High-Voltage Protection Circuit

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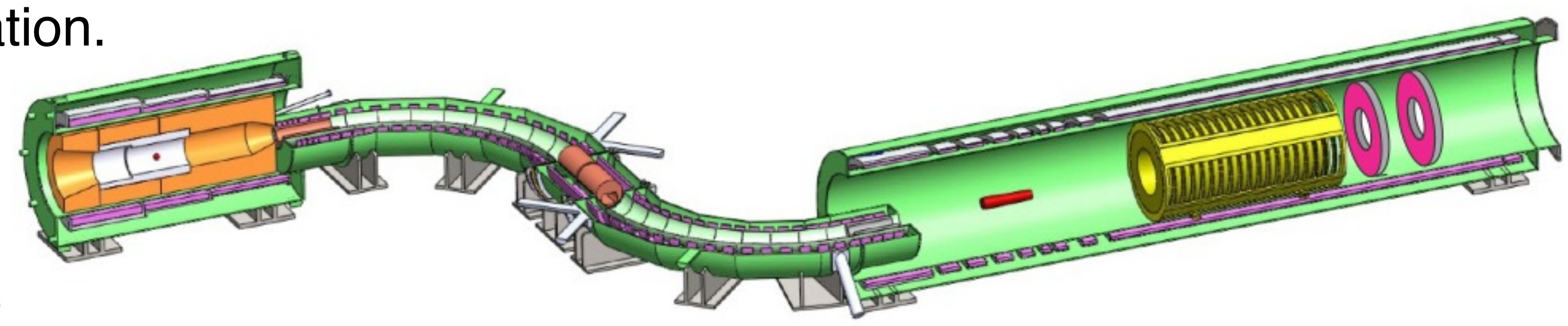
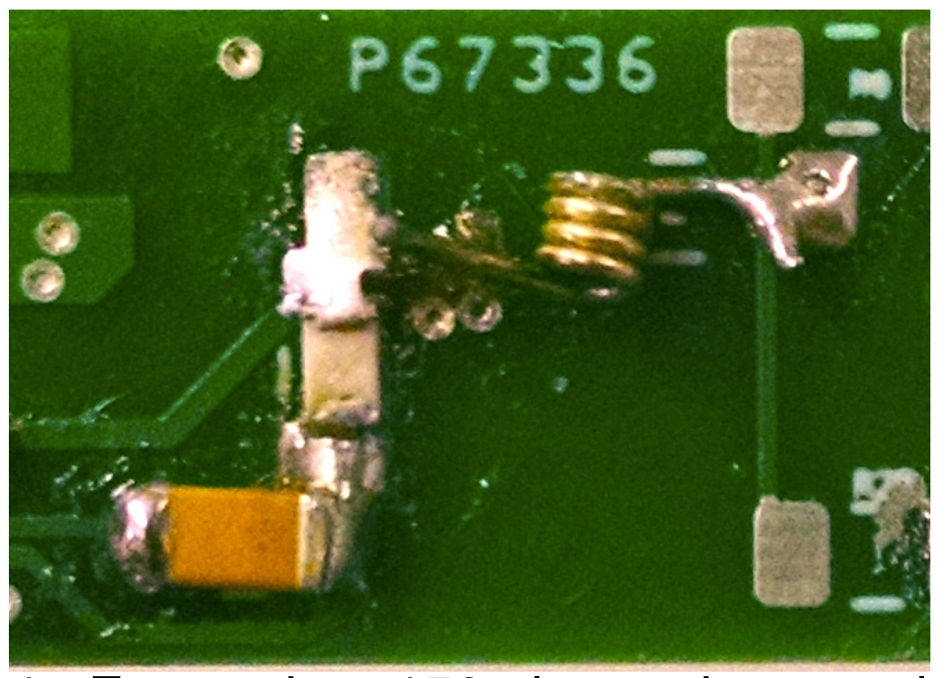
CCI Program

Mu2e aims to uncover new physics by observing the neutrinoless decay of a muon into an electron, a charged lepton flavor violation. In addition to a high-intensity beam of particles, Mu2e will require extraordinarily sensitive data collection throughout the detector. The tracker will consist of 20,000 individual straws. In order to minimize downtime on the experiment in the event of straw failure, each wire in the Mu2e tracker needs the ability to be turned off individually and without physical access to the detector.



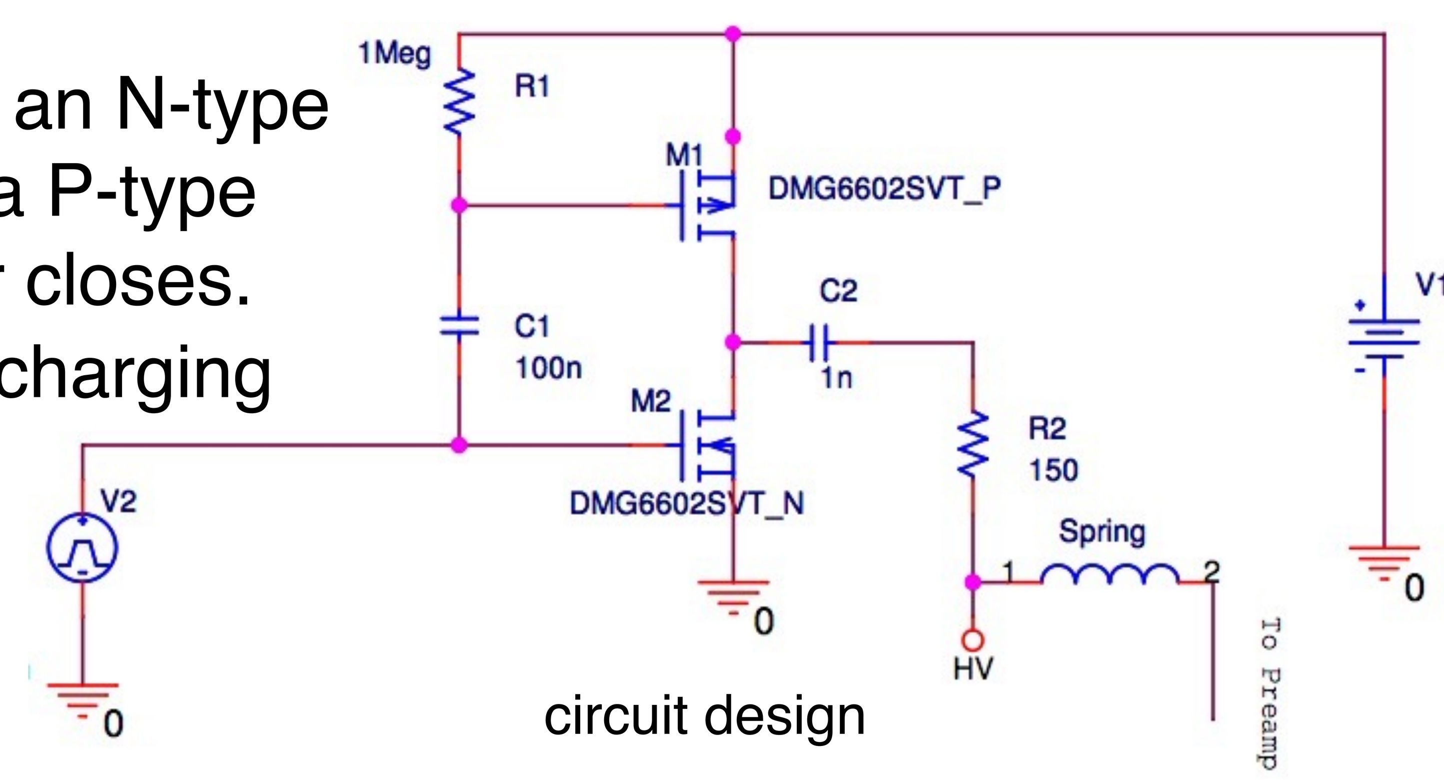
the production, transport, and detector solenoids for Mu2e; tracker shown in yellow



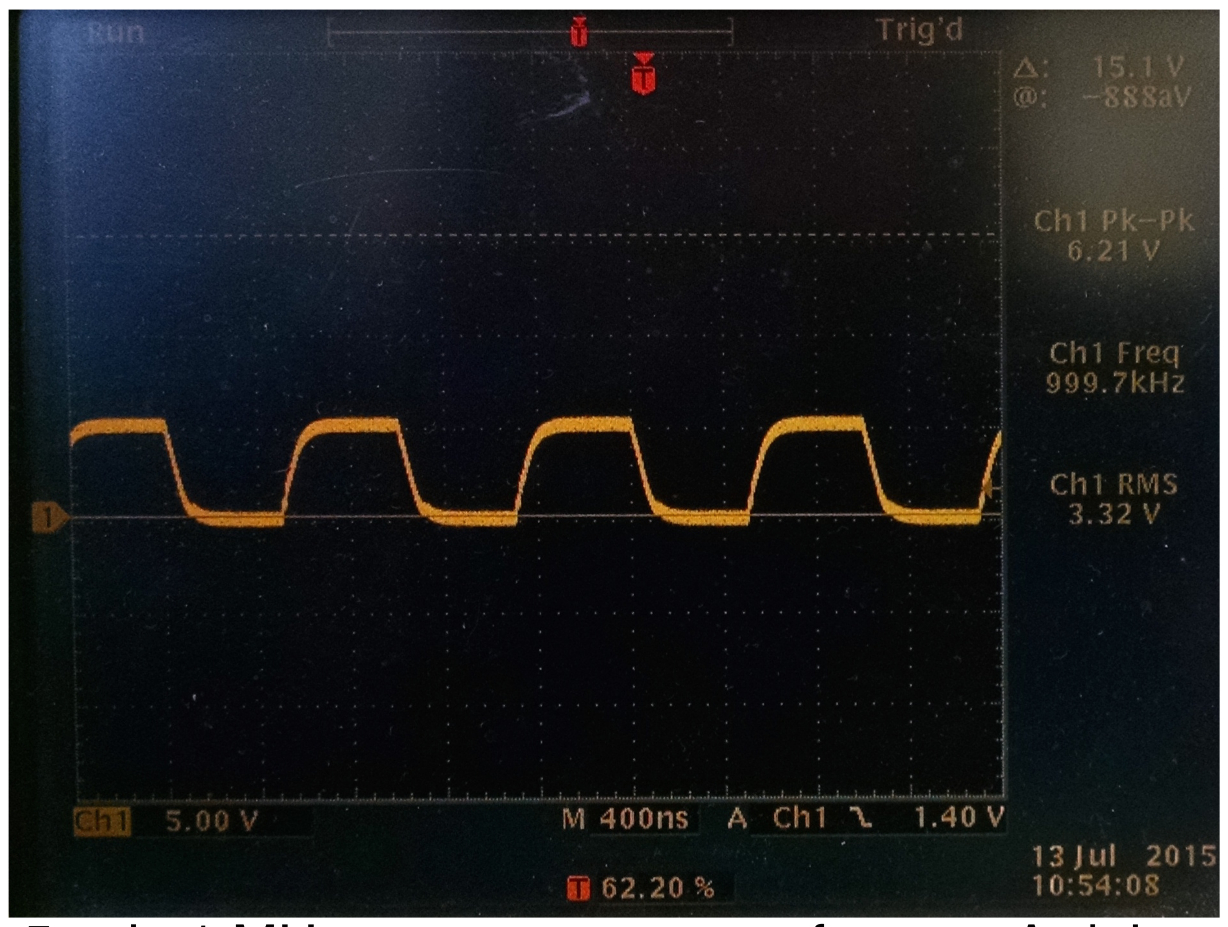
1 nF capacitor, 150 ohm resistor, and beryllium-copper torsion spring on a preamplifier board

This will be accomplished through the use of a fuse that can be blown remotely. The wire in each straw will operate at 1500 volts, so the fuse mechanism will have to be robust enough to reliably pass high voltage and be isolated from the low-voltage slow controls that will trigger the fuse. It also must be small enough to fit on the preamplifier board that is mounted at the end of each straw. A small beryllium-copper torsion spring is used to pass the high voltage. One side is soldered with a low-temperature solder to the side of a 150 ohm resistor. By dissipating enough power across the resistor to heat it and melt the solder, the spring deflects and disconnects the high voltage. In order to protect the slow control circuitry implemented in a microcontroller, a 1 nanofarad capacitor is used in front of the resistor.

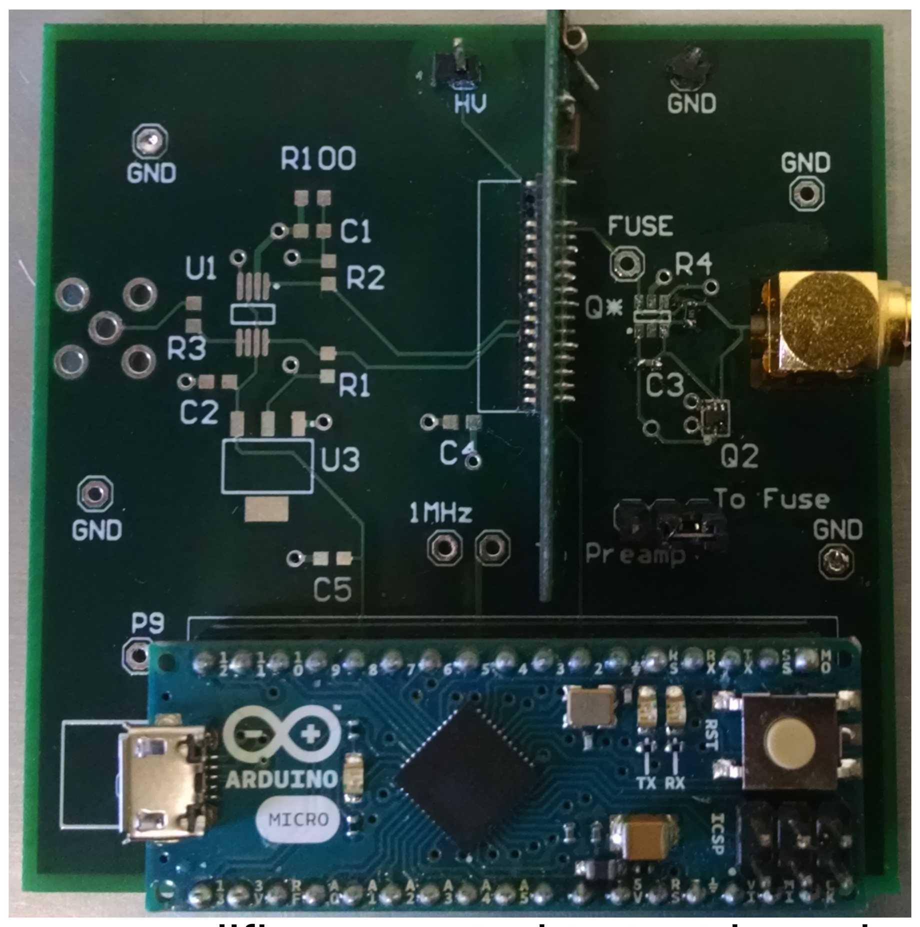
The microcontroller sends a 5 volt, 1 megahertz square wave to the gate of an N-type enhancement mosfet, and across a 100 nanofarad capacitor to the gate of a P-type enhancement mosfet. These switch in tandem, opening one when the other closes. This allows 36 volts from a connected power supply to flow back and forth, charging and discharging the 1 nanofarad capacitor and sending 10 volts RMS across the 150 ohm resistor. This dissipates 667 milliwatts across the resistor, reliably heating it enough to melt the low-temperature solder and trip the fuse.



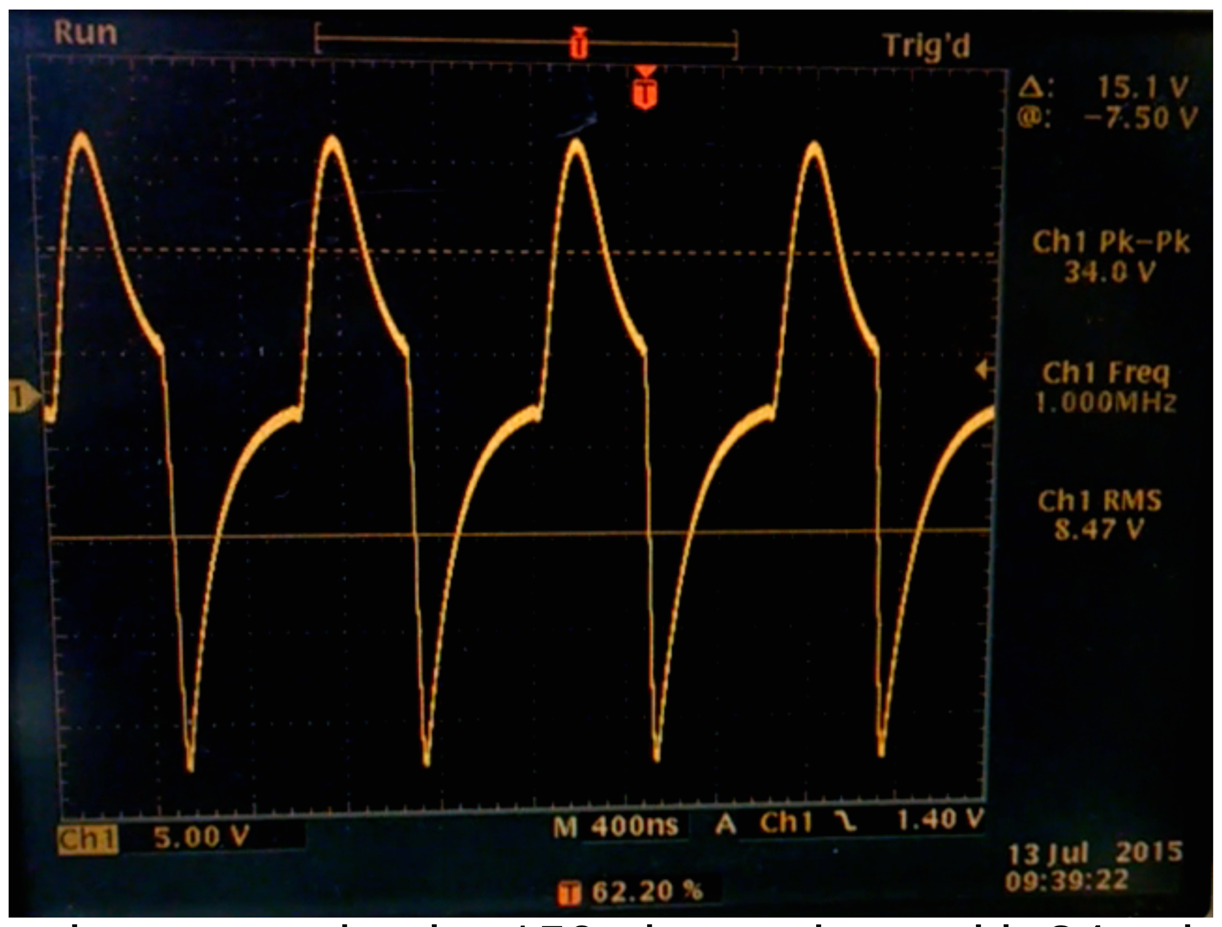
circuit design



5 volt, 1 MHz square wave sent from an Arduino



preamplifier mounted to test board with an Arduino microcontroller



voltage seen by the 150 ohm resistor with 34 volts connected at V1

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