Short-circuit Finding Brush

At the very core of modern electronics is the printed circuit board (PCB). Each PCB is carefully engineered so that every component is connected *just right*, enabling you to turn on your favorite TV show, play a computer game, or even save a life.

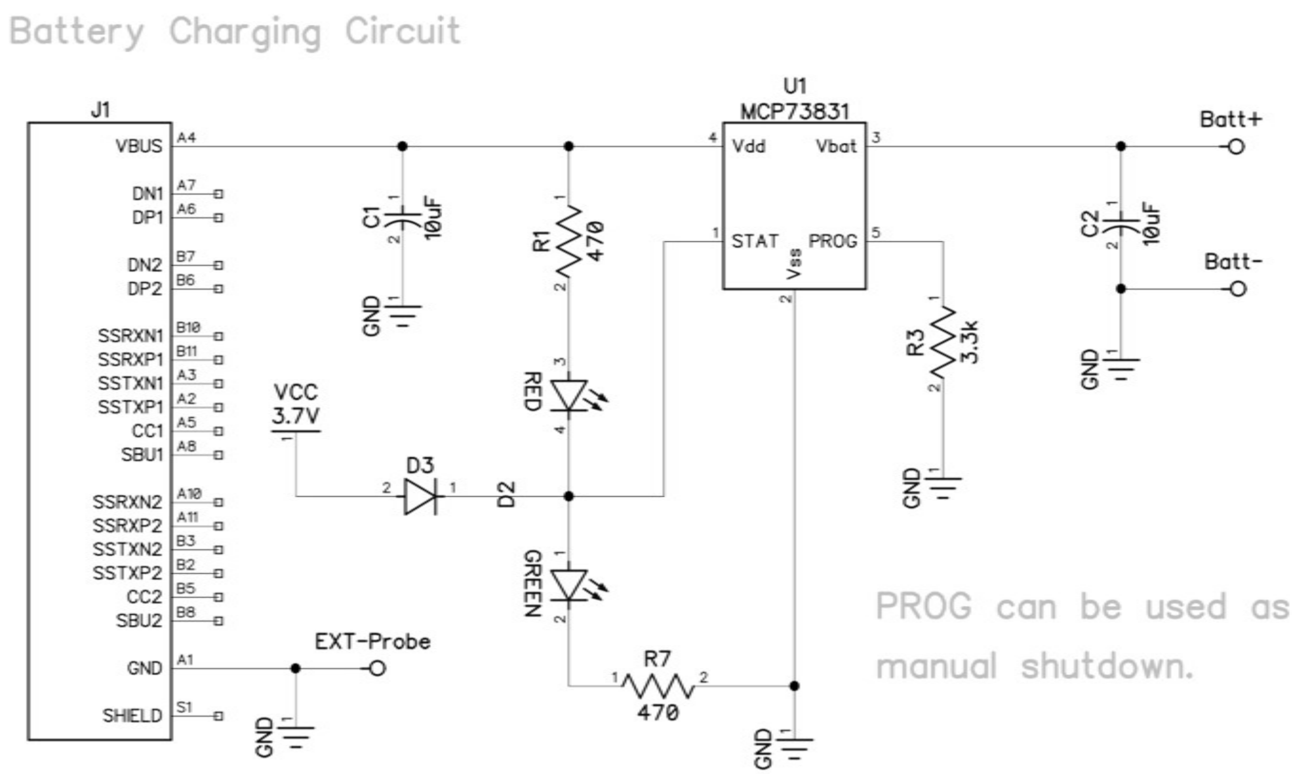
Every PCB design fulfills a *schematic diagram*. Electronics engineers follow the diagram to know just what components are required and how to connect them together. The schematic diagram is an illustrated description of an electronic circuit design.

In the previous installment of this series we examined the 3D case design.

Come with us now on a reverse engineering adventure as we explore the schematic diagram of the ENA Short-circuit Finding Brush!

The diagram is split into a handful of sections:

1.Battery Charger



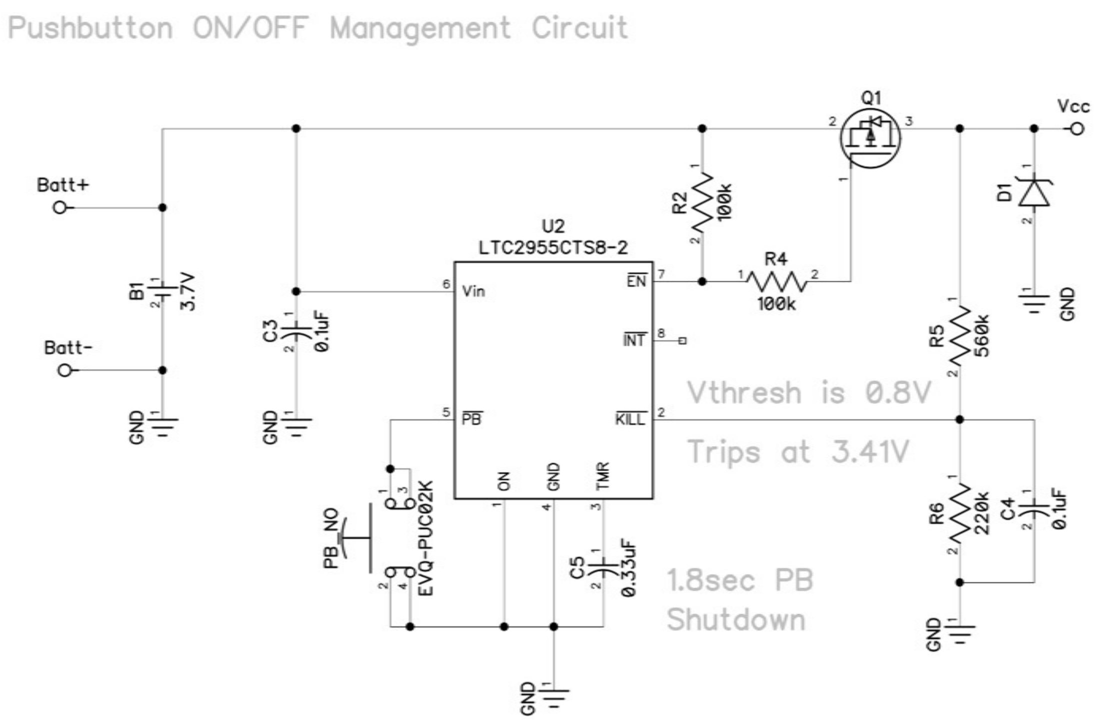
Ah, the battery charger. How could we live without it?

It maintains the internal 3.7 Volt battery when a powered USB-C cable is plugged into the tool. The operation is pretty straightforward since we make use of Microchip's MCP73831, a dedicated battery charger Integrated Circuit (IC):

1. User plugs in USB cable to connector J1
2. IC detects the power and checks battery charge status (Batt+, Batt-)
3. IC begins charging and illuminates RED LED (light emitting diode) if battery is drained
4. IC illuminates GREEN LED once battery is full and charging is complete.

The charging speed is determined by resistor R3 and is set to a reasonable value.

2.Power Supply



The power supply circuit allows the user to turn the power of the tool on and off. That is especially important for conserving power in a small battery powered tool. Here, again, we use an IC to do the heavy lifting, in this case Analog Devices LTC2955 which is a Pushbutton On/Off controller.

When the pushbutton on the tool is pressed, the tool turns on instantly. Then, the user must press and hold the button for nearly 2 seconds to power the tool OFF when desired. This is to prevent unintended brief presses of the button from turning off the tool during use. The 2 second delay is set using capacitor C5.

Transistor Q1 is the electrical power switch. When the IC commands the power to be on, the transistor connects the battery through to the rest of the circuit. When the IC commands the power to be off, the transistor then breaks the connection to the battery.

The supply also implements an undervoltage cutout scheme with the IC and Q1. As the battery loses its charge, the voltage drops below 3.7 Volts. You do not want to use the battery if it has become too discharged since that is not good for the battery. So, we cut off the power supply any time that the voltage drops below 3.41 Volts (the battery is nearly empty at that point).

The threshold is set using resistors R5 and R6.

The circuit also protects the tool from overvoltage conditions. Diode D1 is a special kind of diode called a Zener diode. It is connected in such a way that, if the battery voltage much exceeds 3.7 Volts, excess voltage will be clamped down and the power redirected away from the main circuit. Kind of like an electrical shield of sorts.

3.Continuity Tester and Buzzer

The Continuity Tester and Buzzer consists of a bit of Analog Magic with some op amps, and of course a couple of 555 timer ICs for good measure.

The function of this circuit is to trigger the buzzer when the user presents a high to very high continuity (short-circuit) to the probes of the tool. The continuity threshold is adjustable–should I buzz on a rusty nail or only on a piece of clean copper?

The circuit operates in six distinct parts:

1. Reference Level Generator
2. Continuity Generator
3. Continuity Sense Amplifier
4. Continuity Threshold Detector
5. Continuity Trigger
6. Continuity Buzzer

The *Reference Level Generator* (R9, R13, R16) provides, well, two reference values to compare against. One value is used in the Continuity Generator and the other in the Continuity Threshold Detector. It does this with a string of resistors

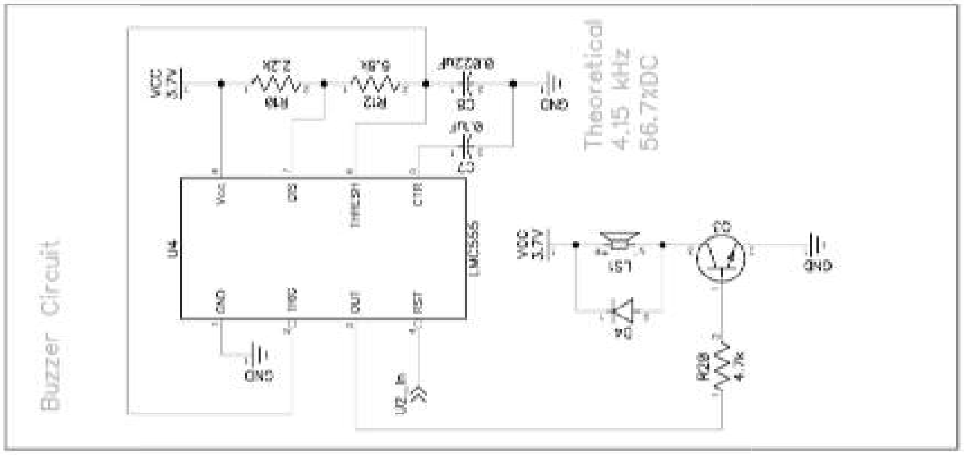
Second, the *Continuity Generator* (U5.1) drives a small current through whatever is being probed by the user. This generates a sense voltage which indicates how much continuity is being probed.

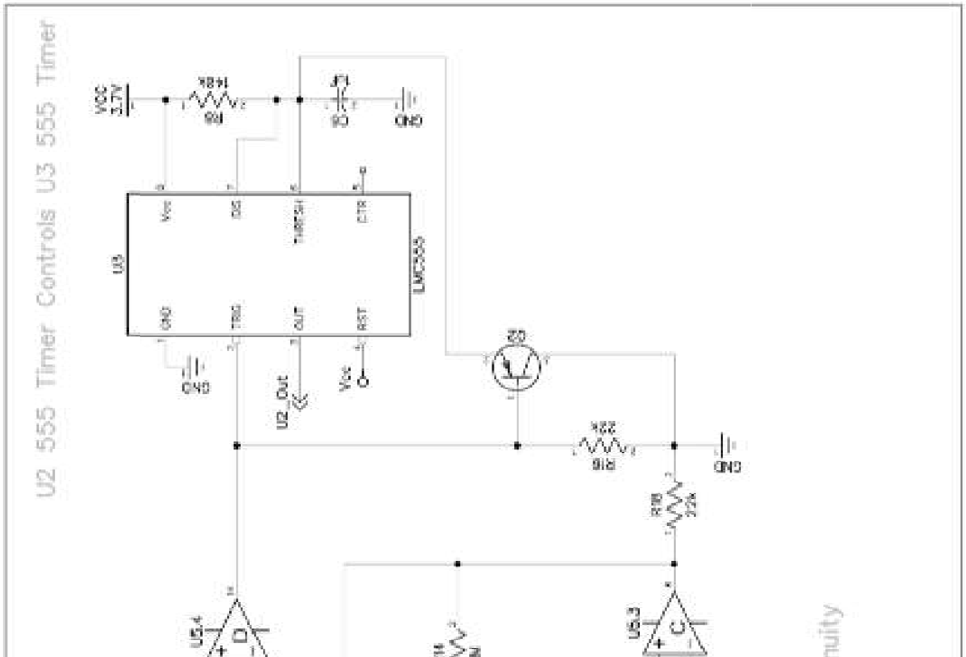
Third, the *Continuity Sense Amplifier* (U5.2) reads the continuity sense voltage and amplifies it (makes it bigger) based on the chosen continuity buzz threshold. The adjusted sense voltage is passed on to the Continuity Threshold Detector.

Fourth, the *Continuity Threshold Detector* (U5.3, U5.4) compares the adjusted continuity sense voltage to the threshold value from the Reference Generator. When the threshold is crossed, a signal is sent to the Continuity Trigger to indicate continuity is found.

Fifth, the *Continuity Trigger* (U3, Q2) turns the Continuity Buzzer on and off depending on the signal received from the Continuity Threshold Detector. When continuity is detected, the Trigger immediately turns the Buzzer on. When continuity is no longer detected, the Trigger turns the Buzzer off after a small time delay (R8, C6), unless continuity is detected again in the meantime. This time delay is important because it ensures the user hears a beep even when continuity is detected only very briefly, such as when sweeping the brush quickly across a PCB.

Finally, at long last, the Continuity Buzzer (U4, Q3, LS1) generates an audible tone to the user whenever the Continuity Trigger indicates to do so. U4 operates as an electrical oscillator (tone generator), and Q3 sends the tone signal to the buzzer, LS1.


Buzzer Circuit
Theoretical
4.15 kHz
56.7%DC
LM555
U4


Op-Amp Circuit
U2 555 Timer Controls U3 555 Timer
Adjusts Continuity
Threshold
LM555
U3
Brush
Probe Tip
EXT-Probe