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APPLICATION NOTE ON THE DESIGN OF SIX-VOLT BATTERY-OPERATED RECEIVERS

Because many farms and rural communities have little or no power-line facilities, radio receivers intended for these unelectrified localities must depend upon battery supply for the primary source of power. It is desirable, therefore, that these specialized receivers have low power consumption and obtain their high-voltage supply from the filament-supply battery. Consideration of these requirements has directed the trend in modern battery-operated receiver design toward the use of series-parallel arrangements of 2-volt filament-type tubes, the filaments being connected so as to facilitate operation from a 6-volt storage battery. The same battery also furnishes plate power through the use of a small motor generator or a vibrator unit, similar to those commonly employed in auto-radio receivers.

Heretofore, it has been the custom to use one or more indirectly heated tubes in certain portions of the circuit for this type of receiver in order to minimize the noise output which results from the use of B-supply units. However, the use of such tubes does not always guarantee an acceptable noise level. The current drain of the receiver is also higher than necessary because a heater type of tube requires more power than a corresponding filament type. The use of heater-type tubes in this specialized type of receiver is an especially significant disadvantage in view of the necessity for more frequent battery charging, a necessity not always compatible with local conditions. It is the purpose of this note to show how the exclusive use of 2-volt filament-type tubes in this type of receiver can provide minimum power consumption and a negligible noise level without resorting to special circuit design or the use of costly filters.

The Causes and Elimination of Noise

One of the most objectionable characteristics of battery-operated receivers having mechanical B-supply units is the high noise level caused by common coupling between A and B circuits and by circulating currents in the chassis, set wiring, and cable shields. Noise arising from these causes can be minimized only by reducing common coupling and circulating currents to a minimum. The use of indirectly-heated tubes does not in any way reduce the magnitude of the causes of the noise; their use is merely an expedient to reduce the effects.

When the motor commutator or vibrator of a B-supply unit is connected to a source of constant emf through leads having some resistance, the fluctuating current drawn by the B-unit causes variations of voltage at its input terminals; the alternating component of this pulsating voltage is the ripple, or noise, voltage. Thus, if the filaments of a receiver's tubes are connected to the same source of emf by means of the same B-unit leads, the voltage applied to the filaments will have a noise component, which will be amplified by the succeeding tubes. In other words, under these conditions, the battery leads form the common coupling element between the filament and B-unit circuits.

Elimination of noise from this cause may be effected to a large extent by running separate leads from the filaments of the tubes to the battery, since the low internal resistance of a storage battery (about 0.005 ohm for a fully-charged cell) provides nearly perfect regulation; it has, therefore, nearly zero ripple voltage across its terminals. This method will necessitate the use of separate on-off switches for the separate circuits; however, d.p.s.t. switches which are an integral part of variable resistors are now available. A further reduction of the noise level due to common coupling may be realized by eliminating common A- and B-circuit connections in the B-supply unit itself. There are types of self-rectifying vibrators that have a single, uninsulated reed common to the primary and secondary circuit; because this reed is a common coupling element between A and B circuits, it gives rise to a noise voltage across the filament terminals. The use of a split reed, one section for the A- and one for the B-circuit, will eliminate this common coupling. Similarly, any common A- and B-circuit lead in the motor generator unit should be removed and the connection made in the receiver proper.

Noise caused by circulating currents may be minimized by adequate shielding and by-passing. Although no specific rules regarding the elimination of circulating currents can be set down, there are several general remedies which should be tried first. The leads from the storage battery to the B-supply unit should be shielded and the shield grounded to the frame of the B-unit. This unit, together with its directly associated components, should be housed in a metal container and then mounted on the chassis as far removed from other circuit elements as space permits. If at all possible, the B-unit and its associated components should be separated from the receiver, connected to the receiver by a shielded cable, and the shield grounded to the receiver chassis at a single point. Under no circumstances, should this shield act as a conductor of A- or B-current. It is also necessary to by-pass the input and the output circuit of the

B-unit directly to the negative A-lead on the input side and to the negative B-lead on the output side, respectively. In any case, shields and chassis should not be used as terminals for by-pass condensers in the B-unit. The somewhat common practice of placing the vibrator of the B-unit on one corner of the chassis and the power transformer on another corner contributes largely to the generation of circulating currents; the consequent necessity for using an excessive number of large by-pass condensers increases the cost of material and labor. The judicious placement of the B-supply unit and its components, therefore, results in reduced manufacturing costs.

Test Verification of Suggested Methods

The effectiveness of these precautionary measures was verified by two separate tests. In the first, a receiver which obtains its plate power from a small motor generator mounted on the chassis was connected to a storage battery in the more prevalent manner: common battery leads were used for the A- and B-circuits; a single, shielded cable was run from the battery to the receiver; and the shield was grounded at the most convenient point. No precautions regarding the proper terminal points for B-unit by-pass condensers were observed. The sensitivity and noise output of the receiver were measured. Then, separate A- and B-circuit leads were run, the B-circuit leads were shielded and grounded to the shield can of the B-unit, separate A- and B-circuit switches were installed, and B-unit input and output by-pass condensers were terminated at the negative A-wire and the negative B-wire, respectively. The sensitivity of the receiver was again measured and found to be the same as that previously obtained. Noise measurements were then repeated. Figure 1 shows the revised circuit and tube complement, and Table I the measurement data.

TABLE I

NOISE OUTPUT WITH 1000 KC INPUT

Test Conditions	Noise Output in Milliwatts	
	Original Circuit	Revised Circuit
21 Microvolt Carrier, No Modulation	10.0 MW.	5.6 MW.
210 Microvolt Carrier, No Modulation	10.0 MW.	0.78 MW.
2100 Microvolt Carrier, No Modulation	263.0 MW.	0.5 MW.
21000 Microvolt Carrier, No Modulation	290.0 MW.	0.125 MW.
210000 Microvolt Carrier, No Modulation	338.0 MW.	0.125 MW.

NOTE: A 21 microvolt carrier, 30% modulated, was required for 50 milliwatts output both in the original and revised circuits.

It is apparent that a very material decrease in noise levels resulted from the changes and that the noise levels of the revised receiver are far below any generally accepted value. Of particular significance is the decreasing noise level with increasing carrier strength in the revised circuit; this should be compared with the opposite effect that existed in the original circuit. This phenomenon of increasing noise with carrier is caused by modulation of the carrier by the noise; this modulation did not exist in the revised receiver.

In order to segregate as much as possible noise originating in the receiver itself from that due to the use of the motor-generator, a series of oscillograms were taken of the noise voltages existing in certain sections of the revised receiver with the i-f portion short-circuited. These oscillograms showed that the peak ripple voltage across the motor commutator was about 20 millivolts, across the filament of the 32 about 0.5 millivolt, and across the output about 100 millivolts. The noise frequency was approximately 400 to 500 cycles. The storage battery voltage was 5.8 volts at the time the oscillograms were taken, so that the internal resistance of the battery was somewhat high, though representative of average operating conditions.

The second series of tests was conducted on a receiver using a synchronous-vibrator type of B-unit. Sensitivity and noise measurements were made with conventional shielding, common coupling, and by-pass condenser terminals. The circuit was then changed to that shown in Figure 2 and the sensitivity and noise measurements repeated. Of special importance is the use of the split-reed vibrator in the B-unit to avoid A- and B-circuit coupling; the original unit employed a single, uninsulated reed. Table II shows the results of these measurements.

TABLE II

NOISE OUTPUT WITH 1000 KC INPUT

Test Conditions	Noise Output in Milliwatts	
	Original Circuit	Revised Circuit
5.5 Microvolt Carrier, No Modulation	5.25 MW.	1.0 MW.
55 Microvolt Carrier, No Modulation	4.5 MW.	1.53 MW.
550 Microvolt Carrier, No Modulation	13.8 MW.	0.03 MW.
5500 Microvolt Carrier, No Modulation	5.25 MW.	0.03 MW.
55000 Microvolt Carrier, No Modulation	8.00 MW.	0.03 MW.

NOTE: A 5.5 microvolt carrier, 30% modulated, was required for 50 milliwatts output both in the original and revised circuits.

It is seen that here, too, a very substantial reduction in noise level and carrier modulation resulted from the improvements. A comparison of Tables I and II should not be attempted because of the different sensitivities of the individual stages and the wide differences in mechanical layout and wiring.

One of the most important advantages of the exclusive use of filament-type tubes is the low power consumption. The filament circuits of Figures 1 and 2 draw 0.32 and 0.38 ampere, respectively; this should be compared with other circuits using one or more indirectly-heated tubes. Each of these circuits shows the method of obtaining proper bias for each tube, and the inserts show, respectively, the biases on all tubes with no signal. The a.v.c. circuit for each receiver is also given.

The circuits in this note are merely suggested as possible arrangements for the tube complements used. In this respect, it should be remembered that in any series arrangement of filaments the total filament current is the sum of the normal current due to the storage battery and the plate currents returning to negative B terminal through tube filaments. The addition of shunt resistors across certain filaments to maintain the filament voltage of each tube at its rated value of 2.0 volts will insure normal life performance.

From these test results, it may be concluded that the exclusive use of filament-type tubes with proper circuit precautions can provide minimum filament power consumption and negligible noise level to meet the special requirements of receivers employing mechanical B-supply units.

SCHEMATIC RECEIVER CIRCUIT

WITH MOTOR GENERATOR HIGH-VOLTAGE SUPPLY

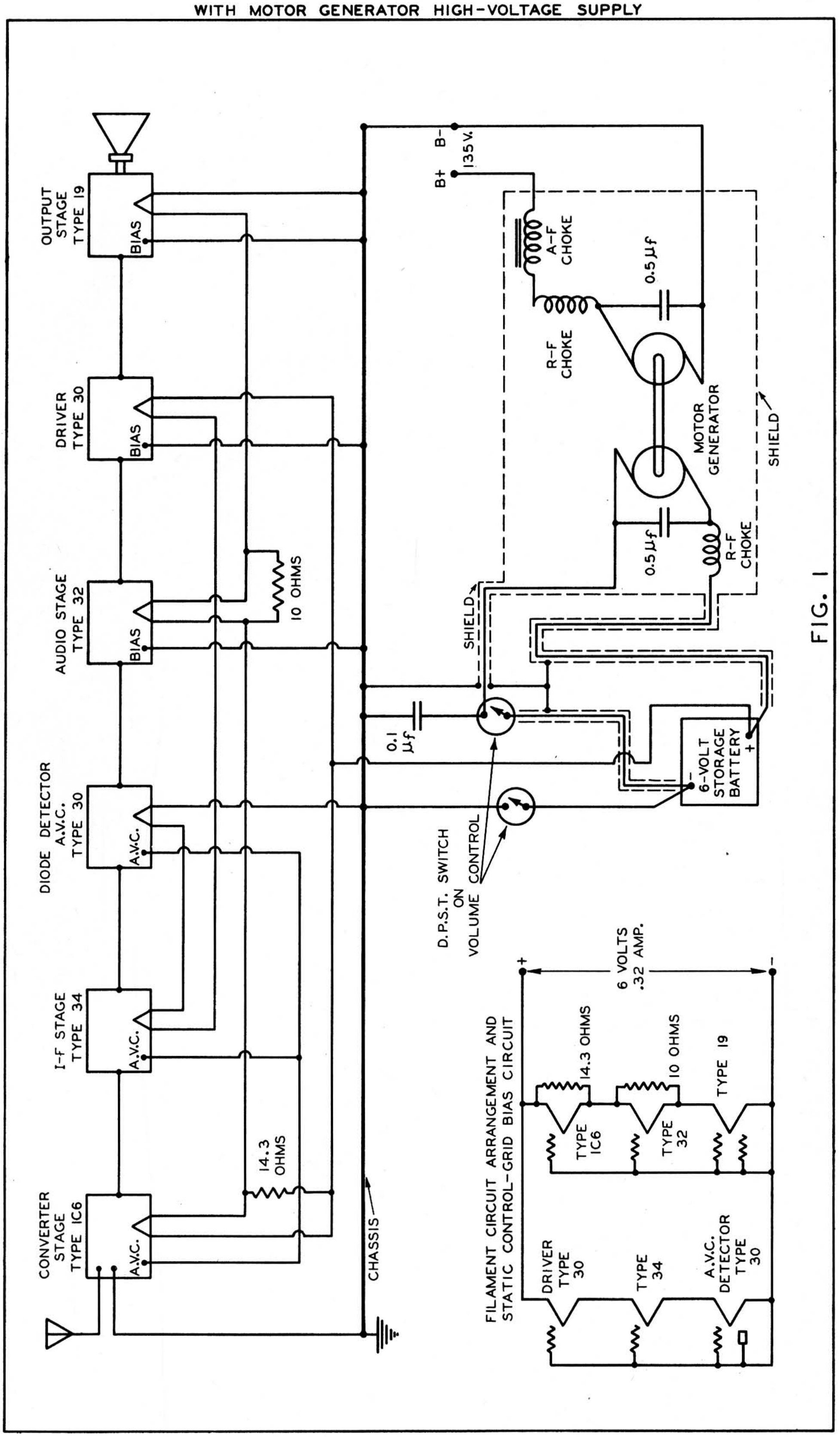

FIG. 1

SCHEMATIC RECEIVER CIRCUIT

WITH VIBRATOR HIGH-VOLTAGE SUPPLY

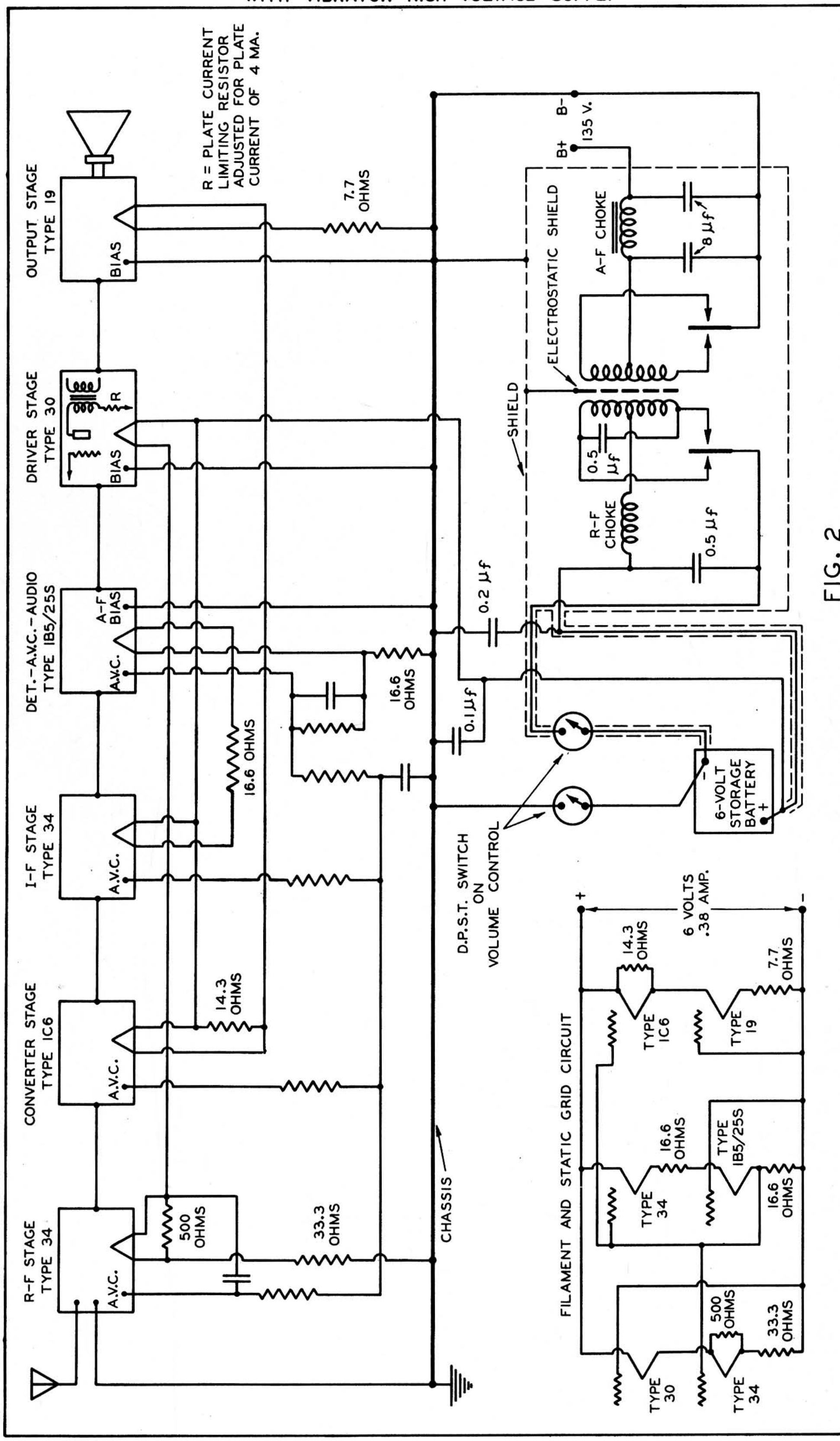

FIG. 2