Yaesu Musen FL2000B *revamped*

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VK2QF has extended the life of his Yaesu FL 2000B Linear Amplifier with considerable ingenuity. However, constructors are warned that potentially lethal high voltages are employed in this amplifier and only experienced people should tackle this project

HAVING USED the old "FL2000B" amplifier on the ten metre band for 50Mhz dx liaison for some years in its original form until one day a heater failed and went accross to the plate inside valve 1 giving a healthy spark and "all lights out" around the place. Needless to say some sort of service was due, especially since the HT had been shorted! Replacements for the 572B's were not considered due to their prohibitive price and poor survival. So some alternatives were seriously considered.

An initial "lash up" trial of two wartime 813 Pentodes was a failure due to low gain and excess plate stray capacitance placing the plate circuit beyond resonance on the ten and fifteen metre bands, (more on this topic later).

Not perturbed by this failure I continued to concentrate on a solution that proved to be utterly successful in the end.

The parameters for the project were the following;

- Low IMD.
- Durability.
- A valve that would operate in any position.
- Low cost and recycling of otherwise discarded equipment.
- Minimal noise commensurate with adequate performance and heat removal,
- Parts must be on hand and or be made readily within a basic workshop,
- No physical changes to the appearance of the cabinet or front panel was allowed,
- High gain and equal performance across the range of bands that the amplifier was designed for, (in fact 10db of gain was realised meaning a Kenwood TS 570s as a driver will run a signal 3Db down on the legal limit Singlesideband signal),
- The basic design of cathode driven circuitry was to remain therefore any selected valve must either be a triode or more importantly be capable of triode (GROUNDED GRID CONNECTION), this was met by the chosen valve.

It is not intended to give a comprehensive description of the project as it is assumed that the builder will have sufficient experience to carry out the modifications to fruition. Furthermore this work only applies to the YAESU MUSEN FL2000B amplifier, just how this unit is different from later models eg, FL2100(B) is not known by the author, so should any builder decide

CATHODE TUNING CHART.

VSWR	INPUT INDUCTOR	INPUT C	OUTPUT C
1.4:1	Less one turn L202 = 15t > 80 mx	320 pf	150 pf
1.2:1	Less one turn L203 = 10t > 40 mx	400 pf	150 pf
1.2:1	Remove slug L204 = standard > 20 mx	250 pf	125 pf
1.2:1	Remove slug L205 = standard > 15 mx	110 pf	115 pf
1.2:1	Less one turn L206 = 4t > 10 mx	100 pf	140 pf

Note: 15 and 10 metre bands have variable capacitors to optimise loading. All fixed capacitors are SILVERED MICA types

Figure 1

TANK COIL CHART.

10 mx	4 turns from plate end
15 mx	8 turns from plate end
20 mx	12 turns from plate end
40 mx	20 turns from plate end
80 mx	29 turns from plate end

Figure 2

to modify one of these it remains their responsibility to adapt any differences in the basic design and circuit.

It is also necessary to highlight at the outset all inherent dangers when working with mains powered equipment let alone the HIGH TENSION voltages encountered in this amplifier as designed by YAESU MUSEN. This HIGH TENSION voltage is 2,400 volts which it needs to be made clear that contact with this is definitely lethal, so unless those who may attempt this work are experienced at working with these voltages it is recommended by the author that the work be done under the supervision of an experienced technician. ***It is worth noting at this juncture that the author never "powered up", "worked on" or "modified" the amplifier without its full shields and covers fitted, during each phase of development, also the mains supply wiring is controlled by an "ELCD" or earth leakage cicuit detector.***

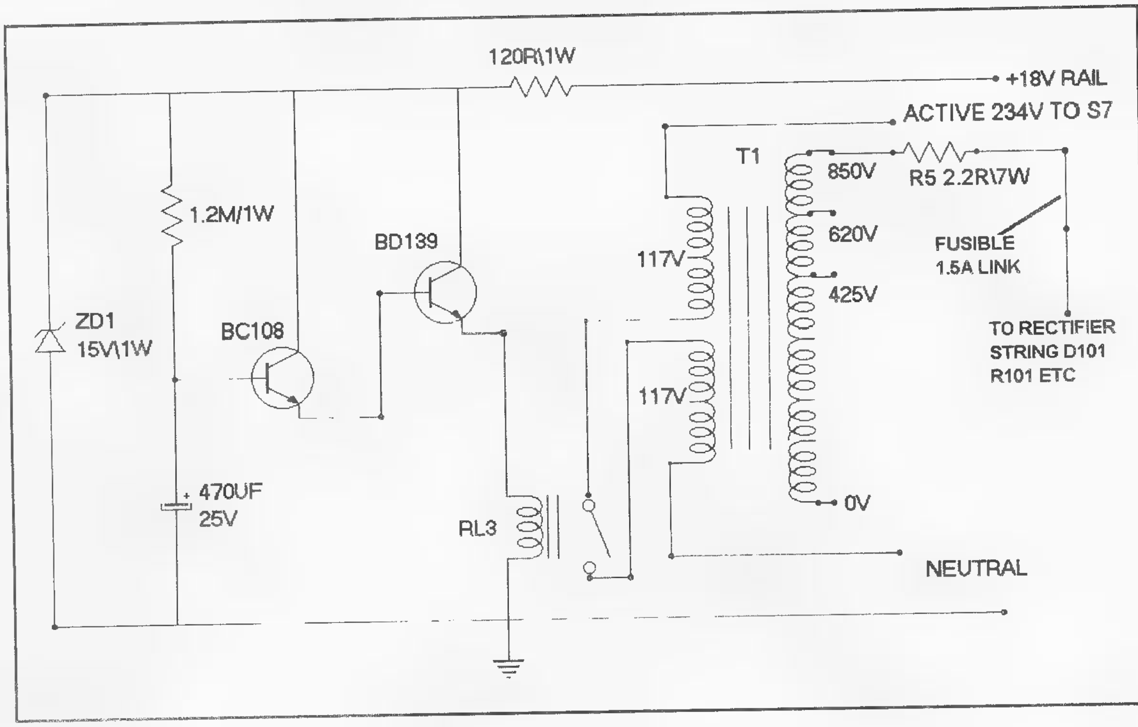

Figure 3. Timer Circuit

To modify the amplifier the constructor will need the following;

1) 8352 / 4CX1000K tetrode in known good electrical condition, these seem to sell for approximately $100 at hamfests. (It is possible that a similar result could be obtained with alternative valves, eg; 4CX1000A and 4CX1500B as they are electrically and mechanically similar).
2) Metal lathe.
3) 10 mm PTFE or perspex rod.
4) 90 mm stormwater pipe.
5) 65 mm alloy bar stock.
6) 8 x 220uF 400v or better miniature electrolytic capacitors
7) Air spaced capacitor 100pf to better than plate capacitor ratings of air gap.
8) 600pF to 1000pF 30Kv or better coupling capacitor.
9) 1 x 65ohm 20w resistor.
10) Sundry miscellaneous hardware, pcb, relays and signal components.
11) Miniature blower to deliver a minimum 40cfm of air at 13mm Hg water column.

The simplicity of the project is the relinquishment of the need for the SK820 BREECHLOCK socket. These sockets are unprocurable and cost more than the valve at retail prices. Grid grounding and mounting are accomplished in one operation with both the Screen and Control grids being clamped together in a simple alloy split ring made from bar stock.

The three rings that compose this clamp are as follows;

- Screen ring, width 3mm,
- G1\G2 ring which is a snug fit into the lands between these two sets of radial terminals,
- Base ring of 3mm which is under the G1 terminals.

These are cut in half and bolted every 120° over the valve ceramic body. A thread is cut into the top or screen alloy ring and bolts which have three simple flat mounting lugs which reach out beyond the perimeter of the 70mm diameter hole that must be made in the wall of the former Grid compartment vertical chassis. As the tolerance of the valves varies it is up to the individual constructor to ensure that sufficient clearance is provided for thermal expansion of the valve when in use, therefore as a guide the author used 0.5mm oversize for the alloy mounting rings based on the mean cylindrical measurement of the prototype 8352.

The 8352 is relocated to centralise the anode radiator in the plate compartment away from the original valve one mounting position.

The cathode compartment is largely unmodified except for;

L202 - L206 as per the chart Fig 1.

S2 is relocated away from the the terminals of the 8352.

All unused holes in the compartment are fully sealed against RF and air leaks to maximise system performance, (silicon sealant is ideal for sealing the air leaks with bolts and washers for the smaller unused chassis holes).

The L2 bifilar choke is connected by leads directly soldered to the Heater and Heater Cathode terminals of the 8352, do not omit C205 as performance will be degraded.

A new rear panel is folded to suit the blower outlet and this will be quite up to the individual circumstances to determine it's dimensions.

In the plate compartment some extensive development work must be done. To ensure adequate cooling for the 8352 and the fully mounted blower must be tested to ensure adequate back pressure drop across the plate radiator.

A simple chimney is fashioned from 90mm stormwater pipe, this product must

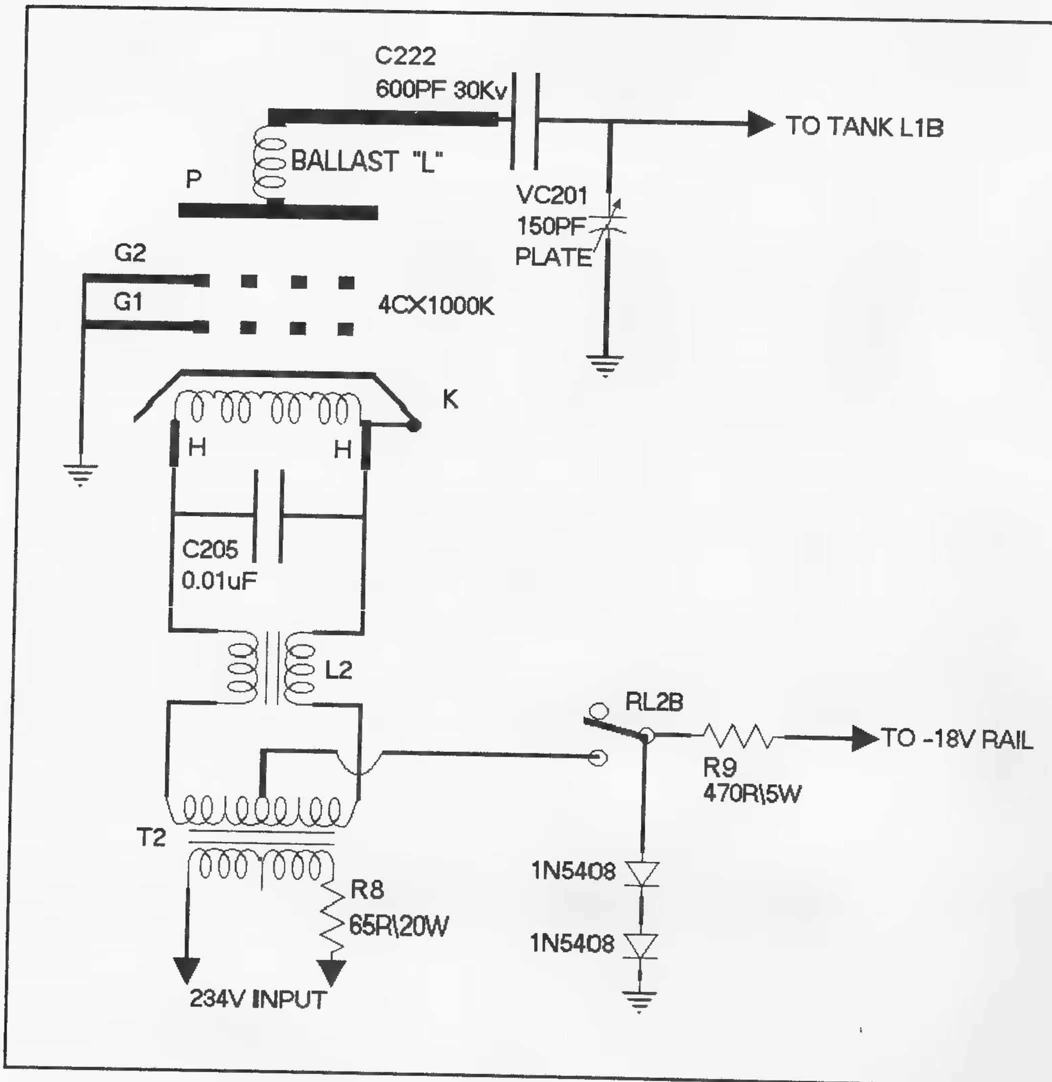

Figure 4. Main PA circuit

be given the "DIELECTRIC TEST" in the xyl's microwave oven before placing it in service. To test a sample piece of pipe place it in a microwave oven along with a suitable small dish of water to act as a dummy load, give the oven a series of short runs and test for any temperature rise in the sample. As a guide it is felt that the cream or white colour pipes give the best dielectric properties and in the authors case no heat could be detected at all with what was used as the chimney for 8352.

Once the 8352 is mounted and the chimney is fitted it is essential to assess the capacity of the blower to deliver sufficient air to cool the valve under all conditions. The miniature blower in use on the prototype is rated to deliver 100cfm into an unrestricted outlet. In practice it is delivering much less but critically it's pressure differential was measured at 13mm hg water column in the cathode compartment using a simple PVC tube sealed to the chassis. Although VARIAN specify 25cfm at 5mm water column it is safer to err on the side of oversupply.

The plate compartment is also modified ref fig 4.

L207 is repositioned and L208 / L209 are discarded. This is because the stray plate capacitance of the 8352 in this chassis situation causes the tank circuit to be beyond resonance on the upper HF bands of ten and fifteen metres. The solution to this is to place a 7 turn 20mm diameter (14 b+s wire guage) ballast inductor from plate to L207 (see fig 4 "Ballast L").

C222 is prone to failure in these amplifiers and should not be left in circuit as to do so would be dangerous, a serious replacement must be found and the author used a 600pf 30Kv coupling capacitor. A common value for these capacitors is 1000pf, this value is the original circuit design and either would be suitable provided the voltage rating is correct, around 10Kv upwards.

Other plate compartment mod's are. . .

The connecting shaft from S1 to S2 was replaced by a machined length of perspex as the original caused arcing (when the amplifier was driven) in the S1 universal coupling.

The tank coil is removed, cleaned with acetic acid (Vinegar) and re-tapped as per Fig 2.

All lines around the directional coupler are replaced with 6mm teflon coaxial cable, this will improve stability and circuit losses.

C224 usually fails in normal use and must be replaced by a 100 pf air spaced capacitor mounted in the bottom side of the plate compartment, this capacitor must be of equal or better voltage rating than that of the plate capacitor VC201. On the subject of VC201 it has a 50mm long earth strap which is a source of MF parasitics in these amplifiers so replace it with a piece of braid from the stator to the adjacent solder lug on the front panel.

On the topic of the standby condition of the amplifer it was considered important to have minimum heat dissipation around the shack. especially since this is a rather large valve in a small chassis. Unlike the original circuit the 8352 cathode is floating on receive. So the author hunted around for a design that filled the need here (ref 1). This ARRL design (a two valve passive grid 600w linear amplifier with floating cathode) was experimentally tried during run-up of the 8352 on the "bench". No problems have been encountered with this idea, measurement of the cathode voltage in standby shows 6.0v only, this is quite acceptable "self bias" and the unit does not emit any noise that will interfere with the imcoming receive signal.

The bias circuit for the amplifier has on transmit RL2B close to two 3amp (1N5408) diodes at the centre tap of the heater winding, this is biased by a 470 ohm resistor (ref fig 4 R9) from the minus 18 volt relay rail. It was found neccesary due to the high "Gm" ("Mutual transconductance") of the 8352 to "push" minus 2 volts onto the cathode for a standing current of 50 mA via the 470 ohm resistor, bearing in mind this will vary from valve to valve also. In transmit under drive this rises to plus three volts of operational dc bias. It is in this transmit condition that another important condition must be tested in the later stage, that of the stability of the whole amplifier when all tuning controls are rotated through their ranges on all bands. No instabilities were encountered at all on any band when the unit was at transmit (no drive) drawing it's 50 mA idle current.

It is next essential to assure a 3 minute heater run up delay timer which after switch on delays by a predetermined time constant of r/c as per Fig 3 (this circuit is powered by rectifying via D1 and filtering C1 the 13 volt winding in the original heater transformer T2). This timer controls RL3 which closes the circuit of T1 to the AC supply thus enabling HIGH TENSION voltages.

With a cathode driven amplifier it is imperative that HIGH TENSION voltage is present whenever their is a possibility of drive being applied. To avoid destroying the 8352 a HIGH TENSION sensing circuit Fig 5, comprising Q1 / Q2 and RL2C which isolates the PTT line in the absence of HIGH TENSION voltage. This circuit is turned on by a 10M ohm sensing resistor from the junction of R110 and R109 in the rectifier string. Relay 2 must be a high speed type to ensure good semi-break in characteristics.

Also in Fig 5 is the DC control circuitry for the blower motor. Builders will have to adapt their own circumstances to suit in this area. The prototype blower was highly modified. Initially it's AC motor was removed and a substitute 3000 rpm high torque DC unit with bronze bearings was modified to take ball races, (most costly minor parts in the whole project!). This motor is totally shielded against noise leakage for maximum receiver performance. Power for the DC motor is via an external "shack" supply of 13.8v. It is recommended that the same supply is used to power the exciter "rig" so that as as safety measure should it fail (the 13.8v supply) the amplifier cannot be keyed. At power on, rectification of the 13v winding on T2, triggers Q5 thereby ensuring air is delivered whenever heater volts is applied. A transmit blower boost (to air supply) is via a pair of contacts in the cathode relay (RL2A), this has the benefit of low audible noise on receive and maximum air delivery during transmission periods. Blower speed on standby is controlled by RV1.

This circuit also encompasses one more essential feature for protection of the 8352 and this is an after cool rundown timer Q3 / Q4. When the amplifier is turned off after heavy work it is possible to leave the 8352

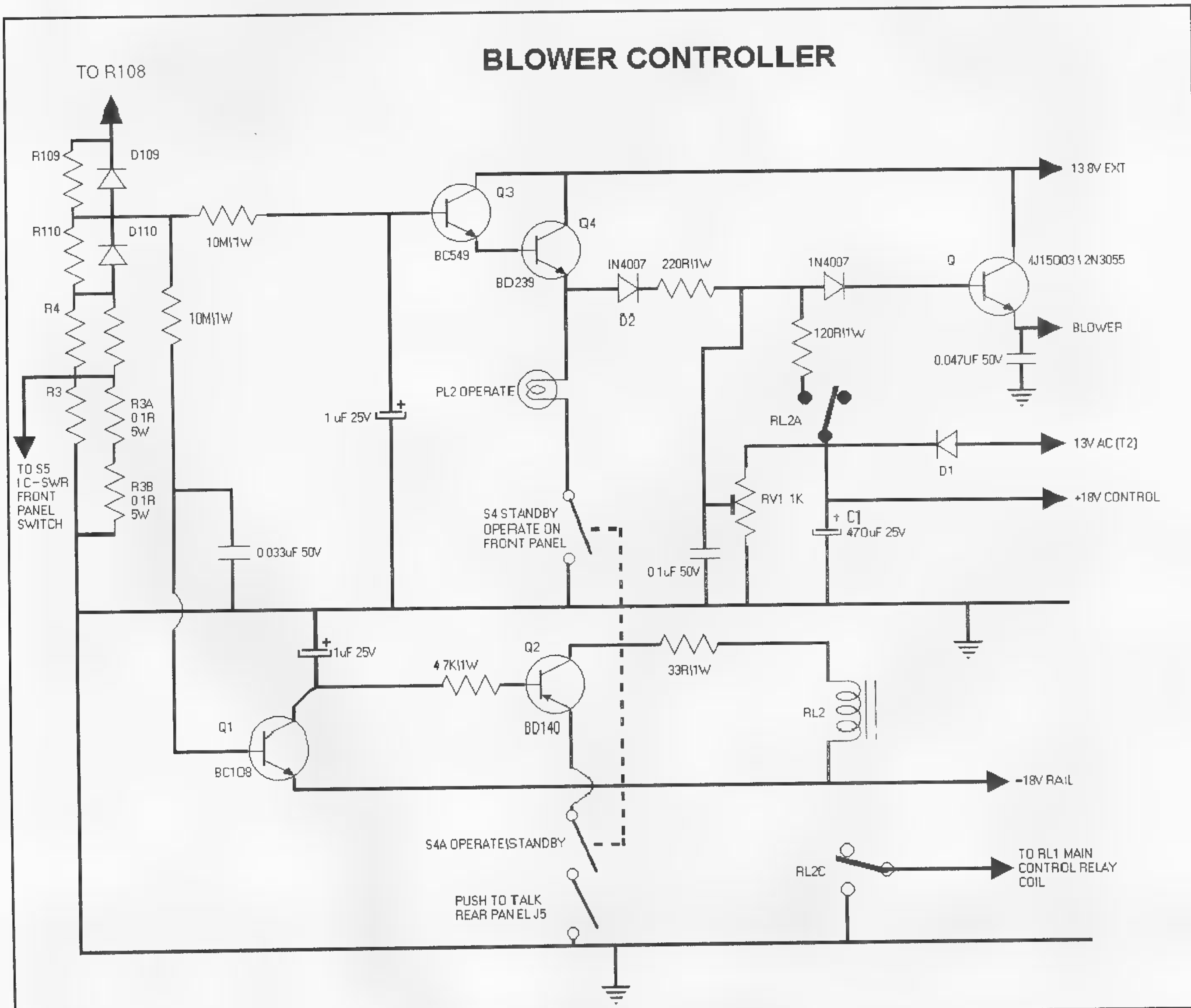

Figure 5. Blower Controller

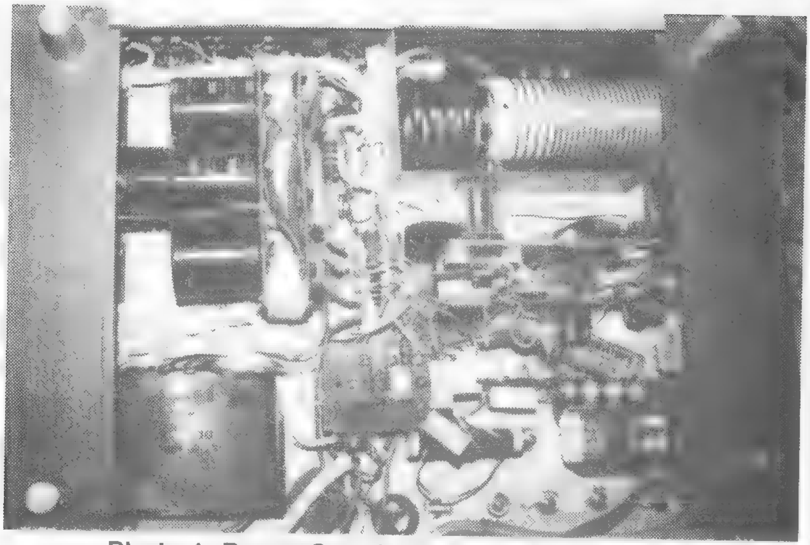

Photo 1: Power Supply and control systems

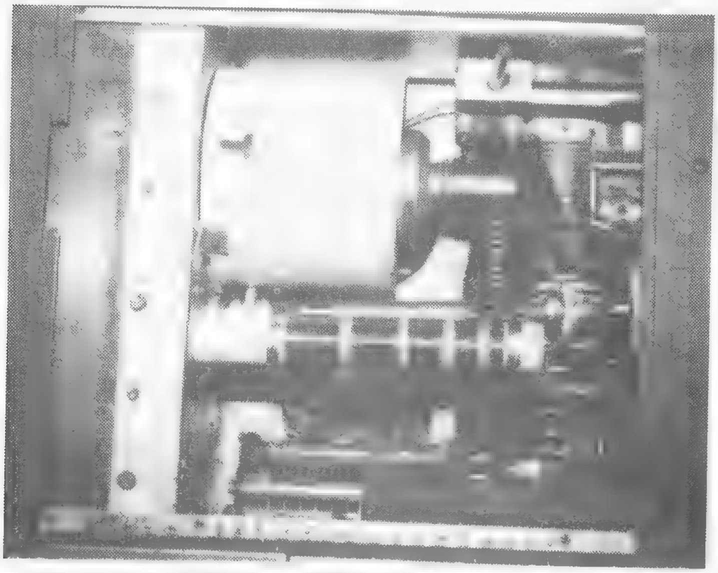

Photo 2. Output section — general layout

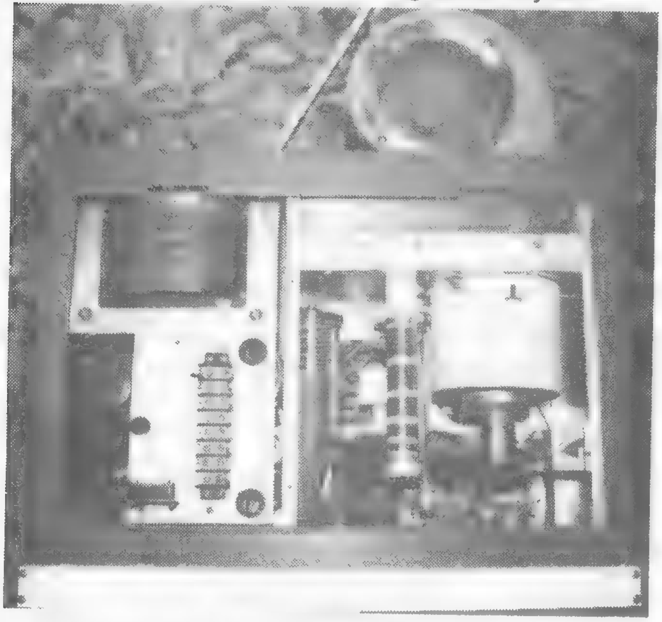

Photo 3.Amplifier — general layout (Blower)

overheated so rather than having to wait with the equipment whilst it aftercools for two minutes this is taken care of. The circuit senses HIGH TENSION voltage via a 10M ohm resistor at the cold end of the rectifier string (junction of R110 / R109) and continues powering the blower motor (via Q3, Q4, D2 and Q5) as the HT voltages bleed away.

Also in the power supply area attention must be given to the voltage doubler. The original capacitors must be replaced with suitable units to provide a total capacity of 25uF or better. By substituting 8 220uF miniature capacitors a total of 27.5uF was achieved. The need for this modification cannot be stressed too highly as performance will be severely degraded and IMD (intermodulation distortion) will increase if this area is not upgraded.

Other PSU changes are R4 the bias resistor (ref fig 5), is deleted and tapped in half to act as a surge limiting resistor. Two 0.1 ohm 5w resistors (ref fig 5 R3A & R3B) are placed in parallel with R3 thus doubling the plate meter scale to FSD of 1,200 m/A. A 2.2 ohm 7 watt surge (ref fig 3 R5) limiting resistor is placed in the T1 HIGH TENSION tapping point, this goes to a fusible link as a safety precaution.

The hazard sheet from Varian specifies a tolerance for the heater voltage of six volts ⁻/⁺5%. To ensure that it is correct remote leads were attached to the terminals of the 8352 and with air applied, the whole system was run so that the voltage could be read. T1 / T2 (both original units) are fully tapped out in their primary circuits to the 234v position giving them the best settings to run the 8352, even so the heater voltage from T2 is in excess so a 65 ohm 20 watt resistor (ref fig 4 R8) was needed in the primary circuit to correct this critical voltage.

Tuning and Testing

Once the constructor is totally confident all the modifications are complete a small amount of drive should be applied to the circuit and the alignment process begun. Setting of the input inductors is essential, this is best done with reference to the chart of modifications in Fig 1 and the Yaesu owners manual.

As a guide peak all tuning controls and measure the reflected power in the exciter line. Assess the necessary changes to be made either to the appropriate inductor or capacitors that are modified in the input circuit.

Since developing the amplifier it has had many hours of "ON AIR" use, mainly for semi break-in CW contesting where it has performed faultlessly. Whilst no "Lab'" attempt has been made to assess the IMD performance of the 8352 it appears using the equipment available that it is either the same to better than original.

One more point to bear in mind is that this amplifier had in it's original condition the ability to exceed the legal power limit for the Amateur service in Australia. The "revamp" described in this article also has the potential to exceed the power limit and constructors must ensure that the Regulations are complied with.

So there it is a faulty piece of equipment returned to vastly better use, now is the time to rebuild whilst the "SOLAR WINTER" is on and be prepared for bigger and better "DX" in cycle 23.

References

1: ARRL handbook for 1976, page 184 "A 160 Meter Amplifier".

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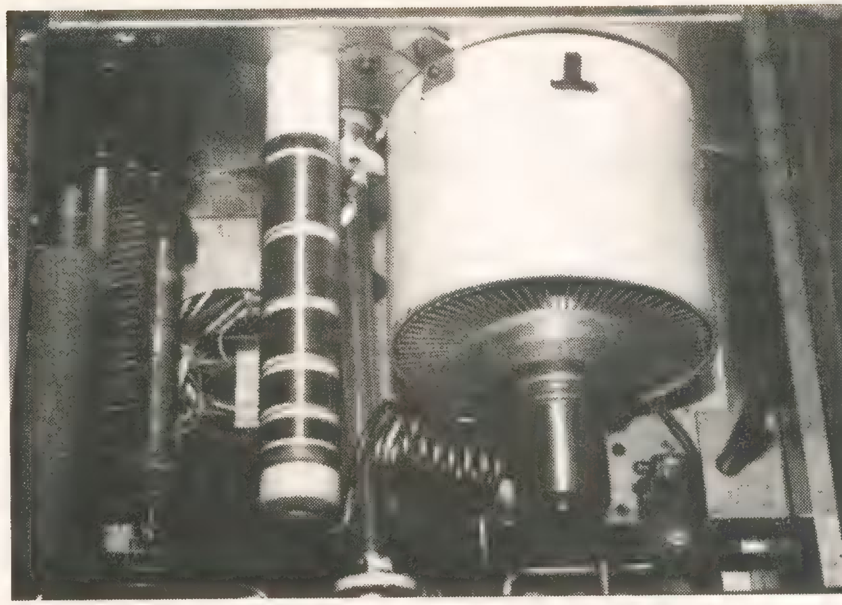

Photo 4. Output stage — tube detail