

# **Adjustable Line Voltage Limiter Uses a Ground Fault Circuit Interrupter**

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Voltage limiters using varistors are commonly used to limit the amplitude of short duration voltage spikes lasting typically less than 10 mSec. When protection is required against long duration over-voltages, where the line voltage reaches over 130V for seconds or minutes, then another solution must be used. This can happen when the neutral wire at the distribution panel makes erratic connection, or when voltage bumps occur on the distribution network. Other applications also include over-voltage protection on AC generators.

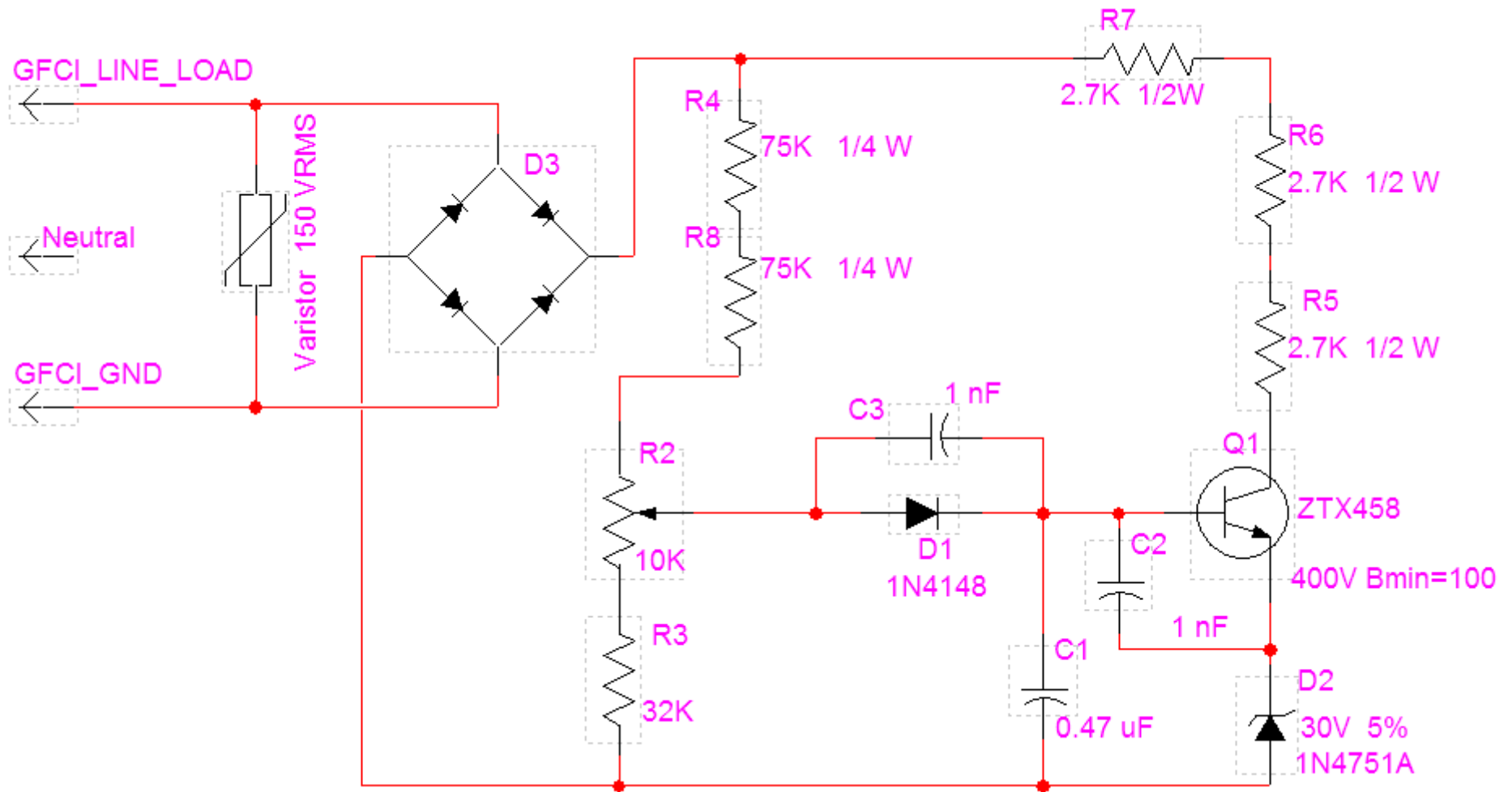
A GFCI (Ground Fault Circuit Interrupter) may be used to implement over-voltage protection since it has a fast response time of less than 25 mSec when responding to ground currents over 5 mA. The circuit (fig. 1) is connected between the GFCI load side and ground. An over-voltage will cause the circuit to draw an AC current above the 5 mA trip limit of the GFCI and trigger it, disconnecting its own outlet and the remaining downstream outlets. At normal line voltage, say 120V, transistor Q1 is barely conducting and this residual current (about 0.7 mA) comes from resistors R4, R8, R2 and R3.

When the line voltage increases to over 120 V, transistor Q1 starts to conduct a small fraction of every half cycle of the line period. Capacitor C1 and diode D1 stretch these current pulses. Resistors R4, R8, R2 and R3 make up an adjustable voltage divider with R2 allowing adjustment of the limiter voltage. The divider total resistance is a compromise between low residual current and a sharp knee in the voltage vs current curve of this circuit. Typically Q1 will start to conduct just above 120V and trigger the GFCI at 133V, (fig. 2). Q1 collector resistors R5, R6 and R7 limit the current to less than 20 mA peak. They are series connected to increase power dissipation and divide the peak voltages such that the maximum allowable voltage across the resistors is less than 200V under line transient conditions. The varistor at the input will clamp any short duration pulse to less than 400V, protecting transistor Q1. Zener diode D2 sets Q1 threshold level of conduction. A 1W diode is used at D2 having a 40 ohm dynamic impedance to minimize reduction of the transistor effective current gain. Capacitors C2 and C3 shunt the D1 and Q1 base-emitter junction to prevent false activation by stray RF fields. This circuit is easily implemented on a small PCB at the rear of the GFCI. It can also be fit in an electrical enclosure and connected to an existing GFCI outlet using a standard three-prong plug.

Note that this circuit will not prevent the GFCI from performing its normal protection against ground faults.

Additional details may be found at: <http://ve2azx.net/VoltageLimiter.pdf>

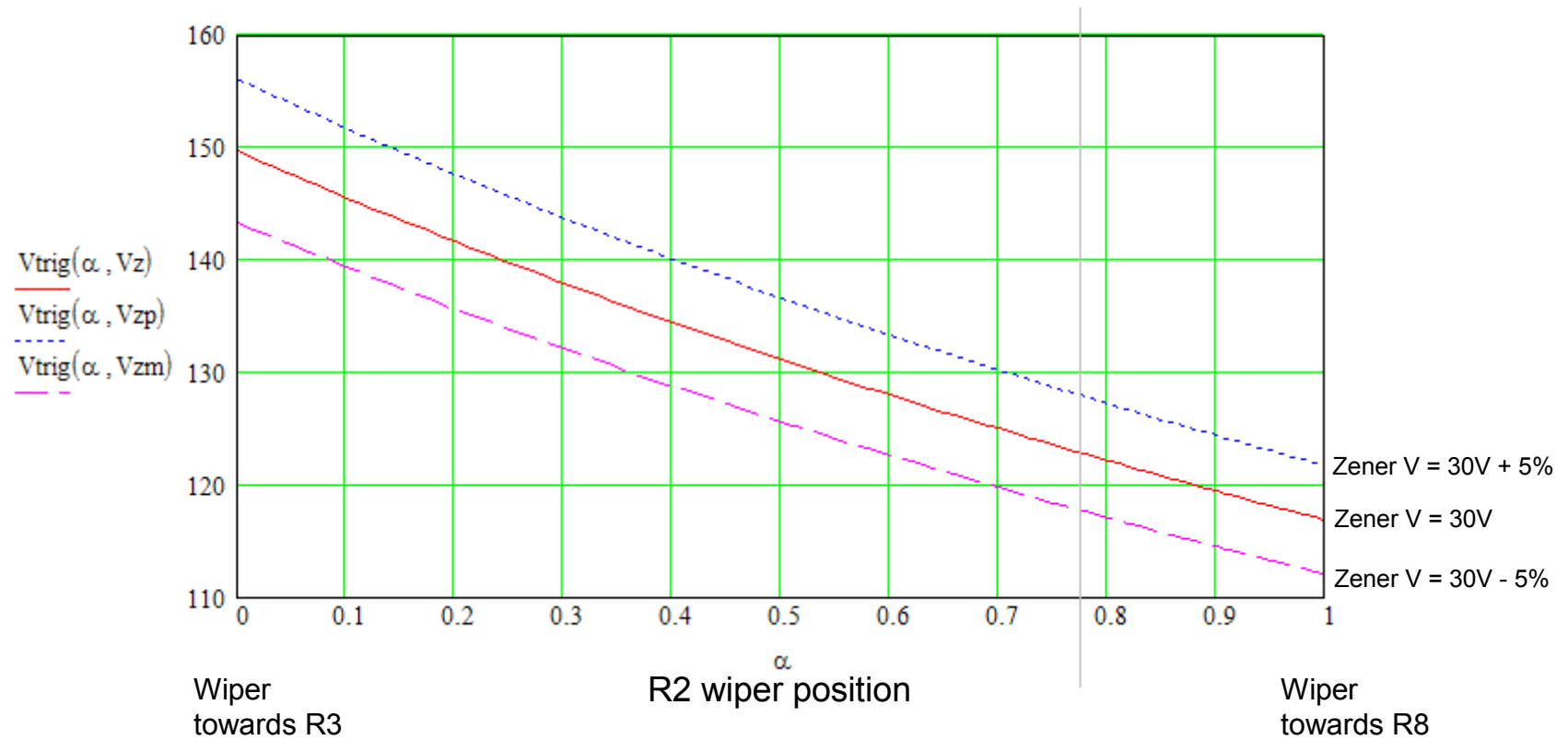
# Circuit Schematic



# Range of Adjustment of the Trigger Threshold vs R2 pot position

Ref: LimiteurVoltage.mcd

Divider: 150K – 32K

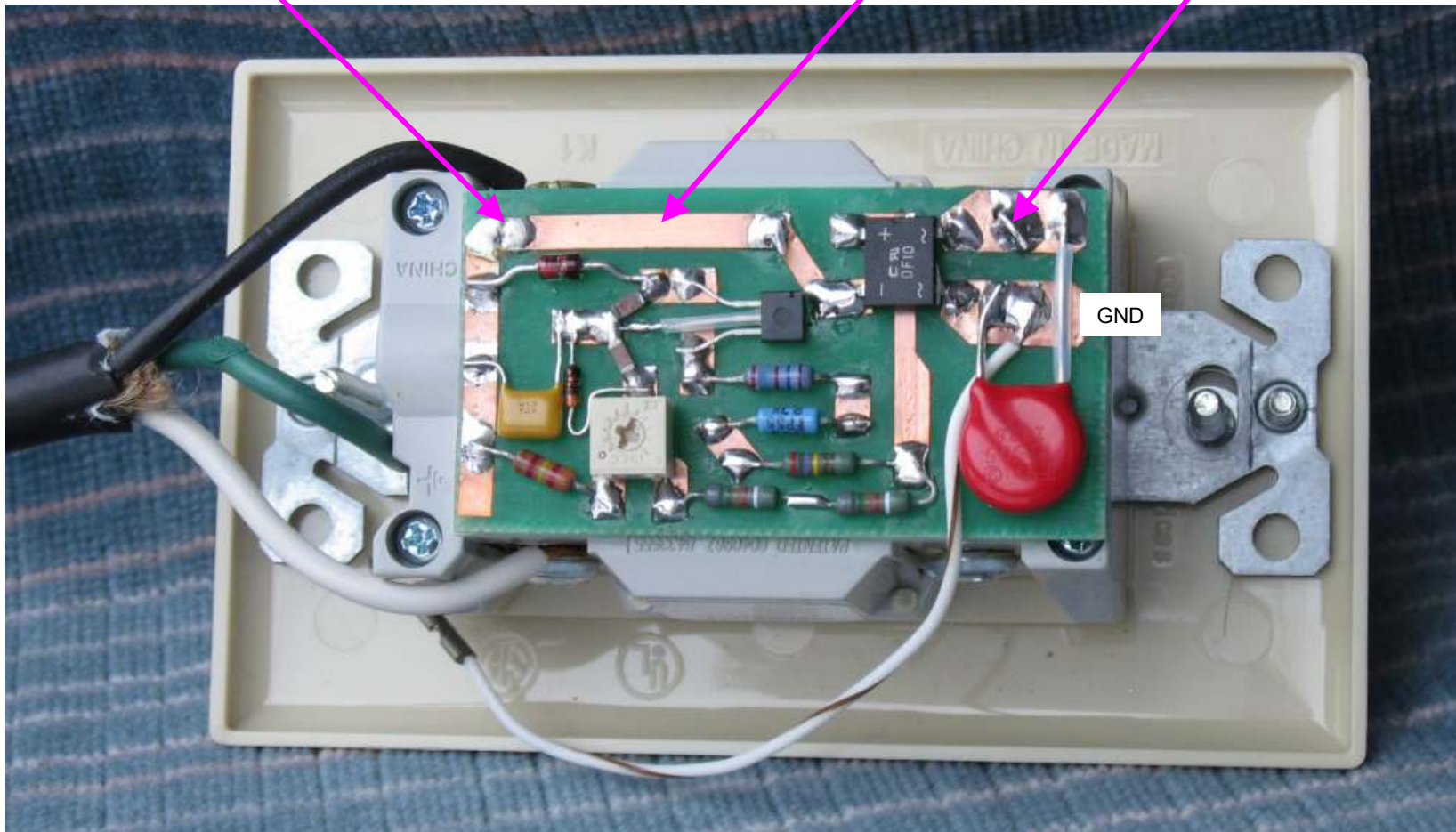


## Top view

Make a solder bridge between traces.  
Solder will not flow under the trace.

0.125 in. Wide  
copper tape

Wire #16 ou 18 thru PCB  
to connect at LINE - LOAD

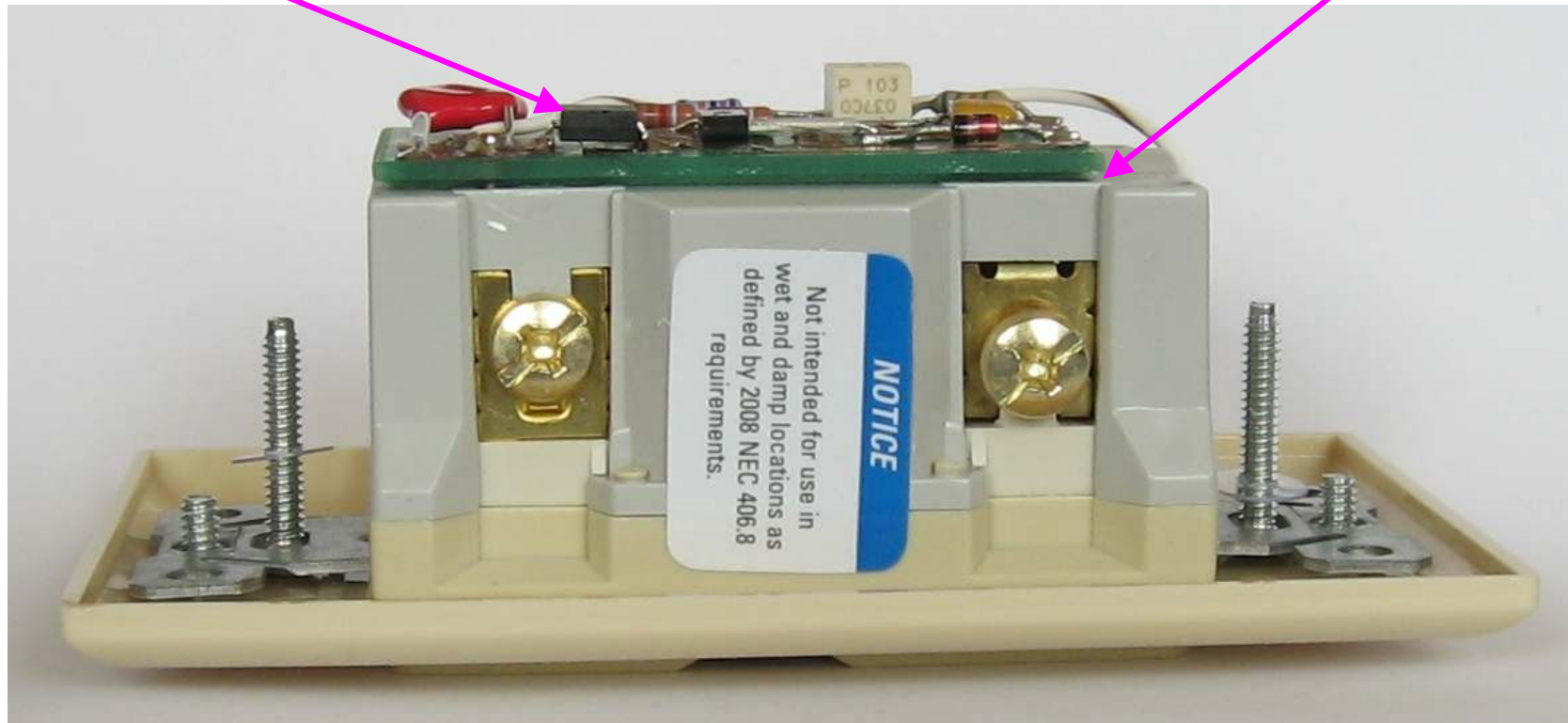


Note: Before soldering, polish copper traces using fine sandpaper.

## Side View

Bend the 4 pins of the  
rectifier bridge.

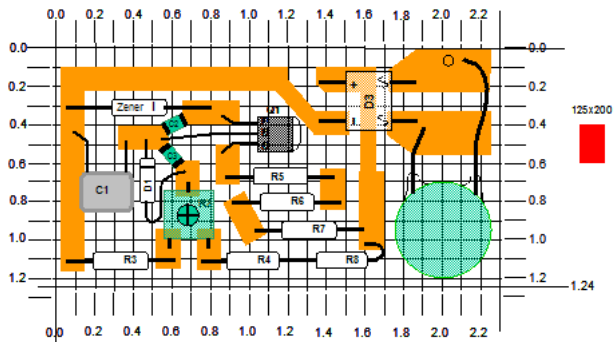
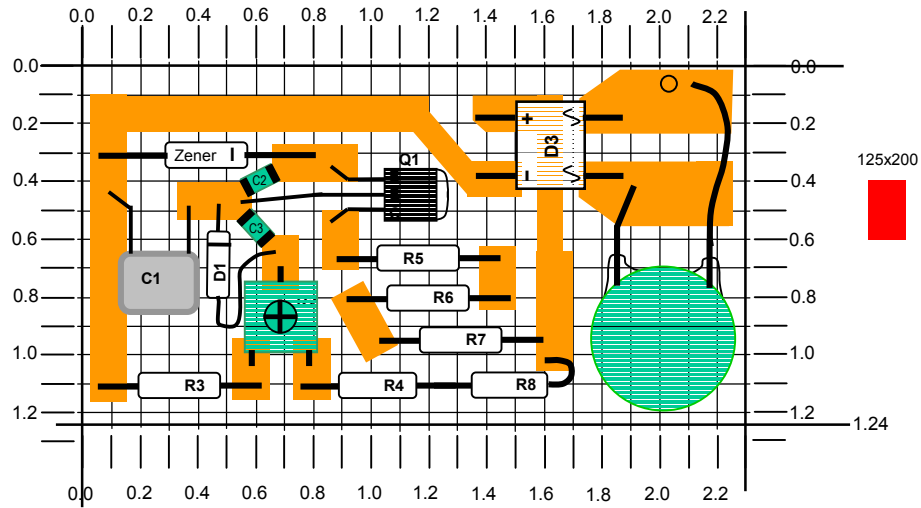
Foam tape was  
used to hold the PCB.



GFCI made by: Cooper Wiring Devices

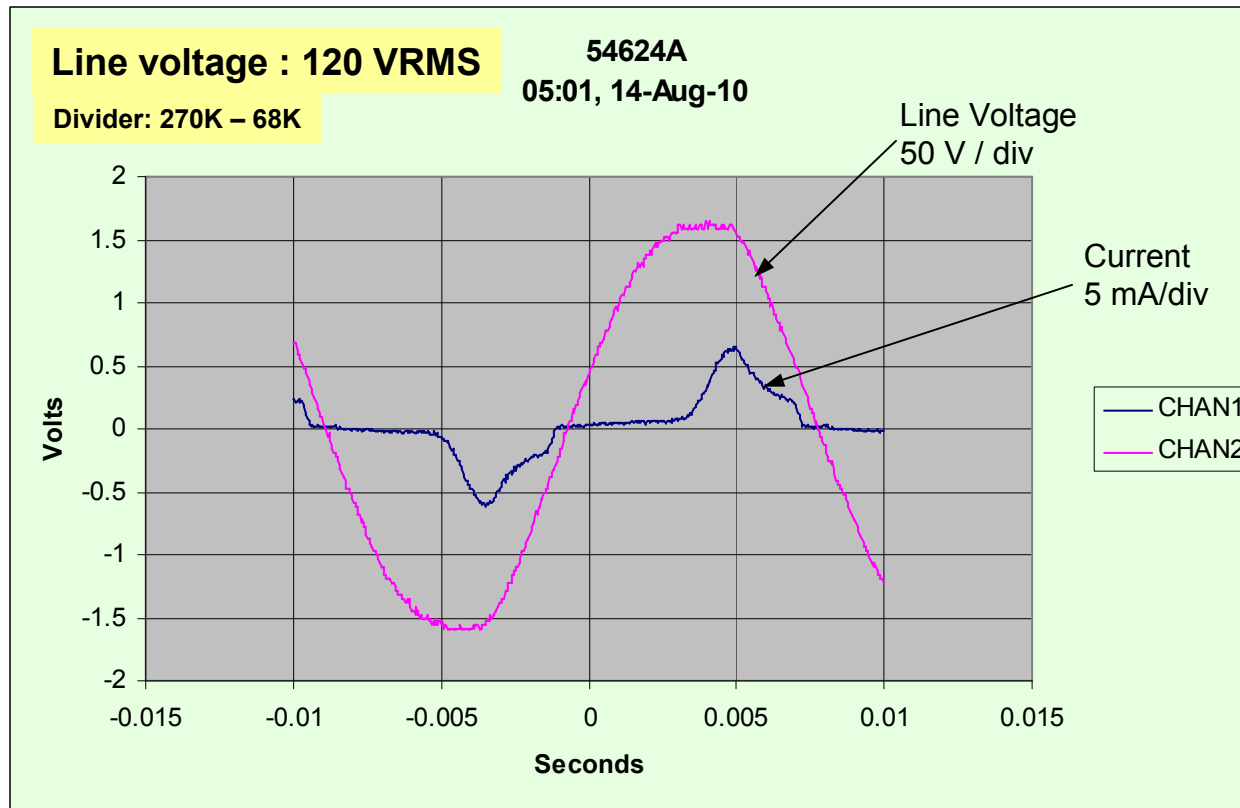
<http://solutions.cooperwiringdevices.com/common/brands.cfm?pg=Detail&brandName=CWD%20Residential&category=Receptacles:%20GFCI&id=17946>

# PCB Layout



Print this sheet. The bottom circuit should be approx. actual size. Useful during construction to verify the actual dimensions.

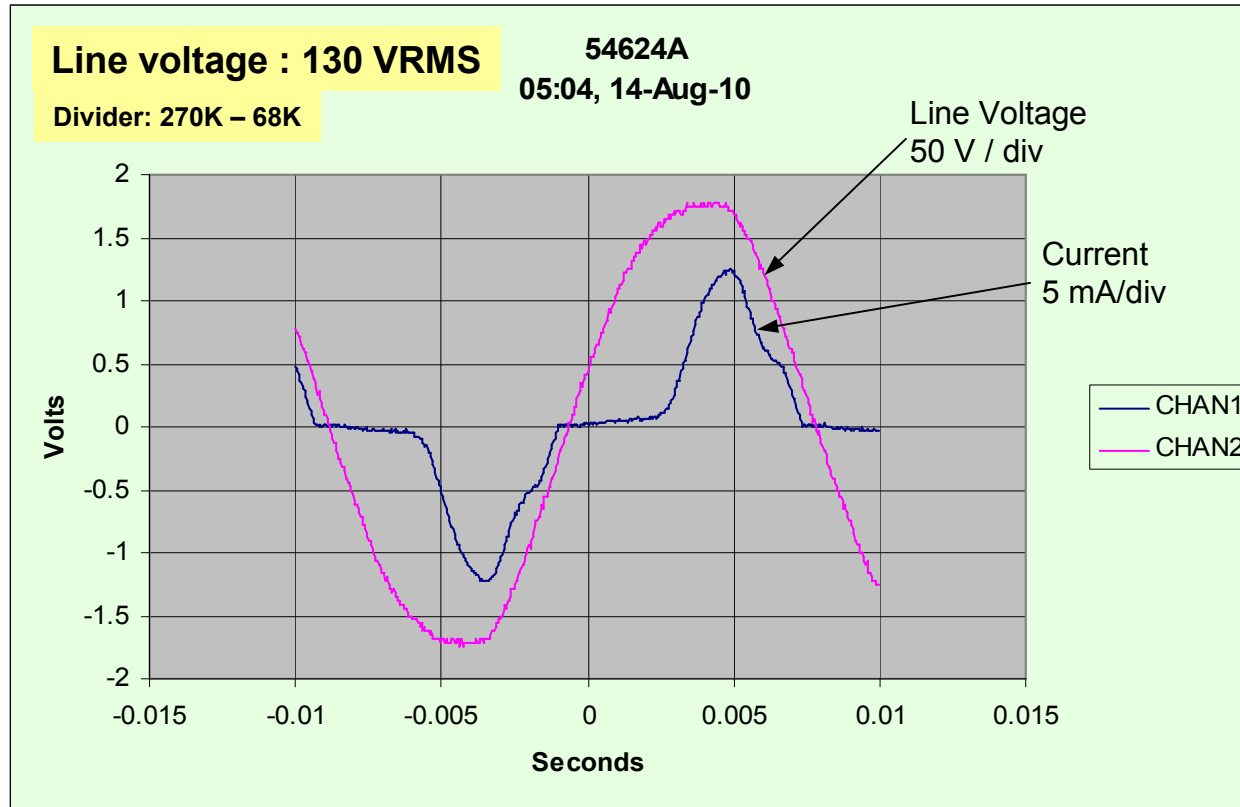
Waveforms of line voltage and limiter current using  
Voltage divider R4+R8, R3: 270K – 68K



Measured RMS current = 2.5 mA

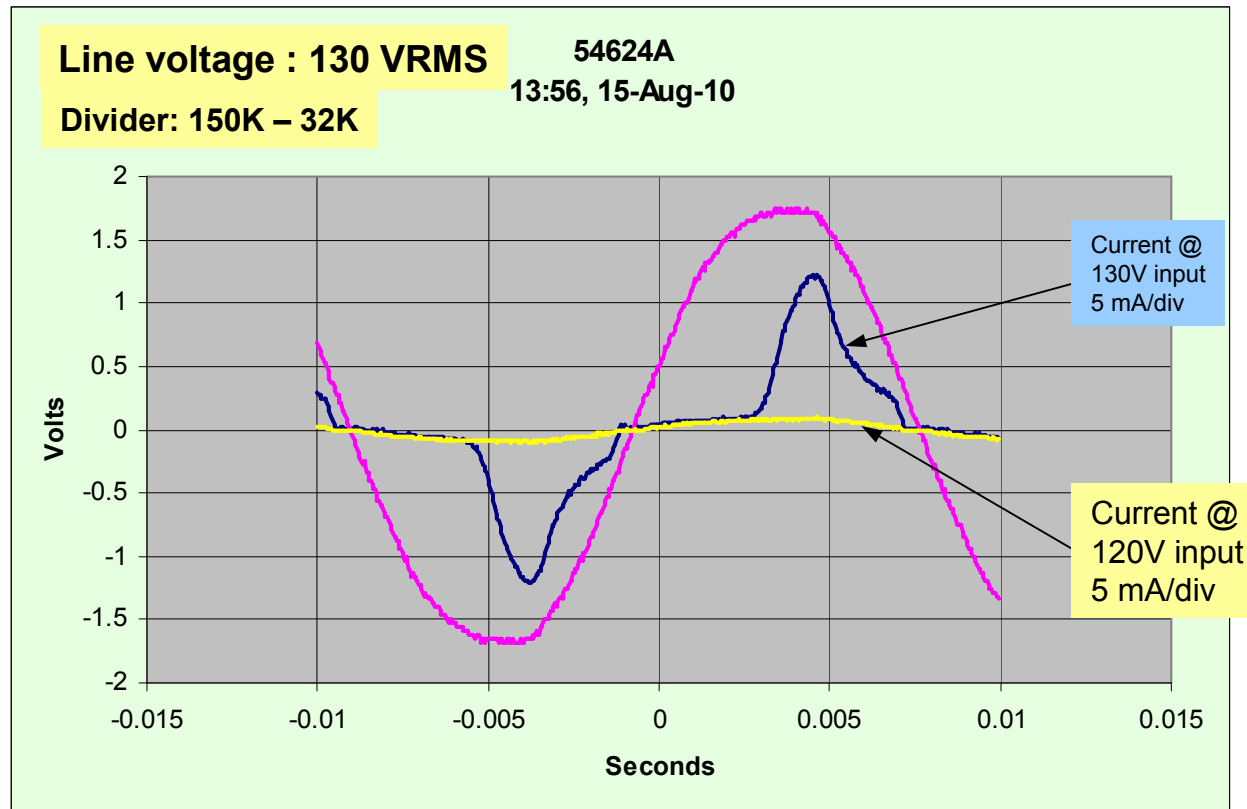


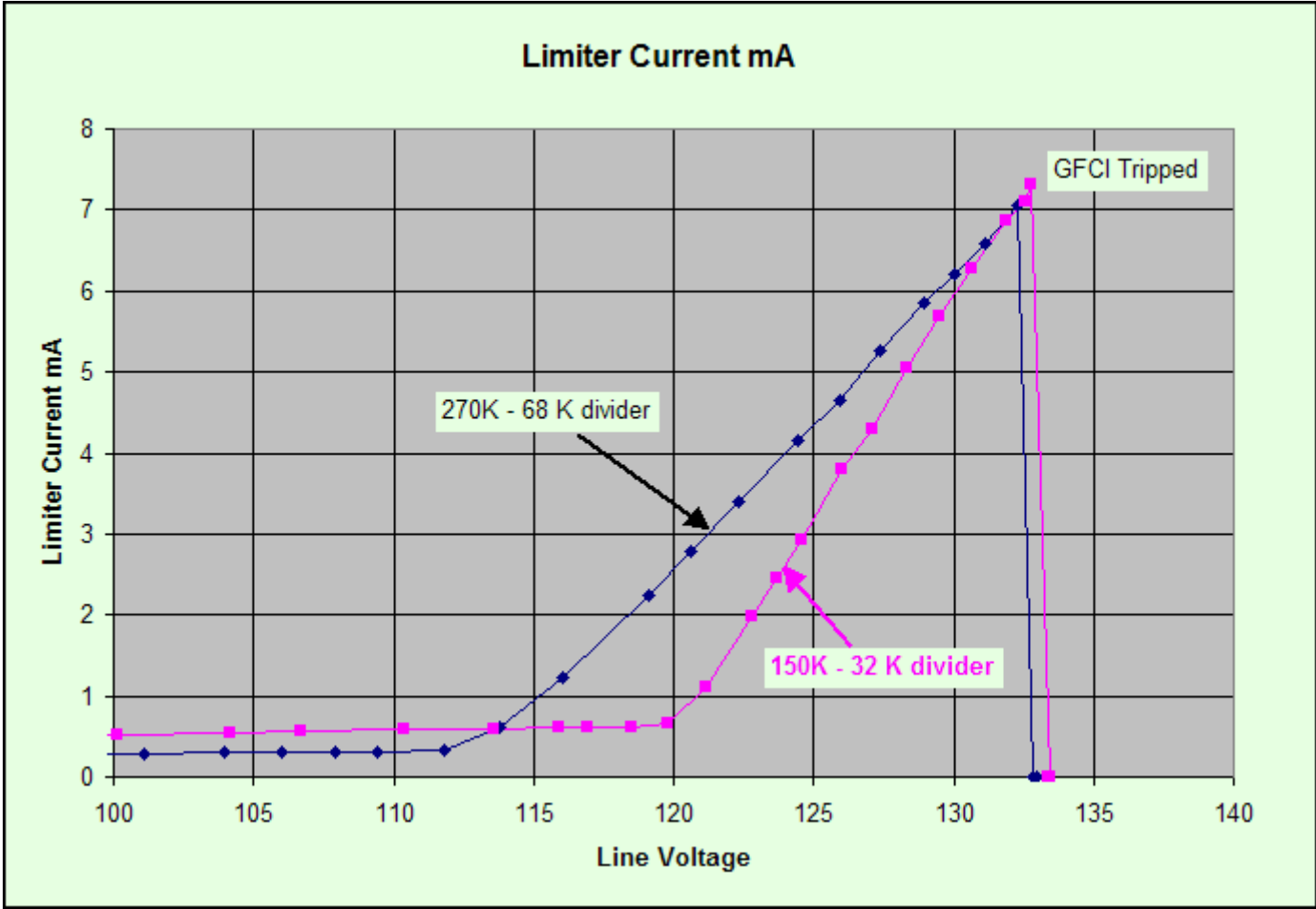
Waveforms of line voltage and limiter current using  
Voltage divider R4+R8, R3: 270K – 68K



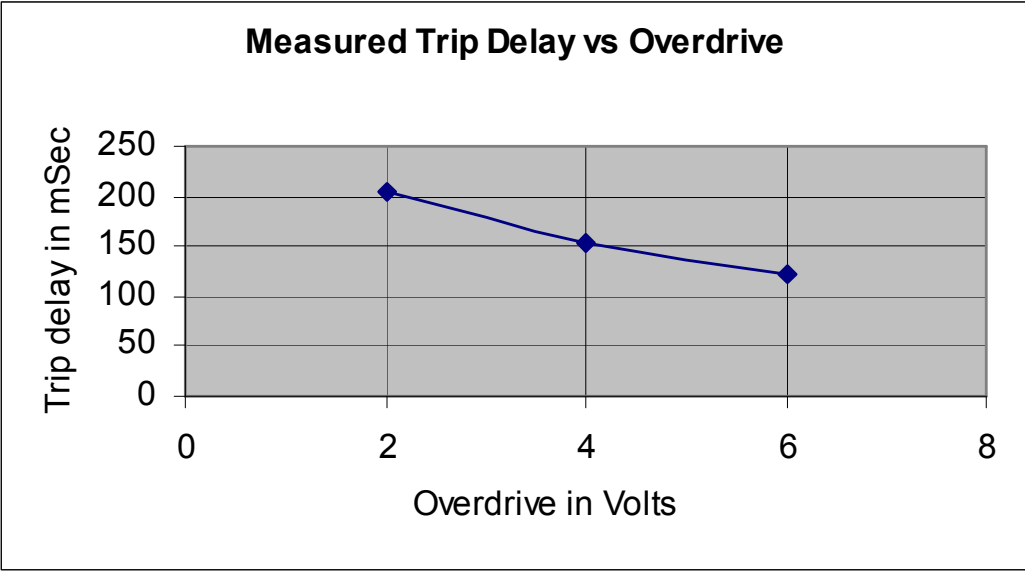
Measured RMS current = 7 mA

Waveforms of line voltage and limiter current using  
Voltage divider R4+R8, R3: 150K – 32K





The lower impedance divider (150K – 32K) gives a steeper slope, with Q1 hardly conducting at 120 V. This value has been used in this design.



## NOTES

The peak/RMS current required by the GFI will vary depending on the manufacturer. I tried 2 GFI's from two manufacturers and I based my design on the least sensitive that triggered at 14 mA peak, (or about 7 mA RMS. However both met the 5 +/-1 mA spec when the current is a sine wave)

As shown on pages 8 to 10, the current waveform is far from a sine wave. Transistor Q1 only starts to conduct for voltages above 120 V RMS as shown in the graph on page 11. Its current waveform will be close to zero for the first 80 degrees, then quickly rise to its peak value and start decaying after 110 degrees. This gives a measured average total power in resistors R5, R6 and R7 of 0.5 Watts at 130 V and 0.95 Watts at 133 V input. (the set trigger level). This distorted current waveform gives a 4 to 1 peak to average power ratio, instead of the usual 2 to 1 ratio for sine waves.

The average power dissipated in the collector resistors R5, R6 and R7 is found by multiplying and summing the instantaneous values of voltage and current for half a cycle. The average power is found by dividing the sum obtained by the number of points. This exercise should be done for the particular brand of GFI used, to insure that the dissipation in resistors R5, R6 and R7 is not exceeded should the line voltage run just below the trigger point for some time.