At the Repair Bench – TYT MD-9600 June 2026

Every now and then, I will come across a repair that must be made, but by all rights, *should **never** have been necessary!* That is the case with this month's case-history, which revolves around a TYT MD-9600 mobile transceiver (Figure 1). This model is a compact but capable 50-watt mobile type that offers VHF/UHF dual-band analog modes as well as being DMR capable. This one came to me from a relatively new ham who had been given the radio in what was said to be like-new condition. That, however, did not last very long.

Figure 1 - TYT MD-9600 transceiver

In order to use the radio correctly, a power supply was needed, and I was able to provide him with a suitable power supply after much discussion as to exactly what was needed in terms of amperage. A lengthy conversation had taken place in which I tried to determine the current needs of this model. First, we checked the user manual, which provided no information regarding current demands of the transmitter. The owner then tried a web search, which low-balled the current to an unrealistic level. Ultimately, I decided on a minimum current target based solely on the fuse that was installed in the radio power cord, which was a mini-ATC 15A (BLUE) fuse. In any event, I decided that I had a power supply in my repair queue that would fit the bill for him and made plans to get it to him as soon as the repairs that it needed were finished.

Fast-forward to the day that the owner gets the repaired power supply unit (PSU). He connected the radio to the PSU, but he got no result when attempting to power on the radio. He ultimately called me and asked me what was wrong. It was during that conversation that I finally got the shocking news (pun intended) that led me to the repair that is the subject of this article.

It turns out that while he was waiting for the repaired PSU to get into his hands, he decided to go ahead and operate the radio… by connecting its power cord directly into a 120VAC receptacle! Needless to say, that was not a resounding success. The radio, obviously, suffered some damage and would need repairs before it would, if ever, get on the air.

OK – so what damage was done to the radio? In this situation, the owner was extremely fortunate. The damage was limited to a charred 15-ampere mini-ATC fuse and a shorted P6KE24A TVS diode, as well as several electrolytic capacitors which had been supplied with voltages well in excess of their maximums. These included a total of four (4) 470µF/25V types and one 47µF/25V type. The final damaged component was a 2SJ377 MOSFET in the power conditioning circuit. A schematic excerpt detailing the pertinent portion is shown in Figure 2.

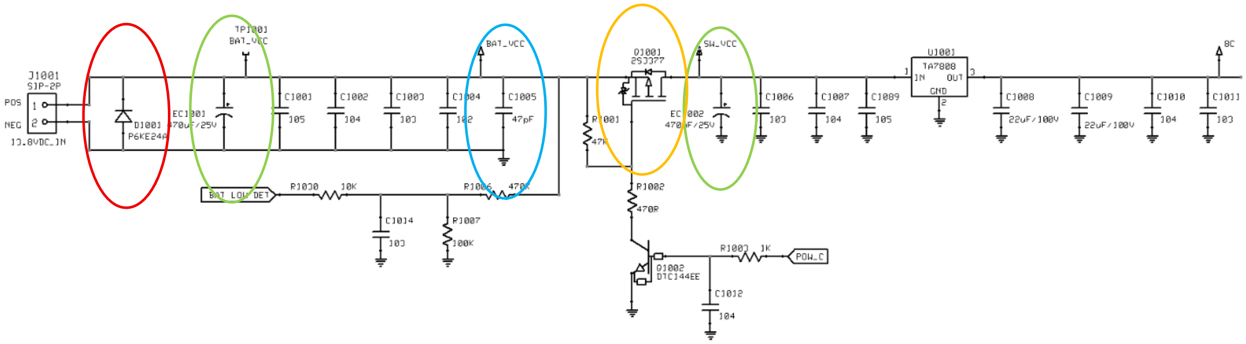

Figure 2 - Schematic diagram excerpt - power inlet and conditioning

The P6KE24A is a unidirectional transient voltage suppressor (TVS) that is installed across the incoming DC supply line (circled in red in Figure 2). This device is rated at 600W, with a reverse standoff voltage (V_R) of 20.50V and a breakdown voltage (V_{BR}) of 22.80V (minimum) to 25.80V (maximum). The clamping voltage (V_C) is 33.2V at a maximum peak pulse current (I_{PP}) of 18.4A. So… what do all of these values mean, and just what does a TVS do… and how does it do it?

TVS diodes are specifically engineered to absorb and dissipate high-energy transient pulses extremely quickly. These diodes function similarly to a pressure relief valve for electricity, operating in three distinct states based on the circuit's voltage:

- Normal Operation (Standoff): Under normal conditions, the voltage remains below the diode's Reverse Standoff Voltage (V_R). The diode has high impedance and acts as an open circuit, drawing only a tiny amount of leakage current (nanoamps) so it doesn't interfere with the main circuit.
- Transient Event (Breakdown): When a sudden voltage spike exceeds the Breakdown Voltage (V_{BR}), the diode enters *"avalanche breakdown"* within nanoseconds or picoseconds. It rapidly changes from high to low impedance, creating a path to shunt the excess current to ground.
- Clamping: During the surge, the diode "clamps" the voltage across it to a specific Clamping Voltage (V_C). This is the maximum voltage the protected downstream components will see, which must be lower than their damage threshold.
- Automatic Reset: Once the spike passes and the voltage returns to normal levels, the TVS diode automatically resets to its high-impedance state.

As might be inferred from the preceding explanation, TVS diodes are intended to deal with rapid, short-duration spikes... but *not* with a prolonged influx of high-voltage alternating current. Based on the specification values listed earlier for the P6KE24A device, any way that you look at it, 120VAC input with zero current-limiting is a recipe for failure of the TVS, which in fact it did. It failed in a short-circuit condition. In all likelihood, once the TVS failed to a short-circuit condition, the AC arc at the fuse would probably have been extinguished by the circuit breaker for the particular circuit in use tripping out and opening the circuit, effectively shutting off the incoming current.

The TVS is normally installed with its cathode to the positive side of the power input circuit. It is placed directly across the incoming 13.8VDC terminals. A P6KE24A TVS diode subjected to 120VAC will likely fail to a short circuit within microseconds to a few milliseconds, depending on the source impedance of the power line. The P6KE24A is designed for low-voltage DC protection (20.5V working voltage) and cannot survive the sustained energy of a 120VAC line.

The expected failure timeline would most likely look something like this:

- *Clamping* (nanoseconds or picoseconds): The diode will engage almost instantly (typically in less than 1.0ps) once the voltage exceeds its breakdown of ~22.8V.
- *Overheating* (microseconds): At the peak of a 120VAC cycle (~170V), the diode will attempt to clamp the voltage to roughly 33.2V. This creates a massive voltage drop across the diode while shunting extremely high current.
- *Destruction* (milliseconds): Because the diode is only rated for a 600W peak pulse (1ms duration), the continuous power from the AC line will rapidly exceed its thermal limits. In a typical "hard" connection to a wall outlet, the silicon junction will melt and fail in a shorted condition almost immediately during the first half-cycle of the AC wave.

A summary of the effects of applying 120VAC to this particular TVS is provided in Table 1 below.

Table 1 - Effects of 120VAC on P6KE24A TVS

Device Parameter	P6KE24A Rating	120VAC Impact
Reverse Standoff (V_R)	20.5V	Constantly exceeded (~170V peak)
Breakdown (V_{BR})	22.8V - 25.2V	Diode conducts nearly the entire cycle
Clamping Voltage (V_C)	33.2V	Diode tries to "fight" the 170V peak
Steady State Power	5.0W	Power dissipation will be in the hundreds or thousands of watts.

So… all of this brings up another question. Why does the TVS fail to a short circuit rather than simply going open? The typical failure mode for TVS diodes like the P6KE series is a short circuit. When the semiconductor material is subjected to over-specified voltage or current, the silicon junction melts and forms a conductive path, which becomes the shorting path for the current.

It should be noted that the plastic DO-15 case of the P6KE24A TVS diode will sometimes explode under such conditions, as the mains current surge causes such rapid heating that the plastic case fails catastrophically. However, the silicon path usually shorts first.

It is during the extremely short period of time while the TVS diode was in its clamping mode of operation that the damage occurred downstream of the TVS diode's location. Specifically, five aluminum electrolytic capacitors failed – four rated 470µF at 25V (circled in green in Figure 2) and one rated 47µF at 25V (circled in blue in Figure 2). Note that only two of the failed 470µF capacitors appear in this schematic excerpt – the remainder are located in another circuit branch that tees off this power segment. A single 2SJ377 P-Channel enhancement mode MOSFET (circled in orange in Figure 2) was also damaged. This device failed in a modality that resulted in a short-circuit from drain to source. The failure of the electrolytic capacitors was because the clamping voltage of 33.2V exceeded the working voltage rating of 25V for these capacitors.

Let's talk about the charred fuse for a minute. It must be understood that the ATC/ATO family of automotive fuses, while quite ubiquitous today, are absolutely *not* rated for use in alternating current circuits at all – and especially not so at mains voltage levels. The datasheet AC rating is *0VAC* for the entire family of ATC/ATO and mini-ATC/mini-ATO fuses. The reason is because these fuses are not designed to extinguish the arc that occurs at fuse opening with the energy levels present in AC mains voltage circuits. It is this arc that caused the extensive charring of the fuse, the welding of the fuse to its connector inside the fuse holder, and also the melting that was evident in the fuse holder for this fuse. During the period when the arc is active, current is still moving into the radio, and is fully capable of doing damage to the radio.

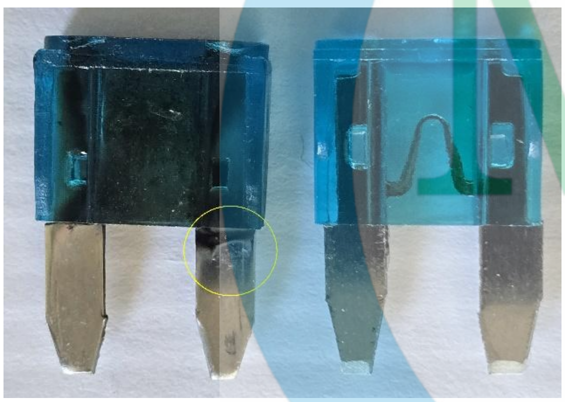
Figure 3 - Charred fuse vs. new fuse

The illustration at Figure 3 shows the spent, charred fuse from this radio next to a new 15-ampere mini-ATO fuse for comparison purposes. When I asked the owner to remove the fuse so that we could get an idea of its condition (before I knew about the 120VAC debacle), he said that he could not get it to come out of the fuse holder. As a matter of fact, he could get one side to come up, but not the other. A close look at the spent fuse tells the story. Note the yellow circle in the Figure 2 photo. It surrounds the spot where the fuse blade was actually welded to the connector in the fuse holder. What does that say about current levels in that fuse holder?

Moving on to the capacitors that were damaged in this event, there were a total of five capacitors in need of replacement. One of these was a 47µF/25V radial aluminum electrolytic capacitor, while the remainder were all 470µF/25V types. I replaced all of them with high-quality low-ESR +105°C devices, all of which were in stock here. The temperature rating is important in a mobile radio, as automobile interior temperatures can get quite high during the summer. That ambient heat is transferred into the componentry of the radio, which, when energized, only gets hotter. Did you ever notice how much more the mobile radio fan operates during summer months than in winter time?

The MOSFET was replaced with one of the same part number, which I happened to have on hand. It is a surface mount device that mounts flat on the PCB via its drain tab and its gate and source leads, which have a modified gull-wing form. Removal of the failed

MOSFET was a simple matter of applying a focused hot air stream to “float” the device, where it could be lifted out with tweezers. After a bit of clean-up of the board, the new transistor was placed and soldered in.

The failed capacitors are all through-hole devices, easily removed with the use of my HAKKO FR-301 vacuum desoldering tool. Replacement capacitors were positioned in accordance with their polarities, and then were soldered into place. All very straight-forward. That brought me to the TVS diode.

As was stated earlier, this diode is soldered directly across the incoming 13.8VDC source leads. In this installation, the two power leads pass through the PCB from the upper surface, being soldered on the lower surface. The lower surface is also where the 2SJ377 MOSFET is installed. The P6KE24A TVS diode is soldered directly to the inlet wire solder joints on the PCB. Thus, the TVS protection is the very first thing that this incoming power encounters.

The MD-9600 has a bi-level power output scheme, which varies slightly between the VHF and the UHF bands. On VHF, the power output maximums are 25W and 50W, while on UHF, these values are 25W and 45W. In live testing of the radio post-repair, we saw 47.5 watts output on the VHF band and just about 40 watts on the UHF band. While testing on VHF, tuned to the GCARC VHF repeater at 147.180 MHz and dumping the output into a resistive but non-inductive dummy load, the test signal was nonetheless picked up by the repeater and passed along, garnering responses from Club members on the air.

The radio passed all of its post-repair testing, including deviation and frequency stability. As such, it was returned to its owner, who was quite grateful that the radio had been salvaged from its unfortunate damaged state.

Sometimes, even what seems like a hopelessly damaged unit can be restored to health fairly easily. Approach the problem in a logical manner, first evaluating, then testing and diagnosing, and finally repairing the problem. Remember too that each and every radio has its own unique power needs, and those needs should be noted and then adhered to when placing the radio into operational service.

See you next month!