PA89
Vibration Monitoring Amplifier

Validyne ENGINEERING CORPORATION

MODEL PA89

VIBRATION MONITORING AMPLIFIER

1.0 GENERAL

1.1 Description

The PA89 is a complete vibration monitoring amplifier plug-in module to the Validyne MC1 Multi-Channel Transducer System. Piezoelectric accelerometers are connected directly through a front panel coaxial connector to an internal impedance converter, or from an external converter through the circuit board connector.

A connector on the rear panel of the MC1 case provides a constant current source and input for operation with an external impedance converter. A switch on the front panel selects either internal or external impedance converter operation. This switch also has a center position which disconnects both inputs so that a test point jack on the front panel may be used as a calibration signal input. During normal operation the test point may be used for monitoring the signal which is going into the amplifier after the impedance converter.

Two outputs are provided. One provides ±10V peak, at 100ma, capable of sustaining a direct short indefinitely without damage to the amplifier, and a second, attenuated to ±1V peak. The attenuation factor may be changed to suit a particular situation.

A function switch allows for the proper selection of non-integrating and integrating amplifiers such that the output is proportional to Acceleration (g's), Velocity (in/sec) or Displacement (inches). Then, with seven selectable gain settings and ten-turn continuous sensitivity adjustment the output can be adjusted to read-out acceleration, velocity or displacement in equivalent engineering units or other convenient units.

Internally selectable low pass filters provide for the modification of the 20 KHz frequency response to 60, 200, 600 and 2000 Hz.

All power requirements of the PA89 are supplied by the MC1 Module Case.

2.0 SPECIFICATIONS

2.1 Electrical

Input:

Internal Converter;	Single ended, output from piezo-electric accelerometer; shunt resistance of 510 megohm shunted by 6pf capacitance
External Converter:	Single ended, output from external impedance converter; provides 4ma constant current for converter
Gain:	Switch selectable steps of 10, 25, 50, 100, 250, 500, and 1000 times referred to Output A
Minimum Input for F.S. Output:	±10mV peak
Maximum Input:	±10 V peak without damage
Gain Vernier:	Continuously variable, 0 to 100% at each gain setting

Output:

Output A:	±10 volts peak @ 100ma
Output B:	±1 volt peak @ 10ma short circuited. (Output B voltage can be changed by changing internal resistors.)

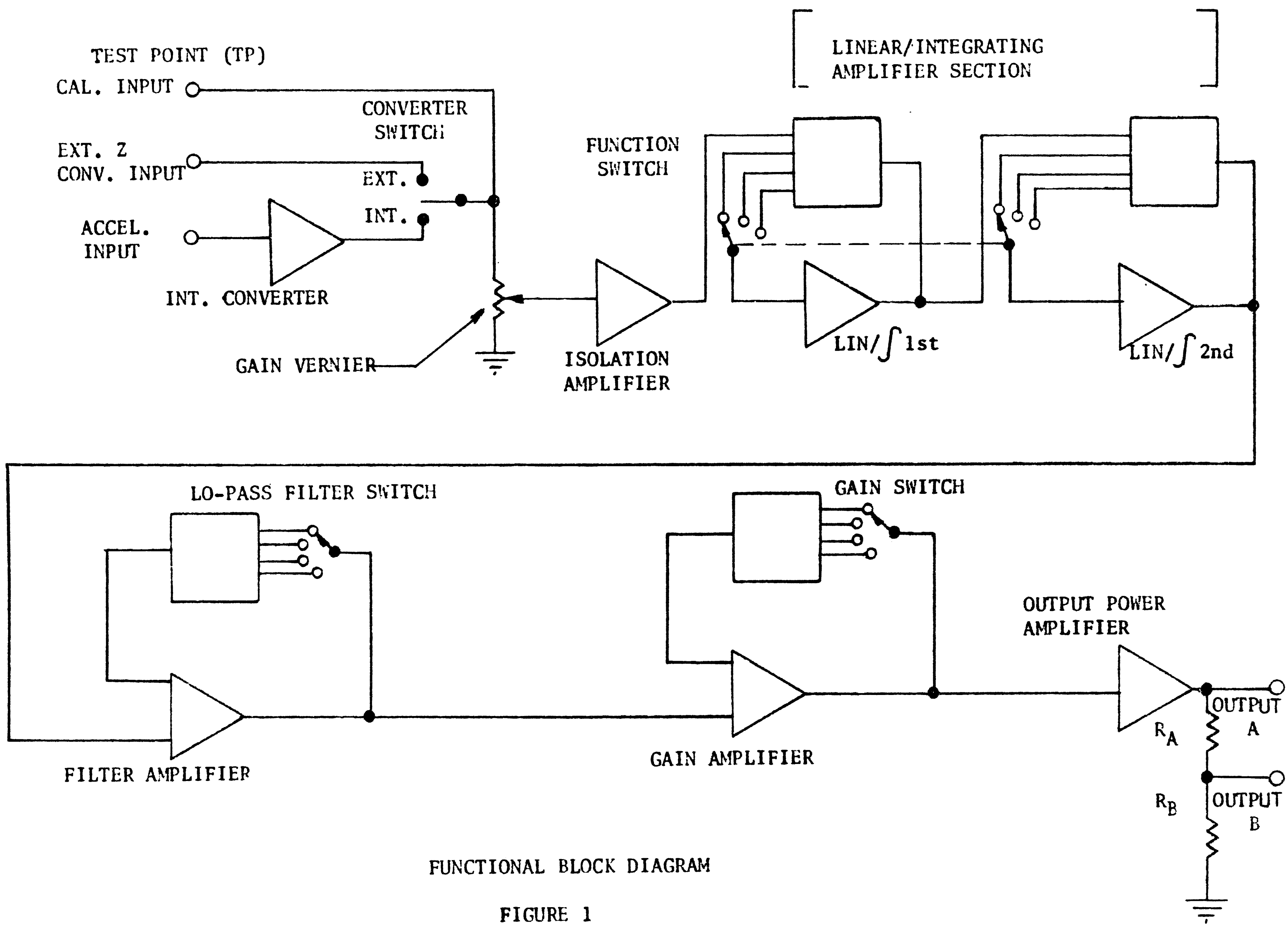
Output Impedance:

Output A:	Less than 1 ohm
Output B:	Approximately 100 ohms
Frequency Response:	Flat ±5% 2Hz to 20 KHz wide band, with selectable low pass filter of 60, 200, 600 and 2000 Hz
Harmonic Distortion:	1% maximum
Residual Noise:	0.5% F.S. maximum 0-20 KHz
Operating Temperature:	0-160^{o}F
Power Requirements:	±15V DC supplied from MC1 Module Case

2.0 SPECIFICATIONS (Continued)

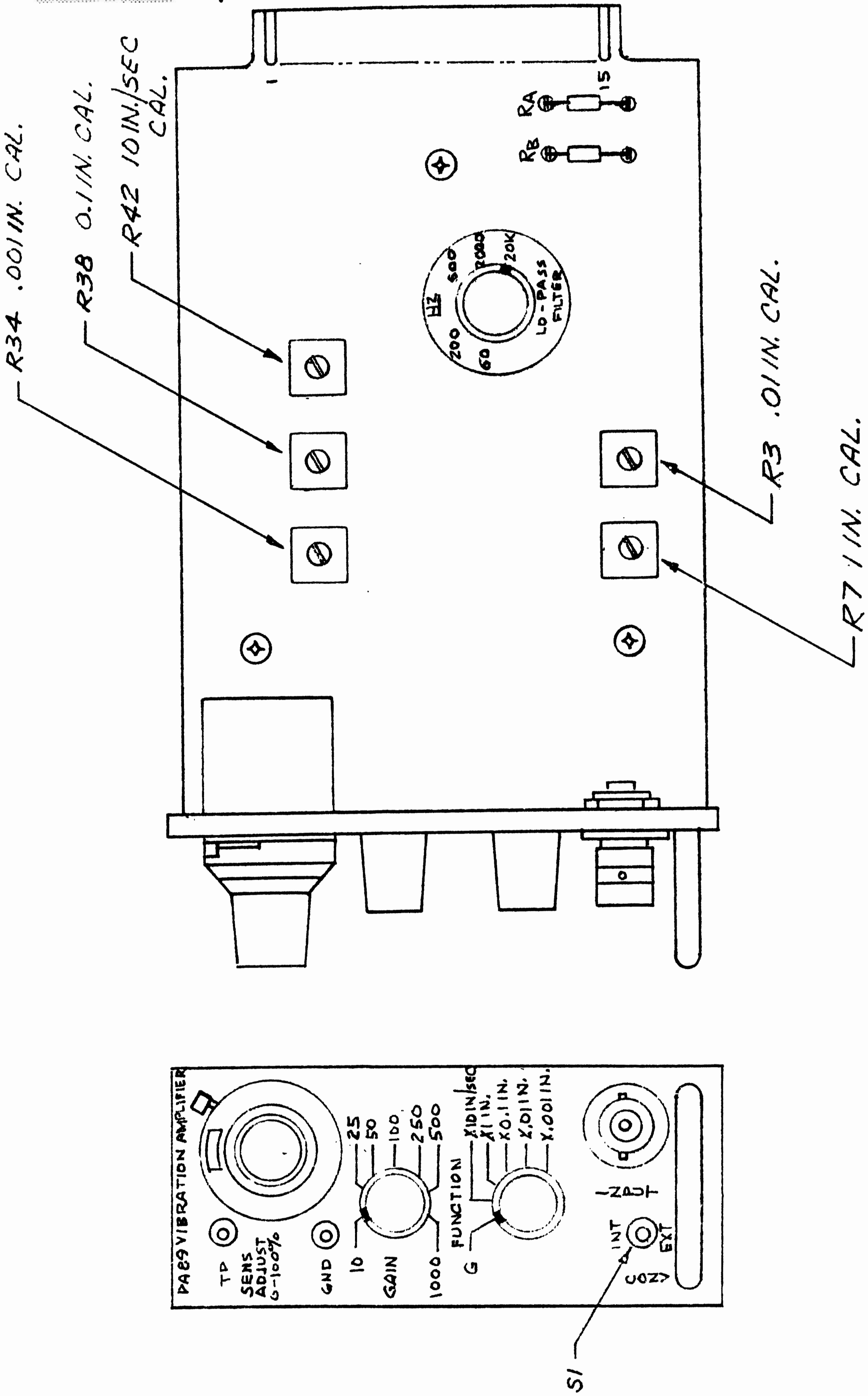
Controls:

Gain:	7-position rotary switch
Gain Vernier:	10-turn, calibrated dial
Function:	6-position rotary switch
Converter:	Internal/External impedance
Selection:	3-position toggle switch
Filter Selection:	5-position rotary switch (behind panel)
Input Connections:	Accelerometer input on front panel BNC-F5 External Converter input on MC1 Case back panel, WK-4-32S
Output Connections:	Two XLR-3-32S on MC1 case back panel
Length:	7 inches
Width:	1.6 inches
Height:	3.7 inches
Weight:	Less than 12 ounces



FUNCTIONAL BLOCK DIAGRAM

FIGURE 1



PA89 COMPONENT LAYOUT

FIG. 2

3.0 OPERATION

3.1 Installation

The PA89 is plugged into any available position in the MC1 Module Case regardless of whether power is on or other cannels are in operation. There will be no effect on adjacent channels.

3.2 Input/Output Connections

3.2.1 Accelerometers are connected directly to the PA89 through the isolated BNC connector on the front panel marked "INPUT".

3.2.2 When an external impedance converter is used, the output of the converter is connected to the PA89 through the WK-4-32S receptacle marked "TRANSDUCER INPUT" on the rear panel of the MC1 module case with the following pin assignments:

Pin 1 - No connection

Pin 2 - PA89 input (external impedance converter power input)

Pin 3 - Circuit Ground

Pin 4 - No connection

A two conductor shielded cable should be used for this connection. The mating connector is a WK-4-21C. This input connection is a 4ma constant current source for the impedance converter.

3.2.3 The "TP" (Test Point) and "GND" pin jacks on the front panel are used for calibration signal input as well as for monitoring the convertor output signals at the input to the isolation amplifier stage of the PA89.

3.2.4 The two outputs are obtained from two separate XLR-3-32S receptacles marked "OUTPUT A" and "OUTPUT B" on the rear panel of the Module Case.

The pin assignments are the same for both receptacles and are as follows:

Pin 1 - Output

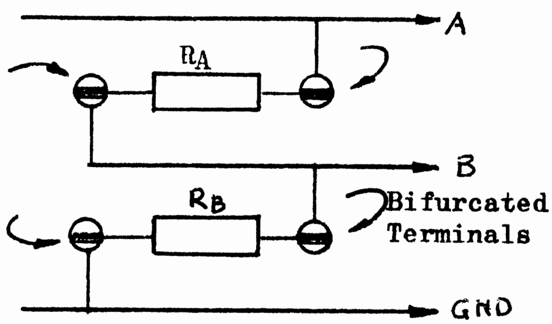
Pin 2 - Circuit Ground

Pin 3 - Chassis Ground

The mating connectors are XLR-3-11C

3.0 OPERATION (Continued)

3.2.5 Output B is set at the factory to be one-tenth of Output A or nominally ±1 volt peak full-scale. This relationship may be changed by changing the two resistors in the bifurcated terminals on the printed circuit board. Referring to Figure 2, these resistors are arranged schematically as follows:



$$\text{Output B} = \frac{R_B}{R_A + R_B} \times 10 \text{ Volts}$$

where $R_A + R_B \geq 1000$ Ohms

3.3 Grounding

The circuit ground is isolated from chassis ground. The shield in the input cable is connected to circuit ground. It may be desirable, in some cases, to connect circuit ground to chassis ground to optimize noise rejection. Chassis ground is available in both output receptacles on Pin 3, and circuit ground on Pin 2. If these two grounds are connected, the connection should be made at the common system ground point.

3.4 Input Selection

Putting the CONVERTER switch in the "Int." position selects the accelerometer input on the front panel, while the "Ext." position selects the external impedance converter input on the back panel. Putting the switch in the center position disconnects both inputs so that a calibration signal may be applied to the amplifier through the test point jacks.

3.5 Gain Adjustment

3.5.1 The GAIN switch on the front panel provides seven maximum gain settings of 10, 25, 50, 100, 250, 500, and 1000 times, which represent gains, referred to Output A, of 20db, 28db, 34db, 40db, 48db, 54db, and 60db.

3.5.2 The SENS. ADJUST control on the front panel allows for continuous gain adjustment of 0 to 100% throughout the range of each GAIN switch setting.

3.0 OPERATION (Continued)

3.6 Function Selection

3.6.1 Placing the FUNCTION switch in the "G" position makes the voltage output of the PA89 proportional to acceleration (g's).

3.6.2 The voltage output will be proportional to velocity with the switch in the "X10 in/sec" position, and bears the relationship of 10 in/sec per g input. (See 4.0, Calibration)

3.6.3 The voltage output is made proportional to displacement with the switch in the "x 1 in.", "x 0.1 in.", "x 0.01 in.", or "x 0.001 in." positions, in which case the relationships to the input are: 1 in. per g, 0.1 in. per g, 0.01 in. per g and 0.001 in. per g.

3.6.4 Figure 3 shows the relation between output and input voltages for various functions and gain switch positions. With the function switch in the acceleration or velocity positions, the gain switch is used to make major gain changes. For displacement output, both the function and gain switches affect the system gain.

3.7 Frequency Response

3.7.1 Figure 4 shows the frequency response curves for constant acceleration input at various filter switch positions. This switch is located internally on the circuit board as shown in Figure 2. For all switch positions, the high-frequency rolloff is -12 db per octave.

3.7.2 Figure 5 shows the PA89 transfer characteristics for operation in the vibrational velocity and displacement modes. The curves are based on a constant voltage (acceleration) input and show how the output decreases inversely with the frequency for the single-integration (velocity) mode, and inversely with the frequency-squared for the double-integration (displacement) mode in accordance with the relations between sinusoidal acceleration, velocity, and displacement. Figure 5 also shows the usable frequency ranges for the velocity and displacement modes.

3.8 Operational Limits

The operational limits of the PA89 are determined by the available gain, frequency response, and output signal-to-noise ratio. In addition, the response characteristics of the accelerometer must be taken into consideration when setting up a vibration measurement system.

Accel. Input	Function Sw. Pos.	Gain(1) Sw.Pos.	PA89 OUTPUT (2) (3)		
			Accel.	Velocity	Displ.(4)
1mv/G	G	1000	1V/G	--	--
	X10 in/sec	1000	--	$\frac{0.1V/IPS/G}{f}$	--
	X 1 in	1000	--	--	$\frac{1V/in/G}{f^2}$
	X0.1,.01,.001	1000	--	--	Above X10,100,1000
10mv/G	G	100	1V/G	--	--
	X10 in/sec	100	--	$\frac{0.1V/IPS/G}{f}$	--
	X 1 in	100	--	--	$\frac{1V/in/G}{f^2}$
	X0.1,.01,.001	100	--	--	Above X10,100,1000
20mv/G	G	50	1V/G	--	--
	X10 in/sec	50	--	$\frac{0.1V/IPS/G}{f}$	--
	X 1 in	50	--	--	$\frac{1V/in/G}{f^2}$
	X0.1,.01,.001	50	--	--	Above X10,100,1000
50mv/G	G	25	1.25V/G	--	--
	X10 in/sec	25	--	$\frac{0.125V/IPS/G}{f}$	--
	X 1 in	25	--	--	$\frac{1.25V/in/G}{f^2}$
	X0.1,.01,.001	25	--	--	Above X10,100,1000
100mv/G	G	10	1V/G	--	--
	X10 in/sec	10		$\frac{0.1V/IPS/G}{f}$	--
	X 1 in	10	--	--	$\frac{1V/in/G}{f^2}$
	X0.1,.01,.001	10	--	--	Above X10,100,1000

(1) Sensitivity adjust at 100%.

(2) All outputs will change directly with Gain Switch Position--e.g., changing gain from 100 to 1000 will increase output by 10X.

(3) Over usable frequency range; see Figures 4 and 5.

(4) Displacement in inches peak-to-peak.

FIGURE 3

OUTPUTS FOR VARIOUS INPUTS & GAIN SWITCH POSITIONS

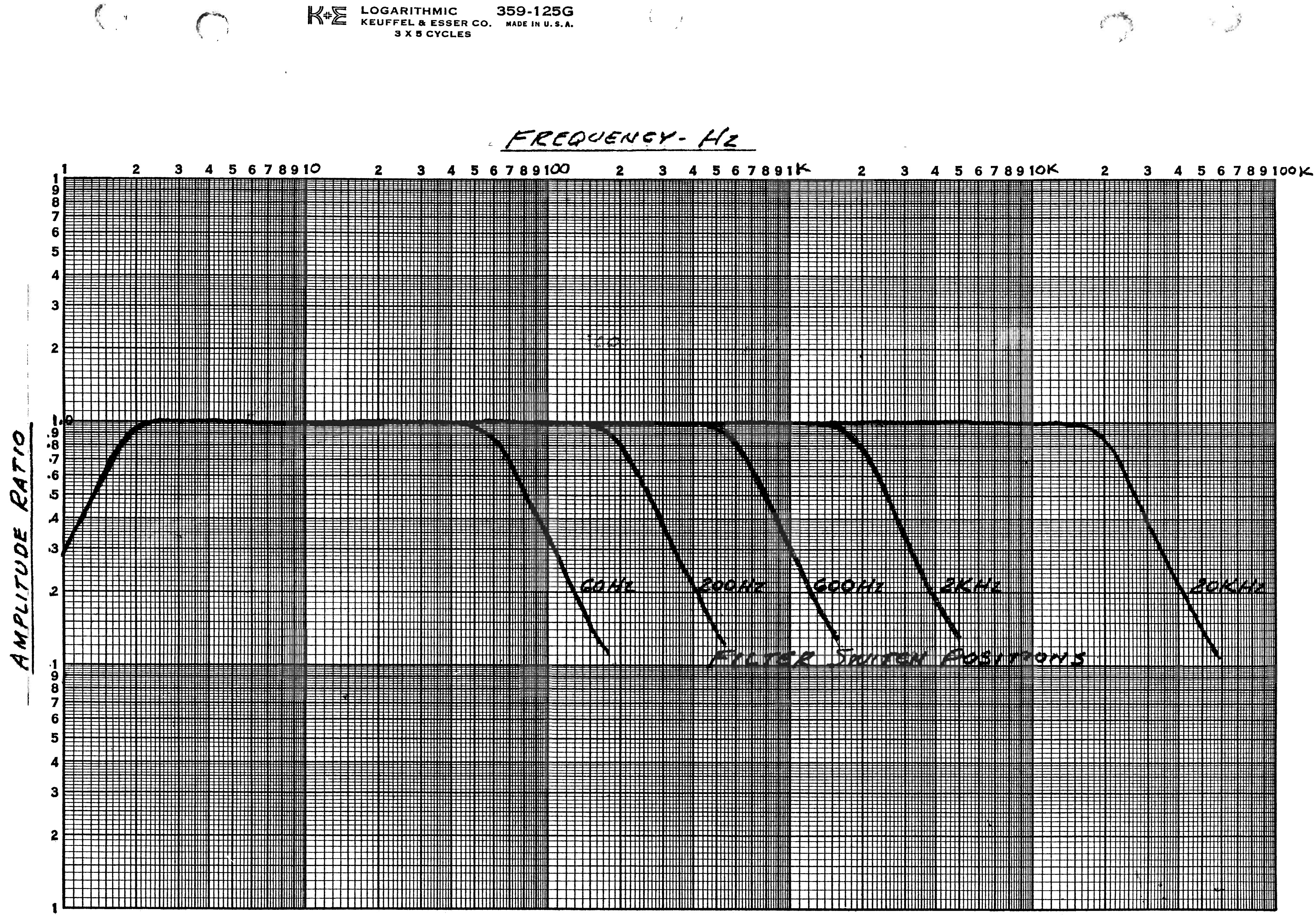


FIGURE 4- FREQUENCY RESPONSE FOR CONSTANT G INPUT

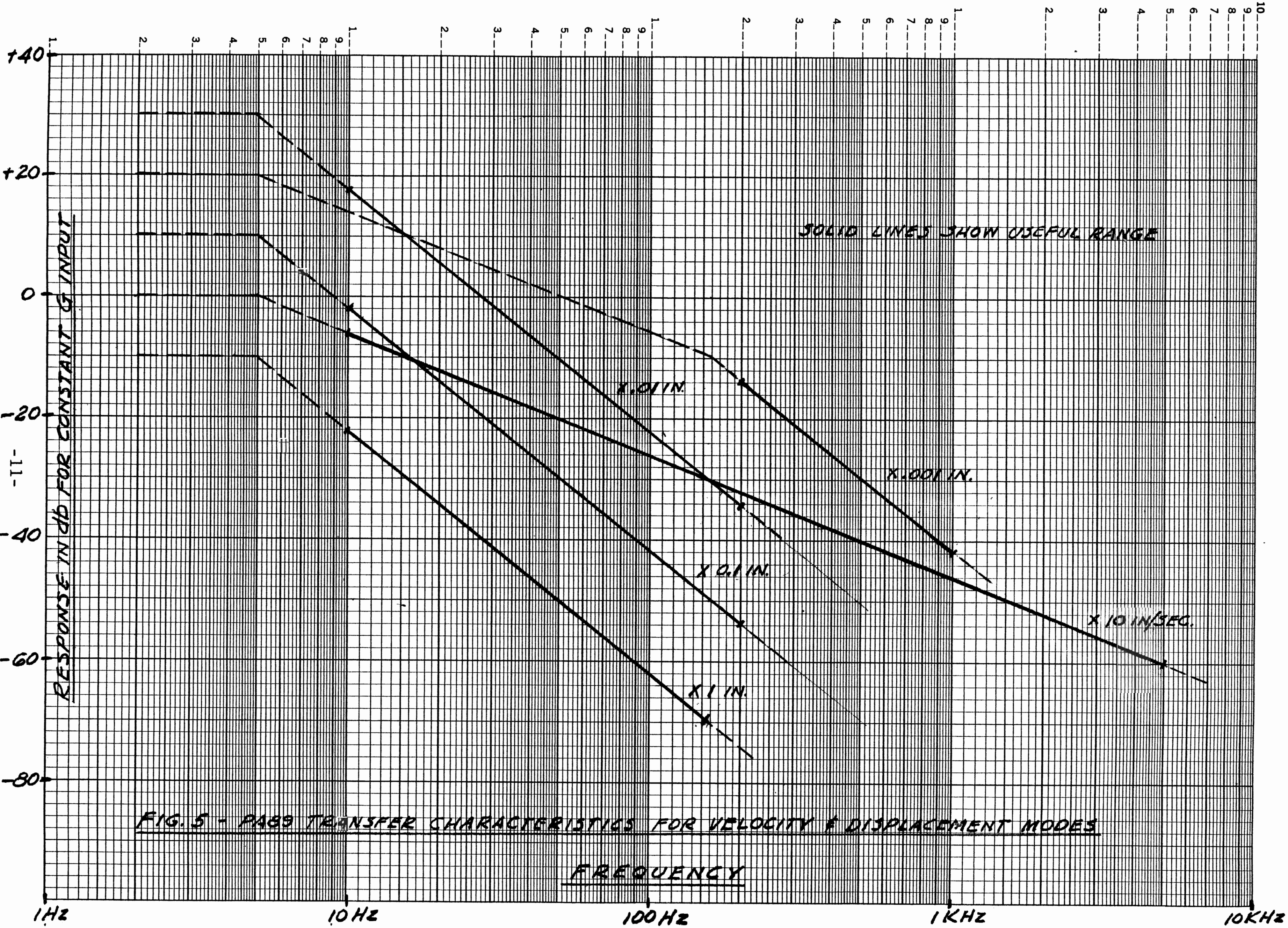


FIG. 5 - PA89 TRANSFER CHARACTERISTICS FOR VELOCITY & DISPLACEMENT MODES

VIBRATION NOMOGRAPH

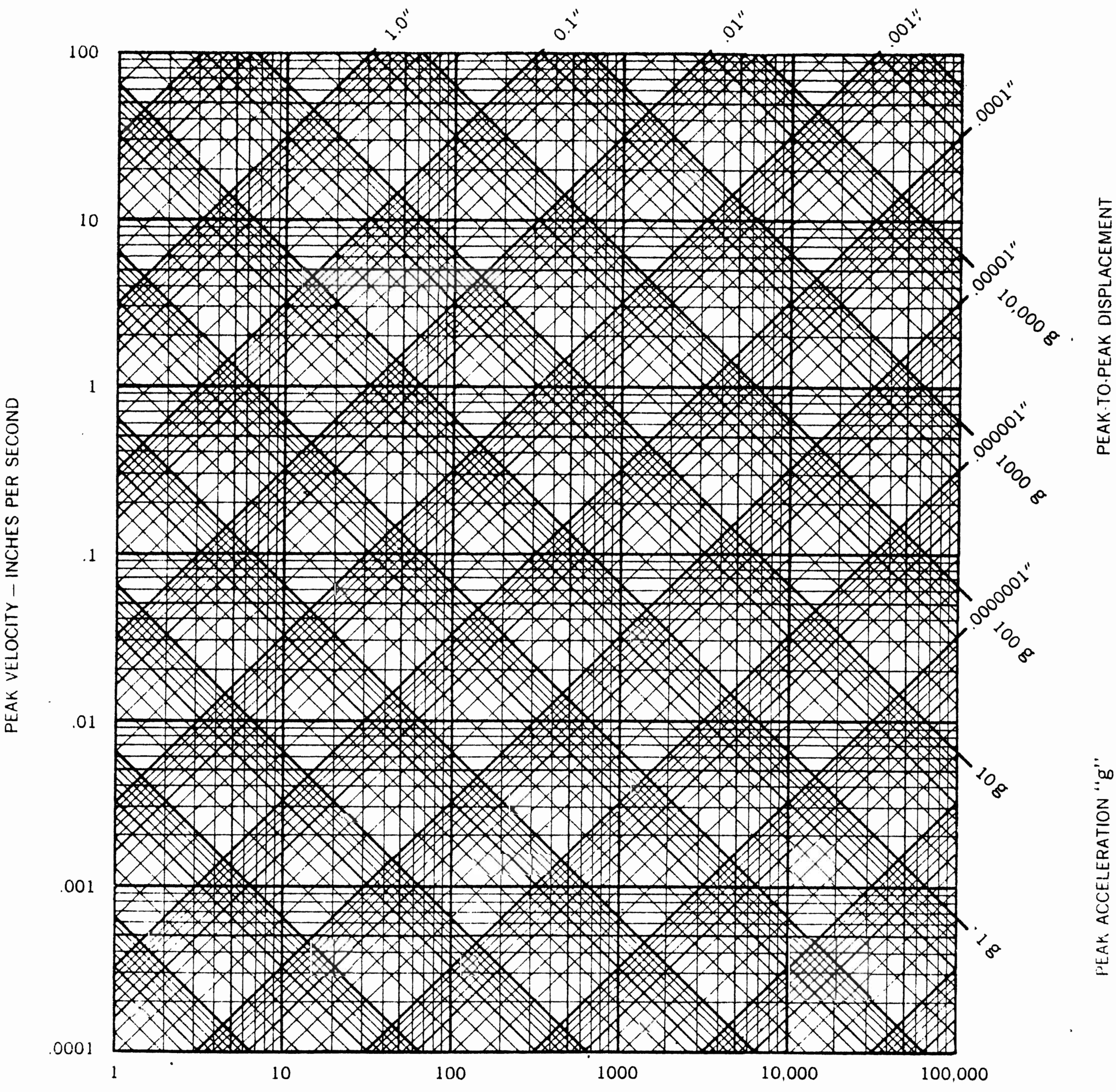


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FIGURE 6

3.8 Operational Limits (Continued)

3.8.1 Piezoelectric accelerometers typically have voltage outputs ranging from 0.5 mv/G for high-G ranges to 100 mv/G for low-G ranges. As shown by Figure 3, the selectable gain ranges have been chosen to make the PA89 compatible with almost all such accelerometers.

3.8.2 Piezoelectric accelerometers normally have a low damping coefficient and generally provide a fairly flat frequency response from 2 Hz to 20% of the resonant frequency which is usually from 20 KHz upward. Selection of the filter frequency, as well as the accelerometer response, must take into consideration the accelerometer resonance frequency and the desired frequency range of interest. For example, a low-range accelerometer with a resonance frequency of 20 KHz calls for a filter pass-band of 2 KHz in order to (a) provide a flat response and (b) eliminate any 20KHz noise resulting from accelerometer ringing at the resonance frequency. In cases where lower frequency measurements are desired in the presence of high-frequency vibrations, lower filter frequency settings may be useful.

3.8.3 For acceleration measurement, the broadband frequency response is flat from 2 Hz to 20KHz, as shown in Figure 4. For velocity and displacement measurement, the usable frequency response is shown in Figure 5. The low end is limited by the integrator characteristics, and, for practical purposes, the high end is limited to the output at -60 db below full-scale acceleration output.

3.8.4 Figure 5 shows that the PA89 charactertistics allow velocity measurement from 10 Hz to 5 KHz, and displacement from 10 Hz to 1 KHz. These ranges encompass the practical ranges of mechanical vibration measurements by the use of piezoelectric accelerometers, as illustrated by the following table:

Frequency	Peak Velocity Per G Peak	Displacement Pk-Pk Per G Peak
10 Hz	6.14 in/sec	0.196 inch pk-pk
100 "	0.614 "	0.002 " "
200 "	0.307 "	0.0005 " "
500 "	0.123 "	0.00008 "
1000 "	0.061 "	0.00002 "
5000 "	0.012 "	--

Figure 6 presents a nomograph which shows the relations between acceleration, velocity, displacement, and frequency for sinusoidal vibration.

4.0 CALIBRATION

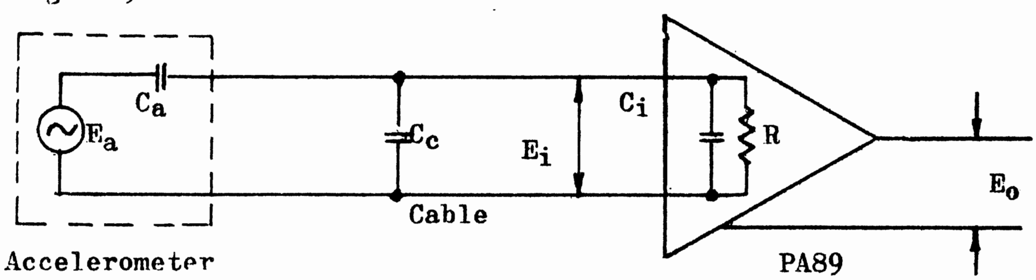
4.1 Accelerometer Input

4.1.1 The most accurate method of calibrating the PA89 for use with a particular piezoelectric accelerometer is to place the accelerometer on a shake-table, connect it to the PA89 through the cable that is to be used in service and drive it at a known acceleration and frequency. The gain adjustments on the front panel may then be set such that the desired output sensitivity, volts per g, is obtained.

4.1.2 Very often this procedure is not practical and it is necessary to calculate the voltage that will be present at the input to the amplifier, using the accelerometer manufacturer's calibration data, and the cable and amplifier input parameters.

This voltage, then, is applied as a calibration signal to the "Test Point" terminal on the front panel, using a laboratory signal generator, to simulate the accelerometer output, allowing the "GAIN" and "SENS ADJUST" controls to be adjusted to produce the desired output sensitivity.

4.1.3 In our calculations, the accelerometer will be considered in a simple equivalent circuit as a voltage generator and internal capacitor. The other circuit parameters which must be considered are capacitance of the cable connecting the accelerometer to the PA89 and the PA89 input capacitance. (Refer to the following figure.)



E_a = accelerometer open circuit voltage

E_i = input voltage to PA89

E_o = system output voltage

a = acceleration (g's)

$S_a = \frac{E_a}{a}$ = accelerometer voltage sensitivity (mv/G)

$S_i = \frac{E_i}{a}$ = calibration voltage sensitivity (mv/G)

$S_o = \frac{E_o}{a}$ = PA89 output sensitivity (mv/G)

C_a = accelerometer capacity (pf)

C_c = cable capacity (pf)

C_i = PA89 input capacity (pf)

A = PA89 gain

4.1.3 (Continued)

The voltage sensitivity at the PA89 input will be:

(1) $$S_i = \frac{C_a \times E_a}{C_a + C_c + C_i}$$

and the output sensitivity will be:

(2) $S_o = A\ S_i$, where A, the amplifier gain, is determined by the GAIN and SENS ADJUST settings.

Using a signal generator and an AC voltmeter, the calculated input voltage sensitivity, S_i, is applied to the TP (Test Point) input terminals. With the CONVERTER switch in the center position, the gain controls are adjusted until the desired output sensitivity (volts/g or mv/g) is read at the output terminals.

Example: What will be the input voltage sensitivity using an accelerometer with an open circuit voltage sensitivity of 70 mv/g, a capacity of 450 pf and at the end of 20 feet of cable with a capacity of 29 pf per foot?

We know:

S_a = 70 mv/g

C_a = 450 pf

C_c = 20 x 29 = 580 pf

C_i = 6 pf (PA89 input capacitance)

using equation (1),

$$S_i = \frac{450 \times 70}{450 + 580 + 6} = 30.4 \text{ mv/g}$$

Therefore, 30.4 mv would be applied to the TP terminal to simulate 1g of acceleration at the accelerometer.

4.1.4 If an external impedance converter is to be used, these calculations are made using the length of cable between the accelerometer and the converter, and using the converter manufacturer's specifications on the input capacity, C_i. The converter gain can be assumed to be a factor of 1 unless the manufacturer specifies otherwise, in which case the calibration voltage sensitivity applied to the TP terminal would be,

$S_i = A_c\ S_i$, where A_c is the specified converter gain.

4.1.5 It should be pointed out that a specified sensitivity is to be understood as meaning "peak millivolts per peak g" or its equivalent "rms millivolts per rms g". Note, however, that a voltage of 10 millivolts peak is approximately 7.07 millivolts rms, and an acceleration of 1g peak is 0.707g rms, and therefore,

10mv/g = 10mv pk/g pk = 10mv rms/g rms =

= 7.07 mv rms/g pk = 14.14mv pk/g rms

4.2 Gain Calibration

4.2.1 The gain controls may be set, approximately, before applying the calibration voltage by using equation (2) and noting that the amplifier gain is represented by the product of the GAIN setting and SENS. ADJUST setting.

Thus:

$$A = \frac{S_o}{S_i} = \frac{(\text{GAIN setting}) \times (\text{SENS. ADJUST setting})}{S_i} \qquad (3)$$

Going back to our example above, let's assume it is desired to have the output sensitivity in engineering units such that 1.0 volt represents 1g of acceleration.

Thus, for our example:

$$A = \frac{1000\ (\text{mv/g})}{30.4\ (\text{mv/g})} = 32.9$$

Now, as the SENS. ADJUST can never be greater than 1.0 or 100%, the nearest GAIN setting which includes A is picked, which in this case is "50".

Then:

$$\text{SENS. ADJUST setting} = \frac{32.9}{50} = 0.658$$

Therefore:

GAIN is set at 50

SENS ADJUST is set at 0.658 or 65.8%

Now when the calibration voltage is applied the SENS. ADJUST control can be trimmed to get the exact output reading.

4.2.2 Once the PA89 has been calibrated in the Acceleration mode, it is also calibrated in the Velocity and Displacement modes as designated by the FUNCTION switch position. That is, if the output sensitivity has been adjusted so that 1.0 volt represents 1g, then 1.0 volt represents 10 in/sec. in the Velocity Mode and 1.0 volt represents 1 in., 0.1 in., 0.01 in. or 0.001 in. in the Displacement Mode.

4.2.3 When operating in any of the modes the output sensitivity may be changed within the limits of the GAIN control without going back to the "simulated input procedure". If the GAIN control is placed at a new setting, the new output sensitivity will have the same relationship to the original sensitivity as the new GAIN setting has to the original setting. For example, if the original output sensitivity is 1.0 volt/g at a GAIN setting of 50, then at a setting of 100 the sensitivity will be 2.0 volt/g, etc.

5.0 PRINCIPLES OF OPERATION

5.1 Referring to the Functional Block Diagram, the high impedance signal from a piezoelectric accelerometer is changed to a low impedance voltage signal proportional to acceleration by the internal impedance converter with unity gain. The converter output voltage is coupled to an isolation amplifier through the converter select switch and the vernier gain control.

5.2 An external impedance converter is supplied a constant current from Q1. The input signal derived from this source is coupled to the isolation amplifiers through S1 and the vernier gain control, R16.

5.3 The test point jack is connected directly to the output of either the internal converter or the external converter so that these signals may be monitored. With the converter select switch in the center position this test point may be used to inject a calibration signal.

5.4 The output of the isolation amplifier which is proportioned to acceleration is fed to the non-integrating/integrating amplifier where the input signal is operated upon, as selected, such that the final output is proportioned to acceleration, velocity or displacement. Full-scale span is governed by reference to 1 "G" at the input stage.

When the "G" position is selected, both stages of amplifiers/integrator amplifiers are operating at unit gain; therefore, the output is proportioned to "G's".

When the "X10 in/sec" position has been selected, the first stage amplifier operates at unity gain and the second stage is operating as an integration amplifier. The net result is that the output is now proportioned to the integral of the first stage or velocity (in/sec).

When the "X1 inch" is selected, both stages become integration amplifiers. The output is then proportional to the double integral of the acceleration signal from the isolation amplifier, and is in units of displacement (inches).

When the "X0.1", "X.01" and "X.001" positions are selected, the double integration described above applies. The only difference is in the integrator sensitivities which have been increased for lower level signal processing.

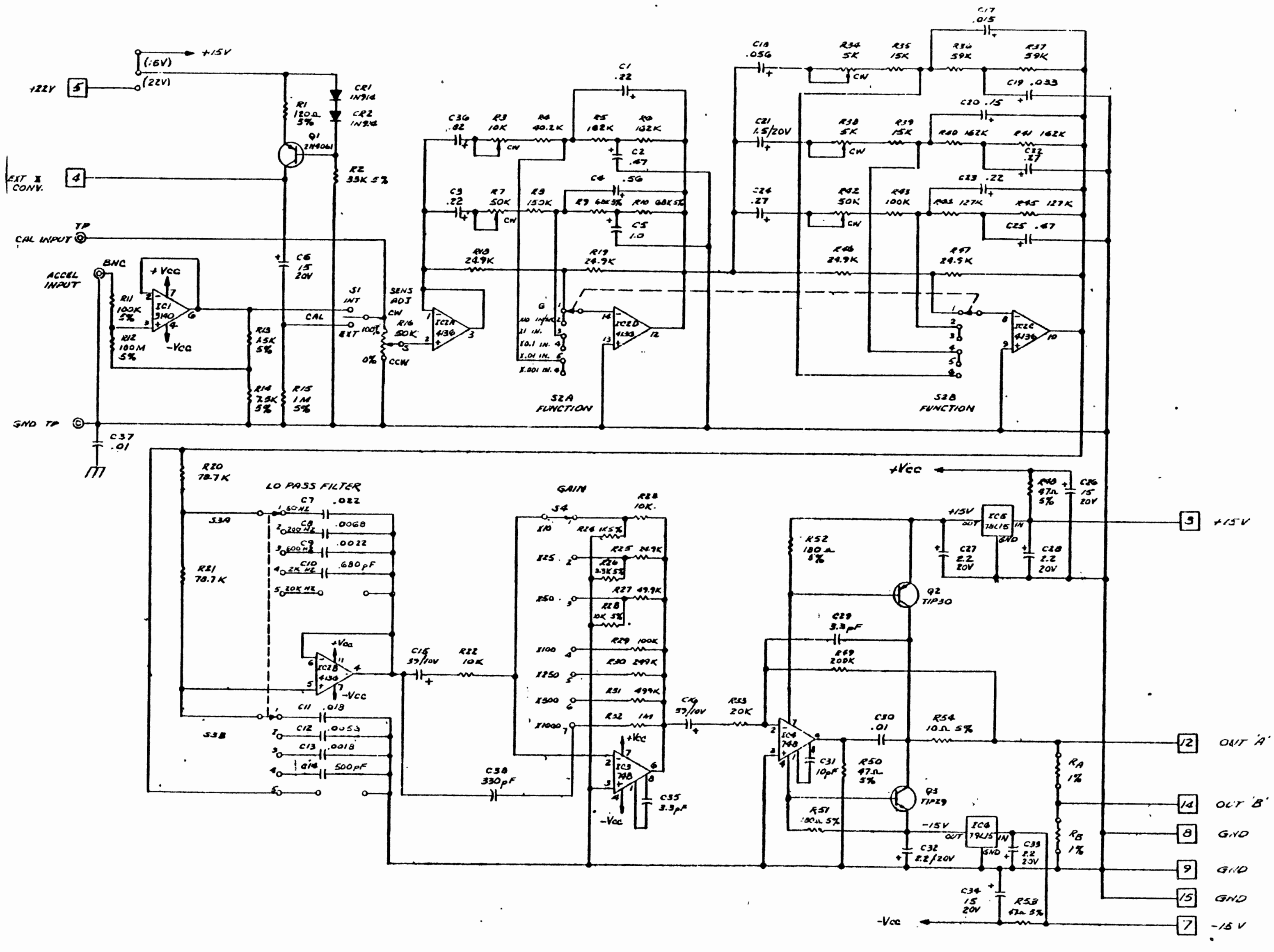


FIGURE 7. PA89 Schematic