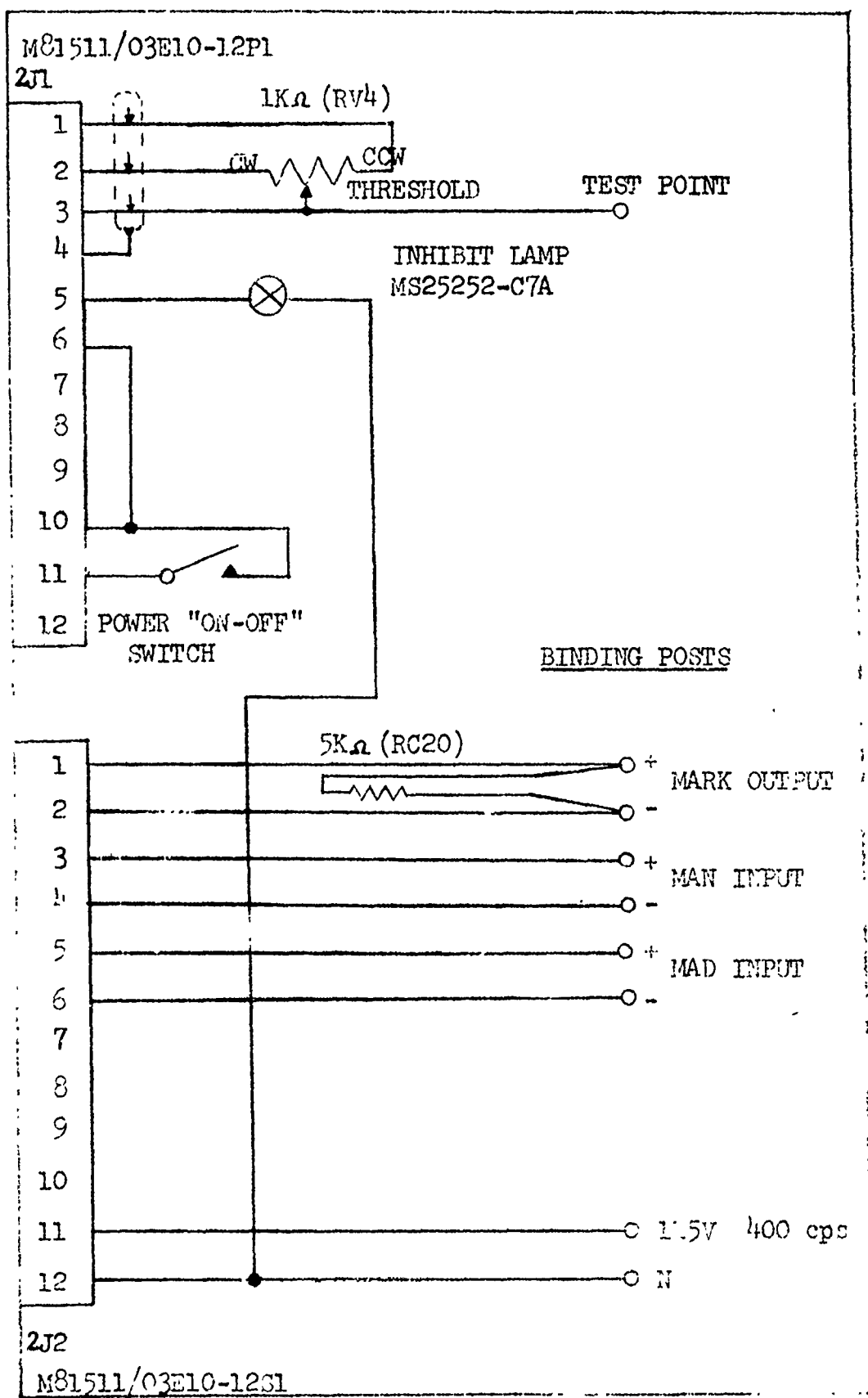
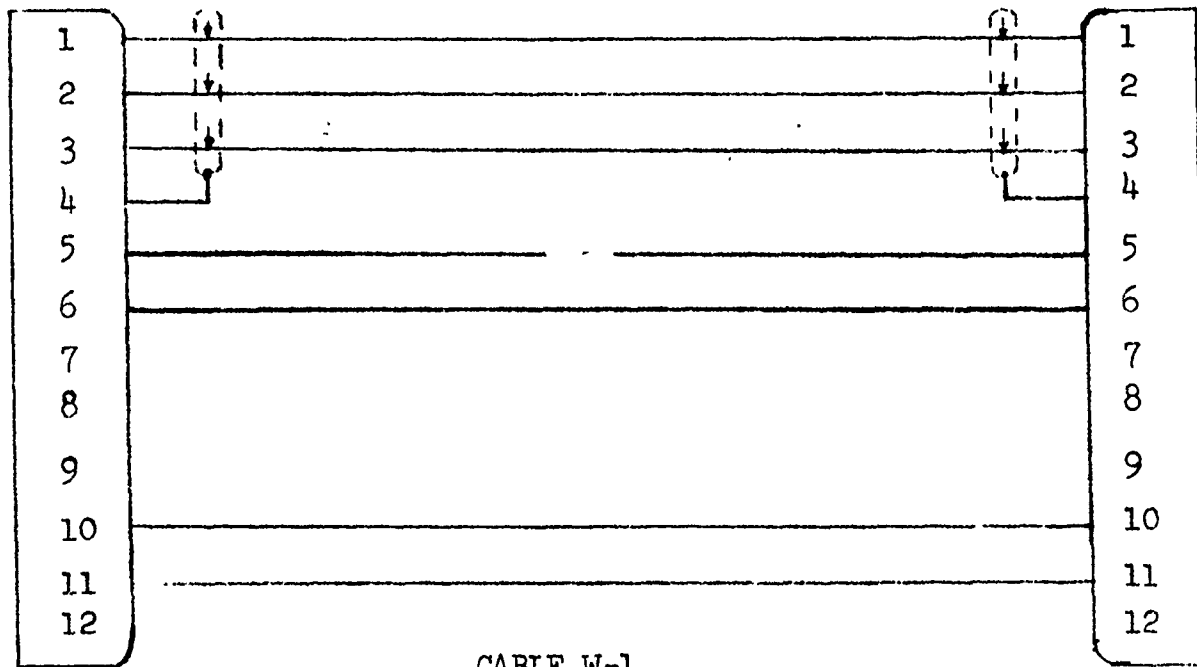


FIGURE 15 - TEST PANEL

SPECIAL TEST EQUIPMENT

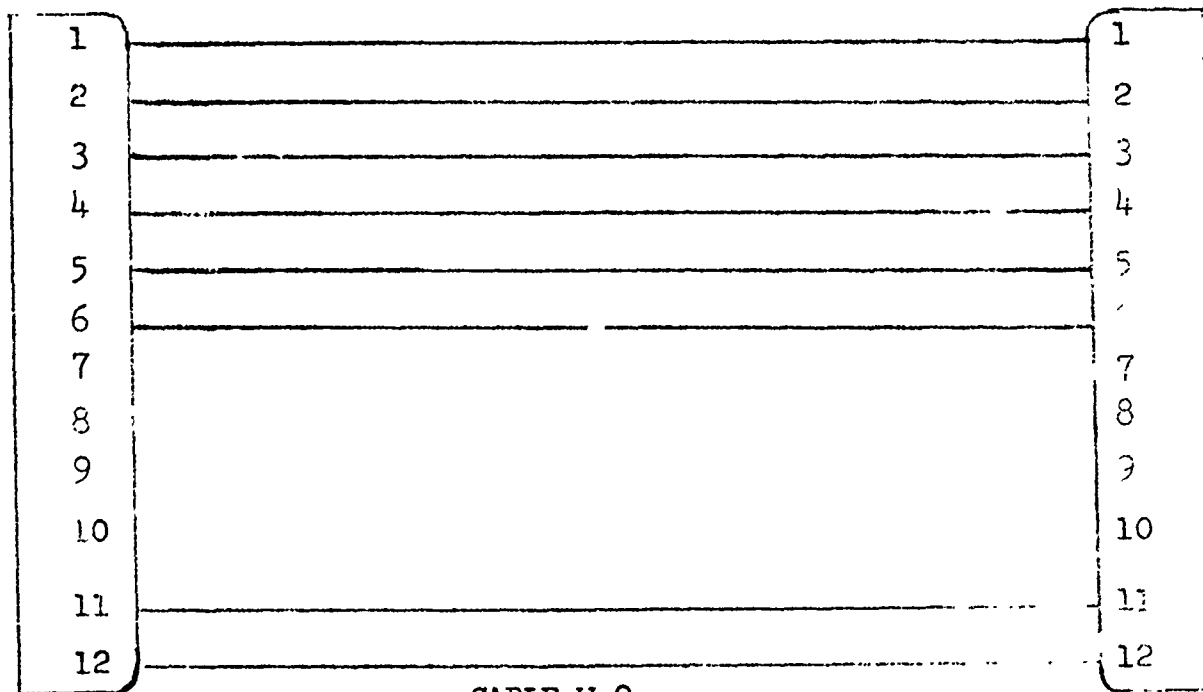
M81511/06E10-12P2
1P1

M81511/06E10-12S1
2P1



M81511/06E10-12S1
1P2

M81511/06E10-12P1
2P2



BOTH CABLES: LENGTH 12 FEET
WIRE GAUGE 22

FIGURE 16 - TEST CABLES

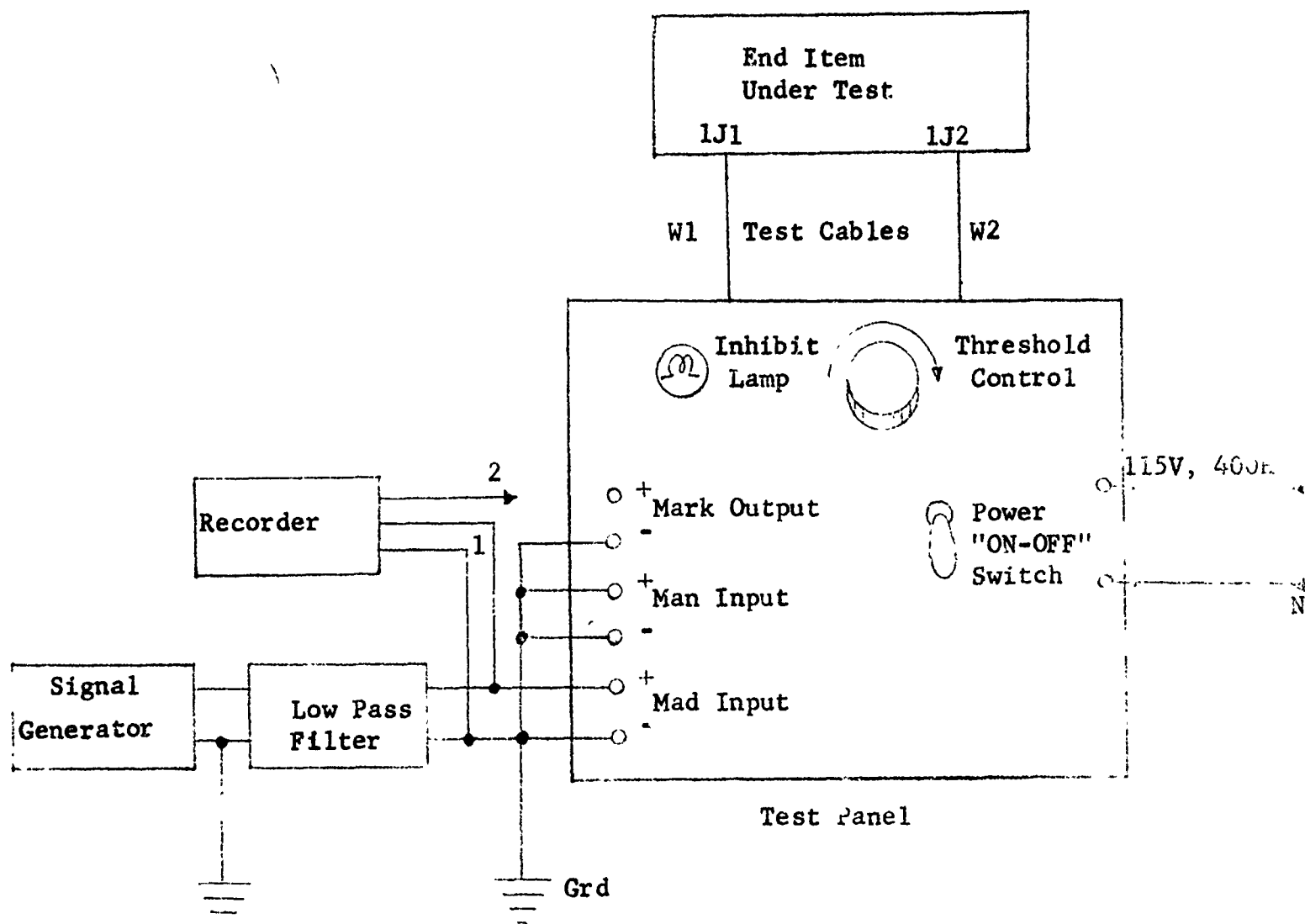


FIGURE 17 - TEST SET-UP FOR RECOGNITION CHANNEL VERIFICATION

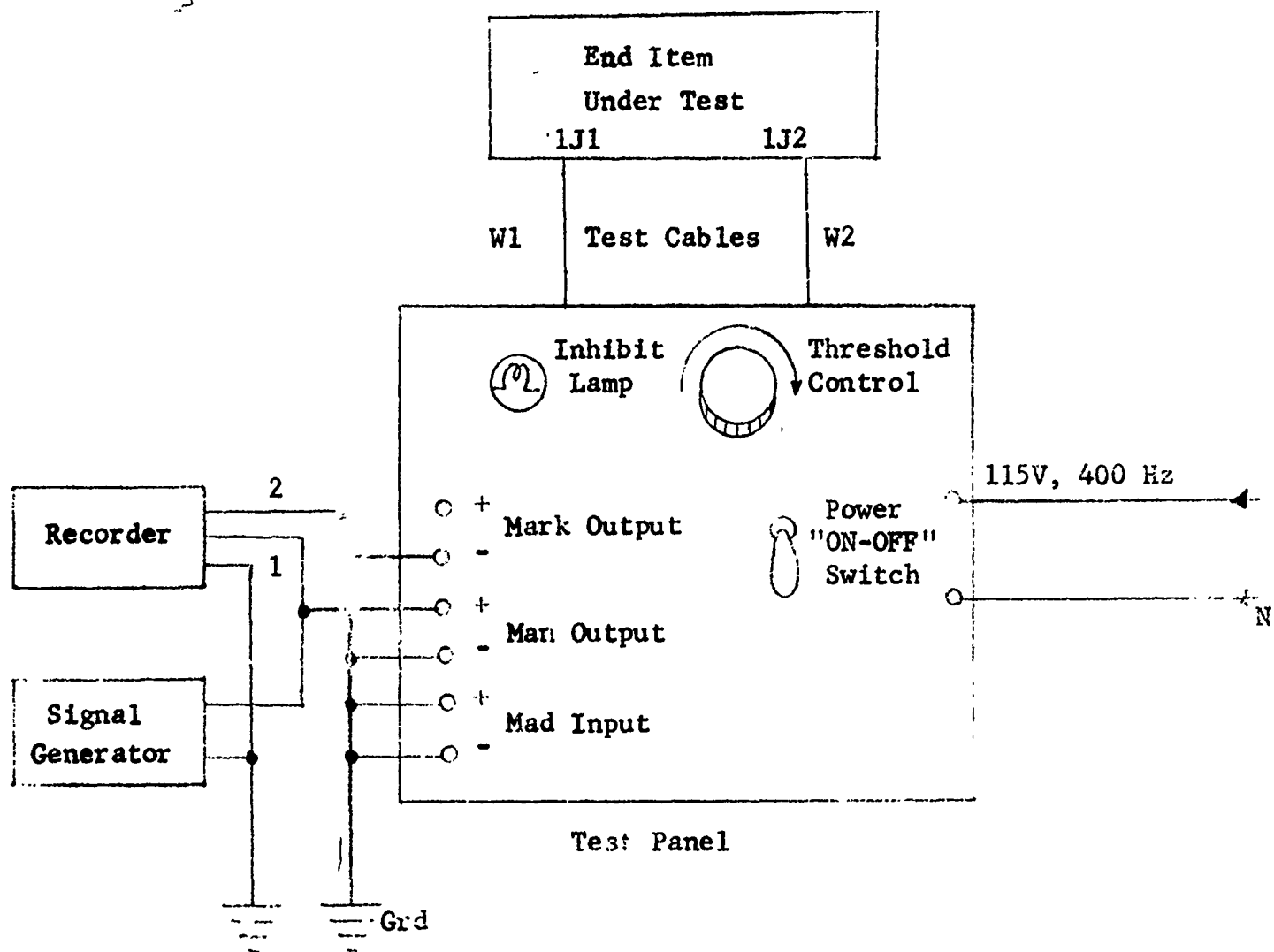
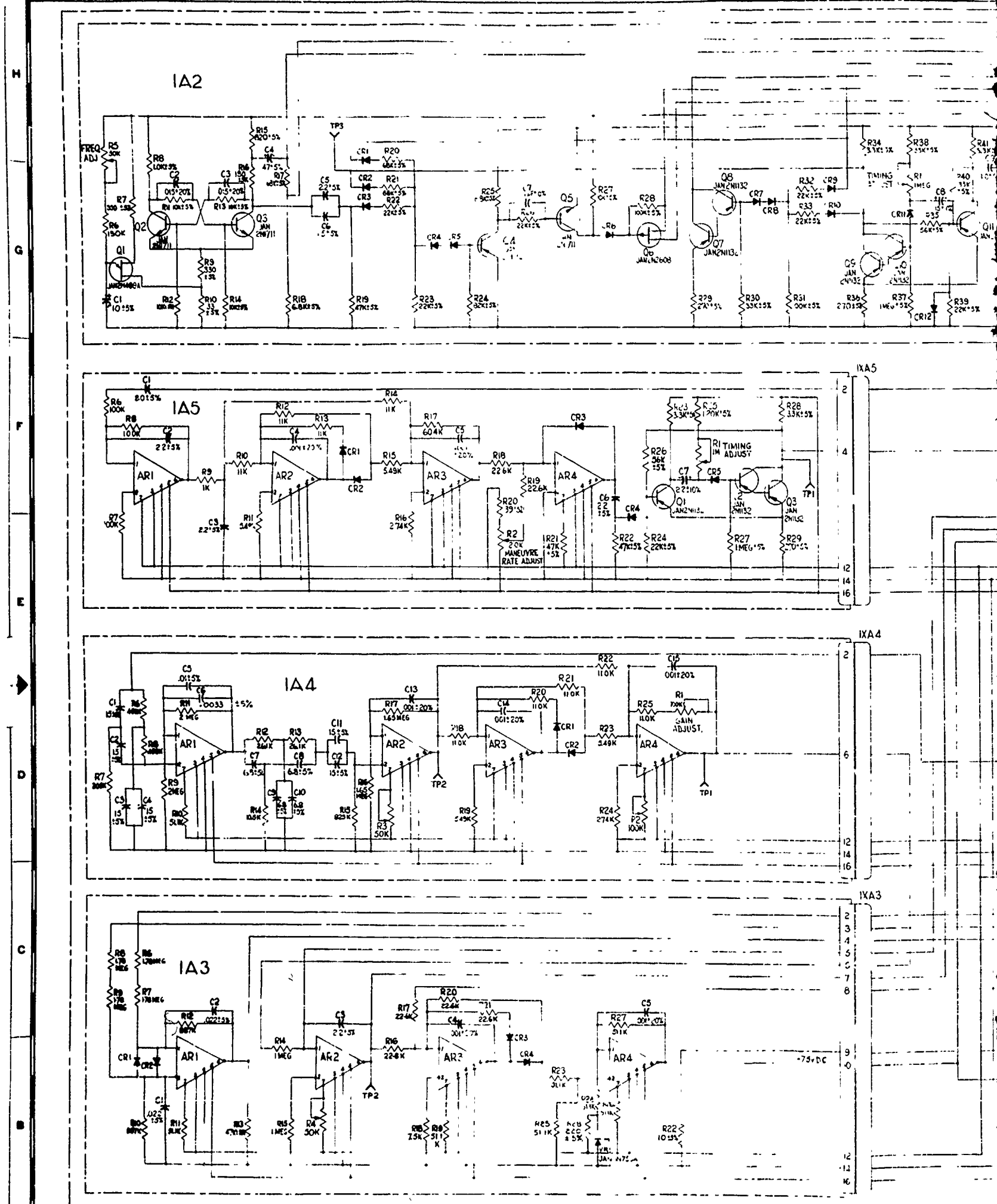


FIGURE 18 - TEST SET-UP FOR MANEUVER CHANNEL VERIFICATION



NOTES: 1. UNLESS OTHERWISE SPECIFIED, ALL RESISTORS ARE 1% TOLERANCE, CAPACITORS ARE 5% TOLERANCE.
 2. UNLESS OTHERWISE SPECIFIED, ALL CAPACITORS ARE 5% TOLERANCE.
 3. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN FOR COMPLETE DESIGNATION PREFIX WITH APPLICABLE SUBASSEMBLY NUMBER. EXAMPLE: IA2C1, IA2C2, ETC.
 4. DESIGNATIONS R1, R5 ARE 1% TOLERANCE. VARIABLE RESISTORS ON ALL SUBASSEMBLIES.
 5. INTERPRET DRAWING IN ACCORDANCE WITH THE STANDARDS PRESCRIBED BY MIL-STD-883C.
 6. ALL AMPLIFIER CONNECTIONS FROM PIN NO. 4 TO GND.

A

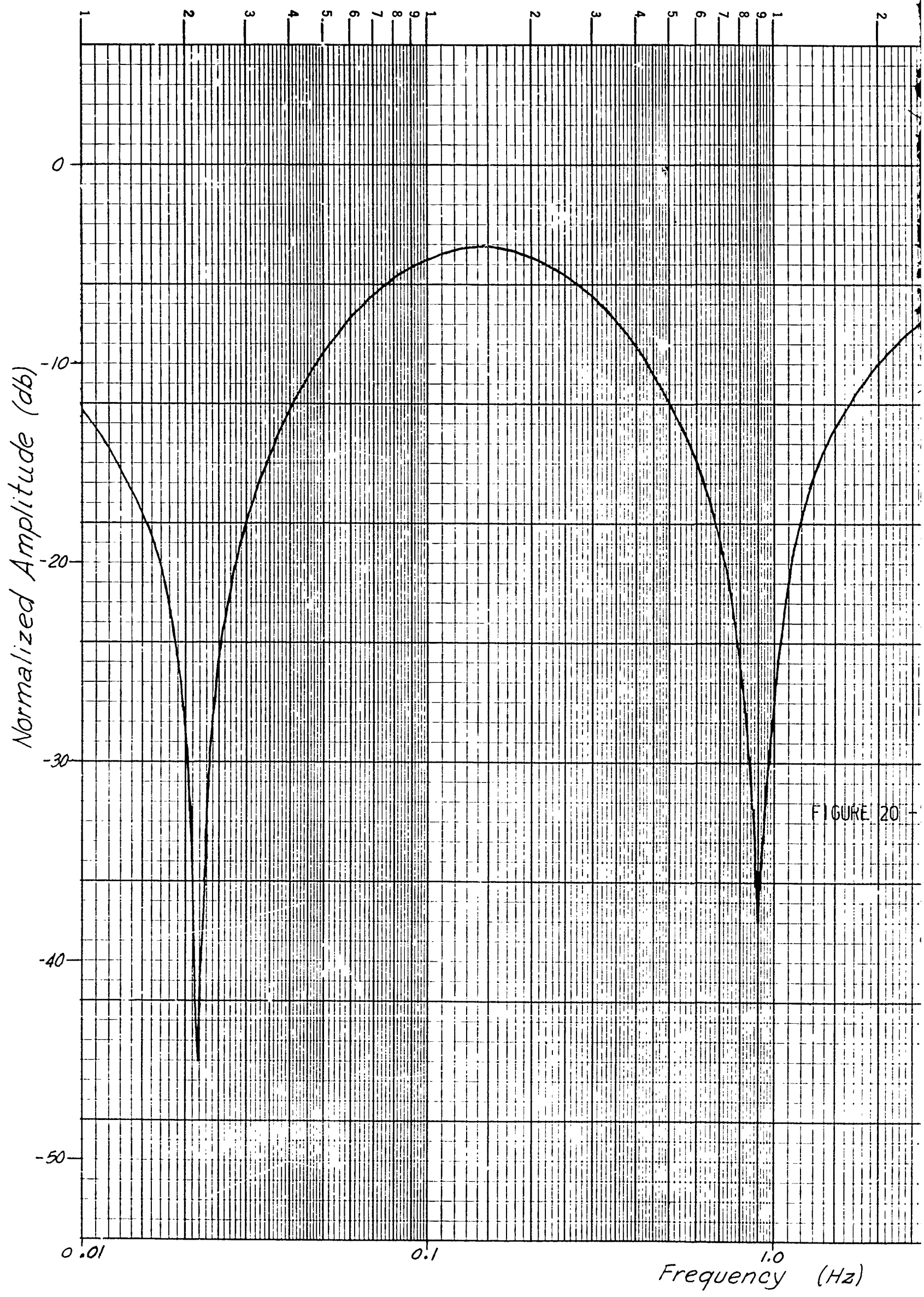


FIGURE 20

U

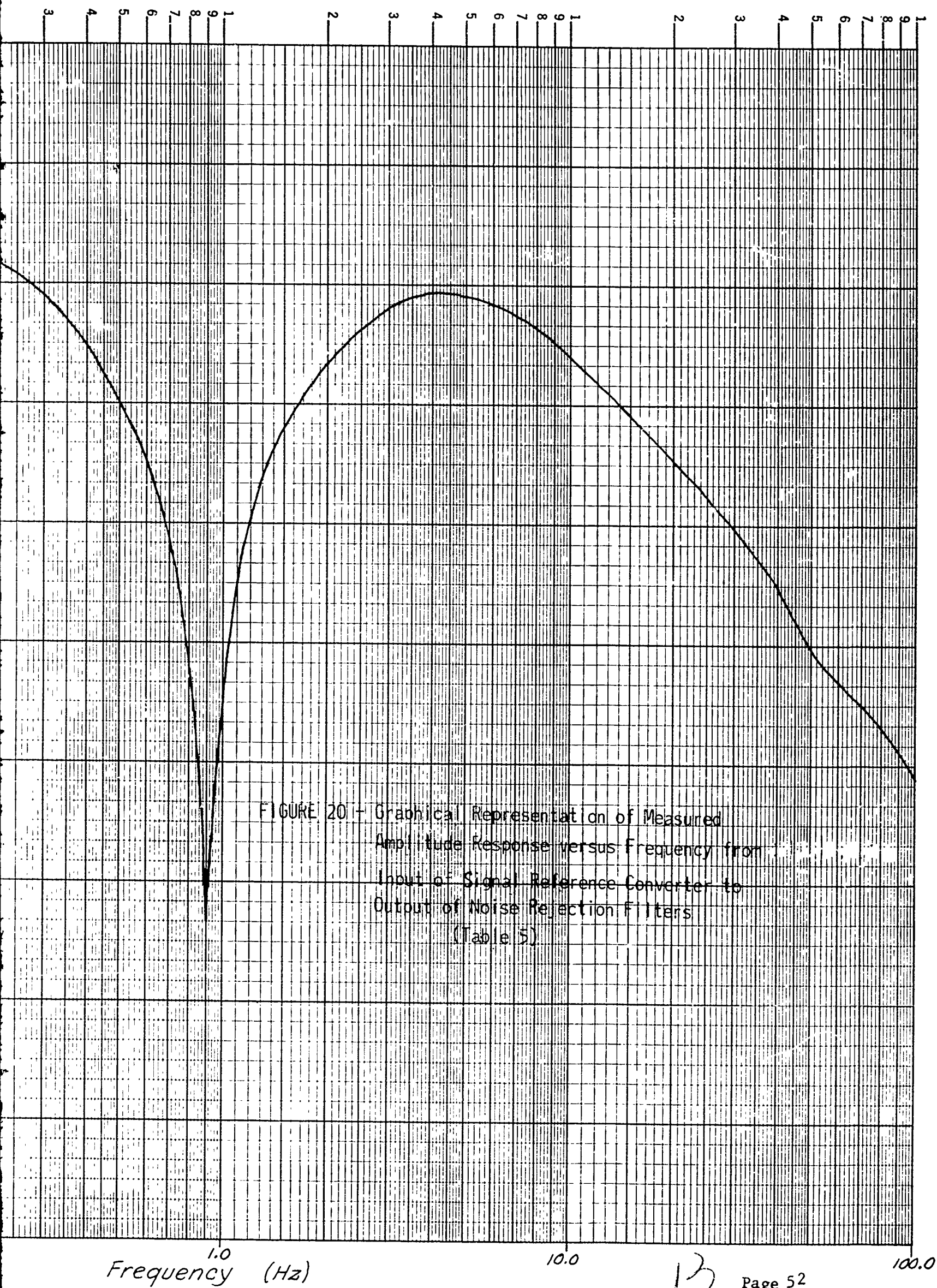


FIGURE 20 - Graphical Representation of Measured Amplitude Response versus Frequency from Input of Signal Reference Converter to Output of Noise Rejection Filters (Table 5)

13

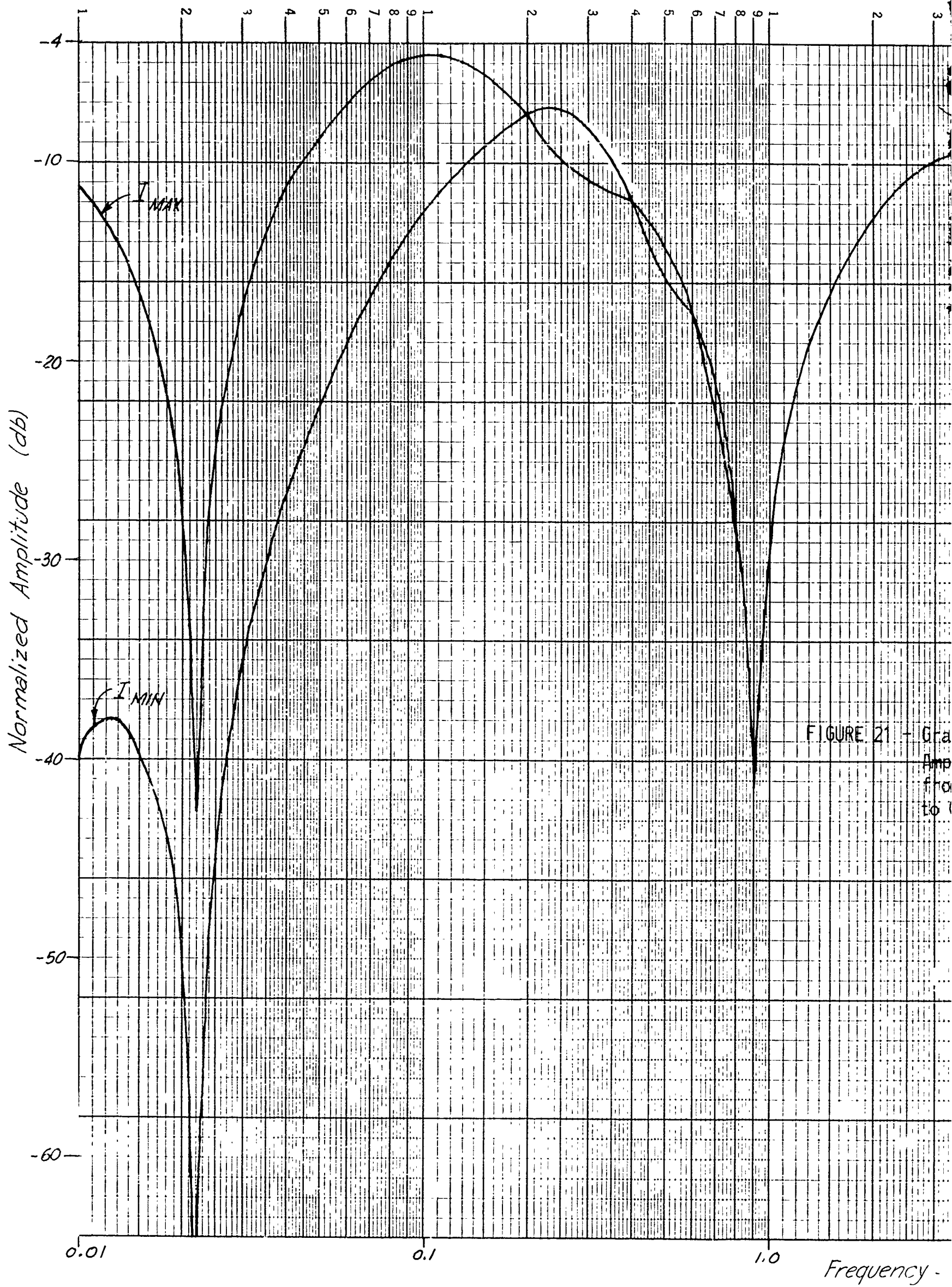


FIGURE 21 - Gra
Am
fro
to 7

H

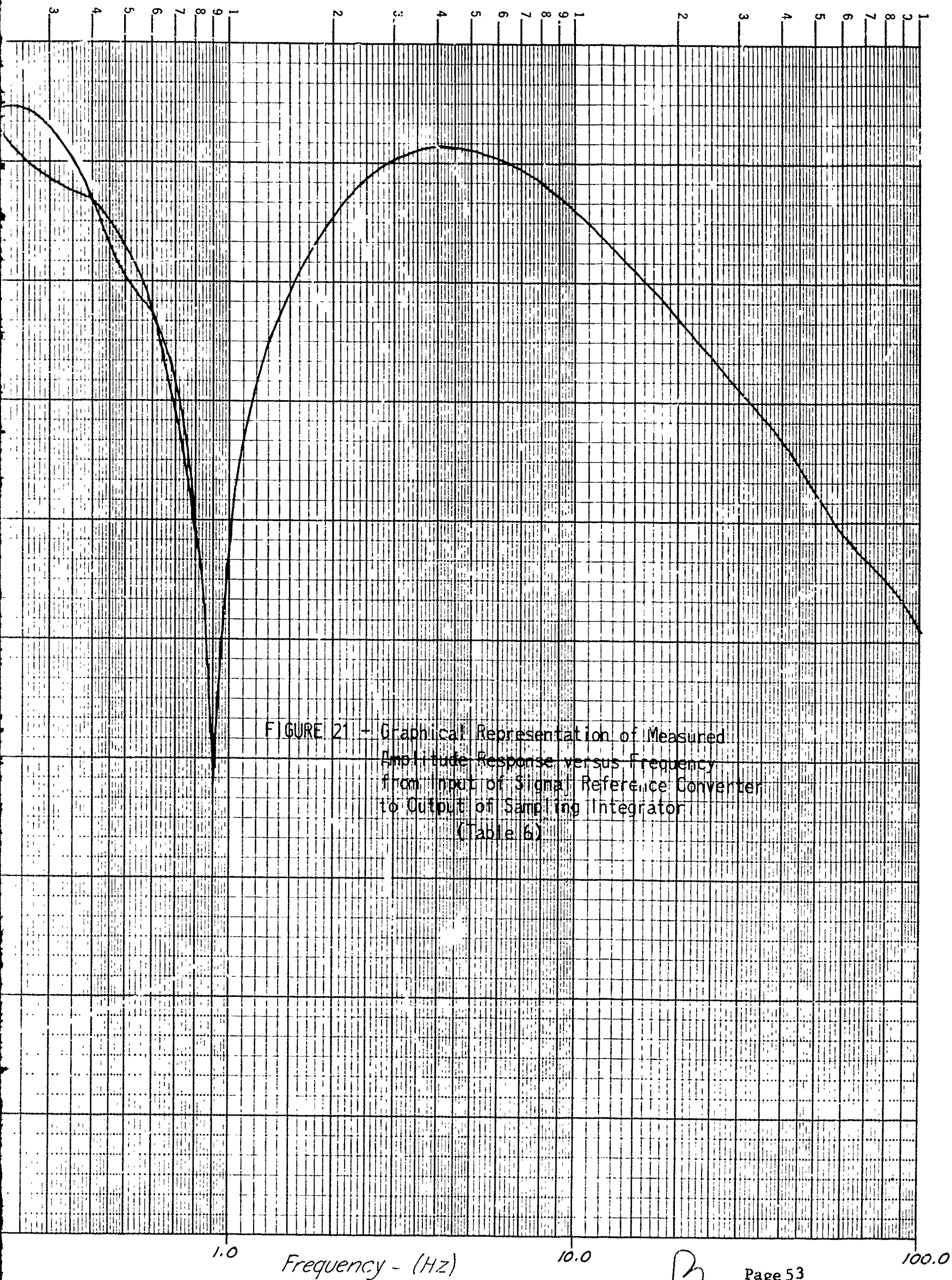


FIGURE 21 - Graphical Representation of Measured Amplitude Response versus Frequency from Input of Signal Reference Converter to Output of Sampling Integrator (Table 6)

B

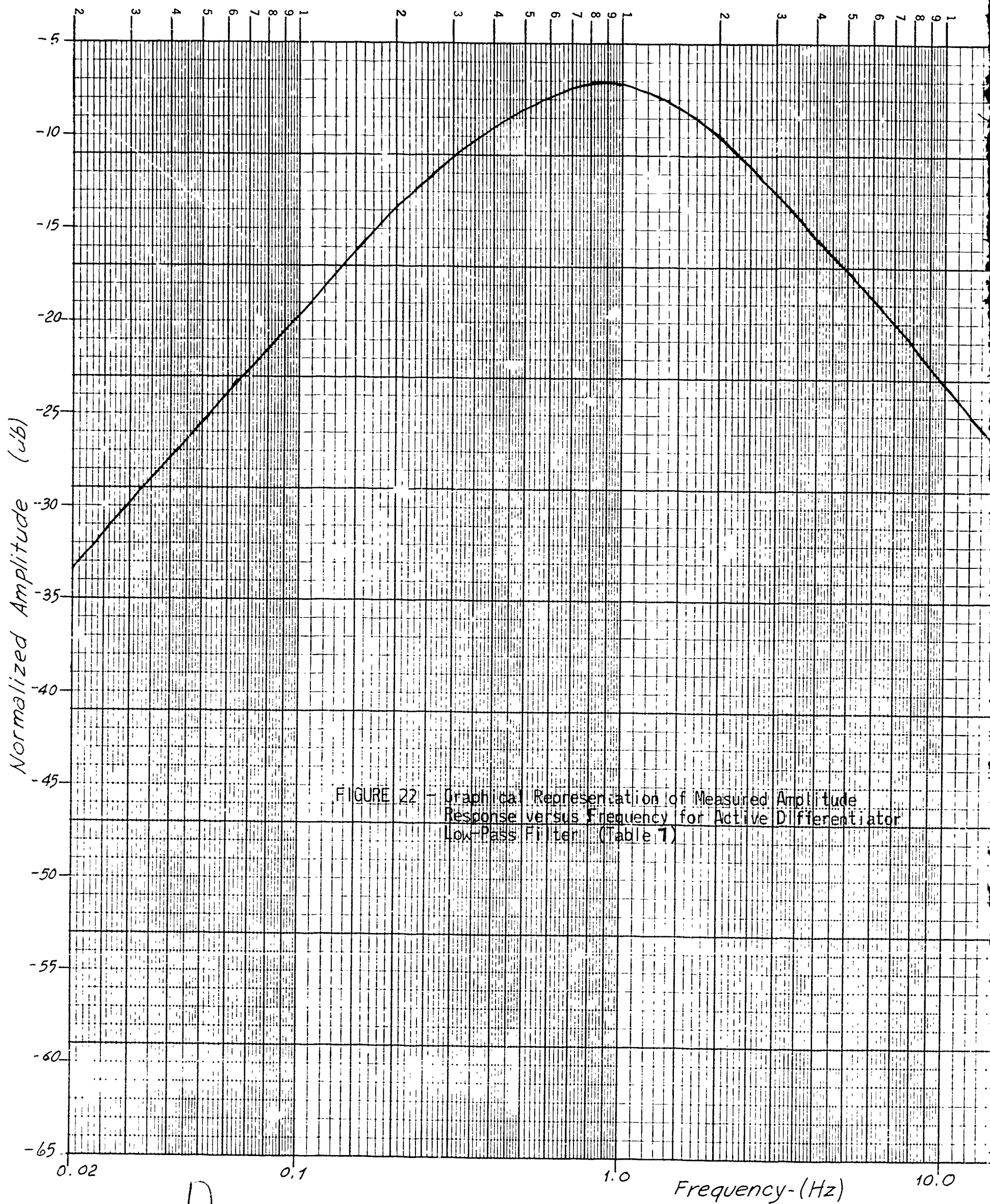
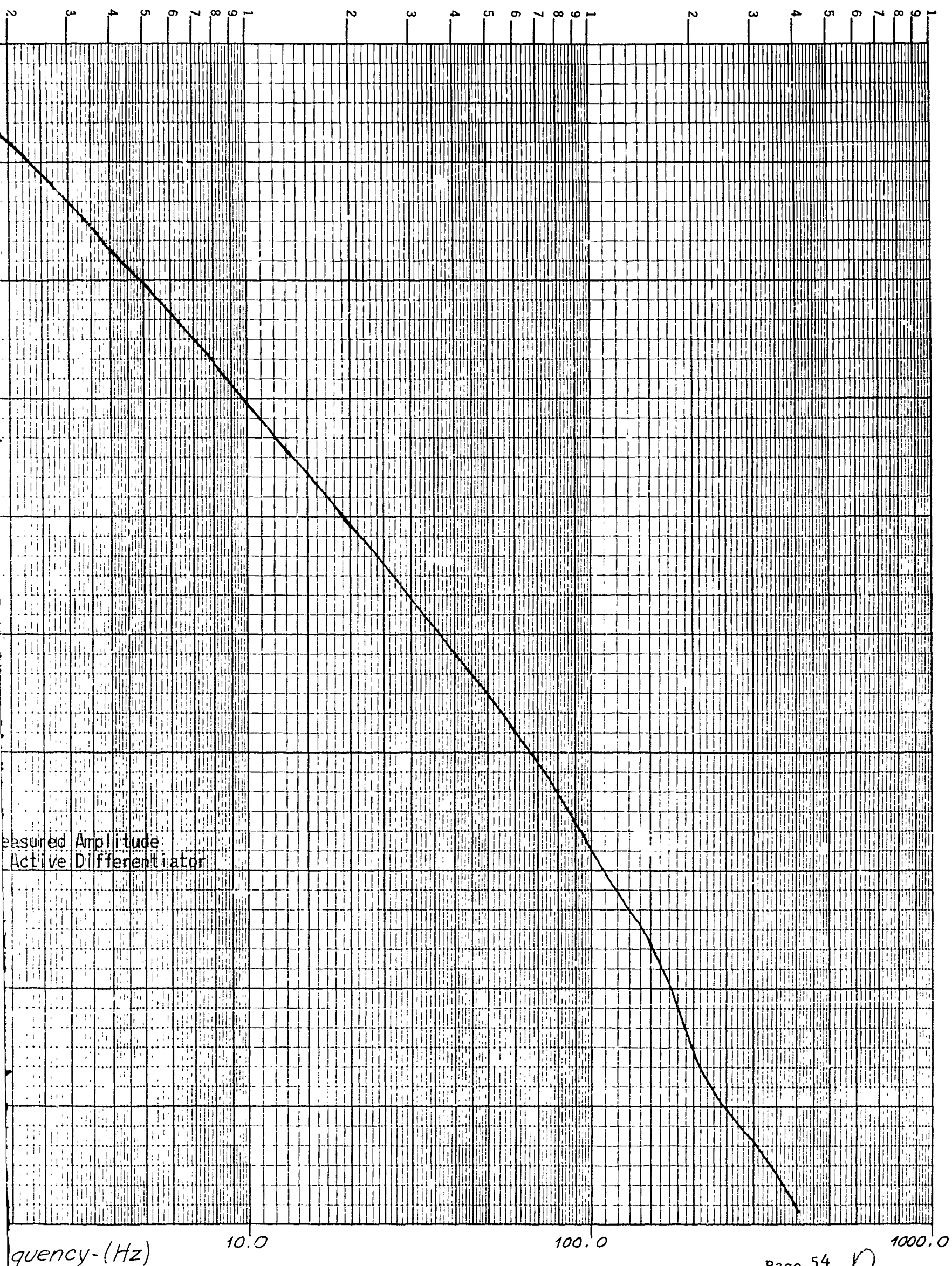


FIGURE 22 - Graphical Representation of Measured Amplitude Response versus Frequency for Active Differentiator Low-Pass Filter (Table 7)

A



Measured Amplitude
Active Differentiator

8. SUMMARY

a. Development of End Item

(1) Electronic Circuitry - At the beginning of the contract a thorough investigation was undertaken in order to determine the most feasible, reliable and economical circuits that could be used within the end item while conforming to the specification requirements of MIL-D-81465(AS). Once the circuits were determined, transfer functions were derived and a complete theoretical analysis performed. Each circuit was then breadboarded separately and verified for performance and drift over the temperature range of - 55° to + 72°C. Having obtained satisfactory operation from each individual circuit, operational tests on the complete end item were then performed.

(2) Mechanical Assembly - While the breadboard version of the end item was being verified in the laboratory, the mechanical configuration and packaging was being designed. Attention was primarily directed towards its overall physical dimensions, weight, maintainability and environmental requirements as specified in MIL-D-81465(AS).

b. Description of "End Item" Magnetic Variation Indicator ID-1559/ASA-64

(1) General - The function of the Magnetic Variation Indicator ID-1559/ASA-64 is to increase the probability in the recognition of submarine type signals in the presence of geologic and equipment background noise as detected by the Magnetic Anomaly Detector (MAD) system. It also provides rejection of detected aircraft maneuver generated noises by time correlation with the maneuvers of the aircraft. Its output consists of one or more voltage pulses whose amplitude is proportional to the strength of the detected signal. These pulses can be displayed on strip chart recorders and/or serve as input to integrated ASW system computers or other such storage and warning devices.

The Magnetic Variation Indicator ID-1559/ASA-64 was developed to operate in all types of aircraft designated for anti-submarine warfare (ASW) equipped with MAD equipment.

9. APPENDICES

a. Test Results

- (1) Environmental Laboratory Section of RCA Victor Company Ltd:
"Report of Test on Detecting Group, Submarine Anomaly AN/ASA-64." RCA Victor Company Ltd., 1001 Lenoir Street, Montreal 30, Quebec, Canada, November 28th, 1967. Total number of pages 31, Report No. 90545.2, File No. 57.3.1.33 (Unclassified).
- (2) Environmental Laboratory Section of RCA Victor Company Ltd:
"Report of Test on Detecting Group, Submarine Anomaly AN/ASA-64." RCA Victor Company Ltd., 1001 Lenoir Street, Montreal 30, Quebec, Canada, November 28th, 1967. Total number of pages 68, Report No. 90545.3, File No. 57.3.1.33 (Unclassified).
- (3) Environmental Laboratory Section of RCA Victor Company Ltd:
"Report of Test on Detecting Group, Submarine Anomaly AN/ASA-64." RCA Victor Company Ltd., 1001 Lenoir Street, Montreal 30, Quebec, Canada. January 15th, 1968. Total number of pages 181, Report No. 90545, File No. 57.3.1.33 (Unclassified).
- (4) Quality Assurance Section of CAE Industries Ltd: "Reliability Assurance Test Report on Detecting Group Submarine Anomaly AN/ASA-64." CAE Industries Ltd., Electronics Division, P.O. Box 6166, Montreal 3, Canada, August 2, 1968. Total number of pages 68, Report No. 2750-Q1 (Unclassified).

b. References

- (1) Research and Development Section of CAE Industries Ltd:
"Top Mechanical Drawing of Magnetic Variation Indicator ID-1559/ASA-64, Dwg. 35181-51101." CAE Industries Ltd., Electronics Division, P.O. Box 6166, Montreal 3, Canada, (Unclassified).
- (2) Research and Development Section of CAE Industries Ltd:
"Top Mechanical Drawing of Test Bench Harness Dwg. 35181-51682." CAE Industries Ltd., Electronics Division, P.O. Box 6166, Montreal 3, Canada (Unclassified).
- (3) R.P. Sallen and E. L. Key: "A Practical Method of Designing RC Active Filters." IRE Trans. on Circuit Theory, Vol. CT-2, No. 1, pp 74-85, March, 1955, (Unclassified).
- (4) Application Engineering Section of Burr-Brown Research Corporation: "Handbook of Operational Amplifier Active RC Networks." Burr-Brown Research Corporation, International Airport Industrial Park, Tucson, Arizona, 1966 (Unclassified).

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11. SUPPLEMENTARY NOTES Throughout this report the Magnetic Variation Indicator is referenced as "the end item"		12. SPONSORING MILITARY ACTIVITY Naval Air Systems Command, Department of the Navy, Washington, D.C.
13. ABSTRACT This report summarizes the engineering design, development and testing of the Magnetic Variation Indicator ID-1559/ASA-64 which forms part of the Detecting Group, Submarine Anomaly (SAD) AN/ASA-64*. The approach adopted consists of: 1) A complete breakdown and concise description of each circuit used within the end item. 2. The derivations of formulae pertaining to unique circuits within the end item including their theoretical evaluations, and 3. Actual test results obtained from bench testing a production version of the end item. A comparison of actual and theoretical results shows that the end item meets the operational requirements of MIL-D-81465(AS). Finally referenced within the report are Test Results demonstrating that the end item meets the Quality Assurance Provisions of MIL-D-81465(AS).(U). (see continuation sheet) Page 59		

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14. KEY WORDS	LINK A		LINK B		LINK C	
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*The Detecting Group, Submarine Anomaly (SAD) AN/ASA-64 to MIL-D-81465(AS) dated 15 April 1967, consists of the following items:

<u>Item</u>	<u>Title</u>	<u>Type of Designation</u>
1	Magnetic Variation Indicator	ID-1559/ASA-64
2	Control-Indicator	C-7639/ASA-64

Under contract N-00019-67-C-0282, CAE Industries Ltd., has manufactured Item 1 only. Item 2 is not being manufactured as a separate entity but its controls and indicators form part of the Selector Control Panel C-7693/ASA-71.(U)