A Noise Canceling Electronic Edge Finder, version 2.1

By R. G. Sparber

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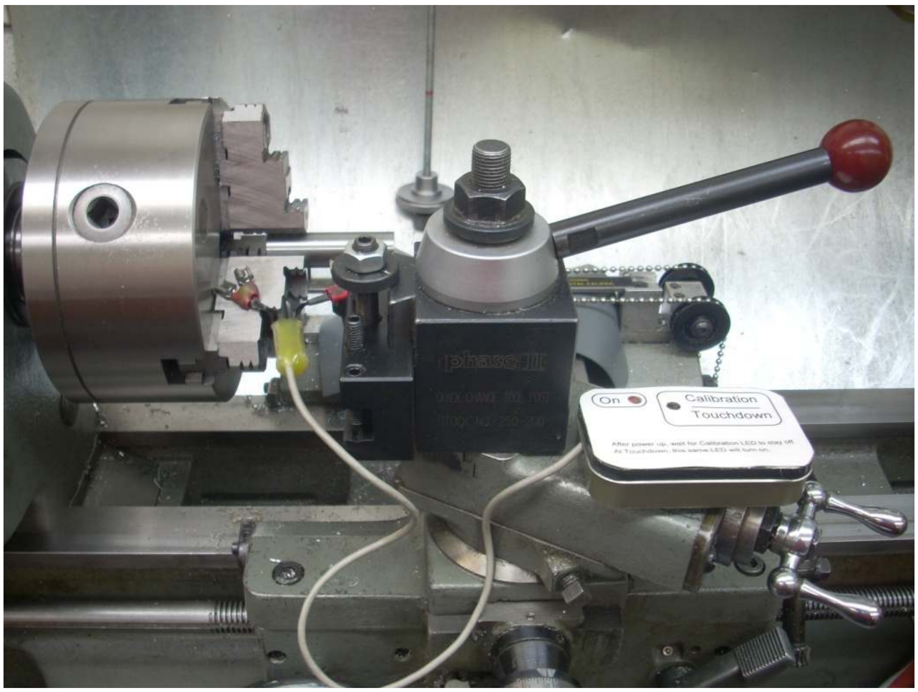

This is the third in a series of designs that address the problem of detecting touchdown of the cutter on a work piece mounted on a lathe.

The first design[2] works for lathes with spindle bearing resistances greater than 2 ohms[3] as found in many hobby grade lathes. The second design[4] works for lathes with resistances greater than 0.01 ohms which can be seen in commercial grade lathes and those with sleeve or Babbitted bearings . The version presented in this article also works with spindle bearing resistances greater than 0.01 ohms plus tolerates a large amount of electrical noise radiated from the power line.

The current that passes through the spindle bearings is 20 milli amps at a maximum voltage of 0.7V.

Mark Cason has developed a circuit board and plans to sell finished devices.

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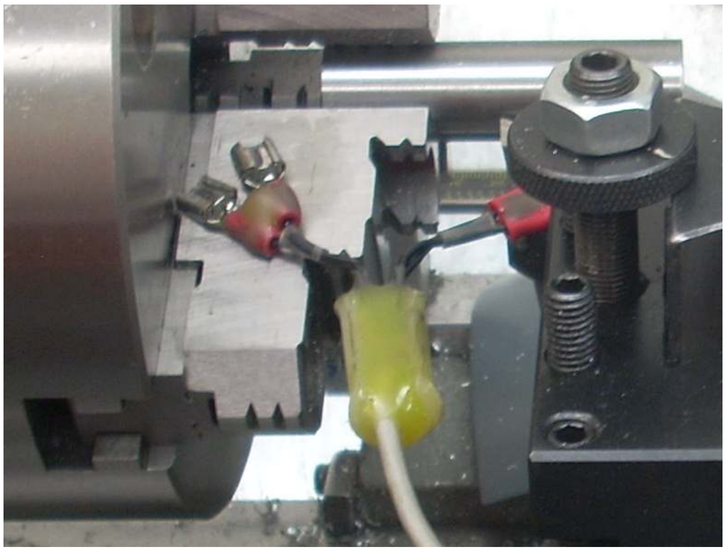
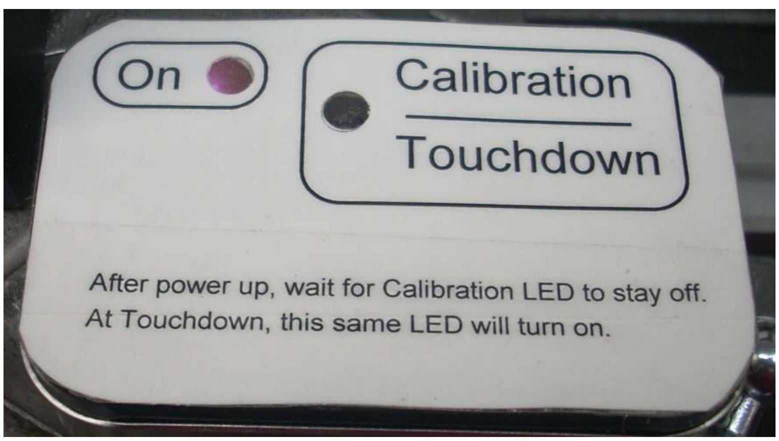
[1] You are free to copy and distribute this document but not change it.
[2] http://rick.sparber.org/rctf.pdf for details.
[3] See http://rick.sparber.org/ueef.pdf for an explanation.
[4] See http://rick.sparber.org/sceef.pdf for details.

Operation



The EEF has two probes each with two magnetic clip. These probes are stored on the non-conductive top of the EEF's enclosure.

In preparation for detecting touchdown, one probe is placed on the chuck while the other probe goes on the tool holder. This action automatically powers up the EEF and starts the "Calibration" process.



The Calibration/Touchdown LED turns on while the circuit measures and compensates for the ambient electrical noise in the lathe plus the spindle to cutter resistance. This normally takes less than 10 seconds. When done, this LED turns off.

The EEF is then ready to detect touchdown. When the cutter comes in contact with the workpiece, the Calibration/Touchdown LED turns back on and stays on for at least 1 second.

Returning the probes to the top of the box powers down the EEF.

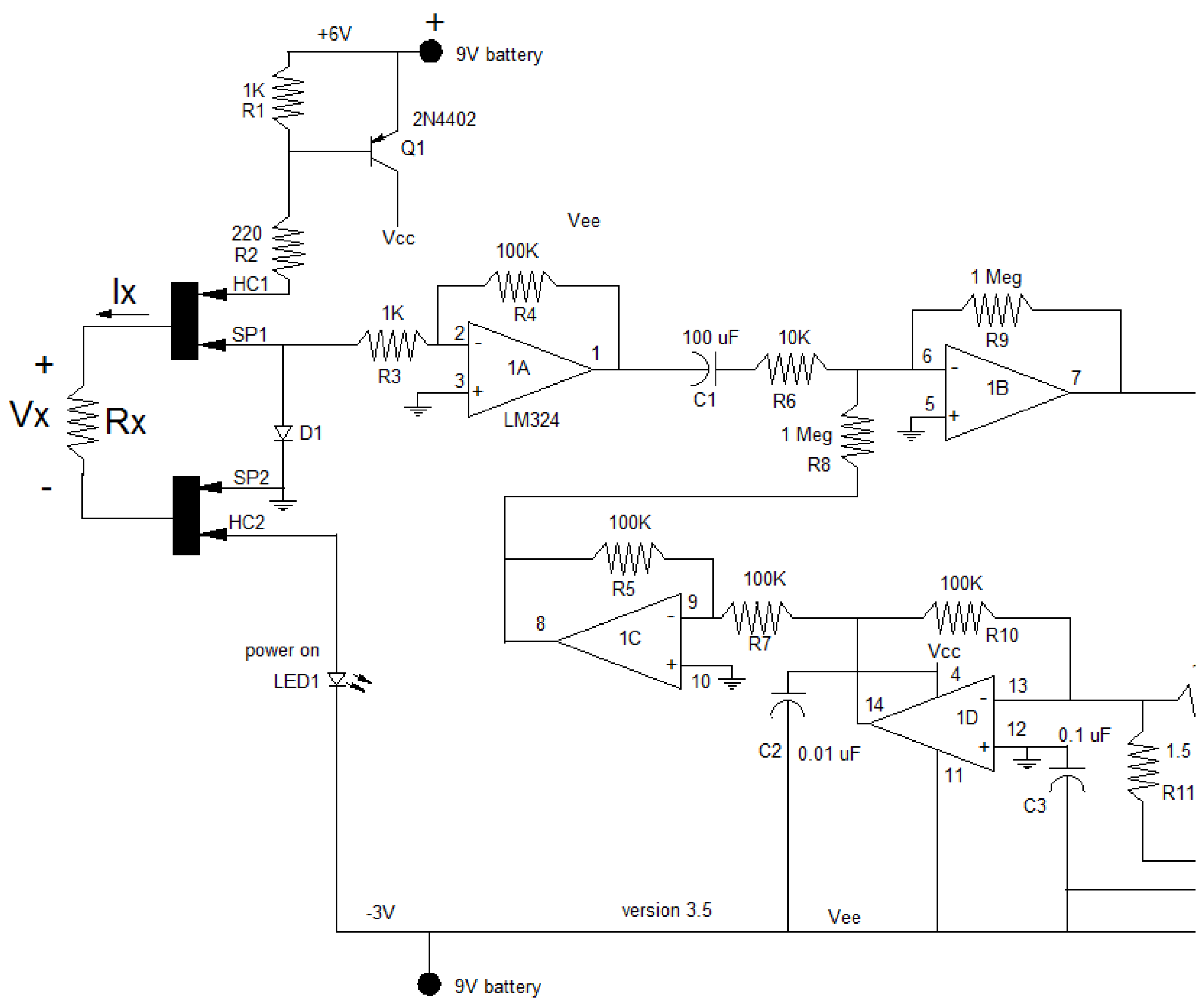
Schematic

The circuit was designed with an eye towards low cost and ease of obtaining parts. All resistors can be 1/8 watt except for R2 which should be ¼ watt. Note that C1 is non-polarized.

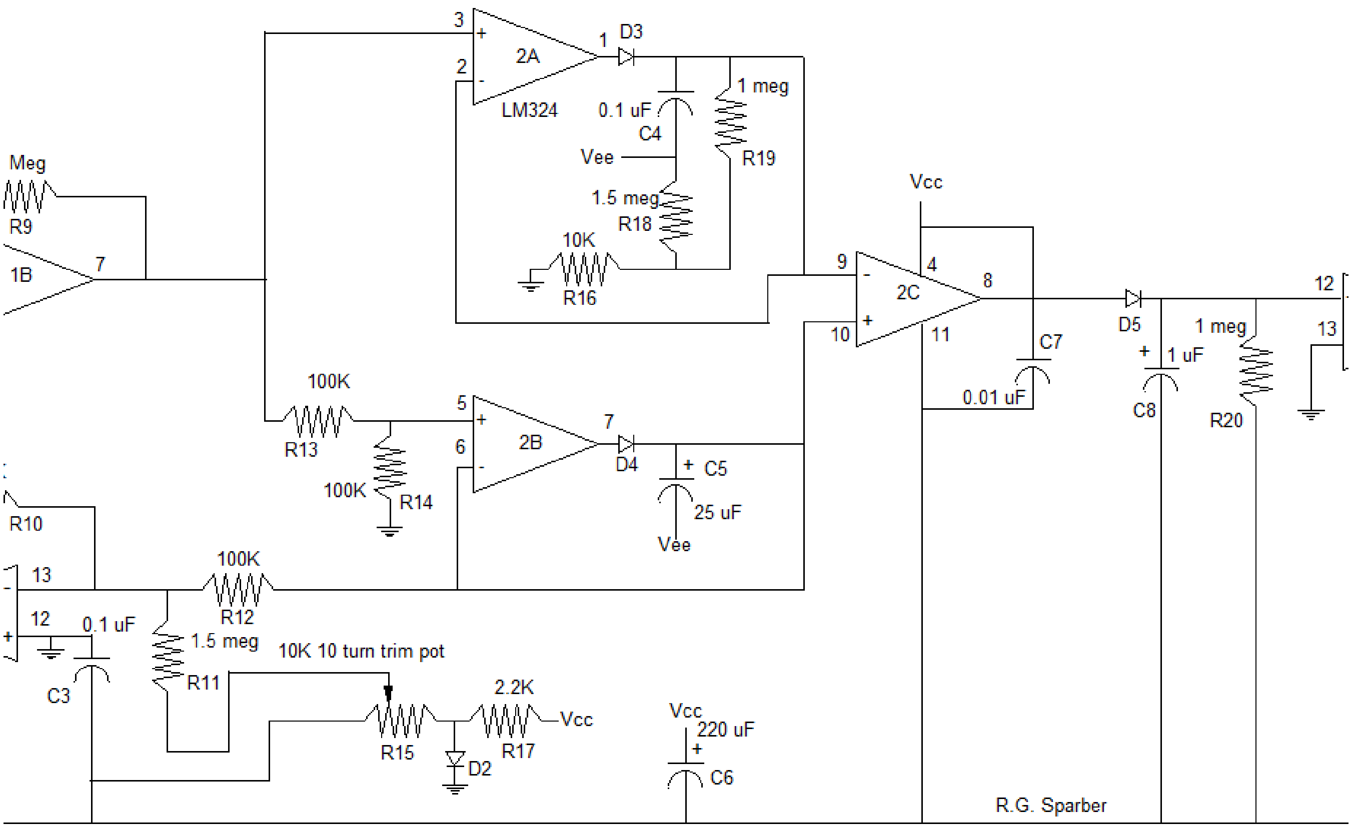
The PNP transistor plus the 4 diodes can be any low power type. The two LEDs are similarly common. I also employ two LM324 quad op amps. This is a very old design yet gets the job done. Best of all was the price of 25¢ each at Circuit Specialists®.

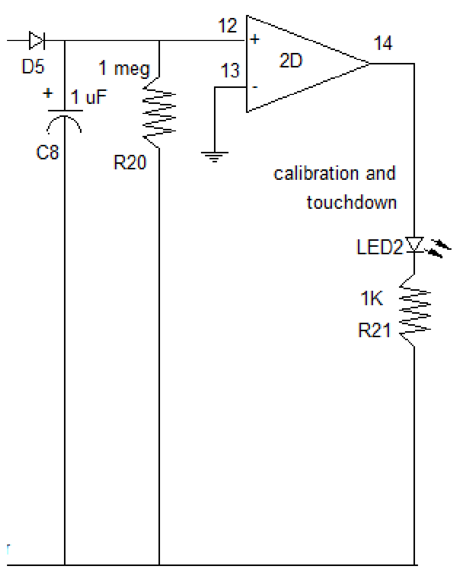
The probes were made from spade lugs with magnets inside[5].

I have broken the schematic into 3 parts to make it easier to see.



[5] See http://rick.sparber.org/electronics/mwc.pdf for details.


Meg
R9
1B
7
3
2
2A
LM324
1
D3
0.1 uF
C4
1 meg
R19
Vee
1.5 meg
R18
10K
R16
Vcc
9
4
2C
8
10
11
C7
0.01 uF
D5
1 meg
1 uF
C8
R20
12
13
100K
R13
5
6
2B
7
D4
C5
25 uF
Vee
100K
R14
R10
13
100K
R12
12
0.1 uF
C3
1.5 meg
R11
10K 10 turn trim pot
2.2K
Vcc
R15
D2
R17
Vcc
220 uF
C6
R.G. Sparber


D5
1 meg
1 uF
C8
R20
12
13
2D
14
calibration and
touchdown
LED2
1K
R21

Parts List

Resistors (±5%; 1/8 watt except as noted)

Value	Quantity	Places used
220 ohms ¼ watt	1	2
1K	3	1, 3, 21
2.2K	1	17
10K	2	6, 16
100K	7	4, 5, 7, 10, 12, 13, 14
1 Meg	4	8, 9, 19,20
1.5 Meg	2	11, 18
10K 10 turn trim pot	1	15

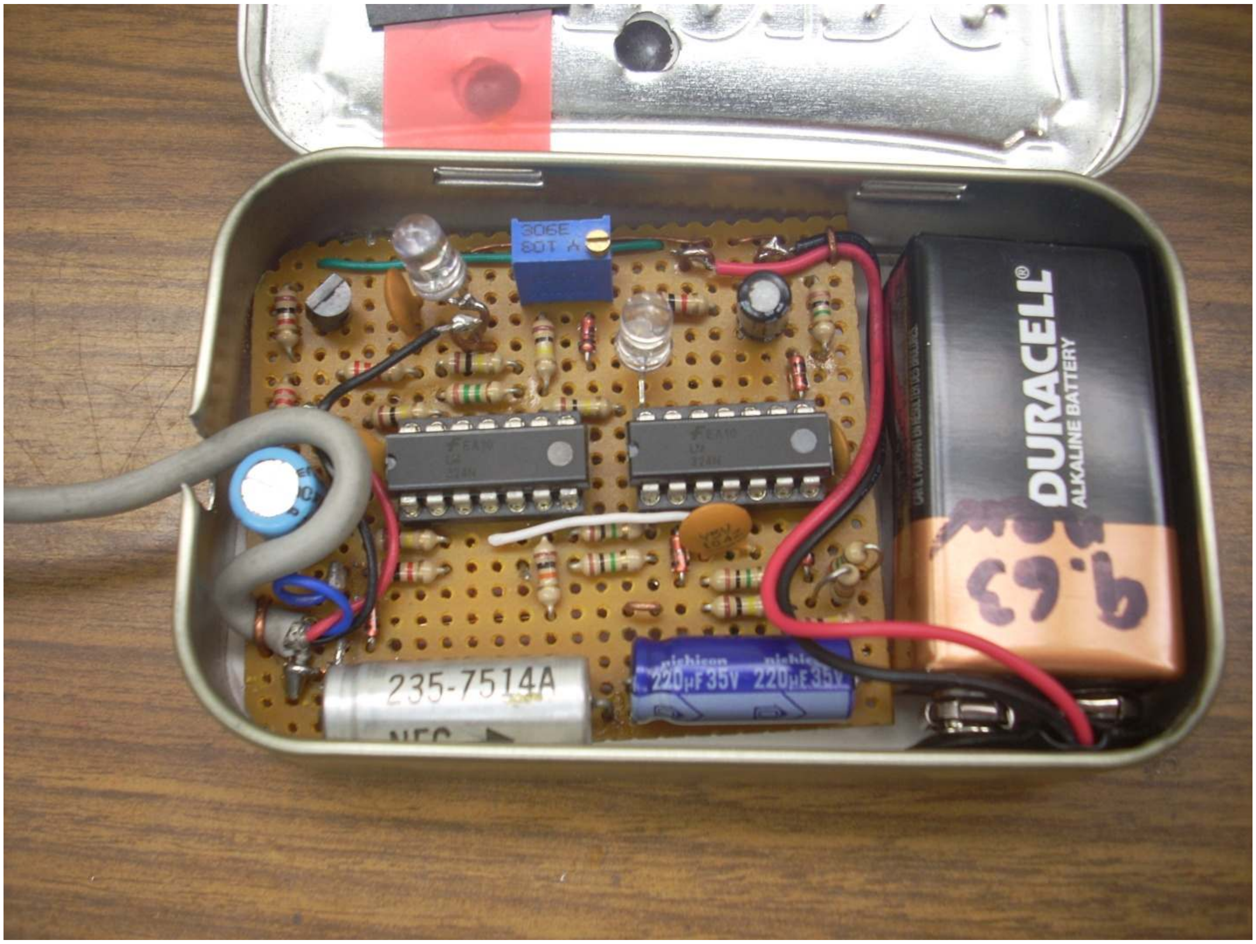
Capacitors

Value	Quantity	Places used
0.01 uf ceramic	2	2, 7
0.1 uf ceramic	3	3, 4, 8
1 uf 16V electrolytic	1	8
25 uf 16V electrolytic	1	5
100 uf 6V non-polarized	1	1
220 uf 16V electrolytic	1	6

Diodes

Description	Quantity	Places used
Super Bright white LED	2	LED1, LED2
general purpose signal diode	5	1, 2, 3, 4, 5

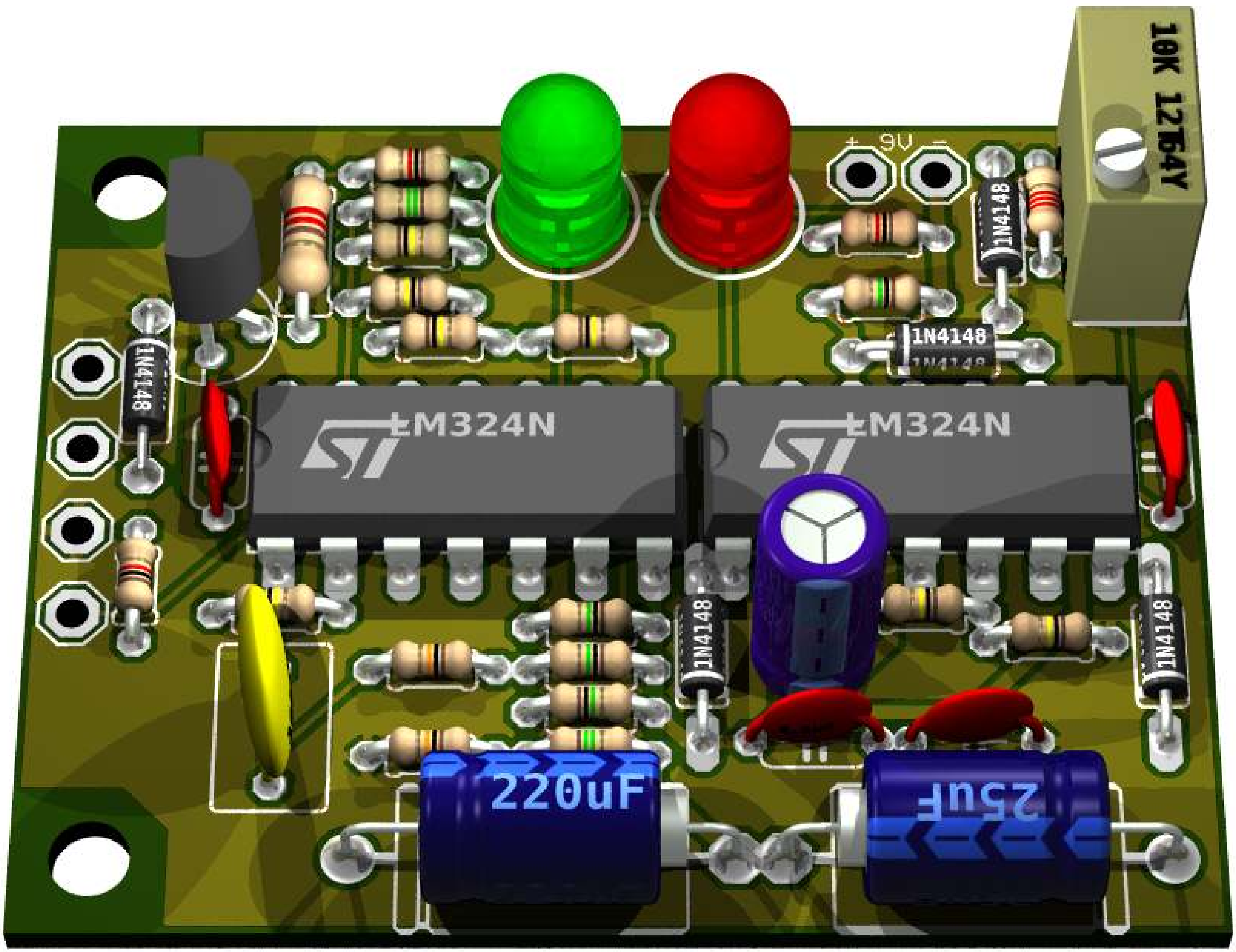
Transistor: 2N4402 (or any other general purpose PNP)
Integrated Circuit: two LM324 (a quad op amp)
Probes
9V battery connector
9V battery
Altoids® box (minus the candy…)
Perforated circuit board material or etched circuit board.



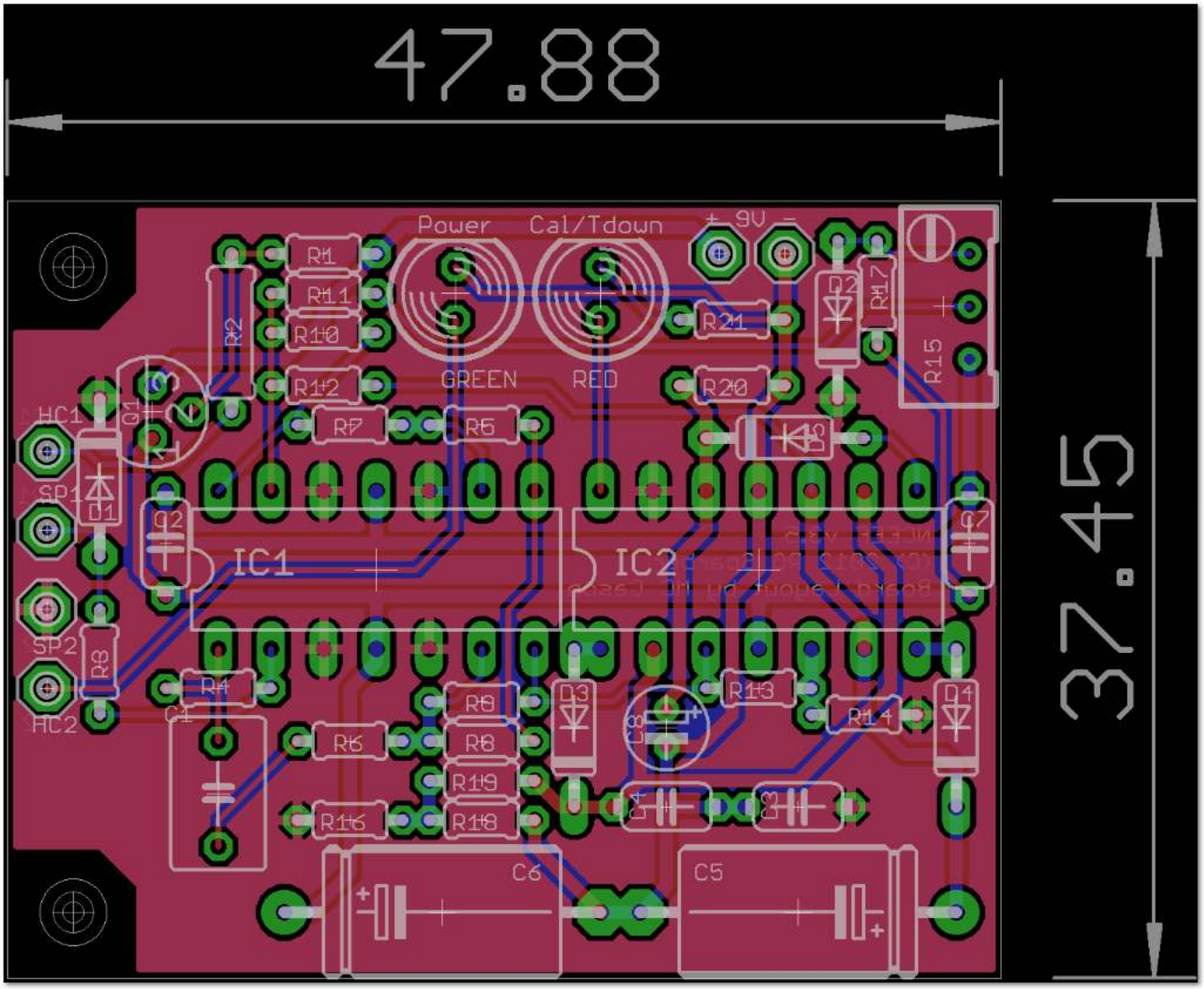
Here is my prototype using point to point wiring.

Mark Cason's Fine Work: 3D Rendering and Circuit Board

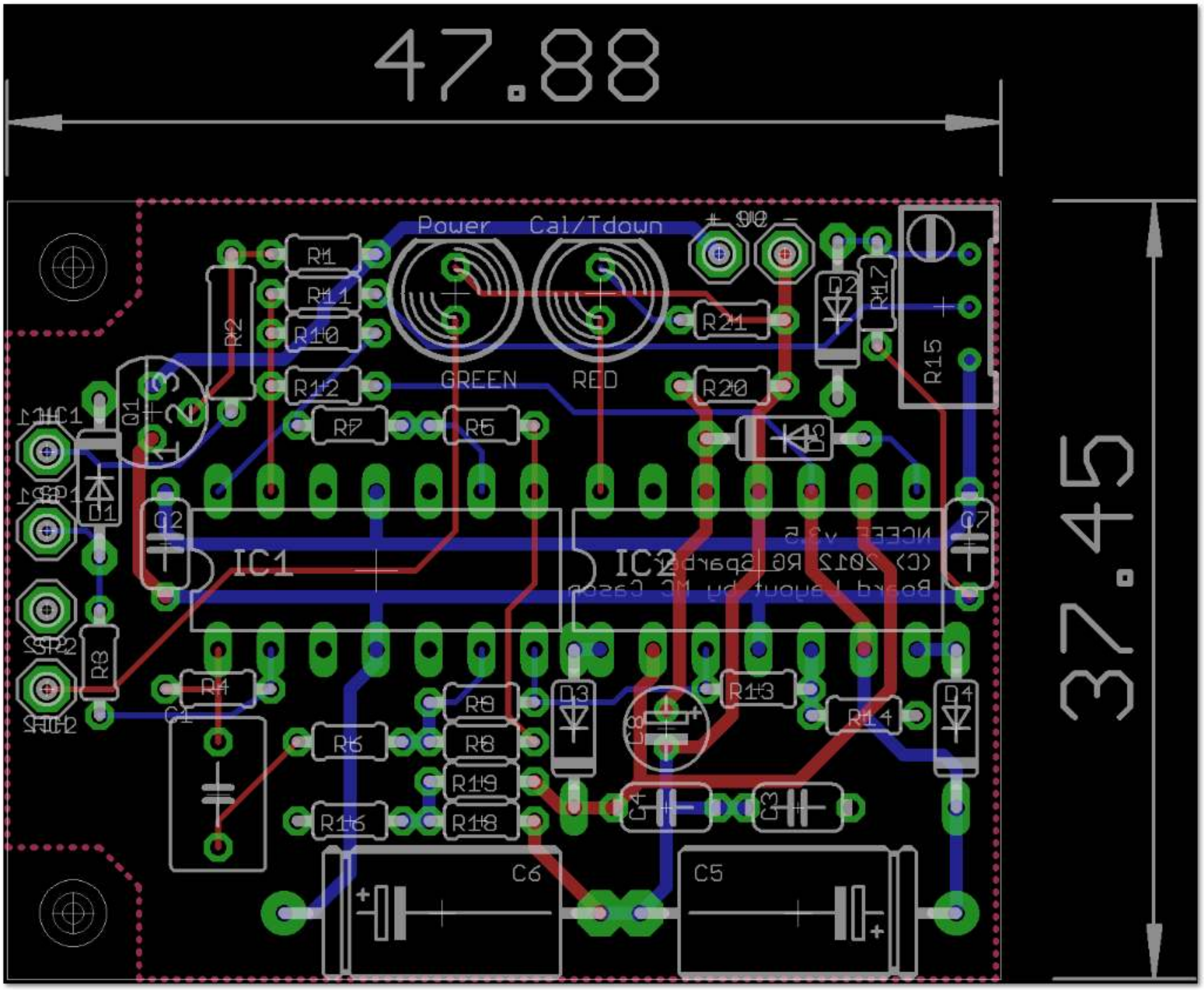
I have been very fortunate to have received a lot of help from Mark Cason. The following is the result.



This looks like a photograph but is actually a computer rendering of the finished product.



This is the top view of the double sided board Mark has developed. It also shows parts placement. The large red area is all ground.



This shows the bottom traces in blue and the top traces in red.

Theory of Operation

The EEF has two modes: Calibration and Touchdown.

During Calibration, the circuit measures the AC voltage between its probes and induced in the probe wires[6]. It also measures the resistance between the probes. It then generates a threshold that must be crossed during Touchdown. When done generating this threshold, it turns off the Calibration /Touchdown LED.

During Touchdown, the circuit measures the change in voltage caused by the cutter coming in contact with the work piece. This change can be as small as a few micro volts.

The AC noise is mostly 60 Hz although a much higher frequency voltage is also present. That tiny drop in voltage was seen by the circuit and triggered the change in output.

When no noise is present, the circuit can detect a 0.6 ohm touchdown in the face of a 0.01 ohm spindle bearing resistance. As the noise increases, a small decrease in sensitivity occurs. Details are provided in the Appendix.

The circuit is designed to see a sudden drop in voltage as touchdown. It cannot differentiate between real touchdown and high speed spikes radiated into the room. When the EEF was tested on a CNC mill, it reacted to every pulse of the drive motors rendering it useless.

I have tested the circuit in 3 home shops. One of these shops has both 220V and 3 phase run in plastic conduit. It was extremely (electrically) noisy around the 3 phase mill and 220V lathe. The circuit worked on the lathe but could not complete calibration on the mill.

Measurements on the lathe indicated that the noise level was about 30 times higher than the signal being detected[7].

Failure to complete the Calibration phase is an indication of varying electrical noise. Every time this noise changes amplitude, the circuit must calibrate to it. If you see the Calibration/Touchdown LED stay on or flickering, it is an indication of a constantly changing noise level. Look for a poor ground on the machine that

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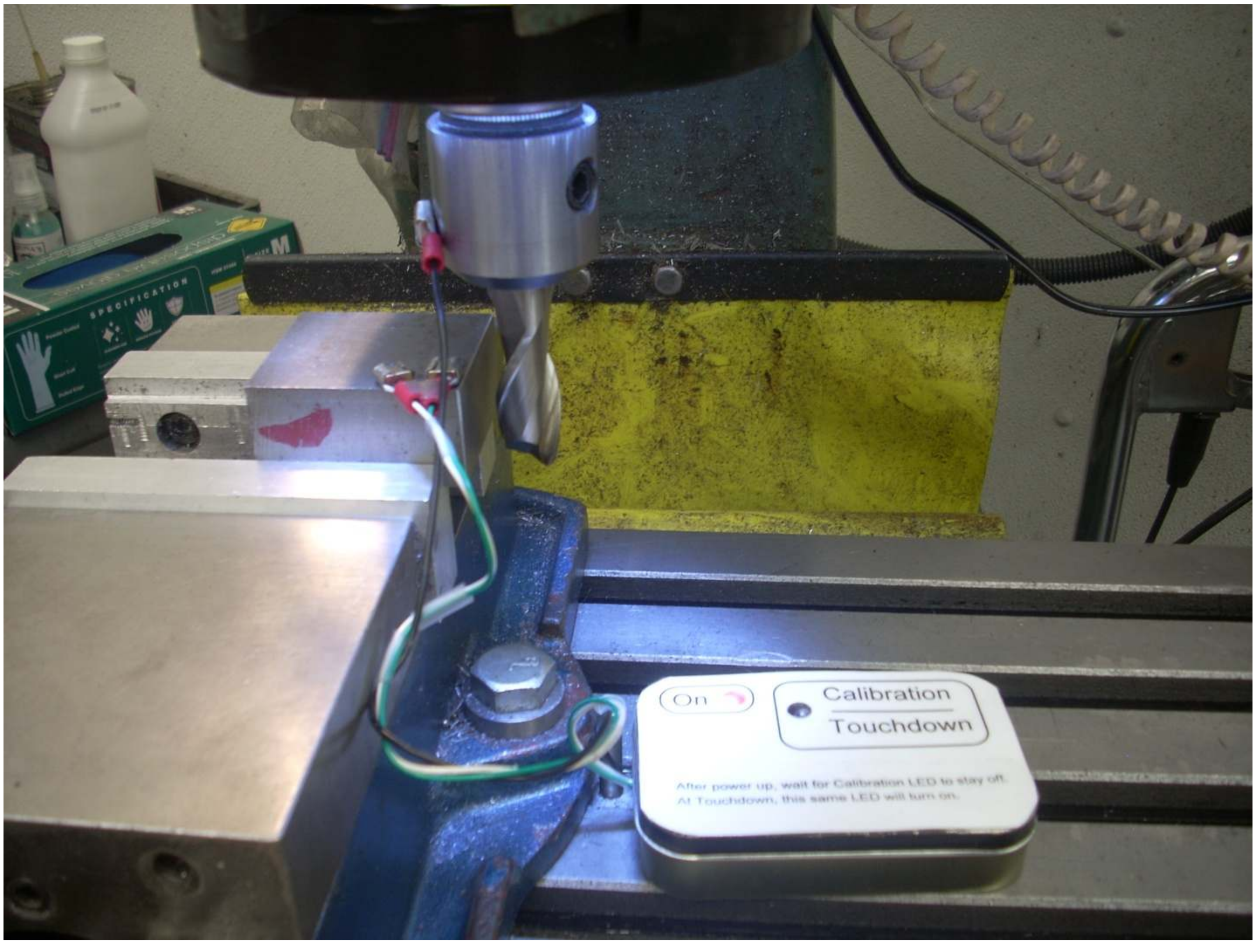
[6] To minimize noise pick up, keep the probe wires twisted together as much as possible.

[7] The noise voltage at the probes was 92 micro volts while the valid signal was 3 micro volts.

would permit power line noise to couple into the spindle and cutter. As mentioned above, watch out for plastic conduit which has no shielding capability and cannot carry a low resistance ground.

One trick I have used in high noise environments is to pass a small AC current from cutter to chuck. This current will generate a tiny AC voltage that is stable. It will obscure any small but unstable AC. I used a 1 mA RMS 60 Hz current derived from a small transformer with a resistor in series with the output.

Use on a Mill



The EEF can be used on a mill. The end mill cutter must be turned so some part of the flute's cutting edge can come in contact with the reference surface.

Acknowledgements

Thanks to Gregg K. of the Valley Metal club for consulting on this circuit. Thanks to Dan B. and Tim C. also of this club for letting me trial the circuit in their shops.

A very special thanks to Mark Cason for his many hours of work on the circuit board and bill of material. I look forward to seeing him sell these devices.

I welcome your comments and questions.

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Appendix: Performance Equations

These equations can be useful if you can measure both 60 Hz AC and DC millivolts. Connect your meter between IC1/pin 7 and the probe connection marked COM. Record both voltages when in Calibration mode.

Divide the AC voltage by 7070 to get V_x used below**.** This assumes that it does not vary by so much that the Calibration/Touchdown LED flickers or stays on.

During a normal calibration, the DC voltage at IC1/pin 7 relative to COM should slowly rise until it reaches a voltage greater than 0. At this point the Calibration/Touchdown LED should turn off. If the voltage is positive but the LED is off, switch to AC because it is probably unstable.

The Calibration value, $\mathbf{V_{10}(0^-) - V_9(0^-)}$, must be stable and negative for this phase to conclude. "0^-" means the time just before touchdown.

$$\mathbf{V_{10}(0^-) - V_9(0^-) = -2200\ V_x - 10\ mV}$$

where V_x is the voltage across D2. V_{10} and V_9 are pins on IC2. (1)

The Touchdown value, $\mathbf{V_{10}(0^+) - V_9(0^+)}$, must be positive. "$0^+$" means the time just before touchdown.

$$\mathbf{V_{10}(0^+) - V_9(0^+) = -1700\ V_x - 166\Delta R_x - 10\ mV}$$

where V_x is the voltage across D2. V_{10} and V_9 are pins on IC2, ΔR_x is the parallel combination of the spindle resistance and the touchdown resistance minus the spindle resistance (it will always be negative). (2)

The larger the V_x, the longer it will take for (1) to be stable.

Notice in (2) that as V_x increases, it takes more ΔR_x for the equations to have a result greater than 0.