

# Notes for building the UNSET Beta board

## Identification:

At this time there is only one board version exists. It is called the Beta board, or Beta version. It can be identified by the marking “**TUBELAB UNSET V2.2**” in copper between the silkscreen V5 label and R1. If another revision of this board is made it will have a different version number, IE V2.3 or V3.0. **These notes only apply to the V2.2 board.**

## Known Issues:

The board is electrically usable as is, but there are some mistakes in the silkscreen that will prevent it from working if simply stuffed with part according to the BOM (Bill of Material).

**IMPORTANT:** The polarity of diodes D101, and D201 near the driver mosfets, which are mounted on the two heat sinks in the middle of the board is wrong. The diodes **MUST** be installed in the **opposite direction** from what the silk screen shows. D1, D2, D3 and D4 are correct, install them matching the silkscreen. If D101 or D201 are installed as the silkscreen shows, the corresponding mosfet will not conduct, and that channel will not have any current through the output tube (can't set bias).

Resistor R112 is incorrectly labeled R48 on the board. Install the resistor for R112 in the holes marked R48 on the board. This is between Q102 and V101.

Q102 is incorrectly labeled Q103.

The pin numbers for the pads near the output tubes did not make it into the silkscreen. It turns out that I had put them on the wrong layer in Eagle. Wiring the output tube matrix may be a bit easier if it is done before the tube sockets are inserted, or written on the board near the pads themselves, since the pin numbers on the silkscreen for the sockets will be covered up once the sockets are inserted.

There is no resistor R10. Microsoft ate it. Nice and crunchy, slight metallic aftertaste, pairs well with fried mosfet. I have plenty of those.

## Unique Build Features:

As with the other Tubelab boards, the component parts can be installed on either side of the PC board. Two sets of holes are provided for the TO-220 mosfets. The center lead for the TO-92 mosfet must be bent in the opposite direction from what the silkscreen shows if it is to be installed on the non-silkscreen side of the board. The tube sockets **MUST** be installed on the silkscreen side of the board.

There are two sets of holes for mosfets Q1, Q102, and Q202. Only **ONE** mosfet is installed in the board. Which hole set you use will depend on which side of the board you are populating. There are only one set of holes for the heat sink, which use the same holes regardless of which side of the board they are on. This is different than the TSE-II board where there are one set of holes for the mosfet, and two sets of holes for the heat sinks. See the pictures.

The heat sinks are grounded. An insulator with thermal paste is needed with parts that have an exposed metal tab. The tab on Q1 is connected DIRECTLY TO B+. I have run my board on voltages up to 660 volts, the limit of my biggest power supply. I have not found a plastic coated mosfet that will survive in high voltage builds for Q1. Accidental contact with that, or any similar high voltage can cause loss of vocabulary and bladder control, worse, or much worse. The heat sinks are grounded to minimize the risk. Q102 and Q202 operate with less than 1 volt on their tab, but grounding the tab will short out the metering points, so an insulator is needed there too unless plastic coated parts are used.

These boards can be used with any octal output tube. Since there are dozens of possible pinout combinations for hundreds of possible output tubes a unique matrix system was employed. The builder should determine which output tube will be used before the board build and install 6 or 7 wires from the pads near the tube socket to the appropriate busses between the sockets, or between the sockets and the heat sinks. This is usually easier if done before installing any of the large components like the heat sinks and tall capacitors.

You will install two jumpers, one for each heater pin to the most convenient hole in pair of busses between the tube sockets. The heaters could be wired in parallel or series. The output tube heater circuit independent of the driver heater circuit, and may be of a different voltage. It is elevated to the average voltage on the two output tube cathodes, which varies with bias voltage. This circuit should not be grounded, or connected to the driver tube cathodes unless the builder understands the H-K voltage requirements for all tubes in the amplifier and verifies that they are met.

You will install a jumper wire for each active element of each output tube to the most convenient hole in the cathode, control grid and screen grid buss for each tube. The screen grid buss is shared for both output tubes. There is no buss for the plate connection. You will run a wire jumper from the plate pin, or install the wire to the plate cap into the unmarked hole near the OPT connector that is routed to the plate wire on the OPT. There is no explicit buss or hole for the suppressor grid. For the EL34, and the few sweep tubes that have a separate connection for G3, simply run a jumper wire from the G3 pin to the cathode.

## **Other concerns:**

### **Blown Mosfets:**

Many years ago, one could simply find a mosfet that met the required voltage, current, dissipation, and capacitance requirements and use it in a linear circuit like a source follower or voltage regulator. The old 2SK2700 used in the original TSE was chosen in this manner and it proved to be quite reliable. Things like SOA (safe operating area) and secondary breakdown were worries only associated with BJT's. In the 15+ years since the TSE was designed mosfets evolved to meet the market. In today's market the majority of all mosfets sold are used in switching or other on-off applications, and they are optimized for this service as well as being migrated to a finer geometry process. A typical switch mode mosfet may experience a catastrophic failure when operated well within it's published ratings if operated in the linear region. This failure was previously unknown, and is similar to, but not caused by the same mechanism as the secondary breakdown failure in a BJT.

The biggest issue that I have faced in the multi-year development effort that has become the UNSET has been mosfet failure. The N-channel mosfet used for the screen supply has been the biggest issue. I have blown up dozens of parts in cases where the part was operated well within it's published ratings. Yes, expecting a mosfet to drop 400 volts or more while passing up to 50 mA on peaks is not what the manufacturer intended, but well within the published SOA specs. My work at Motorola on linear (LTE) and constant envelope (FM) transmitter design brought me some insight into this issue in GaN and SiC parts, so it's not just a silicon thing, it is a mosfet thing. Unfortunately, about 6 years since that work, several mosfet suppliers, notably ON Semi / Fairchild still do not acknowledge that it is a problem, and have not changed their documentation. Others like ST have simply removed the DC line from their SOA curves. Any part where the DC line simply matches the rated maximum dissipation curve for all voltages and currents can not be trusted, and a part with no DC curve should not be used for continuous operation on DC (the screen supply). This eliminates the majority of all the mosfets made today. A mosfet where the "suggested applications" are all switch mode devices should not be used on DC, especially if there are no SOA curves at all. I have seen mosfets where the "applications" include "push pull amplifier" or "push pull audio amplifier." These terms could (and do) often refer to a class D amp, and again these mosfets can fail. When the mosfet fails it usually fails to a short. A shorted fat in the screen supply will put full B+ on the screen which is well above the spec in a TV sweep tube. Bad things could happen. The most likely failure would obviously be some serious fireworks inside the tube, but I have not seen that happen. In fact, I have not blown a tube in an UNSET board yet! Why? The screen supply also feeds the cathode bias supply, and an overvoltage here simply cuts off the tube.

What can be done to prevent these failures? The obvious answer is to use a mosfet rated for, and tested for LINEAR mode of operation at the voltage ranges we will see in use. Another option is to add resistance in series with the drain of the fet. The board does not have provisions for this, but a modification is shown to do this.

Mosfets designed for linear mode exist, and I have been using some IXYS parts with good success. As expected, these are not as cheap as the typical switch mode fet. The IXYS IXTP15N50L2 is a part created for use in the linear region, and recommended Applications include Linear Amplifiers, Programmable loads, and current regulators, all of which impose a constant DC voltage across the part. The "tested" SOA is 400 volts at 375 mA which is about half the rated maximum dissipation. It is only rated for 500 volt maximum operation though. It is also about \$9 each. In theory the screen supply output is 180 to 190 volts, so a 500 volt fet should be safe at 680 volts. This is what I currently have in my board and it has been to 660 volts which is the limit of my biggest power supply. This part would be my first choice in an amp running on a B+ supply of 500 volts or less.

It has always been the belief of many solid state experts that depletion mode mosfets do not have the same secondary breakdown mechanism that the typical enhancement mode fet has. IXYS does have some depletion mode mosfets with linear mode applications, and some SOA data in the linear region. The IXTP3N100D2 (about \$3.50) is a 1000 volt part "tested" at 800 volts and 94 mA, 75 watts on a 125 watt part. The 75 degree curves allow for 100 mA at 700 volts and about 180 mA at 400 volts, well within the operation of this board.....I have blown one up though. This was traced to a full power square wave oscillation at about 40 KHz due to a missing ground and a sloppy bench top layout. The big Hammond OPT is a giant capacitor at these frequencies, so the IXYS part, and some of my previously failed parts were likely subjected to some serious over spec operation. This is discussed further later in this document. I put in the IXTP15N50L2 part which lived through this abuse, allowing me to find the true cause.

The P channel mosfet in the cathode circuit of the output tube also operates in the linear region. The part listed in the BOM is not specified for use in this mode, but to date there has been only one failure which was caused by the full power oscillation which blew up several parts in one big bang.

More to come.

### **Suggested Modifications:**

The N-channel mosfet in the screen supply has been the only real problem with this design. This issue can be minimized by adding a 2K 5 watt ceramic resistor in series with the mosfet drain. This requires some board modifications.

The P-channel mosfets in the output tube cathodes supply bias for the tubes. A shorted fet will put the tube into full ON mode, and some sweep tubes can pass AMPS of current. I have added a 2 amp Pico fuse in series with my cathodes. So far I have not blown one.