

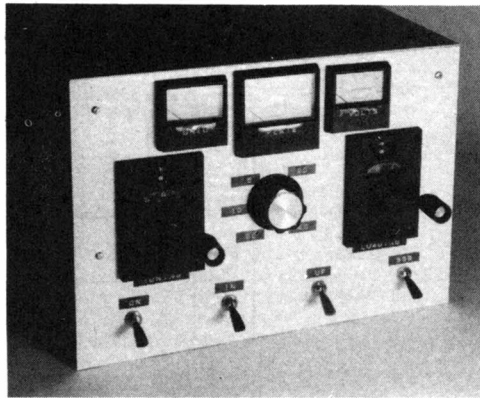
A TWO-KILOWATT AMPLIFIER USING THE EIMAC 8877 TRIODE

One of the easier projects for the amateur to undertake is the construction of an amplifier for use on the hf bands. Generally speaking, the mechanical aspects of the construction are more difficult to handle than the electrical ones. And, as with any construction project, acquiring the parts can be difficult. The two-kilowatt amplifier shown here is designed for dependable service at the maximum legal power input allowed in the United States. The component ratings are generous and the construction is heavy duty. Since power handling capability is typically determined by physical size, most of the components used here are large and accordingly, a split arrangement has been employed allowing the placement of the power supply on a separate chassis from the amplifier compartment.

Another feature sets this amplifier apart from most others described in the literature; the air is exhausted from the top of the tube socket instead of the conventional pressurized chassis air-flow system.

The Circuit

The triode, a 3CX1500/8877, is connected in a grounded-grid configuration which provides about



Front view of the 8877 amplifier. The non-sequential numbering of the band switch is discussed in the text. A switch is provided to allow the selection of proper bias for the mode in use at the time.

the most simple layout possible. The output tank circuit is a pi-network with vacuum-variable capacitors used for both input and output tuning. A 2.5-mH rf choke is connected between the output

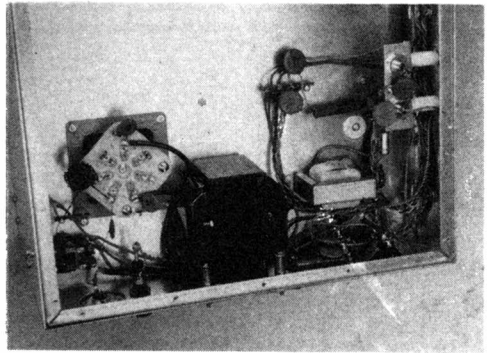
end of the tank and ground to prevent B plus from appearing at the antenna terminals should C1 develop a short.

A passive, untuned, capacitor-coupled circuit is used to apply rf-drive energy to the 8877 cathode. Since a moderate amount of bias is permitted, L1 is incorporated to provide isolation from rf to the bias-developing Zener diodes. The highest recommended bias voltage for use on ssb is 8.2, but for cw operation, where IMD is not important, 22 volts is developed which nearly places the tube at cutoff (zero no-signal plate current). A 10-k Ω resistor is included in series with the Zener-diode circuit to assure complete cutoff of the 8877 during receiving periods. It is switched out of the circuit during transmit periods by a set of contacts on K1.

Antenna transfer along with bias switching is accomplished with two relays. Sequencing can be an important factor since it is very undesirable to provide drive to the 8877, remove its bias, all before the output circuit relay has closed and stopped "bouncing." This is accomplished by the use of a vacuum relay shown as K2 in Fig. 1. K2 is many times faster in operation than K1 and accordingly, the antenna is placed on the amplifier output circuit well ahead of drive arriving at the cathode of the 8877. Voltage to operate both relays is developed by T2. Since the relays are connected in a fashion to allow straight-through operation of an exciter or transceiver to the antenna in the de-energized position, interruption of the voltage from T2 during transmit periods with it is undesirable; to have the amplifier "on line" and developing power, is all that need be done. S4 serves that function.

Metering of three operating conditions of the amplifier is accomplished with three meters instead of one or two. The purpose is first, to eliminate a switch for selection, and second, to provide continuous indication of the important parameters of the 8877. Of course, operator error is reduced since it is impossible to assume a meter is measuring one thing while a switch is selected for another. Both plate and grid current meters are direct-reading instruments — no shunts are needed. A string of resistors is used at R1 to multiply the scale of the 500- μ A meter to indicate zero through 5000 volts. R1 is constructed of 10 resistors, one-watt in size and one-megohm in value. The purpose is to keep the applied voltage across each resistor below 600. A 1000-ohm resistor is included at the meter end of R1 to keep the voltage low should the meter winding become an open circuit.

Another feature of this particular amplifier is the use of a motorized Powerstat for control of the high-voltage circuit. The ability to select the operating plate voltage from the front panel of the amplifier is a feature desired by the builder of the project and need not be duplicated. If voltage control is not used, the power transformer used in the high-voltage power supply should be selected to provide about 3000 volts. This is a suitable compromise for efficient cw and ssb operation at the maximum power input levels. In actual operation, the amplifier shown in the photographs is



Bottom view of the amplifier chassis. L1 is shown near the tube socket. It is wound on a T-50-2 Amidon toroid core. The Zener diodes are mounted on a plate and secured to the side chassis wall.

used with 3400 volts during ssb operation and 2500 volts for cw conditions.

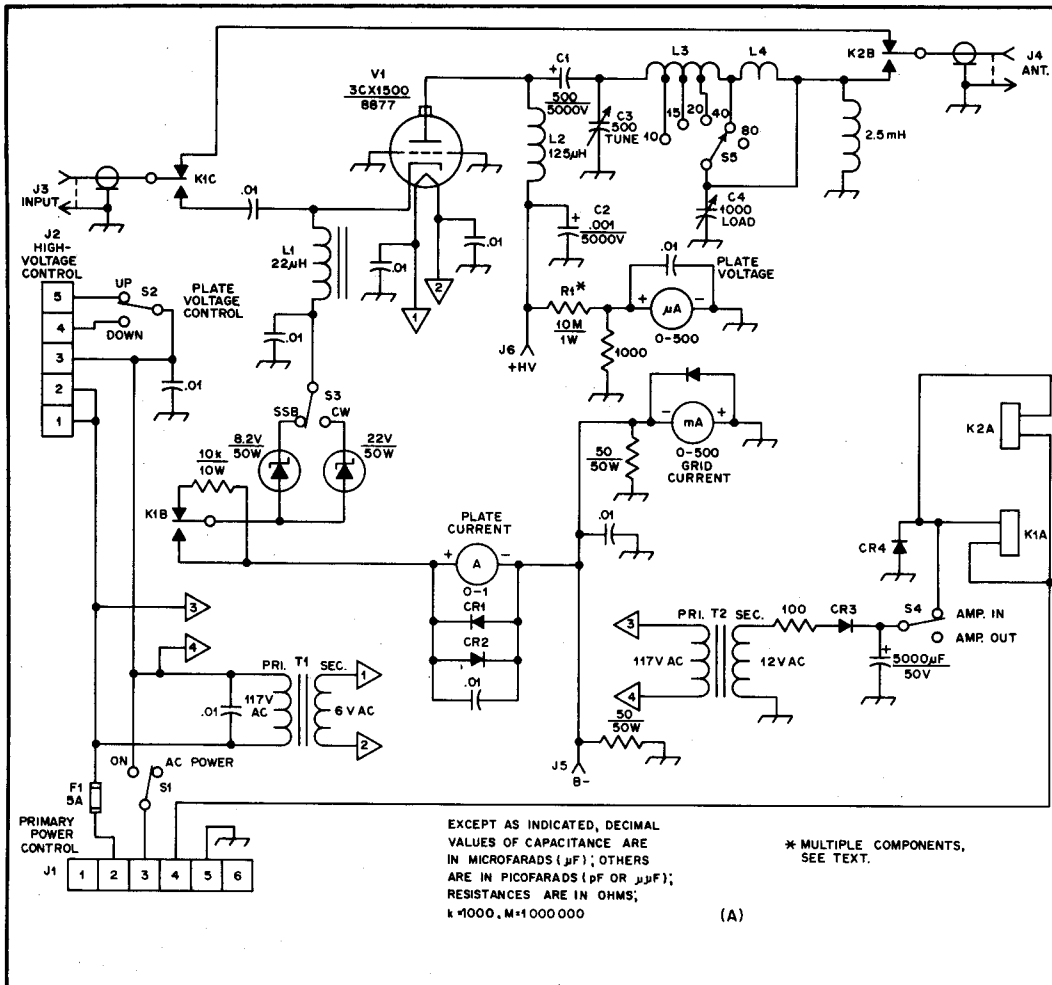
Several 50-ohm, 10-watt resistors have been placed at various points in the B-minus circuit, both in the amplifier-chassis compartment and on the power supply chassis. This prevents the B-minus lead from creeping above "almost ground" potential should a defect develop in the grid-current metering circuit. Also, included in the B-plus lead is a 10-ohm resistor which will help prevent component damage should a direct short take place in the amplifier compartment.

Mechanical Construction

The split-chassis configuration offers several advantages. First, it allows the amplifier compartment to be somewhat more compact because the power supply can be located elsewhere. This consumes less space on the operating desk. It also divides the weight into parts; the heavier section may be placed on the floor. The power supply may be equipped with wheels to give it mobility. The only disadvantage with having a two chassis system comes when portability is desired.

The power supply has been assembled on an aluminum plate which is 1/4-inch thick. Casters are provided because the plate transformer itself weighs about 80 pounds. The capacitor bank for filtering has also been mounted on the aluminum plate. A circuit board is used to interconnect the capacitors and is supported above the plate with ceramic pillar insulators. A screened covering is provided to keep unwanted objects from contacting the high-voltage system. The power supply relay (T3 primary connection) and the Powerstat have been assembled separately and may be interconnected to the power supply chassis plate via an interconnecting cable. Mounting both the plate transformer and the Powerstat on the same chassis would render it unmovable!

The power supply bleeder-resistor network



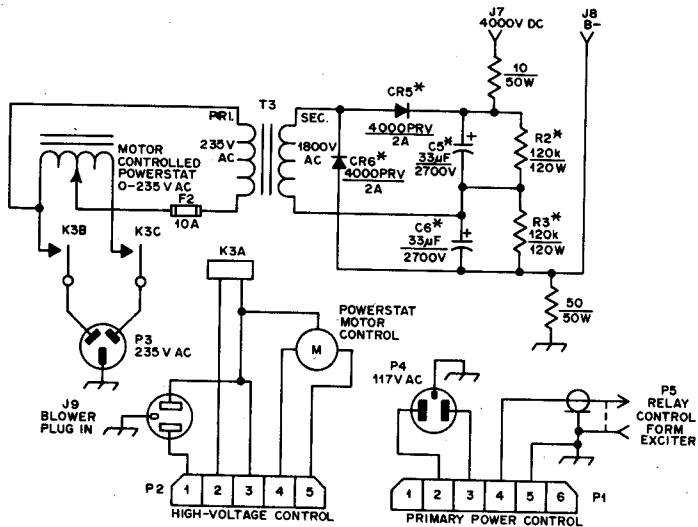
must be placed in a position to allow air to flow past it and rise through the top screen cover. R2 and R3 each consist of six resistors (12 total) rated at 20-k Ω and 20 watts each. A similar bank of 12 capacitors connected in series constitutes the filter network. Each filter capacitor in the circuit has one of the bleeder resistors connected directly across it in order to assure equal voltage division. Each capacitor is rated at 200 μF and 450 volts.

CR5 and CR6 consist of series diodes similar in hookup to the capacitor and resistor network described above. Each individual diode is rated at 1000 volts; the four series connected equal 4000 PRV. The current rating for each diode is two amperes.

No provisions have been made to operate this plate supply from a 117-volt ac source. Accordingly, if one wishes to have such capability, a suitable transformer must be substituted for T3 shown in Fig. 1. It should be pointed out, however, that the plate supply is the only portion to operate with a 234-volt line. The amplifier filament circuit

and voltage-source circuits for the relays along with the blower all operate from 117 V ac.

The amplifier portion of this system is constructed on an aluminum chassis which is 14 \times 17 \times 4 inches. The 14-inch dimension was chosen as the front-panel side to conserve space on the operating table. A bottom cover for the chassis is cut from a large section of aluminum perforated stock while the area above the chassis top is completely sealed and made airtight. The amplifier top cover is solid stock but has a four-inch flange (stovepipe material) mounted directly above the 8877 tube. Hot air is exhausted via this port using an external "blower" which has been set up to draw air rather than force it. The procedure is simple; just connect the four-inch hose coming from the pipe flange to the blower intake port. Place the blower exhaust outlet in a position so that it will not be restricted. The cold air is drawn in under the amplifier chassis, passes through the 8877 and socket, then out the stovepipe to the blower. The air from the blower is heated and



*MULTIPLE COMPONENTS, SEE TEXT.

(B)

Fig. 1 — Circuit diagram for the 8877 two-kilowatt amplifier. Component designations not listed below are for text reference only.

- C1 — 500-pF transmitting capacitor, 5000 volts (Centralab 858 series).
- C2 — .001- μ F transmitting capacitor, 5000 volts (Centralab 858 series).
- C3 — Vacuum variable, 500 pF maximum, 7500 volts.
- C4 — Vacuum variable, 1000 pF maximum, 5000 volts.
- C5, C6 — Six 200- μ F units (See text.).
- K1 — Dpdt, 5-A contacts. Coil voltage is 12 volts dc.
- K2 — Vacuum relay, spst. (Torr Electronics TFI or equiv.)
- K3 — Power relay, 10-A contacts, 117-V ac coil.

- L1 — 25 turns wound on an Amidon T-50-2 toroid core.
- L2 — 125 μ H, 2 A (Hammond Mfg.).
- L3 — Strap-wound inductor, 12 μ H total tapped at 2-1/2 turns for 10 meters, 3 turns for 15 meters, 5 turns for 20 meters and 14 turns for 40 meters. (E. F. Johnson 232-626).
- L4 — 5 turns of 1/4-inch copper tubing wound the same diameter as L3.
- S1, S3, S4 — spst, 3 A (Radio Shack).
- S2 — spdt, 3 A with spring return to center off position (Radio Shack).
- T1 — primary 117 V ac, secondary 5.0 V ac, 10 A. (Hammond Transformer).
- T2 — primary 117 V ac, secondary 12 V ac at 3 A.
- T3 — plate transformer, 234-volt ac primary, 1770-volt (Hammond Transformer 105677).

should not be directed at anything which might run normally warm (power supply components). In fact, the warm air may either be directed out of the radio shack in the event the heat is undesirable or the heat may be applied to one's feet in the winter season if the system is being used in an unheated basement atmosphere. Of course, one of the key features of a solid shield enclosure for the rf compartment is the reduction of unwanted radiation of fundamental or spurious energy which could cause TVI.

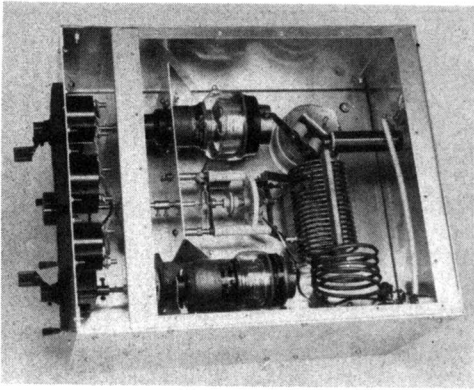
Care must be given to the mechanical installation of the high-voltage connectors and the cable used to transport 3600 volts of dc from the power supply to the anode of the 8877. Millen high-voltage connectors were used throughout. One problem developed during the testing phase of this project. A steel screw and nut were used to mount one of the connectors and apparently the Bakelite material cracked during installation. A discharge path developed across the crack creating loud noises and popping fuses. Nylon or Teflon hard-

ware is recommended for mounting the Millen connectors if voltages above 3000 are anticipated.

Operation

Since this project is one which should not be undertaken by an inexperienced builder, some of the basic steps of pretest will not be discussed in detail here. Suffice it to say that ordinary primary voltage checks and switching should be confirmed as being in correct working order before placing primary power to the high-voltage supply. The 3000-volt circuit *must* be treated with respect — it can seriously injure or even kill a person coming in contact with it! Operation of the motor-controlled Powerstat can be determined by operating the system on the 117-volt primary, leaving the plug to the 234-volt line disconnected.

A word of caution: *The air flow system must always be used when any power is applied to the 8877 — even filament.* And if drive power should



Top view of the 8877 amplifier. The three meters are separated from the rf compartment with an aluminum shield.

never reach the 8877 *unless* that tube has plate voltage applied. Of course, if one applies plate voltage and drive, he should be prepared to dissipate the power output from the amplifier into a dummy load of suitable rating.

One particular disadvantage of having the amplifier completely enclosed in a solid shield is the inability of the operator to visually spot any arc or component failure. During the initial testing of this amplifier, occasionally an arc would occur. While the arc was audible, the operator had to inspect the inner compartment very carefully to determine the cause of the malady. In fact, the arc had to be "encouraged" to a point where damage was easily identified!

Actual operation of the amplifier is quite simple. A feature which simplifies tuneup is the use of turn-counting dials for both the plate tuning and plate loading. Once the proper tuning has been established, one can log the numbers and return to them anytime. It is quite easy to touch up the dial settings for proper operating conditions once the approximate settings have been determined.

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the grid current shows 40 mA, and maximum output power occurs in conjunction with a "dip" in plate current and a "peak" in grid current all at the same time as the plate tuning control is adjusted. A condition of high grid current is usually a result of insufficient loading or too much drive power. If a low grid current condition exists and loading control decrease doesn't correct it, more drive power is indicated.

Tuneup for single sideband at the two-kilowatt level can be done only during dummy load conditions because it requires key-down conditions in excess of the legal-limit power restrictions. There is no way to tune this amplifier into an antenna at reduced power input and then drive it up to the two-kilowatt rated input point. The procedure for adjustment is identical to the one described above for cw operation. The one exception is plate-power input as indicated by the meters should be two kilowatts. Then, when the proper settings have been determined, the ssb drive signal is adjusted so that peak readings of plate current show about one half of that shown for key-down operation.

The lack of a tuned-input circuit solves several problems normally encountered when constructing an amplifier. The main advantage is that there need not be two band-switch decks with long leads (or even worse, two band switches!) nor space given to the inductors and capacitors. The driving impedance of the 8877 is very nearly 50 ohms and requires very little power to drive it to full power input. The tuned-circuit characteristics would reduce the drive requirement even further and should be considered by anyone wishing to use a 20-watt driver. For those amateurs using modern-day exciters in the 100-watt output class, some reduction in exciter gain control may be necessary. Exciters with more than about 150 watts of output power available should not be used without due consideration being given to an attenuator. The measured power required for this particular amplifier and tube shown was 50 watts to achieve a kilowatt on cw and about 70 watts for two kilowatts (this was in conjunction with a plate voltage change between modes) for ssb service. Slightly more drive power was required on 10 meters.

Problems

Some of the difficulties which come with making an amplifier of this category operate correctly are worthy of mention. First, as discussed earlier, some components which seemed adequate for 2500-volt systems failed when 3600 volts of dc was applied. The Millen connectors were one example. While the failure was not the fault of the component, care must be given to the maintenance of insulation integrity. RF voltages developed in the tank circuit of this unit are substantial. Several problems with the band-switch contacts were encountered. Even though the plate output inductor has unused turns shorted out by the band switch, the shorted section of the coil can (and

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most likely will) have extremely high voltages present on it. In order to solve an arcing problem one of the band-switch tap positions had to be swapped with another. The band-switch markings on the front panel are not sequential. A solution to the problem would no doubt come if one were to use a continuously shorting switch.

Another difficulty which plagued this constructor was the propensity for the amplifier to show large amounts of negative grid current on 80 meters along with erratic plate current and poor efficiency. The calculated value for L2 is 95 μH . The original choke used at this point measured 87 μH even though an inductance of 95 was called for.

After many hours of tank-circuit troubleshooting, it was decided to change the plate choke. The new one had an inductance of 125 μH and the 80-meter problems disappeared.

Collecting the Parts

Most of the component parts used in the project were purchased from surplus dealers or were donated by the manufacturer. Special thanks to James Millen Inc., Hammond Transformer Corporation, Simpson Electric, and Eimac for keeping the total cost of the parts to well within the allowable limits of any ARRL Lab project.

AN AMPLIFIER FOR QRP TRANSCEIVERS

The circuit of Fig. 1 shows a 15-watt output plug-in amplifier suitable for use with the HW-7 transceiver, or with any 2-watt class rig designed for hf-band work. The nucleus of the circuit is Motorola's new MRF-line transistor, the 449A. Unit cost is \$13 for the part, and it will deliver up to 30 watts of output to 30 MHz as a Class C amplifier. Operating voltage is 13.0 dc. Rf drive requirements for full output are under 1 watt. Another member of this transistor family is the MRF450A, which will provide 50 watts of output with 2 watts of drive. It costs \$16.50 according to a quote from an East Coast supplier.

Table I lists L and C values for 15 watts of output. The network is based on a loaded Q of 4. The X_L and X_C values given in Fig. 1 can be used to obtain inductance and capacitance values for frequencies other than 7, 14, and 21 MHz.

A 50-ohm, 3-dB attenuator pad is used at the amplifier input to assure less than 1 watt of drive without the need to modify the output stage or driver of the HW-7. The base shunting resistors of Q1 consume additional drive power while aiding amplifier stability. Another advantage of the attenuator is that it provides a resistive termination for the HW-7 across its operating range — 7 to 21 MHz. Without the attenuator the complex input impedance of Q1 would be reflected through T1, and the reactance seen by the HW-7 could be troublesome. A complex X_L and X_C condition exists at the input of a power transistor, and reactance amounts vary with operating frequency.

Circuit Notes

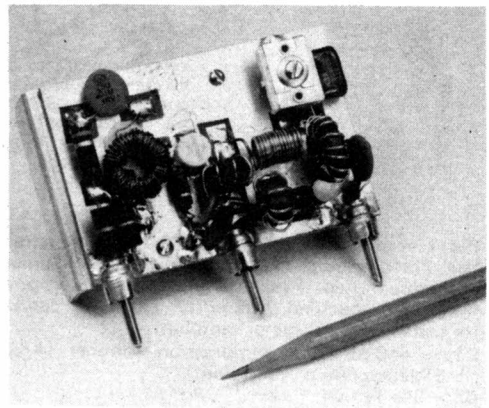
A conventional broadband toroidal transformer is used at T1. Equal performance was noted when comparing this transformer to transmission-line transformers. The latter consisted of two 4:1

transformers in cascade, effecting the desired 16:1 transformation ratio. A conventional transformer requires but one toroid core, and it is easy to build. For that reason it is specified here.

RFC1 serves as a low- Q collector choke, RFC2 is used as a decoupling choke to prevent rf energy from entering the HW-7 via the 13-volt line.

Performance

Motorola rates the MRF449A at 50-percent efficiency. Our lab findings bring that figure closer to 60 percent at 15-watts output. The output waveform from the circuit of Fig. 1 is exceptionally "sanitary." No distortion could be seen on the sine wave, as viewed on a 50-MHz scope, while delivering 15 watts into a 50-ohm dummy load.



Shown here is the assembled amplifier as originally described in *QST* for December, 1975.