Mines Branch Technical Bulletin TB 67

AN ALL-SOLID-STATE ULTRASONIC POWER OSCILLATOR

by

R.H. Goodman* and A.H. Bettens**

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ABSTRACT

This report describes a versatile all-solid-state power oscillator originally designed for use with an ultrasonic agitating system.

The unit produces a variable frequency sine wave (25 to 100 kc) with a power output of 20 watts into output impedances of 8, 8,000 and 10,000 ohms. The circuit is completely protected from short circuiting of the output.

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OSCILLATEUR ULTRASONIQUE TRANSISTORISÉ

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RÉSUMÉ

Le present rapport décrit un oscillateur transistorisé versatile mis au point d'abord pour servir dans les systèmes d'agitation ultrasonique.

L'appareil produit une sinusoïdale à fréquence variable (25 à 100 kc) avec une alimentation de 20 watts à impédances de 8, 8,000 et 10,000 ohms. Le circuit est complètement protégé contre les courts-circuits de l'alimentation.

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INTRODUCTION

This report describes an all-solid-state power oscillator originally designed for use with an ultrasonic agitating system. However, after its completion, many other uses have been found, either for the complete system or for some of its electronic modules. The entire power oscillator and the power supply are mounted in a Hammond # 140 IF cabinet and are completely self-contained. For the original application, a power of about 20 watts and a frequency range from 25 to 100 kc were required. Because the input impedance of the ultrasonic drive was unknown, the driver was designed to operate into a wide range of impedances.

DESIGN OF THE SYSTEM

A block diagram of the power oscillator is shown in Figure 1, and each individual block will be described in detail in the next section of this report, "Description of Individual Circuit Boards". Several important design features will now be described.

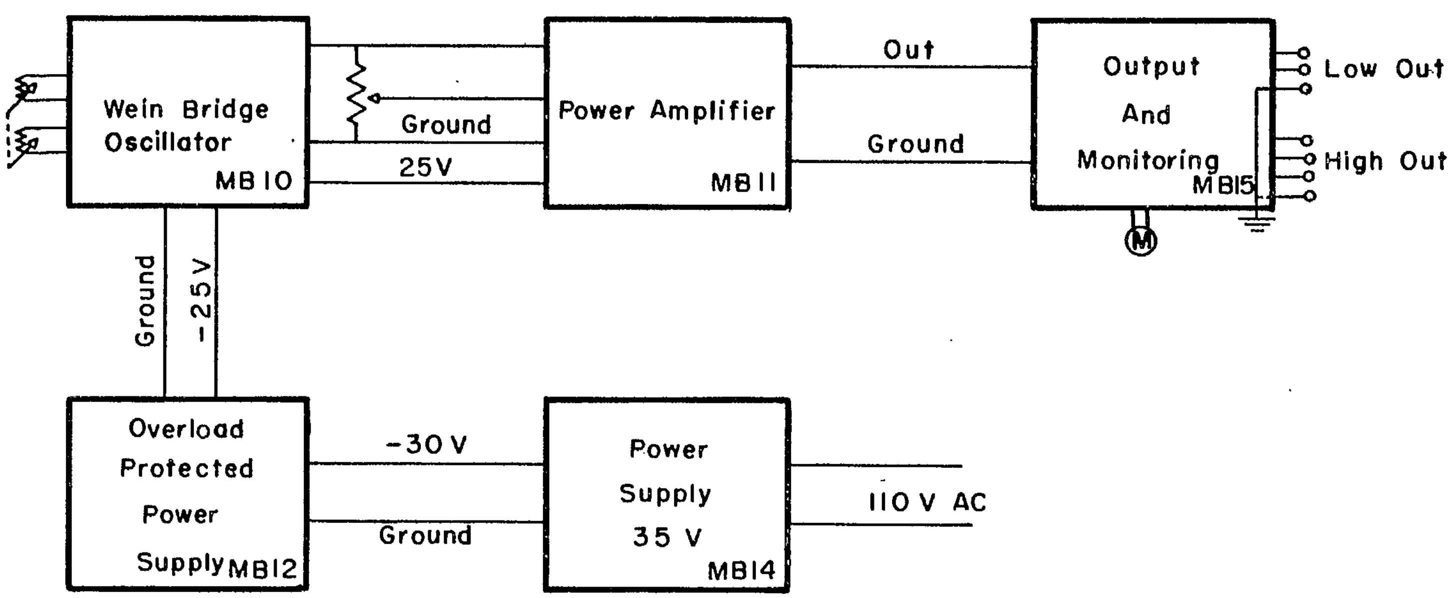


Figure 1. Ultrasonic power oscillator.

The output of the oscillator is fully protected from unintentional abuse. The output may be shorted, or a voltage may be fed into the output, without damaging the components in the system. In the event of prolonged overload or short circuit of the output, the power supply will trip and remove all voltages from the circuit. This condition is indicated by a light on the front panel; the power supply must be reset manually. The overload level can be preset. A self-contained power meter monitors the output, which is also fused. The instrument is essentially a wide-band amplifier driven by a Wien-bridge oscillator. Both units are supplied by a voltage-regulated, current-limited power supply.

DESCRIPTION OF INDIVIDUAL CIRCUIT BOARDS

Printed circuit techniques, previously described in reference (1), were used in the construction of this instrument. It is composed of five sections:

a) Power supply
b) Overload-protected power supply
c) Wien-bridge oscillator
d) Power amplifier
e) Output and monitoring circuit.

Each will now be described in detail.

a) Power Supply

The power supply (Figure 2) employs a Hammond H167V filament transformer (110V a-c to 36V a-c, 2 amp). The 36V output of the transformer is rectified by 4 diodes BYZ13. The negative side is filtered by a 10-ohm wire-wound resistor and a 500-mfd 50V condenser and provides 30V d.c. An on/off pilot light indicator (GE 327) is connected from the centre-tap of the transformer secondary to one side of the same secondary. The power supply is protected by a 0.5-amp fuse on the a-c line.

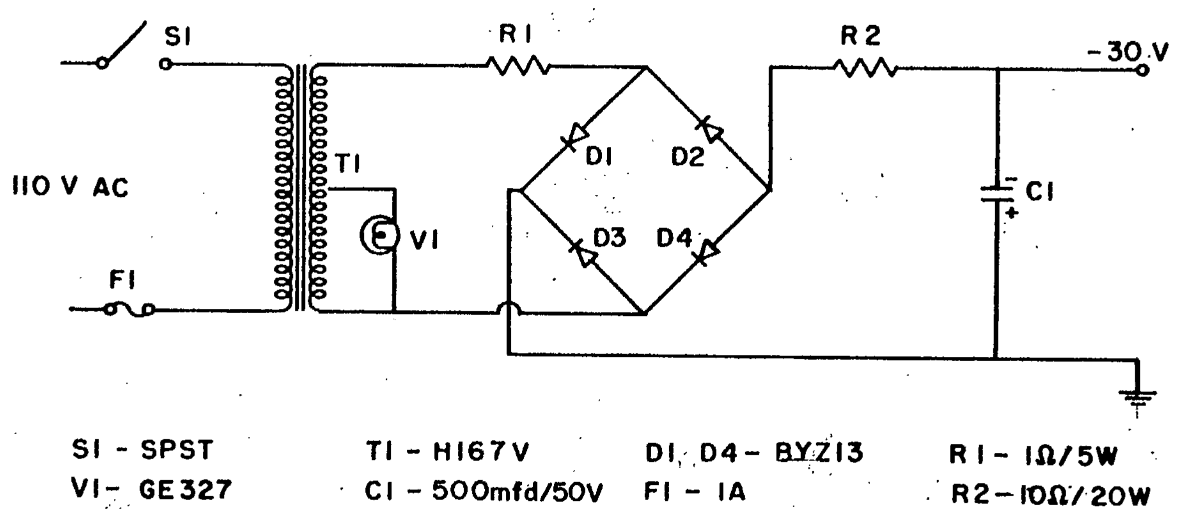
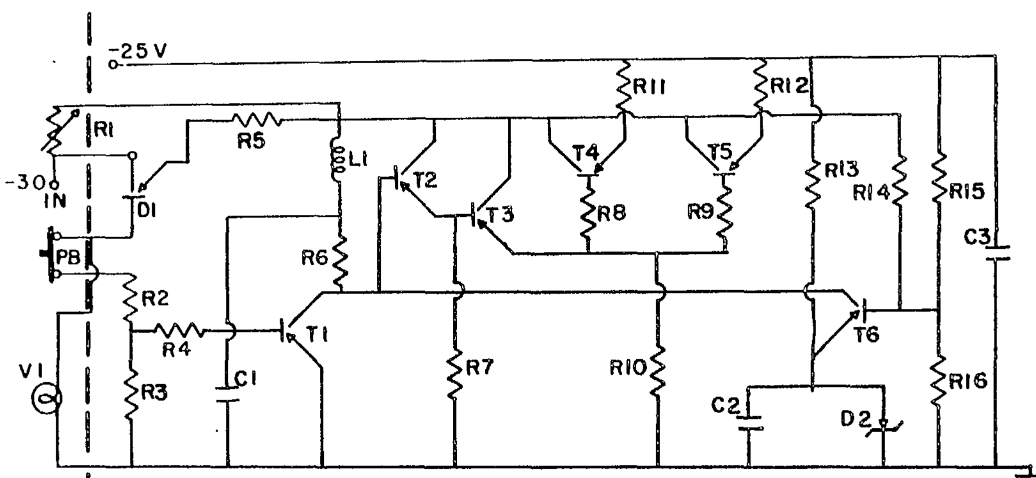


Figure 2. Power supply.

b) Overload-protected Power Supply

The regulator portion is of straightforward design, as shown in Figure 3. The main series transistors T4 and T5, in parallel, control the voltage drop between the input and output. The output voltage, suitably divided by R15 and R16, is compared by T6 with the Zener diode D2. When the output voltage is too high, T6 will draw more current, causing an increased voltage drop across the load resistor R6. This lowers the base voltage of T2 and hence its emitter voltage, which is developed across R7. The lower voltage drop across R7 reduces the base voltage of T3 which causes the emitter voltage of T3 to drop. This lower voltage reduces the current in the series transistors T4 and T5 and hence lowers the output voltage, thereby compensating for the original variation. This process is obviously reversible should the output have been too low. The output condenser C3 provides an a-c bypass, while C2 bypasses the Zener diode.
The protection consists of silicon control rectifier (SCR) D1 and transistor T1, with associated circuitry. The principle of the overload protector is based upon the trigger sensitivity of the SCR. When the voltage at the gate exceeds a certain level, D1 conducts and will remain conducting until the circuit is opened by the push-button system. The voltage drop across R1 determines the trigger point and is proportional to the output current.



FRONT PANEL

R1-2 Ω	R10-1.8K	C1-50/50 V	T1- 2N2429	
R2-680 Ω	R11-0.3 Ω	C2-2/10 V	T2-2N2429	L1-146Y
R3-330 Ω	R12-0.3 Ω	C3-10/50 V	T3-2N457	
R4-2.7K	R13-10K		T4-2N457A	PB-N-Closed
R5-47 Ω	R14-15K	D1-2N1595	T5-2N457A	
R6-10K	R15-5.6K	D2-82215	T6-2N2429	V1-327
R7-8.2K	R16-680 Ω			
R8-22 Ω				
R9-22 Ω				

Figure 3. Overload-protected power supply.

R5 acts as a limiting resistor to protect the SCR. If R1 is increased, the protection circuit will trigger at a lower current. When the SCR conducts, the transistor T1 also conducts and causes a voltage drop across R6. As described above, this will lower the output voltage and prevent damage to the system. The pilot-light V1 indicates an overload situation.

c) Wien-Bridge Oscillator

A Wien-bridge oscillator (Figures 4 and 5) was chosen for its stability and wide frequency range. A simplified circuit is shown in Figure 4 and the complete circuit in Figure 5.

When referring to Figure 4, it can be seen that this is a frequency-dependent Wheatstone bridge. The off-balance of the bridge is amplified and fed back into the bridge. At a frequency determined by R_A C_A R_B C_B, this feedback will sustain oscillation (2). The oscillation frequency is given by:

$$W = \frac{1}{\sqrt{R_A R_B C_A C_B}}$$

or, if $R_A = R_B$ and $C_A = C_B$,

$$W = \frac{1}{\sqrt{R_A C_A}} .$$

In Figure 5, the elements of the bridge R1, R3, R2, R4 and C1, C2 are equivalent to R_B, R_A, C_B, C_A of Figure 4. R7 is equivalent to R_D and TR1 is equivalent to R_C. TR1 is a thermistor which regulates the amount of output power and thus the size of oscillation. Transistors T1, T2 and T3 form the high gain difference amplifier. The Zener diodes D1 and D2 provide isolation and regulation for the oscillator, while the variable resistor R10 allows adjustment of the output amplitude.

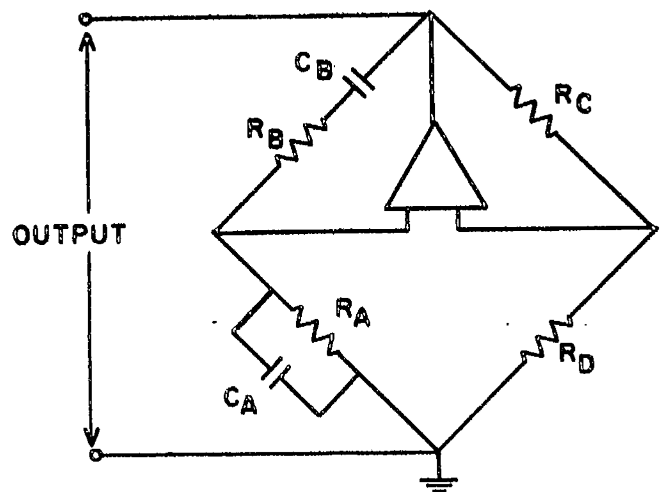


Figure 4. Wien-bridge oscillator.

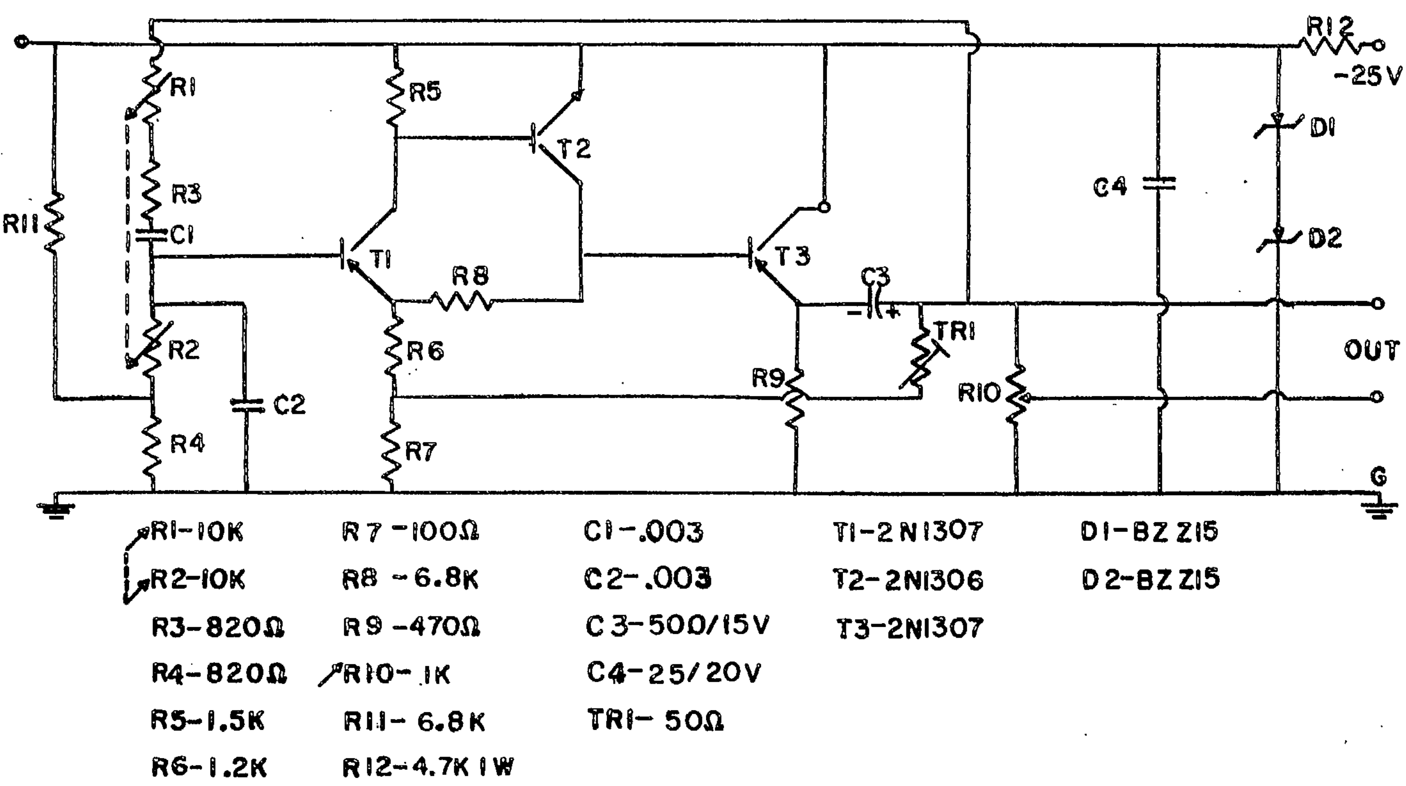
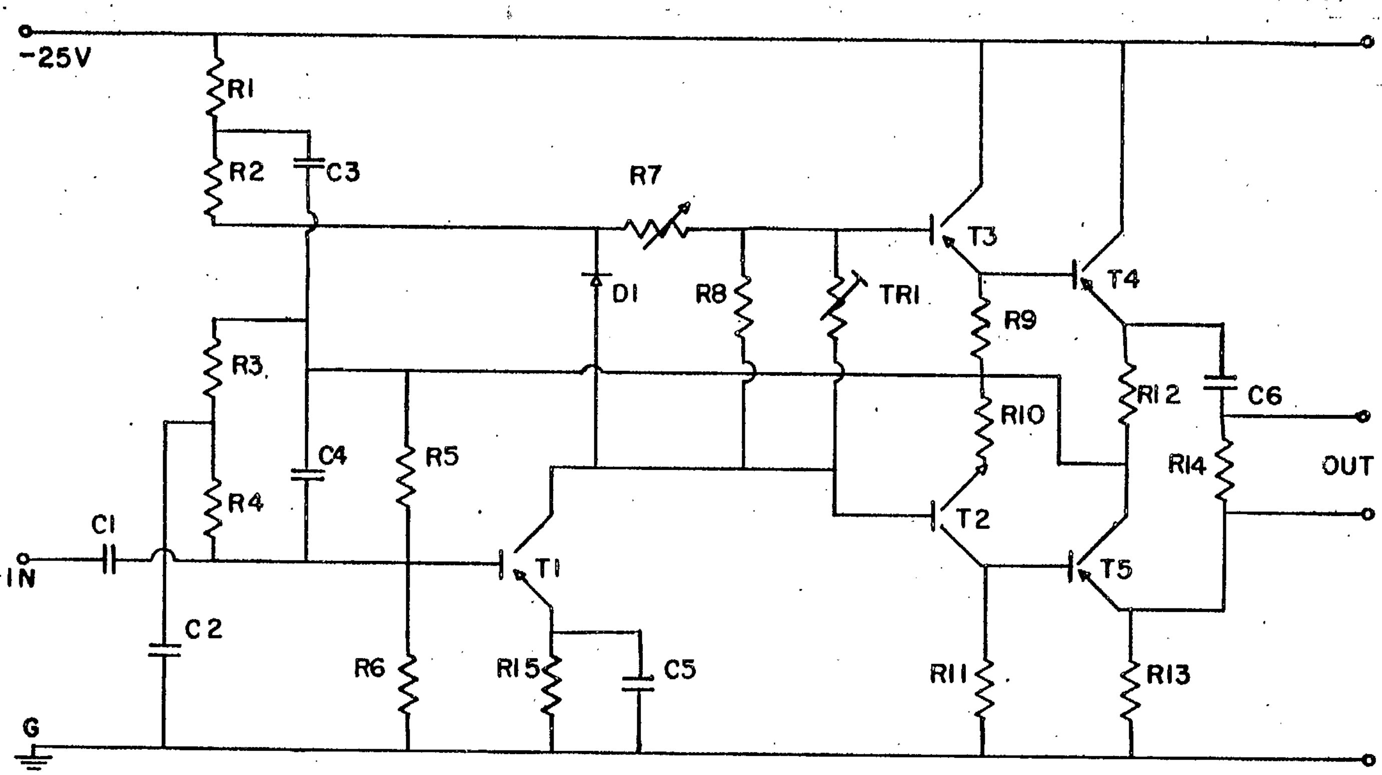


Figure 5. Wien-bridge oscillator and amplifier.

d) Power Amplifier

The input to the power amplifier, shown in Figure 6, is a-c coupled by condenser C1 to the base of T1, where the signal is inverted and appears as the output across the load resistor R2. The diode D1 provides a constant potential difference between the bases of T2 and T3. Since the latter is an emitter follower and the former is an inverter, out-of-phase signals are presented to the base of the output transistors T4 and T5. The output is coupled by C6 to the load. R12 and R13 are current-limiting resistors. R14 provides a permanent load so that the electrolytic condenser C6 has always the required polarity. Feedback is provided by R5 and C4. The remaining resistor-condenser network establishes the proper biassing. The thermistor TR1 prevents run-away by biassing the transistors T2 and T3 to cut off if the system should become overheated. R7 is used to adjust the balance between T3 and T2 and consequently between T4 and T5.



R1-1.2K	R7-500Ω	R12-1Ω1W	C1-30/25V	T1-2N1307
R2-5.6K	R8-1K	R13-1Ω1W	C2-40/6V	T2-2N1306
R3-4.7K	R9-68Ω	R14-22Ω	C3-100/1	T3-2N1307
R4-39K	R10-10Ω	R15-470Ω	C4-15PF	T4-2N1907
R5-390K	R11-68Ω	TR1-500Ω	C5-100PF	T5-2N1907
R6-3.9K			C6-500/25V	D1-BY100

Figure 6. Power amplifier.

e) Output and Monitoring Circuit

The output power is monitored by measuring the voltage drop across a ½-ohm resistor as shown in Figure 7. The a-c voltage is rectified by a diode bridge, the output of which is coupled to a 500 microampmeter. The fuse shown in Figure 7 protects the system. The Hammond H148P transformer provides a selection of 3 high-impedance outputs. The desired output impedance can be selected by a switch on the front panel. The output may come either directly from the amplifier or from an appropriate tap at the output transformer secondary.

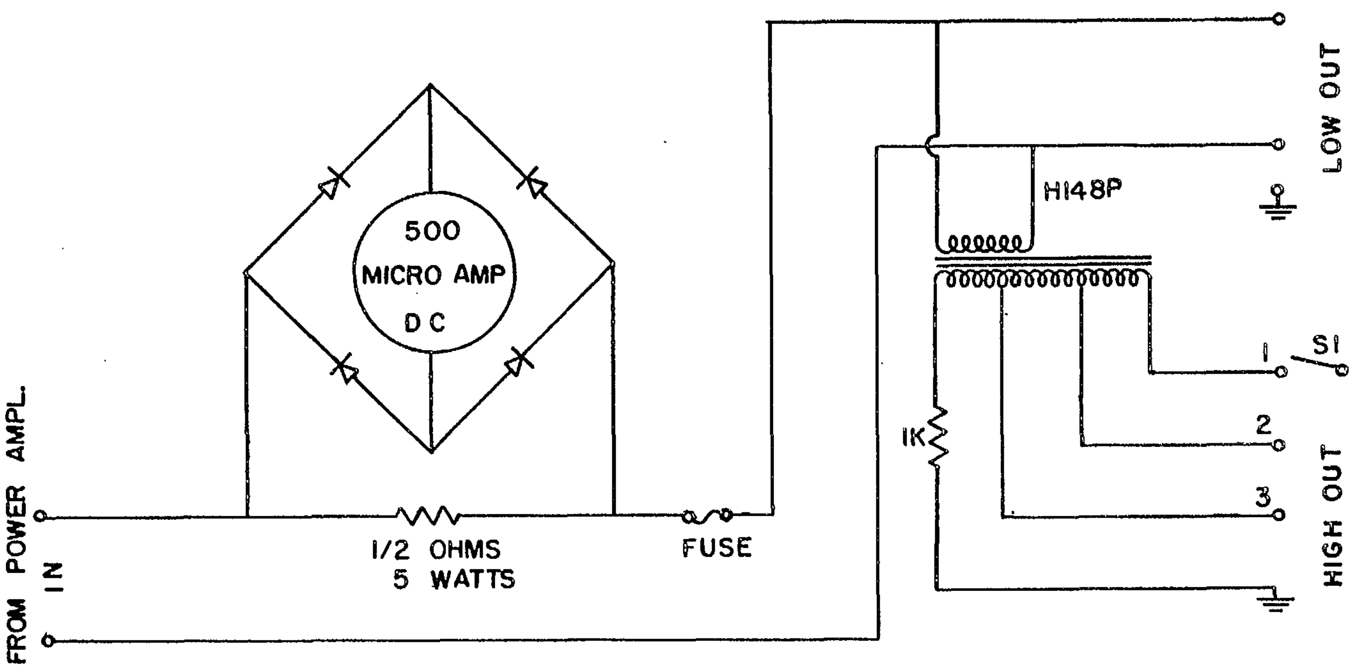


Figure 7. Output and monitoring circuit.

PERFORMANCE

All circuits performed as designed. The output power is in excess of 20W, more than adequate for the ultrasonic agitating system. Several other uses for the amplifier have been found since it was developed (see references 3 and 4).

Photographs of the chassis layout and front panel are shown as Figures 8 and 9.

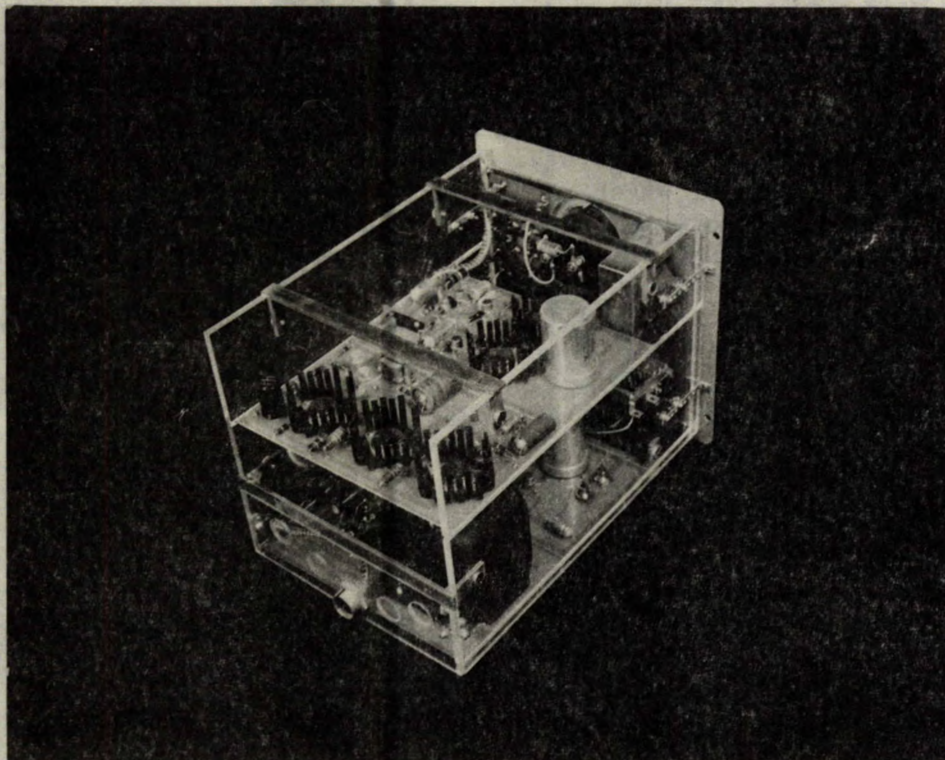


Figure 8. Chassis layout.

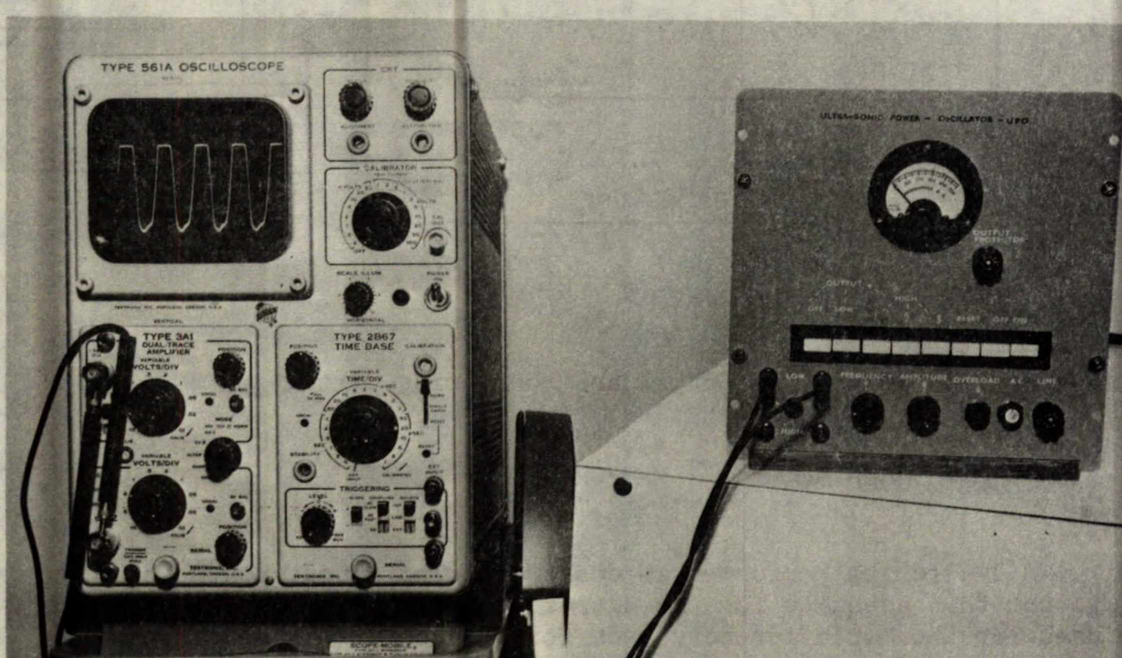


Figure 9. The front panel.

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REFERENCES

1. A.H. Bettens, "Procedure for the Fabrication of Printed Circuit Boards", Mines Branch Technical Bulletin TB 60, Department of Mines and Technical Surveys, Ottawa, Canada, 1964.

2. "Basic Theory and Application of Transistors", Department of the Army Technical Manual TM-11-690, March 1959. Superintendent of Documents, U. S. Government Printing Office, Washington 25, D.C.

3. G. Alexander, "Development of an Improved Temperature Controller for Phase Equilibrium Studies", Investigation Report IR 64-109, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada, 1964.

4. G.E. Sharpe and R.G. Pinard, Mineral Sciences Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa; unpublished report on an experimental reflectivity spectrum plotter for small field analysis of polished sections (1963).

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