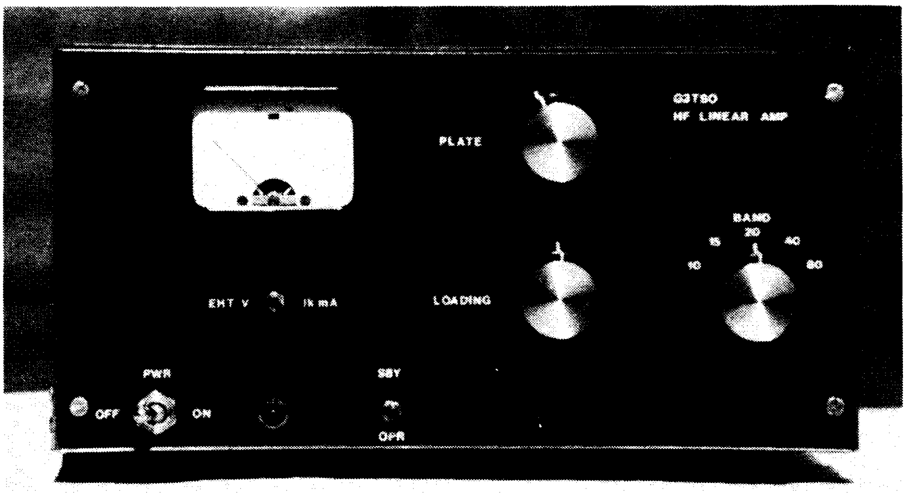


Medium power HF linear amplifier

MJ Grierson, G3TSO/KD3CL, describes a very useful add-on for a low-power transceiver

The linear amplifier described was designed to compliment the G3TSO Modular Transceiver (RadCom October/November 1988) and is capable of being driven by any exciter producing from 5 to 25 watts RF output. It is ideal for use with the Cirkit Kit PA now popular amongst many amateurs as a low-cost reliable solid state PA unit capable of producing up to 20 watts output.

As a confirmed solid state man, many may be curious as to why I resorted to a valve design; the answer is quite simply that I had in the bottom of my junk box a number of components that might otherwise never have been put to use. The cost of building a valve amplifier and PSU is probably very close to that of a solid state unit and PSU, but if you already have half the components in stock then a valve design may represent the most cost-effective solution. The construction of valve equipment is becoming very difficult due to the poor availability of suitable components, and this project is only recommended for those with a junk box or the patience to search around the rallies for the components.

The amplifier is based on the 'Quarter Gallon Amplifier' (ARRL Handbook 1980); it was designed to raise the power of a US 'Novice'-type rig from 25 to 160 watts. The original design included some unobtainable components and has been adapted to utilize those components that the author could find. The valves used are the 6KD6 American line output tubes available in the UK for about £10.50. The bases may be less easy to obtain and the more common PL509 or EL509 types could easily be used as an alternative. Suitable heater supplies for the PL509 have been described in recent *Technical Topics*.

WARNING!

This amplifier operates from the AC mains and develops HIGH VOLTAGES which can be LETHAL. Great care must be taken when making adjustments. This is especially important if the constructor is not familiar with high voltage equipment.

CIRCUIT DESCRIPTION

The amplifier uses two 6KD6 television line output tubes operated in grounded grid. The screen and suppressor grids are directly earthed and the control grids are earthed to RF by capacitors C13, C14. Negative bias is applied to the control grids via independent bias pots enabling equal standing currents to be set on each valve.

RF input is fed to the cathodes of the valves via two series resistors R1, R2, whilst a DC return to ground is provided by the choke RFC1. The input impedance of the cathode circuit varies across the bands and appears to be in the range of 75Ω to 250 Ω; an input matching circuit is therefore required if the amplifier is to be fed from a solid state exciter. This may take the form of either a tuning unit or a fixed tuned filter.

The anode circuits are conventional using a pi-output circuit. Parasitic stoppers comprising 47Ω carbon resistors wound with 5 turns of 18 SWG wire are connected directly to the anode caps.

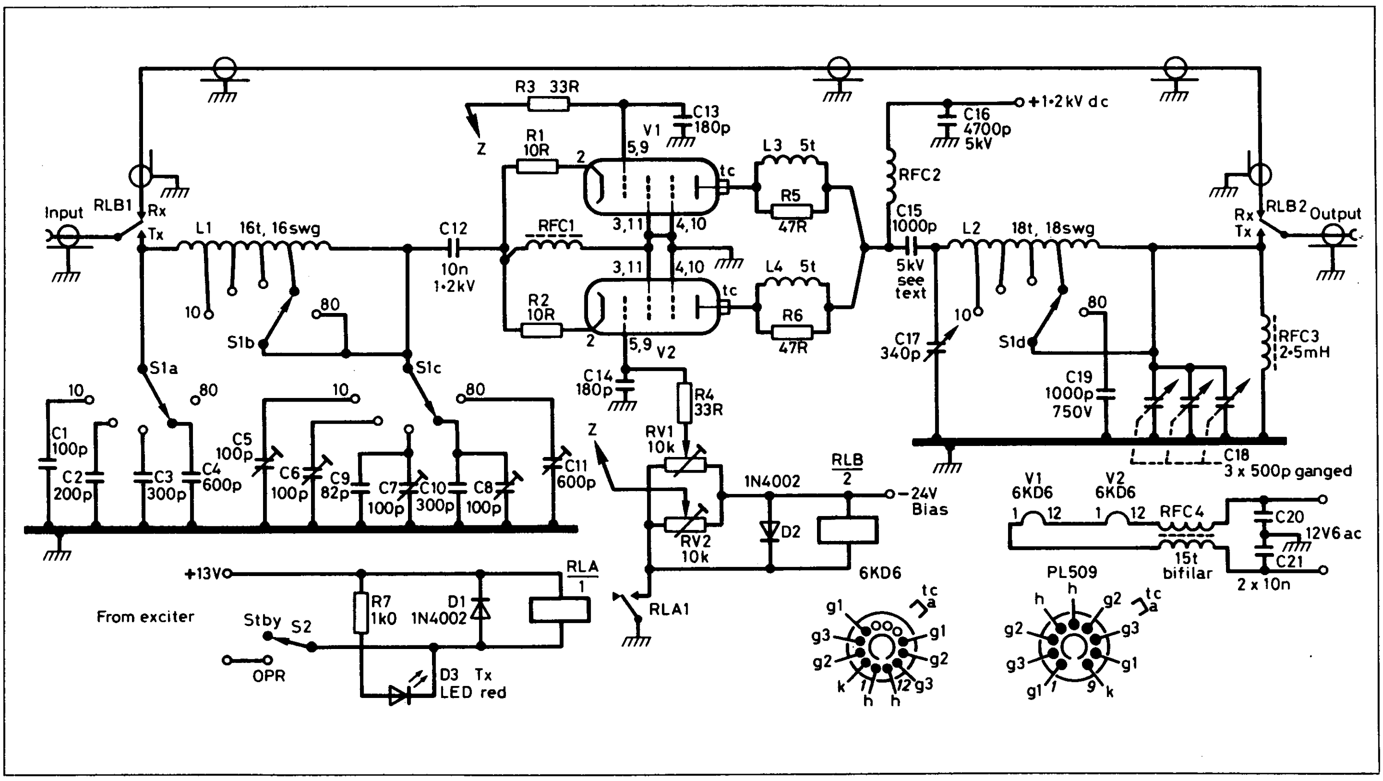


Fig 1. Main circuit

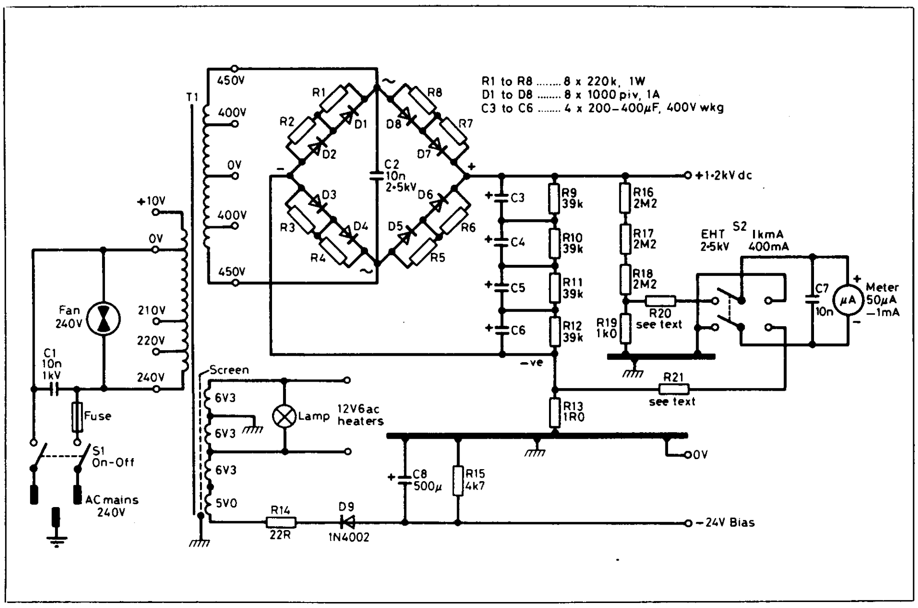


Fig 2. Power supply circuit

RFC2 is often a critical component as it must not display any resonances in any of the amateur bands to be tuned.

Nevertheless, it is a simple single layer choke consisting of 40 turns of 24SWG wire on a 0.5in TUFNOL former. C15 is a high quality mica capacitor of at least 5kV working and is the only isolation between the EHT and the antenna socket. 500pF door knob type capacitors used in TV EHT circuits may prove suitable for this application; two should be connected in parallel. Some protection of the output is provided by RFC3, a 2.5mH RFC which must be capable of blowing the fuse if C15 should go short circuit. A choke should therefore be found with fairly heavy gauge wire.

More often than not line output valves are operated with an HT voltage of about 600V. With their high internal capacitance, the anode matching can be quite a problem especially on ten metres where efficiency drops off rapidly. By using an anode voltage of 1.2kV, the anode load impedance is raised and more sensible pi-output values can be used. C17 is a difficult component to obtain and should ideally have a log law in order to spread out the minimum capacitance which is necessary to tune 10 metres. A reasonably wide spacing is also required, ideally at least 3.5mm. Suitable items can be found at rallies but not in large quantities. If necessary, a 100pF linear variable could be used with a fixed value mica capacitor switched in parallel for 40 and 80 metre operation. L2 (removed from a FT101) is wound on a ceramic former and switched using a ceramic wafer switch S1d which is ganged to a further rotary switch containing the wafers S1a, S1b and S1c, required to switch the input matching filter. L2 had a double spaced winding for 10 metres. Such a coil former is not likely to be found easily and it may be preferable to use a separate 3 or 4 turn coil wound from heavy gauge wire for the 10 metre band. C18 is a standard air spaced 3 gang 500pF broadcast type capacitor.

The heaters are RF decoupled from the AC supply by winding 15 bifilar turns on an old ferrite rod approximately 3 inches long and 3/8" diameter; the grade was unknown, but it was probably a medium wave antenna rod. As the heater supply is balanced, no RF decoupling capacitors are used. However, the use of 10nF ceramic capacitors between the cold end of the RF chokes and ground may be necessary if using an unbalanced supply.

The bias supply is used to set the operating conditions of each valve individually, and approximately -6V sets the standing current to 20mA per valve which coincides with a voltage drop of 0.2V across R1 and R2. When in standby, the negative bias is increased by raising the bias pots above ground by RLA, thus reducing the standing current. The transmit relay RLB is also switched on the bias line.

INPUT MATCHING

The input matching circuit was not included in the original ARRL article and the amplifier was initially built without this circuitry. The amplifier worked perfectly well but it proved necessary to place a small ATU between the exciter and the linear to effect a reasonable match. This proved rather cumbersome and the pi-input circuit was added. Initially, individual pi-filters were tried for each band, but there was an element of mutual coupling and it would have been necessary to short out the circuits not in use in order to tune the input correctly. The compromise system of using a tapped coil was therefore adopted. The values were determined experimentally and may vary from one amplifier to another. On 80 metres the input filter is an L match. A number of compression trimmers are used to enable the input to be tuned for minimum input SWR or maximum output. There is no reason why the input filter should not

COMPONENTS LIST

AMPLIFIER

L1	16 turns, 16 swg tinned copper 1" dia 8 turns per in. Tapped at 3 turns, 4 turns, 6 turns and 10 turns
L2	18 turns, 18 swg tinned copper, 1.5" dia. First 4 turns treble spaced, remainder double spaced. Tapped at 3t, 4t, 6t, 9t
L3, L4	5 turns, 18 swg enamel on 1W carbon resistor
RFC1	40 turns, 24 swg enamel on ferrite rod or toroid. (800u)
RFC2	40 turns, 24 swg enamel on Tufnol or ceramic 0.5" dia former
RFC3	2.5mH, 500mA
RFC4	15 turns, 18 swg enamel bifilar on ferrite rod 3" x 3/8"
S1a, b, c	3x1 pole, 6 way
S1d	1 pole, 6 way ceramic ganged to S1a, b and c
S2	Single pole toggle
RLA	Single pole 12V
RLB	Double pole change-over 12 or 24V. Aerial change over relay
V1, V2	6KD6, EL509/EL519 or PL509/PL519 with bases
C1	100pF silver mica
C2	200pF silver mica
C3, 10	300pF silver mica
C4	600pF silver mica
C5-8	100pF compression trimmers
C9	82pF silver mica
C11	600pF compression trimmer
C12	0.01uF 1.2kV disc
C13, 14	180pF or 220pF mica 500V working
C15	1000pF 5kV silver mica ex TV door knob type
C16	4700pF 5kV disc
C17	340pF wide-spaced (3.5mm) log law variable or 100pF linear plus switched parallel silver mica (80 and 40m)
C18	3 gang 500pF airspaced broadcast variable
C19	1000pF 750V silver mica
R1, 2	10R 3W carbon
R3, 4	33R 0.5W
R5, 6	47R 1W carbon
R7	1K 0.25W
RV1, 2	10K wire wound potentiometer
D1, 2	1N4002
D3	Red l.e.d.

POWER SUPPLY

T1	600 to 900V secondary at 200mA plus LT
D1-8	1000 piv (1N4007) 1A
D9	1N4002
R1-8	220K 1W
R9-12	39K 5W
R13	1R 3W wire wound
R14	22R 1W wire wound
R15	4K7 3W wire wound
R16-18	2M2 1W
R19	1K 1W
R20	see text (4k7)
R21	see text (6K6) 3x2K2
C1	0.01uF disc 2.5kV
C2	0.01uF 2.5kV disc
C3-6	200 to 400uF 400V electrolytics
C7	10nF disc 50V
C8	500uF 35V electrolytic
S1	Double pole ON/OFF
S2	Double pole change over

Fuse holder, Fan, Meter 50uA to 1mA
Plugs and sockets as required

SOME SUGGESTED COMPONENT SUPPLIERS

Sendz Components, Shoeburyness, Essex (0702 332992) for door knob capacitors, electrolytics, airspaced variables and high voltage capacitors.
SITEK, Leighterton, Tetbury, Glos (0666 89 307) for wirewound pots, electrolytics and high voltage door knob caps.
PM Components Ltd, Gravesend, Kent (0474 333762) for valves, bases and anode caps.

be tuneable; however, the introduction of another tuning control was considered undesirable. The input circuitry must be screened from the amplifier output.

POWER SUPPLY

The power supply must be able to supply a heater voltage to suit the valves in use, a bias supply and an EHT voltage of between 800V and 1.4kV.

I used a Parmeko Admiralty type transformer having a 450-0-450V winding and a number of 6.3V and 5V heater windings. New transformers would be extremely expensive but many surplus types can be found at rallies. Full wave rectification of the HT winding provides approximately 1150V for the EHT supply. The two valve heaters are connected in series and fed from two 6.3V windings connected in series; this permits balanced heater wiring to be achieved. Three heater windings are connected in series to provide approximately 24V negative bias. This is ample for bias requirements and to operate the transmit/receive relay; it is also adequate for cutting off the valves on standby. The original ARRL design obtained the operating bias by placing a power zener diode in the cathode - such devices do not appear to be readily available in the UK with sufficient power rating. The circuit used is considered to be better as it allows for equalizing the standing current of both valves.

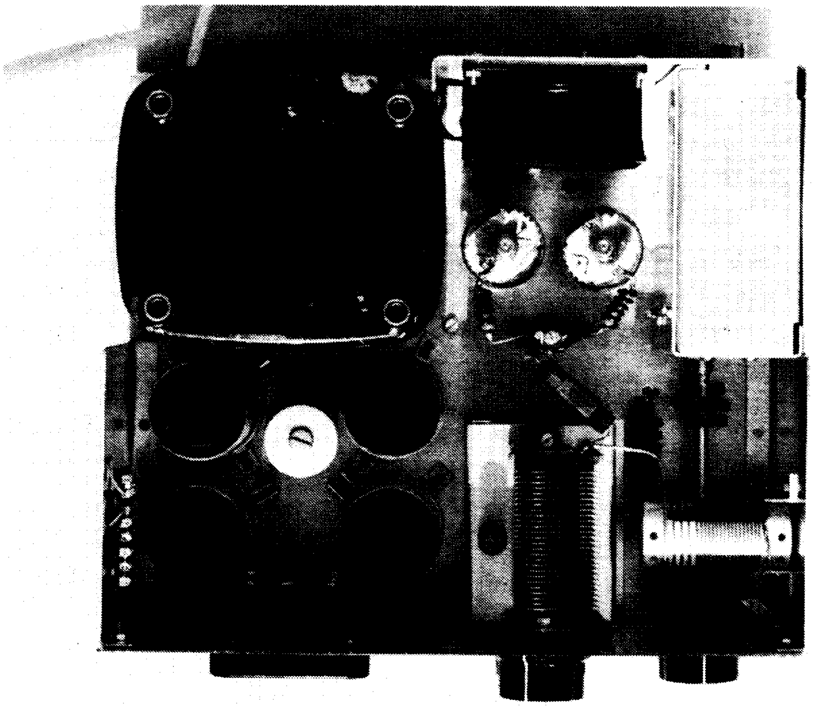
The EHT supply is rectified using a bank of silicon diodes, D1-8; they have equalizing resistors connected across them, R1-8, to ensure an equal voltage drop across each diode. The DC voltage produced is 1.4 times the AC voltage and is applied to a reservoir capacitor comprising 4×400μuF 450V electrolytics connected in series. Again, they have equalizing resistors connected across them which act as a bleeder system to the EHT supply. The value of these resistors is not at all critical but they must be of equal value and adequate wattage if they are not to overheat and break down. The capacitors must be adequately insulated as they are not at earth potential. They are mounted on a sheet of 1/4" thick perspex which was then mounted on threaded stand-off pillars.

Metering is accomplished by connecting a suitable microammeter or milliammeter as a voltmeter. R13 is a 1 ohm wire-wound resistor in the earth return of the EHT supply. By measuring the voltage drop across this resistor we have a measure of the total current being drawn. R21 is designed for a 50μA meter with a 1500R internal resistance - to provide 400mA FSD, it will have to be recalculated for a different meter. Similarly, R16-19 form a potential divider across the EHT and measurement of the voltage across R19 will give a measure of the EHT voltage. R16, 17 and 18 must not be replaced by a single resistor in case of a short circuit failure. Again, R20 may need to be recalculated for a different meter movement, or EHT voltage; it is calibrated for 2.5kV FSD indicating about 1/2 scale for 1.2kV.

A mains operated fan is connected across the primary of the mains transformer and serves to blow cold air over the two PA valves.

CONSTRUCTION

The amplifier is constructed on a chassis measuring 10"x12"; layout is not critical though the output tuned circuitry should not contain excessively long wires and should be screened from the input tuned circuitry. The actual size will be very dependent upon the components used and should not be finalised until most of the components have been collected. Locating the PSU and amplifier on the same chassis is preferable to having separate units when high voltages are employed. Components can be laid out on a sheet of paper prior to marking out the chassis to ensure adequate clearances between components. Front panel layout can be arranged to suit the individual constructor. All input, output and control sockets are located on the rear panel together with the bias pots.



Top view

OPERATION AND TUNING

The power supply should be tested first to ensure the correct voltages are available. Heater voltages of 6.3V or 12.6V for the 6KD6, 40V for the PL509 (80V for series heaters) and between 800 and 1400V for the EHT. *Do not forget to take the necessary safety precautions when operating on high voltage equipment, it is LETHAL.*

With power supplied to the amplifier it is first necessary to set the PA bias. Adjust both bias pots fully to the negative end of the pot. With a 50 ohm dummy load connected to the output, activate RLA. The T/R relay RLB should operate and the PA

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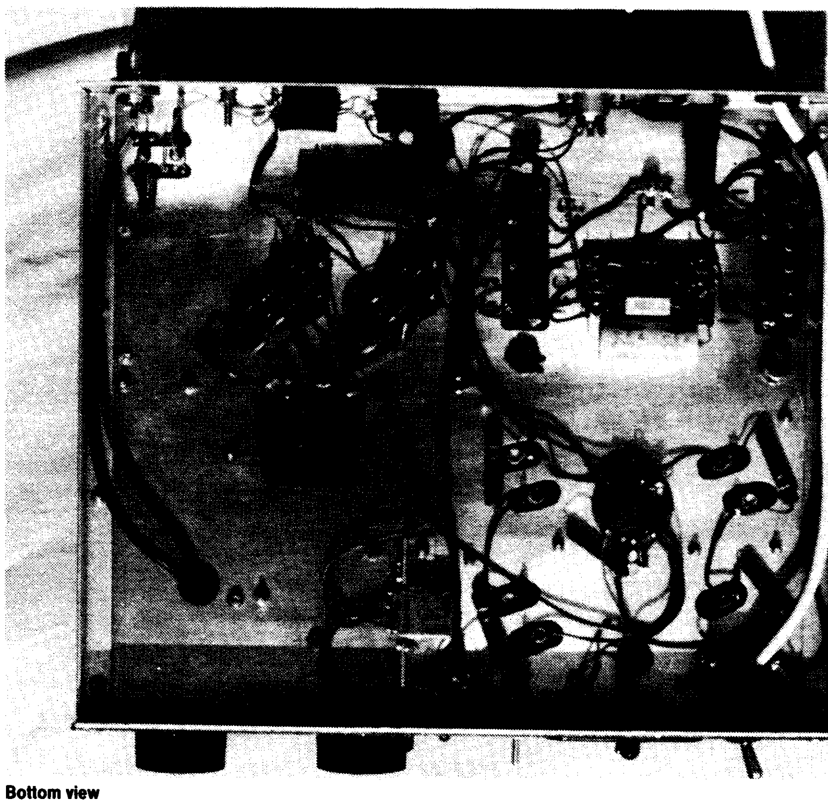
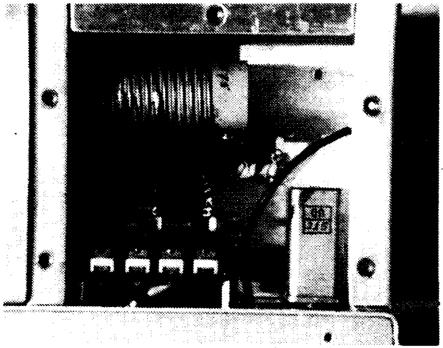


Bottom view

(continued from p37)

current should be very low. Place a voltmeter across R1 and adjust RV1 for 200mV (20mA) standing current. Repeat this operation with RV2 for 200mV across R2. The PA current should now indicate 40mA.

Rotate C17 and C18 from min to max capacitance: the PA current should remain stable. In general, grounded grid amplifiers are very tame and no instability should result. Select the appropriate band and apply drive to the linear from the exciter; the output may be tuned for a dip in cathode current in the conventional manner, or alternatively, by monitoring the output power, the amplifier may be tuned for maximum output. The input SWR should be monitored and the input network tuned to minimise the input SWR, or alternatively, may be tuned for maximum output. It will be necessary to adjust slightly some of the values of the input tuning capacitors for optimum results. If you do not mind tuning an external matching unit in the form of an ATU, the input circuitry can be omitted completely. The PA current will be approximately 250mA for 200W output on 80 metres and rises to a maximum of about 300mA on 10 metres due to the reduced efficiency.



Input tuned circuit

Rear view

CONCLUSION

The author's amplifier has proved very successful, providing up to 200 watts output and 10dB gain. Efficiency is high, but inevitably drops off on 10 metres where 120 watts output is about the maximum for 20 watts of drive. From 80 to 15 metres, 20 watts of drive can produce a full 200 watts RF output, however, the fixed tuned input circuit may reduce the drive level resulting in a nominal 160 watts RF output. Reports on the air have been very encouraging with no signs of splatter or distortion. The amplifier runs very cool with no signs of heating of the mains transformer or the PA valves, even when the amplifier is operated continuously key down for long periods of time.

It is possible to drive this amplifier up to over 300 watts output, however, this is not recommended in the interest of valve life and linearity. The amplifier is ideally suited to placing on the end of the many QRP transceivers currently being constructed.

The construction of a valve amplifier is no easier than a comparable power solid state amplifier; the valve design requires more effort to get working and requires retuning every time the frequency is changed. However, many amateurs are more familiar with valves and if, as in my case, the junk box contains some of those elusive parts, the valve design can still represent a viable project. □