STATION QRP

TUBE SHORTWAVE TRANSMITTERS

75 WATT GU-50 AM TUBE SHORTWAVE TRANSMITTER

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Introduction

This transmitter is to a design that has been approved in the UK for use on MW by the UK Regulator Ofcom. Also the HF versions have been approved by the German Regulator, Bundesnetzagentur, BNetzA and the Danish agency, IT-og Telestyrelsen (National IT and Telecom Agency – NITA) as to their specifications for frequency stability, suppression of harmonic output, audio quality and spectrum occupancy.

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 these circuits 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 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

The design work and consequent build involved

This story begins with a request for a powerful top-notch AM shortwave broadcast transmitter with parts used that will be available for years to come and had to comply with international standards so HFCC membership for which could be applied.

The power output was to be between 50 to 100 Watts and to cover the 49 and the 41 meter band. Operation was from the mains supply and comprehensive metering of supplies was to be provided.

Having seen the results of solid-state shortwave transmitters self-destructing with what have been called the “World’s Fastest Fuses” namely MOSFET’s, the rugged vacuum tube was specified in the RF section of the TX.

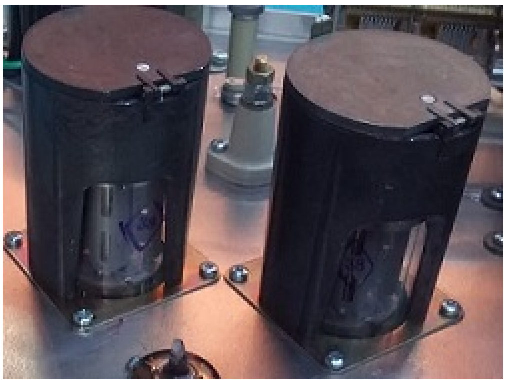
Where do you start?

Often these days the most critical component to acquire is a suitable mains transformer to supply the high voltage for the tubes. For this an ex-Telecoms one was available that had many windings but the most important one was the HV winding, it was 465V AC rated at 380mA. There was a low voltage 6.6VAC winding that could be used to power the heaters in the tubes but in this application it was deemed easier to just use the HV winding and control the switch on of the HV by just the mains input to it.

The heaters for the tubes would be from a separate transformer.

The next consideration is that of the tubes to be used. With the opening up of the Former Soviet Union there has been a gradual release of radio components from that Communist era. Most are in plentiful supply. One particularly fulfils our needs and that is a Soviet copy of the WW2 LS50 German tube; now known as the GU-50, in Cyrillic ГУ-50. The folklore HAM name is 'Poltinnik' meant 'half-ruble' becaue of its very reasonable price and availability. The GU-50 is a single-ended tube with no top-cap and has an anode dissipation of 45W.

The tube base is unusual and in USSR times there were at least three variations of the tubeholder to suit. All had a device whereby the tube could only be inserted one way, it was impossible to fit it 180° wrong. The bases used this time were of the high quality ex-USSR military type and were of die-cast metal and ceramic construction. A locating channel is provided to ensure the tube can only be inserted correctly.



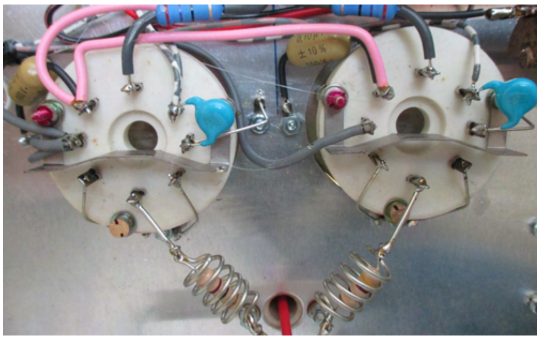
Frank Philipse has a good source via www.tubedata.info or use the following links:

GU-50 Russian:
http://frank.pocnet.net/sheets/018/g/GU50.pdf

GU-50 Polish:
http://frank.pocnet.net/sheets/175/g/GU50.pdf

These tubebases are hard to find now but the Chinese market a ceramic base equivalent, type FU-50, but there is no index pin so you have to be sure to fit the tube the correct way round!

Two GY-50 wired in parallel are required for the power output specified.



For the rest of the tubes in the transmitter the choice is determined by the heater voltage of the GU-50, which is 12V at 0.78A, as then a single 50VA transformer can be used to supply all the tubes. A driver tube is needed and the US 12BY7A (or its UK equivalent type 6870) fits the bill well as it has a 12V heater option at 0.64A (6.3V is also available).

Protection needs to be provided for protection of the GU-50's if the RF drive to them fails as only auto-bias is used – there is no separate bias supply. For this a clamp tube is used and again with 12V heaters at 0.64A the QQV03-10 / 6360 VHF transmitter tube was perfect having the ability to pass some 70mA anode current at 250V.

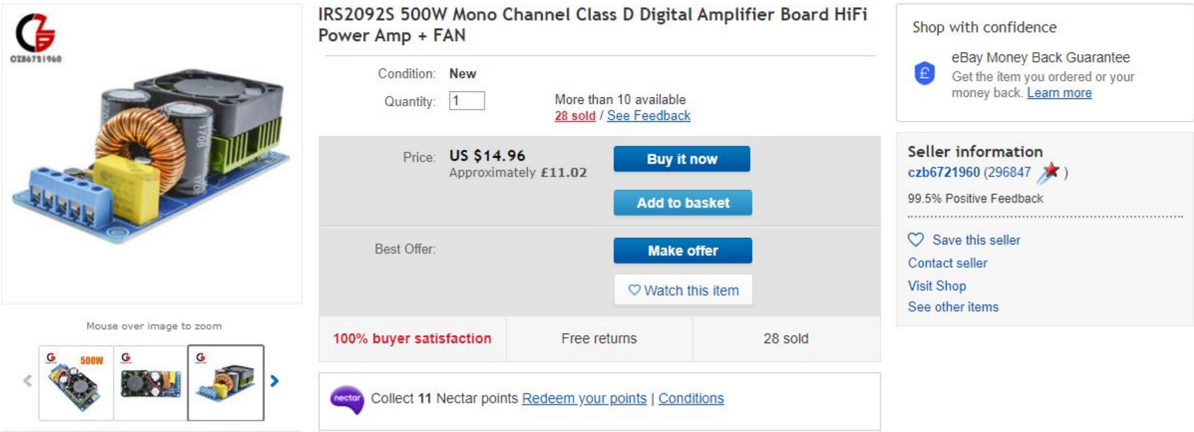
The chassis and case is the next consideration. With many items now in 19" racks, the idea of rack-mounted equipment is well accepted and over the years radio communications equipment became one of the first users.

There was range of Radio-Telephone equipment manufactured by the New Zealand company Tait and featured "bookcase" style units plugged into a rack mount chassis. With all the bookcase channel runners and rear connectors removed and some horizontal fixings sawn down; it was possible to fit a flat aluminium 1.6 mm thick base as a chassis making a width of 450mm and a depth of 300mm. The available rack mount height of 250mm was a little on the small side but luckily the GU-50 are not tall tubes.

Whilst there was room for all the RF components and modulator components including the modulation transformer on this chassis there was no room for the power supplies for the HV and modulator. So an alternative enclosure was sought. This was an aluminium box that had been previously used for an Antenna Tuning Unit. It was in good condition as it had not been installed outdoors.

Modulator

The modulator to be used was a Chinese IRS2092S module rated at 500W maximum for a supply of ±65V. It is possible to use a ±42V supply as not that much power is required for this transmitter. It is available on eBay;



The module is small enough to fit on the RF chassis next to the modulation transformer.

It requires 1.5V pk to pk audio signal to drive it so an audio preamplifier is needed. This is on a small pcb 80mm x 50mm and will run from the ±42V supplies.

For use on HF the frequency response of the audio needs to be altered to cut frequencies above 6kHz and below 200Hz. The preamplifier pcb incorporates circuitry to do this as well as the ability to mono up a stereo feed on L and R if required. The audio input impedance is 10K.

To monitor the input audio this was supplied with a small module to drive it. This module needs a 12V DC supply and with the 12V heater transformer available a DC power supply was built to give 12V DC at up to 400mA using a 7812 voltage regulator. Two more meters are on the chassis front panel and they are Grid Drive (20mA FSD) and PA Cathode current (400mA FSD).

Having now a two chassis/box arrangement it is possible to collect together all the components needed.

The build

The power supply chassis/box needs to accommodate the following components: the large HV transformer, a high voltage bridge rectifier using 8 x BY448 diodes, HV smoothing capacitors, fuses and a smoothing choke. For the modulator ±42V supplies, a 100VA 2 x 32V 160VA toroidal mains transformer,

2 x 10,000µF smoothing capacitors and fuses. There is a timer pcb to enable Full/Reduced power switching.

A HV voltmeter and one reading 0 – 1000V was provided on the front of the power supply.

Switching for AUX ON, HV ON and REDuced or FULL power is included and a filtered mains input socket are required as well as an output connector.

The placing on the chassis/front panel output tuning network of the Power Amplifier (PA) Tune and PA Load variable capacitors are the starting point. PAL is positioned first and then PAT is next door. It's best if they have their operating shafts level. There is enough room above these components to accommodate the 50 mm diameter PA tuning coil.

Also required were that all the controls and input output sockets on the front panel so below the PAL was placed the SO-239 output socket and to the left of it a BNC socket providing a fraction of the RF output for RF monitoring to an oscilloscope or other test equipment.

The audio input sockets in this case RCA Phonos are to the left and then a Modulation level control then a BNC input socket for a Frequency Synthesizer module, continuing over to the RHS are some LED indicators and then a Drive Tune control.

The meters are positioned next with the Grid current meter in the middle, the VU meter to the left with the Cathode current meter to the right.

The 12V heater transformer is on the chassis as it the modulation transformer with the modulator module next to it.

These large components when positioned, indicate what space is left for the GU-50s, the 12BY7A and the QQV03-10. There is a mounting area needed for the 2.5 mH 400mA RF Choke for the HV supply to the GU-50 and room for a ceramic feed-through connector for the anodes of the GU-50 underneath to be connected to the RFC above.

The 12BY7A can be used as a crystal oscillator (CO) so a crystal socket is needed next to it and a slide switch to select CO or synthesizer input. The distance from the 12BY7A to the GU-50s is 100mm.

Chassis metalwork

With all the positions of all the major components decided it is time to start the metalwork and cut the 34mm holes for the GU-50 tubeholders, 19mm holes for the B9A tubeholders for the 12BY7A and QQV03-10 and 49mm for the Chinese meters. Chassis punches are available to do this and make for a very neat finish.

Smaller holes, 3mm, 4mm etc are then drilled for the transformers, LEDs, tagstrips and smaller components.

For holes where cables will pass through the chassis use rubber/plastic grommets to protect the cable rubbing on the metal.

A right angle bracket is needed to mount the Drive Tune variable capacitor, it is attached to the chassis by two M3 bolts with shakeproof washers and nuts. There needs to be a 6.3mm hole in the bracket for the capacitor. Make a point of always using shakeproof washers on all the nut and bolt fixings for tubeholders and transformers and include solder tags too so that a ground chassis connection can be made.

Take care to mount the PA Tune and PA Load capacitors so that there is no drilling debris (swarf) allowed in between the plates or even worse any fine metal filings. These will cause a RF flashover on carrier or an even bigger one with modulation!

Cut a 16mm hole near to the 12BY7A and mount a 28mm slide switch using M3 nylon nuts and bolts as shown in the photograph. This is the switch that changes the 12BY7A from a crystal oscillator to a buffer stage if a synthesizer is used instead of crystals. This switch does need to be insulated from the chassis, hence the nylon fixings.

Mount the audio preamplifier board on four M3 pillars and the same for the IRS2092S

In the power supply unit can be seen the two 10,000µF 50V smoothing capacitors. Using 28mm cable tie bases with ties to secure them, these are stuck to the chassis. A link is made in 1.6mm tinned copper wire between the negative connection on one capacitor and the positive connection of the other, this link is then connected to the chassis by the same wire to a solder tag. All the ground connections in the power supply are to this link.

Some red terminal blocks can be seen, these are secured by 3.5mm self-tapping screws from underneath into the plastic holes provided.

Above these capacitors is a sub chassis on which are four 220µF 450V electrolytic capacitors. This chassis is secured by two M4 pillars that are 30mm long. The capacitors are again on cable tie bases and secured with cable ties.

The large toroidal mains transformer is fixed to the rear vertical panel of the power supply box by a long M6 bolt.

An International Octal tubeholder is used as the output voltage connector. Various supplies leave on this including 230VAC mains for the heater transformer, the ±42V DC for the modulator and pre-amplifier, the HV supply, a 12V DC feed to the power supply and chassis/earth returns.

There are two tagboards to be prepared for the power supply; one is for multiple connections for the mains wiring and is on top of the smoothing choke. The other is to connect the eight BY448 diodes in a bridge rectifier configuration for the HV supply and is mounted on stand-off insulators on the chassis base.

Wiring up the circuits

Start with the power supply case and connect up the mains wiring from the input filter to the switches etc and incorporate the supply fuses as indicated. Carry on with the low voltage wiring to the modulator and connect up the chassis mounted bridge rectifier and the 2 x 10,000µF capacitors. Now wire up the HV side from the main HV transformer via the fuse to the BY448 bridge rectifier and on to the smoothing capacitors. Note that both lots of the 2 x 220µF capacitors require 150kΩ 2W resistors across each capacitor to equalise up the DC voltages across the pair, as the capacitors are in series they make a combined value of 110µF at 900V rating.

Into the 49mm hole on the front of the power supply insert the Chinese 1mA meter, connect the negative terminal to chassis and the positive one to HV+ via a 4W 1 MΩ resistor, this is the voltmeter and 1mA indicated equals 1000V DC.

A Chinese timer board is also in circuit, this gives the option of running at reduced power for say, tune up of the transmitter and then a switch to full power can be made. If the REDuced/FULL switch is left on Full and the main HV switched on then the tx comes up first at reduced power and then after 0.75 seconds automatically switches to full power. The 12v DC needed to power the Chinese timer comes from the TX chassis as a 12V supply is on board there.

Install the rest of the wiring on the transmitter chassis starting with the mains to the heater transformer and then add in all the 12V ac heater wiring to the tubes and the heater returns to chassis.

That’s most of the wiring; now the components

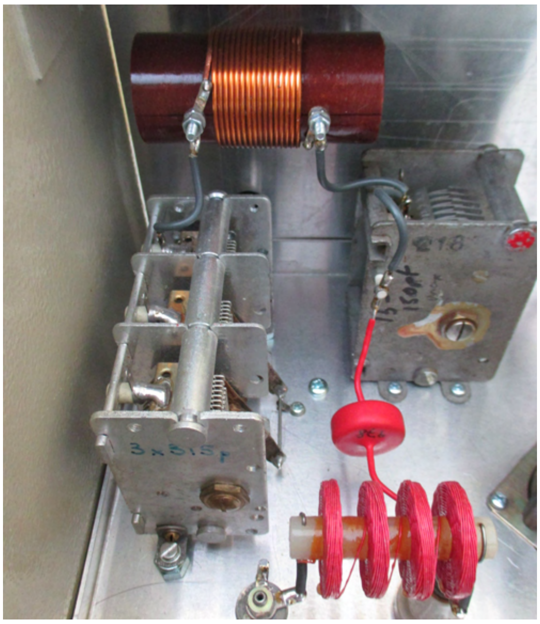
Now start to select all your components for the TX chassis. Wire up a stage at a time say the QQV03-10 clamp tube and then carry on to the output tubes and finally wire in the crystal oscillator/buffer amplifier. This is the hardest stage because of the switching.

Then proceed to the inter-wiring between the stages for the various voltages.

Transfer now to the top of the chassis and wire up the larger components including the PA Tune and PA Load capacitors, don’t forget to connect a wire from PA Load that goes down through the chassis via a grommet to the SO-239 socket underneath, a second wire goes upwards to the PA coil that is mounted on pillars above the variable capacitors.

Connect up the modulation transformer to the wires from below again via grommetted holes.

Put operating knobs on Drive Tune, PA Tune and PA Load capacitors.



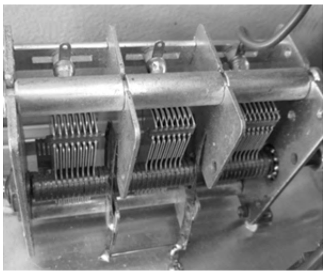
Testing the units by stages

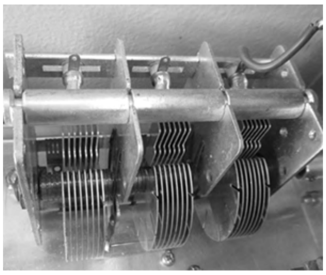
Only fuse the mains inlet to begin with 6.3A/250V 20mm type and leave all the rest out. Put all the tubes in their correct sockets. Connect up the tx to the power supply via the IO plug/socket. Switch on and see that the heaters light in all the tubes. Put the fuse in the 12V ac supply to the 12v power supply on the tx chassis. Switch back on again and check for a 12V DC feed.

Now connect a 50Ω test load via a power meter to the SO-239 output socket, close the PA Tune and PA Load capacitors to maximum capacity. Insert a crystal in the holder and select CO on the slide switch.

Insert a 630mA 20mm fuse into the HV ac fuseholder.

Keeping PA Load fully closed open PA Tune about halfway.

a)


b)


Note that the maximum capacitance is achieved when the plates are "meshed" together (a), that is, they are inter-laced. Minimum capacitance is achieved when the plates are "unmeshed" (b), that is, they are not inter-laced.

Now switch on the mains to the transmitter and after waiting 30 seconds or so for the heaters to warm up switch on the main HV. Expect to see about 600V DC on the voltmeter. Now immediately tune the Drive Tune capacitor and look for a peak of grid current on the grid meter tune it for a maximum value.

Straight after turn PA Tune capacitor and look for a dip in the cathode current, open up PA Load a little and the cathode current will rise, carry on loading up and re-dipping until the current is 200 mA; that is about 10 on the meter. Recheck the Drive Tune and see that it is about 6 to 8mA. Also look at the output power meter; you should have about 40 Watts output.

Now switch to full power, the HV meter should read about 725-775V, the PA current will read about 12 to 14 corresponding to 320mA or so. The grid meter should now read 8 to 10mA

That 8 to 10mA current drives a relay and its closure is indicated by the Mod Interlock LED on the front panel. The contacts on this small 48V DC relay when closed switch 12V DC to a large 12V 10A relay. The contacts for this are in series with the audio output from the 500W amplifier to the low impedance winding of the modulation transformer, so with zero or insufficient grid current on the GU-50s there is no chance of applying modulation. This is to prevent damage to the modulation transformer.

Modulation

The next area to test is that of the modulation, firstly the supply 4A(T) 20mm fuses from the toroidal transformer to bridge rectifier in the power supply unit need to be inserted in the holders.

Before powering ensure that the Mod Level control is fully counter-clockwise that is to minimum and that you have a tone source or programme material available to feed the input socket. You will need an oscilloscope on the BNC monitor socket so that the modulation envelope can be inspected

Re-power as before and check that all RF output is as before. Apply modulation and check the 'scope.

Problems ahead!

A 1000Hz sinusoidal tone was used and the waveform was checked. Whilst it was OK at low modulation levels there was severe distortion to it at higher levels and chunks of the sine wave was missing. On a nearby radio it sounded terrible! With the No. 2 input of the ‘scope directly across the output of the amplifier it was possible to see that the distortion was there.

On these power amplifiers there is a protection circuit to prevent damage in the event of a short circuit across the output, this was coming into play to protect the amplifier.

Just to be sure the No. 2 ‘scope probe was transferred to the input of the power amplifier and all was perfect there at any volume level. So it appears that these amplifiers do not like to power into the nasty reactive load of a modulation transformer, only a loudspeaker!

To be sure a regular amplifier was looked out, this was a 100W MOSFET type made in the UK by BK Electric type OMP-100. This has self-contained ±65V supply rails and the BUZ900/BUZ905 transistors are worked hard.

Note that a similar lower powered BUZ900/905 design is also a possibility; but with only ±42v DC supply there is not enough modulation power available to modulate to 100%. This was a shame as of course there were the ±42V DC rails ready to go.

The OMP-100 was jury-rigged into the circuit and connected up. As expected all was now perfect with the modulation to over the 100% level.

So to the third enclosure

The main RF chassis was worked upon and the IRS2092S was removed along with the ±42V power supply in the power unit. To hand was a ±15V DC power supply board; this was installed in the power unit and fed from the switched mains to the main HV transformer, it provides a supply for the audio preamplifier and the wires that were used for the ±42V DC are now used for the ±15V DC.

Also to that mains connection was run a female IEC lead to output mains from the power supply. This will be the source of mains to the new modulator enclosure in which the OMP-100 is mounted.

The new enclosure can be seen in the photographs. It was formerly a Euro-crate and designed for bookcase units. In their place was added a single 2mm thick aluminium sheet and the OMP-100 was mounted using M6 bolts of 30mm length and spacers comprising 15mm cut sections of copper water pipe. The 30mm gap gives plenty of room between the on-board air cooling fins on the amplifier and a 120mm Papst 240V ac fan as blown cooling is needed on this amplifier. To the other open side of the Euro-crate was added a sheet of aluminium grille so that there was airflow through the crate.

Connections to the rear included mains on a IEC flying male lead, a RCA-phono socket for audio input and a Neutrik LS socket connector.

Leads were added to the RF chassis in the form of a screened lead terminated in a phono plug and a Neutrik LS plug.

On the RF chassis the audio preamplifier supply circuitry was altered to cope with the now ±15V DC supplies from the previous ±42V DC as the 2K2 resistors were removed and replaced by 220Ω components.

Final power tests

Following the major changes the whole system was tried and proved to be OK on RF power output and modulation to both the test load and to a tuned dipole antenna for the 49mb.

With the test load back on different crystals were tried for 49 meter band (5900 - 6200 kHz) and the 41 meter band (7200 - 7450 kHz) and the settings of the Drive Tune, PA Tune and PA Load variable capacitors were recorded.

A frequency synthesizer and associated wideband amplifier were then connected into the front panel BNC socket. The slide switch adjacent to the 12BY7A was selected to “Buffer” from Crystal and operation over the two bands was checked on many frequencies.

This left just the VU meter driver board to be adjusted. The trimmer potentiometer on the board was set such that at 100% modulation the meter read “0 VU” on tone modulation.

Circuit diagrams RF Stages, MOD Stages, Mains Distribution & Power Supply

Click here to download PDF with complete circuit diagrams (file is about 2Mb)

Technical Data & Instruction sheet

Click here to download PDF with instruction sheet (file is about 0.5Mb)

Building in progress; The photographs

Click here to download PDF with photographs of building in progress (file is about 1.5Mb)

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