Making a Over Discharge Protection for Makita Batteries

by Noloxs

DISCLAIMER: All you do in life is at your own risk. So... You know... Stay safe.

I have pretty much since I got my first Makita power tool though "I can makes some cool stuff with does batteries". I had initially, but wrongly, assumed that the Makita batteries had build in overdischarge protection, mostly because it is stated in their brochures that they have, which would mean that they will cut the power themselves when they become discharged. Therefore I started making adapters for the batteries, I had already made an adapter for my TS100 soldering iron and a variable bench power supply before I learned that the batteries does not have this kind of overdischarge protection, but instead only "notifies" the tool that the battery is discharged.

So before getting to invested in making adapters for the batteries, I instead decided to make a simple circuit that I could embed in my adapters, that would disconnect the power once the battery is discharged.

This Instructable will describe all the steps I went through to make it, **so if you are only interested in how to build the final circuit, then skip to step 2 for the schematics**

NB. This ONLY applies to Makita batteries with the little star.

Supplies:

Tools

- Soldering tools

Materials used in this Instructable:

- Makita battery (With star marking)
- Battery connector
- N Channel MOSFET (IRLB8721)
- N Channel MOSFET (IRFP3006)
- N Channel MOSFET (2N7000)
- P Channel MOSFET (IRF5305)
- 10K Ohm resistor
- 100 Ohm resistor
- Thick wire
- Perf board
- Heatsinks etc. (Optional)

Step 1: Reverse Engineering When and How to Shut OFF

Hoping for an easy solution, I of course started by contacting my local Makita representative and asked if it was possible to get some documentation/information regarding how the overdischarge function works. The answer was however unfortunately no. The only thing I was able to confirm was that the batteries does indeed not cut the power themselves, but only in combination with tools with the star marking cut power.

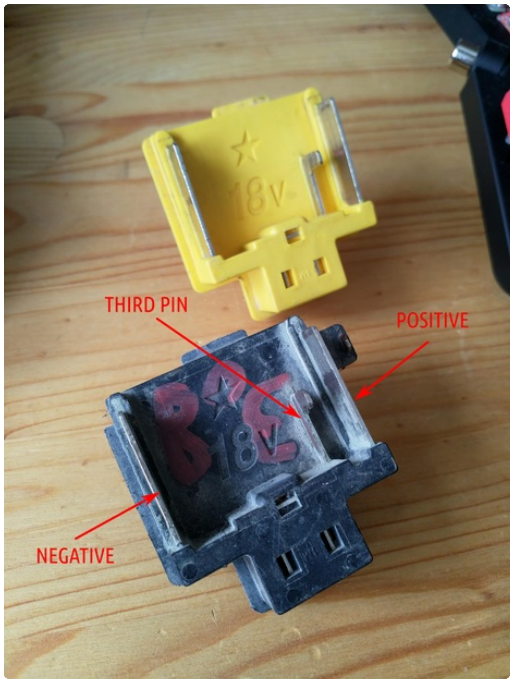
I knew that I needed to focus on the third pin of the battery connector as it is the only difference between the old tools and batteries (The ones without the star and protection) as the old only have 2 pins.

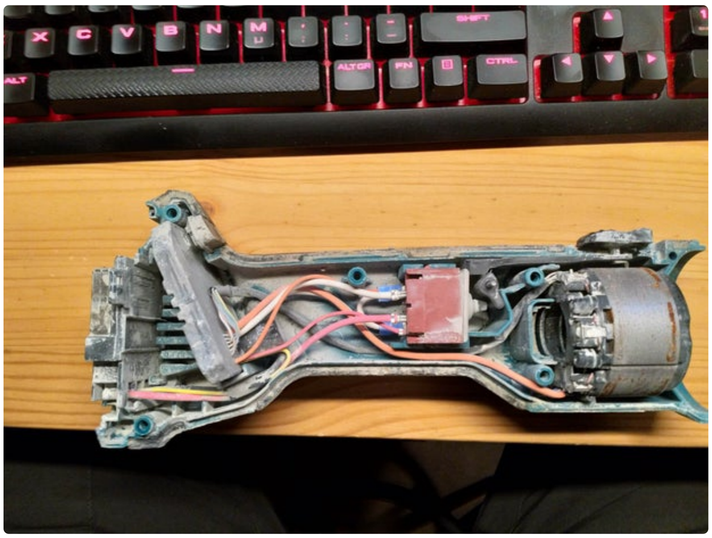
I asked around and was able to get my hands on a bunch of broken tools, that I disassembled in hopes of learning more about how Makita themselves had made such a circuit. This however in many cases turned out to be some more advanced circuitry covered in a plastic, which made it very hard to investigate further.
Fortunately among all the broken tools there was a more simple cordless drill which showed me how the system works.

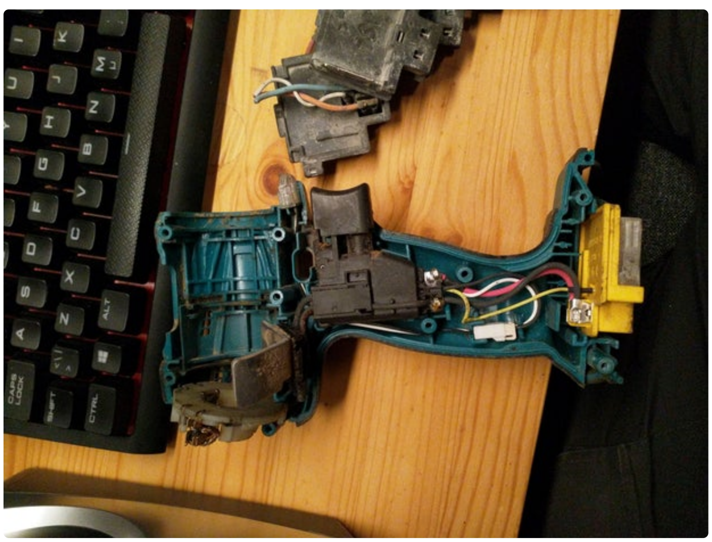
As seen in the photo, the drill uses a simple N-Channel MOSFET which will allow power to run through when its source pin is high and cut the power once it is low. This would mean that the third pin on the battery should have a high voltage until it is discharged and then show 0v.

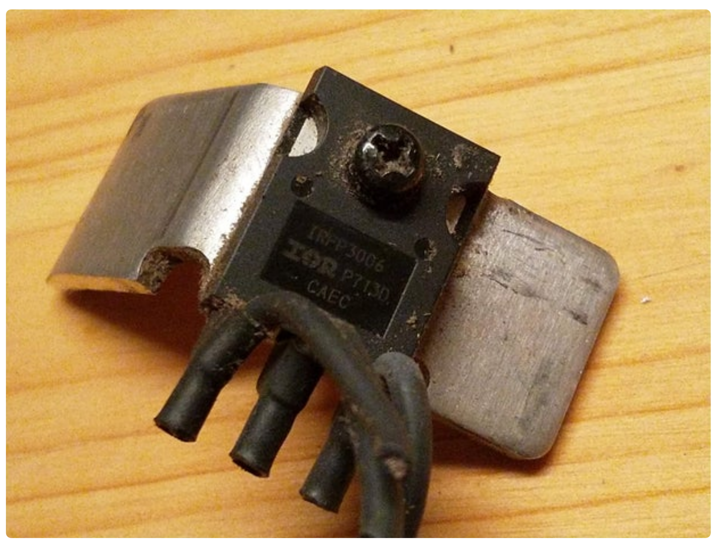
To confirm this I connected my multi-meter to the batteries and started taking some measurements. It was then just a matter of running my screwdriver and periodically taking measurements so that I could follow the voltage level of the positive pin as well as the third pin as the battery slowly discharged. Once the voltage levels of the positive pin hit 12v the third pin would drop to 0v.

To verify my results I asked the Makita representative, and he was able to confirm that the voltage at which the overdischarge triggers is around 12v.
As a side note this voltage seems as a bit low to me, but this Instructable is not about researching and determining if Makita has done it correctly, so I left it at: "A big company like Makita, probably knows what they are doing".









Step 2: Designing a Circuit to Shut OFF When Discharged

From my testing I was able to determine that the third pin would have a voltage between ~19v and >12v representing fully charged and completely discharged and of course 0v when the overdischarge protection kicks in.

So based on the discovery that Makita uses a MOSFET to cut the power once discharged, meant that there was only one major question left that needed to be answered. Should I do HIGH side or LOW side switching?

Unfortunately the answer really depends on what you are making. If you are making a lamp that utilizes the Makita batteries, then I would use LOW side switching, simply because it is more efficient, cheaper and easier. But when making something that powers a bit more complex electronics, then I would use HIGH side switching, as electronics likes to be grounded.

> Think of it like this: If you would deem it fine to just yank out the ground wire to turn your thing off, then do low side, else use high side switching.

So for the sake of this Instructable I have made three versions, so you can choose the one that best matches your needs.

> NB. I am not an electrical engineer, so I didn't calculate the optimal combination of components, but based it on the components I had laying around as well as some basic guidelines.
> I was also unable to find or get any information from my Makita representative regarding the batteries amperage limits, both continues and peek so I have no idea what their max values are.

I will not be going into detail about how a MOSFET works or what the difference between N and P Channel MOSFET are etc. as you are able to find much better resources explaining this, by simply Googling it.

I have chosen different MOSFETs based on my needs and what I had laying around. So source the MOSFET that best matches your needs. Just make sure that the Maximum Gate-Source Voltage (Vgs) is capable of handling the 12 - 19v range of the signal pin.

LOW side Makita switching

The LOW side switching circuit that I found in the Makita drill is as basic as it gets. It uses the IRFP3006 N channel MOSFET with the battery's signal connected directly to its gate and its negative connected at the MOSFET source and drain connected to the negative part of your load.

The reason why this works is that the signal pin from the Makita battery never floats but is always either 0v or 12+v, otherwise you would probably want a pull down resistor attached (See LOW side switching)

LOW side switching

This setup is similar to the Makita switching, but there is three differences:

1. I have added a 100 Ohm resistor in series between signal and gate to protect the MOSFET from potential in-rush of power.
2. I added a 10K Ohm pull-down resistor even though this might technically not be needed as the battery might already have this included on the signal pin. This is too keep the MOSFET OFF and not potentially having it turning on and off by having the signal pin floating.
3. I changed the MOSFET for another N channel MOSFET, the IRLB8721, Just to show that you can easily swap the MOSFETs

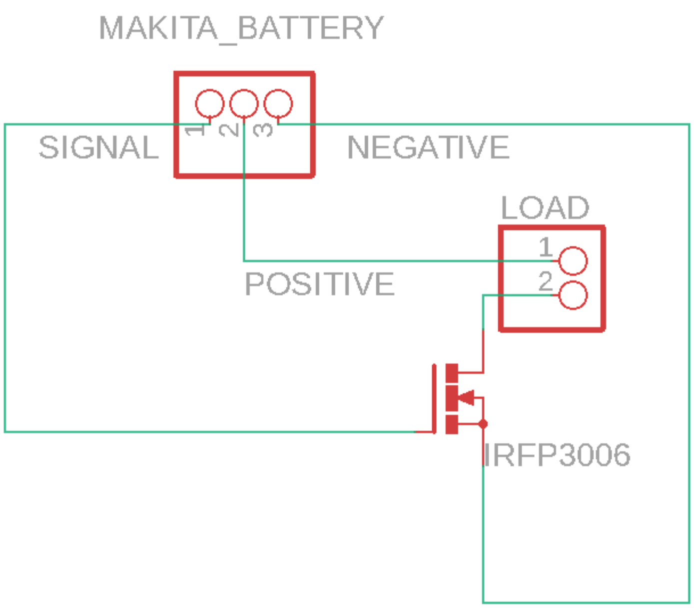
HIGH side switching

The point of HIGH side switching is that you disconnect the positive instead of the negative connection.

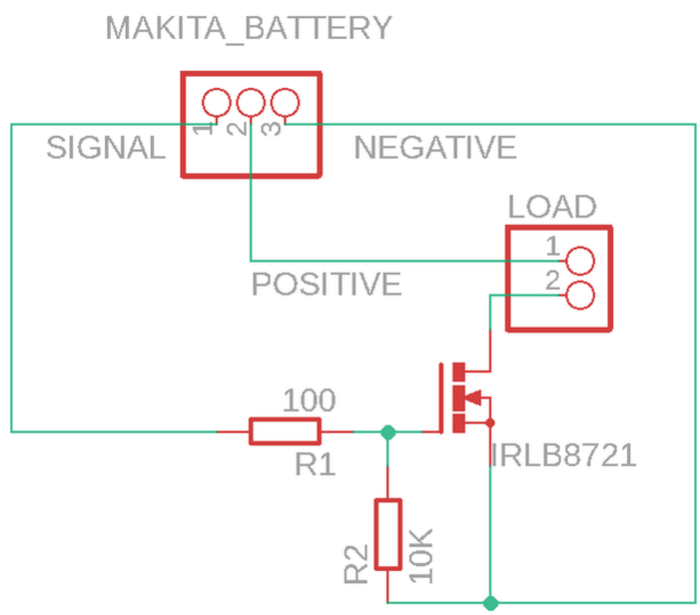
So if we e.g. had a circuit that would build up large amount of capacitance disconnecting the power would allow it to discharge through the negative connection, which is preferable to most electronics systems.

However because we are limited by the positive trigger signal from the battery, means that we cannot simply substitute the N channel MOSFET for a P channel MOSFET.
Instead we will, as shown, need to use a N channel MOSFET (2N7000) to trigger the P channel MOSFET (IRF5305) adding 100 Ohm resistors (R1 & R2) at the gates as well as a 10K pull up resistor (R3) and a 10K pull down resistors (R4).

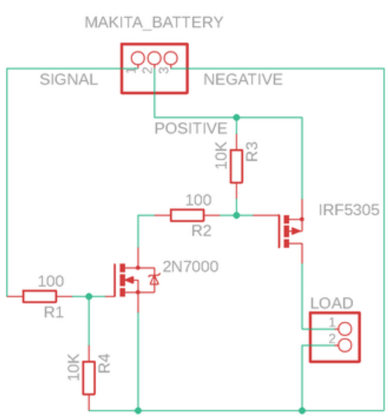
What this circuit does is basically invert the signal pin so that it can trigger the P channel MOSFET. This however also means that the circuit will always draw a tiny amount of power, so you should still disconnect the battery when not using it and not leave it connected.



Original Makita switching



Low side switching



High side switching

Step 3: Making the Protection Circuit

High side implementation

For my high side switching implementation I started by making a prototype of the circuit on a breadboard, following the previously described schematic and although it might look a bit messy, it is rather quite simple.

This allowed me to test the circuit and verify that it would work as intended before spending time on making it into a more permanent part of my battery powered bench supply.

After verifying that it works, I mounted the circuit to a perf-board and added a heat-sink to the MOSFET, which probably is complete overkill, but it never hurts.
I then added the circuit to my bench supply, which ended looking a bit mashed together, as I already had the bench supply build and had to add the circuit as an afterthought.

Finally I performed a full test by simply using the power supply to run some power hungry appliances until the overdischarge protection kicked in.

The bench supply is able to monitor the voltage level of the batteries so that I could make sure that would cut the power around the 12v.

Low side implementation (Makita original)

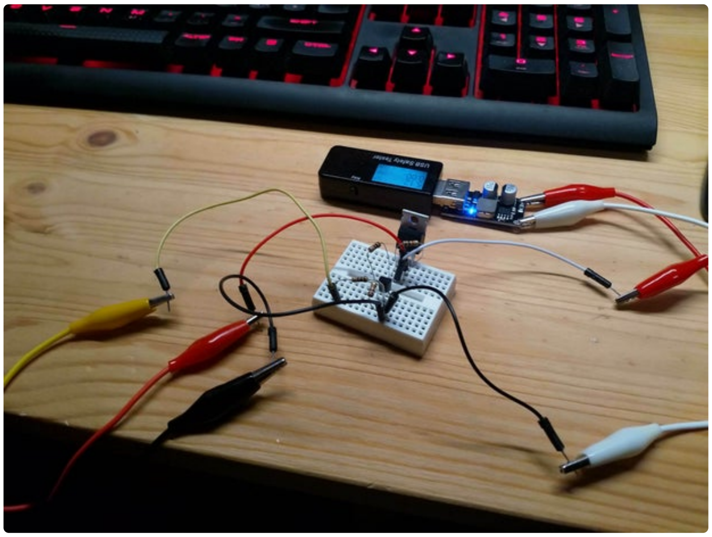
For the low side implementation I decided on going with the same implementation as I found in the drill I disassembled. That means simply wiring a IRFP3006 N channel MOSFET to the battery connector and that is it.

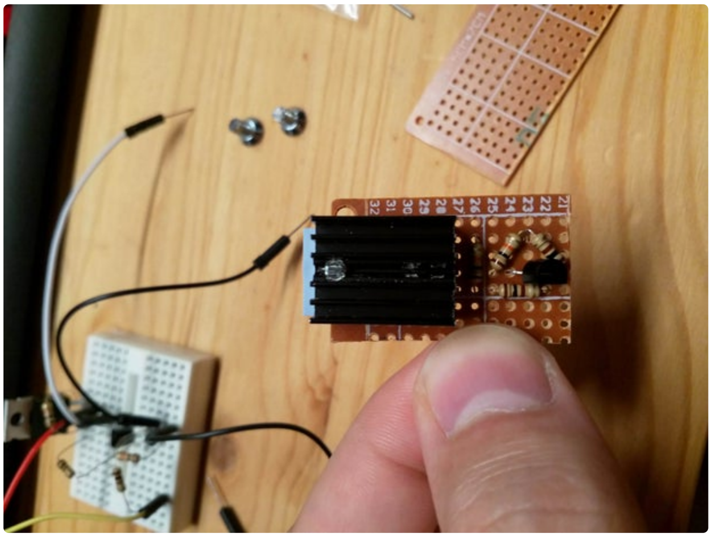
I did however for my Makita to XT60 converter add a big beefy heatsink. This is however mostly because the amount of power that I intend to draw varies depending on what I am attaching and because it is attached to the printed body, and I don't want it to heat up and deform.

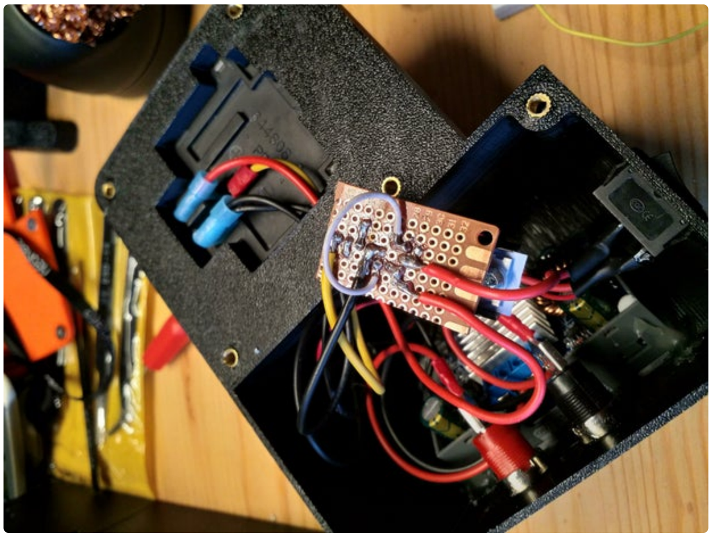
Similarly to when testing the high side switching circuit I again just attached some power hungry appliances until the battery was empty and watch as it turns off.

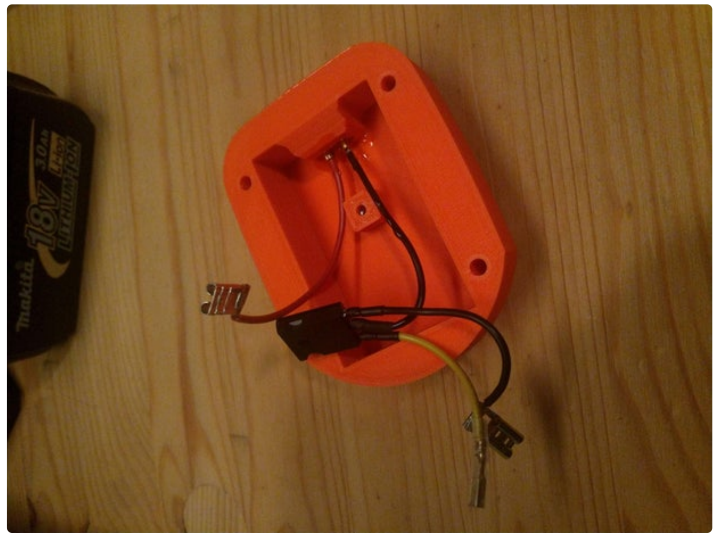
That is all.

If you have any questions, constructive feedback or









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