Heater Supplies for Amplifier Hum Reduction

FREDERICK W. SMITH

A practical method for reducing hum to a minimum

WHEN hum is perceptible in the output of an amplifier, the listener notices a lack of "presence" in the reproduction of program material. This effect is especially objectionable where the background noise level of the signal is extremely low, as in frequency modulation reception.

The existence of hum in an amplifier usually may be attributed to three sources [1,2,3]:

a) Insufficient plate supply filtering.
b) Electrostatic or magnetic pickup in low level stages.
c) The cathode heater circuits.

Of these three, the first is the easiest to eliminate, because little practical difficulty is experienced by the designer in reducing plate supply ripple below any predetermined value.

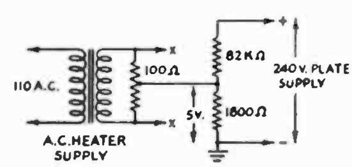

Fig. 1. Hum reduction method used in a program amplifier.

Electrostatic or magnetic pickup may be reduced by a variety of devices which include shielding, the isolation of power supplies from the amplifier proper, and the use of a non-magnetic amplifier chassis.

Cathode Heater Hum

The remaining and most obstinate source of hum is that due to the cathode heater circuits. If the heaters of the tubes incorporated in an amplifier are supplied with alternating current of power-line frequency, a hum having both fundamental and second harmonic components will appear in the amplifier output. This hum is due to various causes. Direct sources naturally include hum pickup from heater circuit leads and hum leakage through socket capacitances. Less obvious, however, are such other sources as heater-to-cathode leakage, capacitive coupling between the heater and other electrodes, or actual heater emission to other elements within the tubes.

A number of methods have been devised to eliminate some of these defects with varying success. A representative arrangement employed in a commercial program amplifier is illustrated in *Fig.* 1. In this circuit, a positive bias of approximately five volts is applied to the heater circuits of the amplifier stages through a hum-balancing potentiometer placed across the 6.3-volt heater supply transformer winding. The positive bias on the heaters prevents heater emission while the effects of capacitive coupling between the heaters and control grids are balanced out by proper adjustment of the potentiometer.

However, even with special precautions and care in the design of an amplifier stage having an a-c heater supply, there generally remains a residual hum amounting to from five to fifteen microvolts between grid and cathode, which is not negligible in a low-level stage.

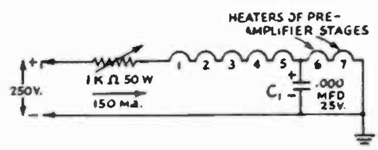

Fig. 2. Typical 150-ma d-c heater circuit.

The ultimate solution to the hum problem, therefore, is to use heater power sources that are either of the direct-current or the high frequency alternating current type. Substitution of either of these in the usual amplifier will result in a minimum reduction of five to ten db in hum level, and consequently this feature has been incorporated in many of the newer equipment designs.

The two types of heater excitation just mentioned may be classified in actual application according to whether a series or parallel heater connection is employed.

Series Connection

With the advent of tube types having 150-ma heaters, it has been possible to employ conventional power supplies to furnish direct-current heater excitation. A typical circuit of this type described by Clark[4] is shown in *Fig.* 2. Here the output voltage of a power supply capable of furnishing sufficient current for both plate and heater circuits is applied to the series connected, 12 volt, 150-ma heaters of the amplifier tubes. Heater current is adjusted to the proper value by means of *R*1 and additional filtering is supplied for the heaters of the preamplifier stages by the inclusion of capacitor *C*1, which is of the order of 1000 μf.

A number of difficulties can be experienced with this type of circuit as follows: when a burnout occurs in the heater string it is difficult to determine rapidly which of the several heaters is defective. Also, in the event that either of the heaters on the ground side of capacitor *C*1 should open up, *C*1 will fail unless it is rated to accommodate the full supply voltage, thus endangering the remaining heaters in the string. It is also possible for this same filter capacitor to discharge itself through a new replacement tube, causing a second burnout, if it is not provided with a bleeder resistance.

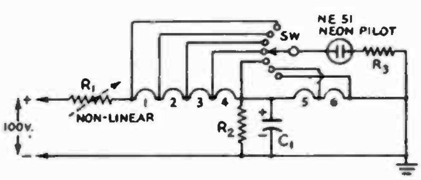

Fig. 3. Improved d-c heater supply circuit.

An improved circuit designed to avoid these difficulties is presented in *Fig.* 3. Here the series resistance, *R*1, is a special non-linear type having a negative temperature coefficient such that initial current surges during the warmup period are eliminated. Non-linear resistors designed for this application are obtainable either from the

Keystone Carbon Co. (Type 701) or the Carborundum Corp. (Type F). A typical unit suitable for this purpose has a resistance of approximately 1400 ohms at room temperature and 200 ohms at its normal operating temperature of about 300° F[5]. The filter capacitor for the preamplifier stages, *C*1, is rated to accommodate the full supply voltage and is furnished a discharge path through *R*2. Finally, a simple voltmeter circuit consisting of a neon pilot lamp in series with a current-limiting resistor, *R*3, has been included to facilitate rapid checking of heater circuit operation. Should an "open" occur, the lamp will give no indication when switched to the ground side of the defective tube and will indicate the full supply voltage on the other.

Parallel Connection

The excitation of parallel-connected heater circuits naturally poses a problem in low voltage, high-current, power supply design. The heater current requirements of even a modest amplifier may be from 3 to 5 amperes, and only a rectifier of the selenium type can handle such a load efficiently. A suitable circuit employed by the author to eliminate hum in a recording amplifier is shown in *Fig*. 4. The output of a 10 volt rms filament transformer is applied to a bridge-type selenium rectifier, producing sufficient current in this case to excite all heaters except those of the power amplifier tubes. If the power supply and power amplifier are located on a chassis separate from the lower level stages, it is advisable not to employ a common ground return for both the heater and signal circuits, because any remaining hum component in the heater current will introduce a hum voltage in series with the signal which appears at the input of the power amplifier stage.

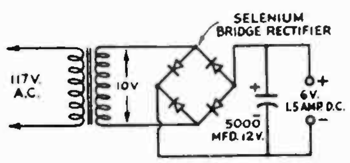

Fig. 4. Hum-free heater supply for parallel heaters.

H-F Heater Supply

Because of space requirements, the type of supply just discussed may not be very convenient to install in existing equipment. A much neater solution to the problem of equipment modification for hum reduction may be found in the high-frequency alternating current type of heater supply. Such a supply may be compactly installed in a chassis space of 2" by 2" and requires but 40 ma of plate current and .45 amperes of heater current.

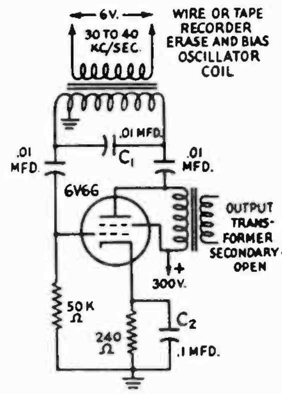

Fig. 5. High-frequency power supply for heater excitation.

The circuit itself, as illustrated in *Fig*. 5, is based on the high-frequency oscillator circuits currently employed in magnetic tape or wire recorders to supply supersonic bias and erase current. Such a supply will furnish up to two amperes at six volts, depending on the plate voltage applied to the oscillator, and generally operates at a frequency of from 30 to 40 kc/sec.

Best results will be obtained if *C*1, the oscillator tank capacitor, is of the mica variety, and it should be emphasized that the cathode bypass, *C*2, must not be omitted, since the resulting degeneration will make the oscillator difficult to start and cause its regulation to be poor. The waveform produced by this type of circuit tends to be rather impure, and some difficulties with harmonic radiation may be experienced where such a stage is installed near or on a radio receiver or video amplifier chassis.

Regulated Supplies

In a number of specialized applications, not only is it necessary to employ d-c heater supplies, but in addition, all heater voltages must be closely regulated. Such instances arise in the design of the direct-coupled amplifiers associated with certain types of electroencephalographs, spectrophotometers, and apparatus for nerve potential studies.

In these cases, regulation of heater potentials serves to eliminate cathode drift resulting from the variation of electron emission velocities with cathode temperature. The necessity for regulation in these applications can be appreciated from the fact that for a typical tube type, the heater voltage must be held constant within 1% if an effective voltage fluctuation of 10 millivolts in the cathode circuit is to be avoided.[6]

The heater circuits employed may again be either series or parallel, depending upon the type of regulated source which is available.

For the series arrangement, the conventional voltage regulated power supply which has been fully discussed elsewhere[7] may be employed. In this type of supply, a single 6AS7G, used as the series regulating tube, will deliver sufficient output to supply not only 150 ma of heater current but plate currents as well. It may be noted that in certain of these units, where a highly regulated output is achieved through the use of a large loop gain, the heaters of the control amplifiers are themselves placed across the output of the supply.

If a parallel connection of the heaters is desired, a regulated supply based on the circuit illustrated in *Fig*. 6 may be used. Here, regulation of the rectifier unit is achieved by amplifying the voltage variations appearing across the load and applying them to the d-c control winding of a saturable reactor in the primary circuit in such a manner as to cause a compensating change in the a-c line voltage applied to the rectifier.

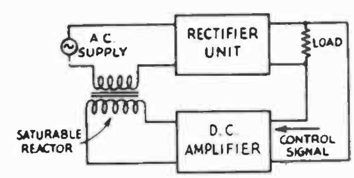

Fig. 6. Regulated d-c heater supply.

A six-volt power supply of this type designed by the author[8], exhibited a change in output voltage of .05 volts with a change in load current from zero to 15 amperes, and negligible variation in output was observed for line voltages ranging from 105 to 140 volts.

References

1. F. Langford Smith, "The Radiotron Designer's Handbook", Third Ed., Part 3, Chap. 24, Distributed by R.C.A. Victor Div., Camden, N.J.

2. F. E. Terman, "Radio Engineers' Handbook", Sec. 5 and 8, McGraw-Hill Book Co. New York, N.Y. 1943.

3. L. B. Arguimbau, "Vacuum Tube Circuits", Chap. 3, J. Wiley and Sons, New York, 1948.

4. D. L. Clark, "A Flexible Decade Amplifier", Audio Engineering, Jan. 1948

5. R. P. Glover, "Surge Protection of Pilot and Heater Circuits", *Electronics*, August, 1947.

6. S. E. Miller, "Sensitive D.C. Amplifier with A.C. Operation," *Electronics*, November, 1947.

7. L. Mautner, "Voltage Regulated Power Supplies," *Electrical Engineering*, September, 1947.

8. F. W. Smith and M. C. Thienpont, "Low Voltage Regulated Power Supplies." *Communications*, July, 1947.