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Technical Note 160

EMISSION STABILIZATION OF THERMIONIC DIODE NOISE SOURCES

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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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ABSTRACT

An apparatus is described which is capable of stabilizing the d-c plate current of a temperature-limited thermionic diode noise source to better than 0.02 per cent, which corresponds to a noise power stability of better than 0.001 db throughout the current range of 1 ma to 100 ma.

EMISSION STABILIZATION OF THERMIONIC DIODE NOISE SOURCES

by

M. W. Randall and M. G. Arthur

1. Introduction

The theoretical mean square noise current per unit bandwidth generated by a temperature-limited thermionic diode is related to the d-c plate current by the relation [van der Ziel, 1954]

$$\overline{i^2} = 2eI \tag{1}$$

where

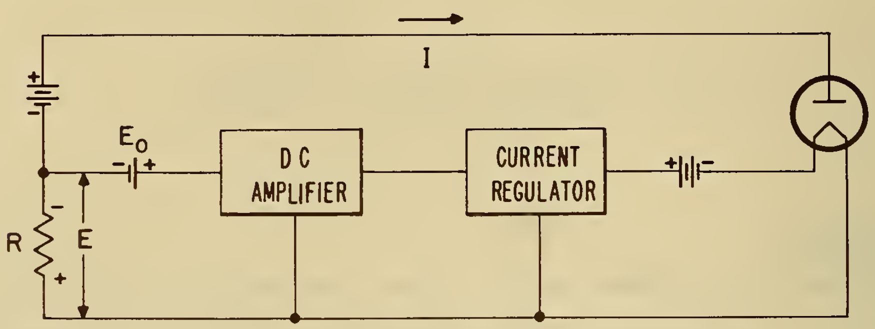
$\overline{i^2}$	is the mean square noise current per unit bandwidth,
e	is the charge of an electron
I	is the d-c plate current.

When such a diode is to be used as a stable source of noise power, variations in the d-c plate current must be held to less than a prescribed value. This paper describes an apparatus which is capable of stabilizing the d-c plate current to better than 0.02 per cent for all values of plate current in the operating range of a typical noise diode.

2. Method

A block diagram of the apparatus used to stabilize the d-c plate current is shown in Figure 1. Plate current, I, passes through a resistor, R, to develop a voltage E = IR. A reference voltage, E_o, is connected in opposition to E such that an error voltage, $E_o - E$, is produced. The error voltage is amplified by a high-gain d-c amplifier whose output controls a current regulator in the diode filament circuit.

This servo loop is made degenerative, and the time variations in the d-c plate current are thereby reduced to acceptable magnitudes.

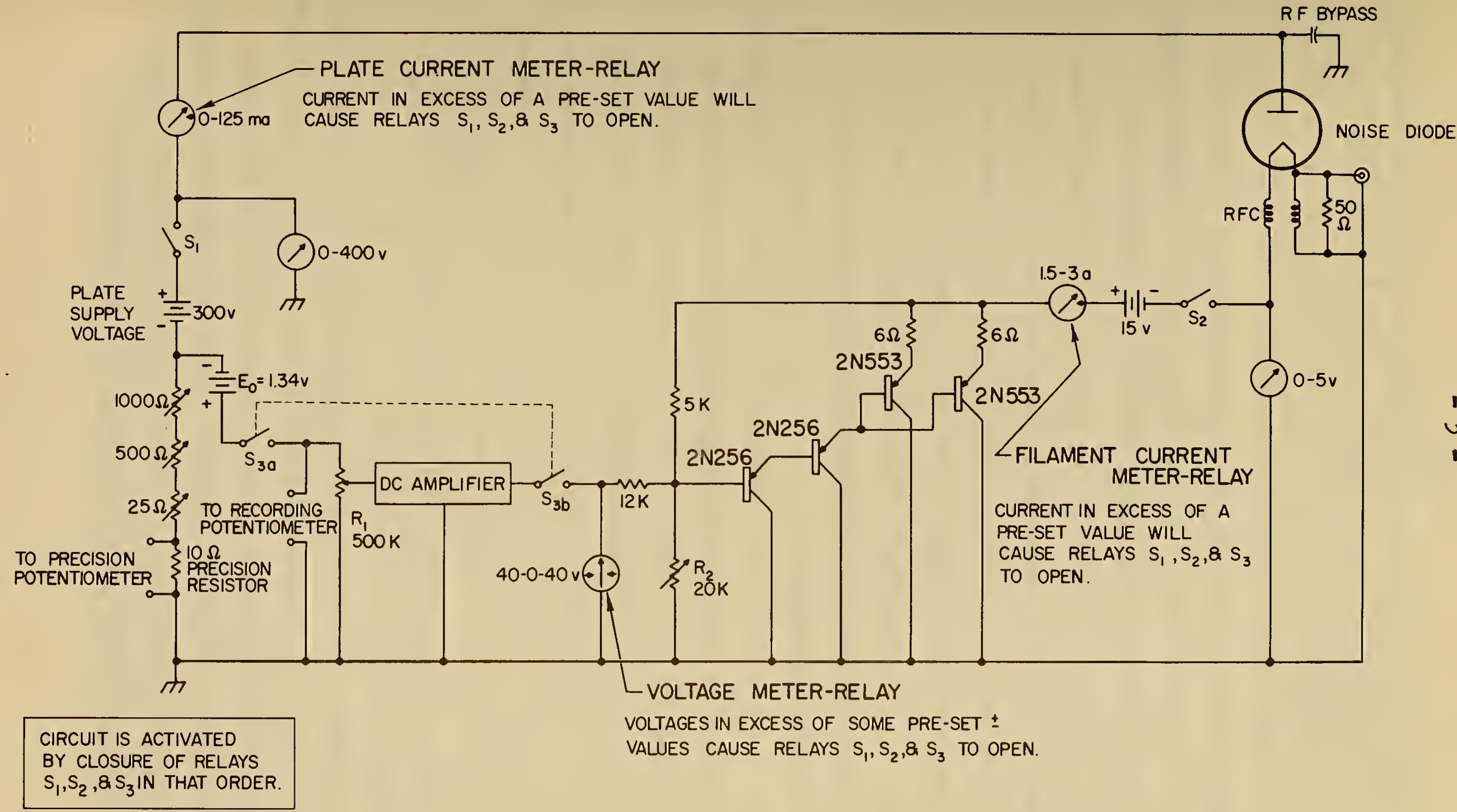


Functional Diagram of Stabilizer
Figure 1

3. Equipment

Figure 2 shows a diagram of the circuit used in the stabilizer. The resistor, R, is made up of three multi-turn precision rheostats which permit coarse, medium, and fine adjustment of plate current. A 1.34 volt mercury cell provides the reference voltage. The d-c amplifier is a stable, wide-band unit which has a voltage gain of 2000. Since the gain control in the amplifier is a step control, an auxiliary gain control, R_1, has been incorporated to permit continuous adjustment of the open loop gain.

The current regulator is a three-stage transistor amplifier with the final-stage power transistors connected in series with the diode filament. This regulator has a manually-operated current control, R_2, which, with the servo loop open, allows the filament current to be adjusted so that the diode plate current can be set to some value in the range from less than 1 ma to greater than 100 ma. When the servo loop is closed, the plate current is controlled by the error voltage and the loop gain. R_2 then provides a means of adjusting loop conditions so that the error voltage may be set to zero. To



SCHEMATIC DIAGRAM OF STABILIZER CIRCUIT

Figure 2

operate the diode at some plate current value, the multi-turn rheostats are adjusted to bring the d-c plate current to the desired value, and R_2 is adjusted simultaneously to hold the error voltage close to zero.

Three meter-relays have been incorporated into the circuit to prevent damage to the diode or to the current regulator in the event of component or power failure. In conjunction with conventional relays not shown in Figure 2, the plate and filament current meter-relays remove supply voltages and open the servo loop when either of these currents reaches a preset maximum. A third meter-relay, with both high and low limit contacts, prevents damage to the current regulator by any excessive voltage from the d-c amplifier.

Figure 3 is a photograph of the main chassis of the stabilizer. The meters, power supplies, and other ancillary apparatus are mounted on separate chassis.

4. Results

As stated in the Appendix, the design objective of this equipment is to stabilize the d-c plate current of a temperature-limited diode noise generator to such an extent that the available noise power does not vary more than 0.001 db from a prescribed value during the period of operation. If resistor R and reference cell E_o are assumed stable, and equation (1) is assumed true, it can be shown that, for $E_o = 1.34$ volts, a change of 0.31 mv in error voltage represents a 0.001 db change in available noise power.

In operation, the servo action maintains the error voltage within the .31 mv limit, as shown in Figures 4 and 5. Critical components, such as resistor R and reference cell E_o have been allowed to reach thermal equilibrium. Figure 4 shows a recording of the error voltage over a period of 9 hours with a d-c plate current of 10.0 ma. Figure 5 shows a similar recording over a period of 13 hours with a d-c plate current of 60.4 ma. In both cases, variations in the error voltage were much less than 0.31 mv for the entire period, the variations being about one order of magnitude smaller for short periods of time.

5. Conclusions

The stabilizer described in this note has been used to stabilize the d-c plate current of noise diodes used in the precision measurement of noise figure of amplifiers and receivers. It has been used with a variety of diodes requiring a maximum filament current of 1.8 amperes at 1.6 volts to 2.6 amperes at 3.4 volts and plate currents of 1 to 100 milliamperes at voltages of 100 to 300 volts.

Although the apparatus described here has functioned satisfactorily in its intended use, refinements leading to circuit simplifications and improved operational convenience are being developed.

6. References

1. van der Ziel, A., Noise, Prentice-Hall, Inc., 1954, page 91.

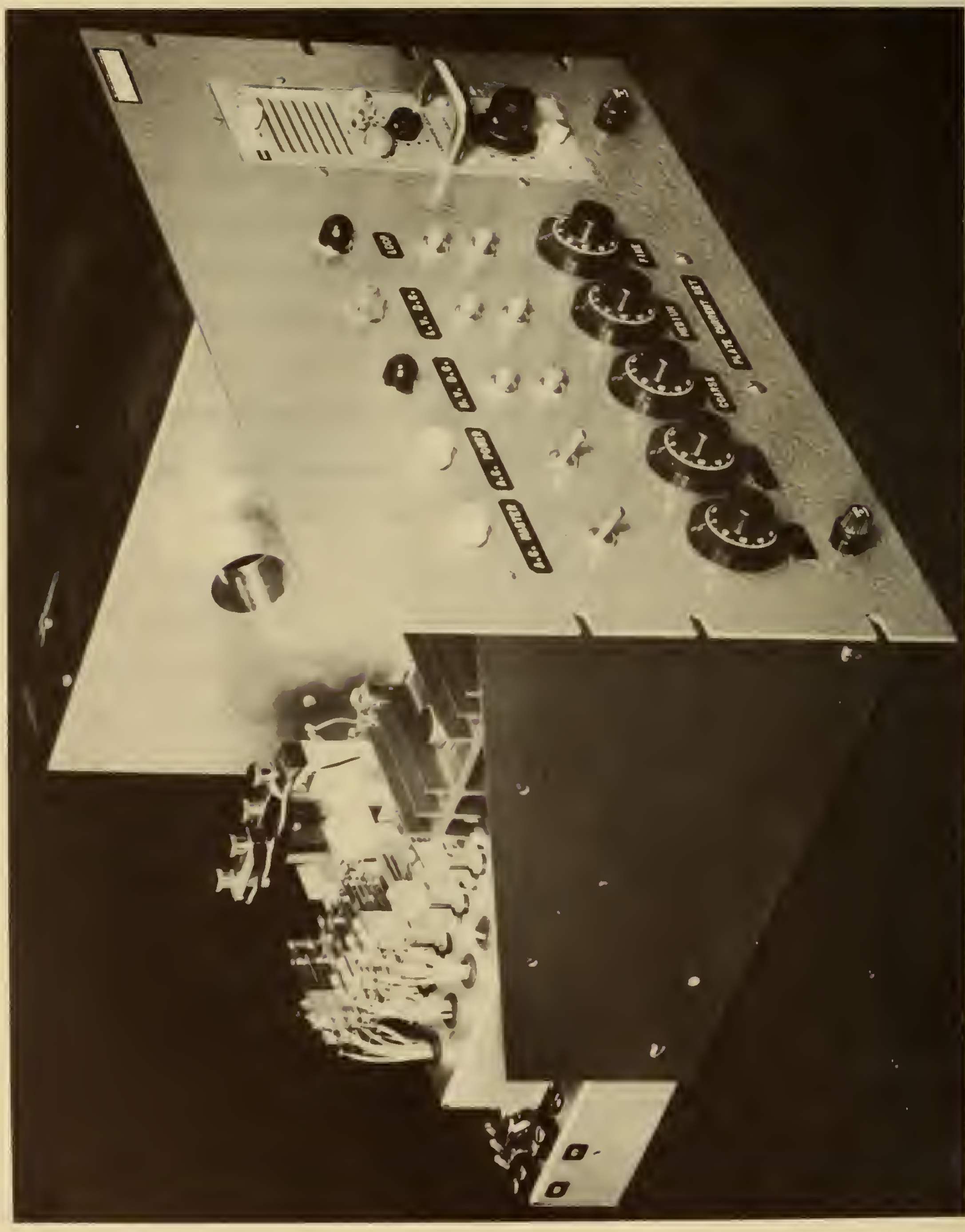


Figure 3. Photograph of Stabilizer Chassis

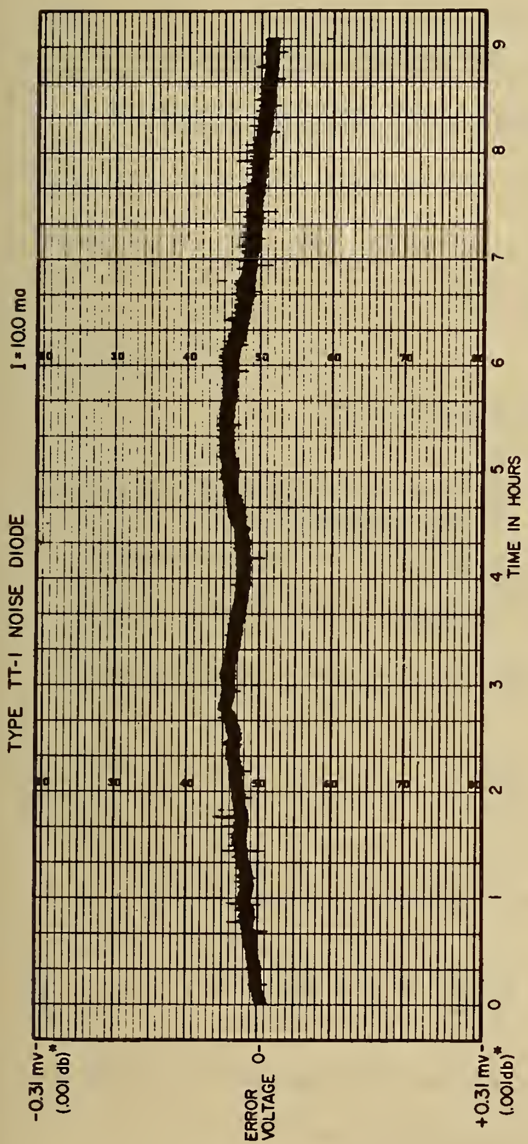


Figure 4

* SEE DISCUSSION IN SECTION 4, RESULTS

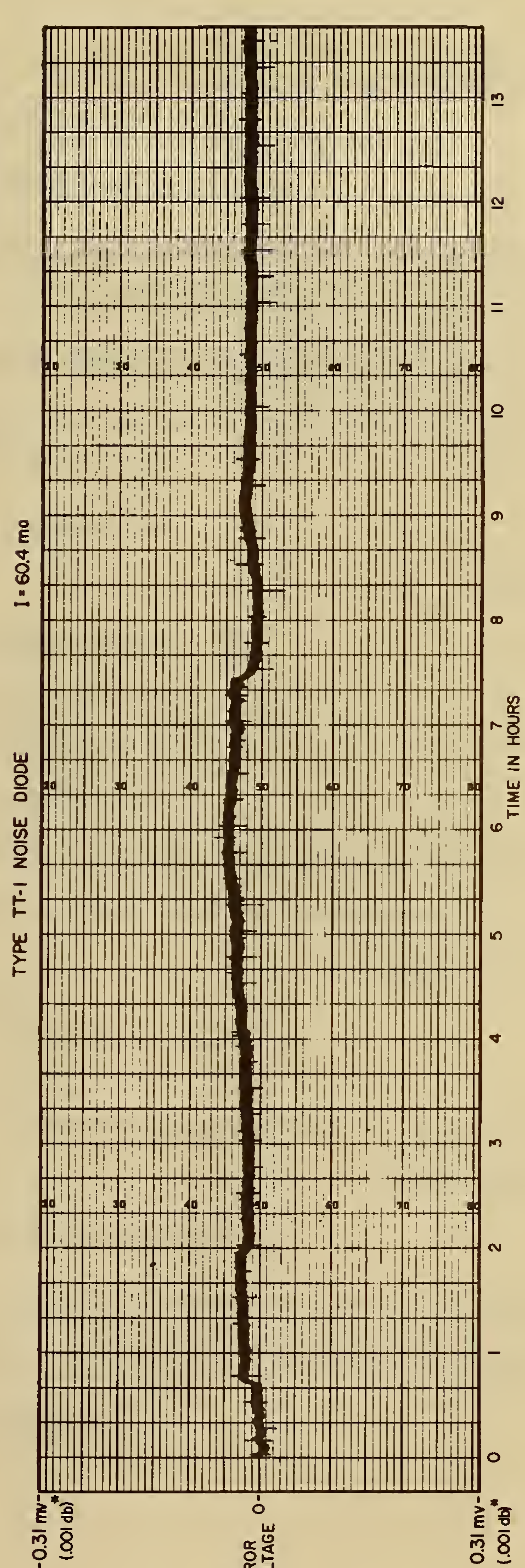


Figure 5

7. Appendix

The design objective of this equipment is to stabilize the d-c plate current of a temperature-limited diode noise generator to such an extent that the available noise power does not vary more than 0.001 db from a prescribed value during the period of operation.

The theoretical available noise power per unit bandwidth of a diode noise generator is

$$\begin{aligned} P_a &= 1/4\, \overline{i^2}\, R_L \\ &= 1/2\, e\, IR_L \end{aligned} \tag{2}$$

where

P_a is the available noise power per unit bandwidth

R_L is the real part of the conjugate-match load impedance.

The other symbols are defined under (1), page 2.

A variation of 0.001 db in available noise power is expressed by the relation

$$0.001 \text{ db} = 10 \log \frac{P_a + \Delta P_a}{P_a} \tag{3}$$

where ΔP_a is the change in available noise power. From (2) it follows that

$$0.001 \text{ db} = 10 \log \frac{I + \Delta I}{I} \tag{4}$$

where ΔI is the change in d-c plate current which produces a 0.001 db change in available noise power. Evaluating ΔI gives

$$\Delta I = 0.0002303\, I. \tag{5}$$

If resistor R and the reference cell of Figure 1 have fixed values, ΔI will produce a change in error voltage given by

$$\Delta E = 0.0002303\,E \tag{6}$$

where ΔE is the change in error voltage corresponding to a 0.001 db change in available noise power.

When resistor R is adjusted to produce zero error voltage with the desired value of d-c plate current, the voltage E equals the value

$$E = E_o = 1.34 \text{ volts} \tag{7}$$

and ΔE has the value

$$\Delta E = 0.31 \text{ millivolts.} \tag{8}$$

Therefore, under the operating conditions specified above, a change in error voltage of less than 0.31 millivolts can be interpreted as indicating a change in available noise power of less than 0.001 db.

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