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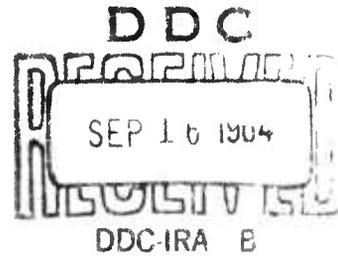
TR 64-73

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TECHNICAL REPORT NO. 64-73

LOW-LEVEL, LOW-FREQUENCY, SOLID-STATE AMPLIFIER



GEOTECH

THE GEOTECHNICAL CORPORATION

3401 SHILOH ROAD

GARLAND, TEXAS

TECHNICAL REPORT NO. 64-73

LOW-LEVEL, LOW-FREQUENCY, SOLID-STATE AMPLIFIER

by

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THE GEOTECHNICAL CORPORATION
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Garland, Texas

30 July 1964

IDENTIFICATION

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Project title: Improved Seismographs

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Project Engineer: J. R. Womack, BR8-8102

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LOW-LEVEL, LOW-FREQUENCY, SOLID-STATE AMPLIFIER

ABSTRACT

This report describes the development of a low-level, low-frequency, all-solid-state amplifier having either analog, broad-band FM, or IRIG FM output. The amplifier was developed primarily for amplification of seismic signals in geographic areas where the low-noise detection capability of a phototube amplifier is not required. The equivalent-input noise level for a passband of 0.1 to 5 cps is 1×10^{-6} v. This is equal to 2×10^{-16} w in the 5 kohm input resistor. Signal common-mode rejection is 86 db and the effects of power-supply variation are negligible. Power requirements are less than 1 w. Operating temperature is from -60° to $+60^{\circ}\text{C}$. By using a special filter, the amplifier is capable of operation over a passband of 0.01 cps to 40 kc. Using analog output, the amplifier has a voltage gain of 1×10^4 and a dynamic range of 57 db. Using broad-band FM carrier output, it has a modulation sensitivity of 465 cps/mv and a dynamic range greater than 60 db.

LOW-LEVEL, LOW-FREQUENCY, SOLID-STATE AMPLIFIER

1. INTRODUCTION

1.1 GENERAL

This report describes the development of an all-solid-state amplifier having either analog, broad-band FM, or narrow-band (IRIG) FM output. The objectives of the development, the design considerations, a description of the amplifier, and test results are included. The purpose of the development was to provide a low-noise, solid-state amplifier with low-power consumption, reliability, and versatility for use in geographic areas where the noise-detection capability of a phototube amplifier (PTA) is not required.

1.2 AUTHORIZATION

The work described in this report was done in partial fulfillment of the requirements of Task 1d, Project VT/072, Contract AF 33(657)-9967. The project is under the technical direction of the Air Force Technical Applications Center (AFTAC) and under the over-all direction of the Advanced Research Projects Agency (ARPA).

1.3 DESIGN OBJECTIVES

The design objectives of this work were to produce a solid-state amplifier with the following characteristics:

- a. Low equivalent-input noise;
- b. Low power consumption;
- c. Long unattended operational life;
- d. High gain;
- e. Large dynamic range;

- f. Large common-mode rejection;
- g. Adjustable passband;
- h. Capability for both analog and FM output;
- i. Immunity from power-supply variations;
- j. Capability of operating under severe field environmental conditions.

The preliminary design specifications for the amplifier are given in the appendix.

2. DESIGN CONSIDERATIONS

Consideration was given to using a mechanical or a transistor chopper in the input circuitry of the amplifier. It was concluded that a mechanical chopper would provide the lowest noise detection capability. However, the expected short life of a mechanical chopper would limit reliability. It was also concluded that the use of a transistor chopper in the input circuitry, while being reliable, would result in a high input noise level. The foregoing conclusions were based on studies of existing reports on choppers.

The work of S. N. Thanos¹ and others has shown that the proper use of certain low-noise transistors in the input circuits of differential amplifiers can yield the desired low equivalent-input noise levels. While the input voltage drift of a transistor differential amplifier is much greater than that of most chopper amplifiers, the effect of the input voltage drift will be greatly reduced if the drift rate appears outside the passband of the amplifier. Since drift in a differential amplifier is caused mostly by thermal changes, proper thermal insulation of the amplifier can keep the drift rate outside the bandpass of the amplifier. Furthermore, capacity coupling between stages will keep the effects of the input dc voltage drift

¹Design and construction of a lunar seismograph prototype model, Final Technical Report, Lamont Geological Observatory, Columbia Univ., 1962

from appearing at the output. The block diagram of figure 1 was based on the preceding concepts.

3. DESIGN DESCRIPTION

3.1 GENERAL

The engineering model of the Solid-State Amplifier, Model 16957, is shown in figures 2 and 3. The following sections describe the engineering model only. Other packaging concepts and amplifier component configurations may easily be derived with a knowledge of the engineering model.

3.2 MECHANICAL DESIGN

The components of the amplifier are mounted in a sealed case to provide a low humidity environment. The presence of moisture in the case would primarily affect the high-impedance circuits associated with the field effect transistors (FET's). The impedance control, attenuator, switch, fuse, and connectors are all provided with hermetic seals to the case. The electronic components are mounted on plug-in printed-circuit boards. These are mounted on the case lid for accessibility. The front panel can be rack mounted.

3.3 ELECTRONIC DESIGN

3.3.1 General

Basically the amplifier provides analog amplification and filtering. Broad-band FM carrier output and narrow-band (IRIG channel) FM carrier output are optional. These optional outputs are provided by the respective VCO and a special amplifier stage which adapts the VCO to the basic components of the amplifier. The VCO and the special amplifier stage replace the bandpass filter and output amplifier stage when FM output circuitry is used. The input impedance control, the step attenuator, and the converter are also optional, since they may be unnecessary in some applications. These optional possibilities make the design more versatile.

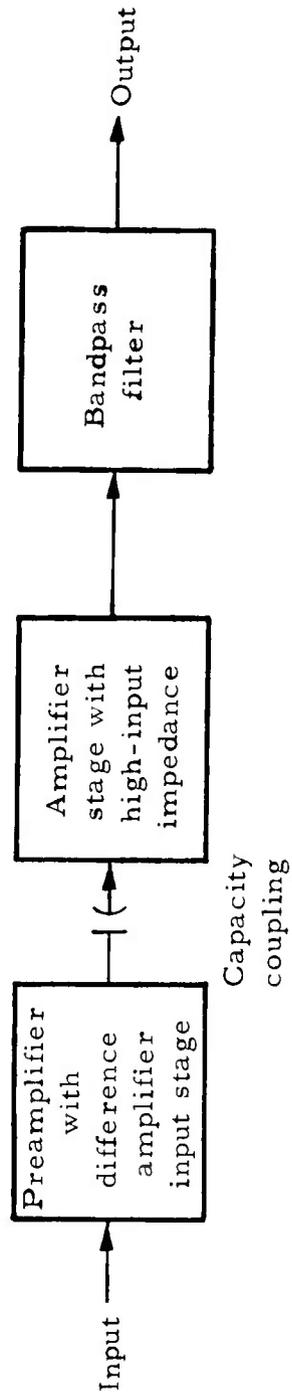
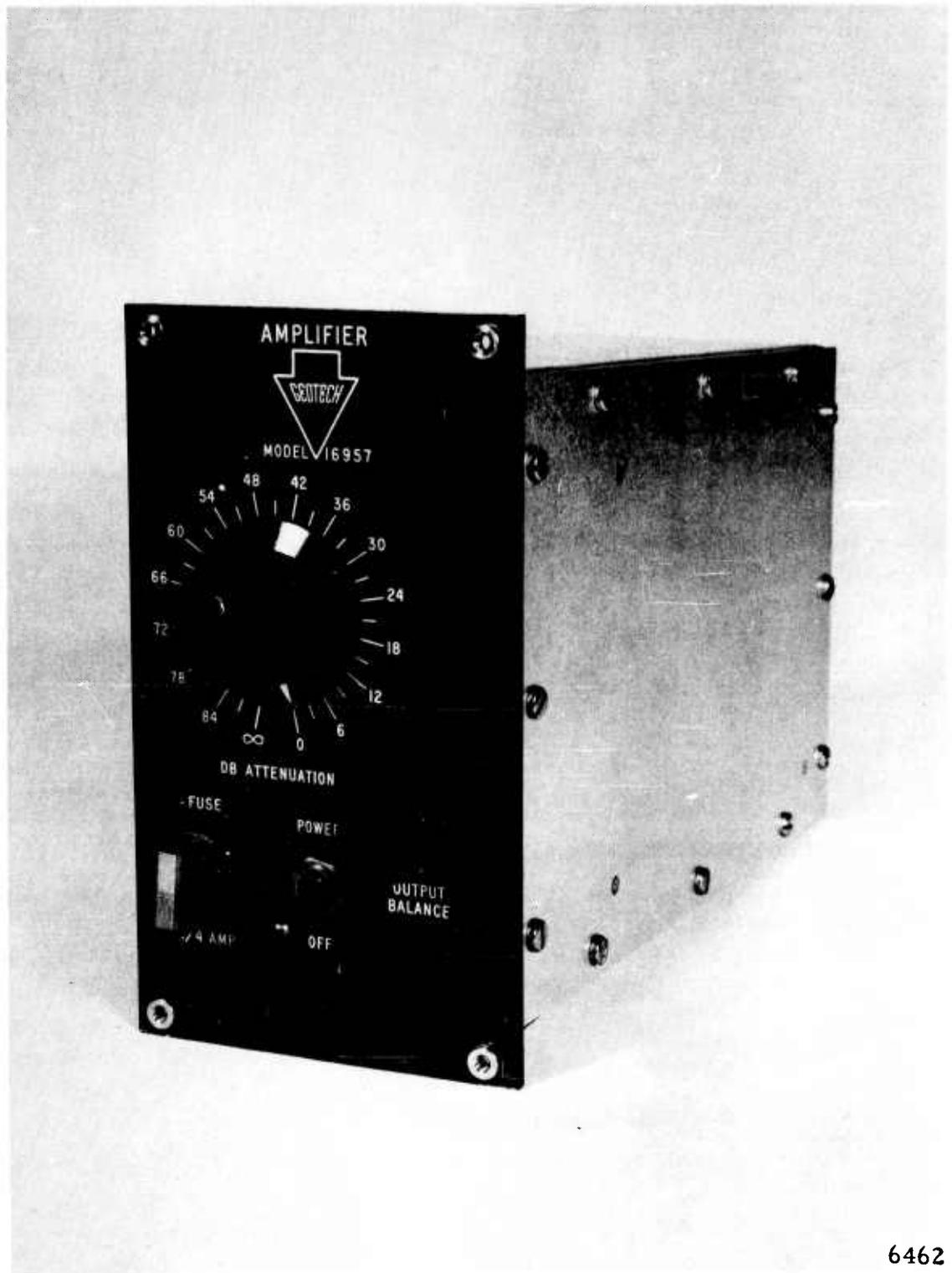
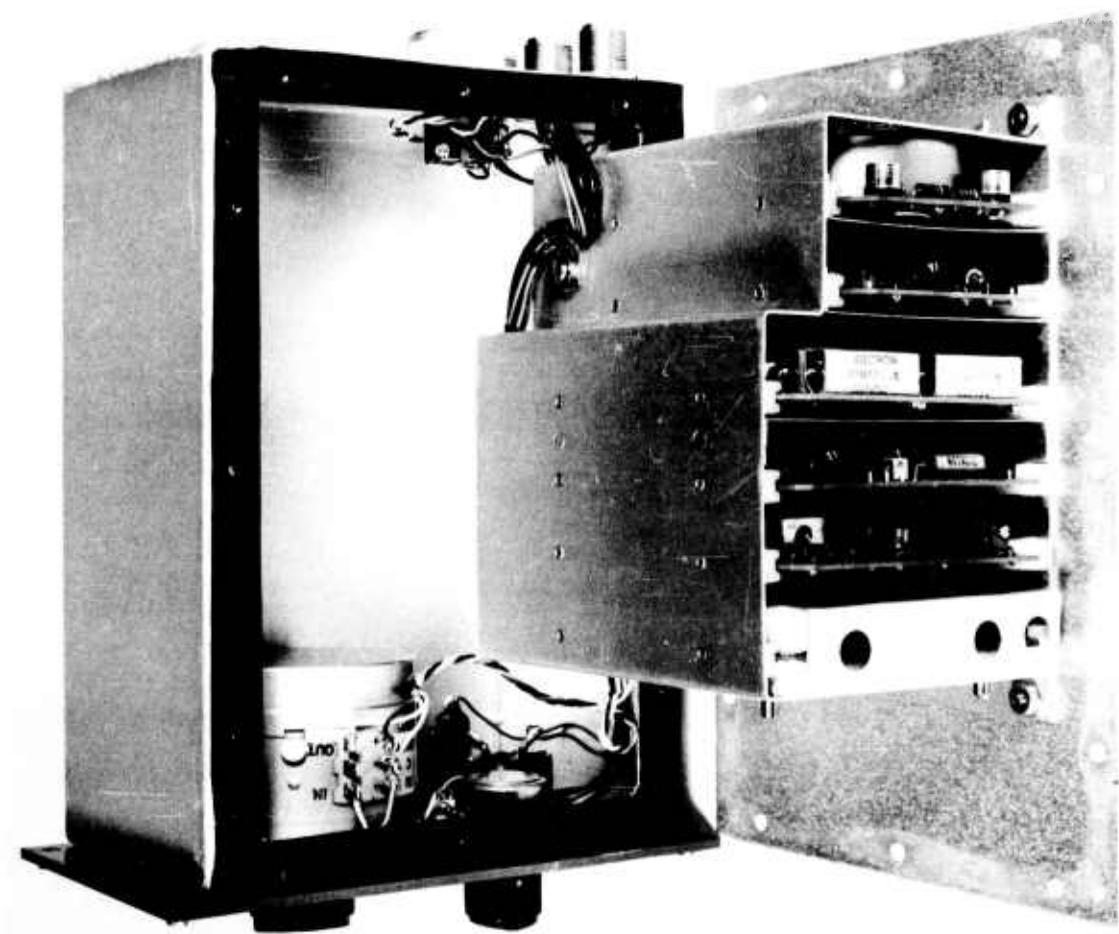


Figure 1. Capacity-coupled low-frequency amplifier, block diagram



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Figure 2. Amplifier, front view



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Figure 3. Side view of amplifier with case open

When analog output circuitry is used, the input and the output circuits of the amplifier may not share a common grounding point. If the output is grounded, the input must be connected to a floating source. If the input is grounded, the output must be connected to a floating load. Any one point on the power supply for the amplifier may be grounded provided the converter is employed in the amplifier.

When FM output circuitry is used, the input circuit, output circuit, and power supply may share a common grounding point or be independently grounded at different ground potentials. This is contingent on the converter being used in the amplifier. When the amplifier with FM carrier output is used in a seismomograph system, the seismometer presents a floating source and the power supply may be grounded at any one point without using the converter in the amplifier.

The solid-state amplifier is composed of a specially designed preamplifier circuit and electronic circuits developed for the Photocell Amplifier, Model 16956. A description of the electronic circuits which were adapted for use in the solid-state amplifier is given in Geotech TR 64-71. For this reason, a complete description of the FM carrier output circuitry is not presented in this report. The circuitry of the amplifier with analog output is described in detail. The schematic diagram for the analog output is given in figure 4. Photographs of the individual boards are shown in figure 5.

3.3.2 Preamplifier

The preamplifier consists of four cascaded conventional transistor differential amplifier stages. Individual stage and over-all feedback is employed for temperature stability, gain stability, and increased input impedance.

Mounting positions are provided on the circuit board at the input terminals for a fixed resistor attenuator circuit to achieve more versatile use of the preamplifier. This attenuator circuit is not used in the engineering model. The input impedance of the amplifier is determined by the input impedance control and attenuator external to the preamplifier circuit board. The input impedance of the preamplifier by itself is approximately 500K. However, the amplifier will oscillate unless it has a low source impedance, such as that provided by the attenuator, or capacitor C102 can be increased in value to prevent oscillation.

The open-loop voltage gain of the preamplifier is approximately 50,000. With feedback, the voltage gain is about 330. The equivalent-input noise level of the preamplifier is less than $1 \mu\text{v}$ rms when the input is shunted with 5 kohm. The preamplifier is thermally insulated with foam rubber. The insulation prevents sudden temperature changes from causing a thermal differential at the two input transistors which would produce a voltage in the bandpass of the amplifier.

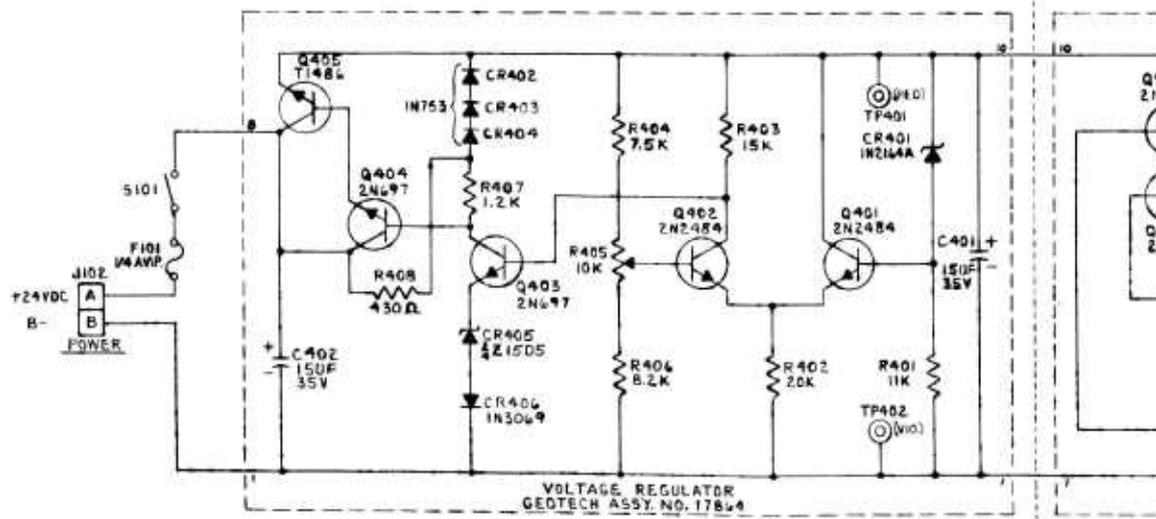
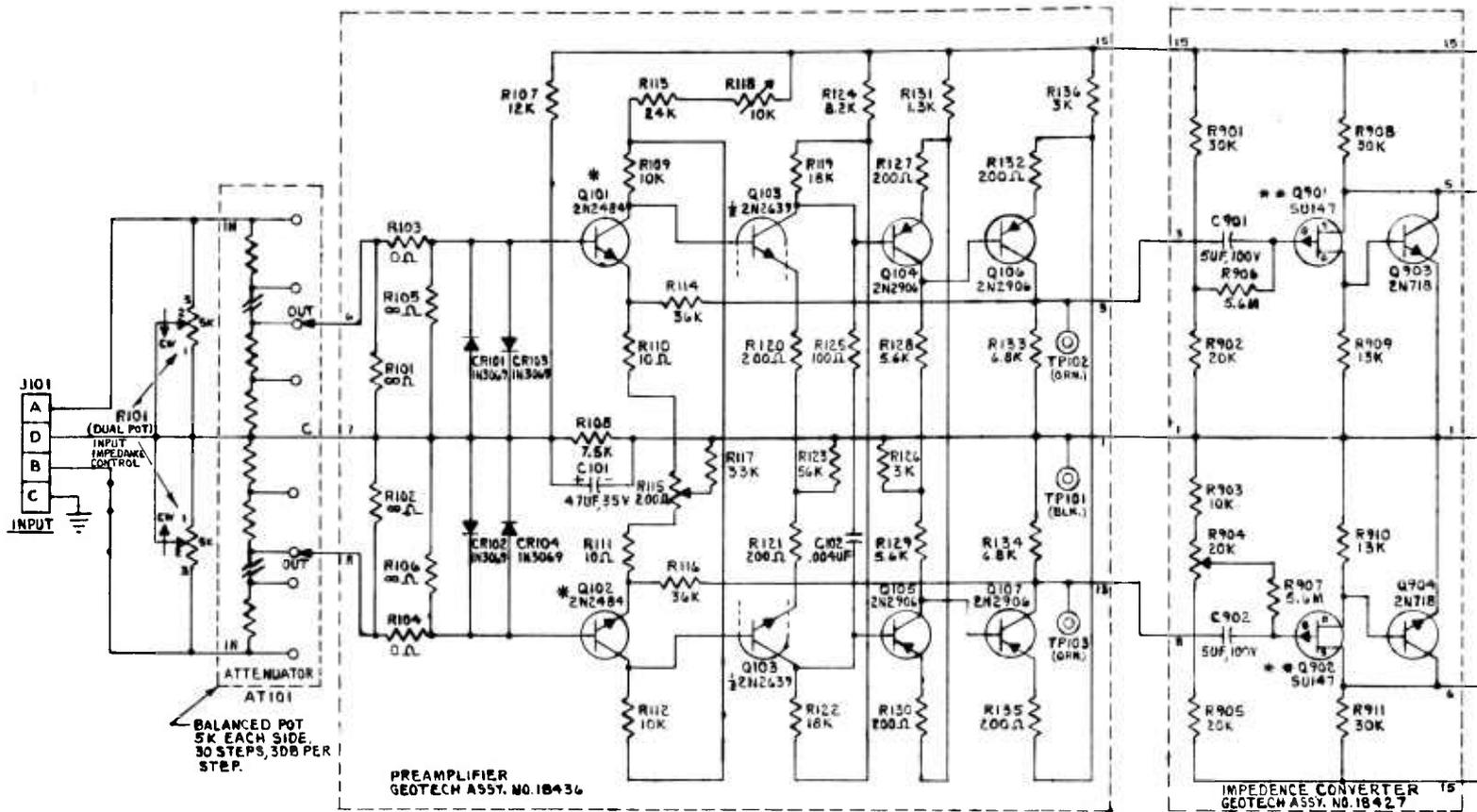
Input transistors Q101 and Q102 are matched 2N2484's manufactured by Fairchild. A matched pair of 2N930's was also tested for use in the input stage. The input noise level was comparable to that produced by the type 2N2484 transistors. Trimpot R115 is used for balancing the output of the preamplifier. Trimpot R118 is used for adjusting the dc level of the output terminals of the preamplifier with respect to power supply minus. C102 and R125 electronically stabilize the preamplifier. The diodes that shunt the input of the preamplifier protect the input differential amplifier stage from large transient signals.

3.3.3 Input Circuitry

The input circuit of the solid-state amplifier is composed of an input impedance control R101 and attenuator AT101. R101 is a dual potentiometer which shunts the input of the amplifier and provides for adjustment of the input impedance of the amplifier in the range from 0 to 5 kohm in a balanced manner. AT101 is a 5 kohm dual-step attenuator and produces up to 87 db attenuation in 3 db steps. The output of AT101 is connected to the input of the preamplifier. Since the input resistance of the preamplifier is high compared to the shunt resistance of AT101, the loading effect of the input resistance of the preamplifier is negligible.

The input impedance control and the attenuator are optional features. A fixed attenuator may replace the two, or the input impedance of the amplifier may be increased above 5 kohm by employing higher-value, fixed-shunting resistors at the input. Increasing the input impedance has the effect of increasing the equivalent-input noise voltage level, and the preamplifier would have to be restabilized by increasing the value of C102. The noise voltage at the input terminals is approximately doubled when the input impedance is increased from 5 to 20 kohm.

1



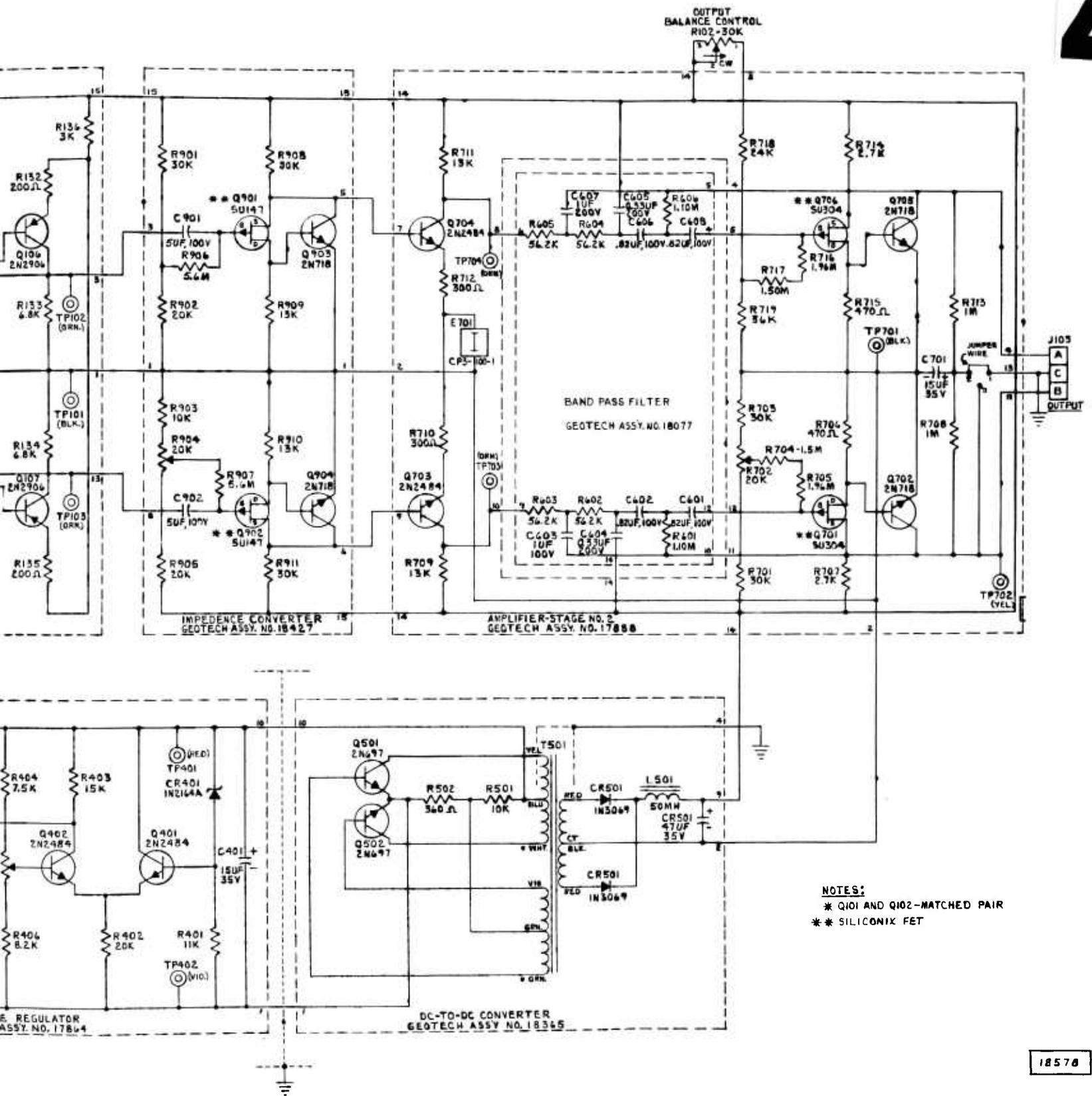


Figure 4. Schematic diagram with analog output

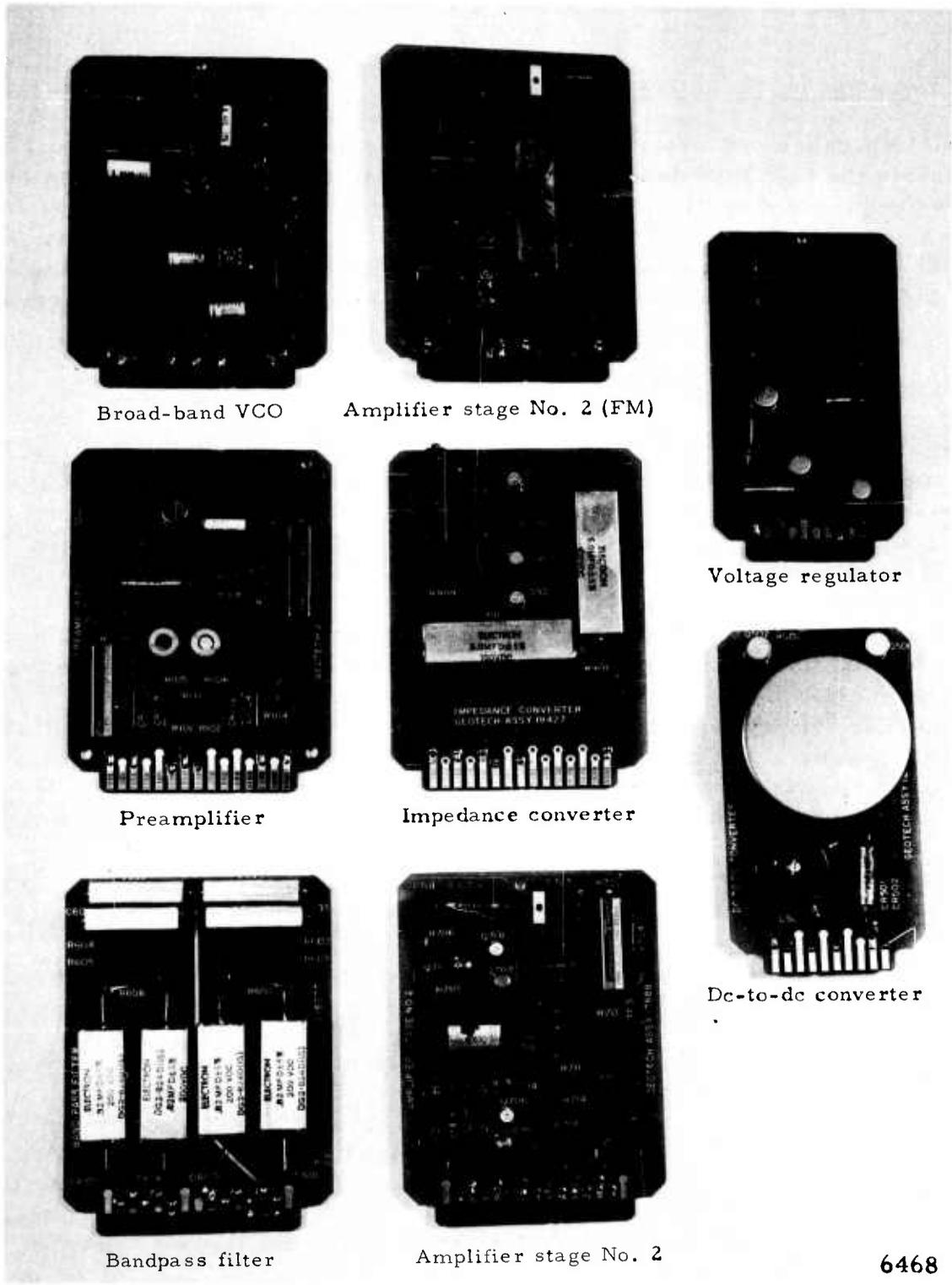


Figure 5. Amplifier circuit boards

3.3.4 Impedance Converter

The impedance converter consists of two balanced FET stages. The FET's provide the high impedance necessary for practical capacity coupling of low-frequency signals. The gain of the impedance converter stage is less than one. The time constant associated with capacitor C901 and resistor R906 is greater than 25 sec. Trimpot 904 is a balance control for the output of the stage. Q901 and Q902 are selected for a prescribed drain current for zero gate-to-source voltage and a given drain voltage.

3.3.5 Amplifier Stage No. 2

Amplifier stage No. 2 consists of a transistor differential amplifier and a balanced FET output. The bandpass filter components connect the output of the amplifier to the input of the high-impedance FET stage. No signal can be coupled through amplifier stage No. 2 unless the bandpass filter is connected to it.

The circuit may be wired for single-ended output or balanced output simply by changing the connections of one jumper wire. The output balance control, potentiometer R102, is located in the bias return circuit of Q706. Amplifier stage No. 2 offers gain stability, common-mode rejection, and a stable low-drift output over a wide temperature range.

The difference amplifier stage is conventional and uses E701, a hermetically sealed constant-current source manufactured by the Circuit Dyne Corporation, for cross coupling. Basically, each half of the output stage is a source follower with Q702 and Q705 acting as current multipliers of Q701 and Q706, respectively.

3.3.6 Bandpass Filter

The bandpass filter contains only RC components. The active components used in conjunction with this filter are in amplifier stage No. 2. The value of the passive components in the bandpass filter determines the filter's characteristics. This mounting procedure allows the use of interchangeable plug-in filters of different characteristics without having to change the active elements employed in the filter circuit. The normal bandpass filter is of maximum flat design and has half-power points at 0.1 and 5 cps with attenuation slopes beyond either cutoff point of 12 db per octave. Considering one side of the active bandpass filter, C606, C608, R606, R716, and R717 are the components which establish the

low-frequency cutoff point. R604, R605, C605, and C607 are the components which establish the high-frequency cutoff point. The midband gain of the bandpass filter is approximately 0.93.

3.3.7 Voltage Regulator

The voltage regulator provides a regulated output voltage from the power-source input voltage which may vary from 22 to 28 vdc. The regulated voltage may be set from 15.5 to 18.5 vdc and is adjusted by R405. Any change in the regulator's output voltage is detected by the unbalance it produces at the inputs of the difference amplifier Q401 and Q402. The output of the difference amplifier is connected to a grounded emitter-amplifier stage Q403. The output of Q403 is connected to the base of transistor Q404 which drives transistor Q405. Q405 acts as an emitter-follower stage with the remaining circuits of the amplifier acting as the emitter resistor. The drive at the base of Q405 is directed in the opposite direction from the original change in output voltage. Thus, the output voltage is held nearly constant by this feedback action. The three diodes, CR402 through CR404, are biased in the forward direction, and perform the function of a 1.8 v zener diode. These three diodes, in conjunction with R408, provide a near constant-voltage supply for the collector circuit of Q403. Capacitors C401 and C402 aid in filtering the output voltage.

3.3.8 Dc-to-Dc Converter

The dc-to-dc converter consists of a conventional transistor inverter circuit, a full-wave rectifier, and a filter circuit. The purpose of the converter is to provide dc isolation between the input dc power-supply voltage and the dc output which supplies power for the electronic circuitry. Since the input to the converter is regulated, the output dc voltage is regulated. The inverter consists of Q501, Q502, R501, R502, and a tape-wound saturable reactor core T501. The full-wave rectifier and filter components are CR501, CR502, L501, and C501.

3.3.9 FM Carrier Output Circuitry

The FM carrier output circuitry developed for the Photocell Amplifier, Model 16956, is adaptable to the solid-state amplifier. Amplifier stage No. 2 and the bandpass filter are removed and replaced by amplifier stage No. 2 (FM), Geotech Assy No. 18074, and either the broad-band VCO, Geotech Assy No. 18371, or the IRIG channel VCO, Geotech Assy No. 18312. A photograph of the IRIG channel No. 7 VCO is shown in figure 6.

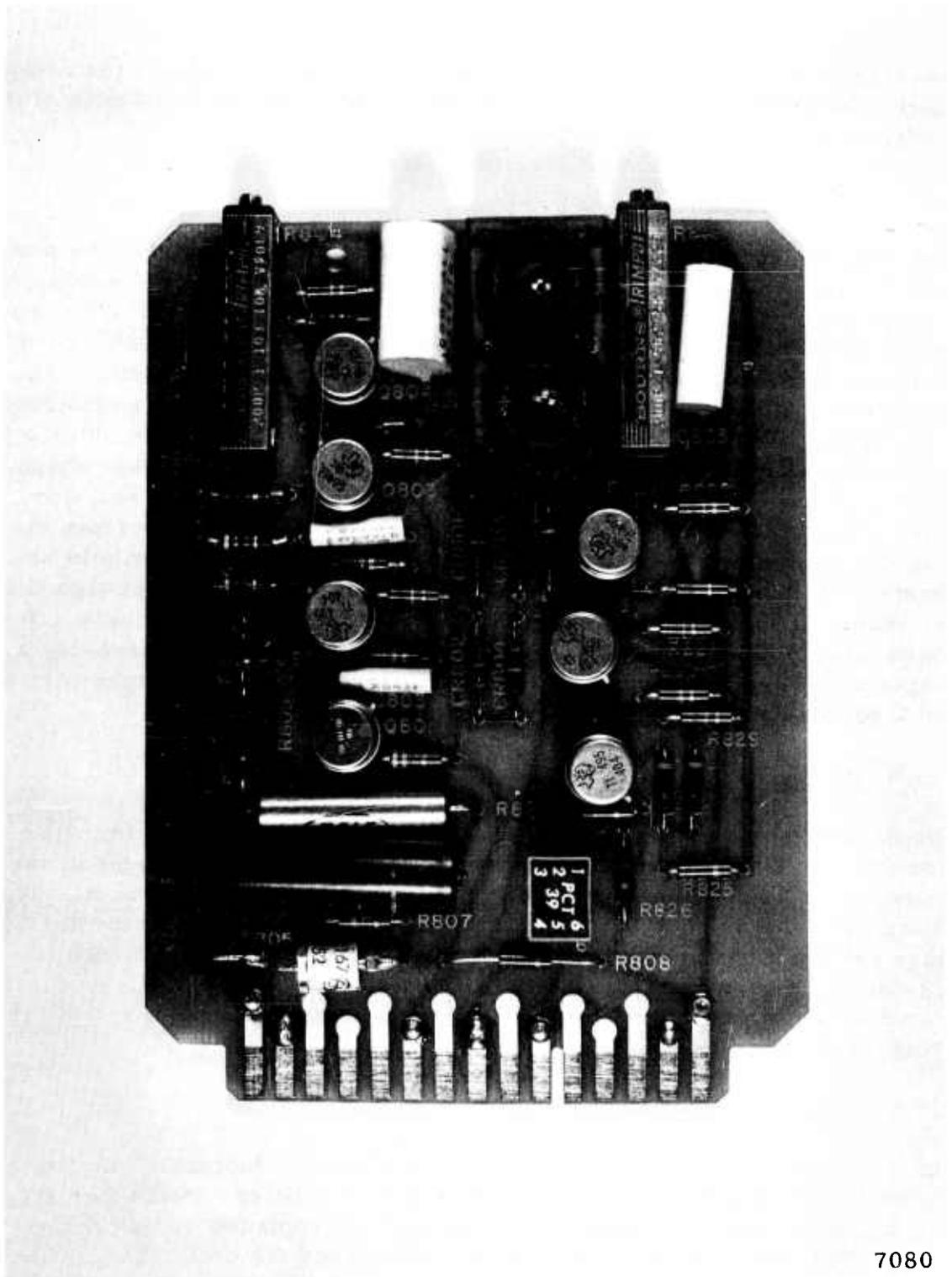


Figure 6. IRIG channel No. 7 VCO

One modification is made on amplifier stage No. 2 (FM) for this conversion. R201 and R203 resistor values are each changed to a value of 1 kohm. The effect of this modification is to increase the modulation sensitivity of the amplifier.

Refer to Geotech TR 64-71 for further discussion concerning these components.

4. TEST RESULTS WITH ANALOG OUTPUT

4.1 GENERAL

The following sections contain the test results of the amplifier with analog output. Figure 4 is the schematic diagram of the circuitry used for the tests.

4.2 POWER REQUIREMENTS

With the input power-supply voltage set at 24.0 vdc, the operating current was 39.5 ma. The nominal operating power is therefore 0.95 w.

4.3 GAIN

The gain was determined by taking the ratio of the measured p-p output signal voltage to the p-p input signal voltage for midband frequencies and at normal operating levels. The observed gain was 9,950.

4.4 NOISE

The block diagram in figure 7 shows the apparatus used in this test. Figures 8 through 10 are reproductions of the resulting noise records. A 1.0 μv p-p input signal is resolved on the records made at 25 $^{\circ}$ and 60 $^{\circ}$ C. A 1.5 μv p-p signal is resolved on the records made at -50 $^{\circ}$ C. From these records, an equivalent-input noise level of 1.0 μv rms was estimated.

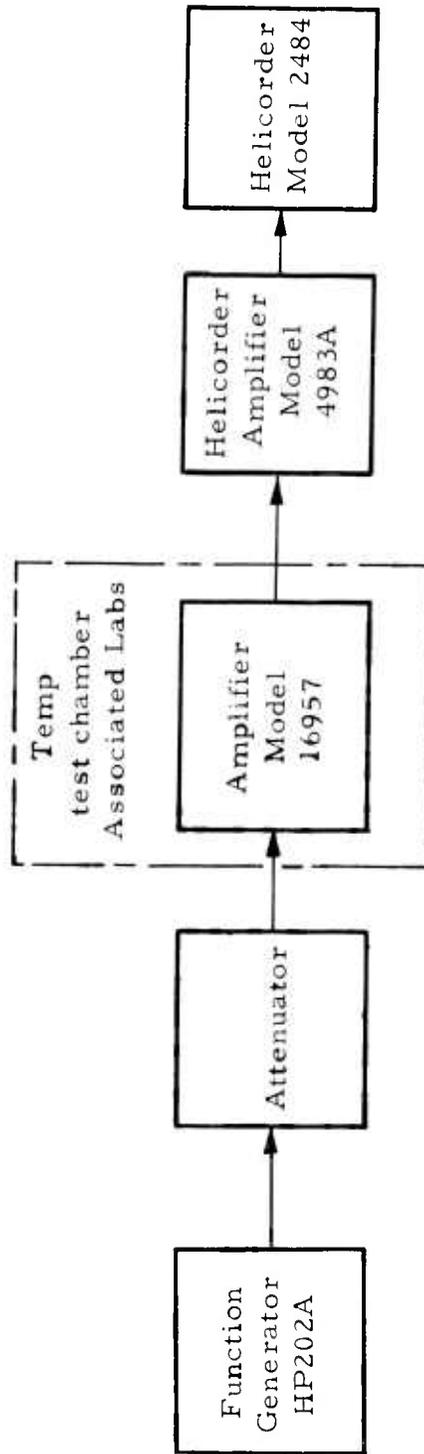
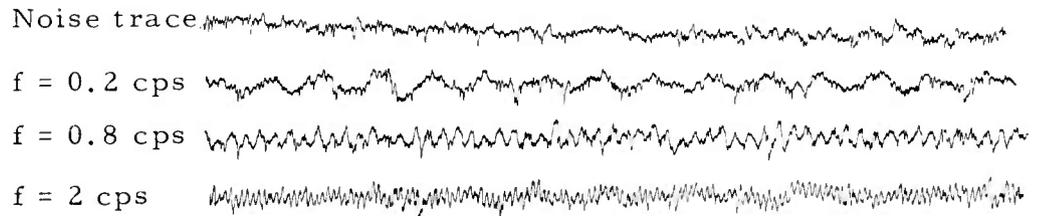
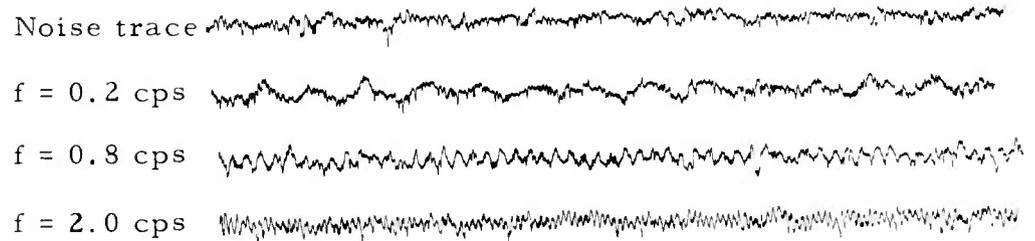


Figure 7. Noise-test apparatus for analog output, block diagram

Power
supply
voltage
= 24 vdc



Power
supply
voltage
= 28 vdc



Power
supply
voltage
= 22 vdc

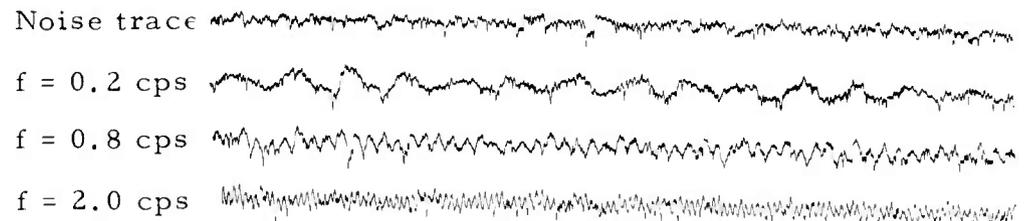


Figure 8. Analog output records of noise and 1 μ v p-p signal
taken at 25°C

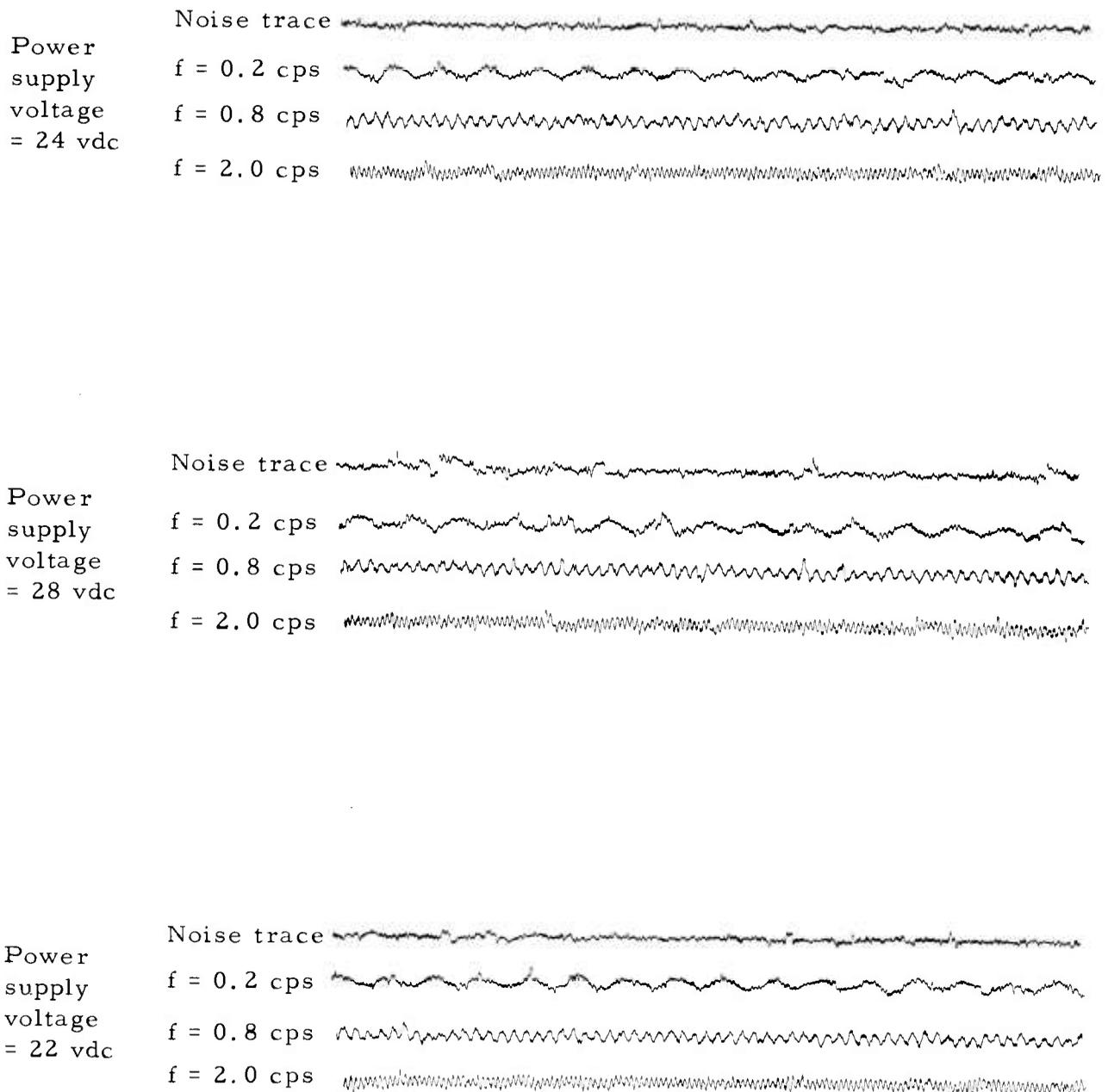


Figure 9. Analog output records for noise and $1 \mu\text{v}$ p-p signal taken at 60°C

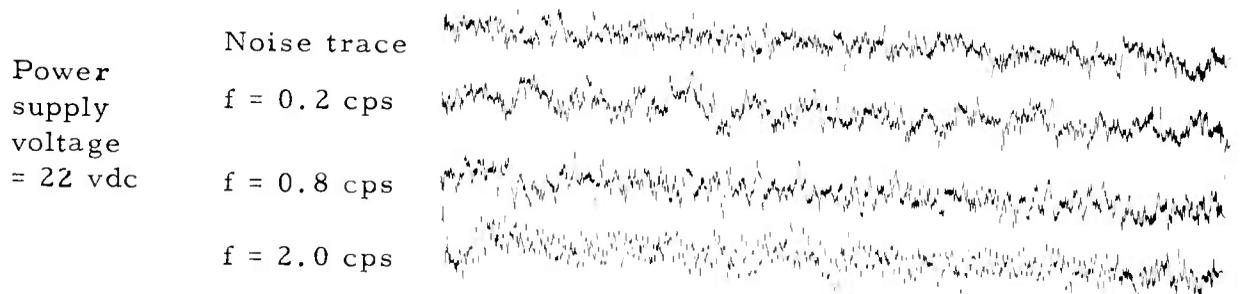
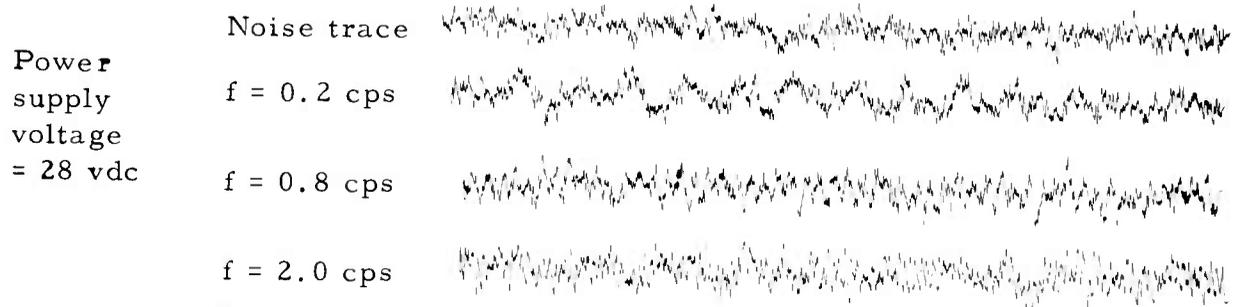
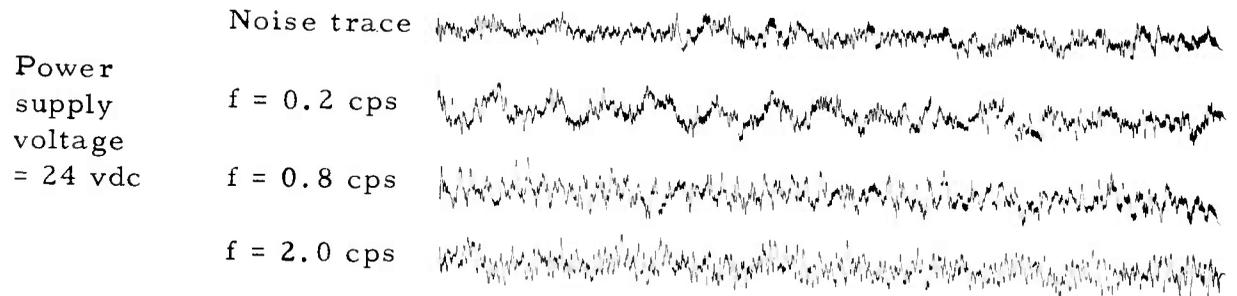


Figure 10. Analog output records for noise and 1.5 μ v p-p signal taken at -50°C

4.5 TEMPERATURE

The amplifier was tested over the temperature range of -60°C to $+60^{\circ}\text{C}$. Figure 11 shows how the gain of the amplifier varied with temperature. The gain did not deviate more than 6% from its nominal value. Figure 12 shows how the output dc voltage offset varied with temperature. Around room temperature the offset was about $1\text{ mv}/^{\circ}\text{C}$. At the temperature extremes the offset rose to about $3\text{ mv}/^{\circ}\text{C}$.

4.6 DYNAMIC RANGE

Figure 13 is a reproduction of a recording of the amplifier output under two conditions: high gain showing noise level, and low gain showing clipping. Using the noise and clipping p-p levels, the dynamic range was computed to be 57 db.

4.7 LINEARITY

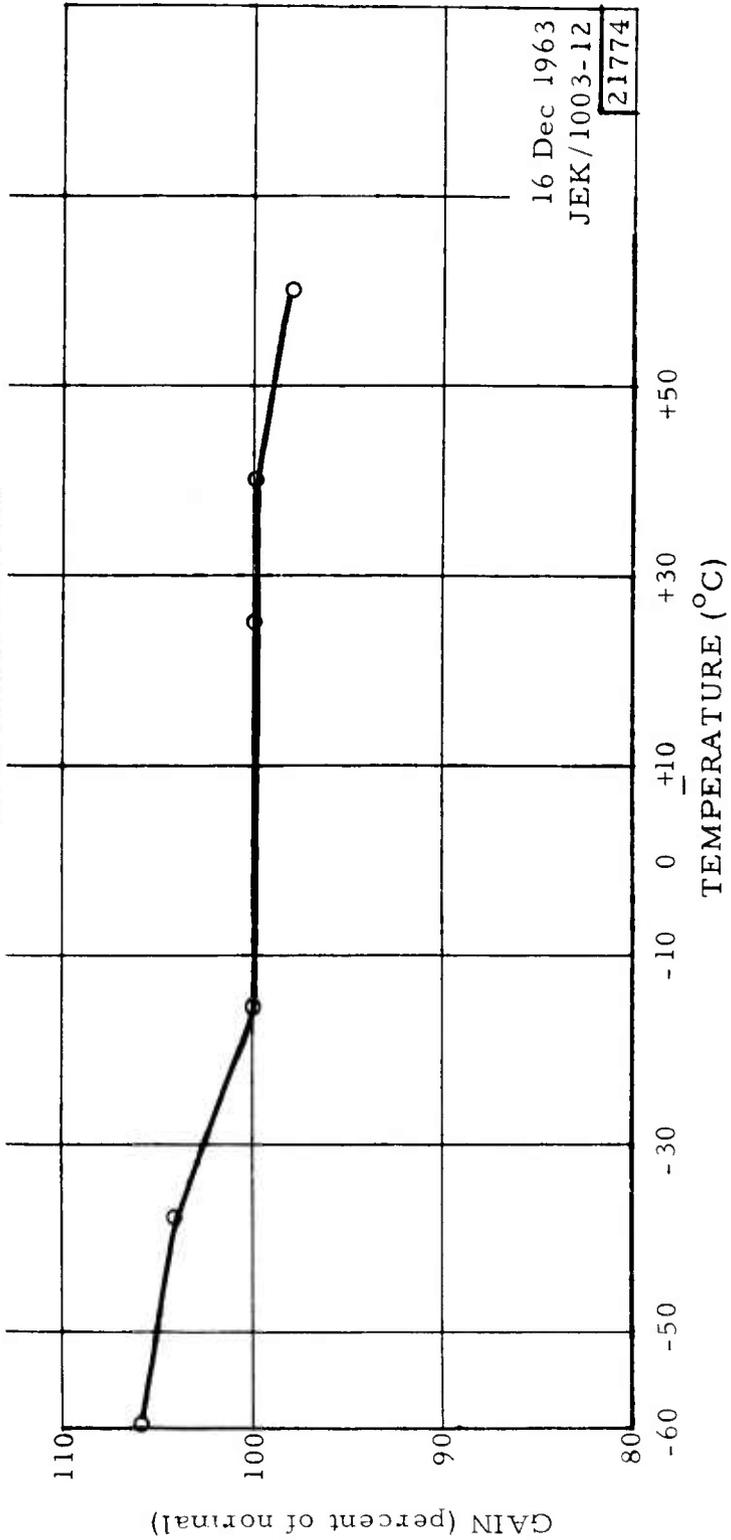
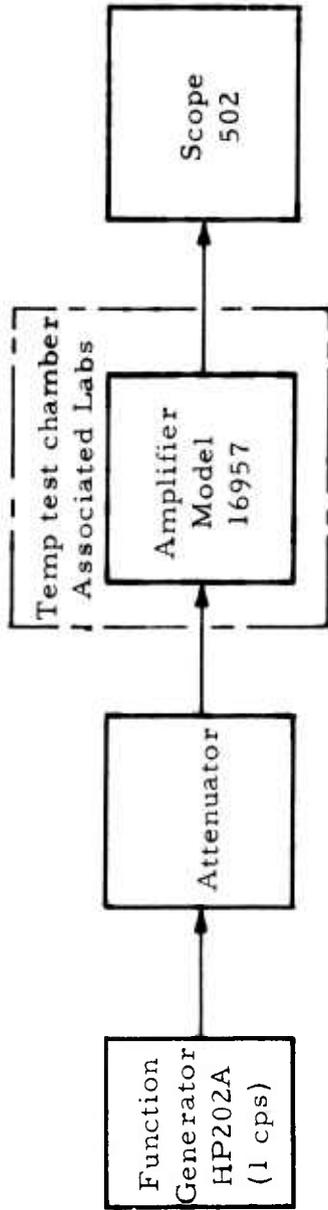
Figure 14 is a scope photograph of a Lissajous pattern of the amplifier's output voltage swing and the amplifier's input voltage swing before attenuation. The frequency of the applied signal was chosen to have zero phase shift between the input and output signals. The resulting Lissajous pattern represents the linearity of the amplifier. The observed linearity is about $\pm 1.5\%$ of the 15 v p-p output swing.

4.8 FREQUENCY RESPONSE

Figure 15 is a plot of the frequency response of the amplifier with a 0.1 to 5 cps bandpass filter. With the low-pass filter components removed from the filter, the maximum operating frequency was measured to be approximately 40 kc.

4.9 POWER SUPPLY VARIATIONS

A 10% step increase and a 10% step decrease of the power-supply voltage was applied to the amplifier. No output voltage above the normal output noise voltage of the amplifier was observed in either case. A change in the power-supply voltage from 22 to 28 vdc caused no change in gain.



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Figure 11. Gain vs temperature, analog output

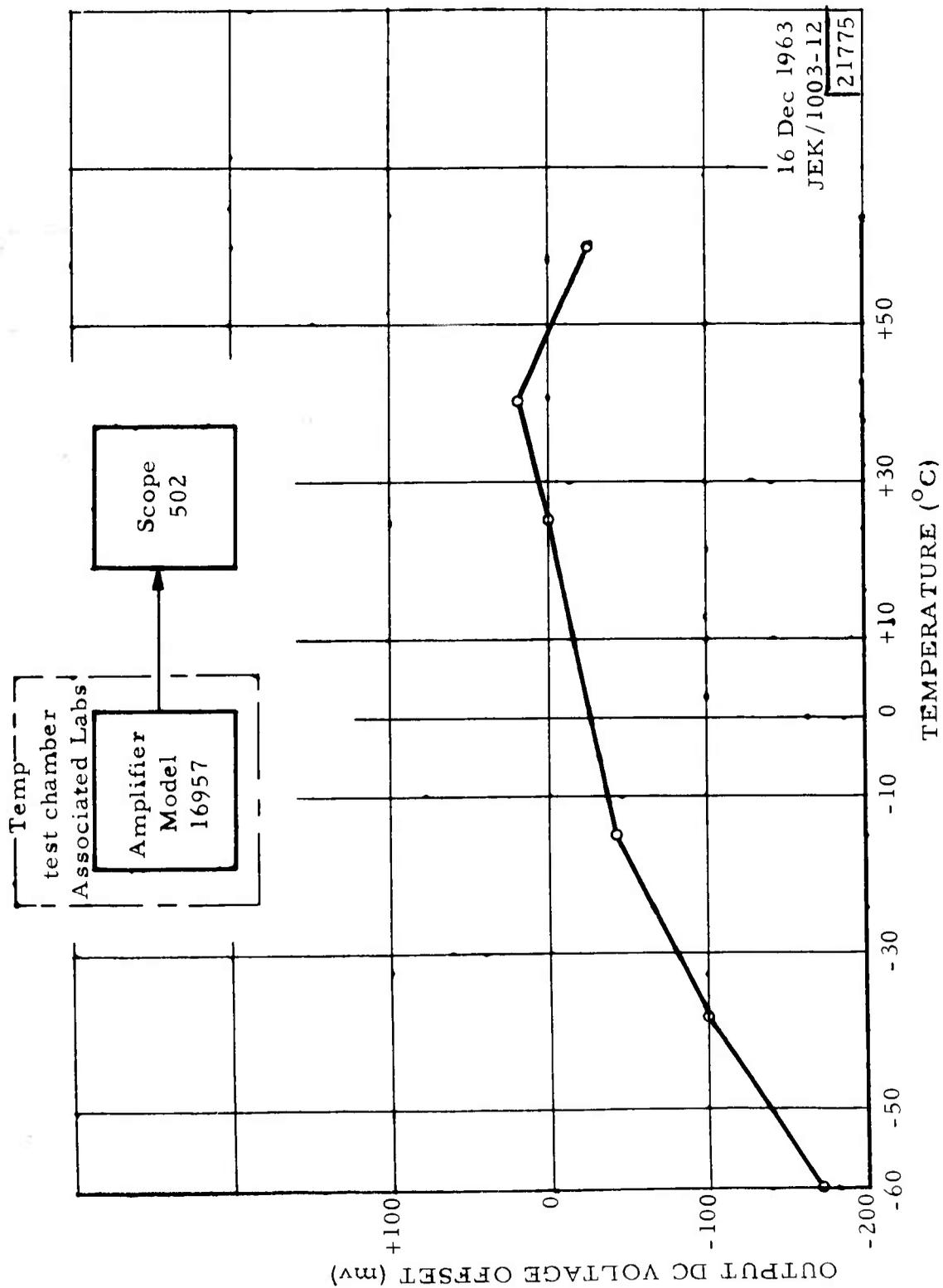


Figure 12. Output dc voltage offset vs temperature



Record:	Noise	Signal
Level:	4 mm p-p	28 mm p-p
Amplifier:	0 db	0 db
Recorder:	0 db	-40 db
Dynamic range:	57 db	

Figure 13. Dynamic range, analog output

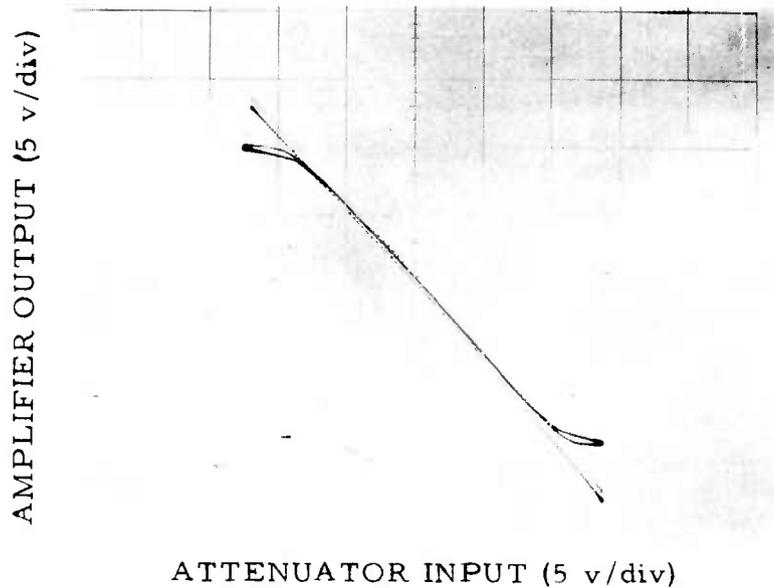


Figure 14. Linearity, analog output. The dotted lines represent $\pm 2\%$ linearity limits for the 15 v p-p maximum rated output

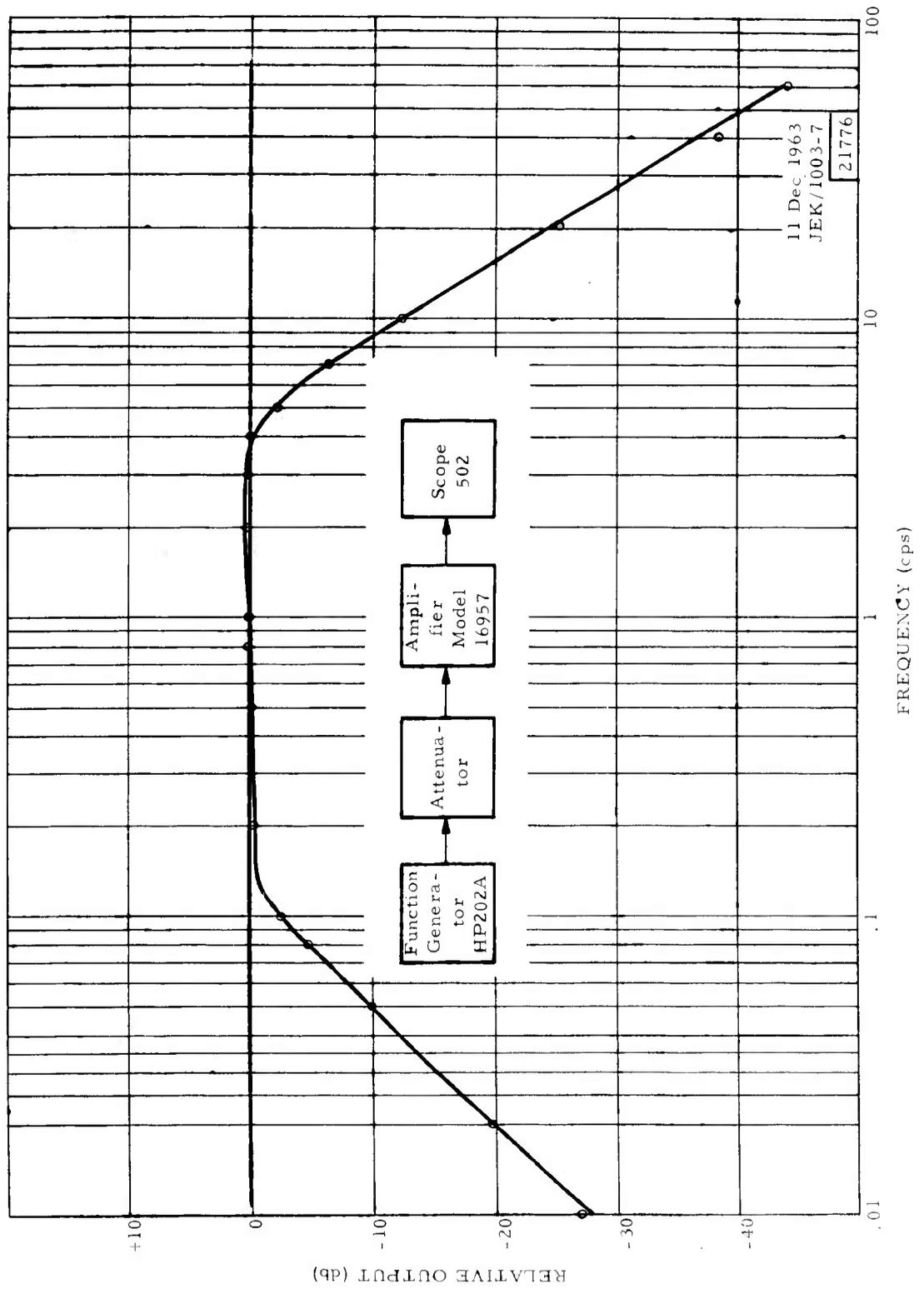


Figure 15. Frequency-response characteristics, amplifier with 0.1-5 cps bandpass filter

4.10 COMMON-MODE REJECTION

The two amplifier inputs (J101 plus A and B) were shorted together and a 400 mv p-p signal was applied between the inputs and common. With the amplifier gain set to 10,000, a 190 mv p-p output was obtained. The equivalent-input signal produced by the common-mode signal was $19 \mu\text{v}$ p-p giving a common-mode rejection of 21,000: 1 or 86.4 db.

4.11 DRIFT

Figure 16 is a reproduction of a record section showing the drift of the amplifier as made on a Photographic Paper Recorder, Model 271.

4.12 HUMIDITY

No humidity test was performed. However, the final case will be hermetically sealed.

4.13 INPUT IMPEDANCE

The maximum input impedance was measured to be 5 kohm.

4.14 OUTPUT IMPEDANCE

A 1-cps sine-wave signal was applied at the input of the amplifier. The amplifier gain was adjusted to produce 4 v p-p at the unloaded output. A 1 kohm resistor was then connected across the output and the output dropped to 3.5 v p-p. This indicates an output impedance of 150 ohms.

4.15 OUTPUT RECORD

The output of the amplifier was connected to a Helicorder amplifier. Without changing any gain settings, recordings were made at several different input levels to show the resolution range of the system. Figure 17 is a reproduction of a Helicorder record with a system sensitivity of $10 \mu\text{v}/\text{mm}$.

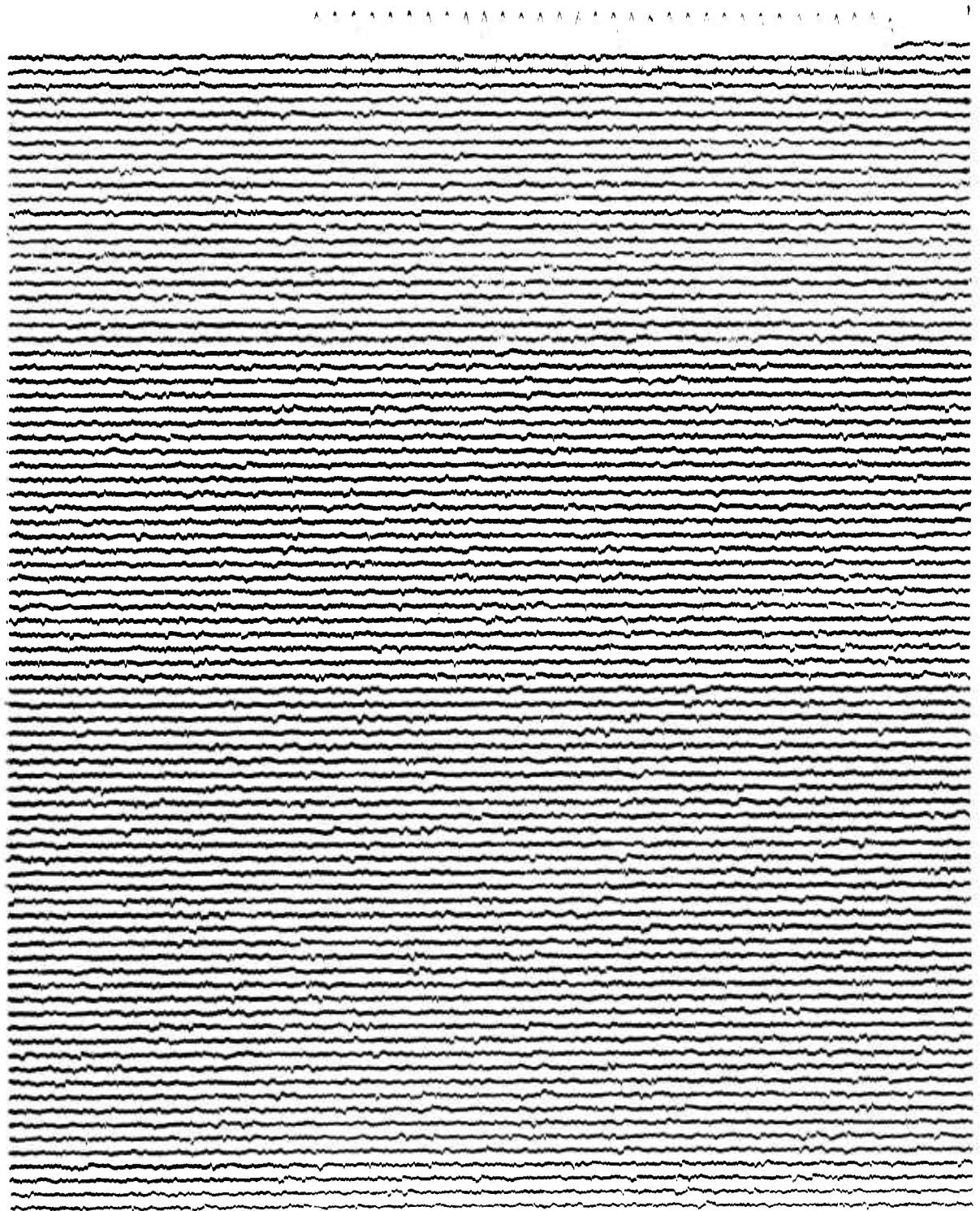


Figure 16. Drift record, analog output (section of a 21-hour photographic-paper recording). Calibration signal is $20 \mu\text{v}$ p-p, 0.3 cps

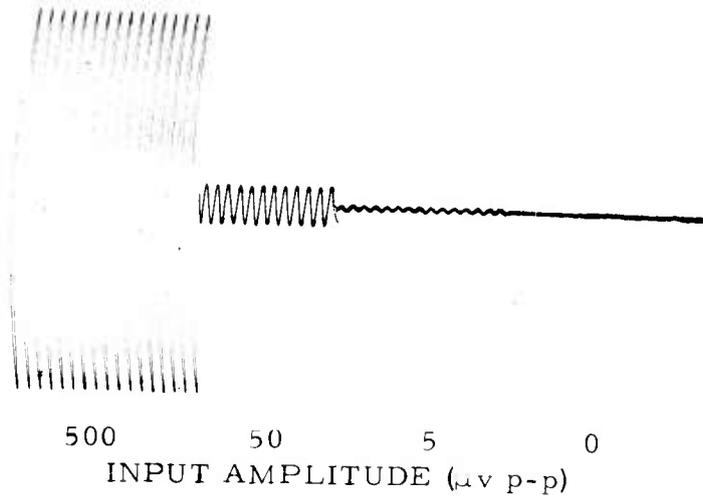


Figure 17. Helicorder record of 1-cps sine wave, analog output

5. TEST RESULTS WITH BROAD-BAND FM CARRIER OUTPUT

5.1 GENERAL

The following sections contain the test results of the amplifier with broad-band FM carrier output. Two circuit boards, the amplifier stage No. 2 and the bandpass filter, were replaced with amplifier stage No. 2 (FM) and the broad-band VCO to obtain the FM carrier output circuitry. Also, the dc-to-dc converter was removed for the following tests. For tests of noise level, gain, dynamic range, and linearity, the FM signal was demodulated by a FM Discriminator, Model 15216.

5.2 POWER REQUIREMENTS

With the power-supply voltage set to 24.0 vdc the input current was 22.5 ma yielding a power demand of 0.54 w.

5.3 MODULATION SENSITIVITY

The modulation sensitivity was measured to be 465 cps/mv. With a 1550-cps center frequency this results in 30% deviation/mv.

5.4. NOISE

The block diagram of figure 18 shows the apparatus used in this test. Figure 19 is a reproduction of the resulting noise record. A $1.5 \mu\text{v}$ p-p input signal is resolved on the records at room temperature.

5.5 TEMPERATURE

The amplifier was tested in the range -64°C to $+62^{\circ}\text{C}$. Figure 20 shows how the gain varied with temperature. Figure 21 shows how the output center frequency varied with temperature.

5.6 DYNAMIC RANGE

Figure 22 is a reproduction of a recording of the amplifier output under two conditions: high gain showing noise level and low gain showing clipping level. Using the noise and clipping p-p levels, the dynamic range was computed to be 62 db.

5.7 LINEARITY

Figure 23 is a scope photograph of a Lissajous pattern made in the same manner as figure 14. As may be observed, the linearity is within $\pm 2\%$ over the 90 v p-p output voltage swing.

5.8 POWER SUPPLY VARIATIONS

A 10% step increase and a 10% step decrease of the power-supply voltage was applied to the amplifier. No output above the noise level of the amplifier was observed in the first case and a 0.1 v temporary output voltage offset was observed in the second case. A change in the power-supply voltage from 22 to 28 vdc caused no change in gain.

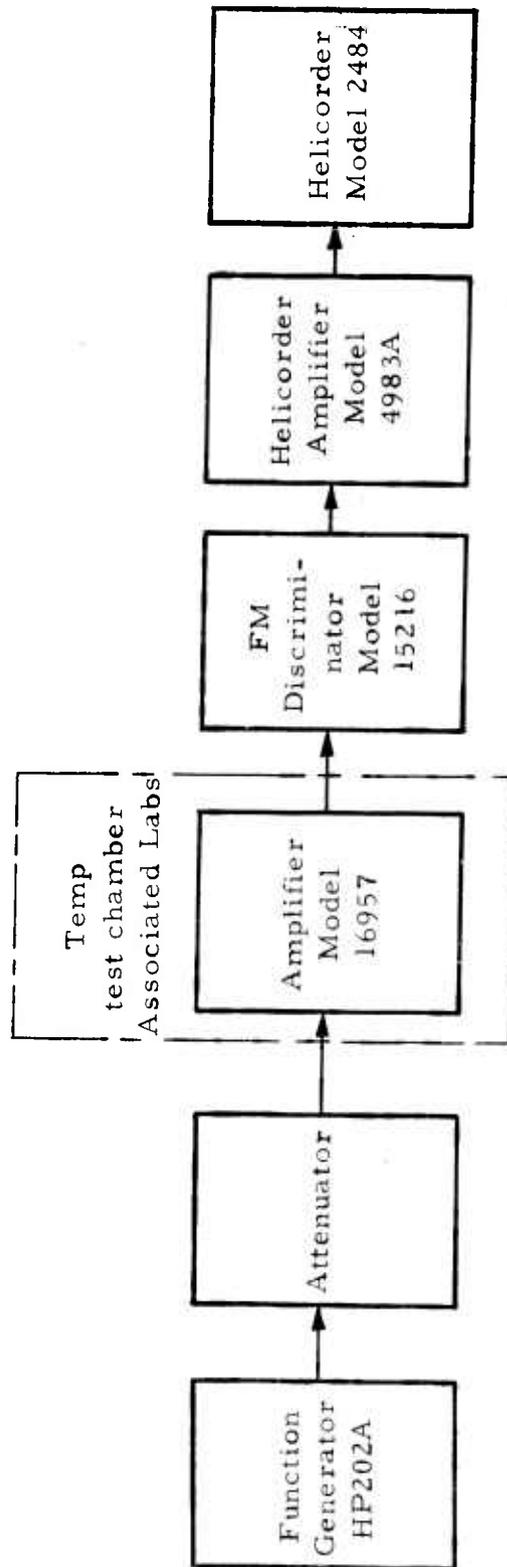


Figure 18. Noise-test apparatus for broad-band FM carrier output, block diagram

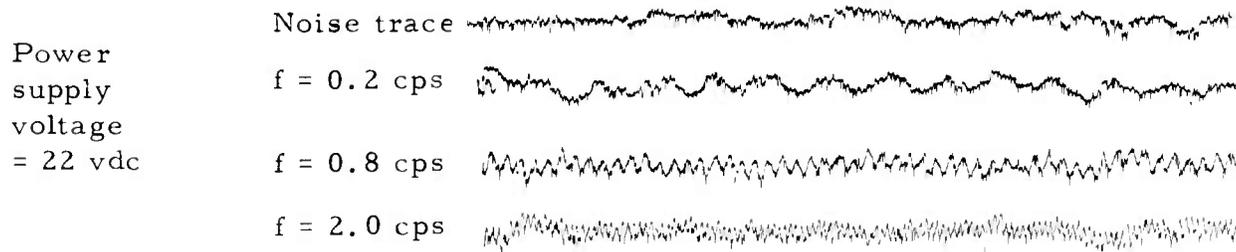
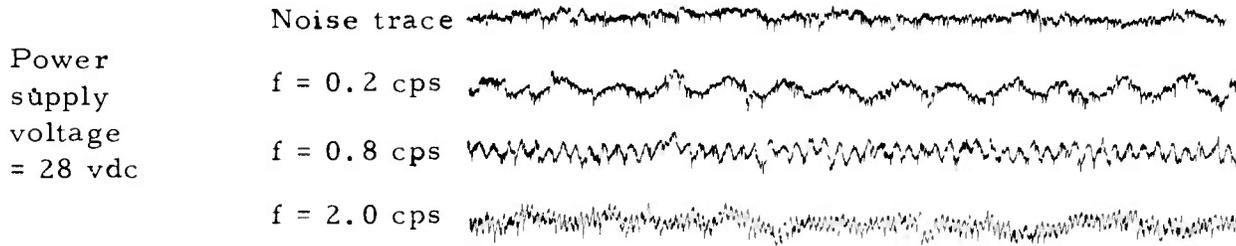
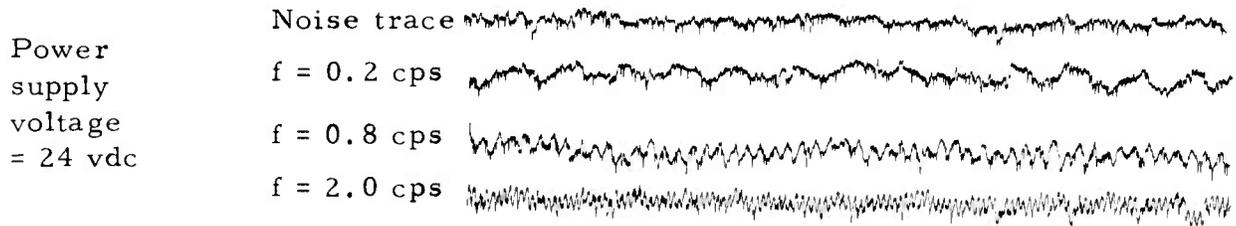


Figure 19. Broad-band FM carrier system output records of noise and 1.5 μ v p-p signal at 25°C

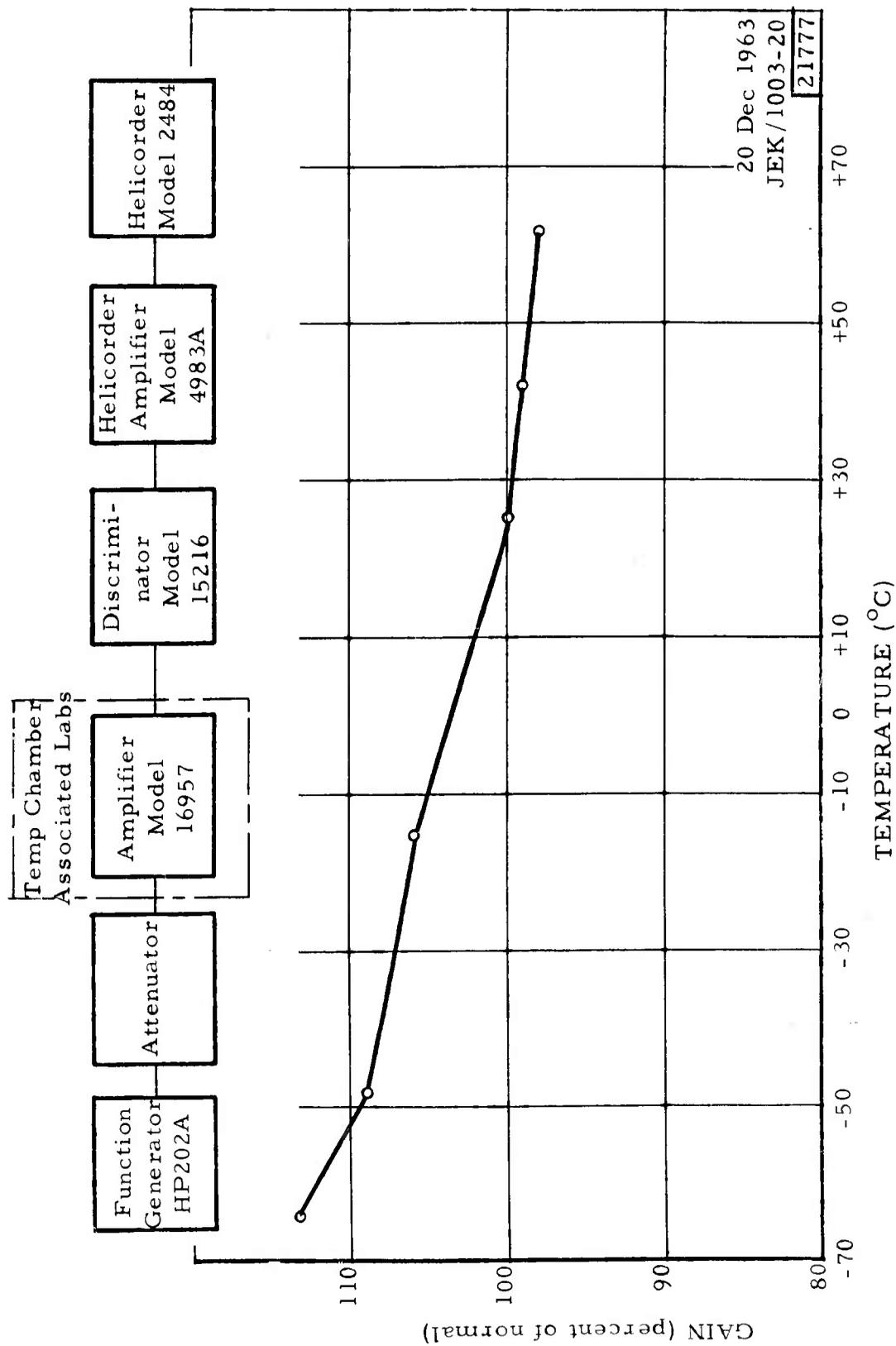


Figure 20. Gain vs temperature, broad-band FM carrier output

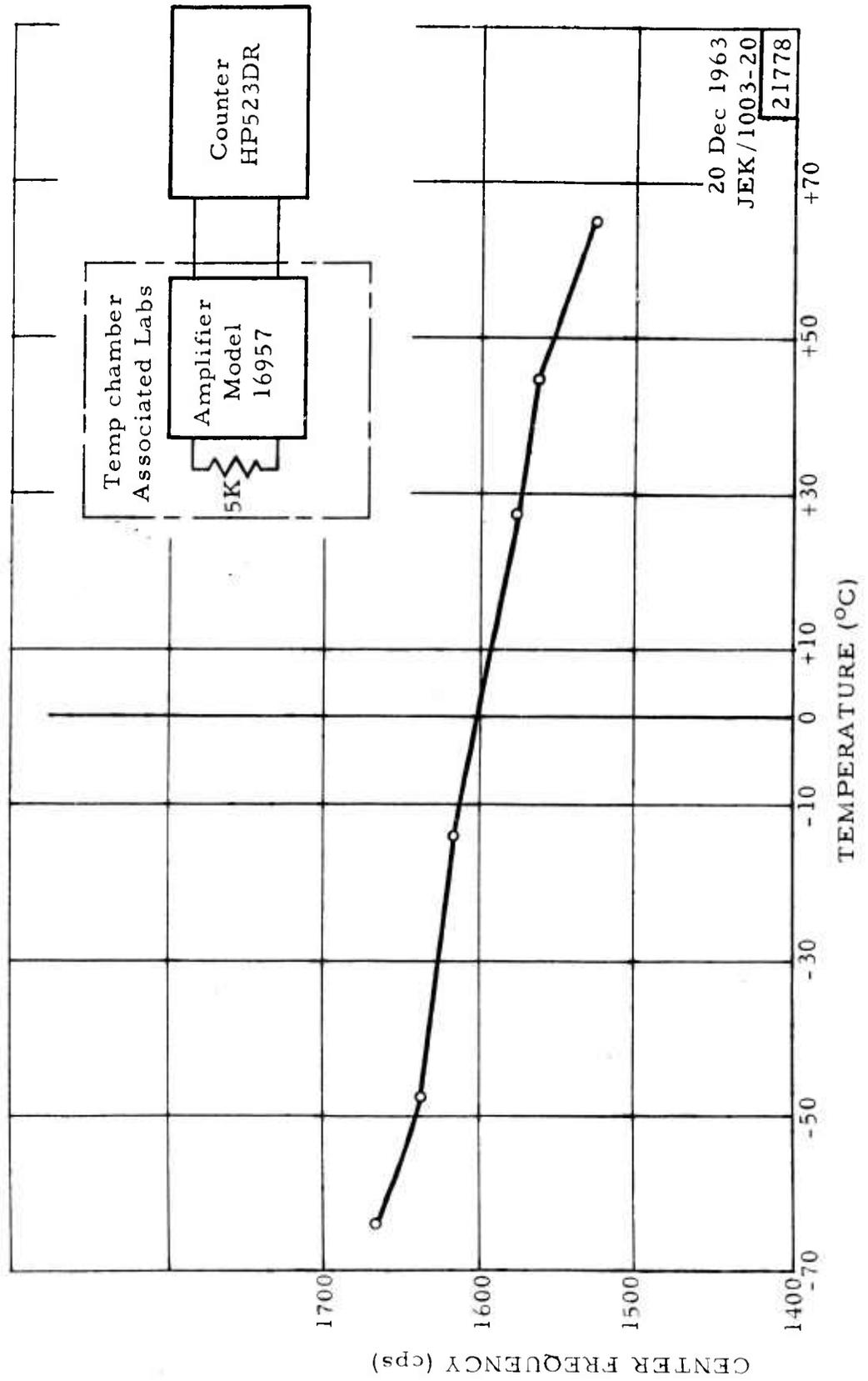
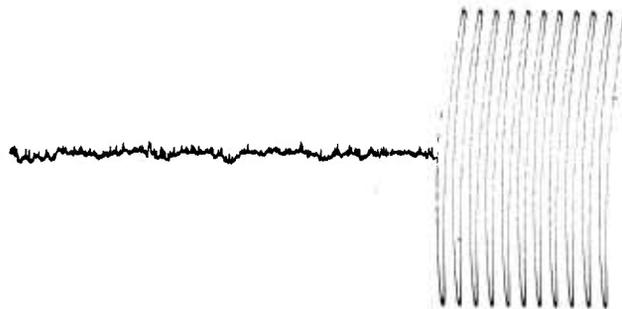


Figure 21. Center frequency vs temperature, broad-band FM carrier output



Record:	Noise	Signal
Level:	3 mm p-p	39 mm p-p
Amplifier:	0 db	0 db
Recorder:	-20 db	-60 db
Dynamic range:	62 db	

Figure 22. Dynamic range, broad-band FM output

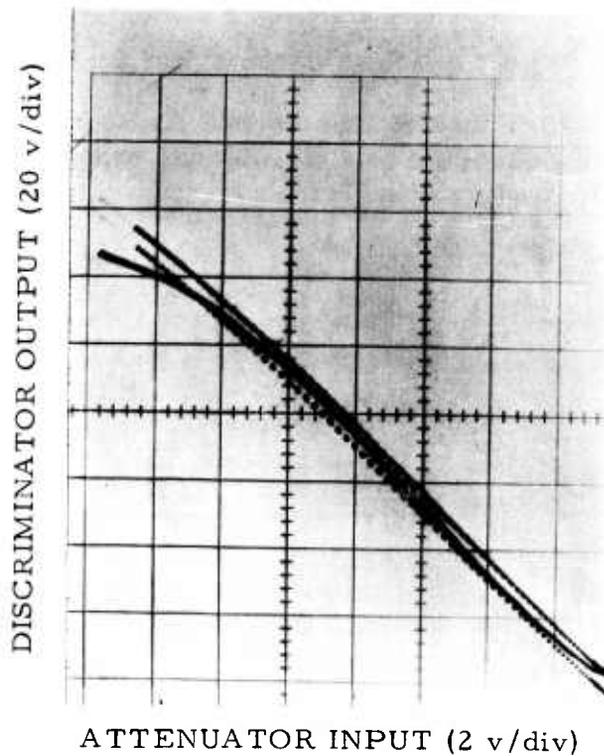


Figure 23. Linearity, amplifier-FM subcarrier-discriminator combination. The dotted lines represent $\pm 4\%$ limits for the 90 v p-p maximum rated output

5.9 COMMON-MODE REJECTION

This test gave the same results as for the analog case. A 400 mv p-p common-mode input signal gave the same output as a 19 μ v p-p normal input signal, yielding a common-mode rejection value of 86.4 db.

5.10 OUTPUT IMPEDANCE

The output impedance was measured to be 600 ohm.

5.11 OUTPUT VOLTAGE

The output carrier voltage measured 2.9 v p-p square wave when the output terminals were terminated by a 600 ohm load.

5.12 OUTPUT RECORD

The output of the amplifier was connected to an FM discriminator and the FM discriminator was connected to a Helicorder amplifier. Figure 24 is a reproduction of a Helicorder record with a system sensitivity of 10 μ v/mm.

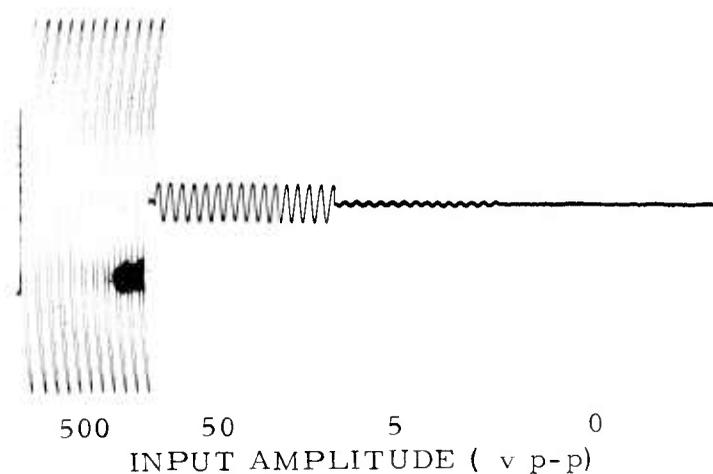


Figure 24. Helicorder record of 1-cps sine wave, FM broad-band carrier output

6. CONCLUSIONS

Based on the above laboratory tests and preliminary operating experience with the solid-state amplifier, it is concluded that the amplifier has the following features.

a. All solid-state construction provides for ruggedness, versatility, and long operating life.

b. The amplifier has an equivalent-input noise of $1.0 \mu\text{v}$ p-p in the bandpass 0.1 to 5 cps at room temperature and, therefore, can detect a 2.0×10^{-16} w signal at its input terminals.

c. The effect of power-supply variations on the performance of the amplifier is negligible.

d. The power requirements are low (less than 1 w).

e. The sealed case and special circuit design provide for amplifier operation under severe environmental conditions.

f. Either broad-band FM carrier, narrow-band FM carrier, or analog output can be provided in the amplifier.

g. Either the source generator or the output load can be grounded. The amplifier using FM carrier output circuitry will operate with the source generator and the output load commonly or independently grounded.

h. The power supply may be independently grounded when the dc-to-dc converter is employed.

7. RECOMMENDATIONS

Since the engineering model has qualified under all of the original design specifications in laboratory tests, it is recommended that several production models be constructed and tested. This will allow the evaluation of production variation of the various system parameters and permit a realistic field test program of performance under adverse environmental conditions.

APPENDIX TO TECHNICAL REPORT NO. 64-73

GEOTECH PRELIMINARY SPECIFICATIONS
SOLID-STATE AMPLIFIER, MODEL 16957

GEOTECH PRELIMINARY SPECIFICATIONS
SOLID-STATE AMPLIFIER, MODEL 16957

1. DESCRIPTION

The amplifier is composed of the following components:

<u>Analog configuration</u>	<u>Coding configuration</u>
Input impedance control	Input impedance control
Step attenuator	Step attenuator
Differential preamp	Differential preamp
Impedance converter	Impedance converter
Amplifier stage	Amplifier stage
Bandpass filter	Voltage-controlled oscillator
Voltage regulator	Voltage regulator
Inverter	
Rectifier and filter	

Features of the amplifier are:

- a. All silicon solid-state devices are used for best temperature stability. No mechanical or transistor choppers are employed.
- b. The input impedance of the amplifier is adjustable for seismometer damping.
- c. Over-all feedback is employed in preamplifier for gain and temperature stability.
- d. The inverter is optional and may provide independent grounding of the power supply.
- e. Either floating input - grounded output or grounded input - floating output connections may be employed.
- f. Capacitor coupling is provided for minimizing output drifts and degradation of dynamic range.

2. SPECIFICATIONS

Input:	Single-ended or balanced Input impedance-adjustable from 0-4 kohm Balanced step attenuator
Noise:	1 μ v rms referred to input in passband of 0.1-5 cps
Power requirements:	1 w
Drift:	Less than 3 μ v peak referred to input in period of 4 hr
Linearity:	$\pm 2\%$ to 80% of max rated output (based on best straight line method)
Signal common-mode rejection:	Greater than 60 db
Power-supply transients:	A $\pm 10\%$ step voltage transient of the power supply shall not cause a change in the output voltage greater than $\pm 2\%$ of max rated p-p output voltage swing.
Operating temperature:	-50°C to +60°C
Humidity:	0-90% relative

ANALOG OUTPUT

Gain:	10K max
Dynamic range:	66 db
Frequency response:	0.1-5 cps (.01-2K cps possible with special filters)
Output:	Balanced 15 v p-p max Output impedance - less than 1K

FM CARRIER OUTPUT

Bandwidth:

Broad-band (400 to 2800 cps)
IRIG channels (1-7)

Output:

Broad-band - 2 v rms square-wave
IRIG channels - 2 v rms sine-wave
Output impedance - 600 ohms

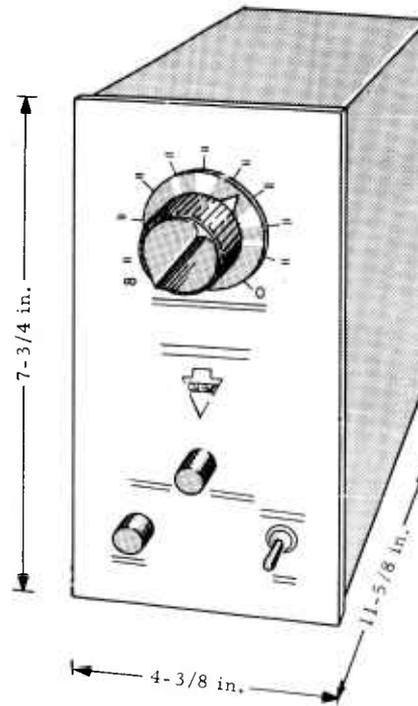


Figure 1. Amplifier, Model 16957, sketch

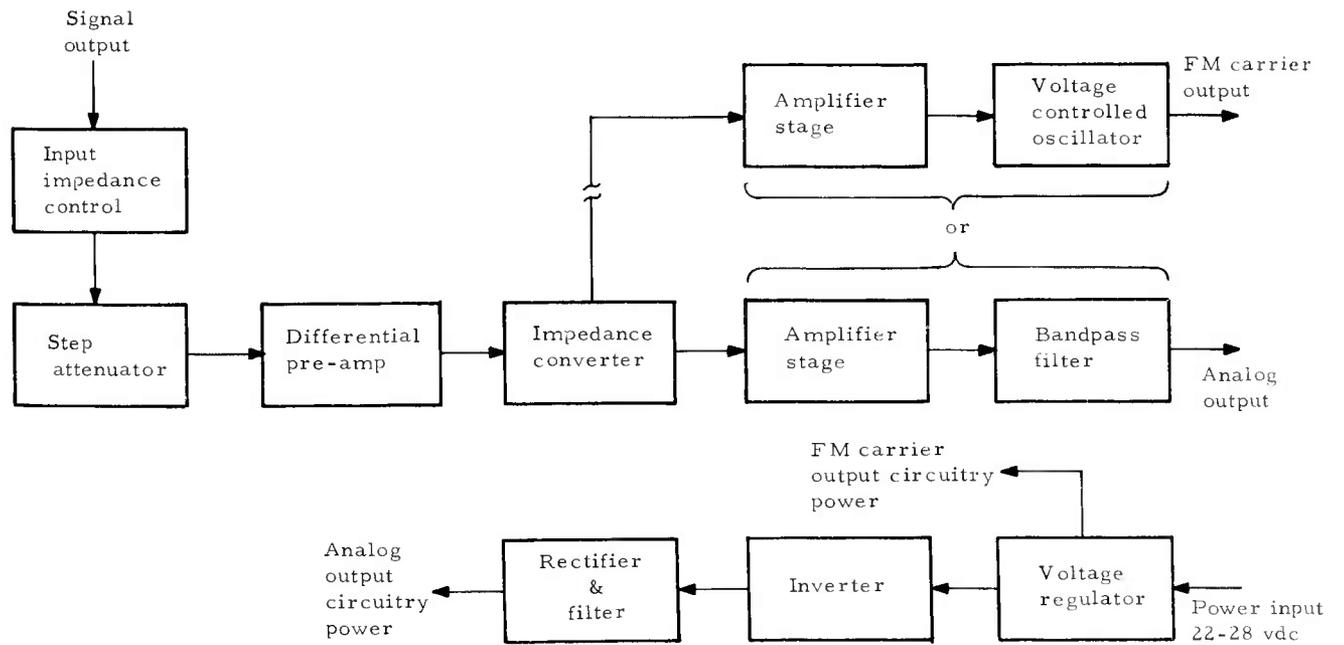


Figure 2. Solid-State Amplifier, Model 16957, block diagram

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