Novice Special

Homebrew
2 Tube Transmitter

Mike Bray, K8DDB

How The Transmitter Works

Taken, with permission, from “How To Become A Radio Amateur”, copyright 1970 by the ARRL

Refer to the schematic of the transmitter on page 7 of the manual. The crystal-controlled oscillator, V1 generates a small amount of r.f. power which is used to drive the amplifier, V2. The amplified power is then fed to the antenna through an impedance-matching network commonly referred to as a *pi network.* The voltages necessary for operating the oscillator and amplifier tubes are furnished by the power-supply circuit shown on page 8. Both oscillator and amplifier are keyed simultaneously by opening and closing the connection between the cathodes of the tubes and the negative side of the high-voltage supply (chassis ground), thus interrupting the plate current flow of the oscillator and the plate and screen current flow of the amplifier. This system is called cathode keying.

The crystal-oscillator circuit is known as the *Pierce* circuit. The frequency of the signal generated by the oscillator is determined by the quartz crystal. An equivalent oscillator circuit is shown in Figure 1. The crystal is equivalent to a resonant circuit, LxCx tuned permanently to one fixed frequency. Therefore, a separate crystal is required for each frequency on which it is desired to transmit. Feedback to induce oscillation is obtained by virtue of the capacitive voltage divider CpCg across the tuned circuit. Cp is the capacitance that exists internally between the tube plate and cathode. Cg is the similar capacitance that exists between the grid and cathode. These capacitances are not adjustable, of course, and it would be only by fortunate circumstance that these fixed values would provide optimum feedback. Therefore, C1 is added externally to increase the capacitance between the grid and cathode. (A tube of different construction and characteristics might require that C1 be placed from plate to ground to increase the capacitance between plate and cathode. In this instance, however, experience has shown that optimum feedback requires more capacitance from grid to cathode.) C1 is a disc ceramic capacitor chosen to provide the amount of feedback necessary to minimize chirp.

Returning to the Novice Special schematic, C2 is used because an r.f. connection between the tube plate and the crystal is required, but a d.c. connection is not necessary. The oscillator would function just as well with C2 omitted, and the plate connected directly to the crystal, but this would place the crystal socket and holder directly in contact with the high voltage supply. This might constitute an unnecessary hazard to the operator, and might cause damage to the tube if the crystal holder were faulty.

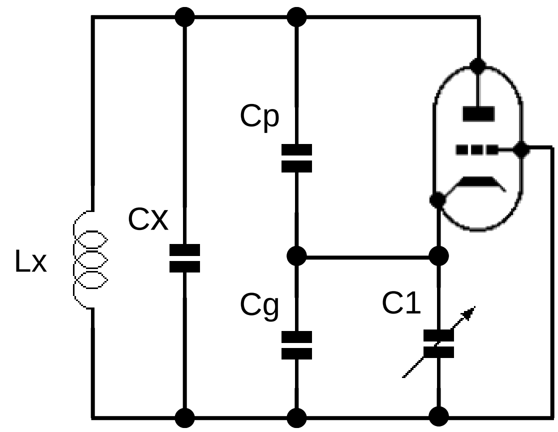


Figure 1 Equivalent oscillator circuit. See text.

The high-voltage supply is connected to the plate of the oscillator tube through R2 and RFC1. If the supply were connected directly to the plate of the tube, the connection would short circuit the r.f. output of the oscillator. R.f. choke RFC1 has a high impedance for r.f., and therefore may be connected across the oscillator without ill effect. The choke has negligible d.c. resistance, so its insertion in series with the d.c. supply causes no significant loss in plate voltage.

Although the output voltage from the power supply is appropriate for the amplifier tube, it is higher than necessary for satisfactory operation of the oscillator. For best frequency stability, and also because excessive oscillator plate voltage may cause the crystal temperature to rise sufficiently to fracture the quartz, it is desirable to use the minimum oscillator plate voltage that will give the r.f. power needed to drive the amplifier. Therefore, the voltage is reduced by inserting resistor R2 between the supply and the oscillator plate.

R1 is the oscillator grid leak that provides a means of biasing the grid of the oscillator tube. C3 and C4 are r.f. bypass capacitors that serve as a low-impedance path for r.f. current that would otherwise have to flow through the keying leads and power-supply wiring, introducing loss in r.f. power, and possibly undesired coupling to other parts of the circuit.

C5 is a *coupling* capacitor. It serves as a means of avoiding overloading of the oscillator by the input circuit of the amplifier. The smaller the capacitance is made, the less the amplifier will load the oscillator. However, if the capacitance is made too small, the amplifier will not receive sufficient driving voltage.

R3 is the amplifier-biasing grid leak. R5 is a series resistor to reduce the screen voltage and limit the screen current so the screen dissipation will not be exceeded. RFC2 is used in the amplifier circuit for the same purpose that RFC1 is used in the oscillator. C6, C7 and C8 are r.f. bypass capacitors. C9 is a voltage-blocking capacitor to remove the d.c. plate voltage from the components of the pi network, while allowing r.f. current to pass.

To operate efficiently, the impedance across the amplifier output must be of the order of a few thousand ohms. The antenna system to be suggested for use with the transmitter constitutes a low-impedance circuit (50 ohms or less.) The circuitry of the pi network transforms this low impedance to the higher value required for efficient operation of the amplifier tube. The network is a selective circuit and thus serves the additional purpose of reducing harmonics (signals at multiples of the crystal frequency that are always generated in a transmitter) that might cause interference to other radio services.

The principal components of the pi network are C10, L1, and C12. C10 is the *tuning capacitor*, the principal element in adjusting the output circuit to resonance. C12 is the *loading capacitor*. This is the principal element in adjusting the coupling to the antenna (adjusting the impedance transformation.)

RFC3 is used primarily as a safety device to short circuit the amplifier d.c. voltage to ground should C9 break down, thus avoiding the possibility of high voltage appearing on the antenna where it would be dangerous to anyone coming in contact with the antenna. Since the choke represents a high impedance, it can be placed across the low impedance of the antenna without affecting the operation so far as r.f. is concerned. C11 is a fixed capacitor added in parallel with C12 to provide the necessary loading capacitance for 80-meter operation.

The pi network output circuit is arranged to give the operator a choice of either 80-meter operation or 40-meter operation. The circuit as shown on page 7 is for 80-meter operation. If 40-meter operation is desired, the 80-meter crystal is replaced by a 40-meter crystal, and the arrowhead going to C11 is transferred to the tap on the coil. This one operation removes C11 from the circuit and shorts out part of L1 to reduce its inductance.

The voltage across R4 is used to actuate the meter M1, and the circuit is so arranged that the deflection of the meter will indicate the value of the combined amplifier plate and screen currents. Thus if 50 mA flows through R4, the voltage drop across R4 will be 100 x 0.050 = 5 volts, according to Ohm's law. This 5 volts will cause a current to flow through R9 and the meter. Since the value of R9 is 10,000 ohms, the current through the meter is5/10,000 = 0.0005 ampere, or 0.5 mA, the current flowing through R4 is 50 mA. Similarly, when the meter reads 0.1 mA, the current flowing through R4 is 10 mA. When the meter reads full scale (1 mA), the current through R4 is 100 mA. In other words, the cathode current (which is the sum of the amplifier plate, grid and screen currents, since all of these currents flow in the cathode circuit), is always 100 times the current indicated by the meter.

Modifications Made to the Transmitter Circuit by K8DDB

I decided to "Sailor Proof" my Novice Special by installing SW1, a dpdt switch which not only switches the antenna to the transmitter while transmitting and to the receiver while in the receive mode, but also prevents keying the transmitter while in "receive."

To allow the use of HC-6/U type crystals, I added another crystal socket in parallel with the FT-243 socket.

To allow for the future use of a VFO instead of a crystal for frequency control, I added an RCA jack to the front panel and a 470 ohm 1 watt resistor (R6) to the oscillator cathode circuit. To reduce oscillator grid capacitance while using a VFO, I made C1 a plug-in capacitor which is plugged into the VFO socket when using a crystal. C1 is a disc ceramic capacitor which is soldered to an RCA plug.

To prevent clicks, and to shape the cw note, a 0.47-uF capacitor, C13, and a 100-ohm resistor, R10, are series-connected from oscillator cathode to ground.

DANGER! HIGH VOLTAGE!

In the equipment described in this manual, the voltage between certain points may run as high as 600 volts. Since individuals sometimes are killed by coming in contact with ordinary 115-volt home lighting circuits, the operator must forever be aware of the potential danger attached to careless handling of amateur radio equipment—particularly transmitters and their power-supplies.

Make it your first rule to form the habit never to touch anything behind the front panel of a receiver, transmitter or power-supply without first turning off all power. Thousands of amateurs, young and old, work daily with equipment carrying voltages as high as 2000 or 3000 with complete safety. But the operator should never forget for a moment that harmless-appearing gear can and has been lethal in isolated instances when the operator becomes careless. **NEVER TOUCH ANYTHING BEHIND THE FRONT PANEL UNTIL YOU ARE CERTAIN THAT ALL POWER HAS BEEN TURNED OFF!**

Testing The Transmitter

To test the transmitter, plug the tubes into their sockets, and a key into the key jack. Plug a crystal into the appropriate crystal holder—an 80-meter crystal for 80-meter operation, or a 40-meter crystal for 40-meter operation. Select the desired band with the band selector switch. Connect a wattmeter and dummy load rated at 10 Watts, minimum, to the antenna connector on the back of the transmitter. (The transmitter should never be operated without some sort of load connected to the output—either a dummy load or an antenna.)

Turn the knob of C12 (LOAD) to its maximum-capacitance position (fully counter-clockwise.) Maximum capacitance will be indicated by an increase in friction as the capacitor approaches maximum. In turning to minimum capacitance, the friction will become less and, at minimum capacitance the adjusting shaft will become quite loose. Set C10 (TUNE) also to maximum capacitance, plates fully meshed (0 on the control dial.)

Connect the power cable between the power-supply and the transmitter, plug the power cord into a 115-volt outlet and turn the switch on the power-supply to its ON position. The red indicator lamp on the power-supply should light. Wait approximately 30 seconds for the tube heaters to warm up. Place the TRANSMIT-RECEIVE switch in the transmit position, then press the key. The meter should show a deflection to about half scale. While watching the meter, turn C10 (TUNE) very slowly counter-clockwise. At some point in the adjustment of C10, there should be a dip in the meter deflection. This is the *resonance* point. The wattmeter will indicate that a small amount of power is being produced. Open the key, and decrease the capacitance of C12 (LOAD) a bit (not more than one turn.) Close the key, and readjust TUNE for the dip point again. (This should require only a small adjustment.) You may notice now that while the dip in the meter still occurs, the dip is not as pronounced as it was on the first trial. Continue this procedure, reducing the capacitance of the LOAD capacitor and returning to resonance with the TUNE capacitor until the wattmeter reads the desired power (8 to 10 Watts is the maximum the transmitter will produce.) Depending on the transmitter output power, the meter should be reading between 50 and 75 mA (0.5 to 0.75 on the meter scale.) Repeat this *tuning* procedure several times until you are thoroughly familiar with it.

CAUTION—A second dip in meter reading may be obtained if C10 is turned near minimum capacitance. This adjustment must be avoided, since the transmitter will be tuned to twice the crystal frequency.

Key the transmitter and monitor the cw note on the station receiver. Select C1 experimentally for the best sounding note—one with minimum chirpiness (19pF for my transmitter.) This completes the tuneup.

When operating into an antenna whose impedance is anywhere between 30 and 70 ohms the foregoing tuning procedure should produce the same results as when the dummy load was connected to the antenna connector. If the transmitter will not load up, check the antenna to make sure it is cut for the correct operating frequency, or use an “antenna tuner” so the transmitter will “see” the proper impedance.

1970 ARRL Handbook Tube Data

6C4

Maximum Ratings:

Plate dissipation (Watts)	5.0
Plate voltage	350
Plate current (mA)	25
DC grid current (mA)	8.0
Frequency MHz full ratings	54
Amplification factor	18
Filament volts	6.3
Filament amps	0.15
Cin pF	1.8
Cgp pF	1.6
Cout pF	1.3

Typical Operation:

Class of service	C-T-O
Plate voltage	300
Grid voltage	-27
Plate current (mA)	25
DC grid current (mA)	7.0
Approx. driving power (Watts)	0.35
P-to-P load ohms	——
Approx. output power (Watts)	5.5

C-T-O = Class C amplifier-osc.

EIA Base 6BG Pin Out:

1 Plate
2 n/c
3 Heater
4 Heater
5 Plate
6 Grid
7 Cathode

5763

Maximum Ratings:

Plate dissipation (Watts)	13.5
Plate voltage	350
Screen dissipation (Watts)	2
Screen voltage	250
Frequency MHz full rating	50
Filament volts	6.3
Filament amps	0.75
Cin pF	9.5
Cgp pF	0.3
Cout pF	4.5

Typical Operation:

Class of service	C-T
Plate voltage	350
Screen voltage	250
Suppressor voltage	—
Grid voltage	-28.5
Plate current (mA)	48.5
Screen current (mA)	6.2
Grid current (mA)	1.6
Approx. driving power (Watts)	0.1
P-to-P load ohms	—
Approx. output power (Watts)	12

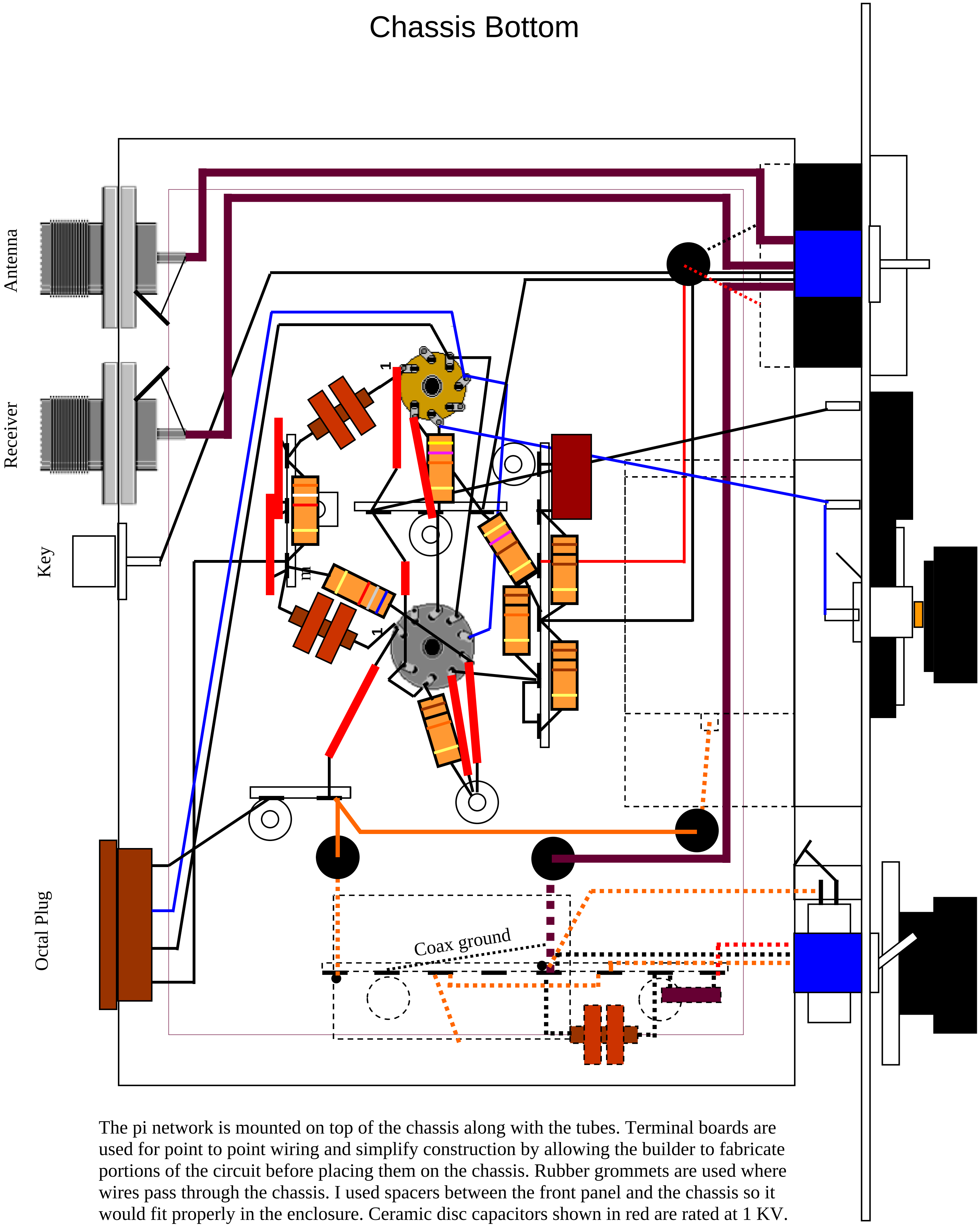
Class of service	C-P
Plate voltage	300
Screen voltage	250
Suppressor voltage	—
Grid voltage	-42.5
Plate current (mA)	50
Screen current (mA)	6
Grid current (mA)	2.4
Approx. driving power (Watts)	0.15
P-to-P load ohms	—
Approx. output power (Watts)	10

C-T = Class C Telegraph
C-P = Class C Plate-modulated telephone

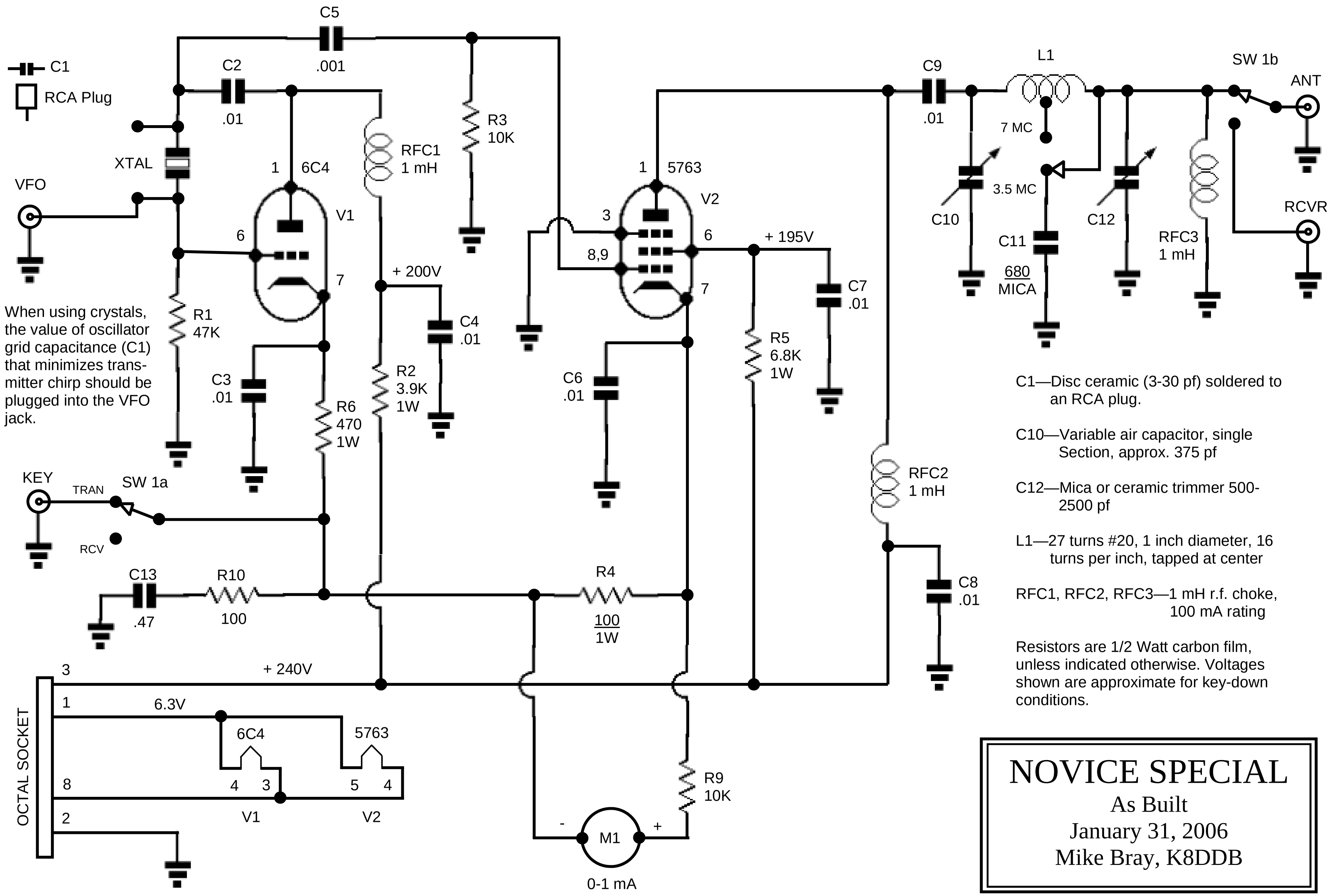
EIA Base 9K Pin Out:

1 Plate
2 n/c
3 Suppressor grid
4 Heater
5 Heater
6 Screen grid
7 Cathode
8 Grid
9 Grid

Chassis Bottom



The pi network is mounted on top of the chassis along with the tubes. Terminal boards are used for point to point wiring and simplify construction by allowing the builder to fabricate portions of the circuit before placing them on the chassis. Rubber grommets are used where wires pass through the chassis. I used spacers between the front panel and the chassis so it would fit properly in the enclosure. Ceramic disc capacitors shown in red are rated at 1 KV.



When using crystals, the value of oscillator grid capacitance (C1) that minimizes transmitter chirp should be plugged into the VFO jack.

C1—Disc ceramic (3-30 pf) soldered to an RCA plug.

C10—Variable air capacitor, single Section, approx. 375 pf

C12—Mica or ceramic trimmer 500-2500 pf

L1—27 turns #20, 1 inch diameter, 16 turns per inch, tapped at center

RFC1, RFC2, RFC3—1 mH r.f. choke, 100 mA rating

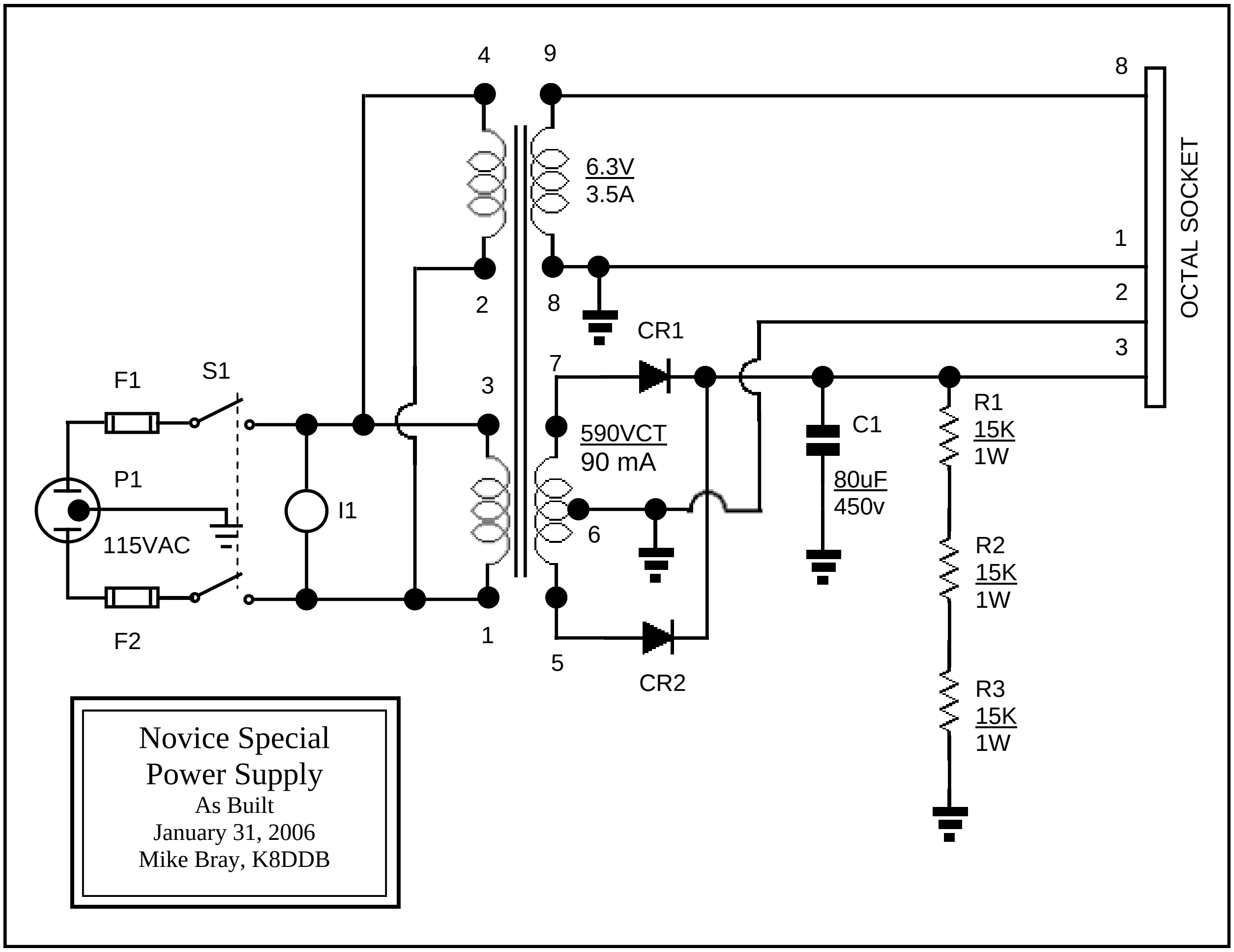
Resistors are 1/2 Watt carbon film, unless indicated otherwise. Voltages shown are approximate for key-down conditions.

NOVICE SPECIAL

As Built

January 31, 2006

Mike Bray, K8DDB



Power Supply Construction

The original schematic for the Novice Special calls for a 500 volt center-tapped, 40 ma; 6.3 volt center-tapped, 2 amp power transformer. The transformer shown in this schematic was salvaged from an old Navy power supply. The electrolytic capacitor called for in the original schematic was a 100uF, 450 volt; an 80uF, 450 volt electrolytic was used instead. The original Novice Special power supply was housed in the same enclosure as the transmitter. I elected to separate the two and used an eight conductor cable fitted with octal plugs to connect the power supply to the transmitter. I used a standard 3-prong grounded plug instead of the 2-prong fused plug called for in the original schematic.

<u>Other parts:</u>

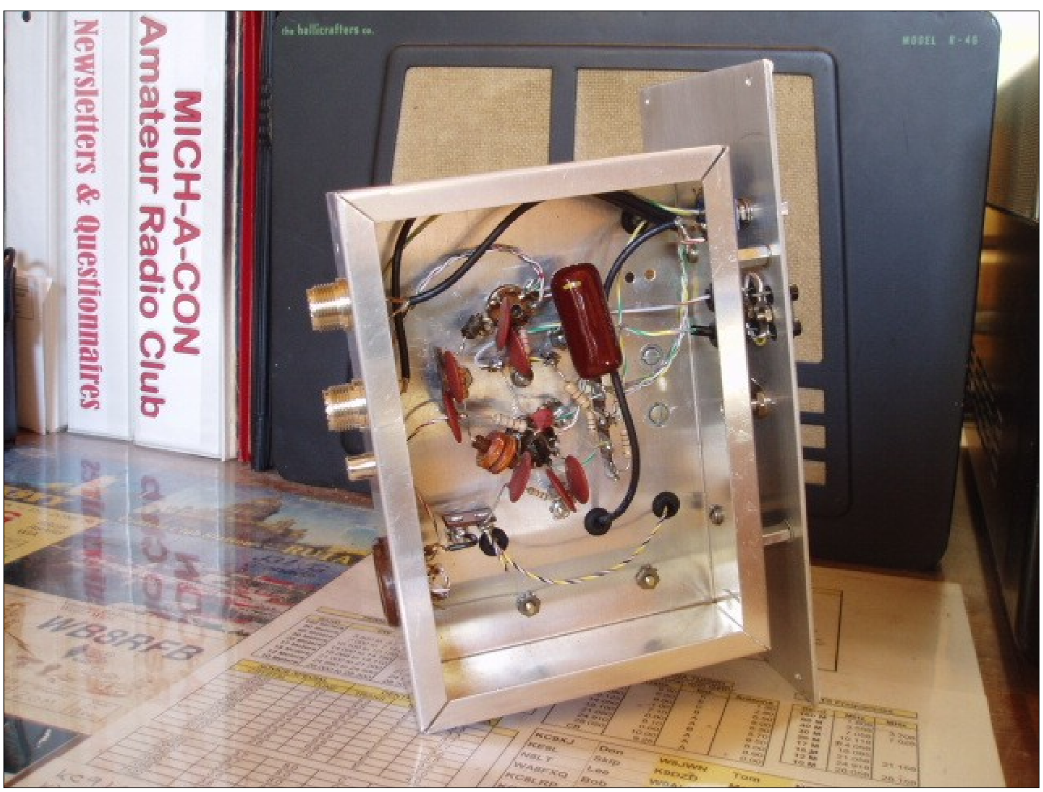
- CR1 and CR2—Silicon diode, 1000 p.i.v., 300 ma
- F1 and F2—1/2 ampere fuse (Littlefuse 3AG)
- I1—115 volt neon panel lamp
- Chassis—9x5x2 inch, Mouser #546-1444-14
- Chassis cover—9x5 inch, Mouser #546-1434-14

Power Supply Operation

The Novice Special power-supply circuit above has a full-wave rectifier using silicon-diode rectifiers. C1 is the *filter capacitor* that smoothes out the pulsations in the d.c. coming from the rectifiers to avoid a rough tone on the transmitted signal. R1, R2 and R3 constitute a *bleeder resistance*, the purpose of which is to discharge the filter capacitor after the power has been turned off. Otherwise, the capacitor might retain a dangerous charge for a long time after turning off the power, and present a hazard to the operator if he probes into the inside of the chassis.

The circuit is protected by two 1/2 amp fuses. I1 is a neon indicator lamp that lights up and serves as a warning when the power is turned on by S1. A 6.3-volt winding on T1 provides power for the tube heaters.

Novice Special Chassis—Top



Chassis Bottom

Novice Special Power Supply

Inside Power Supply Chassis

Parts Sources

Use GOOGLE to search the internet for best prices. Also try your local ham Swap ‘n Shop for good deals.

The following sources have been used by me in the past:

Ocean State Electronics: http://www.oselectronics.com/index.htm
- Power transformer
- Electrolytic capacitor
- Air variable capacitor
- Silver mica capacitor
- Disc ceramic capacitor—1 KV
- 1/2 Watt and 1 Watt carbon film resistors
- Vernier dial
- Wire, coax, multi-conductor cable

Mouser: http://www.mouser.com/
- Hammond Aluminum chassis

Dan’s Small Parts: http://www.danssmallpartsandkits.net/
- Mica trimmer capacitor 500-2500 pF with 1/8 inch shaft

Triode Electronics Online: http://store.yahoo.com/triodeel/index.html
- Octal plugs & strain relief covers
- Octal sockets
- Tube sockets

AF4K Crystals: http://www.af4k.com/crystals.htm
- FT-243 crystals
- Crystal sockets

Vacuumtubes.net: http://www.vacuumtubes.net/
- 6C4
- 5763

Notes

1. Articles describing the transmitter can be found in the 1970 Radio Amateur’s Handbook, page 181, and “How to Become a Radio Amateur”, copyright 1970 by The American Radio Relay League. Description of the transmitter and the circuit diagram was taken from chapter 4 of the latter document. The article is geared toward the beginner and contains a thorough description of both its electrical and mechanical construction.

2. Don’t be discouraged by the cost of the components, which will run much more than a solid state rig. The fun derived from building and operating this little transmitter is well worth the money! I’ve had so much fun with it that I built it twice, once in 1980 shortly after getting my Novice License and again in 2005, this time putting it in a much nicer enclosure, which I found at a Ham Swap ‘n Shop.