LOW NOISE PREAMPLIFIER

LI-75A

INSTRUCTION MANUAL

NF Corporation

57977

MODEL **LI-75A**

LOW NOISE PREAMPLIFIER

INSTRUCTION MANUAL

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SUPPLEMENTARY FIGURES

1. GENERAL DESCRIPTION

1.1 Outline

The LI-75A Low-Noise Preamplifier is intended for use as a preamplifier with the LI-570 Series of lock-in amplifiers.

AC/DC coupling switching and balanced/unbalanced input switching is provided. The input impedance is 100M .

The output is unbalanced and the maximum output voltage is ±10V. The LI-75A is suitable for use with any of the LI-570 Series lock-in amplifiers.

The gain from input to output is fixed at x100 (40dB), and the frequency response ranges from DC to 1MHz. The typical internal noise of the LI-75A is an extremely low 1.2nV/$\sqrt{Hz}$ (1kHz), making it ideal for use in measurement of extremely low level voltages.

When using the LI-75A with lock-in amplifiers other than the LI-570 or 575 (LI-572B, 573, or 574A), the addition of a model PS-70 DC power supply is required.

1.2 Features

* Low noise	1.2nV/$\sqrt{Hz}$ (1kHz), typical
* High common mode rejection ratio	120dB (DC ∿ 100Hz)
* Wide bandwidth	DC ∿ 1MHz
* High input impedance	100MΩ
* Wide dynamic range	150dB or greater
* Excessive input level indicator	

1.3 Specifications (Unless otherwise noted, DC coupling applies)

1.3.1 Input

Input coupling selection	AC/DC
Input connector	BNC-R

Input modes	
A (FLOAT)	Unbalanced
A (GND)	Unbalanced
A-B (GND)	Balanced
Input impedance	100MΩ, 50pF or less input capacitance 0.016 μF coupling capacitance for AC coupling
Common mode input voltage range	±5V (DC ∿ 100Hz, mode A-B, refer to Fig. 6-1
Common mode rejection ratio	120dB (DC ∿ 100Hz, mode A-B, refer to Fig. 6-2)
Input-referred noise level	2nV/$\sqrt{Hz}$ or less (1kHz) With input shorted (refer to Fig. 6-3 and 6-3)
Input-referred offset voltage	Adjustable to 0 (typical drift 10 V/°C)
Maximum allowable input voltage	
DC Coupling	±15V
AC Coupling	±100VDC, ±15VAC

1.3.2 Output

Output connector	Unbalanced (BNC-R)
Maximum output voltage	±10V (2kΩ load, DC ∿ 200kHz) Refer to Fig. 6-5
Output impedance	Approx. 50Ω (400Hz)

1.3.3 Input/Output Characteristics

Gain	x100 (40dB) ±1% (400Hz)

Frequency response	With output level of 3Vrms into a 2kΩ load
DC Coupling	DC ∿ 1MHz $\binom{+1}{-3}$ dB
AC Coupling	0.2Hz ∿ 1MHz $\binom{+1}{-3}$ dB (Refer to Fig. 6-6)
Harmonic distortion	0.03% or less (1kHz) (Refer to Fig. 6-7)

1.3.4 Power Supply

1.3.5 Environmental Conditions

Operating	0° ∿ +40°C, 10 ∿ 90% RH
Storage	-10° ∿ +60°C, 10 ∿ 80% RH

1.3.6 Dimensions 120(W) x 55(H) x 200(D)mm

1.3.7 Weight 1.15kg

2. PREPARATIONS

2.1 Unpacking

When unpacking the LI-75A, first check that damage has not been caused accidentally during shipping. Sufficient care is taken with the unit before shipping. However, a check should be made of such items as loose controls and that all the required accessories have been included, as listed in the table below.

2.2 Preliminary Inspection

The standard configuration of the LI-75A includes the following listed items which should be checked upon preliminary inspection.

LI-75A Mainframe	1
Instruction manual	1
Accessories	
Input/output cables (BNC-BNC, 1m)	3
Power supply input cable (2-conductor shielded, both sides terminated with a 6P connector, 1.5m)	1

* Note: Optional longer cables in increments of 1m are available upon request.

Table 2-1 Carton Contents

2.3 Outer Dimensions

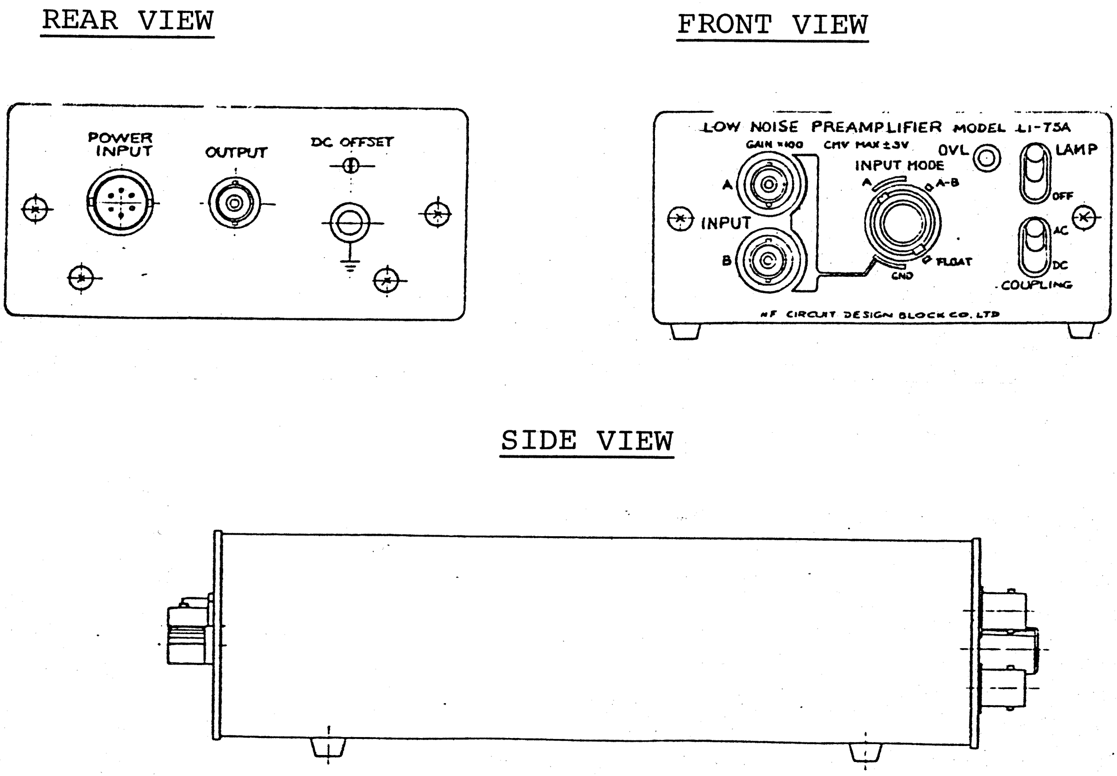


Fig. 2-1 Outer dimensions

2.4 Power Supplies and Grounding

While power supplies and grounding do not cause a problem when using the LI-75A in conjunction with the LI-570/575 power supply output or with the PS-70A power supply, when using the preamplifier with any other type of power supply, take precautions that the power supply span is $\pm 20V \sim \pm 24V$. If operated with a voltage outside of these limits, improper operation as well as damage can occur and this should be avoided at all times.

To ensure safety, it is necessary to ground measuring instruments as well as the system under measurement. This grounding, however, can result in the creation of ground loops which can cause measurement errors and the introduction of noise. Refer to section 3.2 for the correct method of grounding.

3. OPERATION

3.1 Names and Operation of LI-75A Parts

This section will serve to describe the various panel switches and connectors of the LI-75A, using the numbers assigned in Fig. 3-1 below.

Front View

Rear View

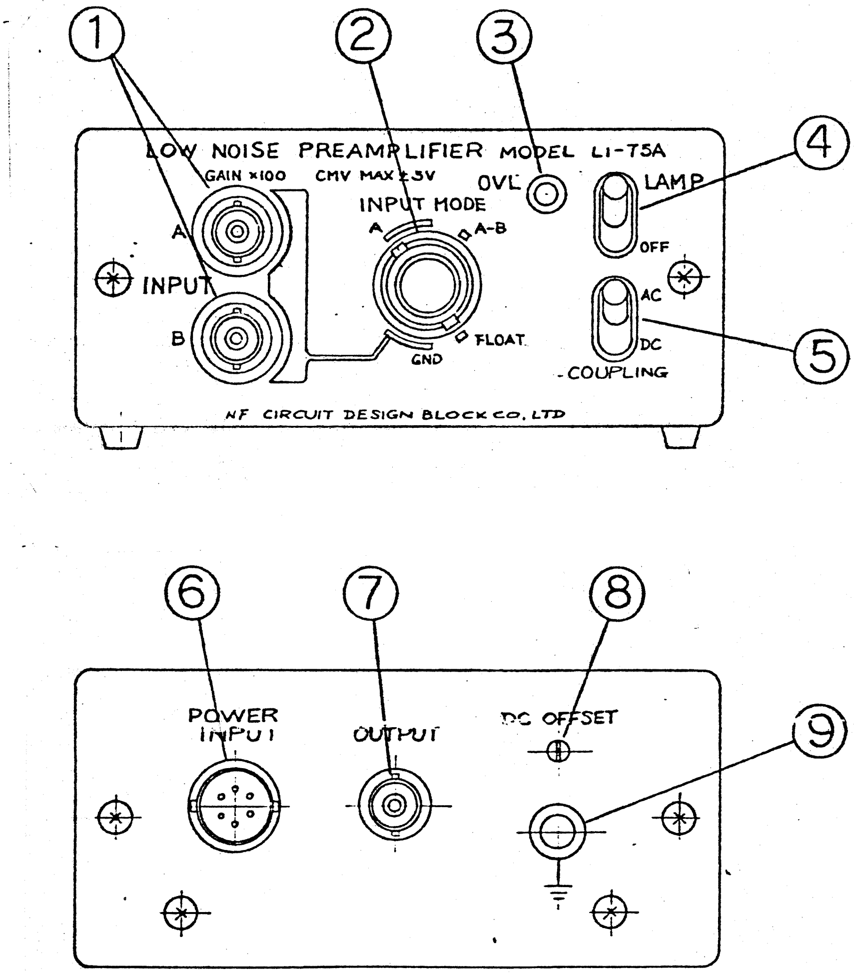


Fig. 3-1 Front and rear panels

1	INPUT A and B Connectors	These are the signal input connectors. Connector A is used for unbalanced input (A (FLOAT) and A (GND)), while connector B is used for balanced input (A-B (GND)).
2	INPUT MODE Switch	This switch is used to select the input mode as A (FLOAT), A (GND), or A-B (GND).
3	OVL Lamp	This lamp indicates an excessive input level. Care is required if the LAMP switch is set to OFF as this lamp will not light, even in the event of excessive input levels.
4	LAMP OFF Switch	This switch is used to extinguish the OVL excessive input lamp.
5	COUPLING AC, DC Input coupling selector	This switch is used to select AC or DC input coupling.
6	POWER INPUT	This is the power input 6-pin metal connector. It is used in conjunction with the accessory cable to provide power to the LI-75A. The pin assignments are as follows. Pin 4: -20V Pin 5: +20V Pin 6: 0V
7	OUTPUT Connector	This is the LI-75A output connector. The output impedance is approximately 50Ω. This does not create a problem when connecting the LI-75A to a lock-in amplifier. However, for other applications, the load resistance should be kept above 2kΩ.
8	DC OFFSET Adjustment	This is the DC offset adjustment trimmer. The output adjustment range is approximately ±0.3V.
9	GND Terminal	This is the LI-75A ground terminal.

3.2 Input and Output Connections

3.2.1 Load Conditions for the Various Connectors

This section will serve to describe the signal source impedance and output connector and load conditions for the input connectors and indicate precautions required with respect to input and output connections.

(a) Input Connector

The input resistance with respect to GND of both input A and B is 100MΩ, the input capacitance being a maximum of 50pF. The relationship between input impedance and frequency is shown in Fig. 3-2.

It is desirable to make the signal source impedance as low as possible, and for differential amplifiers, if the signal source impedance differs between the two inputs, the CMRR (common mode rejection ratio) will be deteriorated. Even if the signal source impedance is the same, if the cable capacitance is not balanced, this deterioration will occur. Therefore, as low an impedance as possible should be used.

(b) Output Connector

The output is unbalanced with an output impedance of 50Ω. The LI-75A may be connected to the LI-570 Series of lock-in amplifiers. When connected to other equipment, the load impedance should be at least 2kΩ.

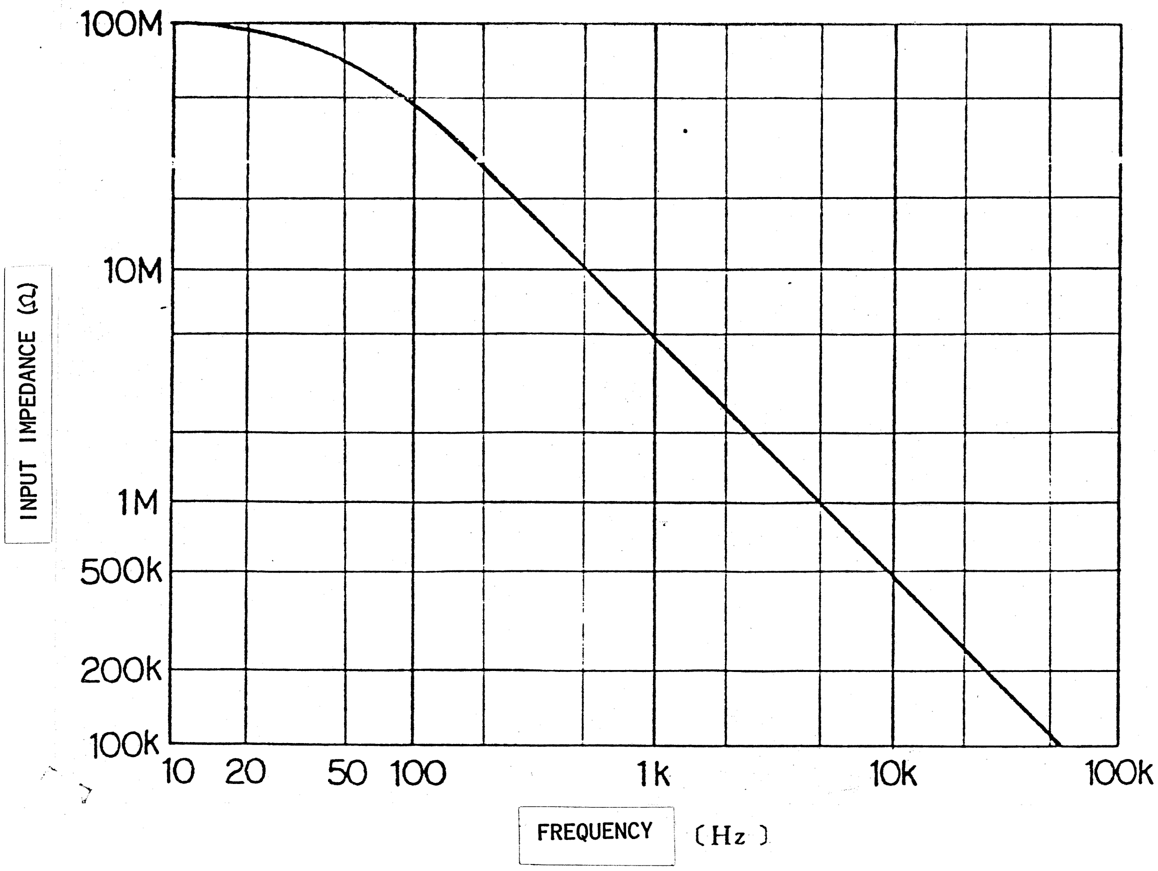


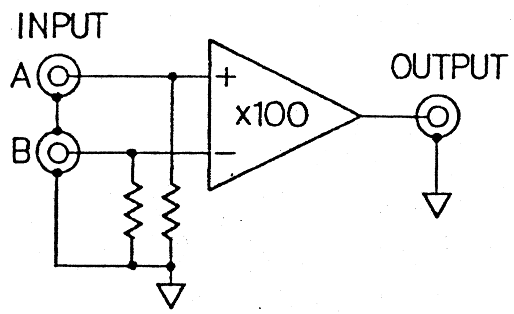
Fig. 3-2 Input impedance curve (typical)

3.2.2 Input Connections

This section will serve to describe the basic methods of making connection to the signal source. Three types of connections are possible.

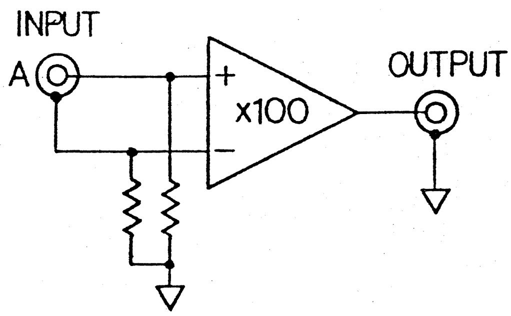
Balanced Input (A-B (GND))

A differential input is used and input connections are made to connectors A and B. This provides the maximum common mode noise rejection and can be used with any application. This connection method is shown below.



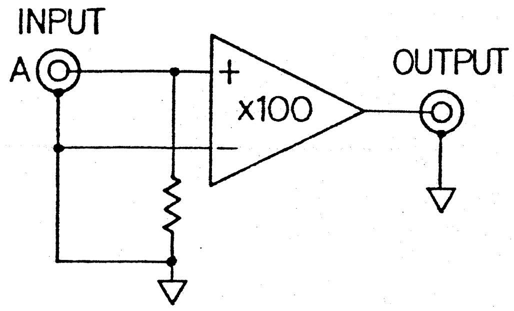
Unbalanced Input (A (FLOAT))

Input connector A is used for unbalanced input. Differential input is used internally and the ground is floated, so that the common mode noise rejection ability is lessened when compared to the DIFFERENTIAL A-B (GND) mode. This connection is shown below.



Unbalanced Input (A (GND))

This unbalanced input also uses connector A. There is no common mode rejection capability with this type of input. It may be used when common mode noise is extremely low in level or when the signal level itself is high. When a signal source is connected, it is not necessary to ground the LI-75A, thus making this mode extremely easy to use. This connection is shown below.



The following points should be considered when making connections between the signal source and the LI-75A and when making ground connections.

* Avoid the creation of ground loops.

* Ensure that the signal voltage is properly connected to the input connector.

* Ensure the minimum noise level.

For the optimum interconnection method, refer to the examples given in section (a) and (b) below.

(a) Connections For a Grounded Signal Source

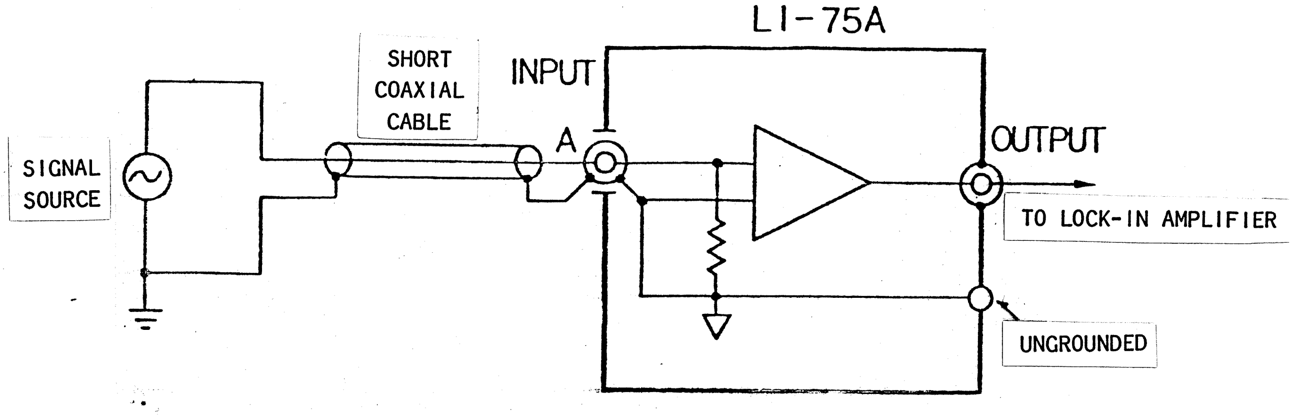


Fig. 3-3 Connections for input mode A (GND)

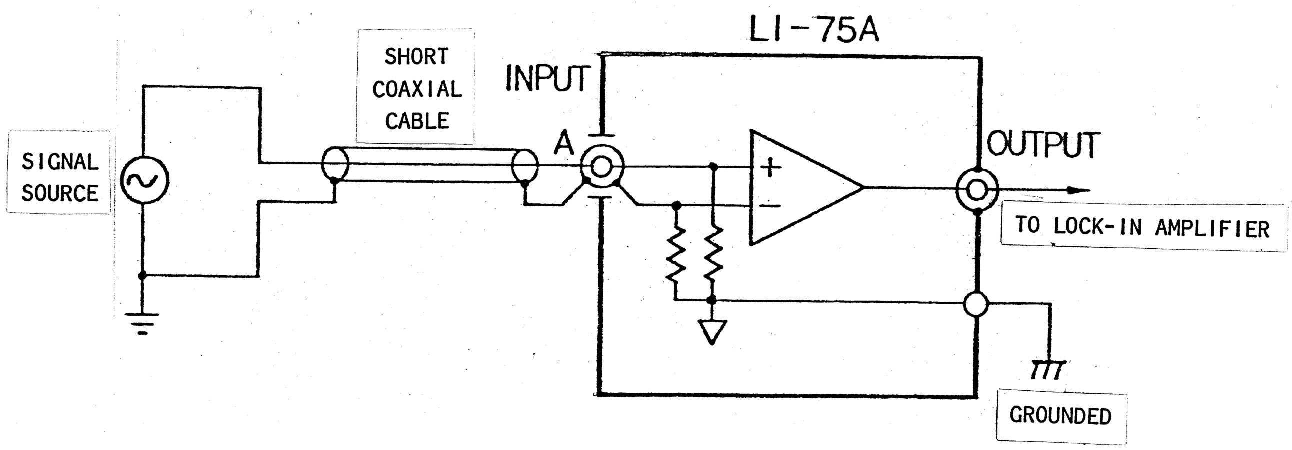


Fig. 3-4 Connections for input mode A (FLOAT)

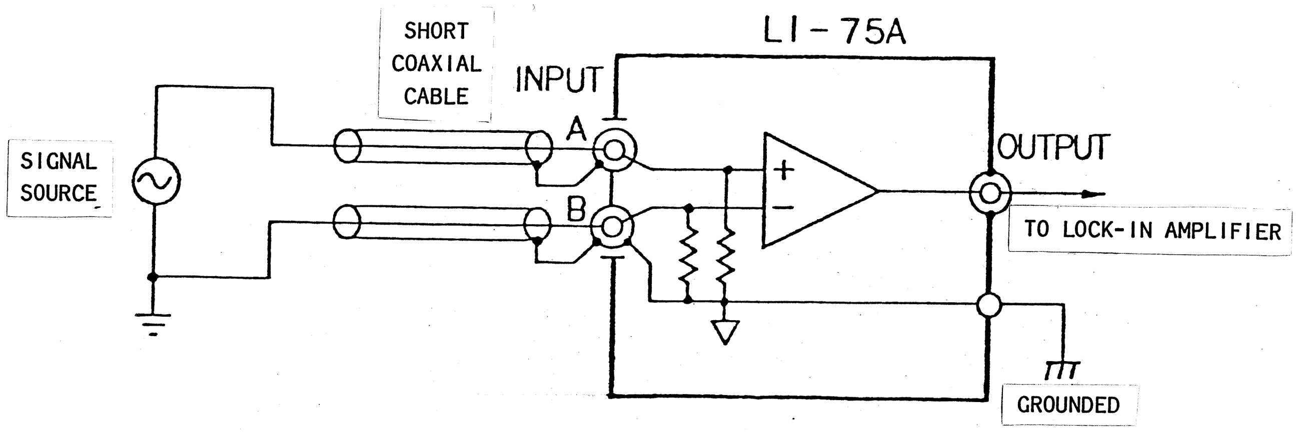


Fig. 3-5 Connections for input mode A-B (GND)

(b) Connections For a Signal Source Which Cannot Be Grounded

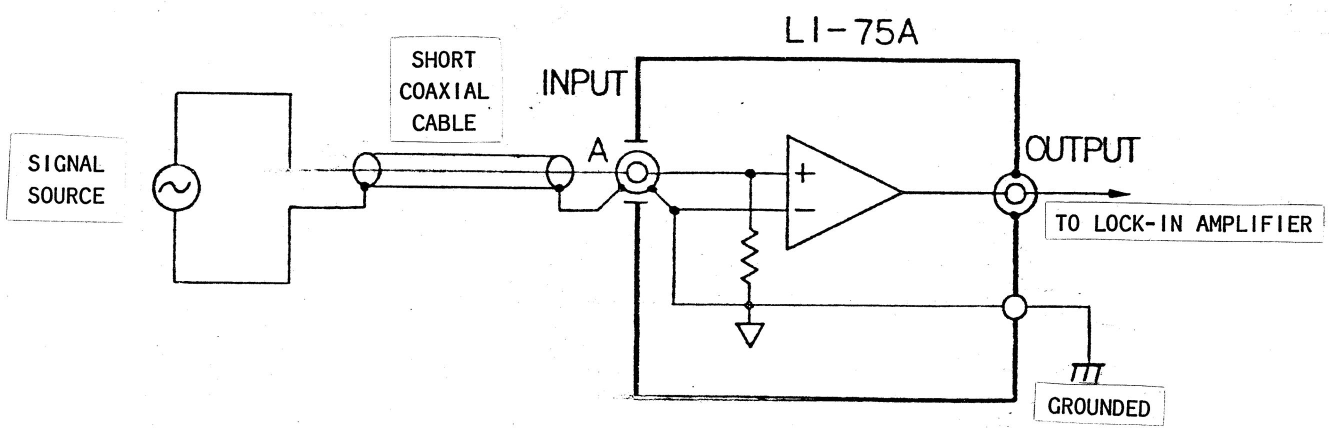


Fig. 3-6 Connections for input mode A (GND)

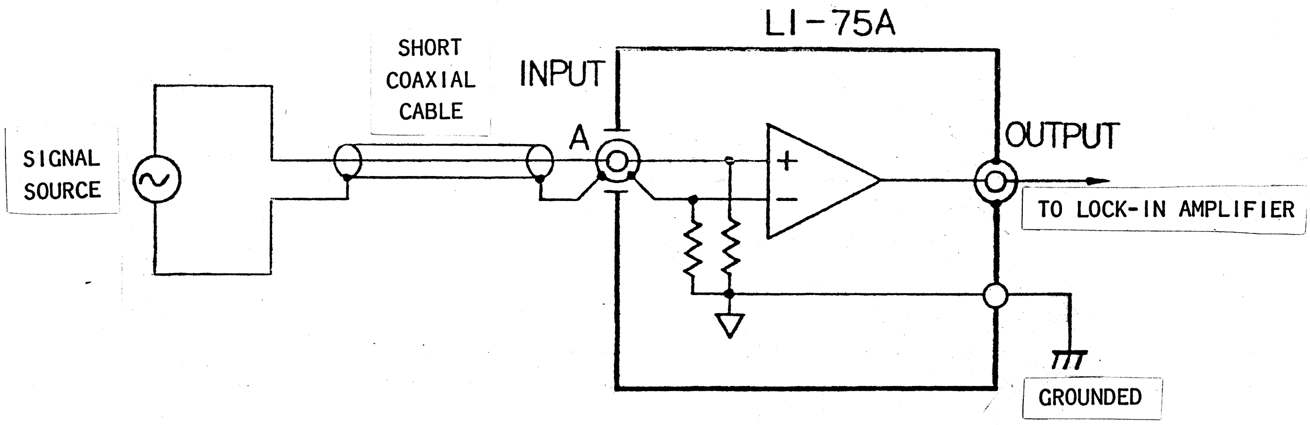


Fig. 3-7 Connections for input mode A (FLOAT)

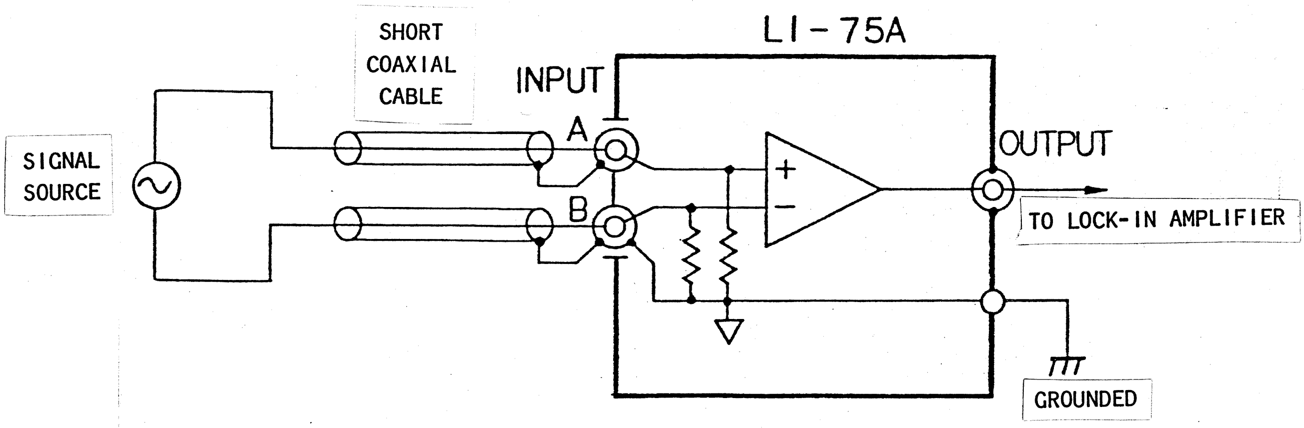


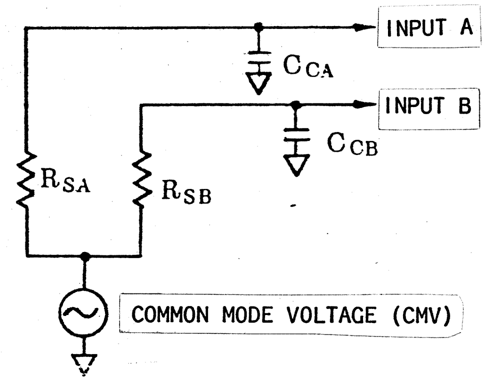
Fig. 3-8 Connections for input mode A-B (GND)

3.2.3 Common Mode Noise

When using the input mode A-B (GND) or A (FLOAT), it is possible to reduce common mode noise. The LI-75A common mode rejection ratio (CMRR) is 120dB or greater in the range DC ∿ 100Hz, with the maximum common mode input voltage in this frequency range being ±5V.

While the actual common mode rejection ratio achieved for these modes depends upon the signal cable and signal source impedance, the common mode noise rejection capability of the A-B (GND) mode is superior. Care should be taken, as in the A (GND) mode, there is no common mode noise rejection capability.

Below is a description of some causes of deterioration in actual common mode rejection ratio.



Common mode voltage input model

R_{SA}: Input A signal source resistance

R_{SB}: Input B signal source resistance

C_{CA}: Input A signal cable capacitance

C_{CB}: Input B signal cable capacitance

In the model above, we can assume that a common mode voltage (CMV) is being applied to the LI-75A input connectors.

1 The CMRR will be worsen if R_{SA} and R_{SB} are large <u>and</u> R_{SA} and R_{SB} are not equal.

2 The CMRR will worsen if C_{CA} and C_{CB} are large (i.e., the signal cables are long) <u>and</u> C_{CA} and C_{CB} are not equal (i.e., the cable lengths are different).

Because of the above-described conditions, to operate the LI-75A at optimum input conditions, it is necessary to make the signal source impedance as low as possible, and make the signal cable capacitance as low as possible (i.e., make the signal cables as short as possible).

3.2.4 Connections To the Lock-In Amplifier

(a) Connections To the LI-575

For either EXT or INT reference signal, the LI-575 input switch must be set to the GND setting.

Refer to section 3.2.2 for the method of connecting the LI-75A to the signal source.

Note: If the signal source and reference signal lines are not isolated, ground loop currents will cause magnification of measurement errors. For this reason, the A-B (GND) or A (FLOAT) input mode should be selected at the LI-75A.

(b) Connections To the LI-570

Set the input switch to FLOAT. Other conditions and connections are the same as for the case of the LI-575.

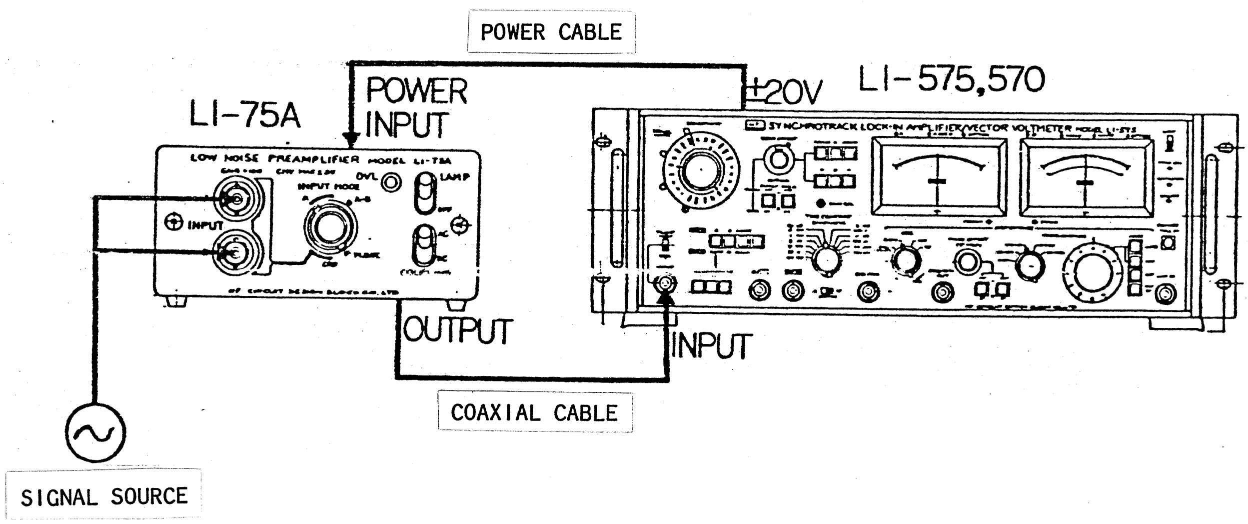


Fig. 3-9 Connections to the LI-575/570 lock-in amplifier

(c) Connections To the LI-572B/573A/574A

Interconnections should be made as shown in Fig. 3-10.

Note: * When using the LI-574A/P-52A, set the P-52A input switch to A (single end).

* If the signal source and reference signal lines are not isolated, ground loop currents will cause magnification of measurement errors. For this reason, the A-B (GND) or A (FLOAT) input mode should be selected at the LI-75A. For the LI-574A, however, if REF-FLOAT is used, the A (GND) mode may be used as well.

* If a power supply other than the PS-70A is used, the following specifications should be provided.

Voltage: $\pm 20 \sim \pm 24$V

Current: ± 50mA or greater

Ripple: $\pm 5mV_p$ or less

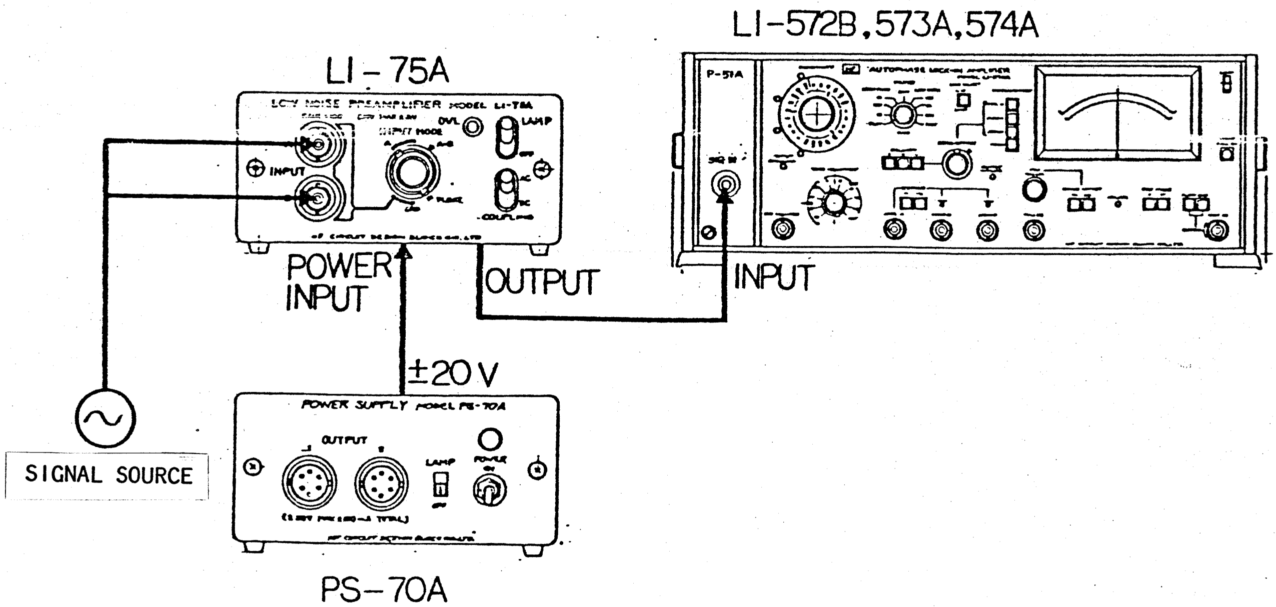


Fig. 3-10 Connections to the LI-572B/573A/574 lock-in amplifiers

3.3 Operation

After verifying that input and output connections as described in section 3.2 have been properly made, set all of the equipment power switches to ON. This section serves to describe those switches and controls not described separately in section 3.2.

AC/DC Coupling switch	The preamplifier should normally be used in the DC coupling mode. If the input signal includes a DC component, this can be blocked by using the AC coupling position. Note, however, that the -3dB point is at 0.1Hz. Also, because of variations in the coupling capacitor for AC coupling, the CMRR may be deteriorated with respect to the CMRR in the DC coupled mode.
Excessive input display lamp OFF switch	When using the LI-75A in a darkroom during experimental work, this switch can be used to extinguish the OVL front panel lamp. It should normally, however, be in the ON position.
DC Offset adjustment	This adjustment can be used to adjust the output DC offset approximately $\pm 0.3V$. The adjustment is made to set the output voltage to 0V.

4. PRINCIPLE OF OPERATION

4.1 Outline

The LI-75A is a differential-input amplifier making use of a dual FET differential amplifier and voltage follower.

As shown in the block diagram in Fig. 4-3, the LI-75A consists of an input setting section, an input differential amplifier section, an output amplifier section, and an excessive input display circuit.

4.2 Block Diagram Description

4.2.1 Input Setting Section

This section is used to switch between the differential input (A-B (GND)) and unbalanced input (A (FLOAT), A (GND)) and between AC and DC coupling modes.

4.2.2 Input Differential Amplifier and Output Amplifier Sections

In a differential amplifier in which the circuit noise figure is virtually determined by the first stage, a low-noise dual J-FET is used. The output amplifier section uses a voltage follower to perform impedance transformation.

The basic input/output relationships are as follows.

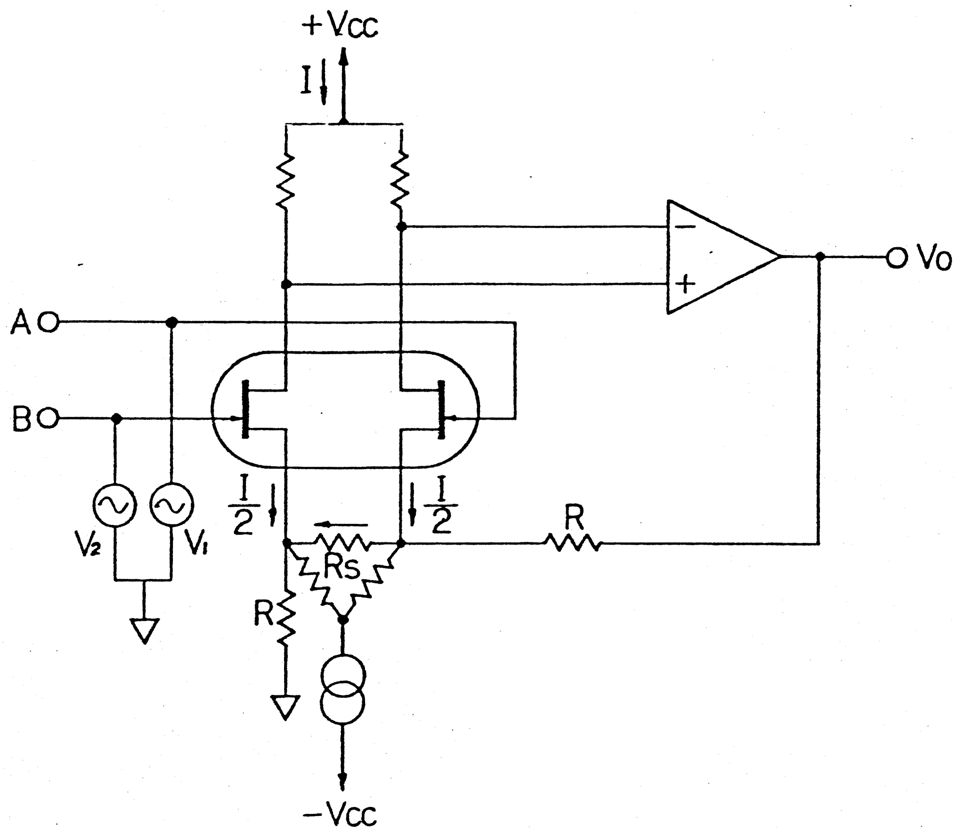


Fig. 4-1 Input/output relationships

In the above-illustrated circuit, we have the following relationship.

$$V_o = (V_1 - V_2)\ (1 + \frac{2R}{R_S})$$

The gain, G is given by the following relationship.

$$G = \frac{V_o}{V_1 - V_2} = (1 + \frac{2R}{R_S})$$

The gain, it can be seen, is determined by the resistances R and R_S, and for the LI-75A, this is x100 (40dB).

4.2.3 Excessive Input Display Circuit

As shown in Fig. 4-2, this circuit consists of the combination of a window comparator and an LED drive circuit.

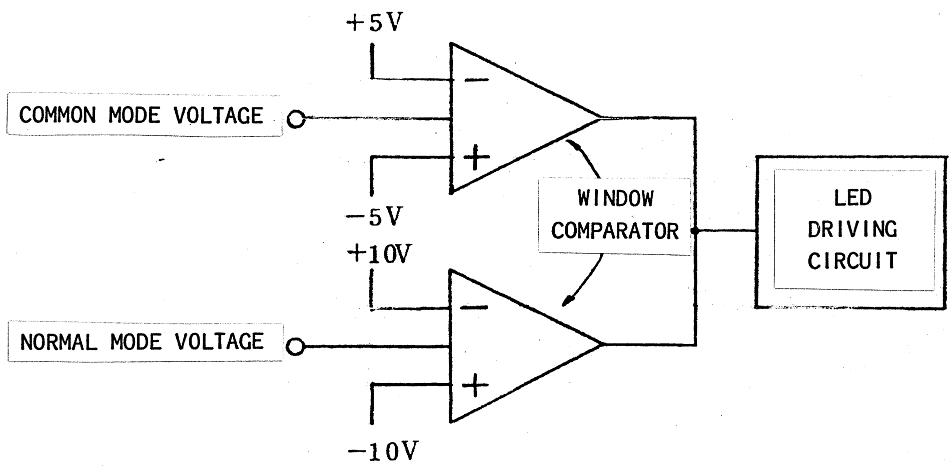


Fig. 4-2 Excessive input display circuit

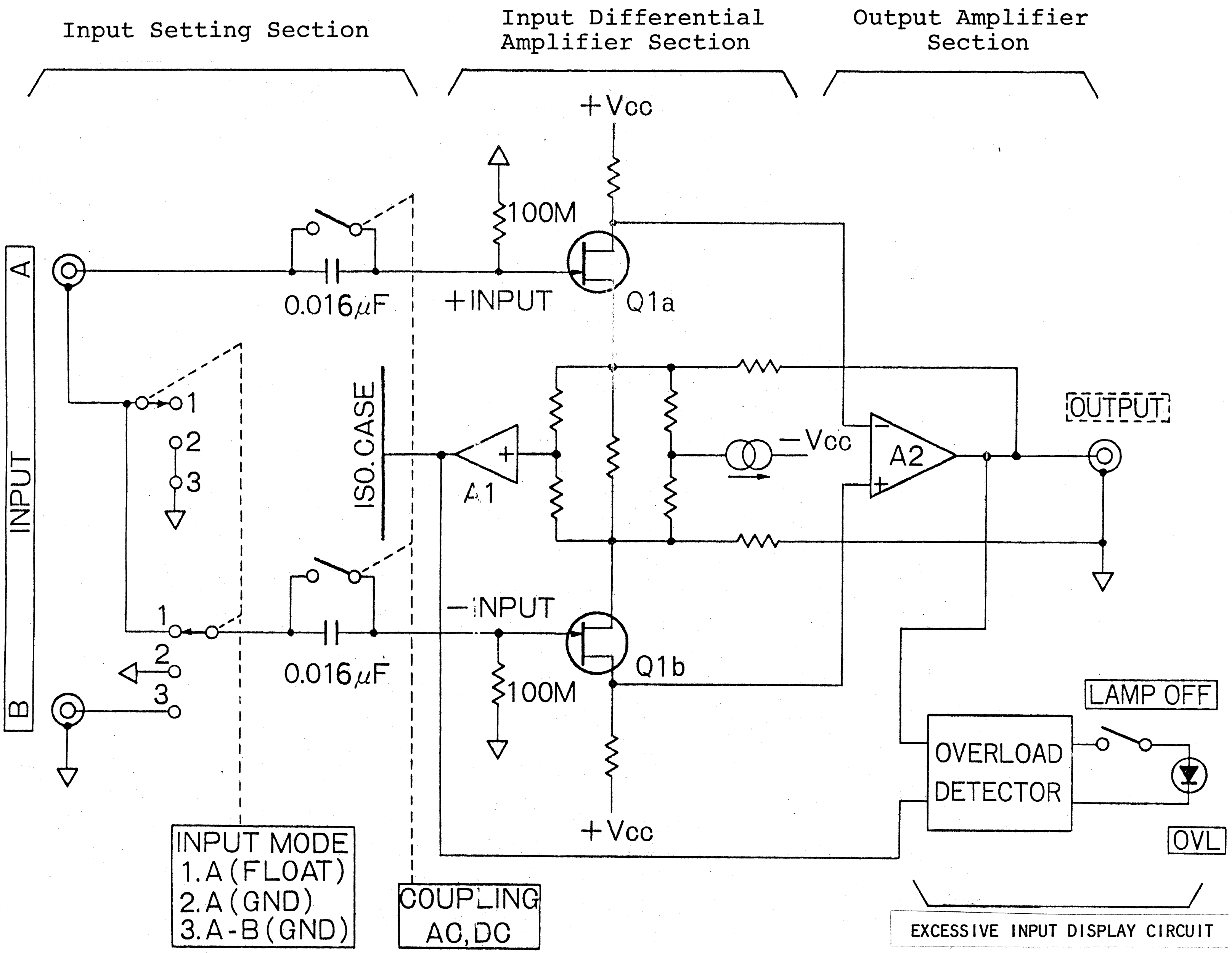


Fig. 4-3 Block diagram

4.3 Noise Figure Considerations

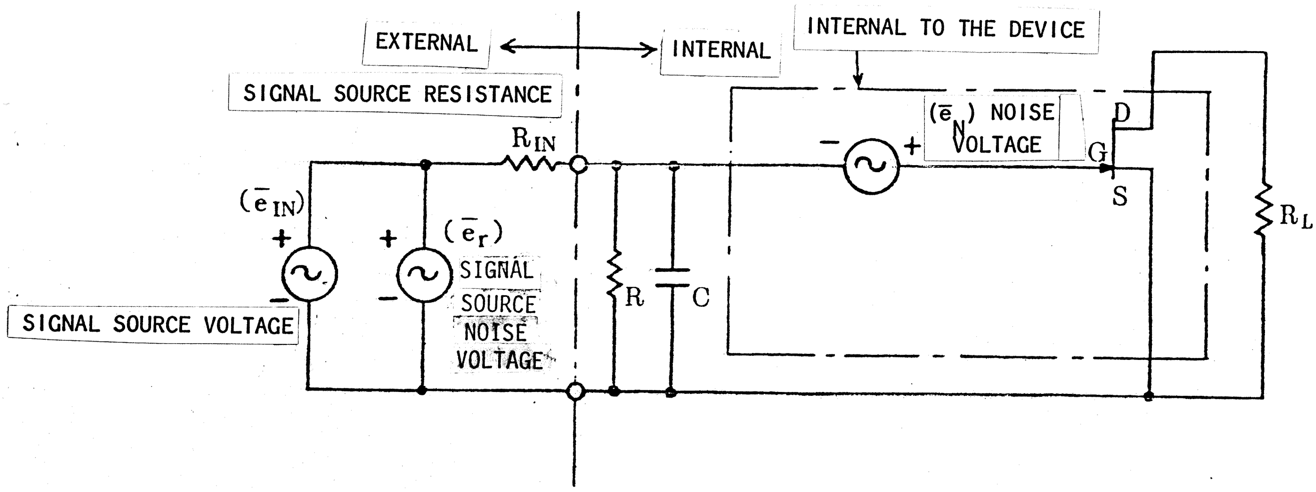


Fig. 4-4 Input section noise equivalent circuit

As shown in Fig. 4-4, the noise figure for the LI-75A can be expressed as follows.

$$NF = 10 \log_{10} \frac{\dfrac{S_{IN}}{N_{IN}}}{\dfrac{S_O}{N_O}}$$

S_{IN}: Signal source power

N_{IN}: Signal source noise power

S_O: Input-referred signal power

N_O: Input-referred noise power

$$= 10 \log_{10} \frac{R + R_{IN}}{R} \left\{ 1 + \frac{(\bar{e}_n)^2}{4KTB \dfrac{R \cdot R_{IN}}{R + R_{IN}} T(f)^2} \right\} \text{ [dB]} \quad \ldots \quad 1$$

B: Bandwidth (Hz)

T: Absolute temperature (K)

K: Boltzmann's constant 1.3805 x 10^{-23} (J/K)

T(f): Normalization of the transfer function of the LP filter formed by R, R_{IN}, and C.

$$T(f) = \frac{1}{\sqrt{1 + \left(2\pi fc \frac{R \cdot R_{IN}}{R + R_{IN}}\right)^2}}$$

Using the noise figure as a parameter, and expressing the frequency along the horizontal axis and the signal source resistance on the vertical axis, we obtain a typical plot (schmoo plot) as shown in Fig. 6-4.

This plot is derived by using R=100MΩ, C=30pF (typical), T=300K, B=1Hz, and e_n=(the actual measured value of input-referred noise voltage), substituted into equation 1.

If for example, the signal source resistance is 500 , and the frequency is 100Hz, the noise figure of the LI-75A in this measurement system would be approximately 1dB (refer to Fig. 4-5 for the method of reading this value).

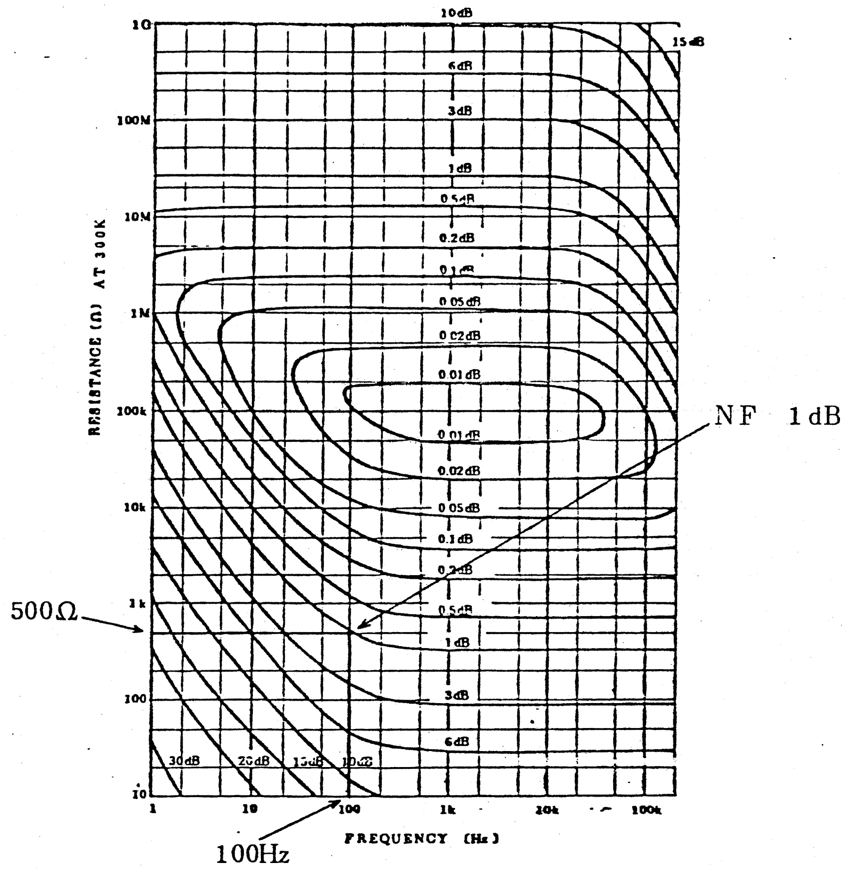


Fig. 4-5 Use of the noise figure schmoo plot

The input-referred noise voltage under these conditions is given by the following expression.

$$(\bar{N}_o) = \sqrt{4KTBR_{IN}}\ \frac{R}{R+R_{IN}}\ T(f)10^{\frac{NF}{20}} \quad [V/\sqrt{Hz}] \quad \ldots\ 2$$

Thus, it can be seen that this plot can be used to determine the input-referred noise voltage of the LI-75A using the various parameter values of the measurement system used.

5. MAINTENANCE

5.1 Outline

Some maintenance is required to maintain the LI-75A in top operating condition. The following 4 types of maintenance may be required.

1. Operational Inspection

   This is an initial check to determine whether the LI-75A is operating to within its specifications.

2. Adjustment and Calibration

   If the LI-75A is not operating within specifications, this type of operation is performed to adjust or calibrate it to within these specifications.

3. Failure Troubleshooting

   This consists of the steps followed to diagnose a failure cause when adjustment or calibration is not successful in restoring normal operation.

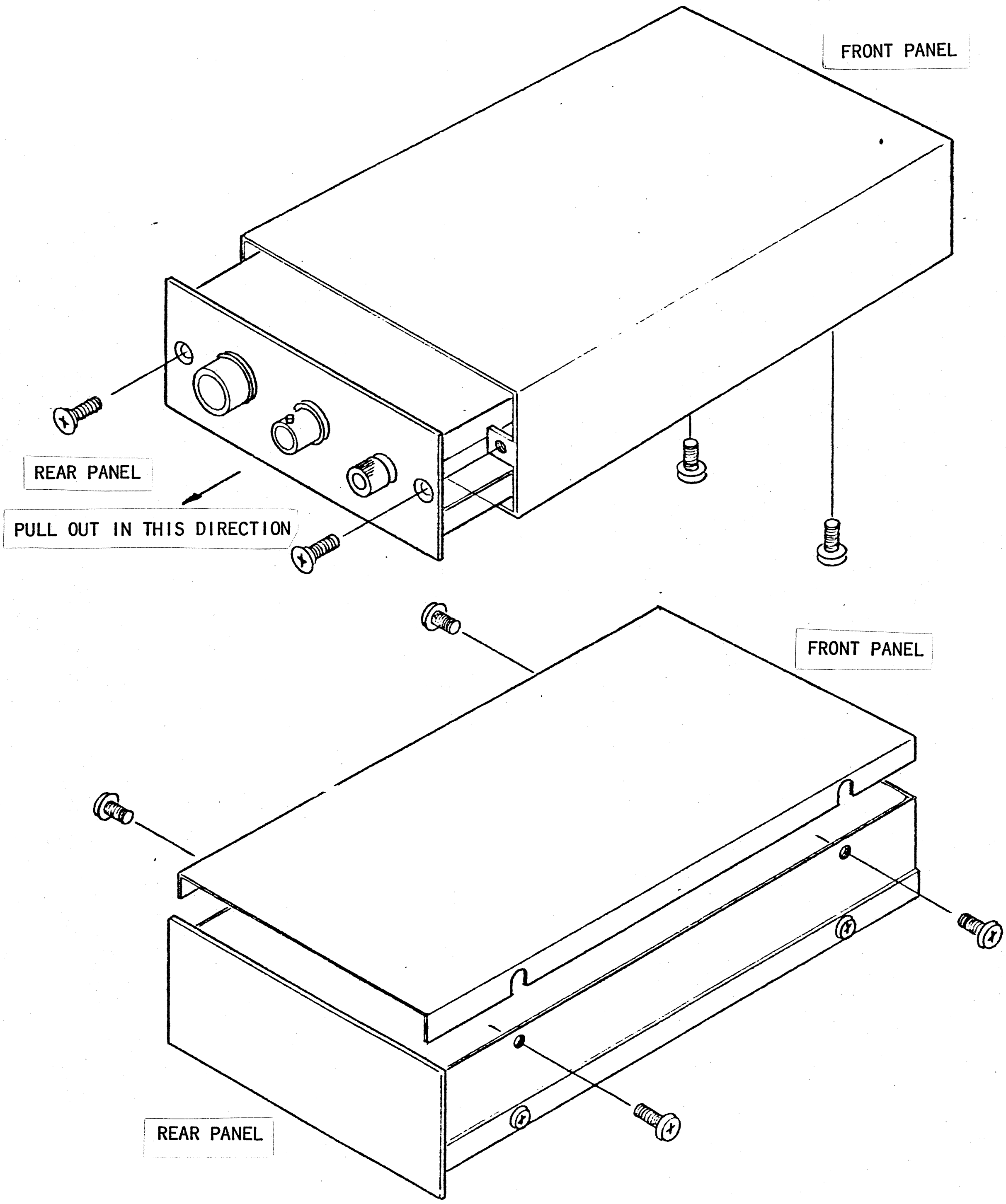
4. Repair

   This section only includes those adjustments and calibration procedures which can be performed by the normal user from the front and rear panels in conjunction with an operational check. For higher levels of inspections, calibrations, and repair, contact your sales representative.

Periodic Preventative Maintenance

Contact your sales representative or contact us directly for information concerning periodic inspection, calibration, and repair.

5.2 Removing the Case



First, remove the 4 screws and remove the outer box. Next, remove the 4 screws on the sides and remove the top cover.

Fig. 5-1 Removing the case

5.3 Operational Checks

5.3.1 Checks Using the Unbalanced Input

Connect measuring instruments to the LI-75A as shown in Fig. 5-2.

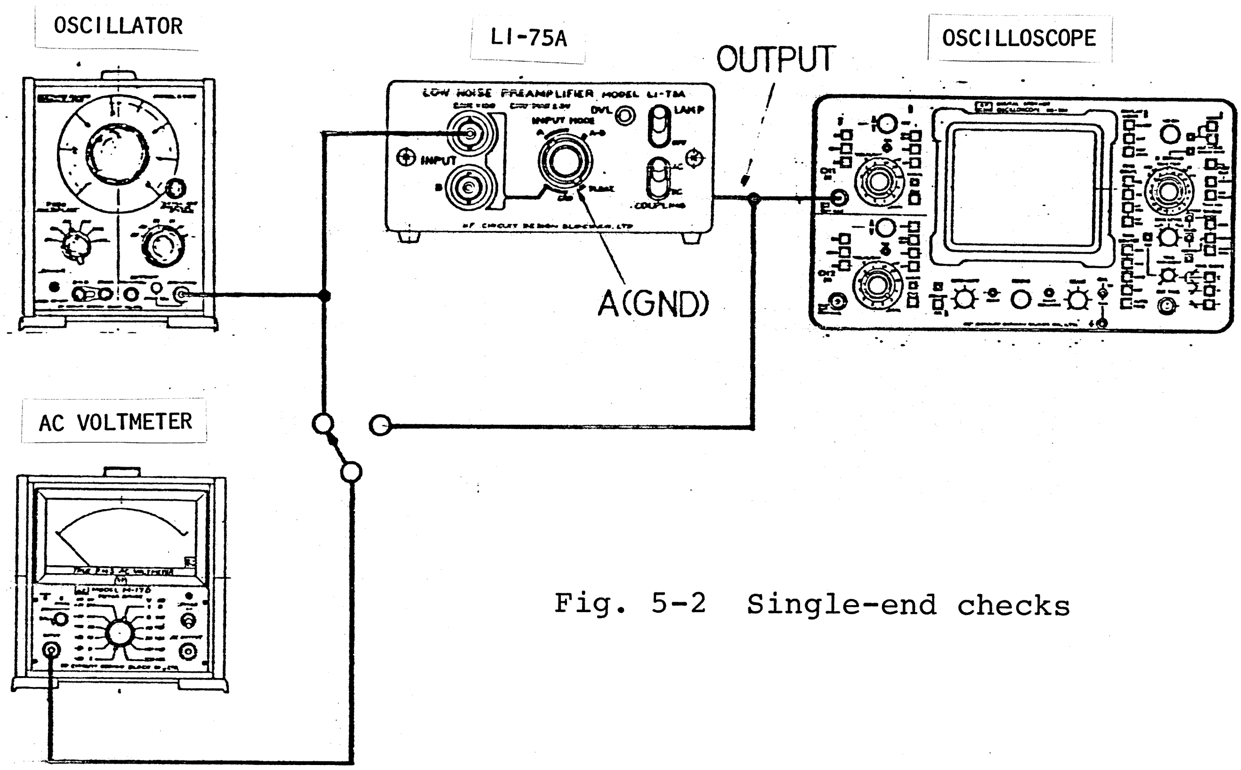


Fig. 5-2 Single-end checks

(a) Output Waveform Check

Observing the output waveform on the oscilloscope, verify that the waveform is not abnormal. The waveform will be clipped at $\pm$10V and at this point the excessive input display lamp (OVL LAMP) should light.

(b) GAIN Check

Adjust the oscillator output to 10mVrms at 400Hz and the LI-75A output should be 1Vrms. If it is slightly off from this value, bring it to this value using RV2 on the PC board.

(c) Frequency Response Check

At 400Hz, adjust the oscillator output level so that the LI-75A output is 0dBm. The frequency response should be as shown below.

DC Coupling	DC ∿ 1MHz $\left(^{+1}_{-3}\right)$ dB
AC Coupling	0.2Hz ∿ 1MHz $\left(^{+1}_{-3}\right)$ dB

(d) Distortion Check

Connect a distortion meter to the output shown in Fig. 5-2. With approximately 5Vrms output level, the harmonic distortion at 1kHz should be 0.03% or less.

5.3.2 Checks Using the Balanced Inputs

Connect measuring instruments to the LI-75A as shown in Fig. 5-3.

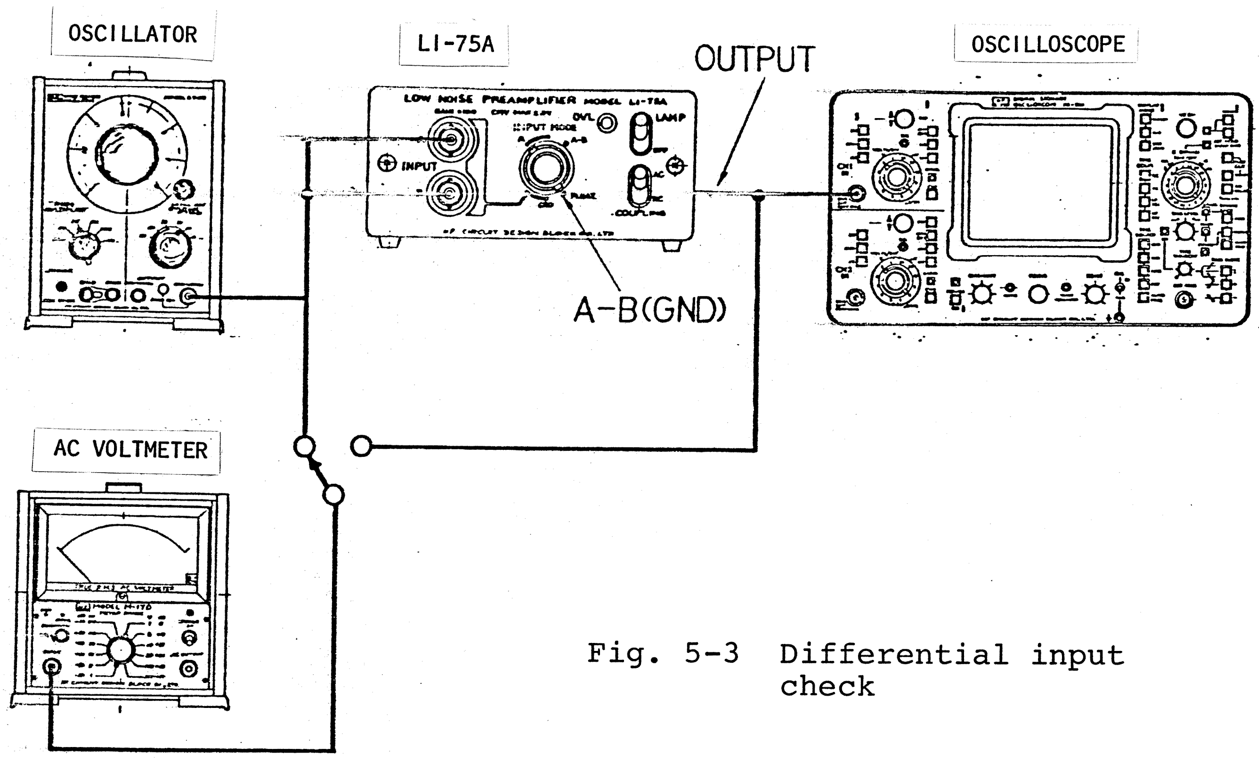


Fig. 5-3 Differential input check

(a) Common Mode Voltage Check

Short the two differential input connectors and apply a 100Hz signal. Gradually increase the input level from 0 to ±5V. No waveform distortion or pulse waveforms should be observed.

(b) Common Mode Rejection Ratio Check

First, adjust the oscillator output to 3Vrms at 100Hz. Next, switch the AC voltmeter to the LI-75A output. The reading on this voltmeter should be below 300μVrms. With 3Vrms applied, if the output is 300μVrms, the CMRR is 120dB. If this condition is not quite satisfied, adjust RV3 and RV4 on the PC board for optimum CMRR, using a trimmer adjusting rod.

5.3.3 Current Consumption Check

With an applied voltage of ±20V ∿ ±24V, the normal current consumption should be ±40mA.

5.4 Failure Indicators

CAUTION

Should a failure of the LI-75A occur, or should some other trouble develop, always perform the following described checks.

If, as a result of these checks, it is judged that a true failure has occurred, contact us with the failure phenomenon and check results. This is an aid to increasing the efficiency of servicing operations and greatly aids in servicing and we strongly request that you cooperate in this matter.

5.4.1 When No Operation Is Possible

* Check whether the power supply cable or the internal battery is not improperly connected.

* Check whether the POWER switch is ON.

5.4.2 No Output

* Check whether or not cable interconnections are improperly made.

5.4.3 The OVER Lamp Lights

* Check whether an excessive input signal is present.

* Check whether switch settings are proper.

6. STANDARD DATA

Standard data representative of the performance of the LI-75A has been included in this document. In the manufacturing stage, every effort is made to ensure that variations in actual instrument performance from this standard data are held to a minimum as a method of quality control.

Therefore, when making actual measurements of performance of this particular unit, since the standard data indicates average values, in some cases actual performance will vary from this data. Since, however, severe tests and inspections are performed to ensure that specifications are satisfied before shipping, rest assured such small variations are not indications of problems.

The following standard data has been provided.

Fig. 6-1 Frequency vs. common mode voltage range

Fig. 6-2 Frequency vs. common mode rejection ratio

Fig. 6-3 Frequency vs. input-referred noise voltage

Fig. 6-4 Noise figure (typical)

Fig. 6-5 Frequency vs. maximum output voltage

Fig. 6-6 Frequency vs. gain

Fig. 6-7 Frequency vs. harmonic distortion

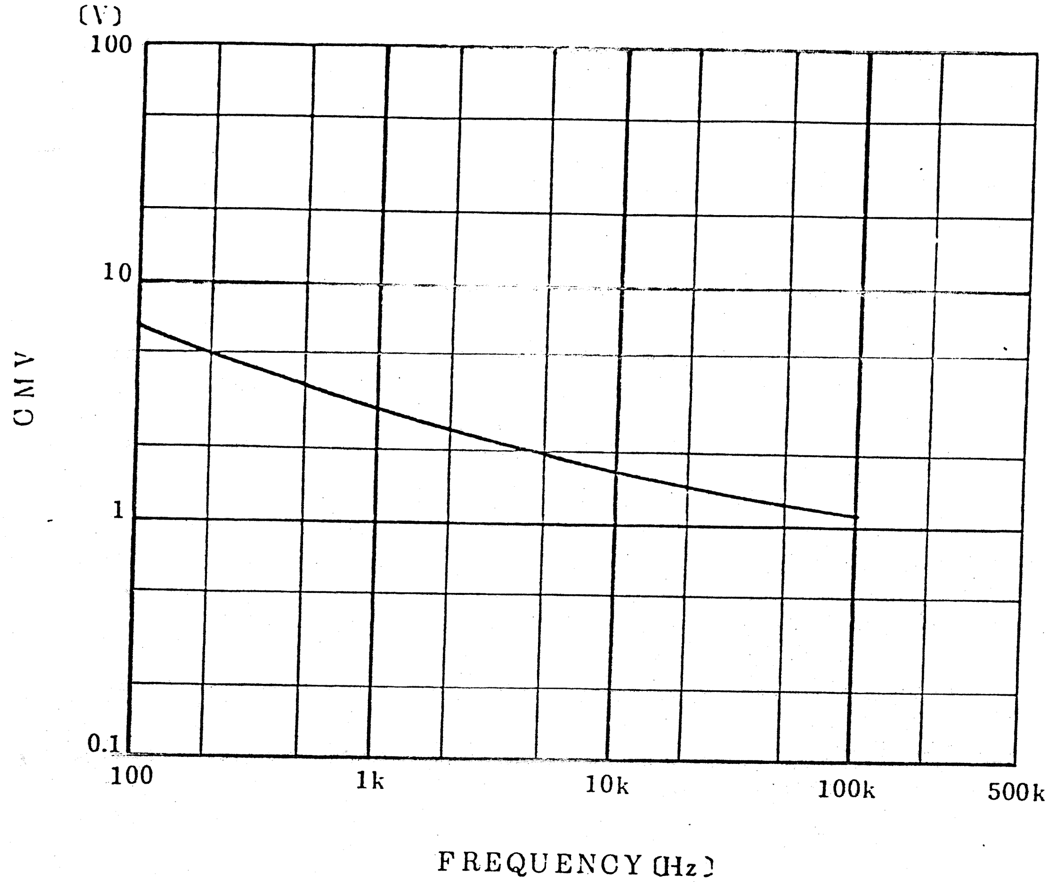


Fig. 6-1 Frequency vs. common mode voltage range

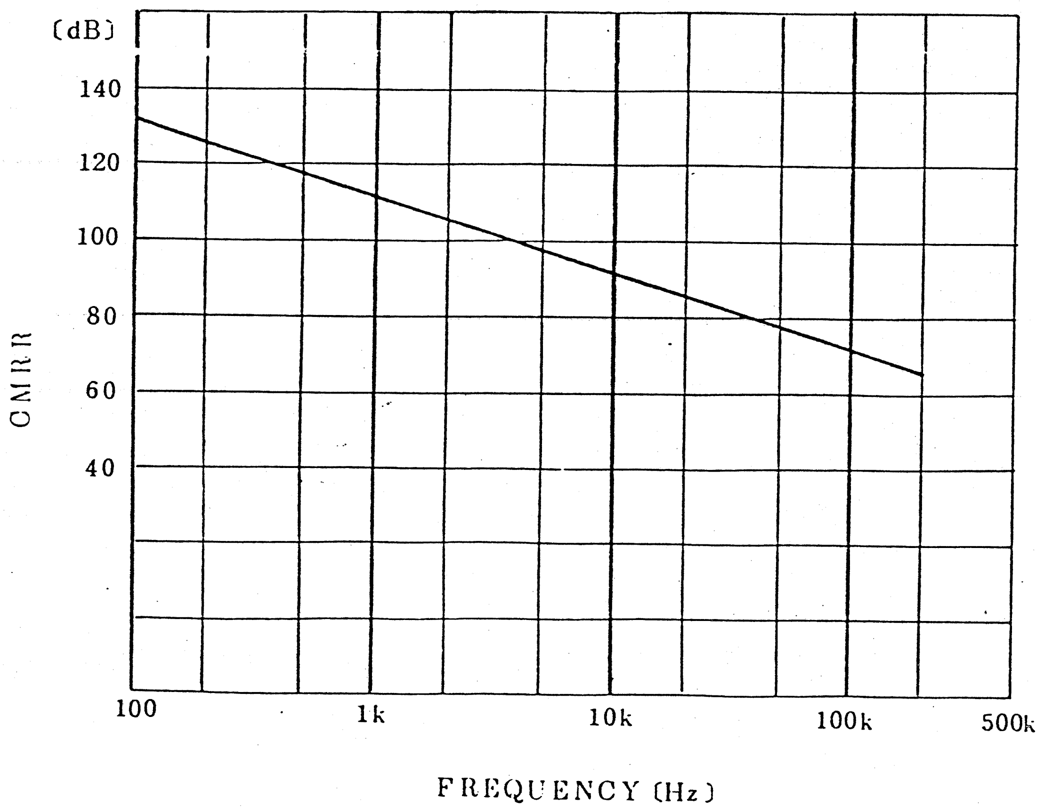


Fig. 6-2 Frequency vs. common mode rejection ratio

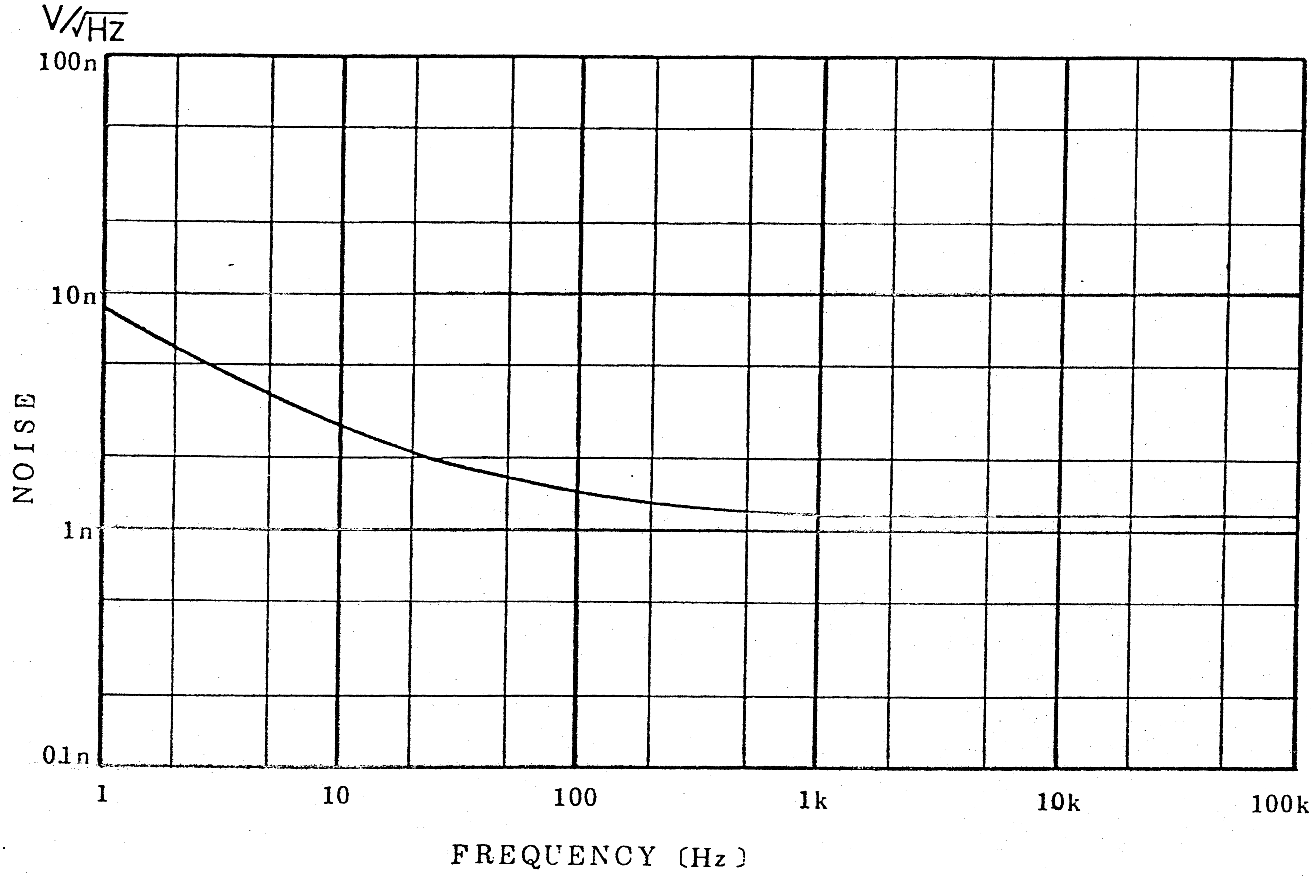


Fig. 6-3 Frequency vs. input-referred noise voltage

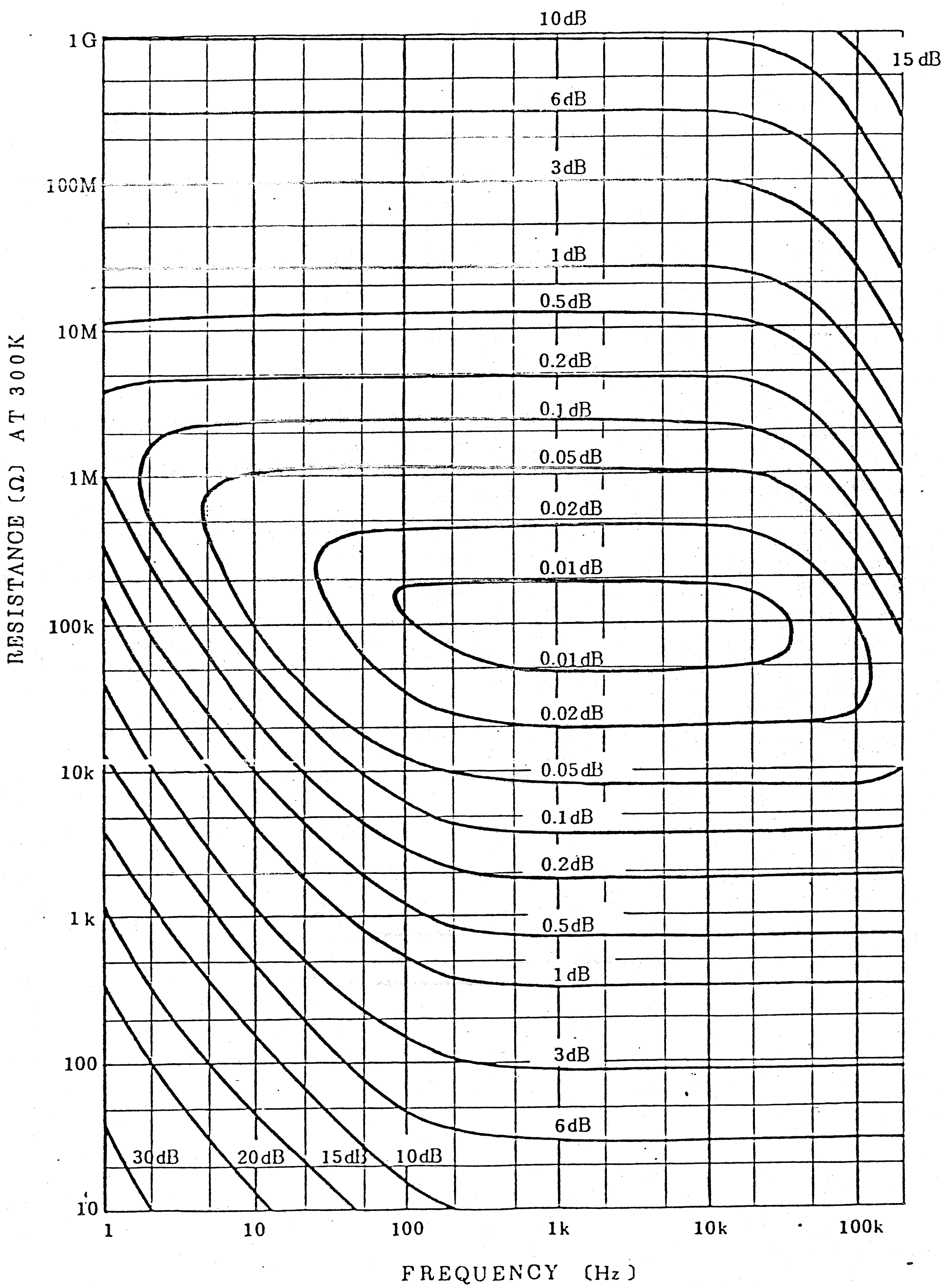


Fig. 6-4 Noise figure (typical)

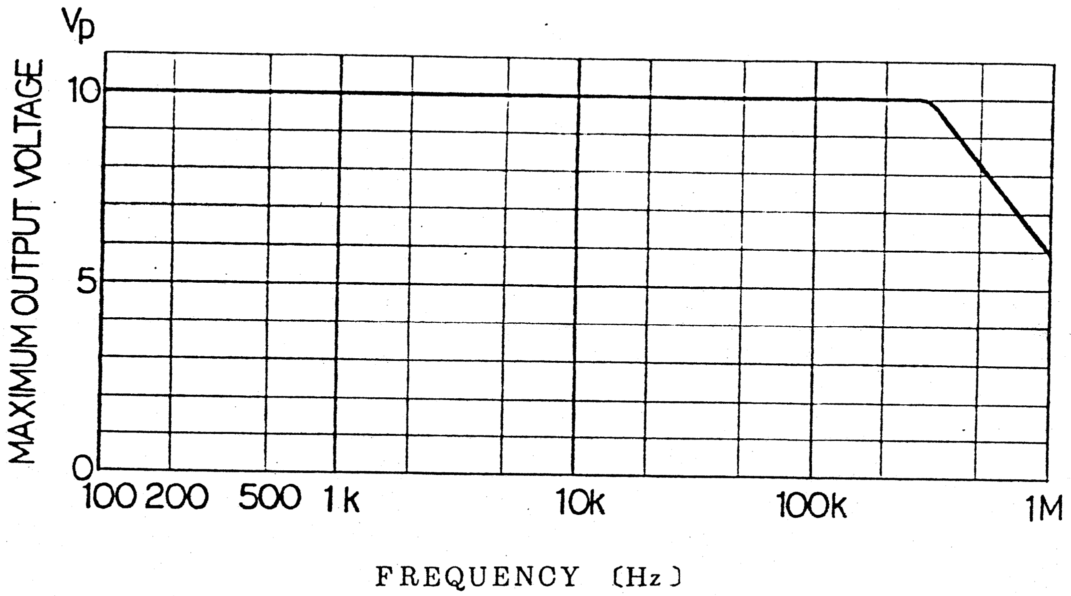


Fig. 6-5 Frequency vs. maximum output voltage

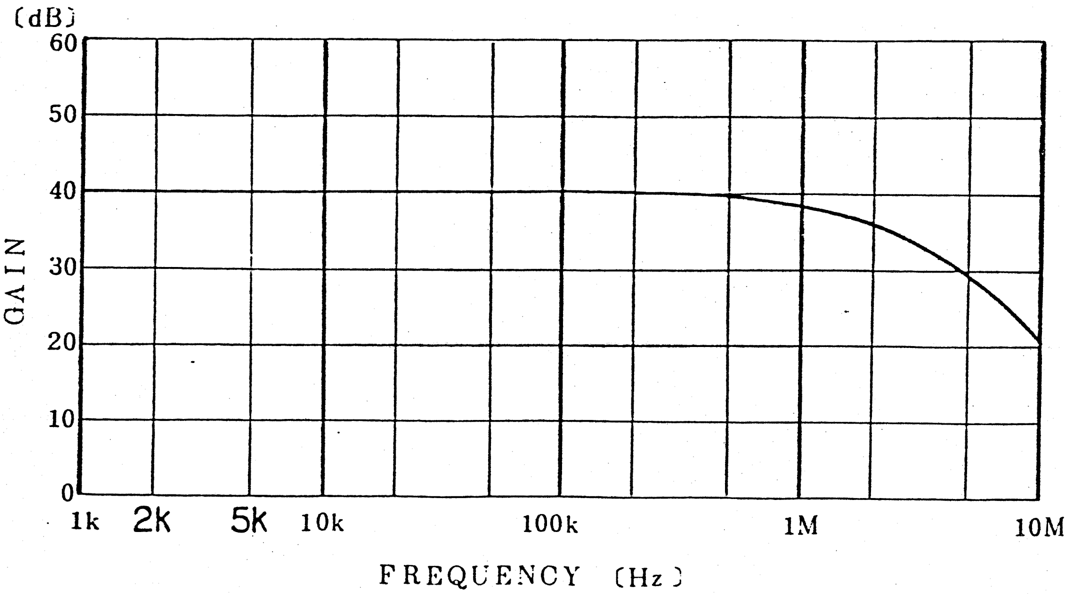


Fig. 6-6 Frequency vs. gain

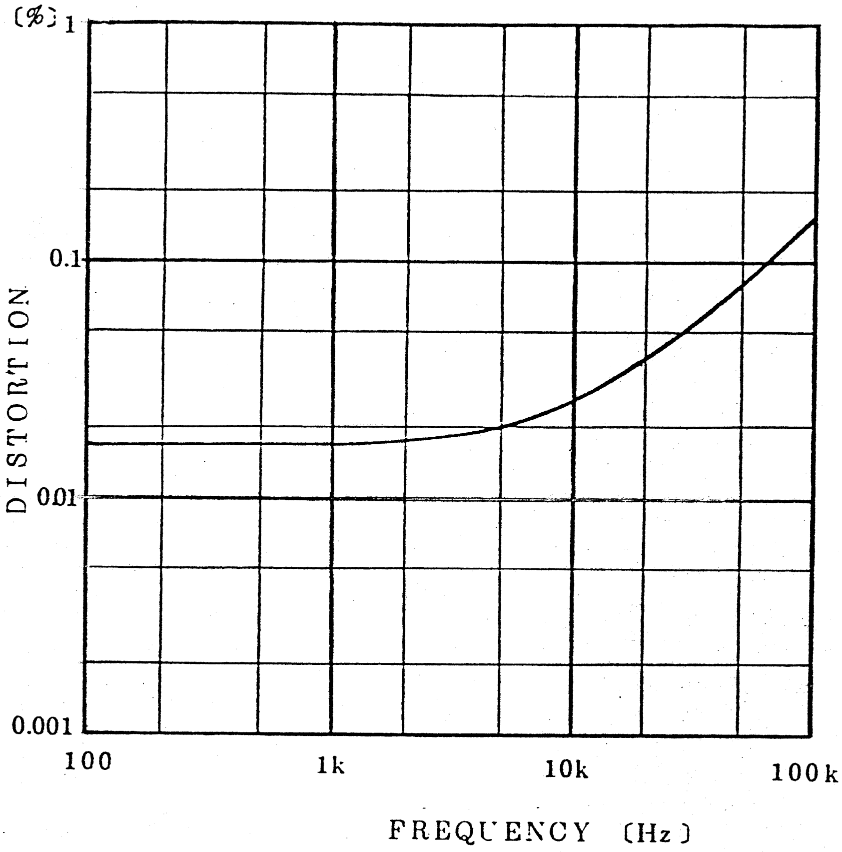


Fig. 6-7 Frequency vs. harmonic distortion (output level 5Vrms, 2kΩ load)

WARRANTY

NF CIRCUIT DESIGN BLOCK CO., LTD. certifies that this instrument was thoroughly tested and inspected and found to meet its published specifications when it was shipped from the factory.

All NF products are warranted against defects in materials and workmanship. Obligations under this warranty are limited to replacing, or repairing of any instrument returned to our factory for that purpose within one year of delivery to the original purchaser. No other warranty is expressed or implied. NF does not assume liability for installation or for incidental or consequential damages.

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