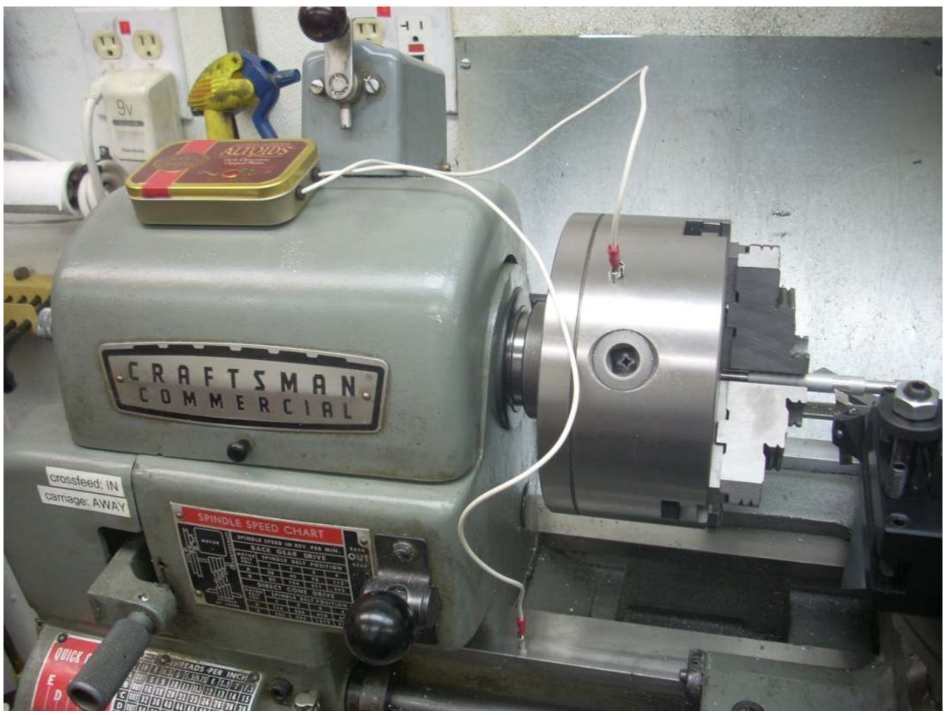
A Precision Electronic Cutter Touch-down Detector, version 7

By R. G. Sparber

Copyleft protects this document.[1]

A video of this device being used on my mill can be seeing at:

http://www.youtube.com/watch?v=QPi83uIxRM0&feature=youtu.be

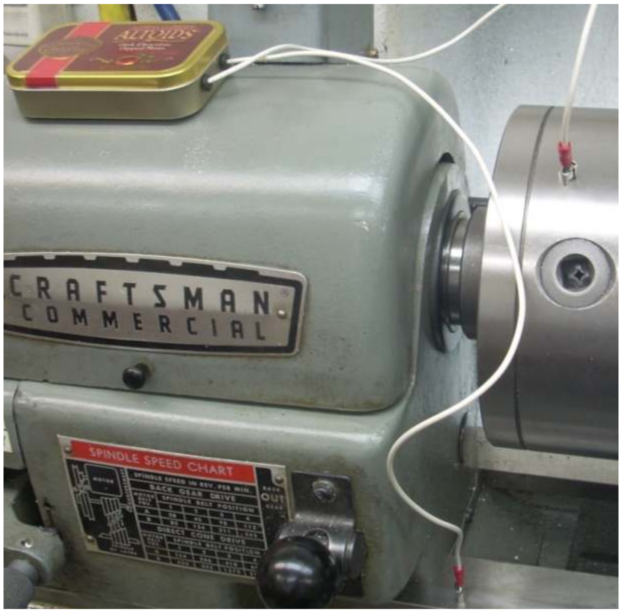


Have you ever needed to set a High Speed Steel cutter so it just touches the work piece? Every time I do it, the cutter digs in a little bit and I find myself taking off a few thou where I thought I was just touching the surface. This is particularly difficult when trying to use a boring bar deep inside a hole.

The device presented here is simply an Electronic Edge Finder but with two unique features.

This first feature tell the difference between the low electrical resistance between all parts of the lathe and the extremely low resistance at the point where the cutter first contacts the work piece.

[1] You are free to copy and distribute this document but not change it.



The second feature is the ease of use. Although there is electronics inside that Altoids® box, there is no power switch. Whenever I must deal with a power switch, it ends up being left in the "on" position and the battery goes dead. With this edge finder, power is on only when the wires are connected to the machine. And while power is on, there is a faint but rather annoying sound to remind me that the battery is being discharged.

Another design feature aimed at ease of use are the clips that connect the wires to the machine. They are magnets[2]. You just toss the end of the wire onto the bare, metallic surface and a good connection is made.

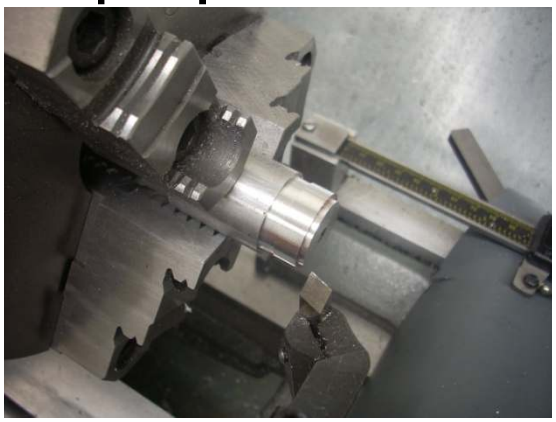
I have done my best to make the ***using*** of this gadget easy. This has meant that the building phase may be difficult for some. Inside the Altoids box is an integrated circuit, a transistor, and a handful of resistors plus a piezoelectric beeper. All parts can be bought at Radio Shack®.

For those with minimal background in electronics, I have drawn the circuit in picture form. This will be followed by a description for those with more knowledge of electronics.

Before starting to build the edge finder, it would be prudent to verify that it will work on your lathe. You will need an ohm meter able to measure down to 0.5 ohms. Put one probe on the spindle and the other on the ways of your lathe. If the resistance is greater than 2 ohms, this device will work. If you see less than 0.5 ohms, try turning the spindle a little. On my lathe the resistance was at least 40 ohms. Moving the spindle caused it to spike to much larger values. I suspect that this reading indirectly tells me how much play I have in the spindle bearings. You may also want to take a measurement with the machine running. If your machine uses sleeve bearings, the resistance will probably be too low to work.

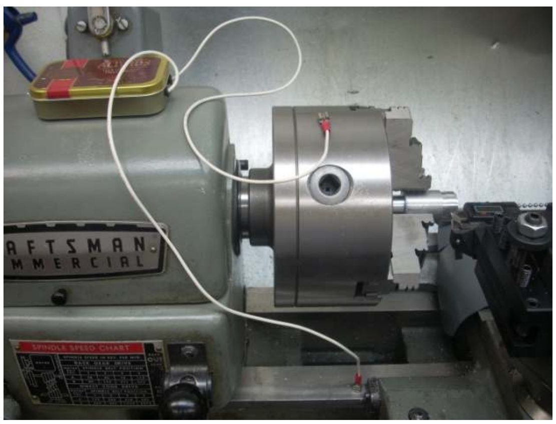
[2] This is standard practice on welding cable ground clamps.

Shop Experience

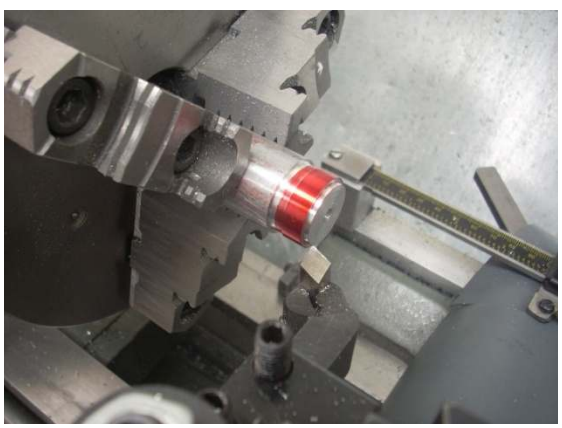


How well can I return the tip of my cutter to a reference surface?

First I chucked up some round stock and turned it true. Then I cleaned the OD and cutter with alcohol to remove all oil and swarf.

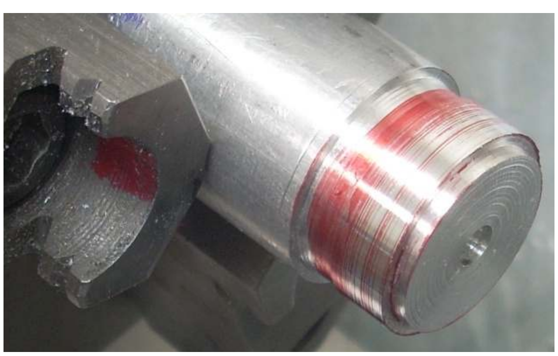


I connected the detector between my 3 jaw chuck and the ways and slowly fed in the cutter until I heard the loud beep. The longitudinal dial was then zeroed. I fed in again and made a small adjustment to the zero point.



I backed out the cutter and coated the surface with dye.

Then I started the lathe, fed in until I reached zero, and took a single pass.



To my amazement, I had removed some but not all of the dye. Now ***that*** is a precise reestablishment of zero.

Physical Design

The edge finder consists of a small metal box with two wires sticking out of it.

Open up the box and you find a 9V battery and a piezoelectric beeper. These beepers are so loud that no effort was made to cut a hole for the sound to get out. The green foam holds the circuit board in place.

Under the foam is a circuit board with a small handful of parts in it[3]. Having all of this room made fabrication easier. All connections were made by directly soldering leads together.

A sheet of rubber was placed under the circuit board to prevent shorts between circuit connections and the metal box.

[3] Diode D1 is not shown in this picture. It was added later.

When not in use, the wires wrap around the box. Magnets at the ends of the wires stick to the box. The red tape prevents them from shorting together and turning on the device.

Here is a close up view of one lug being modified to accept a magnet.

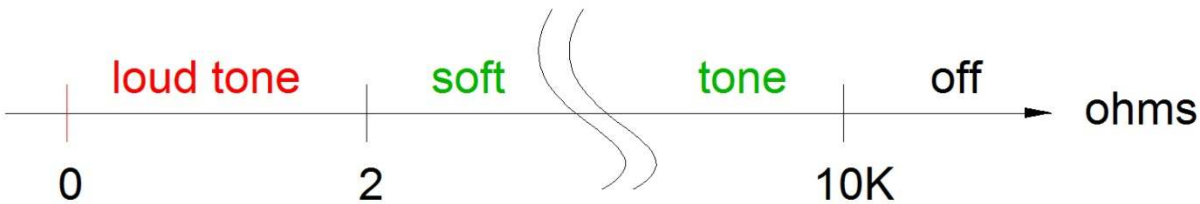
The curled clips are straightened.

A neodymium magnet[4] 1/8" x ¼" x ¼" fits nicely. I formed the sides over the top and bent up the front a little.

4 See http://www.kjmagnetics.com/proddetail.asp?prod=B442-N50

Electrical Design Overview

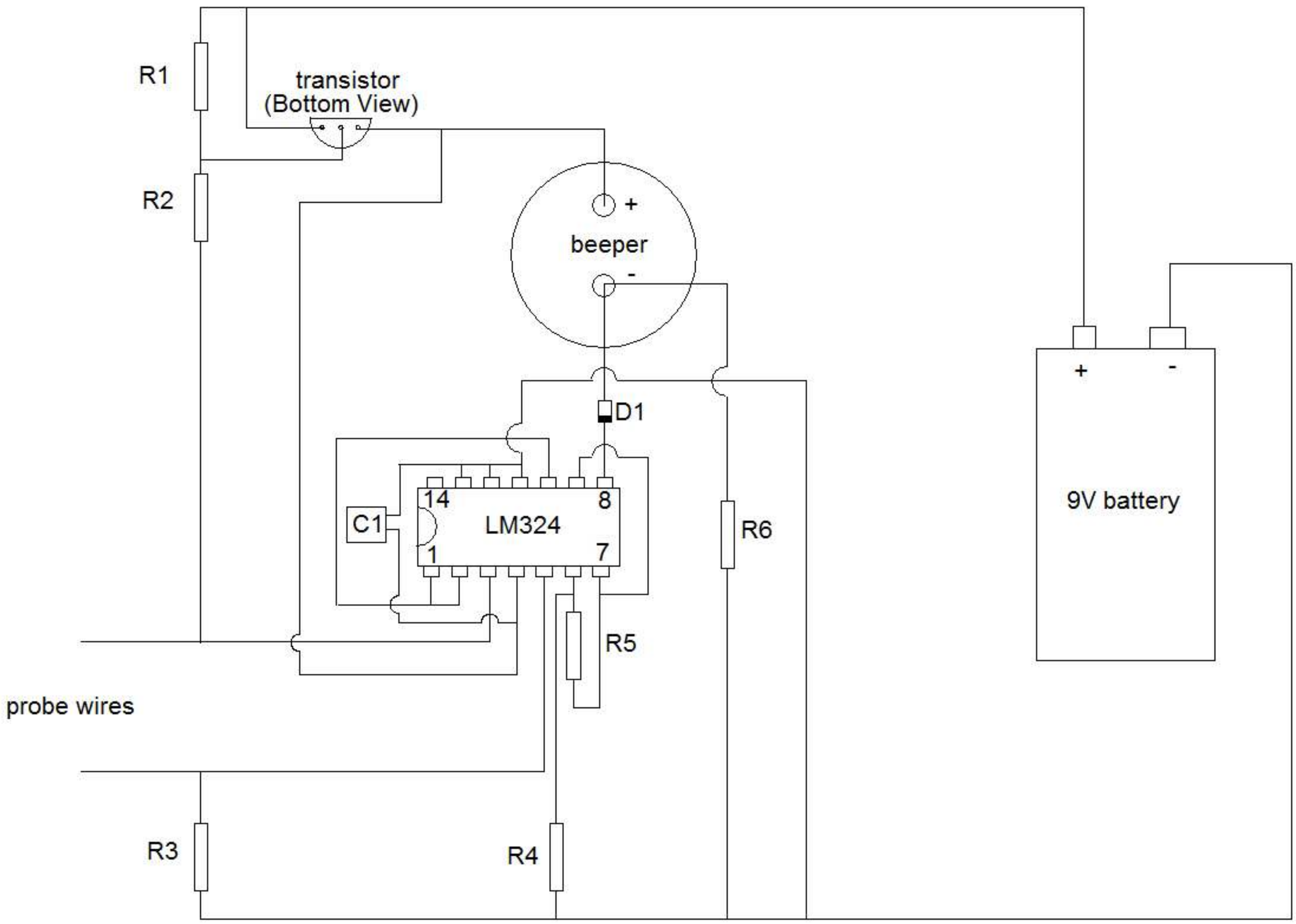
The edge finder is just a glorified continuity checker. What makes it special is its ability to detect when the resistance across it's probes is less than 2 ohms. Most continuity checkers alarm at many hundreds of ohms.



The circuit works by comparing the unknown resistance to a known resistance. This comparison is not dependent on battery voltage. If the unknown resistance is less than 2 ohms, the piezoelectric beeper generates a loud tone. If the resistance is greater than 2 ohms but less than about 10K, there is a soft tone. Above about 10K, the circuit turns off.

Pictorial Assembly View

For those uncomfortable reading schematics, here is a pictorial wiring view. All parts can be bought at Radio Shack (except the Altoids candy box).



name	value	tolerance	color bands
R1	1K	5%	brown/black/red/gold
R2	1K	5%	brown/black/red/ gold
R3	68	5%	blue/gray/black/ gold
R4	33K	5%	orange/orange/orange/gold
R5	1K	5%	brown/black/red/gold
R6	10K	5%	brown/black/orange/gold

C1 is a 0.1 uF bypass capacitor

Transistor: any low voltage general purpose PNP

Diode (D1): any low power/low voltage general purpose diode

Integrated circuit: LM324 (quad op-amp)

Beeper: any piezoelectric beeper able to run on 8V DC

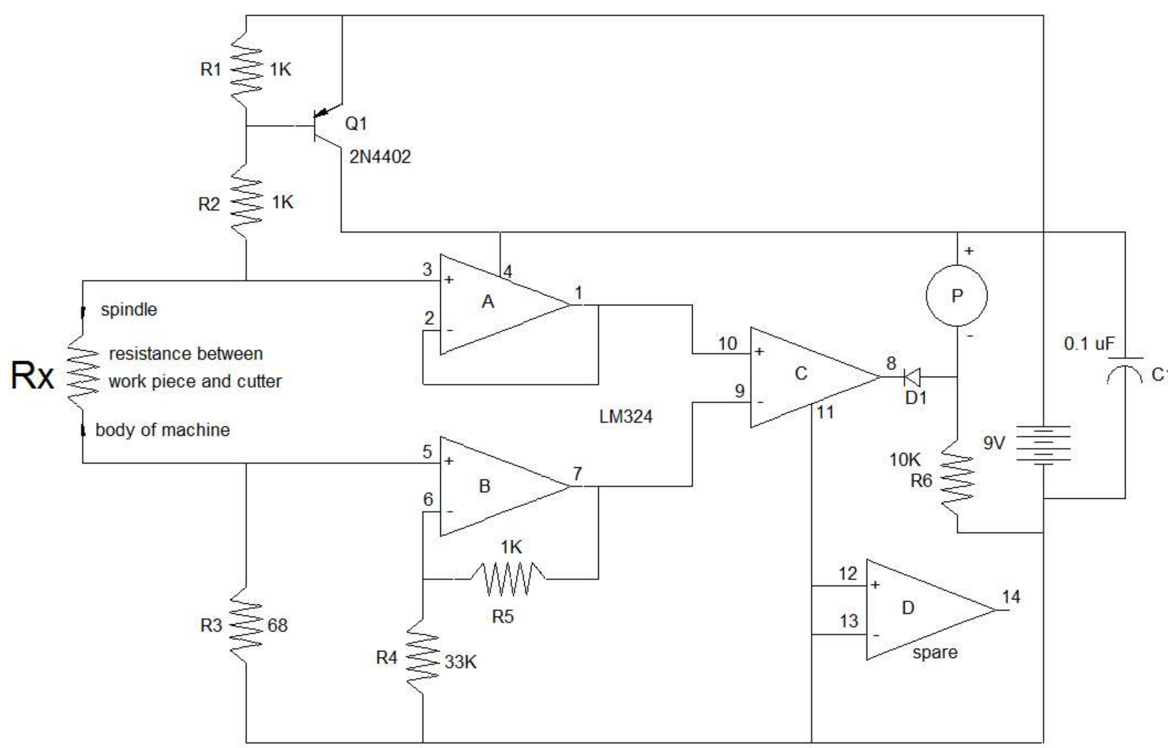
9V battery: nothing special

Keep all wires connecting to the integrated circuit as short as possible.

Note that the solid color band printed on the body of the diode indicates the wire that connects to pin 8 of the integrated circuit.

The value of R6 can be changed to adjust the "power on" warning tone's volume.

Edge Finder



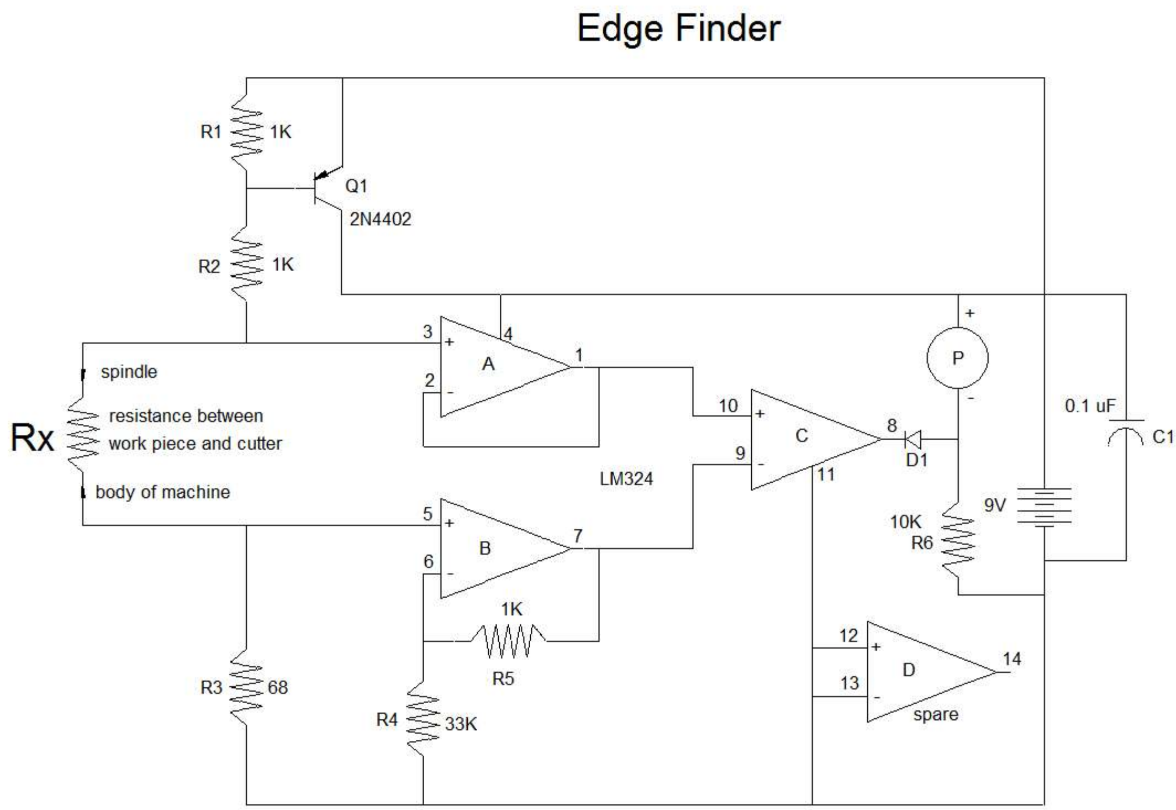
Detailed Circuit Description

Lines that "T" connect. Lines that cross do not connect.

The circuit changes state when Rx is at 2.1 ohms. Above 2.1 ohms but less than about 10K, the voltage at pin 3 with respect to pin 5 (called V_{3-5}) is higher than V_{7-11}. V_{3-5} is equal to V_{1-5}.

With V_{10-9} is positive, op-amp C will have an output voltage near V_{4-11}which is close to the full battery voltage. Diode D1 is back biased and a small current flows through the piezoelectric beeper and R6. A low volume tone is generated to warn the user that power is being used.

Below 2.1 ohms, V_{1-5} is less than V_{7-5}. This causes V_{8-11} to be near zero. D1 turns on and close to the full battery voltage is applied to the beeper. It generates a very loud tone to indicate touch-down of the cutter.



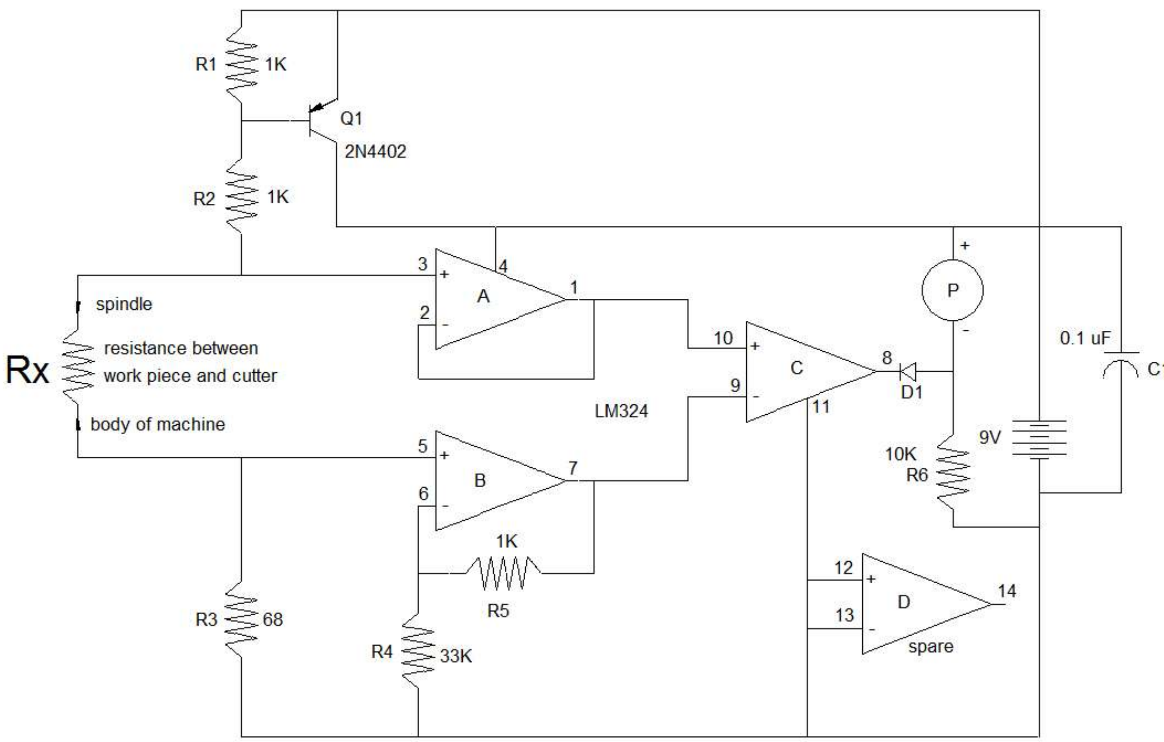
Op amp B measures the test current times R3. It then generates a small reference voltage which is applied to pin 9. The voltage applied to pin 10 is a function of both Rx and the test current. Op amp C compares two voltages that are both functions of the test current. In this way the test current's value drops out of the equation and the circuit is only comparing resistances.

When Rx is greater than about 10K, transistor Q1 turns off and removes power from the integrated circuit and beeper. When the probes see an open circuit, the battery current goes to zero.

C1 should be connected to pins 4 and 11 with the shortest possible lead length.

See pages 6 and 7 for the parts list.

Edge Finder



Analysis:
Datum is the bottom node.

1. I_x is the current through R_x and equals about $(V_{battery} - V_{EBsat1})/(R2 + Rx + R3) = (9 - 0.75)/(1000 + 2 + 68) = 7.7$ mA when R_x is 2 ohms. The circuit is not sensitive to the exact value of I_x as long as it is not near zero. That would generate voltages too close to input offset voltages and cause excessive error.
2. $V_5 = R_3 I_x$
3. $V_3 = V_5 + R_x I_x$
4. $V_3 = V_1 = V_{10}$
5. $V_7 = (1 + R_5/R_4) V_5 = V_9$
6. Using equations 3, 4, and 5:
   $V_{10\text{-}9} = (V_5 + R_x I_x) - (1 + R_5/R_4) V_5 = (R_x - [R_3 R_5]/R_4) I_x$
7. From equation 6: State change occurs at $R_x = [R_3 R_5]/R_4$
8. Applying equation 7 with the specified values: $R_x = 2.06$ ohms

You can adjust the threshold value, R_x , by changing R4:

$$R_4 = [R_3\ R_5]/R_x$$

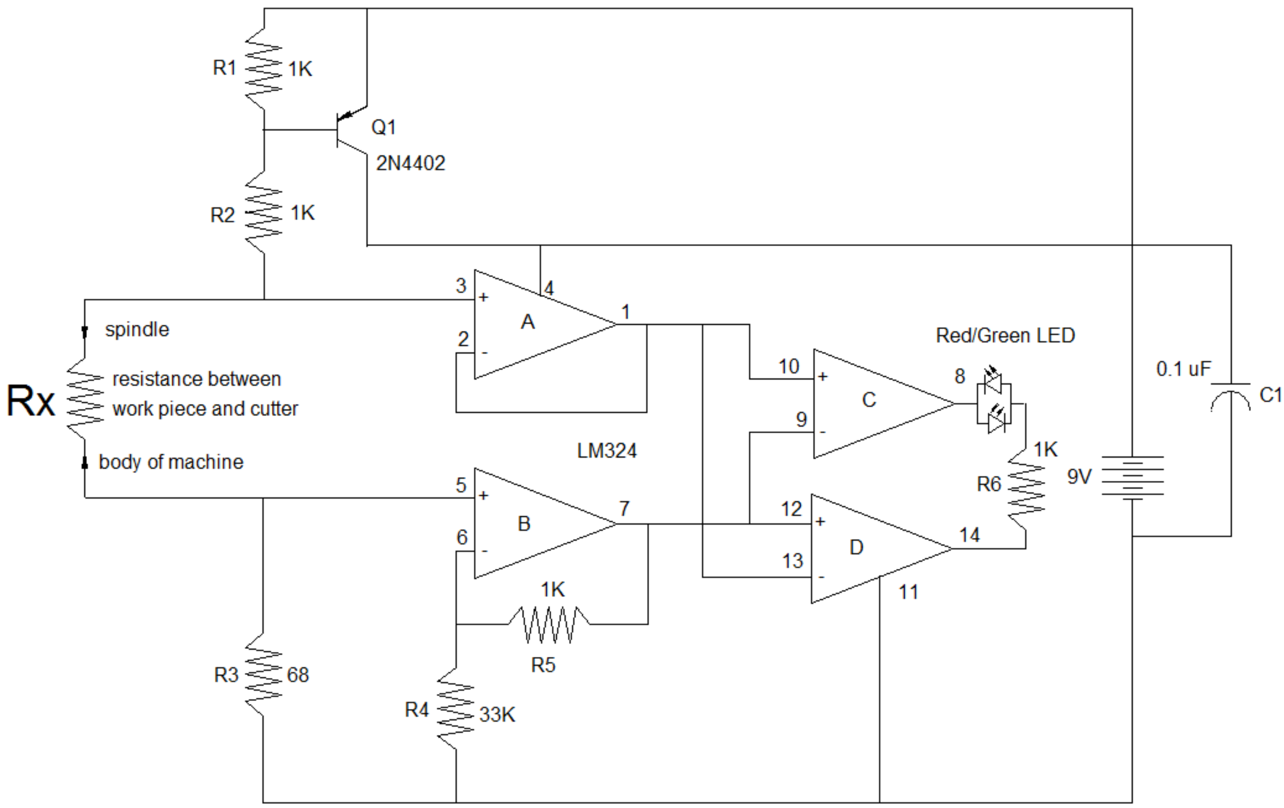
For example, say you find that the resistance between spindle and ways is 1.4 ohms. Then an R_x of 0.7 ohms might be desired.

$$R_4 = [R_3\ R_5]/R_x$$

$$R_4 = [68 \text{ x } 1K]/0.7$$

$$R_4 = 97.1K$$

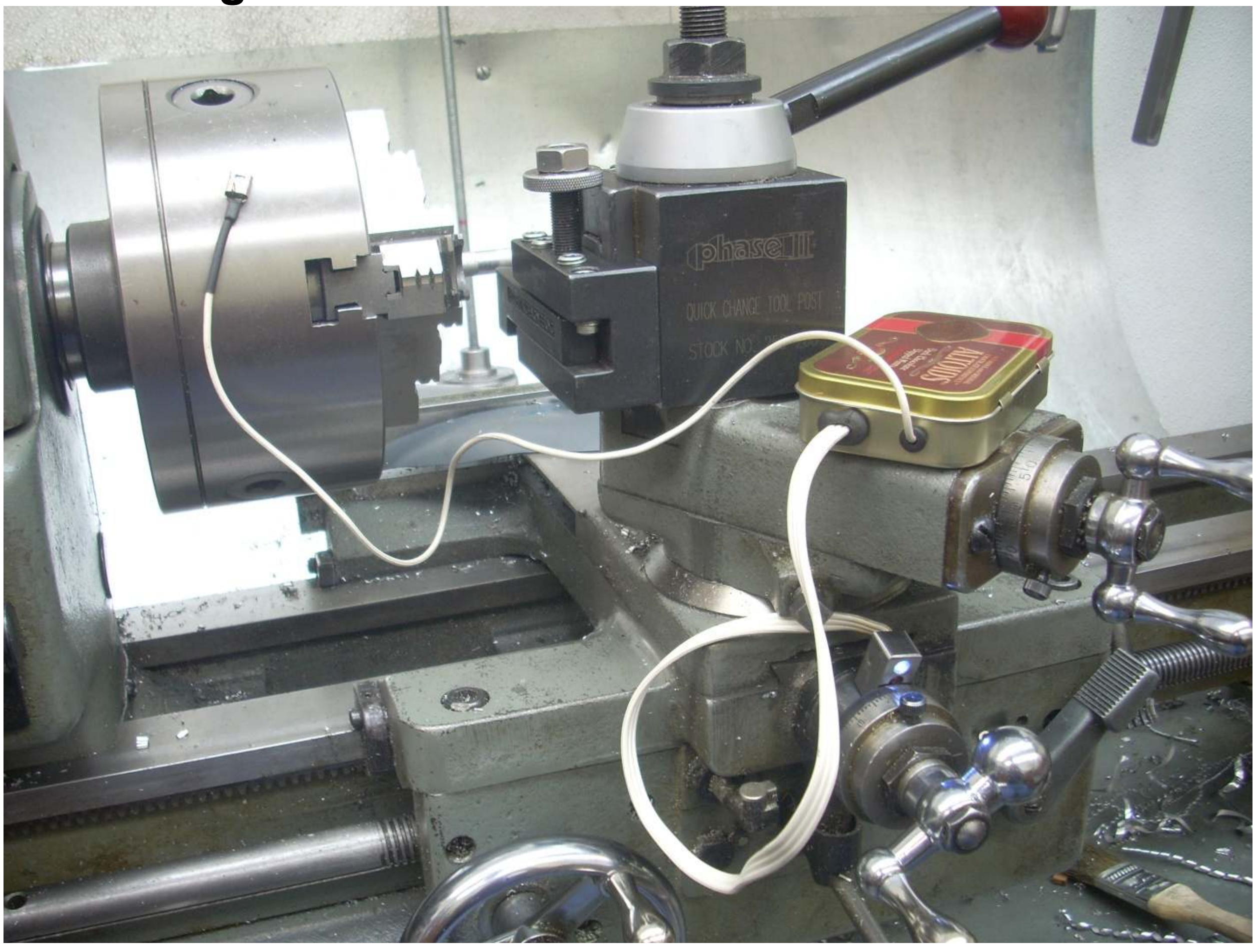
The standard value for a 5% resistor is 100K which gives us an R_x of 0.68 ohms as per the equation in step 7.



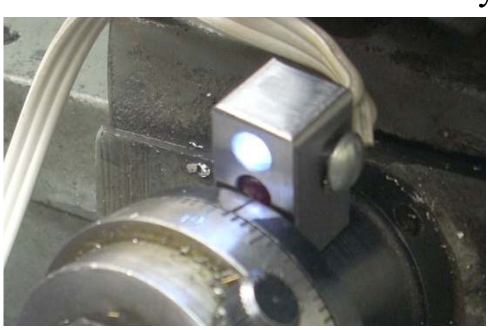
A variation on the design is to replace the piezoelectric beeper with a red/green LED. These LEDs could be positioned to shine on the feed dial making it easy to both monitor the dial's position and the circuit's state. In fact, the "body of machine" probe could be integrated with the LEDs so only two cables exit the device.

When $V_{1\text{-}7}$ is positive, pin 8 rises to near 9V and pin 14 falls to near 0V. That turns on one of the two LEDs. When $V_{1\text{-}7}$ is negative, the polarity across the LED reverses and the other LED turns on. In this way you get a power on visual indication plus a touch-down indication, all in one LED package.

First Design Revision



I have moved the two LEDs from inside the box into one of the magnetic clips. Now the LEDs can shine directly onto the dial.



Before I reach touch-down of the cutter, my dial is illuminated with a Super Bright LED.

Once the cutter touches down, my Super Bright LED goes dark and my red LED comes on. Both LEDs go dark when they are removed from the lathe and placed back on the box.

Acknowledgements

Thanks to Jay B. and Mike Marshall of the Atlas_Craftsman Yahoo group for supplying me resistance data on their machines.

Thanks to Goran Hosinsky for finding a pin assignment error in the schematics.

I welcome your comments and questions.

Rick Sparber
Rgsparber@aol.com
Rick.Sparber.org