STATION QRP
TUBE SHORTWAVE TRANSMITTERS

25 WATT GU-50 AM TUBE SHORTWAVE TRANSMITTER

(PART 1 of 5)

IMPORTANT: *The published circuit diagrams of Station QRP are for educational purposes only. These are offered for the furtherance of the readers' knowledge regarding Radio Frequency design and principles. At all times during operation an assembled unit must be connected to a dummy load. In most countries law prohibits the unlicensed operation of transmitters when connected to an antenna or even to have such equipment present in a fully or partially installed state. All responsibilities for the ultimate use of the diagrams are borne solely by the builder and/or operator.*

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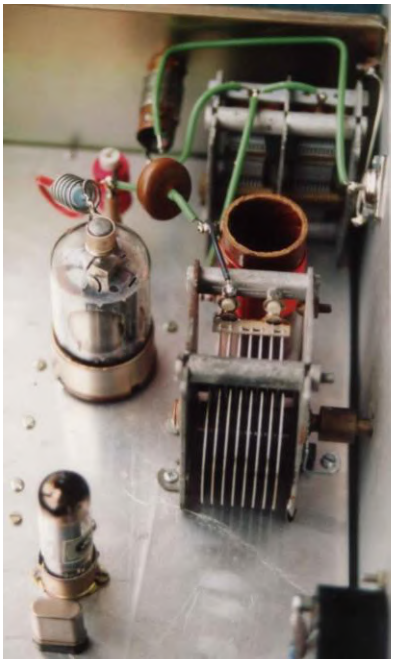
Introduction

On Sunday evening November 17th 1996 I switched on my first AM tube shortwave transmitter on the 43 meter band, 6.955 kHz. 28 years later my tube-journey came to an end with this, final, extraordinary solid design and build.



My first shortwave tube transmitter with CV2179 and 6146B

The Station QRP website (www.stationqrp.com) is especially for you to come into touch with tube technology.

To shed light onto this site that many may not know about but may find interesting, please put a link on your website/blog to spread the word. Thank you.

73's

Warning

Many of the techniques involve the use of mains voltage and high DC voltage so safety considerations are a high priority. Mains voltage and high DC voltage produce lethal electric currents and present a serious risk of personal injury. Untrained or unqualified people should not attempt to build this circuit unless they are confident in safety matters, you do not get a second chance! By visiting this website, you acknowledge all risks and take complete responsibility for your own actions. The Station QRP website cannot be held responsible for any accidents resulting in injury or death caused by any device constructed using the information provided within these pages. This website is strictly for informational purposes only.

The case

It is often the situation that a purchase on impulse at a radio rally can be the trigger for a major project; that is exactly the case here, literally. The attention was drawn to a 'lonely' second-hand case languishing under a stall. It was somewhat battle-scarred, having a number of holes in the top, including one of two inches in diameter through which a lead-out insulator was mounted. The rest of the case – the sides, bottom and detachable front and rear panels – were in a near-virgin state.

The case was 13 inches wide by 10 inches high and 6 inches deep with the one-piece steel top, bottom and sides in a dark grey powder finish paint and a light grey smooth paint finish for the steel front and back panels. Both panels were secured using four round-head screws and, together with the exact Imperial dimensions of the case, suggested the case to be a 1970s pre- metrication product. The base was slotted with 16 ventilation holes, a very useful feature. The heaters for the tubes would be from a separate transformer.

Initial design considerations

In 2007 I came upon the September copy of Megahertz, a French amateur radio publication, within which was a design for an 80 meter AM transmitter.

This used a pair of wartime RCA 815 tubes, one in the PA stage and the other in the push-pull modulator. The 815 is, essentially, a pair of 6L6s in one glass envelope with an International Octal base and two anode top-caps. It was the precursor of the RCA 829B which subsequently led to the introduction of Dutch/UK types QQV06-40A and QQV07-50A.

The French author appeared to have burrowed deep into his junk box as the choice of the rest of the tubes was, to say the least, 'interesting'. The Hartley VFO on 3.5 MHz was a 12BY7A running straight into the PA without a buffer. He did regulate the screen grid of the 12BY7A with two 75 V zener diodes in series, so some attempt was made to stabilise the VFO.

The modulator was, again, unconventional from a US perspective. The triode section of an ECL80 was used as an electret microphone preamplifier, with the pentode section as a driver into an inter-stage push-pull transformer supplying the grids of the 815. The anodes of the 815 were connected to a conventional modulation transformer.

The ECL80 has always been a 'clumsy' tube because the triode and the pentode share a common cathode and, as such, biasing of the two sections is more difficult than it would have been with separate cathodes. The French author employed a bias supply of –100 V for the RF PA stage grids, and used potential dividers to provide –18 V bias for 815 modulator output tube to run in class AB1, –6 V for the grid of the penultimate audio amplifier pentode and –3 V for the grid of the triode microphone amplifier, thus avoiding difficulties with self-biasing of the ECL80.

The first design

A crystal-controlled transmitter appeared to be the best design option because tight frequency control is demanded on two 'spot' frequencies, which can be achieved using switched or plug-in HC-6/U crystals. The best choice of tube for the crystal oscillator is a high gain, high slope, pentode and the 12BY7A fulfils this requirement very well. It has a 6.3 or 12.6 V heater option and an anode current capacity of up to 30 mA. The QRO TT21 80 m AM transmitter also uses this tube in the crystal oscillator. The manufactured 12BY7A is available cheaply on the surplus market and in 'Special Quality' CV4151 or Brimar 6870 numbering.

First thoughts were to use an 815 both in the RF PA and modulator with a Pye 277747 modulation transformer. This transformer had been obtained from a Pye F27AM unit and, on the audio side, was designed for a pair of 6V6s operating in Class AB1, to anode and screen modulate a QQV06-40A. The 6V6s are expected to produce approximately 12 W of audio, but experience over the years has shown that this Pye-made transformer is generously rated and will handle at least twice that output reliably. The drive to the 815 in the modulator could come from a cathode-coupled phase splitter using an ECC81 and possibly a small triode (EC90 or EC91) as a pre-amplifier.

Due regard has to be taken of the audio bandwidth requirements. The task of providing tailored audio response is made all the easier as a result of the proven design of the 'FAT-MAX' audio processor. The design is available as a kit. This processor incorporates a user-selectable dynamic (600 Ω) or electret microphone amplifier stage, limiter/compressor and very accurate user-defined bandwidth limiting circuitry based on a switched-capacitor principle. The audio filter consists of a single 8-pin IC which incorporates the oscillator to drive the switched capacitor cascade. The oscillator is programmed by a single capacitor. Thus, there is one capacitor to specify the cut- off point for the HF end of the audio and, for 2800 Hz, the value is 122 pF. Thus, anyone wishing to use the 'FAT- MAX' in a transmitter where there is a critical requirement to restrict audio frequencies above 2800 Hz, should replace the 68 pF timing capacitor in the original design with 120 pF. Bass cut is also employed to help with received intelligibility. A 12 VDC supply is required.

The French author employed a main HT supply of 350 V from a mains transformer with a 320 V secondary to achieve a quoted 30 W RF output which, to the author, seemed optimistic but this HT voltage could provide the desired 25 W. With up to 175 mA being needed for the RF section, and possibly 150 mA for the modulator output stage, there is a requirement for a CPT rated at 160 VA.

The physical size of the mains transformer was becoming a consideration, given that the aim was to fit the transmitter, modulator and power supply into the case referred to above. In addition, a filament transformer, smoothing choke, modulation transformer as well as bulky electrolytic smoothing capacitors were putting pressure on the available space. Due consideration must also be given to ventilation for the 815s as well as the other tubes.

Final transmitter design

Given that the transmitter design was to be based on an all-tube RF section, a 12BY7A is the best option for a crystal oscillator with a single front panel-mounted HC-6/U socket into which a crystal can be plugged. An RF PA tube is the Russian GU-50, this is a single-ended pentode having an anode dissipation of 40 W and is available at low cost from suppliers in the Ukraine via e-Bay. The tube base is specific but supplies are still available, again via e-Bay. The heater supply is 12.6 V at 0.765 A and, as such, this tube is preferred to the 815. With the GU-50 and the 12BY7A having 12.6 V heaters, a clamp tube with a 12.6 V heater would be ideal so that the transmitter can be run from a single heater supply. A QQV03-10 fulfils this requirement for loss-of-drive protection. The total heater current is just under 1.5 A with this tube complement, so a 12 VAC, 20 VA heater transformer would be satisfactory for the RF stages. An alternative clamp tube could be the PCL83 using just the pentode section; it has a 12.6 V, 0.3 A heater.

Considering the modulator, the modulation transformer has an 8 kΩ anode-to-anode impedance for push-pull audio, a high impedance secondary rated at 125 mA DC and an unused low impedance winding. It has been shown that high power audio from a solid-state amplifier could be coupled into this low impedance winding and so modulate a tube PA stage successfully via the usual secondary winding. For this purpose, it was decided to use a Maplin 'clone' MOSFET 100 W amplifier. The DC power supply rails for this amplifier are specified as ±42 V from a 0–32 V 0–32 V, 160 VA toroidal transformer. However, for a more modest output, a 0–25 V 0–25 V, 100 VA transformer is adequate. This provides ±36 VDC and smaller smoothing capacitors can be used (4700 µF, 50 VW). The heatsink for the MOSFETS and the amplifier printed circuit board can be mounted on the outside of the rear panel to save space inside. Similarly, the entire modulator can be on the rear panel with a die-cast box to contain the 'FAT-MAX' speech processor, the modulation level control and microphone connector. This arrangement also helps to keep RF out of the low-level audio paths.

The transmitter circuit - RF stages

The circuit diagram of the RF stages of the transmitter is shown in **Figure 1**. The crystal oscillator is the usual Colpitts design and the 5:1 capacitive divider consists of 27 pF in series with 120 pF. It is preferable to keep the current flowing through the crystal to a minimum to avoid heating (and drift) but, more importantly, to avoid damage to modern crystals which are made of relatively thin and small diameter quartz wafers. I recall seeing 8.2 pF and 150 pF as possible compromise values for the two components, and there is even a suggestion that the high slope of the 12BY7A is sufficient to maintain oscillation when the upper capacitor is omitted altogether and feedback is provided by the grid to cathode capacitance of the tube.

The 10 µH inductor in the anode circuit of the 12BY7A is wound on a 0.5 inch ceramic former having an adjustable ferrite slug with 27 turns of 26 SWG ECW close-wound. A 100 pF trimmer is used to resonate this inductance to 5.3 MHz with a mica 33 pF capacitor in parallel so that, when in tune, the trimmer capacitor is approximately half-open. Once this trimmer is set for resonance and best modulation, no further adjustment is required: hence there is no front panel 'drive tune' control.

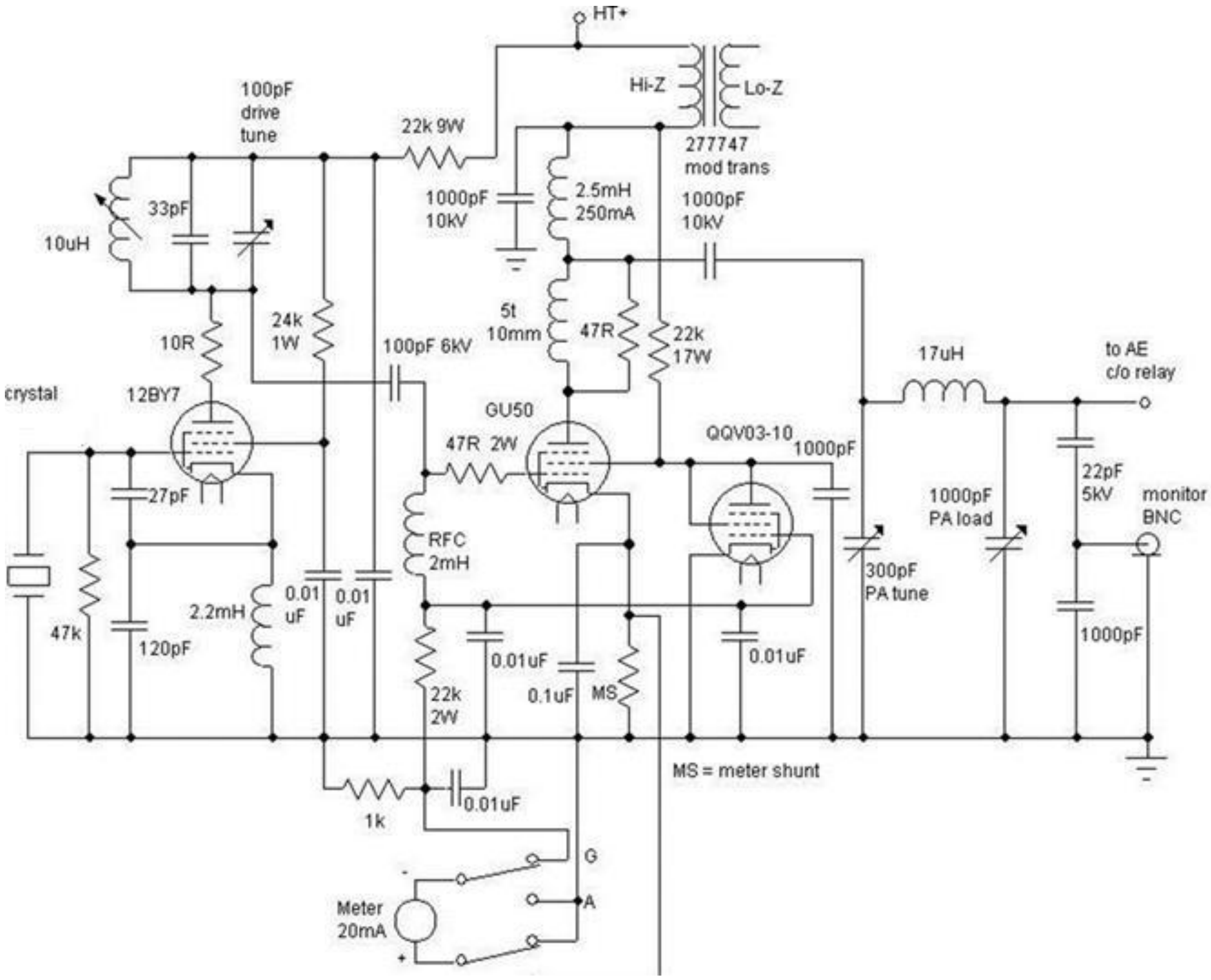


Figure 1. Circuit diagram of the RF section of the transmitter

The RF choke in the GU-50 anode circuit is a 2.5 mH, 250 mA component but values as low as 1.5 mH are satisfactory. The coupling capacitor to the π-network is a 1000 pF, 10 kV red-bodied, wire-ended, component as is the main HT decoupling capacitor on the RF choke.

With space at a premium, the PA tune capacitor is a mid- 60s compact Japanese 300 pF component which was to hand, but a 150 pF component would suffice. Similarly, the PA load capacitor is a 500+500 pF variable, with fairly closed-spaced vanes, as commonly used in 1950s tube portable receivers. The π-network coil consists of 22 turns of 18 SWG ECW close-wound on a 1.25 inch paxolin former. The π-network is designed to work into 50 Ω or 75 Ω loads only. An RF monitor point, for a ‘scope, or quality demodulator, is provided via a BNC socket.

Metering is provided by a single 20 mA FSD panel meter calibrated as such for grid current (typically 5 mA) and connected across a shunt (MS) in the cathode of the GU-50 to permit an FSD of 200 or 250 mA. Typical cathode current meter readings are 120–135 mA. A double pole changeover toggle switch allows selection of metering between grid current and cathode current.

End of part 1