PRECISION INSTRUMENTS FOR TEST AND MEASUREMENT

Instruction Manual
1560-P42
Preamplifier

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- Combinations of functions, special ranges, ratings, or accuracies.
- Replacement for discontinued models from other manufacturers.
- Calibration and repair services - NIST traceable.
- Compliant with ISO 9001, ISO 17025, ANSI Z540-1-1994, and MIL-STD-45662A.

Capabilities

- **R**: 20 µΩ-1 TΩ
- **C**: <1 pF - 1 F
- **L**: 100 µH-100 H

- Accuracy to 1 ppm
- Resolution to 0.1 ppm
- Voltage to 20 kV
- Power to over 1000 W
- Programmable IEEE-488 or BCD

WARRANTY

We warrant that this product is free from defects in material and workmanship and, when properly used, will perform in accordance with applicable IET specifications. If within one year after original shipment, it is found not to meet this standard, it will be repaired or, at the option of IET, replaced at no charge when returned to IET. Changes in this product not approved by IET or application of voltages or currents greater than those allowed by the specifications shall void this warranty. IET shall not be liable for any indirect, special, or consequential damages, even if notice has been given to the possibility of such damages.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF MERCHANTIBILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.

WARNING

OBSERVE ALL SAFETY RULES
WHEN WORKING WITH HIGH VOLTAGES OR LINE VOLTAGES.

Dangerous voltages may be present inside this instrument. Do not open the case
Refer servicing to qulified personnel

HIGH VOLTAGES MAY BE PRESENT AT THE TERMINALS OF THIS INSTRUMENT

WHENEVER HAZARDOUS VOLTAGES (> 45 V) ARE USED, TAKE ALL MEASURES TO AVOID ACCIDENTAL CONTACT WITH ANY LIVE COMPONENTS.

USE MAXIMUM INSULATION AND MINIMIZE THE USE OF BARE CONDUCTORS WHEN USING THIS INSTRUMENT.

Use extreme caution when working with bare conductors or bus bars.

WHEN WORKING WITH HIGH VOLTAGES, POST WARNING SIGNS AND KEEP UNREQUIRED PERSONNEL SAFELY AWAY.

CAUTION

DO NOT APPLY ANY VOLTAGES OR CURRENTS TO THE TERMINALS OF THIS INSTRUMENT IN EXCESS OF THE MAXIMUM LIMITS INDICATED ON THE FRONT PANEL OR THE OPERATING GUIDE LABEL.

Type 1560-P42 Preamplifier-Section 4

4.1 DESCRIPTION.

A complete description of the Type 1560-P42 Preamplifier (Figure 4-1) is given in para. 1.1.3.

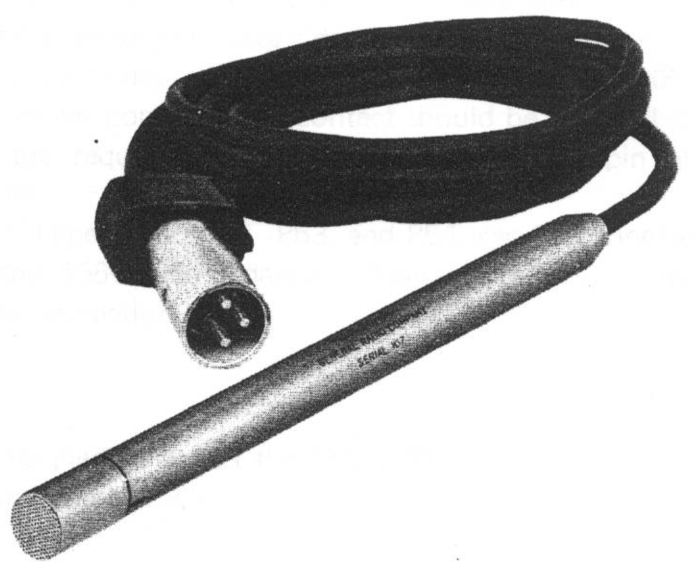


Figure 4-1.
Type 1560-P42 Preamplifier with microphone attached.

4.2 INSTALLATION.

4.2.1 Connecting the Transducer.

NOTE

Although it is not necessary, it is good practice to turn off the power to the 1560-P42 Preamplifier while the transducer is being connected or disconnected. (The FET is diode protected against surges.)

Connection of the transducer to the Preamplifier is made by means of a 0.460-60 threaded coaxial connector. This connector provides electrical contact between the microphone shell and the Preamplifier circuit ground. The ground connection is electrically isolated from the case of the Preamplifier, which serves as a shield.

4.2.4 Adjustments.

Adjustment of the Preamplifier consists of setting two slide-switch controls, labelled GAIN (X1, X10) and 200 V (ON, OFF). These are accessible through cutouts in the outer shell of the -P42. A notch in the slider of each switch is used to set the controls to one position or the other. Use any small tool (such as a screwdriver or ball-point pen) to set these controls.

Gain Adjustment. The gain of the Preamplifier can be set to either X1 or X10 by means of the GAIN switch. It should be set to optimize the dynamic range of the system. For low levels (such as less than 60 dB SPL for −60 dB microphone sensitivity level) and/or for long cable runs, set the GAIN switch to X10, to eliminate the influence of the analyzer noise on the measurement. With high signal levels (above 120 dB SPL for −60 dB microphone sensitivity level) set the GAIN switch to X1, so that the output signal will not be clipped because of overloading. For levels between 60 and 120 dB, either X1 or X10 can be used, the choice depending upon the reading desired on the indicating analyzer.

Polarizing Voltage. The +200-V polarizing voltage for condenser microphones can be turned ON and OFF by adjustment of the slide switch marked 200 V, on the Preamplifier. This voltage is generated in an internal blocking oscillator operating at approximately 60 kHz (refer to the schematic diagram). The voltage is applied to the center pin of the input connector through several decoupling networks. At least +15 V at the Preamplifier terminals is required to ensure stable generation of the 200 V. The 200-V supply is turned on by connecting the low-voltage supply to the oscillator through the 200 V (ON, OFF) switch. Set the switch ON for condenser microphones and OFF for *all* other transducers.

NOTE

The available current from the +200 V polarizing supply is extremely low and not hazardous. However, an increase in input noise due to leakage current may result if the polarizing voltage is left on with ceramic transducers. Use the +200 V supply only with condenser microphones.

The power consumption of the Preamplifier increases slightly when the polarizing supply is ON (the current increases about 2-3 mA above the current of the amplifier circuit of the Preamplifier).

4.2.5 Power.

The Preamplifier can be powered from a number of GR sound-level meters and analyzers, as shown in Table 1-2. The power is applied via the input connector to the Preamplifier. For use with instruments that do not supply power for the Preamplifier, or where insufficient current is available to power the polarizing supply, or for runs with long cables, the 1560-P62 Power Supply is available. This integrated charger and line/battery-operated supply provides the necessary current and voltage for most applications. Refer to Table 1-2 and Figure 4-2 to determine the required current for the length of cable used. Details of the Power Supply and its use with the Microphone Sets are given in Section 5 of this manual.

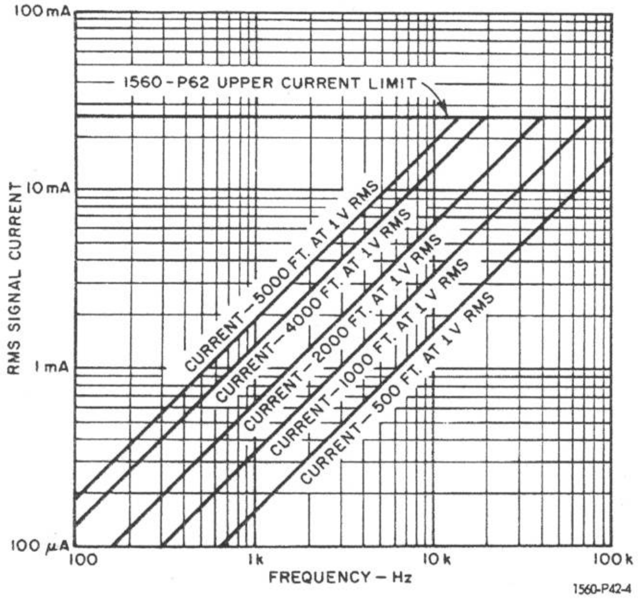


Figure 4-2. Required dc current vs cable length at 1 V, rms.

Although the 1560-P42 Preamplifier is designed to be used with GR instruments that supply the proper power, there may be instances in which the user wishes to use a different supply. This use is entirely satisfactory if certain precautions are taken:

With the class AB output stage, the power supplied to the Preamplifier must be current limited so that the output stage of the Preamplifier will not be damaged if the output is heavily loaded (such as with a short circuit) when a signal is applied to the load. Output currents above 30 mA at rated voltages should be avoided. GR analyzers and the 1560-P62 Power Supply provide this current limitation. Other supplies should be set to give a maximum short-circuit current of 15 mA. If this is not possible, insert a 100-Ω resistor in series with the supply lead (pin 2 of the -P42 output connector), to provide minimum protection (see Figure 4-18).

If the supply current is monitored with a dc milliameter, the true average current (other than the quiescent current) drawn by the 1560-P42 Preamplifier, when the load is driven by a sine wave, is actually twice the indicated current, because the current drawn from the positive lead of the power supply by the class AB output stage occurs during only the positive half of the cycle. In other words, therefore, the reading of an average-reading meter must not exceed 10 mA.

Average current to load $\simeq$ $(mA_{reading} - mA_{quiescent}) \times 2$.

Note that, in a system where cables in excess of 1000 ft are driven, the placement of the power supply will influence the capability of the system (the IR drop in the cable becomes significant). Placement of the supply near the preamplifier will avoid the loss of the powering voltage through the long cable.

4.2.6 Insert Voltage.[1]

General. Provision for connecting an insert calibration signal is provided by a type-274 double jack (PL2) built into the output plug. The insert voltage can be used

1. For a complete discussion of the theory of insert-voltage calibration, refer to Beranek, L. L., *Acoustic Measurements*, John Wiley & Sons, Inc., New York, 1949, pp 601, 602.

to determine the system sensitivity if the open-circuit sensitivity of the microphone is known; it can be used to determine the absolute calibration of the system by direct comparison with a reference microphone; also, an operational check on a system can be made with the insert voltage. The equipment needed for these operations is listed in Table 4-1. The insert terminating resistor is 10 Ω (R20) and the maximum insert voltage is 1 V rms. The signal is applied across the insert resistor, effectively putting the insert voltage in series with the transducer.

Table 4-1

EQUIPMENT REQUIRED FOR USE IN MEASURING SENSITIVITY

Name	Requirements	Recommended*
Oscillator	1 kHz, 1 V	GR Type 1310 Oscillator
Decade Attenuator	0-100 dB in 0.1-dB steps	GR Type 1450-TB Decade Attenuator
Voltmeter	0-10 V ac ±5%	GR Type 1808 AC Millivoltmeter
Analyzer	C or FLAT weighting, 70-100 dB	GR Type 1564 Sound and Vibration Analyzer
Power Supply	20 V, 15 mA	GR Type 1560-P62 Power Supply
Resistor	590 Ω ±1%	———
Sound Source	Stable repeatable source	GR Type 1562 Calibrator
Reference microphone with adaptor to fit input to -P42 Preamplifier	Long-term stability; calibration traceable to NBS	W.E. 640AA
Patch Cords (2)	GR 274 to GR 274, 3 ft	GR Type 274-NQ
Adaptor	Microphone cartridge to 0.460x60 thread	GR 1560-9581
Clip Leads (2)	>1 foot long	———

*Or equivalent.

Determination of System Sensitivity. The following procedure should be used to determine the sensitivity of the system when the open-circuit sensitivity of the microphone is known:

a. Make the setup of Figure 4-3. Connect the oscillator to the 274 insert terminals (the connector at the end of the Preamplifier output cable). Connect the voltmeter between the threaded portion of the input connector and the shell of the Preamplifier, i.e. across the insert resistor (clip leads can be used). Power for the Preamplifier is not needed. In the figure, R_i is the insert resistor (nominally 10 Ω) and R_w is the internal wiring resistance (typically a few tenths of an ohm).

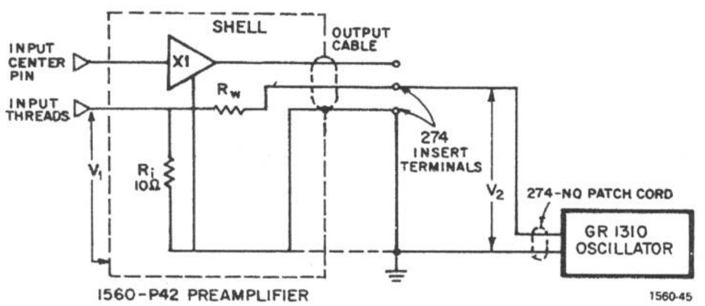


Figure 4-3. Setup for determination of system sensitivity.

b. Adjust the oscillator to 1 kHz. Set its output so that the voltmeter reads V_1 = .01 V.

c. Transfer the voltmeter to the insert terminals and read V_2. The indicated increase in voltage ($V_2 - V_1$) is caused by R_w and amplifier deviation from 0 dB, typically a total of –0.3 to –0.5 dB. This is the loss that must be added to the voltage at the insert terminals to give desired voltage across the insert resistor. Record this value for future use.

d. Remove the adaptor and install the microphone on the Preamplifier. Connect the plug on the output cable from the Preamplifier to the input of the 1564 Sound and Vibration Analyzer. Power for the Preamplifier is supplied by the 1564. The oscillator should remain connected to the insert-voltage terminals, with its output still set to the value of V_2, at 1 kHz.

e. With the Preamplifier operating on X1 gain, note the reading (V_3) of the analyzer (calibrated to read voltage). The difference in voltage ($V_1 - V_3$) is a result of the capacitive loading of the transducer by the Preamplifier and Preamplifier gain or loss.

The ratio of $\frac{V_1}{V_3}$ expressed in dB ($20 \log_{10} \frac{V_1}{V_3}$), is the value to be subtracted from the open-circuit sensitivity level of the microphone to obtain the system sensitivity level.

For example, if the sensitivity level of the microphone is –40 dB re 1 V/N/m^2 and V_1/V_3 = 1.175 (=1.4 dB), then the system sensitivity level is

$R_s = -40 - 1.4 = -41.4$ dB re 1 V/N/m^2.

If a more-accurate method is required, short the input with a GR 1560-9581 adaptor (with shorted terminals) and supply power to the –P42. Note the difference between the voltage at the insert terminals and at the output of the -P42 cable. This method removes simultaneously the errors due to amplifier gain and the wiring loss.

Comparison with Reference Microphone to Obtain Open-circuit Sensitivity.

a. Make the setup shown in Figure 4-4. The 590-Ω resistor at the attenuator output provides the proper 600-Ω load for the attenuator when the 10-Ω insert resistor is driven. Power for the Preamplifier is furnished by the 1564.

b. Connect the reference microphone to the -P42, and place the 1562 Calibrator, set at 1 kHz, on the microphone. (The actual level of the calibrator signal is not important, but it must be repeatable.) Set the oscillator output at zero.

c. Read the voltage output from the Preamplifier on the analyzer. Record the value as V_{ref}. Remove the sound source.

d. Set the oscillator output level for maximum (approximately 10 V) at 1 kHz. Adjust the 1450-TB Attenuator to give a reading equal to V_{ref} on the 1564. Note the setting, A_1, of the attenuator.

e. Turn the oscillator output to zero. Replace the reference microphone with the unknown and place the sound source (1562) on the unknown microphone. Note the 1-kHz reading, V_{unk}, of the analyzer.

f. Remove the sound source and connect the oscillator as before, with the output setting used in step d (10 V). Adjust the 1450-TB attenuator to give a level equal to V_{unk} on the analyzer. Note the attenuator setting, A_2.

g. The open-circuit sensitivity level of the unknown microphone is then

$$S_{unk} = S_{ref} + (A_1 - A_2).$$

For example, if

$$S_{ref} = -30 \text{ dB re } 1 \text{ V/N/m}^2$$
$$A_1 = 4.5 \text{ dB}$$
$$A_2 = 13.5 \text{ dB}$$

then

$$S_{unk} = -30 + (4.5 - 13.5)$$
$$= -30 - 9.5$$
$$= -39.5 \text{ dB re } 1 \text{ V/N/m}^2$$

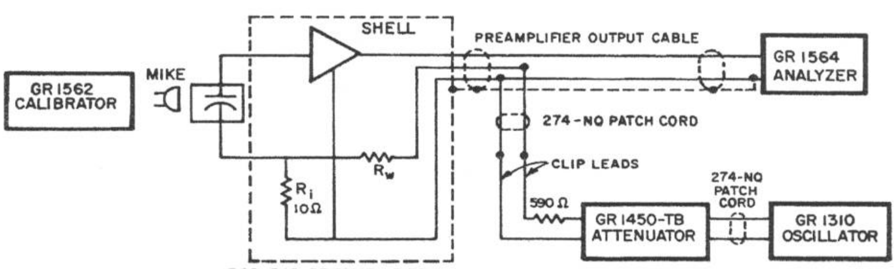


Figure 4-4. Setup for comparison of unknown with reference microphone.

Operational Check of System. When a system has been set up and calibrated, a voltage can be applied to the insert terminals to serve as a reference. Note the values of the insert voltage and the analyzer reading, for future reference. (The absolute values are not important.) As an operational check at a later date, or after system modifications, the same voltage is applied to the insert terminals. A deviation in the analyzer reading from the original reading is an indication of a change in the system response.

4.3 INPUT CONSIDERATIONS.

The equivalent INPUT circuit of the Preamplifier is determined by the FET input stage and its associated biasing and protection networks. Protection for the transistor from surges of the polarizing voltage (with condenser microphones) is supplied by very low-leakage semiconductor diodes. These diodes produce a slight increase in the input capacitance and add some leakage resistance. The 200-V polarizing voltage is supplied through a "bootstrapped" 100-MΩ resistor, which, in effect, increases its ac resistance to well above 1 GΩ. The net input resistance is approximately 700 MΩ. The input capacitance is established by the FET plus the diodes, and is typically 3-4 pF, with 6 pF maximum. (Use of the driven shield minimizes the input capacitance for small-diameter microphones.) As a result of this nominal input capacitance, there is some transducer insertion loss due to the resultant capacitive-divider effect. Figure 4-5 gives the insertion loss for microphones of various capacitances.

A low-frequency roll-off is encountered when the Preamplifier is driven from a capacitive source because of the equivalent input resistance. The "Lower" and "Upper Frequency Range" columns of Table 1-1 give the frequencies at which the response is down 3 dB, for the various microphones. Input protection diodes CR1 and CR2 utilize the signal-source impedance to limit the pk-pk input voltage to the power-supply value. If the 1560-P42 is driven from a 10-Ω or lower source impedance, such as that of a power amplifier, it is important to limit the pk-pk input voltage to the power-supply value, to avoid damaging CR1 or CR2.

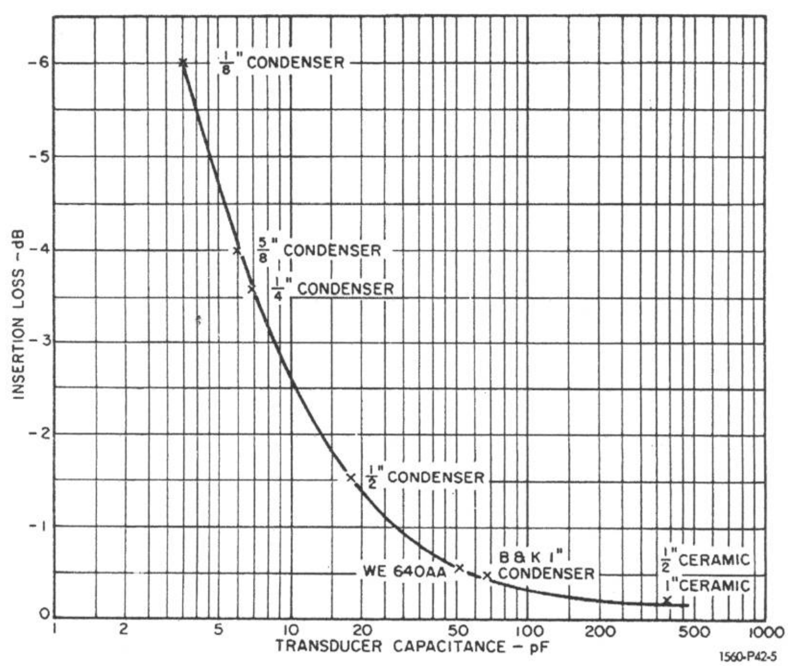


Figure 4-5. Insertion loss vs transducer capacitance.

4.4 USE OF LONG CABLES.

4.4.1 General.

The 1560-P42 Preamplifier is designed with the capability of delivering substantial signal current and signal voltage to the driven cable at the preamplifier output. Thus, longer cables can handle substantially higher signals at higher frequencies than were possible heretofore with other preamplifiers. However, to utilize this capability, the user must have a thorough understanding of the problems to be encountered.

In any system involving active amplification driving a load, the following effects, with their related causes, should be considered:

1. ***Distortion***. Insufficient current to drive the particular load at the desired signal voltage level (i.e., the signal level is too high for the load).

2. ***Change in frequency Response.*** The output characteristics of the amplifier, in conjunction with the impedance of the load, alter the frequency response of the signal.

3. ***Attenuation.*** Also brought about by the interaction of the output amplifier impedance and the load impedance, this is a modification of 2, above, but it is generally considered a flat loss of signal with respect to frequency.

4. ***Power-supply voltage drop.*** This item is a fourth effect, resulting indirectly from the use of an amplifier powered through a long cable. The voltage drop in the power lead of the cable is a function of the resistance of the cable and the current drawn by the driving amplifier. If the amplifier is operating class A-B or B, the current is a function of the output level, the frequency, and the impedance of the cable being driven.

These general problems can be circumvented if one has a thorough knowledge of their causes. It is assumed, in the appraisal of the system, that the ultimate goal is the flattest possible frequency response, with minimum attenuation and minimum distortion, over the range of interest. The following paragraphs should bring about a better understanding of the problems and their solutions.

4.4.2 Definitions.

Short Cables. A short cable is one in which no appreciable change in performance of the system or in measurement results is produced in the frequency range of interest by use of the cable. Thus, for our analysis, short cables can be excluded. In general, short cables for use with the 1560-P42 Preamplifier are those that are 500 ft or less in length.

Long Cables. Long cables are those that alter the signal appreciably when driven by the preamplifier. For our analysis, long cables are those whose driving wavelength is much longer than the cutoff wavelength of the cable. If the frequency of the driving signal is above the cutoff frequency, the attenuation in the cable decreases uniformly as the square root of the frequency. However, for audio frequencies, the cable is invariably being driven well below cutoff frequency. Typically, the wavelength is greater than 5000 ft at 150 kHz for polyethylene dielectric cables.

4.4.3 Equivalent Circuits.

The sources of signal alteration in an amplifier/cable system can be demonstrated best by means of the equivalent circuit of the cable (see Figure 4-6) driven by the amplifier and the equivalent circuit of the output stage of the amplifier. It is the interaction of these elements that produces the alteration on degradation of the signal.

In most microphone/preamplifier applications, where low-level signals are involved, the cable is usually assumed to be an unterminated, unmatched line. It appears as a simple lumped capacitance at the output of the driving amplifier. The equivalent shunt capacitance at the output of the amplifier increases as the length of the cable increases. Thus, in conjunction with the output resistance of the amplifier, a 6-dB/octave low-pass filter is produced with the cutoff frequency decreasing as the length of the cable increases.

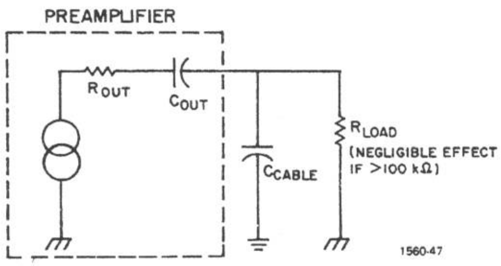


Figure 4-6. Equivalent circuits for the output stage of the Preamplifier and the cable.

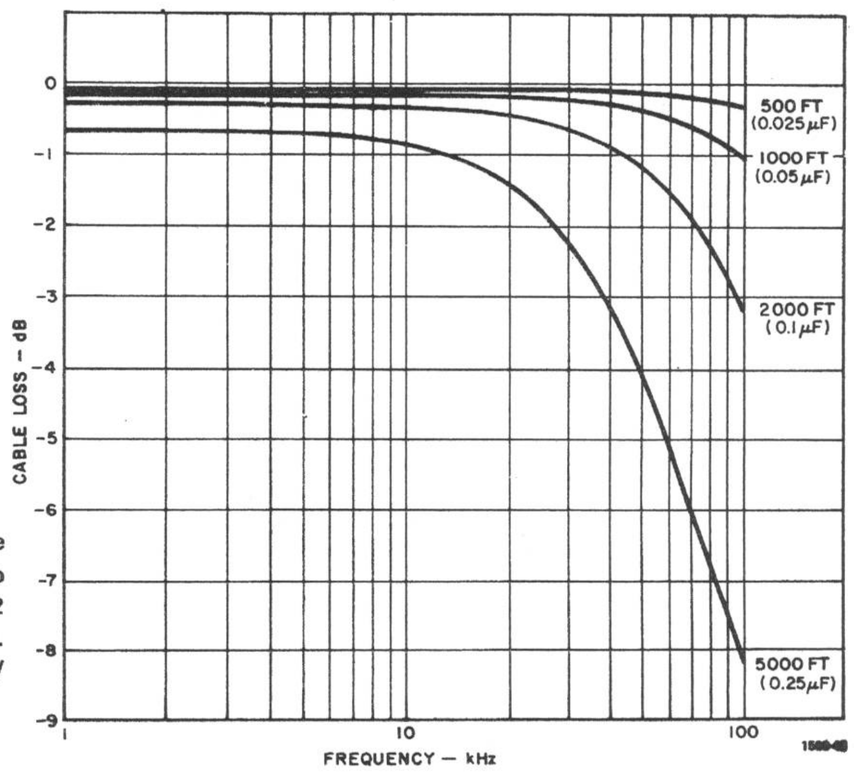


Figure 4-7. Typical cable loss vs frequency, due to output loading of 1560-P42 for a pure capacitance load. Cable capacitance is 50 pF/ft.

Certain cables, whose resistive and inductive reactances are *small* with respect to their capacitive reactance, do behave according to the above simple assumption. In reality, with most audio cables whose equivalent effective impedance is approximately 50 Ω, the resistive and inductive reactances are not negligible, and must, therefore, be taken into account. Indeed, as the cable length increases, the effective load impedance for the amplifier never decreases to zero, but is restricted to the 50-Ω self termination of the cable. Also, a flat loss is introduced at low frequencies by the capacitive divider effect between the output coupling capacitor of the amplifier and the lumped cable capacitance. The cable loss vs frequency for various lengths of 1560-9667 cable (Belden #8771)* is shown in Figure 4-7. For this curve, the capacitance only (50 pF/ft) is used as the effective impedance.

4.4.4 Cable Response.

Figure 4-8 shows the results of these effects on the response, using the same cables, with a 1560-P42 Preamplifier. Because the cable is driven from a low impedance rather than its natural impedance (as would be the case in a matched line) the cable appears as a distributed tank circuit driven from a short circuit. The result is a family of curves with resonant peaks. The frequency is determined by the L/C constants of the cable, and the amplitude is determined by the ratio of the cable resistance to the amplifier output resistance. It should be noted that the actual equivalent circuit of the cable as used is not an unbalanced coaxial system, but rather a balanced system, because the cable braid is a shield, not a return path. This is important when the system response is

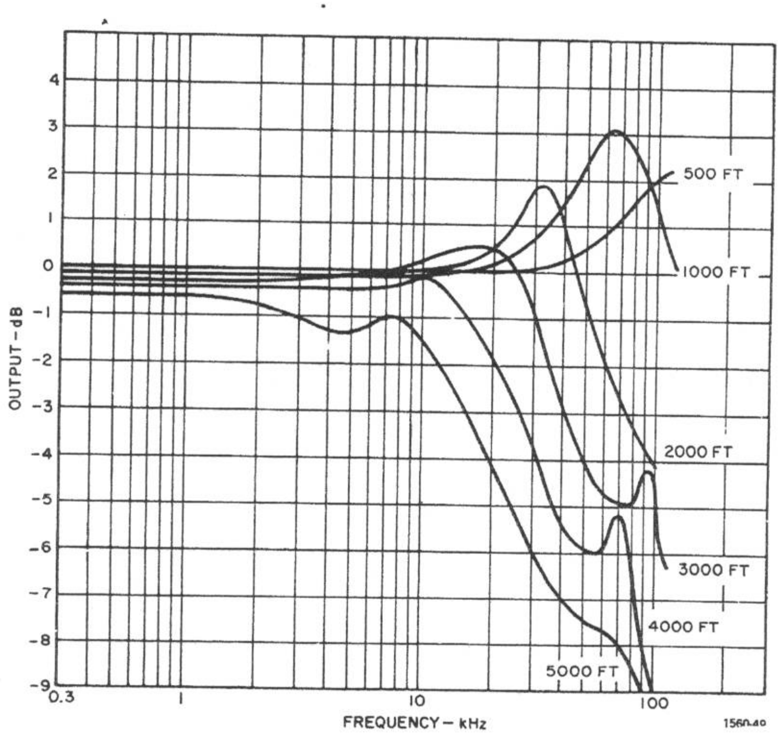


Figure 4-8. Measured cable loss of the Preamplifier vs cable length for Belden #8771 cable. Preamplifier gain is X 1, powered from the receiver end.

*Belden Corp., P.O. Box 5070-A, Chicago, Ill.

measured. The equivalent circuit of the cable is shown in Figure 4-9. For cables up to 5000 ft and frequencies up to 10 kHz, there is little effect on the signal. For longer cables or higher frequencies, the effect must be corrected, or it must be taken into account when the results are evaluated. This can be done by using corrective equalizers or by altering the results mathematically to give a flat frequency response. In both cases, a knowledge of the cable characteristics is needed.

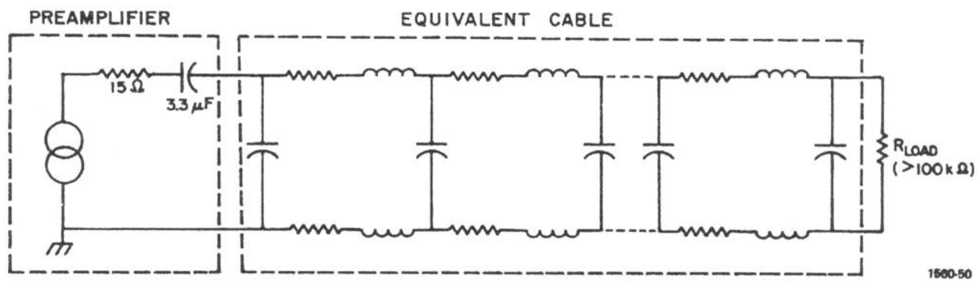


Figure 4-9. Equivalent circuit for long cables.

When a long connecting cable is used between the preamplifier and the measuring instrument, the output from the preamplifier may have to be restricted because of the low reactance load of the cable. Figure 4-10 shows the maximum rms sine-wave voltage at the output of the 1560-P42 versus frequency. The 1560-P62 current-limited Power Supply was used, and the distortion was limited to 1%. The curves are for Belden #8771 cable (50 pF/ft). Refer to Figure 4-11 to convert voltage to SPL in dB re 1 $V/N/m^2$ for a particular microphone. Divide by 10 to obtain maximum output volts with X10 gain on the Preamplifier.

4.4.5 Predicting the Resulting Response.

In general, the impedance of audio cables cannot be controlled, because of the twist of the inner conductors. The impedance may vary from 40 to 100 Ω, depending upon the make and the basic capacitance. While the resistance and capacitance of a cable can be measured quite easily, determination of the distributed inductance is more difficult. Also, once these parameters are known, it is tedious to calculate the response at all the required frequencies of interest. Even when this has been accomplished, it is well to check the results by making an actual measurement, rather than by attempting to predict the results.

4.4.6 Measuring the Cable.

To measure the cable, a stable oscillator and a wide-band voltmeter that cover the frequencies of interest are required. As noted above, the actual cable is a balanced system (i.e., the direct and return paths for the signal have practically the same resistance and inductance). Consequently, when the cable is measured, the return path of the cable must not be short-circuited by the common returns of the oscillator/analyzer combination. With this short circuit, measurements on a coiled cable in the laboratory will not be representative of the cable stretched out, in the field.

4.4.7 Using the Results.

The above measurements should be used to correct the results of the final analysis. A mathematical correction can be time consuming and too slow for real-time analysis. Corrective equalizers can be constructed and placed at the analyzer end, to return the signal to a flat frequency response.

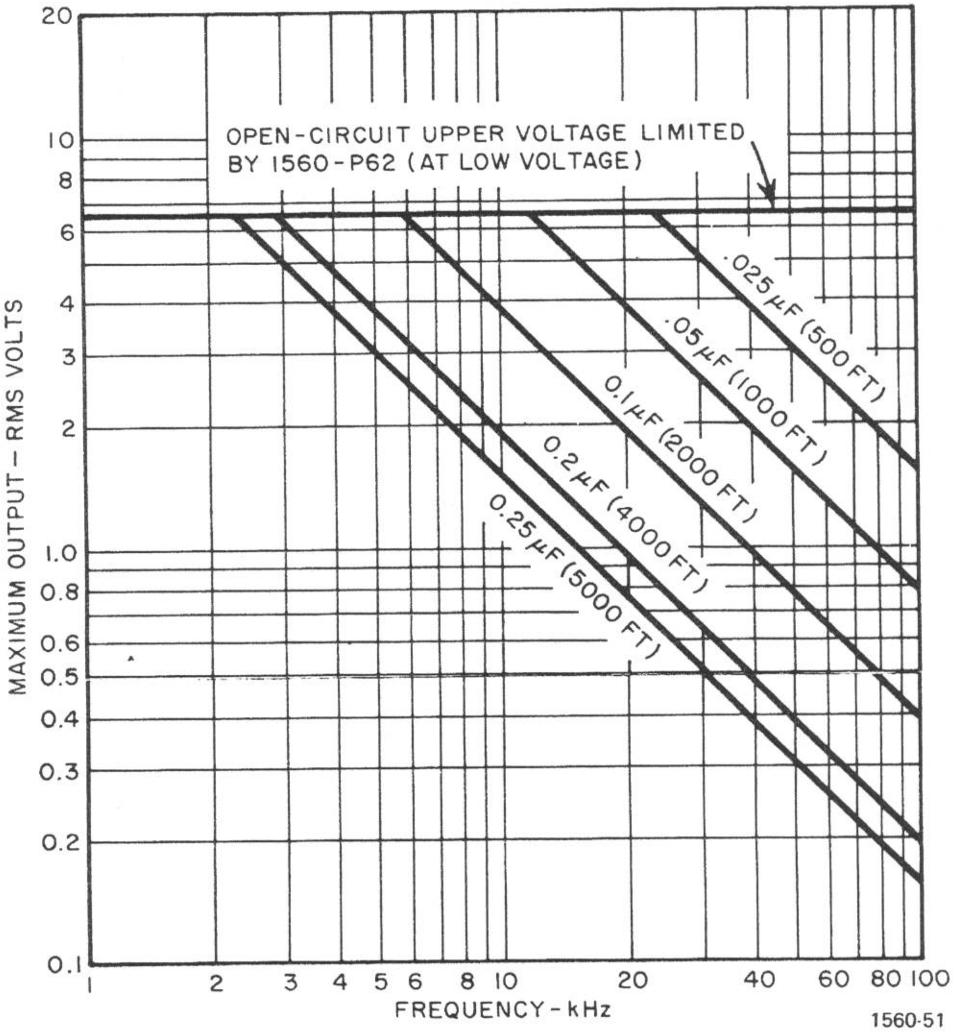


Figure 4-10. Maximum rms sine-wave output voltage for various lengths of Belden #8771 cable (50 pF/ft) at the output of the 1560-P42, using the 1560-P62 current-limited Power Supply with 1% total harmonic distortion limit.

4.4.8 Other Solutions.

Several methods are available to avoid the problem of frequency-response shift by long cables. However, they usually produce new problems:

1. Matching the Cable. This method requires matching the cable impedance at both the source and the load. There is then an automatic 6-dB loss in level, and additional power is required by the amplifier. Most audio cables are 50 Ω impedance; this means that 20 mA is required to drive 1 V rms into the cable. Also, a large output coupling capacitor is needed to drive the cable at low frequencies.

2. Using 600-Ω Cable. This is similar to the above solution. However, the higher impedance reduces the power requirement and the size of the coupling capacitor for

the matched system. With this impedance level, interference is increased. Consequently, matching transformers are used to convert the line from low-impedance unbalanced-to-ground to 600-Ω balanced-to-ground. High-quality transformers must be used to affect a good solution.

3. Using Line Drivers. With this method, amplifiers are placed in the line at such intervals that the frequency alteration is above the point of interest. This requires special feed-through amplifiers and greater power-supply capability.

4.5 NOISE.

4.5.1 Input Noise.

The major source of noise in the Preamplifier is the FET input stage[1] (refer to para. 4.6). However, some additional noise is produced by the protection diodes, CR1 and CR2. The noise spectrum is also influenced by the magnitude of the source capacitance. This capacitance, in conjunction with the real input resistance, shapes the input-noise spectrum. Bootstrapped resistor R1 behaves like a resistor many times larger with respect to the input signal, but for noise, it appears as 100 MΩ.

Figure 4-12 shows the basic 1/3-octave noise spectra from 25 Hz to 25 kHz for several typical source capacitances. The vertical coordinates are given in equivalent sound-pressure noise levels for a microphone sensitivity level of –40 dB re 1 V/N/m^2. Refer to Figure 4-11 to convert the levels to those for microphones of other sensitivities. For example, if the equivalent noise level with a –40 dB re 1 V/N/m^2 microphone is 10 dB, a –50 dB re 1 V/N/m^2 microphone would give an equivalent noise level of 20 dB.

Table 4-2 gives A- and C-weighted and flat-response noise levels for the various source capacitances.

Table 4-2.

INPUT-CIRCUIT NOISE FOR THE
1560-P42 PREAMPLIFIER

Source Impedance	Noise (dB)* A weighting	C weighting	Flat
600 Ω	20.5	22.5	24.5
390 pF	20.5	23.0	25.0
68 pF	23.5	30.0	34.5
47 pF	24.5	32.0	36.0
18 pF	29.0	38.0	41.5
6.8 pF	34.0	43.0	46.0
4.7 pF	36.0	45.0	47.0

*Equivalent sound level for a microphone with a sensitivity level of –40 dB re 1 V/N/m^2 uncorrected for capacitance loading.

1. Johnson, J. B., *Thermal Agitation of Electricity in Conductors,* Physical Review, Vol 32, July 1928, pp 97-109.

Van Der Ziel, A., *Thermal Noise in Field Effect Transistors,* Proc IRE 50, 1962 pp 1808-1812.

Sanderson and Fulks, *A Simplified Noise Theory and Its Application to the Design of Low Noise Amplifiers,* GR Reprint A-88.

NOTE

Although it is not necessary, it is good practice to disconnect the preamplifier power before removing or attaching the microphone.

A period of 10-20 s is required for the input capacitor to discharge through the internal circuitry after the capacitor has been charged to 200 V.

In addition to providing protection for the FET, diodes CR1 and CR2 limit the peak-to-peak input signal to the power-supply voltage. Also, the recovery time for large overloads is greatly enhanced by these diodes; i.e., the amplifier will stabilize in a very short time after overloads.

The effect of the protection diodes, CR1 and CR2, and resistor R1 is to increase the C-weighted noise for 390-pF sources by 1.5 to 2.5 dB and for 18 pF sources by 5 to 7 dB.

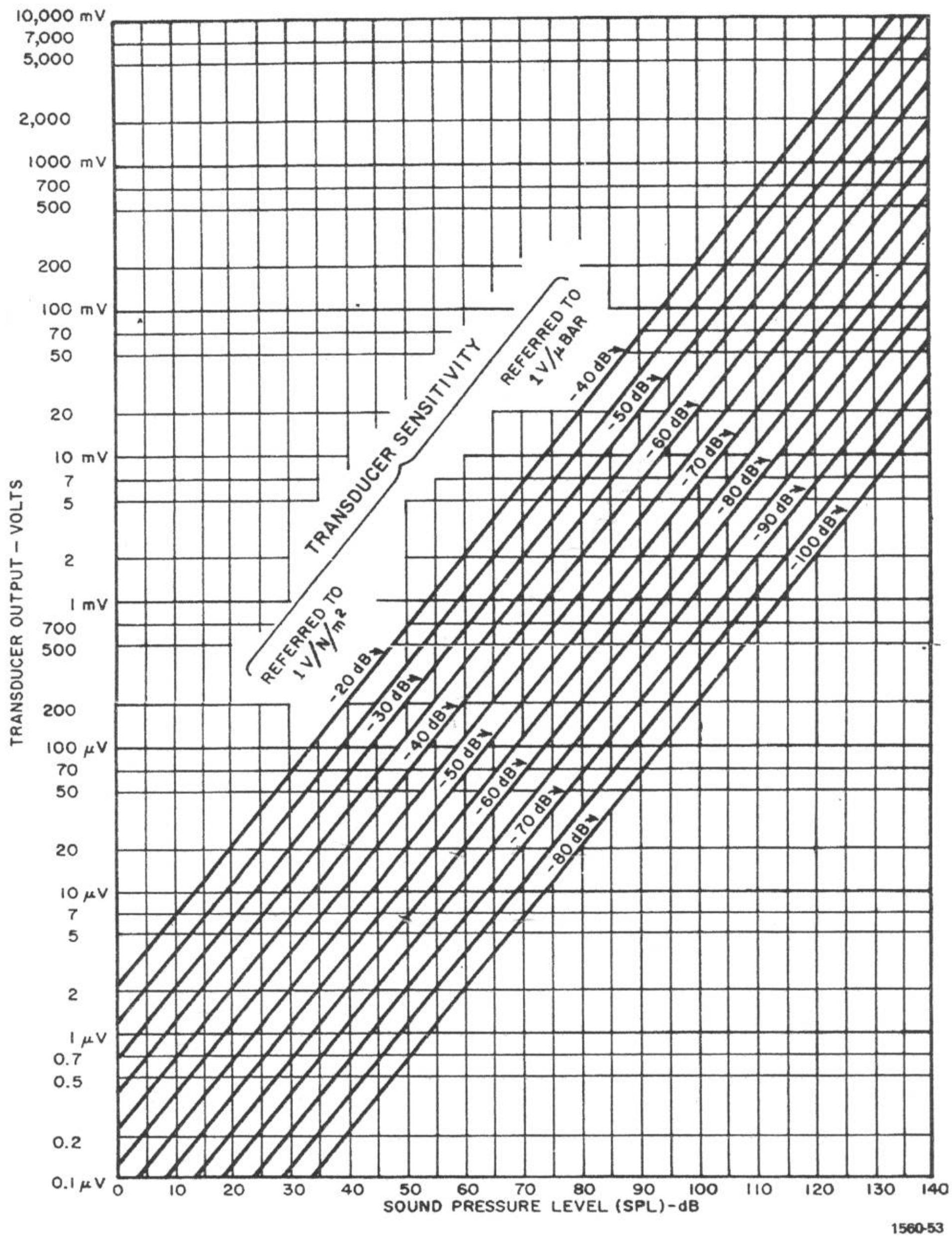


Figure 4-11. Open-circuit output voltage vs SPL for microphones of various sensitivities.

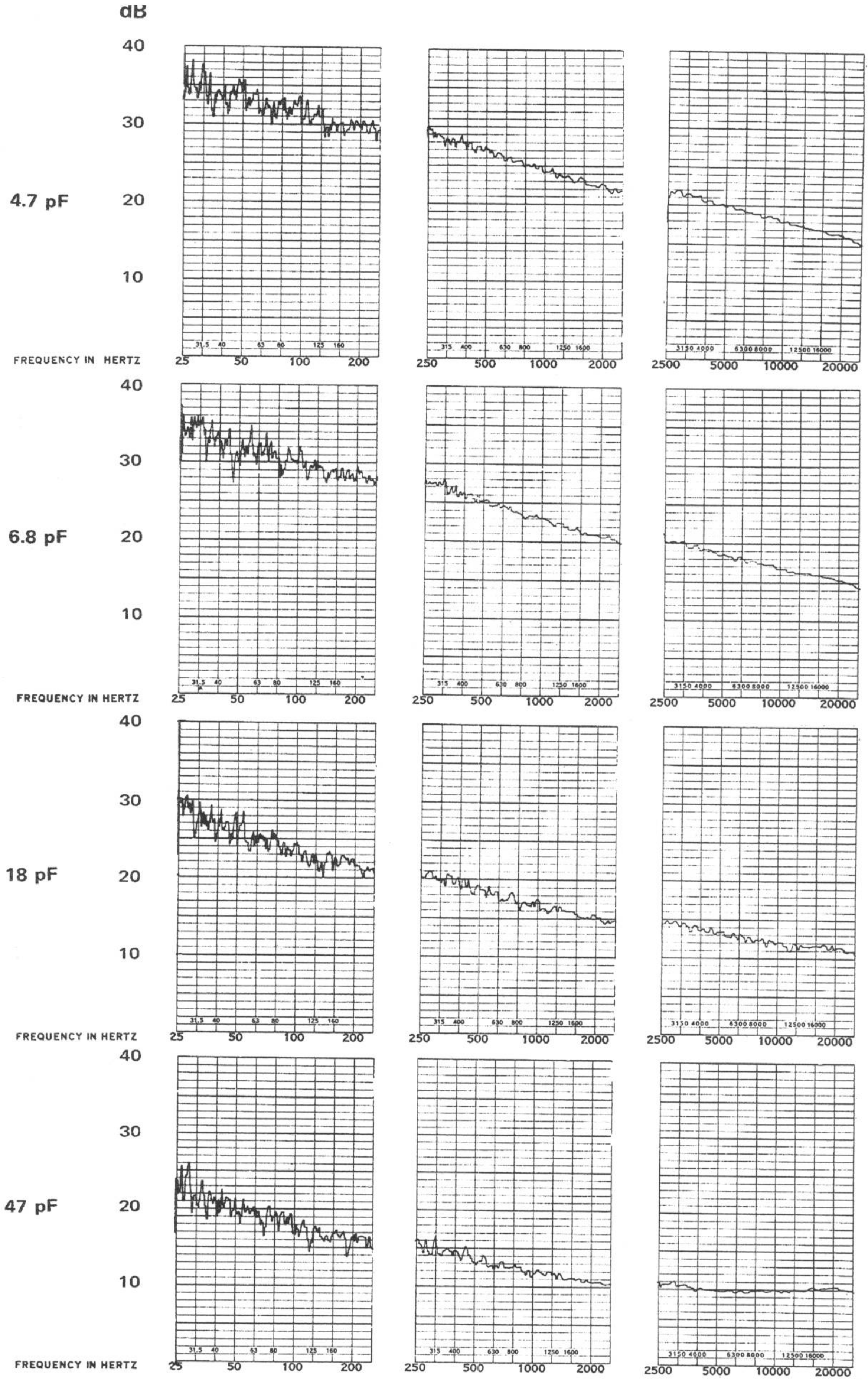


Figure 4-12. Basic 1/3-octave noise spectra for microphones of various source impedances.

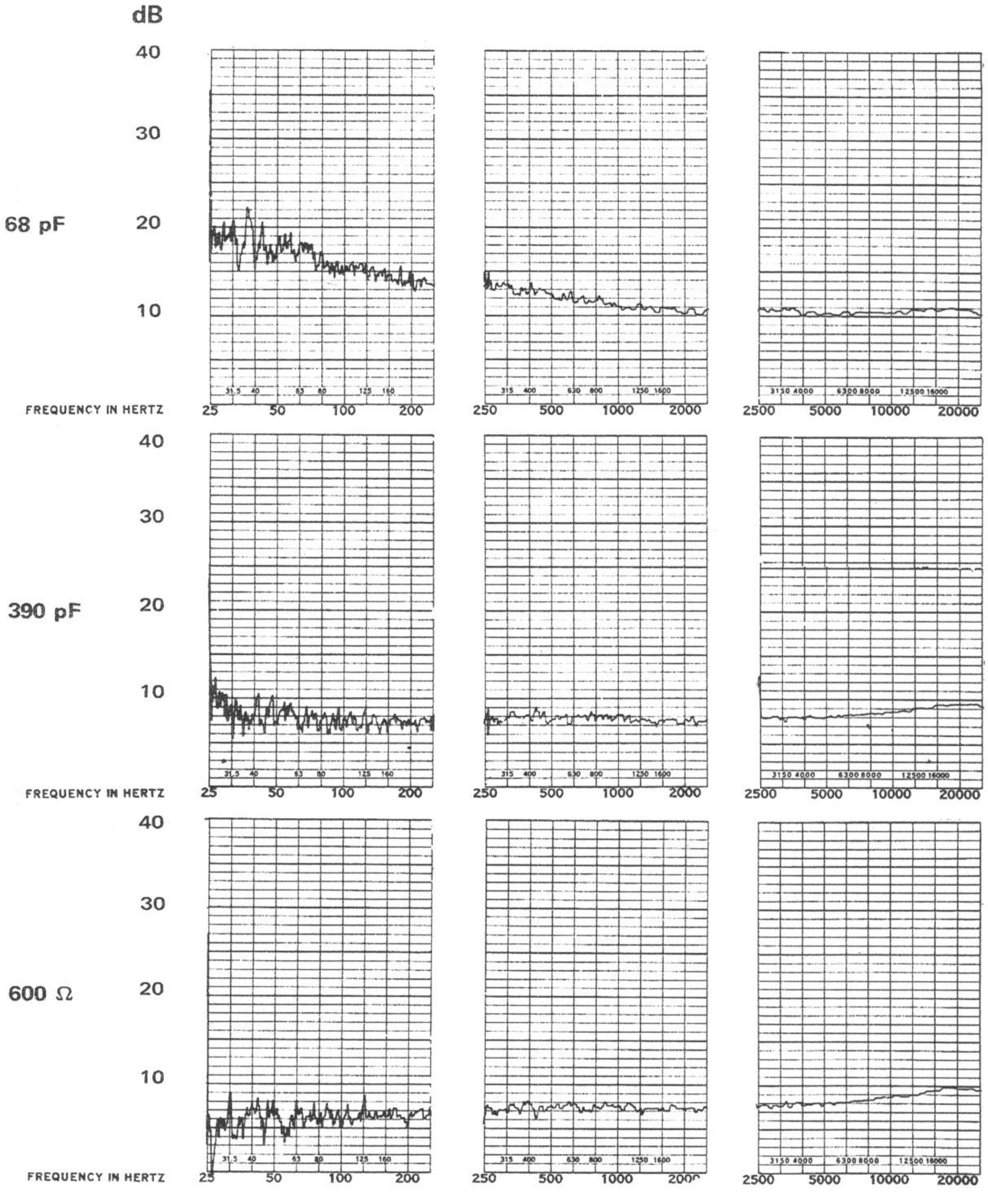


FIGURE 4-12 (cont)

4.5.2 Oscillator Noise.

The source of the polarizing-voltage for condenser microphones is a dc-to-dc converter consisting of a blocking oscillator and doubler-rectifier-filter circuit. The oscillator frequency is typically 60 kHz. Residual oscillator noise is filtered out by the weighting networks or by the filters in the subsequent analyzer.

An analysis using a 1/4-in. or 1/8-in. microphone may require measurements within the frequency range of the oscillator operation. The user should be aware of the magnitude of the oscillator spurs in any analysis. Equivalent input-signal peaks of approximately 6 μV on X1 gain or 18 μV on X10 gain at the fundamental oscillator frequency are typical. Upper harmonic spurs are 3-4 dB lower in magnitude. The size of the spur is relatively independent of the microphone capacitance. Refer to Figure 4-11 to relate this undesired signal level to the equivalent input sound-pressure level for the particular microphone being used.

4.5.3 Low-Supply-Voltage Noise (Oscillator Motorboating).

If the power-supply voltage drops below + 15 V dc, the 200-V polarizing supply will not regulate properly. The result is a low-frequency noise produced by changes in the polarizing voltage. To verify this cause, switch off the 200-V polarizing voltage (the switch on the 1560-P42). If, after the amplifier stabilizes, the noise disappears, a low power-supply voltage should be suspected. Note that condenser-microphone operation requires 2-3 mA more supply current than operation with ceramic microphones. With long cables, the power-supply voltage will drop as a result of quiescent and signal currents. Refer to Table 1-2 to determine whether or not the power supply is operating out of its range.

4.5.4 Power-Supply-Noise Rejection.

If the 1560-P42 Preamplifier is driven from a noisy power source (such as a dc-dc converter regulator), it is often useful to know the degree with which power-supply noise will interfere with the signal. A measure of power-supply noise attenuation vs frequency for a typical microphone/preamplifier combination is given in Table 4-3.

Table 4-3.

Attenuation of power-supply noise*

Frequency (Hz)	Rejection (dB)	
	X1 Gain	X10 Gain
2	−29	−11
10	−40	−20
100	−46	−25
1,000	−46	−25
10,000	−46	−25
100,000	−44	−17

***Measured at the output of the 1560-P42 Preamplifier. Source capacitance of microphone is 390 pF.**

4.6 CIRCUIT DESCRIPTION.

4.6.1 Amplifier Section.

The 1560-P42 Preamplifier consists of two main sections: an amplifier, to provide the gain, and an oscillator, to furnish the polarizing voltage for condenser microphones. To provide the high impedance required for use with either ceramic or condenser microphones, the 3-stage amplifier section incorporates a low-noise FET (Q1) in the input (refer to the schematic diagram, Figure 4-18).

The incoming signal is ac coupled to the gate of Q1. The gate potential is established by the voltage divider, R2 and R3. Approximately half of the dc power-supply voltage is introduced at the gate of Q1. For maximum gain and minimum noise, Q1 should operate near its IDSS value (the value of the current through the drain when the source is shorted to the gate). Resistors R5 and R8 are factory selected, to establish a bias for Q1 such that it will operate near its IDSS value.
Protection against input surges is provided by diodes CR1 and CR2.

A complete dc feedback loop gives increased stability. The 2-position GAIN switch (SW1) is located in the feedback path.

The class AB output stage (Q3, Q4) provides up to 10 mA peak and greater than 1 V rms, to feed long lengths of cable. Crossover distortion is reduced by slight bias via double diode CR3 and resistors R12 and R13. The loading of voltage amplifier Q2 is kept to a minimum by use of high-gain transistors, Q3 and Q4.

A slight roll-off at high frequencies is produced by C3 and R9, to eliminate oscillations at unity gain.

Because of the capacitive nature of the microphones, loading of the capacitive element should be minimized. This is accomplished by placing a driven shield around the input lead. The shield is driven from the source of Q1. Thus, effectively, no potential difference exists between the shield and the input lead, and, during measurements, loading is kept to a minimum.

The output impedance of the Preamplifier is very low (15 Ω in series with 3.3 μF). Normally, it should feed a 100 kΩ (or higher) impedance such as that of a sound-level meter or analyzer. Resistor R15 is inserted in series with the load and provides additional phase margin for capacitive loads. It also prevents damage to the Preamplifier if the output is inadvertently shorted. To give additional short-circuit protection ***the current from any power supply used with the Preamplifier must be limited to 15-20 mA***, as is the case with most GR analyzers and the 1560-P62 Power Supply.

4.6.2 Oscillator Section.

The oscillator section of the Preamplifier supplies the 200 V required by condenser microphones for polarization. This voltage is derived from the pulse transformer T1 and transistor Q5. The oscillator operates at approximately 60 kHz, well above the usual audio spectrum.
Capacitor C6 is charged through resistor R16, turning on transistor Q5. The feedback winding of oscillator transformer, T1, turns off Q5. The turn-on pulse is

transformed by T1 to > +100 V output pulse. Diodes CR5, 6, and 7 serve as a voltage doubler and CR8 is a low-noise rectifier with a breakdown of 200 V.

4.7 SERVICE AND MAINTENANCE.

4.7.1 GR Field Service.

The 1560-P42 Preamplifier is covered by the two-year warranty given at the front of this manual.

The two-year warranty attests the quality of materials and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible. If the difficulty cannot be eliminated by use of the following service instructions, please write or phone our Service Department giving full information of the trouble and of steps taken to remedy it. Be sure to mention the serial, ID, and type numbers of the instrument.

4.7.2 Instrument Return.

Before returning an instrument to General Radio for service, please contact our Service Department or nearest District Office requesting a "Returned Material" number. Use of this number will ensure proper handling and identification. For instruments not covered by the warranty, a purchase order should be forwarded to avoid unnecessary delay.

4.7.3 Minimum – Performance Standards.

The equipment listed in Table 4-4 is required for incoming inspection, periodic operational checks, or trouble analysis of the Preamplifier. The procedures are given in the following paragraphs.

The special dummy microphone used for the noise test consists of a Switchcraft 390P1 adaptor with a 390-pF capacitor inserted between terminals 1 and 3, on one end.

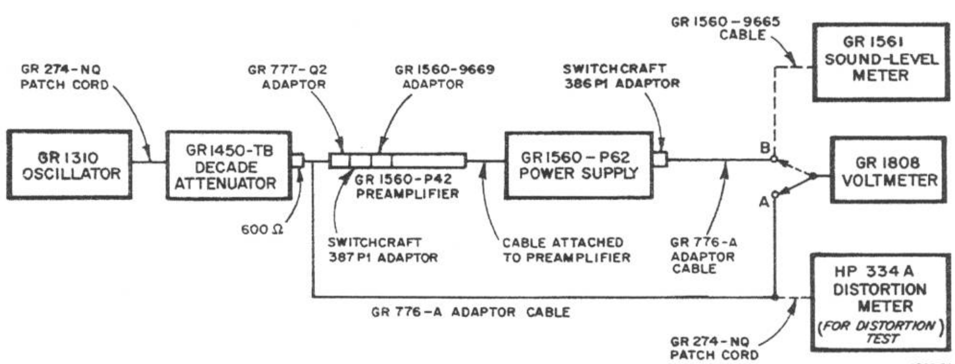


Figure 4-13. Test setup for minimum-performance checks.

Table 4-4

TEST EQUIPMENT

Name	Minimum Requirements	Recommended*
Oscillator	3 Hz-500 kHz 100 mV – 1 V open circuit	GR Type 1310
Decade Attenuator	0-40 dB in 10-dB steps	GR Type 1450-TB
Sound-Level meter	40-150 dB C Weighting	GR Type 1561
Distortion Analyzer	To measure <0.25% distortion	Hewlett Packard Distortion Meter, Model 334A
Ac Voltmeter	100 mV – 1 V	GR Type 1808
Voltmeter	0.2 – 2 V 3 – 20 Hz	Ballantine 316
Power Supply	20 V dc, 15 mA	GR Type 1560-P62
Resistor	600 Ω ±1% (termination)	
Patch cord (2 needed)	GR274 to GR274, 3 ft	GR Type 274-NQ
Adaptor cable (2 needed)	GR274 to BNC plug (male)	GR Type 776-A
Shielded cable	3-pin microphone connector (male) to 3-pin microphone connector (female)	GR Type 1560-9665
Adaptor	GR274 to phone jack	GR 777-Q2
Adaptor	Phone plug to 3-pin female microphone connector	Switchcraft 387P1
Adaptor	3-pin microphone connector	GR 1560-9669
Adaptor	3-pin female microphone connector to BNC plug	Switchcraft 386P1
Special Dummy Microphone	(refer to text)	
Voltmeter	0-25 V, 20,000 Ω/V, accuracy ±2%	GR Type 1806
Oscilloscope	Bandwidth – 50 MHz Rise Time – 1 ns	Tektronix Model 547 with 1A1 plug-in unit

*or equivalent

Gain Check (X1). Make the setup shown in Figure 4-13. The 1808 Voltmeter is to be connected alternately at the output of the 1450-TB Decade Attenuator (connection A in the diagram) and the output of the 1560-P62 Power Supply (connection B).

Use the following procedure:

Set

1450-TB	Attenuation — 0 dB
1310-B	FREQUENCY — 1 kHz
	OUTPUT — 1 V rms
1560-P42	200 V switch — OFF
	GAIN switch — X1
1560-P62	Switch — LINE ON
1808	METER RANGE — 1.5 V

a. Adjust the 1310 output for a reading of +8 dB on the meter at the output of the 1450 attenuator (connection A).

b. Change to connection B. The 1808 must now read 8 ±0.3 dB.

Gain Check (X10). Change the above settings of Figure 4-13 as follows:

1450-TB	Attenuation — 20 dB
1560-P42	GAIN switch — X10

The 1808 must now read 8 ± 0.3 dB.

Frequency Check. Using either the 1808 Voltmeter or the Ballantine 316 Voltmeter in the setup of Figure 4-13, make the frequency measurements indicated in Table 4-5. In each case, perform step A with the voltmeter at point A, then step B, voltmeter at point B.

Table 4-5
FREQUENCY CHECKS

1310 Frequency	1560-P42 Gain	Voltmeter Used	1450-TB Attenuation (dB)	Step A — Reference On Voltmeter: Range	Step A — Reference On Voltmeter: dB Setting	Step B — 1560-P42 Output (dB)
3 Hz	X1	316	20	2 V	10	7 to 13
5 Hz	X1	316	20	2 V	10	9 to 11
20 Hz	X1	316	20	2 V	10	9.75 to 10.25
3 Hz	X10	316	40	0.2 V	10	7 to 13
5 Hz	X10	316	40	0.2 V	10	8.5 to 11.5
20 Hz	X10	316	40	0.2 V	10	9.7 to 10.3
100 Hz	X1	1808	20	1.5 V	8	7.75 to 8.25
10 kHz	X1	1808	20	1.5 V	8	7.75 to 8.25
100 kHz	X1	1808	20	1.5 V	8	7.75 to 8.25
500 kHz	X1	1808	20	1.5 V	8	7 to 9
100 Hz	X10	1808	40	0.15 V	8	7.7 to 8.3
10 kHz	X10	1808	40	0.15 V	8	7.7 to 8.3
100 kHz	X10	1808	40	0.15 V	8	7.7 to 8.3
300 kHz	X10	1808	40	0.15 V	8	6 to 10

Noise Check. In the setup of Figure 4-13, connect the 1808 Voltmeter to point A and the 1561 Sound-Level Meter to point B (the output from the 1560-P62 Power Supply); use the GR 1560-9665 cable. The procedure is given below.

a. Set:

1450-TB	Attenuation – 20 dB
1310-B	FREQUENCY – 1 kHz
	OUTPUT – 100 mV (read on 1808)
1808	METER RANGE – 150 mV
1560-P42	GAIN – X10
	200 V – OFF
1560-P62	Switch – BAT ON (no power cord connected)
1561	Attenuation – 130 dB
	WEIGHTING – C
	METER – SLOW

b. Adjust the CAL control on the 1561 so that its meter reads 134 dB.

c. Remove the input to the 1560-P42 at the output of the 387-P1 adaptor. With the 1560-9669 adaptor still in place, insert the dummy microphone at the input.

d. Change the 1561 attenuation to 40 dB.

The 1561 must now read less than 45 dB.

Distortion Check. Make the setup of Figure 4-13. Connect the 334A Distortion Meter to point B.

a. Set:

1450-TB	Attenuation – 0 dB
1310-B	FREQUENCY – 1 kHz
	OUTPUT – 1 V rms
1560-P42	GAIN – X1
	200 V – OFF
1560-P62	Switch – LINE ON
334A	FUNCTION – DISTORTION

b. Measure the distortion on the 334A to be less than 0.25%.

c. Change the output from the 1310-B to 0.1 V rms (at the input to the 1560-P42) and set the GAIN switch on the 1560-P42 at X10. Again the distortion must be less than 0.25%. If the distortion is higher, check the oscillator distortion (at point B).

4.7.4 Trouble Analysis.

The following details should be helpful in locating the faulty component, if trouble develops in the Preamplifier. When components are disconnected or replaced, use good soldering technique. Use a small tip on the iron and fine-gauge solder. Keep the heat to a minimum.

Amplifier Section. Terminate the input in 600 Ω and turn the 200 V switch off. Table 4-6 gives the transistor voltages with a power-supply voltage of 20 V. Use the GR 1806 Voltmeter (or equivalent) for the measurements. Connect the negative terminal to the ground of the power supply (not to the Preamplifier shield). Be sure pin #1 is connected to ground.

Also, check the + terminal of capacitor C4. With the GAIN switch on X10, this should be approximately 10 V (1/2 of the power-supply voltage). If C4 is at B+, Q2 is probably shorted, and should be replaced (see base connections on the schematic diagram). A short circuit between the drain and source of Q1 will cause Q2 to conduct too heavily, in which case, replace Q1. If it is replaced, resistors R5 and R8 must be selected according to the IDSS value of Q1, the value of the current through the drain when the source is shorted to the gate. Determine the IDSS value by using the circuit of Figure 4-14. Then select Allen Bradley 1/8-W, 5% resistors as shown by Table 4-7.

CAUTION

When changing Q1, use a small soldering-iron tip and fine-gauge solder, with only enough heat to produce good connections. Overheating diode CR1 or CR2 may produce noise, requiring its replacement.

Table 4-6

TRANSISTOR VOLTAGES

	Location	Volts
Q1	—— gate	——
	—— source	11.5
	—— drain	+19.4 (-0.6)
Q2	—— emitter	20.0
	—— base	19.4
	—— colleetor	12.0
Q3	—— emitter	11.4
	—— base	12.0
	—— collector	20.0
Q4	—— emitter	11.4
	—— base	10.8
	—— collector	gnd

Table 4-7

SELECTION OF BIAS RESISTORS FOR Q1.

IDSS Value of Q1 (μA)	R5 (kΩ)	R8 (kΩ)
50-100	12	150
100-175	6.2	75
175-250	3.3	43

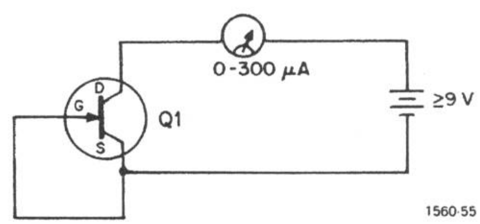


Figure 4-14. Circuit for the determination of the IDSS value of Q1.

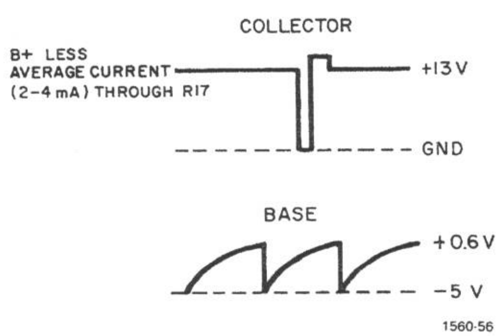
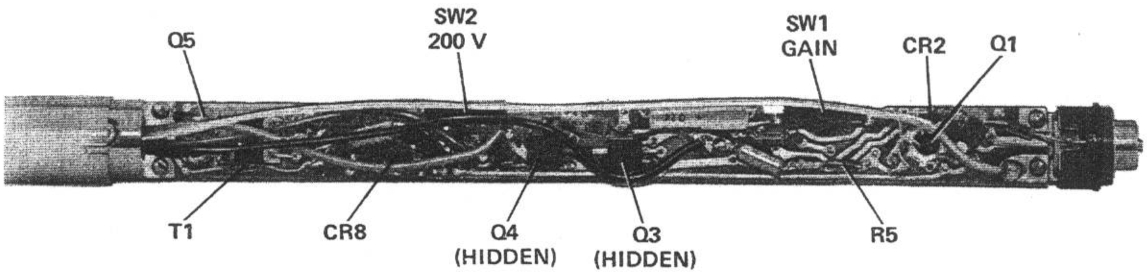


Figure 4-15. Waveforms at transistor Q5.

Oscillator Section. Check the waveforms at Q5, using the fast-rise-time pulse oscilloscope. The waveforms are shown in Figure 4-15.

A dc check for continuity can be made on the transformer windings.

To check for 100 V at the junction of CR5 and CR6, use the 1806 Voltmeter on OPEN GRID. There should be 200 V at the anode of CR7. Diodes CR5, 6, and 7 are very fast rise- and recovery-time diodes, rated at 225 V. Replacements should be made only with type 1N661 diodes, from Texas Instruments Incorporated (Dallas, Texas).



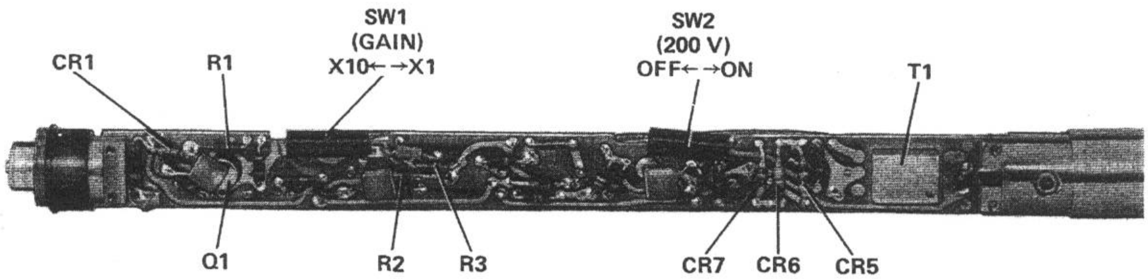


Figure 4-16. Interior views of the 1560-P42 Preamplifier; (top) circuit side of etched-circuit board; (bottom) component side.

1560-P42 PREAMPLIFIER

ELECTRICAL PARTS LIST

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
CAPACITORS					
C1	Ceramic, .001 µF, 10%, 200 V	4400-6440	72982	8121-026-X5RO-102K	
C2	Electrolytic, 80 µF, 20%, 15 V	4450-6300	37942	MTP, 80 µF, 20%	
C3	Ceramic, .001 µF, 10%, 200 V	4400-6440	72982	8121-026-X5RO-102K	
C4	Electrolytic, 3.3 µF, 20%, 60 V	4450-6310	37942	MTP, 3.3 µF, 20%	
C5	Electrolytic, 10 µF, 20%, 30 V	4450-6320	37942	MTP, 10 µF, 20%	
C6	Ceramic, 330 pF, 10%, 200 V	4400-6441	72982	8111-026-X5RO-331K	
C7	Electrolytic, 1 µF, 20%, 35 V	4450-6400	56289	162-D, 1 µF, 20%	
C8	Ceramic, .001 µF, 10%, 200 V	4400-6440	72982	8121-026-X5RO-102K	
C9	Ceramic, .001 µF, 10%, 200 V	4400-6440	72982	8121-026-X5RO-102K	
C10	Ceramic, .001 µF, 10%, 200 V	4400-6440	72982	8121-026-X5RO-102K	
C11	Ceramic, .01 µF ±20% 200 V	4400-6444	72982	8121-M200-651-103M	
C12	Ceramic, .001 µF, 10%, 200 V	4400-6440	72982	8121-026-X5RO-102K	
CONNECTORS					
PL1	Multiple Plug	4220-3000	82389	83M	
PL2	Multiple Plug	4230-2500	82389	A3F	
DIODES					
CR1	Type DHD707	6082-1009	07910	DHD707	5961-929-9967
CR2	Type DHD707	6082-1009	07910	DHD707	5961-929-9967
CR3	MPD200	6082-1033	06751	MPD-200	
CR4	Type DHD707	6082-1009	07910	DHD707	5961-929-9967
CR5	Type 1N661/TI-UNI-G Package	6082-1032	06751	1N661	
CR6	Type 1N661/TI-UNI-G Package	6082-1032	06751	1N661	
CR7	Type 1N661/TI-UNI-G Package	6082-1032	06751	1N661	
CR8	Type CSR-1758D	6083-1079	07910	CSR1758D	
CR9	Type 1N750	6083-1003	07910	1N750	
RESISTORS					
R1	Comp., 100 MΩ, 10%, 1/8 W	6098-7109	01121	BB, 100 MΩ, 10%	
R2	Comp., 100 kΩ, 5%, 1/8 W	6098-4105	01121	BB, 100 kΩ, 5%	

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.
RESISTORS (Cont)				
R3	Comp., 120 kΩ, 5%, 1/8 W	6098-4125	01121	BB, 120 kΩ, 5%
R4	Comp., 1 GΩ, 20%, 1/8 W	6098-8108	01121	BB, 1 GΩ, 20%
*R5	Comp., 3.3 k-12 kΩ, 5%, 1/8 W	6098-2335, -2625 or -3125	01121	BB, 3.3 k-12 kΩ, 5%
R6	Comp., 3.0 kΩ, 5%, 1/8 W	6098-2305	01121	BB, 3.0 kΩ, 5%
R7	Film, 1.05 kΩ, 1%, 1//0 W	6619-3100	75042	CEA-TO, 1.05 kΩ, 1%
*R8	Comp., 43 k-150 kΩ, 5%, 1/8 W	6098-3435, -3755 or -4155	01121	BB, 43 k-150 kΩ, 5%
R9	Comp., 100 Ω, 5%, 1/8 W	6098-1105	01121	BB, 100 Ω, 5%
R10	Film, 10.6 kΩ, 1%, 1//0 W	6619-3101	75042	CEA-TO, 10.6 kΩ, 1%
R11	Comp., 10 kΩ, 5%, 1/8 W	6098-3105	01121	BB, 10 kΩ, 5%
R12	Comp., 27 Ω, 5%, 1/8 W	6098-0275	01121	BB, 27 Ω, 5%
R13	Comp., 27 Ω, 5%, 1/8 W	6098-0275	01121	BB, 27 Ω, 5%
R14	Comp., 100 kΩ, 5%, 1/8 W	6098-4105	01121	BB, 100 kΩ, 5%
R15	Comp., 10 Ω, 5%, 1/4 W	6099-0105	01121	BB, 10 Ω, 5%
R16	Comp., 100 kΩ, 5%, 1/8 W	6098-4105	01121	BB, 100 kΩ, 5%
R17	Comp., 220 Ω ±5%	6098-1225	01121	BB 220 Ω ±5%
R18	Comp., 10 MΩ, 5%, 1/8 W	6098-6109	01121	BB, 10 MΩ, 5%
R19	Comp., 100 MΩ, 10%, 1/8 W	6098-7109	01121	BB, 100 MΩ, 5%
R20	Comp., 10 Ω, 5%, 1/8 W	6098-0105	01121	BB, 10 Ω, 5%
R21	Comp., 3 kΩ, 5%, 1/8 W	6098-2305	01121	BB, 3 kΩ, 5%
R22	Comp., 100 MΩ, 10%, 1/8 W	6098-7109	01121	BB, 100 MΩ, 10%
SWITCHES				
SW1		(1560-7620) (1560-8700)	24655	1560-7620, 1560-8700
SW2		(1560-7620) (1560-8700)	24655	1560-7620, 1560-8700
TRANSFORMERS				
T1	Transformer Asm.	1560-4140	24655	1560-4140
TRANSISTORS				
Q1	Type 2N3457	8210-1082	17856	2N3457
Q2	Type D30A3	8210-1204	24454	D30A3
Q3	Type 2N4124	8210-1154	04713	2N4124
Q4	Type 2N3906	8210-1112	04713	2N3906
Q5	Type D26E1	8210-1205	24454	D2GE1

Lab Adjust

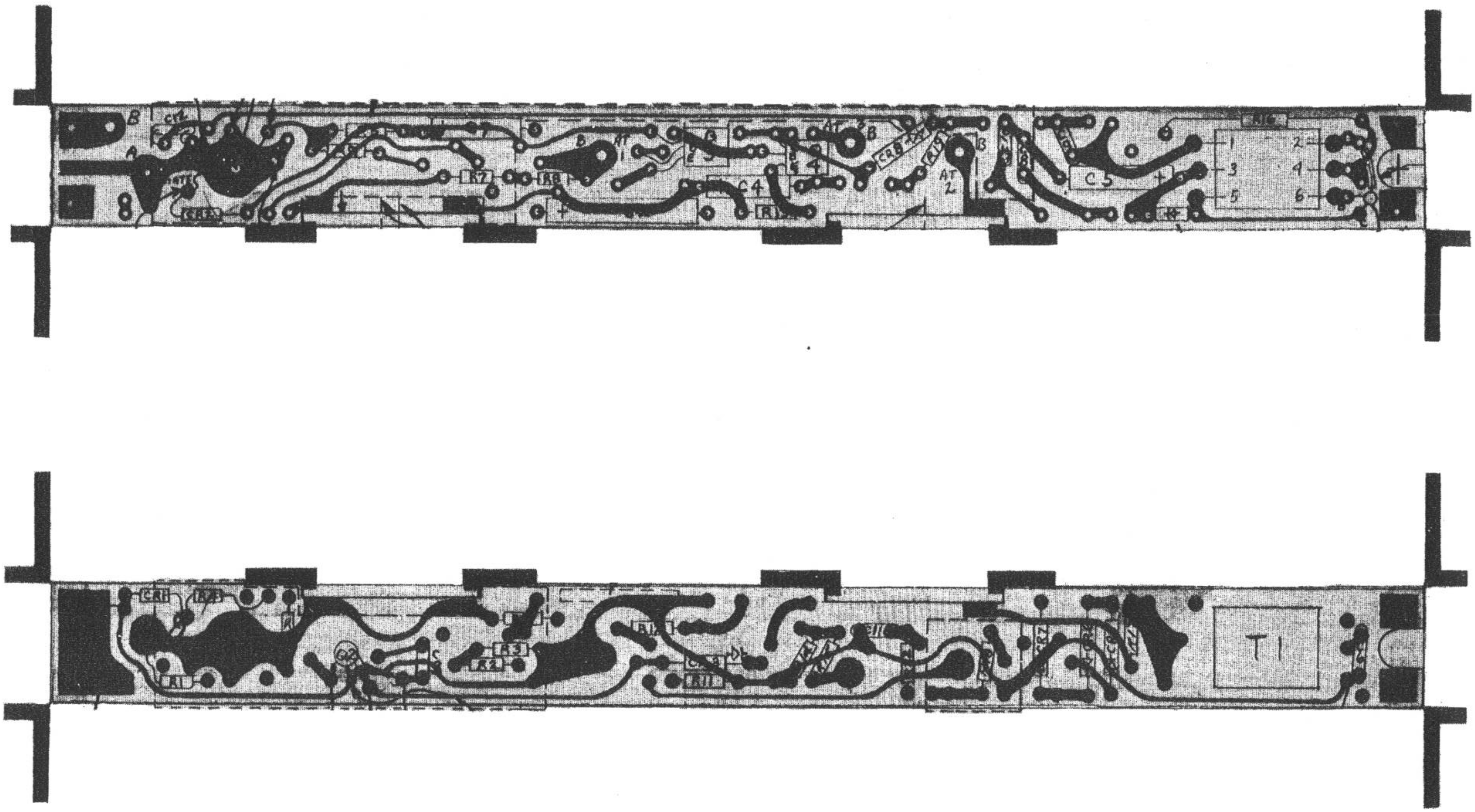


Figure 4-17. Etched-circuit board (P/N 1560-2791) for the 1560-P42 Preamplifier; (top) circuit side; (bottom) component side.

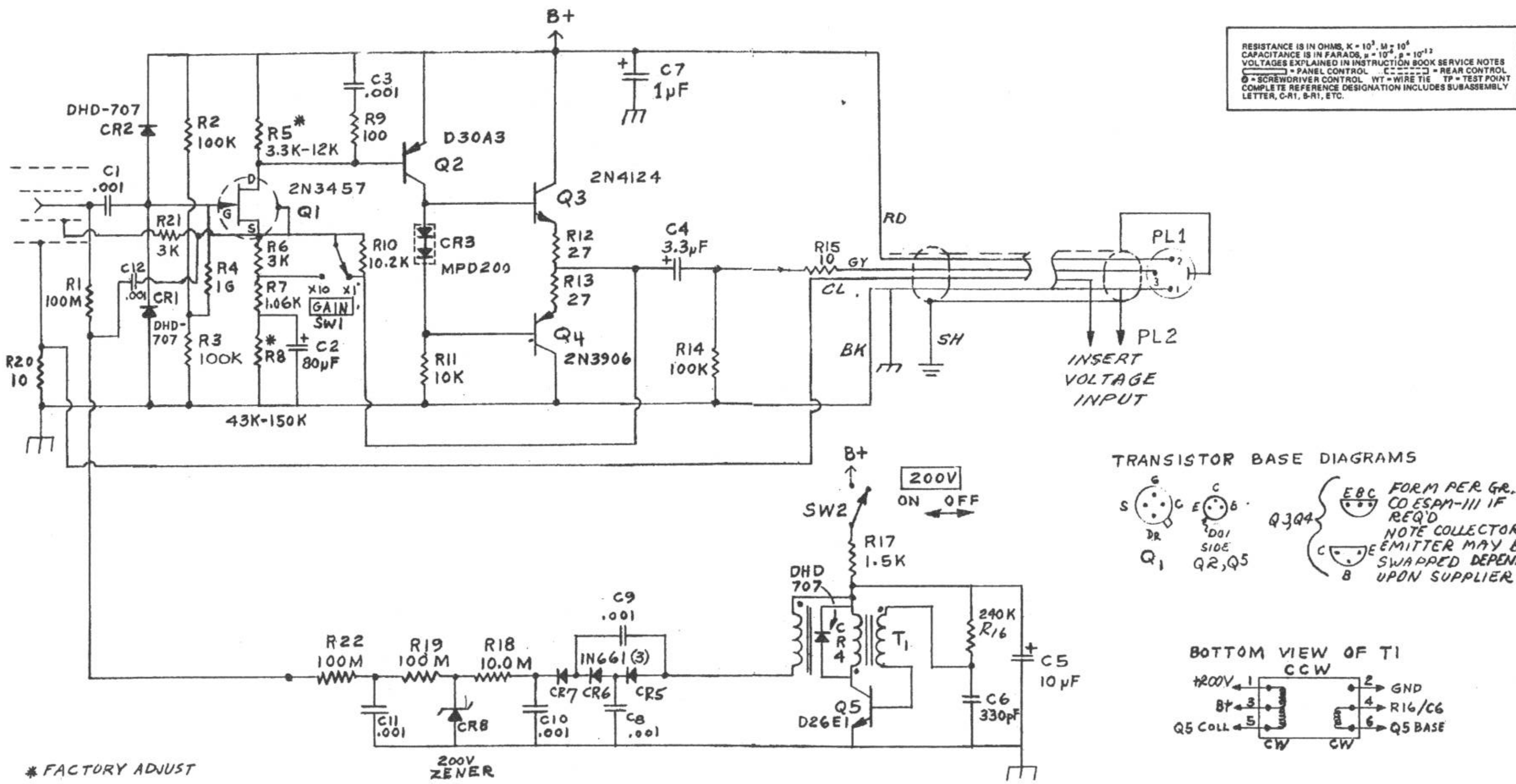


Figure 4-18. Schematic diagram for the 1560-P42 Preamplifier.

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