VERSATILE NBFM TRANSMITTER DESIGNED FOR MOBILE USE

Hi-Fi AMPLIFIER
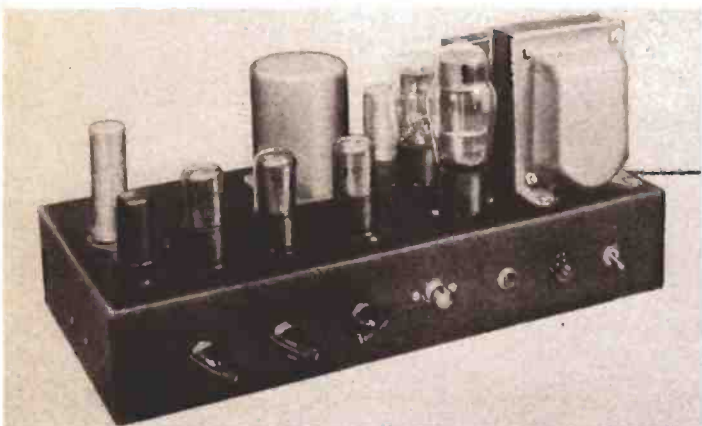
Featuring a low cost resistance-coupled driver stage and independent tone-control circuits for bass and treble, the amplifier delivers 10 watts of audio power with less than 2% distortion

HIGH-FIDELITY AUDIO AMPLIFIER DELIVERS 10 WATTS POWER OUTPUT

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Since the announcement of the RCA-6AS7-G twin power triode, many engineers and experimenters have been asking, "How can we use this tube in a high-fidelity audio amplifier?" Although an initial step in this direction was taken in a speech amplifier previously described in HAM TIPS, the amplifier described in this article goes all the way and gives a wide-range high-fidelity amplifier design capable of delivering 10 watts of audio power in the secondary of the output transformer with a distortion of less than two per cent. At a power output of ½ watt, which is a typical operating value for a home installation, there is practically no distortion (see Figure 3 for distortion characteristic of entire amplifier).

The amplifier features a low-cost resistance-coupled driver stage and independent tone-control circuits for bass and treble. It has sufficient gain to be driven by any medium-output crystal pickup such as the RCA Magic Tone Cell (RCA 211X1) which can be purchased either separately or as part of a crystal phonograph pickup arm assembly, RCA 209X1. By adding a pre-amplifier tube to the amplifier, it can also be used with any of the low-output magnetic-type pickups. A pre-amplifier with suitable compensation for this type of pickup is included in the circuit diagram, Figure 4. A stage-by-stage description of the amplifier follows.

Output Stage

The output stage uses the 6AS7-G operating in a class A push-pull circuit. Two separate cathode-bias resistors are used for bias on the two triode sections. The regulation produced by these two resistors makes it generally unnecessary to provide any special balancing circuit to equalize the current in the two triode units. The plate-supply voltage is 375 volts and the plate current per triode unit is 50 ma. Thus, the developed bias is 125 volts and the effective plate voltage is 250 volts. Each cathode is bypassed with an electrolytic capacitor to eliminate degeneration. Since the 6AS7-G is

10-METER RIG WITH 2E26 FINAL OPERATES ON BOTH PHONE AND CW

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Here is a little rig, a complete 28-Mc transmitter, which can afford the operator much pleasure in either a mobile or fixed station location. This rig will especially hit the spot for those who travel by automobile and are away from home a lot. It is small, light, and versatile enough so that it can be carried about and set up at any location with not much more effort than hooking on the antenna and plugging into an appropriate power source. The transmitter features push-to-talk nbfm, or cw operation in either the 10- or 11-meter band. The power supply may be operated from either 6 V dc or 110 V ac.
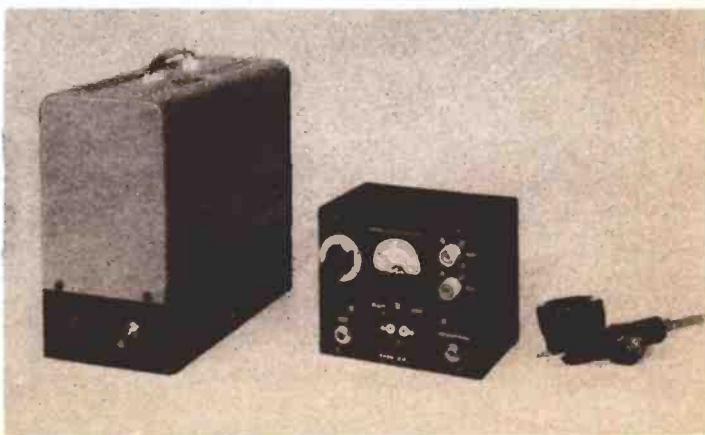
Crystal Reactance FM

The basic device used for obtaining frequency modulation is something new and is known as the Gerber Crystal Reactance System. Its principle of operation briefly is as follows. An inductor, which is tuned slightly higher than the crystal frequency, is inserted in series with the crystal. The total inductance in the oscillator grid circuit is, therefore, increased. In order to meet the conditions for oscillation, the crystal will then assume a lower value of equivalent inductance and a lowering of the crystal operating frequency will result. In Figure 1, a typical reactance curve for a crystal, f_1 and f_2 designate points of series and parallel resonance, respectively.

Point f_n is an operating point which meets the necessary conditions for operation. When an inductive reactance is added to the circuit, the crystal is required to adjust itself to a new frequency, marked f_h for the total reactance to remain constant. If the magnitude of the added inductance is then varied electronically, as with a reactance-tube modulator, the crystal frequency will then swing up and down along the crystal reactance characteristic. Extremely wide deviations are possible with this system; deviations in the neighborhood of 20 kc are not uncommon at even 3 Mc. In this particular application, however, no such deviation is necessary.

READY FOR ACTION!

This efficient looking rig features the new crystal reactance system for obtaining frequency modulation. It's a natural for Amateurs who do a lot of travelling by automobile.
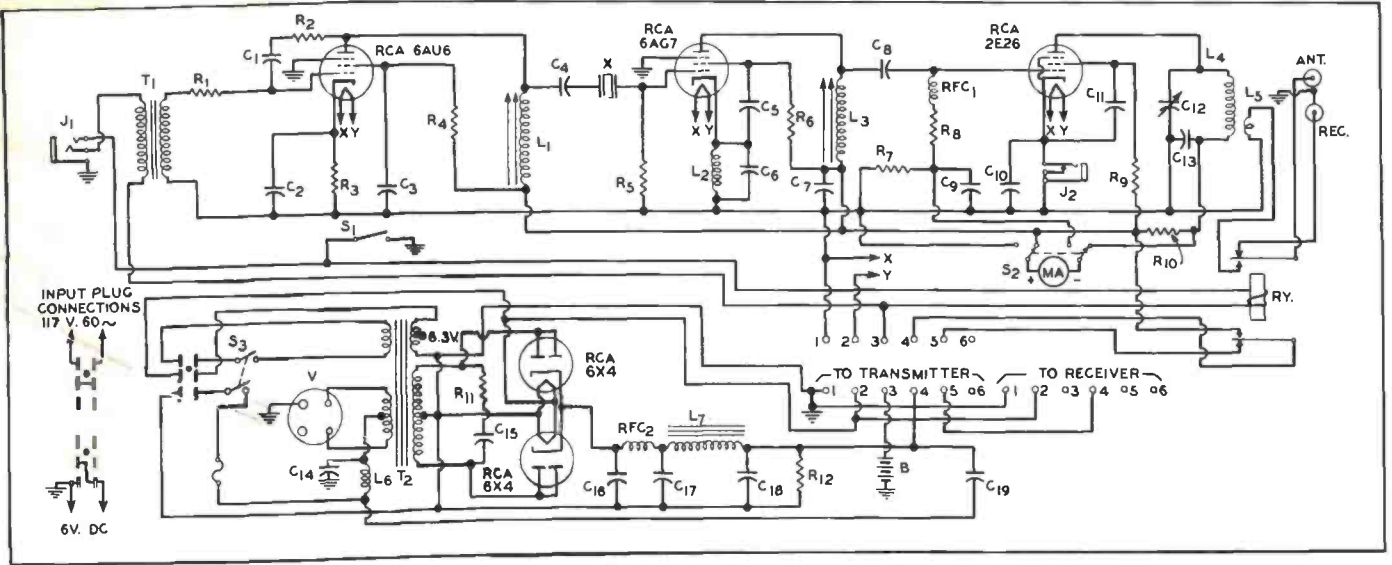
Figure 2. Schematic diagram of the 10-meter transmitter.

MOBILE RIG

(Continued from Page 1, Column 4)

RF Section

The crystal oscillator operates with a 7-Mc crystal and L_1 is the series inductor which produces the frequency deviation. The 6AG7, an excellent tube for oscillator-multiplier service because of its high control-grid screen-grid Mu factor, quadruples to 28 Mc. The
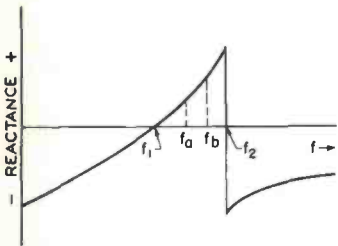

Figure 1. Typical reactance curve for a crystal.

output of the 6AG7 drives a 2E26 final of conventional design to about 10 watts using the described power supply. The oscillator is basically a standard "Hot-Cathode Colpitts" circuit with a few modifications. Because it is desirable in this application to have good harmonic output consistent with low crystal current, the screen of the 6AG7 is bypassed to the cathode, and instead of a conventional 2.5-mh choke in the cathode tank circuit, an Ohmite Z-1 choke (L_2) is used. This choke resonates closer to the crystal frequency, increasing the harmonic output considerably. Because the series inductor and the reactance tube introduce some losses into the oscillator, these two special design features are necessary so that ample drive is available for the final.

The reactance-tube modulator is conventional and uses a 6AU6 miniature pentode, which operates very satisfactorily. Adequate drive to obtain sufficient deviation is available directly from the microphone transformer.

The table below gives voltage and current measurements for the rf section.

	6AU6	6AG7	2E26
Plate volts	290	290	290
Plate milliamperes	3	30	60
Input watts	0.87	8.7	17.4
Screen volts	150	240	180
Screen milliamperes	2	6	10
Control-grid milliamperes	—	—	2.2
Power-output watts	—	—	10

A T-17B surplus Army single-button carbon microphone was used with this rig, the push switch on the mike performing the dual function of energizing the send-receive relay which switches the antenna and B+ from the receiver to the transmitter and controlling the mike current. Because the transmitter was designed to work from either a dc or ac input, it was necessary to include a microphone battery. If only dc operation is contemplated the relay and mike voltage may be obtained from the main storage battery.

It may be observed that there is no front panel control for the oscillator tuning. It was found that if the slug on L_a is set for middle-of-the-band operation, there is no appreciable difference in power output when crystals of other frequencies are used. It proved necessary, however in the interest of efficient operation to provide a tank tuning control on the 2E26 final amplifier.

L_1 should be adjusted to the point where a frequency shift of about 5 kc is observed between the conditions when it is shorted out and when it is in the circuit. It is comparatively simple to adjust the deviation merely by listening to the modulation frequency in a receiver and setting L_1 accordingly; however, it is desirable to check the actual deviation by any of the usual methods.

It may also be noted that provision (J_1) has been made for keying the 2E26 cathode circuit. So that one would not have to keep

BACK STAGE SCENE

An underchassis view of the transmitter reveals simplicity of construction and the compact manner in which wiring and components are arranged.

the mike button depressed to hold in the relay, a separate phone-cw switch, S_1, has been provided. This switch closes the circuit to the relay.

Metering is accomplished by switching a meter (0-10 ma) from the grid to the plate of the 2E26. When plate current is measured, a shunt is automatically connected into the circuit which multiplies the meter readings by 10. The exact value of this shunt (R_{10}) may be calculated or it may be determined by cut-and-try methods.
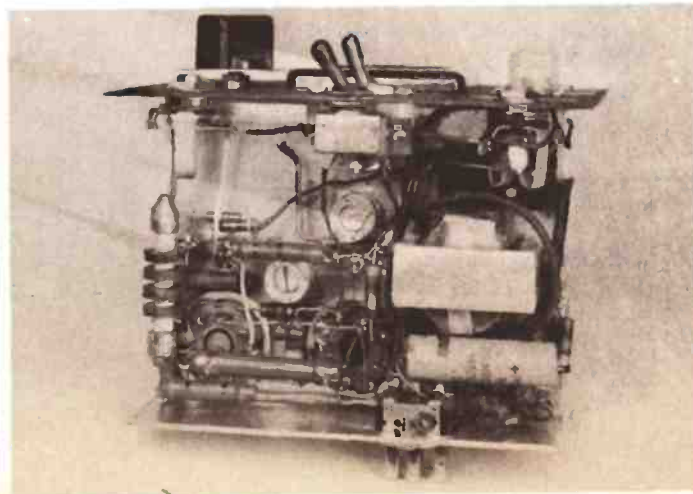
Construction and Layout Details

The entire rf section is built into a 4" x 5" x 6" standard cabinet. The chassis layout is illustrated in the photo on bottom of page 3. From left to right may be seen the relay and the 6AU6, the 6AG7, and the 2E26 with its tank circuit. The deviation control L_1 is under the meter while the oscillator-tank tuning slug is between the 6AG7 and the 2E26. The rf output is brought out to standard co-ax connectors on the front panel.

Power Supply

As mentioned above, the power supply is designed to work from either a 6-volt battery or 110-volts ac. To accomplish this a Thordarson transformer (type T-22R24) with a dual input is used in conjunction with a vibrator. For battery operation, of course, it is desirable to run the filaments from the dc source, so a switching arrangement is included with the power input plugs. A heavy-duty male 6-connector Jones plug on the chassis is used for input and two matching female receptacles are used on the power cables. Connecting the appropriate plug to the unit automatically makes the proper filament connections. Two miniature 6-connector female chassis-mounting-type Jones receptacles are used for output power and con-

MOBILE RIG

trol circuits: one feeds the transmitter and one the associated receiver. A pair of 6X4 rectifier tubes, connected in parallel, will furnish more than enough current to operate the transmitter. Approximately 300 volts is available from the supply.

PARTS LIST

R_1, R_2, $R_4 = 68,000$ ohms
$R_3 = 680$ ohms
$R_5 = 47,000$ ohms
$R_6 = 8,200$ ohms, 1 watt
$R_7 = 47$ ohms
$R_8 = 10,000$ ohms
$R_9 = 10,000$ ohms, 5 watts
$R_{10} = $ Meter Shunt
$R_{11} = 5,000$ ohms, 1 watt
$R_{12} = 220,000$ ohms
C_1, C_4, C_5, $= 100$ $\mu\mu f$, 600 W.V. (Hi-Kap)
$C_2 = 10$ μf, 25 W. V.
$C_3 = 1\mu f$, 400 W. V.
$C_4 = 1,500$ $\mu\mu f$
C_5, C_7, C_8, C_{10}, C_{11}, $C_{13} = $ CRL. Hi-Kaps, 5,000 μf, 600 W. V.
$C_{12} = 15\mu\mu f$, Variable, Johnson 160-107
$C_{14} = 5\mu f$, 200 W. V.
$C_{15} = .01$ μf, 1,600 W. V.
$C_{16} = .01$ μf, 600 W. V.
$C_{17} = .01$ μf, 450 W. V.
$C_{18} = 30$ μf, 450 W. V.
$C_{19} = 100$ $\mu\mu f$, mica
$V = $ Vibrator, Mallory 825C
$F = $ Fuse, 25 amp
RFC_1, $RFC_2 = 2.5$ mh
$B = 6$ V. Battery, RCA-VS009
$T_1 = $ Microphone transformer, Stancor A-4706
$T_2 = $ Dual Power transformer, 6 volts & 110 volts input, Thordarson T-22R24
$J_1 = 3$ conductor microphone jack
$J_2 = $ Key jack, closed circuit
$S_1 = $ SPST toggle switch
$S_2 = $ DPDT toggle switch
$S_3 = $ DPST toggle switch, 15 amp.
$Ma = 0-10$ ma DC meter 3"
$L_1 = 37$ turns, #30 enamelled, 2 layers on Millen Form #69041
$L_2 = $ Ohmite Z-1 choke
$L_3 = 10$ turns, #24 enamelled on Millen Form #69041
$L_4 = 10$ turns, #16, ¾" diameter, ¼" long (air wound)
$L_5 = $ Antenna link—3 turns, #16 over cold end of L_4
$L_6 = $ Hash choke, Mallory—RF583
$L_7 = $ Filter choke—Stancor C-1421
$X = $ Appropriate 7 Mc crystal
NOTE: All resistors ½ watt unless otherwise noted.

UP AND OVER

Tubes and relay are mounted with room to spare on small 4" x 5" x 6" chassis. The 2E26 tube and tank circuit are shown on the upper right portion of the photo.
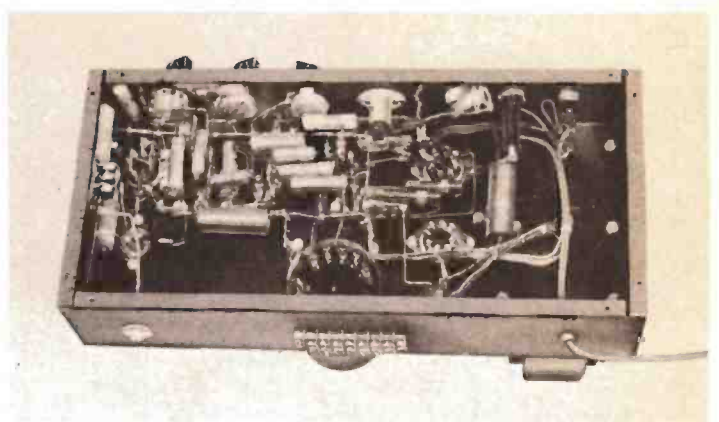
AUDIO AMPLIFIER

a cathode type tube, the heater supply (6.3 volts, 2.5 amperes) is obtained from the same transformer winding used for the other tubes in the amplifier.

Throughout the amplifier, resistance-coupled triode amplifier stages are used. Consequently, the circuit component mainly responsible for determining the frequency response of the amplifier is the output transformer. Use of a low-price, low-quality output transformer is simply not good economy in a high-quality audio system. After some experimentation with transformers in various price ranges, a UTC CG-16 transformer was selected as one of the reasonably priced transformers with good characteristics.

Driver Stage

It has been generally believed that adequate voltage for driving the 6AS7-G could be obtained only by the use of a transformer-coupled driver stage. This type of circuit is used in the speech amplifier mentioned previously. For such an application, transformer coupling is excellent because it provides the frequency cutting so desirable in a unit designed to handle voice-frequency components only. It is an expensive proposition, however, to use a truly high-fidelity audio interstage transformer in a high-fidelity wide-range amplifier. Considerable work was done, therefore, to devise a way to drive the 6AS7-G with a resistance-coupled push-pull driver. The circuit which was finally evolved uses a 6SN7-GT with a plate supply of 375 volts. Because of the voltage drop in the plate load resistors, operation is well within tube ratings. Degeneration, introduced into the circuit by the use of unbypassed cathode resistors, tends to reduce distortion in the output signal to a very small value. The grid resistors of the triodes in the driver stage are returned to the junction of the series cathode resistors to provide the correct bias.

Excitation for the driver stage is obtained from the familiar split-load phase inverter. This method was used in preference to the more common one of obtaining the grid signal voltage for one driver tube by tapping off the load of the other driver stage. The reasons for this choice are: first, the over-all distortion is slightly less because the grids of both driver units are provided with an undistorted signal. Further, the circuit employed is inherently balanced and requires no careful balancing after completion in order to determine the proper point for tapping off the signal for the second driver unit.

Tone Control Stages

Preceding the phase inverter are three additional triode amplifier stages. In order, working back from the phase inverter, these stages are the treble tone-control stage, a voltage amplifier stage, and the bass tone-control stage. In the design of tone control stages several features are desirable. Separate controls should be provided for both bass and treble frequencies; there should be no interaction between the controls; and frequency boost

WIRING DETAILS OF THE AMPLIFIER

A bottom view of the amplifier showing how components are located to obtain maximum fidelity and minimum distortion and hum.

and frequency attenuation should be obtained from the same control without switching. Further, it was considered desirable to avoid the use of any inductors not only because of cost, but also because of possible hum pickup problems.

Interaction between the bass and treble tone controls is eliminated by putting each in a separate stage. The treble tone-control stage is a resistance-coupled amplifier stage with a large unbypassed cathode resistor. A potentiometer (R_{23}) in series with a 0.005-μf capacitor (C_{17}) is connected between the plate of the tube and the junction of the two cathode resistors. From the arm of the potentiometer a capacitor is connected to ground. When the arm of the potentiometer is at the plate end, the plate load resistor is shunted by the 0.005-μf capacitor (C_{17}) and the 0.02-μf capacitor (C_{16}) in series, and the high frequencies are attenuated. When the arm of the potentiometer is at the cathode end, the cathode resistor is bypassed by the 0.02-μf capacitor. This bypass is effective only at the higher audio frequencies and reduces the degeneration in the stage thereby increasing the gain and giving treble boost.
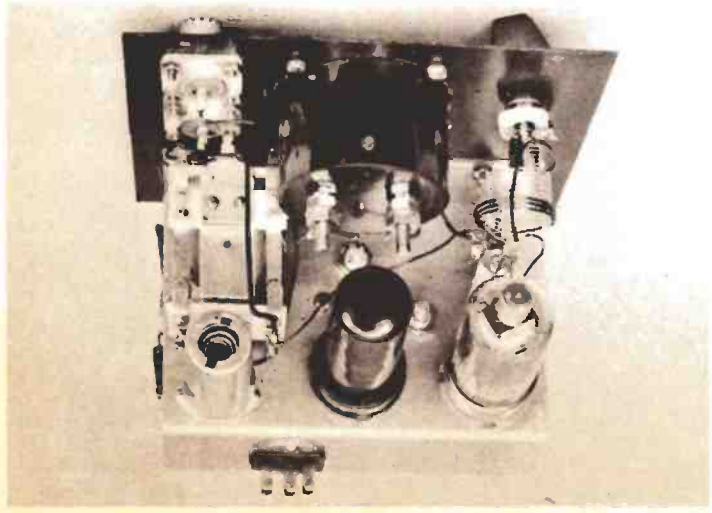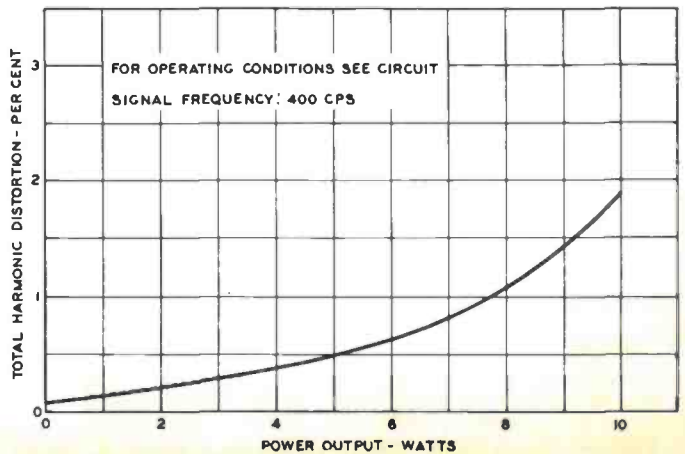
Figure 3. Total distortion versus power output.
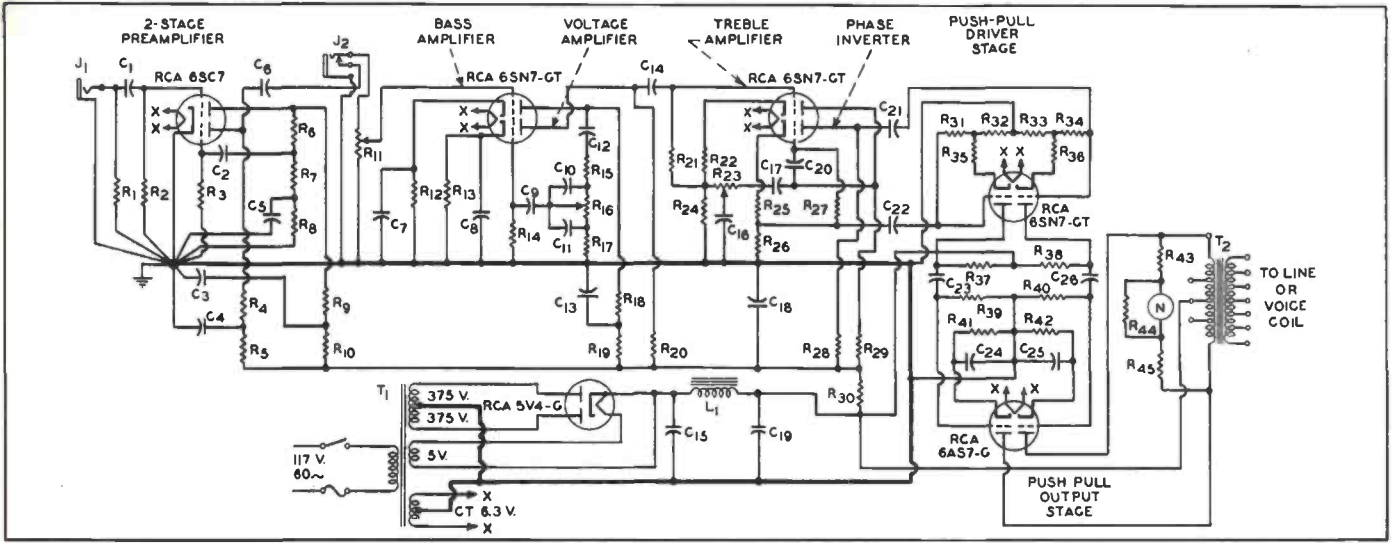
Figure 4. Schematic of the high fidelity amplifier.

AUDIO AMPLIFIER

The bass tone-control network is inserted between the two units of the first 6SN7-GT. It is located in an early stage to avoid boosting any hum voltages produced in any of the later amplifier stages. When the arm of the potentiometer is all the way down, the 0.03-μf capacitor (C_{11}) is shorted out, and bass attenuation is provided by the 0.01-μf capacitor (C_{10}) which limits the transmission of the low frequencies. When the arm of the potentiometer is at the plate end, the 0.01-μf capacitor is shorted out, and the 0.03-μf capacitor serves to increase at low frequencies the output of the voltage divider made up of the 100,000-ohm resistor, (R_{18}), the 0.03-μf capacitor (C_{11}), and the 10,000-ohm resistor (R_{17}). This arrangement provides bass boost.

The circuit constants are so chosen that the tone controls have negligible effect on the output at about 800 cycles. At 60 cycles a boost of 13 db or an attenuation of 12 db is possible. At 6000 cycles a boost of about 10 db or an attenuation of about 11 db is possible. Flat response is provided by intermediate adjustment of the controls. The over-all response of the amplifier for maximum and minimum

adjustment of the bass and treble controls is shown in the curves of Figure 5.

Phonograph Pickup

The amplifier can be driven to full output with a signal of about 0.6 volt RMS at the volume control. The RCA 211X1 Magic Tone Cell crystal pickup has an output of about 1.5 volts and is excellent for use with this amplifier. This pickup gives high-quality reproduction and does not ordinarily require compensation.

If it is desired to use one of the low-output magnetic-type pickups, a pre-amplifier is required. The preamplifier circuit shown in the schematic, Figure 4, will provide the necessary gain and proper equalization for this type of pickup. A rubber shock-mounted tube socket should be used for the 6SC7 to minimize microphonic disturbances.

Hum

In order to obtain satisfactory performance from any high-fidelity amplifier, precautions must be taken to keep hum to an absolute minimum. In this amplifier, hum is kept down by observing the following precautions which serve to prevent minute voltage drops caused by high currents in the

power supply or high-level stages from flowing through a ground circuit which is common to that used in the low level stages. Ground returns are made through a bus and not through the chassis. The electrolytic capacitors in the power supply are not grounded to the chassis but are mounted on insulating washers. The B- or ground bus is run from the center tap of the power transformer to the negative side of the electrolytics and then to the power output stage, the driver stage, and back through the early stages of the unit, picking up the ground returns in succession. The ground bus is finally tied to the chassis near the input jack. The hum output of the amplifier as constructed does not exceed 10 microwatts at the full output level.

PARTS LIST

C_1, C_2 = .05 μf
C_3, C_4 = 20 μf, electrolytic, 450 W.V.
C_5, C_9, C_{10} = 0.01 μf
C_6, C_{16}, C_{20}, C_{21}, C_{22}, C_{23}, C_{24} = 0.02 μf
C_7, C_8 = 25 μf, electrolytic, 50 W.V.
C_{11} = 0.03 μf
C_{12} = 0.01 μf
C_{13} = 8 μf, electrolytic, 450 W.V.
C_{14}, C_{17} = 0.005 μf
C_{15}, C_{19} = 15 μf, electrolytic, 450 W.V.
C_{18} = 10 μf, electrolytic, 450 W.V.
C_{25}, C_{26} = 20 μf, electrolytic, 150 W.V.
T_1 = 375-0-375, 160 ma., Thordarson —T22R33
T_2 = Output transformer, UTC-CG-16, plate to plate load 5000 ohms
L_1 = 12 h, 150 ma., Thordarson T17C00-B
J_1 = Phone jack
J_2 = Closed circuit—phone jack
N = $\frac{1}{4}$ watt neon lamp
R_1 = 5,600 ohms
R_2, R_3 = 3.3 Megohms
R_4, R_5, R_{19} = 33,000 ohms
R_6 = 200,000 ohms
R_7 = 27,000 ohms
R_8 = 180,000 ohms
R_9, R_{10} = 68,000 ohms
R_{11} = 0.5 Megohm, Potentiometer
R_{12}, R_{13}, R_{22} = 1,500 ohms
R_{14}, R_{21}, R_{27}, R_{31}, R_{34}, R_{36}, R_{40} = 0.5 Megohm
R_{15}, R_{45}, R_{45} = 100,000 ohms
R_{16} = 1 Megohm Potentiometer
R_{17}, R_{24} = 10,000 ohms
R_{18}, R_{20}, R_{26}, R_{28}, R_{29}, R_{37}, R_{38} = 47,000 ohms
R_{19} = 20,000 ohms
R_{23} = 0.25 Megohm, Potentiometer
R_{25} = 4,700 ohms
R_{30} = 10,000 ohms, 2 watts
R_{32}, R_{33}, R_{35}, R_{38} = 2,700 ohms
R_{41}, R_{42} = 2,500 ohms, 10 watts—wire wound
R_{44} = 75,000 ohms
All capacitors are 600 volts paper unless otherwise specified.
All resistors are $\frac{1}{2}$ watt unless otherwise specified.
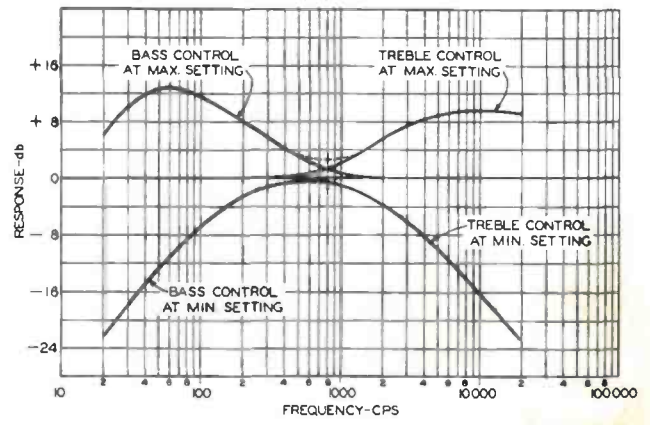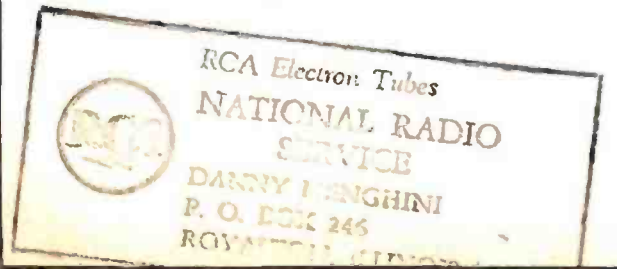
Figure 5. Over-all response of the amplifier for maximum and minimum adjustment of bass and treble controls.