Arc Protection SB-200 series Heathkit

12/17/2022 W8JI Rev1

Years ago, when amplifiers like the Collins 30L1 and Heath SB200 were designed, tubes had better manufacturing quality control. Tubes had better materials and workmanship, more care was taking in manufacturing processes and pumping tubes down. Tube arcs or faults from the high-tension anode to other elements, unless the tube was seriously abused, were uncommon. Such is no longer the case. My business imports hundreds of 811 and 572B tubes a year. We have to high-pot, visually inspect everything we can see, measure filament current, and dynamically test each tube for peak saturated emission and the grid voltage required to reach peak emission. In short, we have to finish the factory inspection on every single tube.

Peak anode voltage in a properly-tuned AB-class amplifier running near class B (low quiescent current and high efficiency) Is nearly twice the dc supply voltage. For example, a 572B tube operating with 2300Vdc + supply rail reaches around 4000V peak positive anode voltage in normal proper operation. If the amplifier is mistuned, driven with common exciter overshoot, or loses the load the peak tank voltage and peak tube anode voltage can skyrocket. The practical limit to the obtainable voltage is when something arcs or breaks down. Voltages of four times the dc supply are not uncommon in mistuned or loss of load cases. This is why 572 tubes that can't reach the 10kV range for anode-to-grid breakdown voltage are questionable.

Contrary to some claims, tank circuit and tube arcs are virtually never from parasitic oscillations:

1.) Tank circuit arcs are from normal tank flyback action when PA tubes are driven into negative anode voltages from excessive drive for the tank circuit loading

2.) The common cause of tube arcs today are poorly manufactured and tested tubes. Generally this is a plasma inside the tube between anode and other tube elements, such as the grid and cathode or filament

Damage from Tube Faults

When tubes arc or fault, anode supply filter capacitors become the damaging energy source. Energy stored in the filter capacitors is current-limited by capacitor and circuit path loop impedance. It is possible that dozens or hundreds of amperes can flow.

The level of this surge is evidenced by collapsed plate chokes, exploded meter shunt resistors, and destroyed meter movements (commonly the grid meter). This surge can even make its way through the input circuit, out the coaxial cable to the radio, and do severe damage to an expensive radio. Since the relay jack is not part of this path, a relay buffer cannot help solve this problem.

The days of being sloppy because tubes were almost perfect are gone now. With modern tubes, ideal designs provide a safe controlled path for anode-to-grid faults. An ideal design eliminates damage from minor quick arcs, while minimizing cost of hard sustained arc-faults:

1.) The positive supply should have as much surge impedance as reasonably practical. This slows the discharge time, limiting the peak current
2.) The grids should be directly grounded. This eliminates passing the fault plasma inside the tube along to the filament or cathode
3.) A controlled path that can sustain high currents should return the fault current as directly as possible to the filter capacitors. This fault current can reach dozens or perhaps hundreds of amperes. **Protection devices should clamp to the lowest possible voltage and safely handle hundreds of amperes**

Retrofitting an older design can be so difficult or invasive a simple compromise must be struck, or no one will make the change.

SB200 or Collins 30L1 Simple Fault Protection

The Collins 30L1 has one of the worst control grid and bias systems among amateur radio amplifiers. Unfortunately, Heath and others copied that basic system.

The application of negative bias to the grids, rather than bias at the filament center tap, prevents directly grounding grids without extensive rewiring. Because the grid floats through a fairly high impedance, the control grid no longer shields the filament and cathode path from tube arc discharges. The grid cannot divert a significant part of fault current to chassis ground.

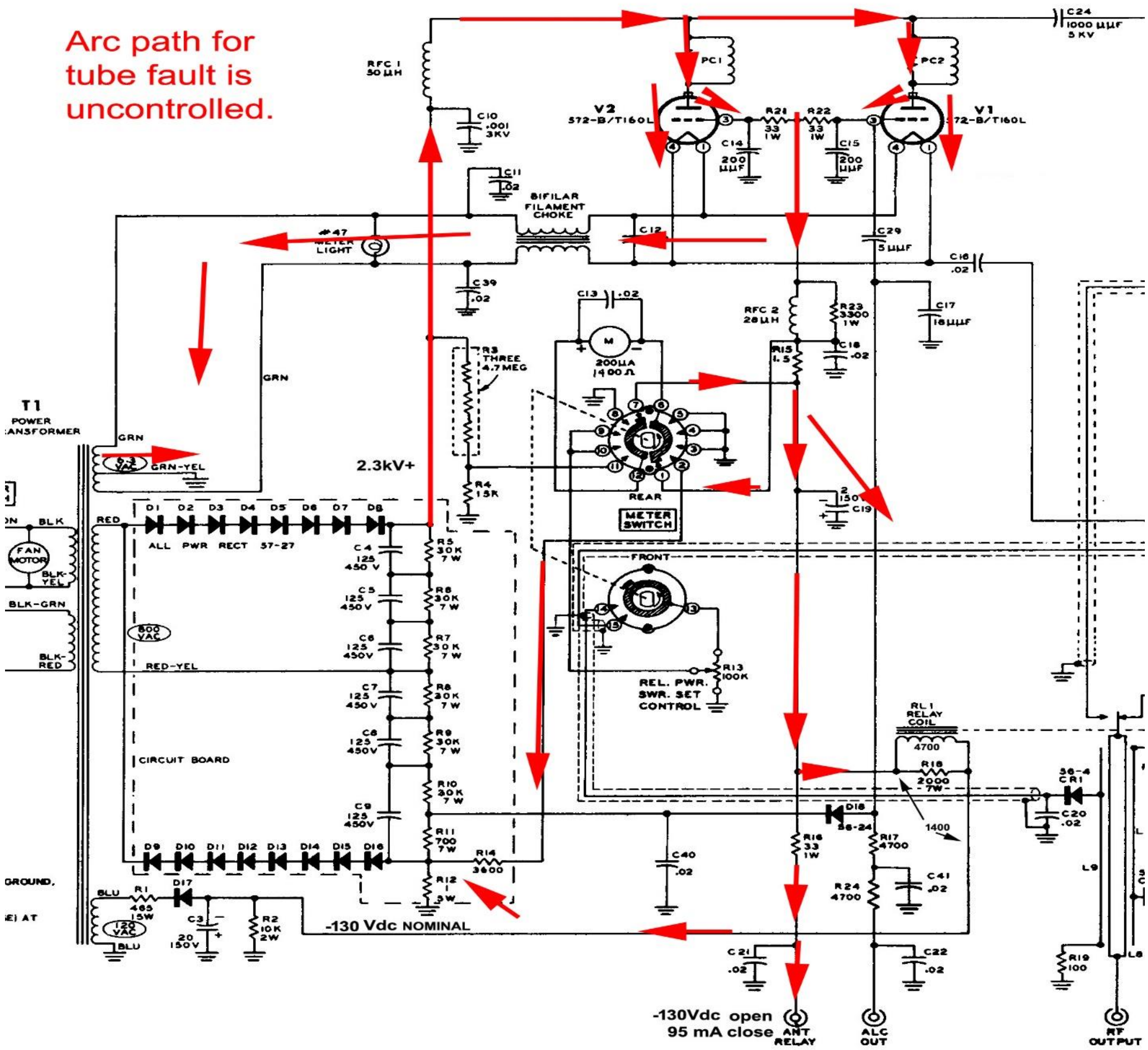
While rewiring is possible and would result in a much safer system, rewiring is far more invasive and time consuming. This is a short quick add-on modification that confines arc damage to a smaller area. This modification takes the meter, meter shunts, bias system, and radio largely out of the fault path. It does this with a minimal number of components:

1.) Two 150V GDT’s for the filament

2.) The optional possible addition of two 230-volt GDT's with one directly from each grid pin to chassis ground (to accommodate standby bias voltage in the 150-170Vdc range)
3.) Two 1N4007 or heavier meter protection diodes (these might become shorted in a severe arc)
4.) One low voltage .1uF bypass disk capacitor
5.) One 10 to 20-ohm, high voltage surge rated 7-watt or larger resistor. This resistor must be surge rated. It adds to the existing capacitor and fault path impedance

No additional meter protection is necessary when this mod is installed. Properly installed, this superior to diodes across the meter.

The original circuit and fault path is:

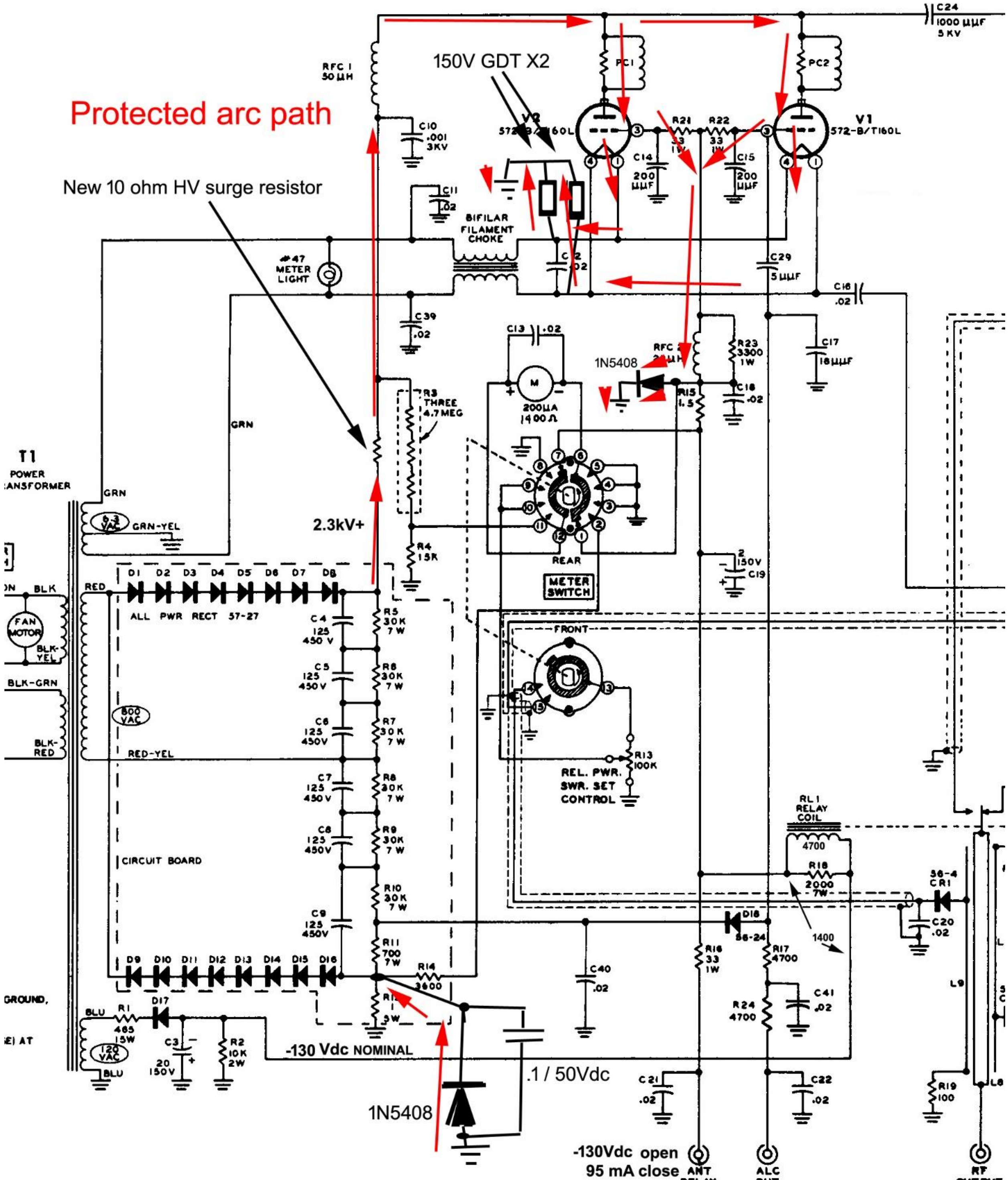


Tracing the fault path, we find a common tube-anode to grid-and-filament fault has no defined path, instead scattering all through components with some percentage even appearing through the input network to the radio’s RF connection.

Modified Circuit

This modification adds a negative power supply rail clamp, grid bias clamp, filament clamps, and surge resistance. It controls and confines the fault path, keeping destructive currents away from expensive or largely irreplaceable components. Some chokes and small readily replaceable components do remain in the fault path. While an additional

230V GDT from grid pin to chassis could also help, there is no simple way to work completely around the poor floated grid system without major invasive work:



Component Selection

A pair of good 572 tubes properly tuned in AB2 are in the 60-ohm driving impedance range. The peak cathode voltage at 100W peak envelope drive power is thus sqrt (60*100) = 77.5 Vrms or ~110V peaks. A 150V GDT has about 25% margin, or over 150-watts drive power at the filament-cathode. It likely would take 200W exciter power to fire a 150V GDT in a properly working SB200 or 30L-1 Collins.

I recommend GDT's because they have very low capacitance and appear as an open circuit until they ionize. When ionized clamping voltage is very low, far below 50 volts. They also can take kiloamperes for brief periods.

I do NOT recommend solid state diode type clamps. They clamp much higher in voltage, in the hundreds of volts. Beside the high clamp voltage, solid state devices cannot take anywhere near the same surge current without failures. They are the wrong device for this application.

Anything allowing the grid bias to rise uncontrollably while the amplifier is driven with RF can fire GDTs.

Be careful using the Harbach soft key. That system has threshold design problems that cause it to go in and out of conduction in rapid pulses. This not only causes your signal to be wider than necessary, the pulsing can fire GDT's. If you have sudden unexplained firing of GDT's, it can be from momentary loss of grid bias path.

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