THE SSB-600

GROUND-GRID LINEAR AMPLIFIER

- 600 Watts DC Input in 600 Cubic Inches

By A. F. Provenzi, W8OLD

FEATURES:

1. Efficient high frequency pi-network output circuit.
2. Complete metering of each tube.
3. Two GL-814 pentodes in zero-bias triode connection.
4. Rugged, compact construction for mobile service.
5. Covers 3.5 to 30 megacycles.
6. Only 6 x 10 x 10 inches in size.

You probably remember the old saying, "Do as I say, not as I do." W8OLD has been saying how to build this mobile SSB linear amplifier for years, after first constructing a model from junk-box parts. He recently has been doing, instead of saying, however, by constructing a new — and much prettier — model of his amplifier especially for this publication.

Over five years of testing in mobile and fixed service have been chalked up by the original model. It has several worthy electrical and mechanical features that make it stand out from being "just another linear amplifier."

THE GL-814 BEAM PENTODE was chosen for an amplifier tube because, when connected as a triode (control, screen and suppressor grids all connected together and returned to the filament) it exhibits zero bias characteristics and draws only 25 milliamperes of plate current with 2,000 plate volts applied. Since the rated plate dissipation of the GL-814 is 70 watts in ICAS service, it was decided to connect two tubes in parallel to obtain about 600 watts DC input linearity. Commercial and Amplifier Service ratings.

IN THIS ISSUE

Copyright 1961, by General Electric Company

SSB-600 Grounded-Grid Linear Amplifier
Simple Sensitive Multimeters
1960 Edison Radio Amateur Award — Recipients
The same reasoning was applied to the leading capacitor (C). A 20 to 320-mfd variable is used for the higher frequencies, and additional capacitors are connected in series in by 8's in steps of 300 mfd. RFC is a safety precaution.

The metering circuit provides for measuring control and screen grid, and cathode potentials in each GL-844 individually. This permits selecting a matched pair of GL-844's (if you happen to have spares around), and is also handy for inquiring that each tube is sharing the load. It also allows you to catch a tube starting to go bad before it has a chance to wreck its mate. Many poor signals are caused by weak tubes, causing the other tubes in parallel to be overloaded or to work under improper loading conditions.

Control grid (No. 1 grid) current is normally considered of great importance. This amplifier also has number two grids wired independent. A "look-saw" in this circuit is not only interesting but educational. This eliminates guessing as to the division of the drive between the control grid and screen grid.

The cathode circuits are metered in the filament center tap. Remember to substitute control grid and screen grid currents from this reading to determine true plate current. Normal cathode current may be read, but it may be abnormal grid current due to drive and loading that is responsible for this reading. WOULD also has built an e f. wattmeter right into this amplifier. The circuit is described in the May-June issue. See LOW-COST RP WATTMETER, page 1.) Forward power up to 500 watts full scale is read in position 1 of C, and reflected power up to 750 watts full scale is read in position 2. Thus, readings of nearly 500 watts forward and less than 60 watts reflected power indicate less than 10 per cent reflected power, and a VSWR of less than 2 to 1. The reflected power position can be precisely calibrated with a 50-ohm dummy load.

CONSTRUCTION OF THIS MODEL was accomplished in a 6 x 10 x 3-1/2-inch deep chassis box (Robel CT-301A Minibox, or equivalent). The parts layout shown in the accompanying pictures and chassis layout drawing, Fig. 2, provides very short 5 circuit leads and good isolation of the input circuit. Nearly all of the 300 cubic inches of volume in the enclosure are occupied, as redrawn will note. The complete enclosure should be constructed first. The 6 x 10-inch end (continued on page 4)
Components for the r.f. wattmeter should be mounted underneath in the center of the chassis before the meter switch, S8, is assembled. Bypass capacitors and other wiring around the tube sockets are installed before the filament r.f. choke is mounted. Return as many bypass capacitors as possible to a common chassis ground. A terminal strip (T6) was installed on this model for external power connections, but a suitable multiple-pin jack and plug can be used if desired.

For remote measurement of control and screen grid currents is made by connecting the appropriate current meter between terminals 4 to 7, as follows:

4 to ground: G2 (right) 55 ma.
5 to ground: G2 (left) 50 ma.
6 to ground: G1 (right) 109 ma.
7 to ground: G1 (left) 100 ma.

ALL COMPONENTS in this amplifier have been chosen to handle higher power. Thus, a pair of GL-813 beam pentodes could be substituted for the GL-814S if the chassis is made larger; 7 x 12 x 4 inches (A. Bad CU-9011A Minibox, or equivalent).

Higher, however, since this chassis also will hold four type GL-814S in parallel, if anyone prefers to run four of these tubes. Larger filament transformers will be required, of course.

If a pair of GL-814S are used, a well regulated negative bias supply will be required to furnish the approximately minus 70 volts of control grid bias required to hold the plate current to a low value with the triode connection. For this your signal would be 3 DB louder at your friend's receiver. This is less than one S unit. It is frequently easier to gain 3 DB with a little antenna work than by many hours and dollars spent on the linear amplifier.

Some amateurs may want to construct this amplifier as a subassembly to go into a chassis that includes a power supply. This chassis may also include a driver amplifier for use with an exciter delivering less than 50 watts output. When built as an assembly to go into a chassis cabinet arrangement the "do it yourself" enclosure construction is not necessary.

The small package, complete amplifier described here was constructed because it was meant to serve as a front end for a later generation.

ADJUSTMENT AND TUNEUP of this amplifier, after construction is completed, should be done carefully to avoid overloading the tubes for extended periods and thus damaging them. Connect 117 volts AC to terminals 1 and 3, and L to an exciter output to deliver about 50 watts. Then tune in the appropriate terminal to the plate circuit tuning (C9) and output (C8) capacitors for maximum output with S1 in position 2 (BP output). Increase the driving power to about 25 watts and adjust the tuning for maximum output. Then in increments of about 40 milliampere of grid current is read for each GL-814S in positions 7 and 8 of S8. Adjust the tuning and loading controls for maximum output, then reduce the driving power a bit and readjust the tuning and loading controls. Optimum point for maximum output above obtained.

For test purposes, increase the plate supply to about 400 volts DC and tune carefully for maximum output, running the amplifier for only a minute at a time. It should be possible to obtain 500 watts CW output on all bands from 3.5 to 28 megacycles at 2,400 plate volts and with a maximum of 40 milliamperes of centinel grid current per tube. Cathode current will read about 200 milliampere per tube. At 2,000 to 2,500 plate volts, CW output will deliver about 400 watts at 28 megacycles, and 40 watts below 2.5 megacycles.

Frequently it happens that an expert's driveable delivering 100 watts power to the antenna load will not supply the necessary drive to the cathode circuit of a grounded-
grid amplifier due to an impedance mismatch. A matching network or coupler should then be used between the excitor and amplifier to achieve a match."

**PERFORMANCE** of the amplifier when constructed as illustrated will assure 60% efficiency at 20 megacycles, rising to 20% at 4 megacycles. This may sound high, but the driving power has not been subtracted from the efficiency figure. The amplifier shows a power gain in excess of 10 times. This means that 60 watts should be fed into the input jack if 500 watts output is desired. There is no way to cheat on these figures!

So far this testing has been done under CW conditions. Now the real test comes with an oscilloscope. Connect the scope to the amplifier test output jack, J. Note the two input and output jacks for easy access to a monitoring spot. Turn on the 500-watt output CW test and set the scope for a good sized CW display. The pattern should be a pure RF carrier. With a grease pencil or crayon, mark the height of this display on the scope screen.

Now switch to SSB and slowly advance the audio gain while speaking into the mike until peaks of the height marked for CW are reached. This indicates that the amplifier is delivering 500 watts peak output. Now adjust the scope for a slow sweep and look at the so called "Christmas tree pattern." Is there any flattening or distortion noticeable at this 500-watt level? or, can the audio level be increased?

If flattening is indicated, plug the scope into the input jack of the linear which will allow monitoring of the exciter. If the same flattening is present, it is coming from the driver. If a display with no flattening is seen, it must be in the linear stage. Try a slight increase in loading by decreasing the load capacitance (C). Did this cure the flattening? With 50 watts of linear drive, at least 500 watts output without distortion should be seen on the scope. It may be possible to further increase the drive without distortion. Remember that the scope is reading an instantaneous voltage. Also remember that the wattmeter will only read average power and so is of no value for this test.

The 500-watt peak output can be directly compared with any other (continued on page 7)

* A suitable pi network, impedance matching, coupler is described on page 4 of the November-December, 1959 (Vol. 16, Fig. 4) issue of 6-Mon News.

**TABLE II — DRILL SIZE LEGEND**

<table>
<thead>
<tr>
<th>Drill Size</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>No. 31 drill 4-49 screw</td>
</tr>
<tr>
<td>B</td>
<td>No. 24 drill 4-35 screw</td>
</tr>
<tr>
<td>C</td>
<td>No. 17 drill 8-32 screw</td>
</tr>
<tr>
<td>D</td>
<td>No. 9 drill 10-32 screw</td>
</tr>
<tr>
<td>E</td>
<td>8-32 inch diameter</td>
</tr>
<tr>
<td>F</td>
<td>6-32 inch diameter</td>
</tr>
<tr>
<td>G</td>
<td>1/4-inch diameter</td>
</tr>
<tr>
<td>H</td>
<td>Socket head 5/8-inch diameter for 7-plate miniature tube socket</td>
</tr>
<tr>
<td>I</td>
<td>Socket head 7/8-inch diameter for 9-plate miniature tube socket</td>
</tr>
<tr>
<td>J</td>
<td>Socket head 1-inch diameter for small octal tube socket</td>
</tr>
<tr>
<td>K</td>
<td>Socket head 1 1/2-inch diameter for large octal tube socket</td>
</tr>
</tbody>
</table>

**FIG. 3. CHASSIS TOP VIEW**

- Chasis parts on WROD's model amplifier with two 814 tube holder. See TABLE II for the sizes of holes keyed with letters. Locations of small holes marked C, E, F, H, I, S, T, and W, are for the components actually used, and should be moved to suit components having different mounting dimensions. The cutout for M, should closely match the connecting terminals on the back of the meter.

**FIG. 4. CABINET FRONT VIEW**

- Chasis parts on WROD's model amplifier with two 814 tube holder. See TABLE II for the sizes of holes keyed with letters. Locations of small holes marked C, E, F, H, I, S, T, and W, are for the components actually used, and should be moved to suit components having different mounting dimensions. The cutout for M, should closely match the connecting terminals on the back of the meter.
SIMPLIFIED SENSITIVE MULTIMETER

A SENSITIVE DC MULTIMETER is always a handy instrument in the amateur radio station. However, complex instruments of this type can be expensive.

"But, they don't have to be," says Chuck, W2UHP. "Look at my simple, sensitive DC voltmeter that the average amateur can duplicate in a single evening.

"I needed a DC voltmeter with very high resistance to check and precisely adjust the negative bias on the control grids of the output stage in the new SSB transmitter I added to my station recently. A conventional 1,000 ohms-per-volt meter would have loaded down the circuit excessively and given me a lower-than-actual reading."

"A quick scan through my junk box under the workbench turned up a 100-microampere DC current meter, a sloping panel meter box, and some miscellaneous banana plugs and jacks, terminal boards and hardware."

"A few minutes of figuring with a pencil — after referring to the 'Measurements' chapter of the 'Radio Amateur's Handbook' — and I had the multiplier resistance values required for several popular DC voltage ranges. I used the following formula to calculate the multiplier values:

\[ N = \frac{1}{R} \]

where \( R \) is the resistance in ohms; \( E \) is the desired full-scale voltage; and \( N \) is the full-scale reading of the meter in milliamps. The 100-microampere meter thus gave a sensitivity of 10,000 ohms per volt.

"Rather than switch in the various multipliers with a tap switch, I decided that each multiplier could be mounted on a terminal board that would plug into the back of the meter case. This provided for future needs by allowing additional ranges to be added at any time."

"This is the philosophy with which the Simplified Sensitive Multimeter was designed."

THE CIRCUIT of the multimeter is extremely simple, as shown in the schematic, Fig. 1. Multipliers plug into J1 and J2, and the leads running to the circuit to be measured plug into P1 and P2. Provision can also be made to measure currents with this instrument by plugging in a shunt of suitable value across the meter at J1 and J2.

**TABLE I — METER MULTIPLIER CHART**

<table>
<thead>
<tr>
<th>Full Scale</th>
<th>Meter Reading Desired</th>
<th>Multiplier for 30 ohm meter</th>
<th>Multiplier for 30 ohm meter</th>
<th>Multiplier for 100 ohm meter</th>
<th>Multiplier for 500 ohm meter</th>
<th>Multiplier for 3000 ohm meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 Volts</td>
<td>5,000 ohms</td>
<td>1,000 ohms</td>
<td>1,000 ohms</td>
<td>40,000 ohms</td>
<td>200,000 ohms</td>
<td>20,000,000 ohms</td>
</tr>
<tr>
<td>1.0 Volts</td>
<td>50,000 ohms</td>
<td>10,000 ohms</td>
<td>10,000 ohms</td>
<td>400,000 ohms</td>
<td>2,000,000 ohms</td>
<td>200,000,000 ohms</td>
</tr>
<tr>
<td>10.0 Volts</td>
<td>500,000 ohms</td>
<td>100,000 ohms</td>
<td>100,000 ohms</td>
<td>4,000,000 ohms</td>
<td>20,000,000 ohms</td>
<td>2,000,000,000 ohms</td>
</tr>
<tr>
<td>100 Volts</td>
<td>5,000,000 ohms</td>
<td>500,000 ohms</td>
<td>500,000 ohms</td>
<td>40,000,000 ohms</td>
<td>2,000,000,000 ohms</td>
<td>200,000,000,000 ohms</td>
</tr>
<tr>
<td>1,000 Volts</td>
<td>50,000,000 ohms</td>
<td>5,000,000 ohms</td>
<td>5,000,000 ohms</td>
<td>400,000,000 ohms</td>
<td>20,000,000,000 ohms</td>
<td>2,000,000,000,000 ohms</td>
</tr>
</tbody>
</table>
Meters having several different full-scale current ranges were tried in the circuit at WURP. Values of the multiplier resistances required to obtain several full-scale voltage readings with meters rated at from 0 to 1000 ma have been tabulated in TABLE 1—METER MULTIPLIER CHART. Multipliers may be assembled from two or more resistances in series to obtain the required total resistance. Five such resistances were used for the multiplier in the model constructed by WURP.

Precision 1-per cent tolerance resistors assure the best accuracy, but inexpensive composition resistors may be combined in series to obtain the correct total resistance. By selecting values carefully, the tolerances in the inexpensive resistors can thus be made to cancel each other out, resulting in a precise total value of resistance.

Shunting resistors will range from a fraction of an ohm, to a few ohms depending upon the full-scale current range desired. They can be made from either nichrome resistance wire, or copper wire.

The exact value of shunting resistance can be determined by plugging in an insulated board into J2 and J4, and then connecting a short wire between J3 and J5. A current of the desired full-scale value is then passed through the meter, and the wire is shortened or lengthened until the meter shows a full-scale reading. Shunts having a few ohms of wire may be wound on 47-ch. 1-watt composition resistors.

CONSTRUCTION DETAILS are shown in the illustrations on this page. The meter cases usually have fendered insulators already in place. Obtain some with a hole to fit the size of meter that will be used. All banana jacks on the rear of the case should be insulated with the fiber washers provided with the jacks. These washers are usually adequate for several hundred volts. Wiring inside the case is run with insulated hookup wire. Standard test leads are connected to J 2 and J 3 on top of the case.

Multipliers are mounted on insulated terminal boards, and fitted with banana plugs spaced to match the multiplier jacks on the meter case.

A separate multiplier board is required for each voltage range. The meter is used in the same manner as a regular multimeter. Polarity of the meter must be observed. Before checking an unknown voltage, be sure to plug in a multiplier for a full scale reading higher than the voltage is likely to be. When storing the meter, plug in a low-resistance shunt across the meter.

This simple multimeter will provide measurements of voltage accurately to within a few percent in circuits where the circuit resistance is up to 15 percent of the full-scale resistance of the multimeter. When constructed with a meter having a full-scale sensitivity of 100 microamperes or less, it will provide useful measurements of voltage in receiver and other low-level circuits.
THE EDISON RADIO AMATEUR AWARD

. . . was established in 1965 by the General Electric Company to provide for public recognition of the many outstanding public services performed by radio amateurs. Many such commendable events go unnoticed each year which otherwise could raise the stature and prestige of all radio amateurs.

The Award is presented annually to a licensed radio amateur who, while pursuing his or her hobby within the limits of the United States, has performed an outstanding meritorious service in behalf of an individual, group, or the general public.

These services range from providing vital emergency communications during emergencies, often in dangerous situations, to organizing complex communications systems, and unique services to an individual.

Candidates for the Award are nominated by letter from individuals, or clubs, associations and other groups familiar with the public service performed by their candidate.

The recipient is selected at the end of January by a panel of distinguished impartial judges from among candidates nominated by persons familiar with the service each candidate has rendered.

Judging centers on the greatest benefit to an individual, group, or community, and is limited to the amount of ingenuity, devotion, and sacrifice the candidates display in performing their services.

The presentation of the Edison Radio Amateur Award trophy and a check for $500 to the recipient is made several weeks later at a ceremony in Washington, D.C., before prominent figures in military, government and civilian communications. . . whose trans-Pacific experiments have set distance records and opened new horizons in UHF communications, have been chosen jointly by the Judges to share the 1966 Edison Radio Amator Award for outstanding service.

This year marks the first time the award has been granted for scientific achievement. Messrs. Thomas and Chambers have devoted four long years to patient and often fruitless experimentation with tropospheric ducting radio propagation phenomena, culminating in a one-way communications distance record of 2,540 miles on the 432 megacycle amateur band.

This and earlier two-way records set over the same California-Hawaii path on 220 and 144 megacycles confirmed the theory that UHF radio communications were not limited to line of sight. Their work has stimulated commercial and military interest and experimentation in communication via this phenomenon.

The judging panel, in comparing their accomplishments to the first trans-Atlantic radio communications in the 1920's, noted that the work of Messrs. Thomas and Chambers further enhanced the standing of amateur radio operators in the scientific world.


Available FREE from your G-E Tube Distributor