Power To The Crumble!

By Dr_Alex

Disclaimer: Lithium power packs are potentially dangerous. Never tamper with them. Never leave any lithium power pack, or any device containing lithium batteries charging in the house over night, especially not in the bedroom. There are many poorly constructed cells on the market that are unsafe. Be wary of unreasonable capacity claims of some lithium power packs. You should also always make sure that the USB cable you are using can handle the current you are going to pass through it!

As you may have seen in some of my posts, I've been using USB power packs to power my Crumble projects. So I thought I would say something about these power packs which hopefully will be of use to Crumble users.

The standard 3 primary cell power pack for the Crumble is ok, but it has limitations. It is only 4.5V and many modules require 5 V to function correctly. If connecting sparkles and motors to the Crumble, the voltage level can quickly drop too low. I have found this to be a particular problem with the ultrasonic measuring device. Then of course, the primary cells do not last very long and they have to be replaced. This is expensive and is bad for the environment.

The Crumble in standby mode also draws about 6 mA, which doesn't sound much, but it does mean that primary cells are not great for projects left running 24/7.

NiMH cells are not suitable, so what to do?

I have had a look at a range of different USB lithium power packs. They output 5 V, they are regulated, overload protected and, they can be recharged up to 500 times, simply by plugging them into a USB port.

But, which one to choose? Are they all suitable? Is the most expensive best? Do you need a big capacity?

Battery capacity is usually indicated by a mAh rating. This is the number of milliamps the battery can supply over one hour before its voltage drops to such a level that no more power must be drawn or the battery (well actually a cell in most cases!) may suffer damage. A "typical" lithium cell (there are lots of different types of lithium cell, with different chemistries and corresponding cell voltages) has a nominal voltage of about 3.7 V and is 4.2 V when fully charged. A deep discharge will go down to about 3 V and the cell should not be discharged so that its voltage drops below 2.8 V, or it may be damaged. There are also limitations on how fast the cell can be discharged, as this can generate excessive heat and could lead to cell venting, fire or explosion.

This mAh rating is usually performed at a relatively slow rate, perhaps over 5, 10 or even 20 hours. This is because you will get more out of a battery or cell if it is discharged slowly. Quick discharges waste energy as heat and so reduce the amount of useful power you can get out. So, you can see that a simple mAh figure from the manufacturer has a lot of caveats behind it! E.g. what was the

discharge rate? What was the cut off voltage? There are many cheap lithium cells available online claiming ludicrous capacities for their size and weight. From what I have seen, some are quite dangerous in their design. So if you are buying lithium cells, make sure you buy a well known brand and also use a reputable supplier – there are many counterfeit cells out there!

However, the cell or battery is just one part. A single cell is nominally 3.7 V and we want to use 5 V for our USB powered devices. Plus, we want to charge it from a USB port and make sure it is overload/short circuit and reverse polarity protected. We also need to make sure it is charged in the correct way, or we might damage the cell. So a USB power pack has to have a charge/discharge **controller board** and it must perform a "step up" process to provide 5 V output from the 3.7 V of the lithium cell or battery. In addition, if there is more than one cell in a pack, it needs to make sure the individual cells are properly balanced in their charging and discharging, or the pack could be destroyed. Some controllers allow the USB output power to be used while connected to a charger, others do not. There are even some controller boards you can buy which will allow you to connect a solar panel so that it can charge the battery and provide 5 V out at the same time.

As with individual cells, I have seen USB lithium power packs for sale online with ridiculous claimed capacities. A couple of years ago, I bought a lithium pack online as an emergency car starter/charger with multiple voltage output options. It claimed an enormous mAh figure. Despite this, I have never been able to start a car with it and when powering my laptop, it dies after about an hour. So buyer beware! I prefer to be able to go somewhere I can trust where I can examine the USB pack before I buy. Look at the size, feel the weight…does it seem reasonable for what it claims?

Most USB packs contain 18650 type cells, which usually start at a capacity of about 1200 mAh and have a weight of around 38 g. This can be a little different, depending on how much protection is built into the cell. High capacity versions go up to about 4000 mAh, and should be heavier, but I would be very suspicious of a cell of the 18650 size that claimed a higher capacity than this!

Another thing to bear in mind is that although the cell or battery inside the USB power pack may have a 2000 mAh rating, it does not mean you will get 2000 mAh out of the pack. The step up process is not 100% efficient (and you are trading current for voltage, the current being supplied from the battery will be greater than the current at the USB output), so expect at best to get something like 60 to 70% of the capacity quoted on the cell/battery. Despite this, it seems USB power pack manufacturers like to claim what is written on the battery or cell, not what you can physically get out of the pack at 5 V.

For running the Crumble, usually projects do not run very long and do not need huge amounts of current, so a USB power pack that can provide up to 1 A and have a nominal capacity of 1200 mAh or more is fine. This is enough to drive a couple of motors and a few sparkles for a reasonable length of time.

Depending on the type of controller board used, **there are two main types of USB power pack**. Those that are "**always on**" ready to supply power and there are those that **go to sleep** after a certain time if insufficient current is drawn. A less common type comes with a switch, so that the pack can be permanently off or on, depending on the switch position.

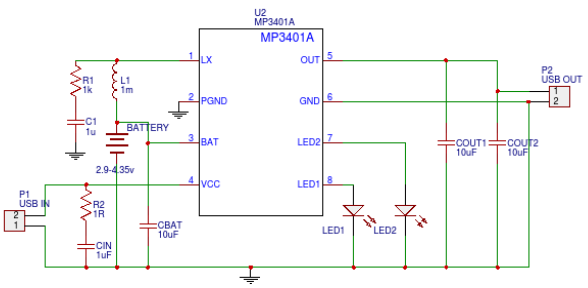
For running the Crumble, unless you can find one with a manual on/off switch, the **"always on" type is best**. I have found that the USB packs that have a sleep mode need at least 80 to 100 mA to stop them from nodding off after about 20 or 30 sec. The last thing you want is for your Crumble project to switch off while it's in a wait state. This could be overcome by putting an additional load in parallel with the Crumble, to make sure 100 mA is always drawn, but this is not ideal.

Although the nature of “always on” packs means power is continually consumed by the controller board, the amount of power being consumed is low and such a pack will stay charged for many days if not used.

Cost: I have seen USB power packs for sale in the shops from £1 to over £100. I do not endorse any particular brand or shop. I don’t like spending excessive amounts of money on this kind of thing, so I have limited myself to under £25. Currently, Asda are doing quite a nice range of reasonably priced USB packs under the “Black Web” label. One is 10,000 mAh at £18 (£15 in the post Christmas sale) and the bigger one is 20,000 mAh priced at £22. The smaller one uses two flat rectangular cells inside it of 5000 mAh each. The larger pack has 6 cylindrical cells inside it, but I was not able to dismantle it fully to see the capacity of each cell. I use one the 10,000 mAh units to power the 5 V power bus on my bike for lights etc and it has no trouble powering that for several hours. The 20,000 mAh pack weighs in at a hefty 500 g and will power my tablet PC for many hours. Asda also sell a small 3300 mAh unit for just £4 under the “Onn” label. This contains a single cylindrical cell, which seems a little larger than the standard 18650 size. These packs are great for powering USB devices and they all come with a level of charge indicator. Unfortunately, they quickly go into sleep mode unless 80 to 100 mA is drawn continuously from them, which is not ideal for Crumble projects.

I was surprised to find in my local Poundland shop USB power packs for sale for just £1. These are sold under the “Signalex” label and have a quoted capacity of 1200 mAh. They are simple plastic boxes housing a 1200 mAh 18650 lithium cell and a small controller board. They can supply up to 1 A and recharge at up to 0.8 A. They are of the “always on” type. I have used them now in many Crumble projects with great success. If the output is shorted or the current demand exceeds 1 A, the output is shut down. They charge the cell to 4.2 V, giving a flashing red light as they charge, which becomes constant once fully charged. When discharging, they give a flashing blue light until battery voltage reaches 3 V, when output is cut off. They cannot be recharged while supplying 5 V output.

The board inside utilises a MP3401 chip. I could not find a datasheet for it, it seems to be a chip manufactured by a Chinese company. I was able to find a circuit diagram on the web, although the pin outs from the MP3401 chip on this diagram did not seem to be in the correct sequence.



Circuit for USB power pack found online using MP3401 chip. NB: numbering of output pins 5 to 8 seems reversed.

Although the capacity of these cheap units is relatively low, I have been able to connect multiples of these USB packs in parallel for when more current or capacity is needed. For one project (my Crumble based ultrasonic cat deterrence garden protection system), I have connected 3 of these USB packs in parallel and I only need to recharge them after more than two weeks. I have even connected multiple packs in series for other projects to give a higher voltage. **This works, but you need to be careful!** If you accidentally input more than 5 V into one pack's output (eg when using croc clips carelessly) it can damage the controller board, leading it to becoming extremely hot and a potential fire risk.

Recently, Poundland have extended their range of USB power packs. They now sell a 2200 mAh pack under the "Power Geek" label. However, breaking with Poundland's ethos, this sells for £2! It is packaged in a "smarter" rounded plastic shell, but inside it is an 18650 size cell with a capacity of 2200 mAh. The controller board uses the same MP3401 chip, but the circuit is a little more sophisticated. It can charge at a slightly higher rate of 1 A, as opposed to the 0.8 A of the 1200 mAh model. Personally, I prefer the more "blocky" package of the £1 model, as it is easier to incorporate into projects, or to stack multiple packs. The £2 model internals can be removed from its plastic shell and housed in the rectangular shell of the £1 model, although in use, the charge and discharge LEDs are not as obvious as they are placed in a different position, they are supposed to be visualised through the end of the package instead of the top.

Poundland also sell a 4000 mAh USB pack, but this seems to be of the auto shut down variety, so I have not bought one yet. It sells for £5, so doesn't really offer much advantage over the cheaper models as these can be wired in parallel to give either 4800 mAh (4x 1200) or 4400 mAh (2x 2200) for £4 and they don't shut down when your project is only drawing 6 mA.

Are there any disadvantages in using USB power packs?

The answer to this is potentially!

The step up process involves the use of an inverter which turns the DC input from the battery at a nominal 3.7 V to an AC voltage, which is then converted to a suitable higher voltage. This is then rectified back to 5 V DC and this is supplied to the output. The rectification process is never perfect and so there can be some AC noise on the output. I have not had the chance to put a scope on the output of any of the USB packs I've looked at so far, but generally I have not had any significant problems using them with Crumble projects. In the past, I have had issues with slight "twitchiness" of servos. I think they are quite susceptible to electrical noise. So after going to a set angle, they will twitch about very slightly. However, this seems to have improved with the latest Crumble software and also, having the "servo off" command once in position seems to help. I have not experienced problems with other devices/sensors. If noise is a problem for a project, it would be possible to add some extra filtering circuits if necessary to the 5 V output from the USB supply.

Another potential problem I've not experienced, but is theoretically possible, is the possibility of **voltage from the power pack travelling back up the USB cable to the PC** you have plugged your Crumble into. USB systems on old computers might not be able to cope with an input current. I imagine Redfern have done a good job of blocking such reverse currents, but I don't know for sure. I've never had a problem, but it's probably a good idea to disconnect any battery from the Crumble before connecting it to a PC for programming.

So these are my experiences with USB power packs and the Crumble. I would be interested to hear from anyone else who has tried this, or has found a better source of suitable power packs.

It would be really nice if at some point Redfern could produce their own official lithium USB pack for the Crumble.

For further reference, I found this very interesting website from someone in Denmark who tests different Lithium cells and chargers:

https://lygte-info.dk/review/batteries2012/Common18650Summary%20UK.html

And finally…

Have fun and be safe…always treat lithium Cells and batteries with respect!