Protecting decoders with TVS diodes

Bob #1 January 22, 2017, 6:46pm

A very talented O-scale modeler recently inquired about the 1.5KE20CA Transient Voltage Suppression diode or TVS diode mentioned in the *Alco C425 tweaking and install* thread. If anyone else is curious, here is a brief description of what these are all about. The following Q and A's are not the same ones originally posed.

What is a TVS diode? TVS diodes are a type high-power zener diode commonly used to protect electronic circuits from static electricity, indirect lightning strikes, and inductive voltage spikes produced by devices such as electric motors.

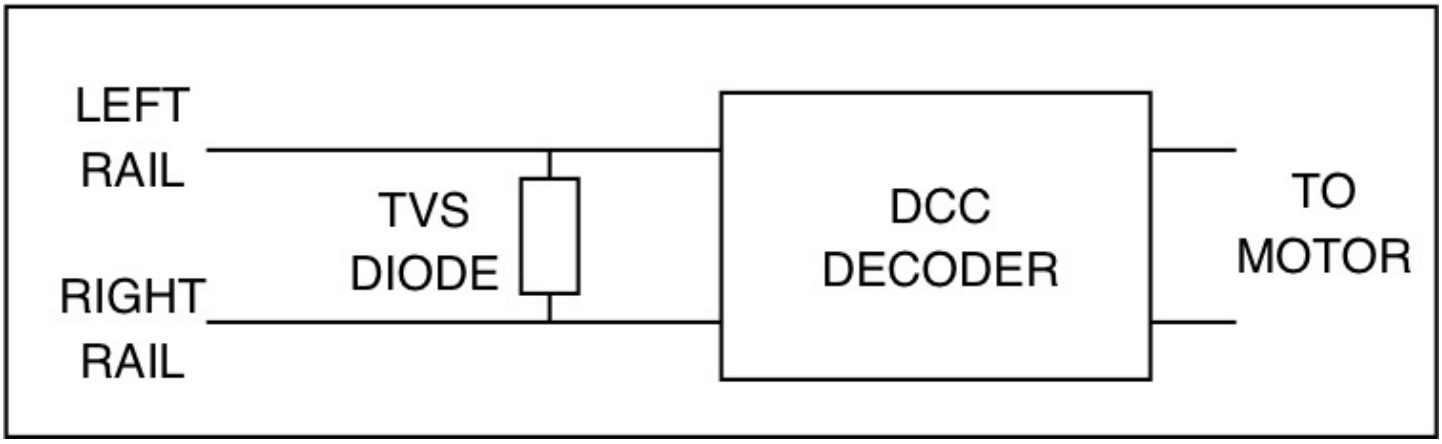
What problem are we trying to solve? On a layout with long DCC bus wire runs, there can be inductive voltage spikes generated along the bus wires that at times have been reported to scramble decoder programming or even cause them to electrically fail. I personally have had a Tsunami 1.0 lose its programming multiple times during short circuit episodes, to the point that it first required a factory reset prior to reprogramming.

What do these diodes actually do? The diodes clamp the maximum voltage entering a DCC decoder to a safe value.

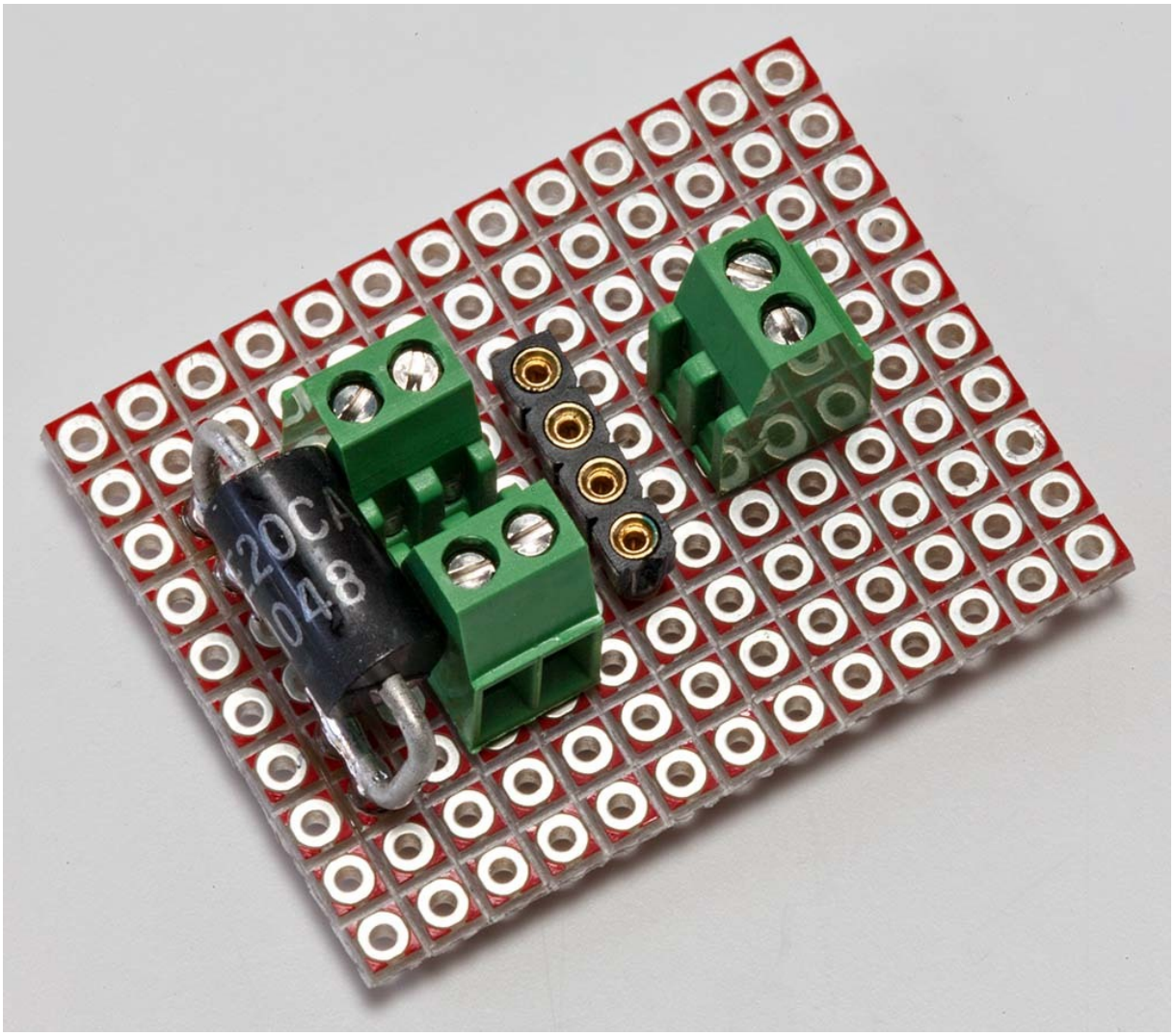
What is the part number? The part we use is a bidirectional diode, number 1.5KE20CA. It connects directly across the rail pickups as shown below. It is inexpensive and available at **Mouser.com** in small quantities.

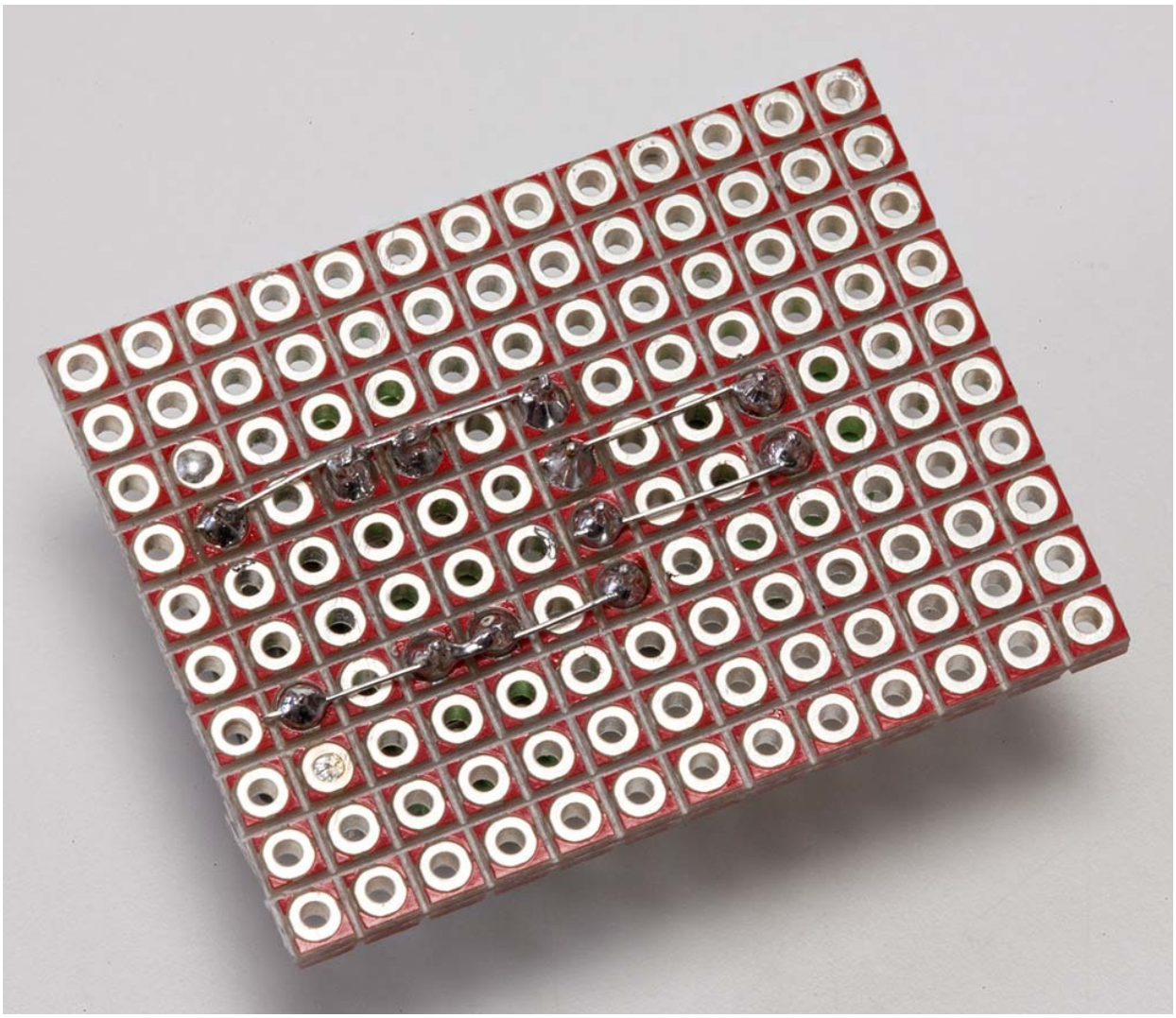
Why put them in locomotives? The A&O is signaled. Putting one of these diodes across the DCC bus feeds under the layout would cause the block to appear permanently occupied.

How are the diodes connected? Connect them across the track pickup wires in a locomotive.

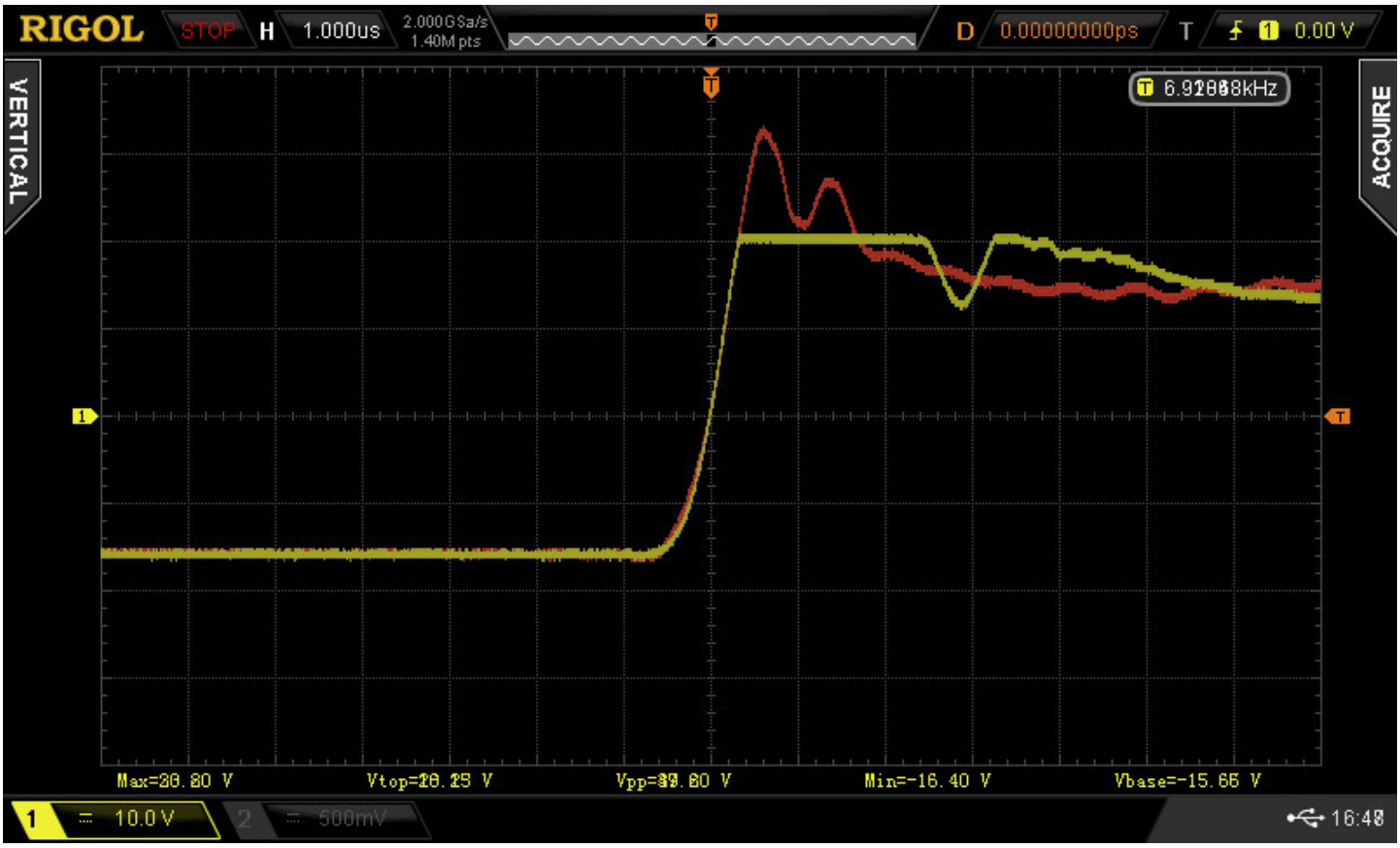


Here are two photos of a small PC board I wired for a Car & Locomotive Shop RS-36. The opposing green terminal blocks receive the track pickup wires. The third green block goes to the motor. The gold and black 4-pin connector feeds the decoder which is mounted inside the car body. The latter is wired so that the mating plug can be reversed if the locomotive runs backwards.





What evidence do we have that these diodes get the job done? Consider the oscilloscope trace shown below.



The red trace shows ringing exceeding 33 Volts near Point Vincent on the A&O. This spot is perhaps 40 feet from the DCC booster. Most decoders are rated to 28 Volts. The yellow trace shows the same spot with a TVS diode laying across the rails. Voltage is now limited to 20.8, so the diode is working. It doesn't get hot.

An far more serious situation occurs during a short circuit episode. Suppose an operator runs his locomotive the wrong way through a switch and causes a short. A short doesn't always stay shorted once it starts. It usually shorts, opens, shorts, opens… until everything comes to a rest. When initially shorted, a large surge current builds in the DCC bus wires. At this location I've measured over 30A before the PSX circuit breaker tripped.

The problem happens when the short opens up. Inductance in the bus wires tries to keep this overload current flowing, and it does so by creating a massive voltage spike. The voltage rises until it is sufficient to force the same overcurrent through whatever impedes it, which at times is a decoder's internal power supply. It is this spike that is a likely cause for a decoder to lose its programming (the aforementioned Tsunami 1) or even worse, total decoder destruction. If you have watched the electrical arc across the contacts of an electromechanical buzzer, you have seen inductance at work.

I hope this description is reasonably clear. Because I am a retired electrical engineer, sometimes I speak with a "thick geek accent." 🙂

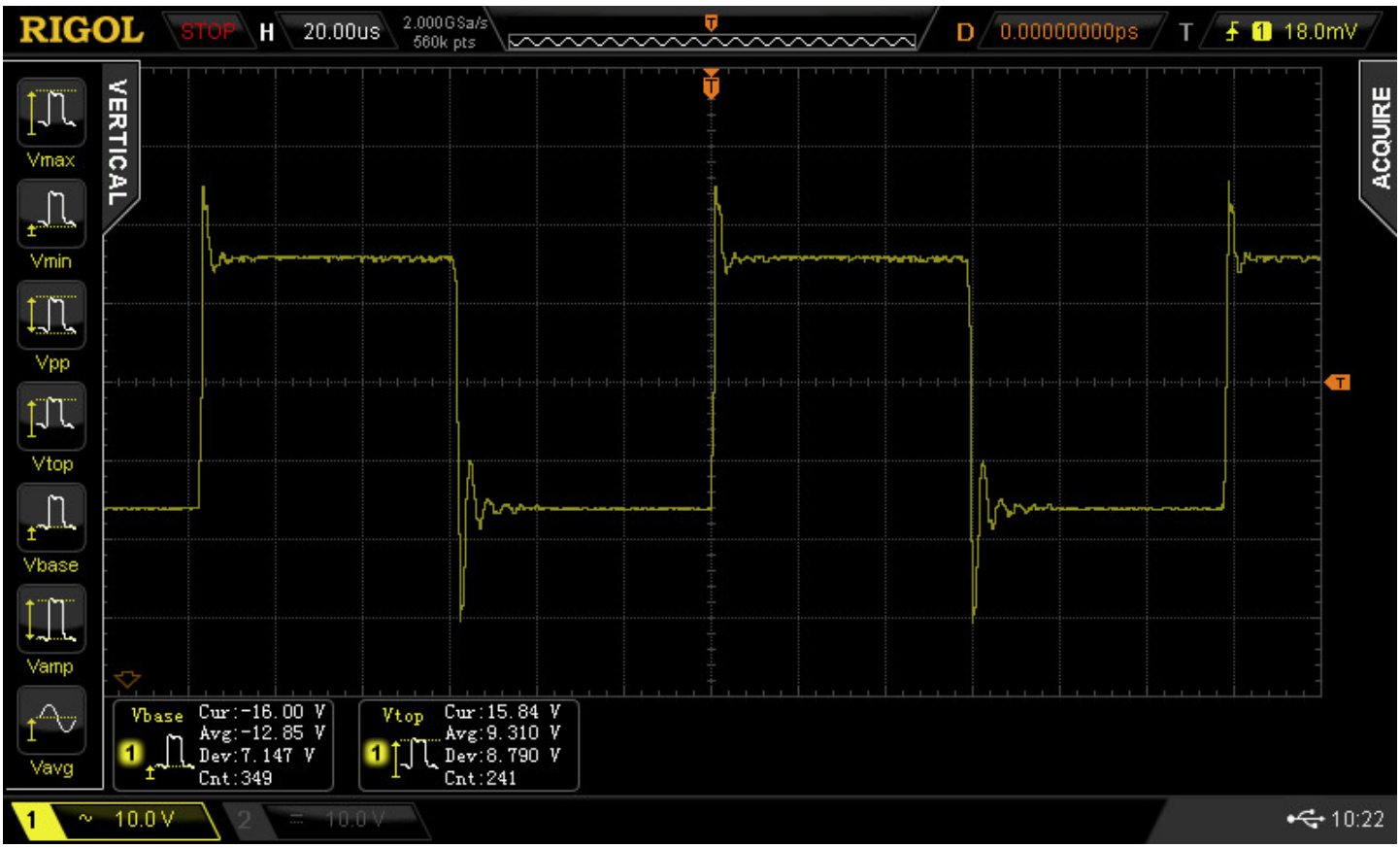
1 Like

Bob #2 November 19, 2017, 8:06pm

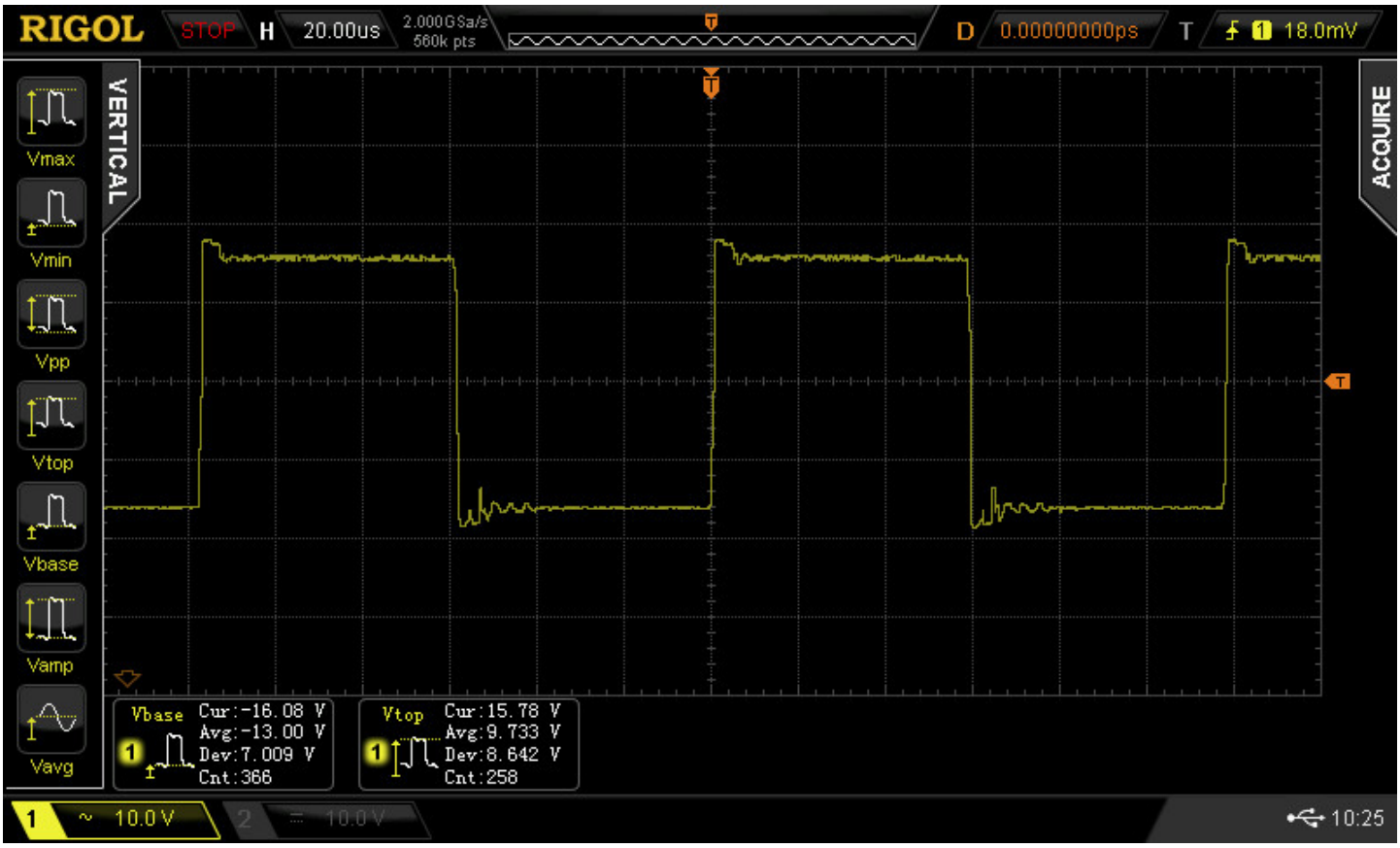
Here are a couple of oscilloscope captures taken at the south end of Joel Beach. I was trying to diagnose a new failure in the signal system, which as it turned out was a flake of metal bridging the gap between detected rails in different blocks. A big shout-out to Vince for suggesting the general place to look!

Anyway, I brought out all the big guns, a 5 1/2 digit Fluke DMM and my Rigol Oscilloscope. During my spelunking, I grabbed a couple of waveform captures that my be interesting.

First up, we have some pretty severe bus ringing. The peak negative voltage with no load on the track briefly exceeded -30 Volts, while the nominal DCC unloaded voltage was about -16.



Next we see the same spot on the rails but with my Alco RS32 #455 on the track. This engine has a 17V TVS diode wired inside, directly across the rail pickups. The big voltage spikes have been tamed.



To quote my friend Jackson from Missouri, “More Better!”

So why not install a TVS diode across the rails instead of inside each locomotive? Because the TVS would be on the *rail* side of a CTC occupancy detector, and would appear to the detector as a ghost train.