eBrompton Build

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Why build an eBrompton ?

The Brompton is a good bike for shopping or commuting and short range leisure trips. The neatness and compactness of the fold is a compelling advantage, you wont have trouble taking it on public transport or storing it in a corner etc. Fitted with a decent set of ‘easy’ wheels and a rear rack you can take it into shops and push it around folded like a small shopping trolley.

I bought a standard 3 speed Brompton some 20 years ago which I used to get to the train station to commute into work in Bristol and Swansea. About 3 years back after retiring and being bored, I added a Swytch electric kit to the Brompton. The now eBike was just fine, great for shopping trips to avoid taking the car or meeting in town for a tea.

Recently I had been noticing how heavy my current swytchified Brompton was, its a little over 18Kg. I had wanted a lighter bike for some time and of course the new T-Line Titanium\Carbon Brompton at 7.45Kg looked appealing, even with the hefty price tag.

However, the T-Line Brompton has carbon forks so unlikely to be suitable for an electric front hub motor. There are no titanium front forks, maybe there will be sometime soon. I did ask, but the standard steel forks would not fit in a T-line.

I picked up a 3 year old 3 speed (Sturmey type hub gear) Brompton, in good condition, that had most all of the steel bolts replaced with titanium ones and other lightweight parts fitted too. It came with all the original replaced parts too, so a handy source of spares. After a bit of work, I had this Brompton down to 8.5Kg, not bad considering the all titanium framed T-Line is 7.45Kg.

One maybe not obvious feature of the Brompton is its popularity, particularly in the far East. As a result of this popularity there are lots of people out there making and supplying replica parts from the most basic to all the way up to replacement titanium frames and all compatible with the classic Brompton. Want carbon wheels ? Well there is a wide range to choose from. Multiple choices for gearing setups etc. Its a modders paradise.

For instance, whilst the Brompton folding pedal is good, its heavy. You can get a set of titanium axle pedals, right fixed, left removable for around £40 and a weight saving of around 200g. Want to replace all those steel bolts used in the brakes with non-corroding lightweight titanium ones, you can, several manufacturers makes sets of them.

One of the significant weight savings, over a standard 3 speed Brompton, is to fit the 2 speed derailleur rear wheel, this is some 600g lighter than the normal 3 speed Sturmey setup.

The ultimate aim of lightening up a Brompton was to convert it to an eBrompton. My experiences over 2-3 years using the swytchified Brompton were that 2 speeds was enough. Recently I realised I had been out on several Brompton trips with the rear hub key puller chain disconnected and I never noticed. So I figured a two speed would be enough. The standard setup is a 12T and 16T cog with 50T on the front chainwheel. You can go up to 17T for the larger rear cog but an 18T requires you to grind the edge off one of the frame tubes. One of the almost standard mods you can do is to replace the standard rear wheel 2 speed cogs with a 3 speed setup, they use narrower cogs and an 11 speed chain. So more gears if you needed them. You can also by kits that replace the rear wheel with a 6\7 speed derailleur setup, so there are plenty of gear options out there.

So I have a 2 speed, possibly 3 speed Brompton, that is only 1Kg heavier that the single speed T-Line, and it cost less than half what a T-Line would be.

Here is the picture of the road ready Brompton ready for conversion. Most bolts and the bottom bracket are titanium, as is the front wheel axle. Titanium rear frame triangle and forks. Tanus

puncture free tyre on the rear, Schwalbe Kojak tyre and Tubolito inner tube on the front. Carbon bars and lightweight brake levers.

How heavy would eBrompton be ?

I have the swytchified Brompton so I know how much weight a front wheel hub motor will add. I have spares of Julet cables, motor cables, KT controller etc to weigh so I estimate that an eBrompton conversion would add around 2.3Kg weight plus that of the battery. A 10S2P 7Ahr battery would be plenty for my needs and adds around 1150g in weight, so the potential conversion would add in total around 3.45Kg. The would take the weight of eBrompton up to just under 12Kg.

Handle bars

If you look a the picture of the folded Brompton below, you can see a problem;

When folded the handlebars are very close to the ground. I have worked around this on my previous Brompton by shortening the bars and moving them off centre a bit.

There is for the Brompton (those manufacturers out in the far east again) a range of options for the bars, standard is aluminium, there is titanium of course and carbon. The standard alloy bars in the picture above weigh 240g and a carbon low rise set weigh a mere 128g, so saving weight and look a the folder layout now;

Well clear of the ground, which is good for shopping trolley mode (coming later).

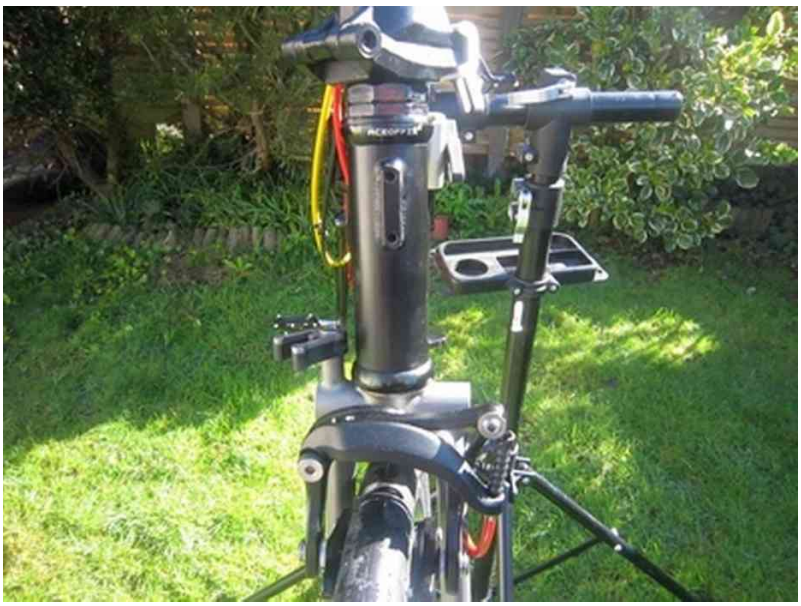
Where to put it all

So where does the battery, controller and all those spare wires go ?

Some Brompton conversion kits put the battery\controller in a bag or case on the front of the handlebars, for example the standard Swytch setup. But using this location means the battery\controller must be removed before folding so you need to have special connectors for all the wires.

Removing the Swytch battery\controller I did find to be a bit of a pain and this eBrompton is as much about convenience as it is about weight. I want the battery\controller to stay in place when the Brompton is folded and used in shopping trolley mode.

One of the key features of a Brompton is a small rectangle of metal with two bolt holes located on the front of the steering tube;



Its the bag mounting block.

It can take a fair bit of weight and its where Brompton locate the battery bag for their own electric Brompton. This location is a good place for the battery, controller and spare wires. Its close to the motor with and the battery and controller can be right next to each other. Wires to the brake lever sensors and display will be short too.

My initial idea was simple, find a suitable small bag, line the inside back with a bit of ply reinforced with glass fibre maybe to stiffen it up and secure it to the bag block. If the bag is small it wont interfere with the fold much and can be left in place, removing the major hassle with the Swytch setup.

Battery

Before I can plan any further there needs to be consideration of the battery dimensions. My current Swytchified Brompton has a 8Ahr battery and that has certainly been enough for the average shopping trip and some longer 2 hour leisure trips too. So I decided that for average use circa 4Ahr would be plenty but also have the option for a larger battery of say circa 8Ahr for longer trips. Having two batteries is good, if you forget to charge after a ride there is always the other one ready and waiting.

A 36V 10S2P of good 18650s would give me around 7Ahr for a weight of 1100g or so. Using high current capability cells I could have a 10S1P of 21700 at 4.5Ahr for around 750g. I realise that the normal view on eBike batteries is that bigger is better, but for example the 36V 10Ahr battery for my eMountain bike weighs in at 2.65Kg which is a major weight for an eBike that you want to be able to pick up and carry.

The latest Swytch kit has a 2.5Ahr battery for the ‘Air’ version and 5Ahr for the ‘Max’ so smaller batteries are not that unusual.

So assuming the bag needed to take the larger 10S2P battery, I worked out the size at around 135mm x 55mm x 70mm and made a model out of foam and card.

I found a suitable looking bag, £5.70 delivered and 103g;

But would the cheap bag be big enough ?

With the controller in the bag, it looks like this;

And with the battery added it looks like this;

With the battery on top the bag closes up OK. So I have a bag that will probably work, although a slightly bigger wider one might be good, store a few tools maybe. And the wires supplied with a standard conversion kit, especially the Motor extension and 1 to 4 extension might need to be shortened to fit in this ‘compact’ bag.

It could be useful if the controller could be put long side across the width of the bag as it would then be possible to attach heat sink fins to the rear of the controller and have them poke out the back of the bag into the open air for cooling, if heat build up is a problem that is. So a larger bag might be a better starting point so I ordered one, more about it later.

There is a range of mounting brackets designed to screw into the bag mounting block and provide a frame for attaching and releasing a bag. I found a bracket that was in two parts, because I might just need the U shaped bracket to attach my own bag battery;

With the bike folded the bag mounted on the block would be in this position, so not in the way much;

Another bag

The other, wider, bag arrived and this does look a bit more useful, its a bit wider, this is it in the position it would be when the bike is folded and the bag is fixed to the bag mounting block;

That location would be OK, so its useful to know that I can use a bigger bag if needed.

That bigger bag is designed for handlebar mounting and you could use that mount if the bag faces backwards, but then see what happens when the bike is folded;

The bag pokes out quite a bit to the side, maybe OK, and easier to setup than using the bag block.

Problems with gears

As mentioned earlier, I had switched the rear wheel from a 3 speed Sturmey Archer hub gear setup to a 2 speed rear Brompton wheel. This 2 speed wheel is around 600g lighter over a 3 speed hub gear setup and ought to be good enough, with electric assist, for eBrompton on most of the rides I do.

The two cogs on the rear are switched with a derailleur type arrangement with a slotted pusher that sits under one of the chain stays and pushes the cogs of the chain tensioner (needed to allow the fold to work OK).

There is a shift lever that attaches to the underneath of the standard Brompton right brake lever, but I had changed to the much lighter Aceoffix levers. I bought a push button 2 speed shifter and fitted it to the left handlebar, see below.

However after a test ride, I realised that this shifter does not really have enough range to shift from one gear to the other. You can adjust the gear inner so that you can be in one gear or the other but you cannot shift. A shift lever with a bit more range is needed, I found a Sun Race friction shifter on eBay that came complete with cable for £9 delivered.

Now perhaps I should have tested the gears before fitting the 34g a pair foam grips, but I did not and to try out the new shifter I had to cut the grip off. Never mind they only cost around £2.40 a pair.

The Sun Race friction shifter had a range of 27mm versus 7mm for the push button shifter. It shifts fine, but the bar clamp has sharp corners and edges, maybe OK on aluminium bars, but not so good on carbon. Perhaps a bit of inner tube as a liner will help. There also really ought to be a ferule where the gear outer exits the shifter body.

The Sun Race shifter is fine for now, but its not exactly small and a more bar friendly clamp would be good. I will keep my eye out for a decent friction shifter.

Conversion kit

There is a base conversion kit out there that can be bought without battery, from TopBikeKit. It comes with a KT controller, LCD4 display (small and light!), brake levers with switches, motor cable, 1 to 4 cable. Its based on Julet connectors and costs about £300 delivered. It would likely fit in the smaller bag I found. There are optional batteries for the kit, a 10Ahr 10S2P based on Samsung 21700 50E or a 15Ahr 10S3P also using Samsung 21700 50E cells. The 10Ahr battery weighs in at 1.8Kg.

The kits use of Julet cables is fine, but for where I want to end up with this eBrompton they are not ideal. First off there can be quite a bit of spare cable, in particular the 1 to 4 cable. Your meant to run the 1 to 4 cable from the controller up to near the handlebars where it splits into the brake, display and throttle connectors. This, together with the short lengths of cable the Julet equipped brake sensors, display and throttle tend to come with, means you probably have a bunch of cables and connectors to fold up and store somewhere between the battery\controller bag and handlebars.

A KT controller that comes with JST-SM connectors could provide a neater and slightly lighter layout. The brake sensors, display and throttle that have the JST-SM connectors on them normally have long cables, typically 150cm, so they can be run direct to the battery\controller bag, cut to length and re-crimped. There would be no joints or spare cable outside of the bag. But JST-SM connectors are not waterproof.

So I ordered the TopBikeKit conversion kit and will initially build it as standard, with the battery and connectors in a handlebar bag sold as a low cost option with the kit. When the conversion is working I can then look at tidying up the setup by moving it all into a hopefully smaller bag on the luggage block on the steering tube. With this approach I will likely get the eBrompton into a working state quicker too.

Conversion kit arrives !

It was ordered on the 23rd April and arrived on the 2nd May, not bad delivery from the far East.

I put a Marathon racer tyre on the wheel (260g) and this is the kit parts, which look OK;

I weighed all the bits (minus battery and motor wheel), bag, controller, PAS, motor cable, display, brake lever and 1 to 4 cable I would need it came to 787g.

I weighed a standard front Brompton wheel (no tyre tube or rim tape) and it was 615g. The kit motor wheel weighed in at 1906g, so adding the motor wheel adds 1291g to the weight of the bike. Thus the total added weight (minus battery) of Brompton to eBrompton will be 2078g, plus a few zip ties.

The PAS

The supplied two part PAS disc does fit on the left crank. The gap between the small curved frame tube that forms part of the triangle by the bottom bracket and the inner surface of the PAS disk is 31mm. The PAS sensor itself is 19mm high when level on the adjustable bracket and can extend to 25mm. So I cut a short bit of 10mm square hardwood, put a bit of sandpaper over the Brompton frame tube and sanded a curve on one side of the bit of wood.

Secured in place with a couple of zip ties the fitted PAS looks like this;

I might later remove the adjustable bracket and add a bit of wood as a spacer.

I was impressed with myself for finding such a simple setup for adding a PAS to eBrompton until I realised the obvious problem. Whilst that position for the PAS was easy to setup, the cable entry is pointing upwards in a please let water in mode.

Another possible issue is that the PAS sensor is a bit vulnerable to getting kicked in that position. An alternative position, where the PAS would be difficult to dislodge is position A on the picture, but that might mean modifying the sensor, which is the opposite approach if you want a quick and easy repair setup.

Motor Wheel Tyres

I had ordered a Continental Contact Urban tyre to try and when it arrived I put it on the front wheel of the non-Electric Brompton and went for a ride. Good tyres, less rolling resistance than a Marathon plus, but lighter by 200g (each!) and apparently with a similar puncture resistance. Lots of good reports about the tyre, they only cost about £16 and easy to fit.

So good for the eBrompton motor wheel I thought, but I was disappointed, they wont stay on the motor wheel rim, when the tyre gets up to pressure it tries to escape the rim, see picture.

On a close look the motor wheel rims do not look the same as standard Brompton rims, a different internal shape and narrower, 16mm versus 17.5mm. Ah well back to the Schwalbe Racers.

Here are pictures of a standard Brompton rim (left picture) and the supplied motor wheel rim (right)

You can see the differences.

Do I have a battery ?

I have been trying to get a custom battery built using a 10S1P pack of Samsung INR21700 40T or SAMSUNG INR21700 50S. Accepted that its a bit of an unknown as to how much the voltage sag under load will affect performance, but I think its worth a try. A 4Ahr or 5Ahr is enough for what I want and its a lot lighter than a 10S2P. However its been suggested that for the custom build a 5Ahr based on the 50S should be used, and they are not due in stock until the end of May.

So I need a battery to carry on with the build and should be able to borrow a 10S2P using Samsung cells in a 10S2P setup. This battery is from a hover board and checking on eBay these batteries are not expensive, about £65, so maybe too cheap to be safe. Anyway for now I only want to use it to check the conversion kit. From the times when I did a lot of flying of radio control models I have several of the fire proof storage bags, so I can put the battery in one of those.

Putting it all together – the first time

I first needed to connect the conversion kit bits together to check it all works. Once I have done that, and given the bike a test ride, I can review and test the battery options and then can I finally work out which bag to use to store the battery controller and cables.

The conversion kit had a handle bar bag designated for the install and it could take a 10Ahr or 15Ahr battery, the bag itself weighed 182g. Using this bag and the kit as is would be the heaviest option.

I put the bag on the handlebars, facing backwards so the Brompton would fold.

I had got hold of a hover board battery, which was 10S2P of 18650 inside the plastic, supposedly fireproof case they use, for testing the setup and it should be representative of the weight of a 10S2P of 18650 battery made of quality cells that would have a capacity of up to 6.7Ahr. I put thehover board battery in the handlebar bag.

I added the controller to the bag, plugged in the 1 to 4 cable and the display, the throttle, connected up the motor wheel and turned eBrompton on. It powered up OK so I checked the wheel size was 16” and set it for mph. The wheel did spin the right way using the throttle as a tester so I plugged in the PAS and rotating the cranks did make the front wheel go.

I tidied up the cables, with all the cable slack being coiled up inside the bag. I then went for a ride.

It performs much the same as my Swytch Brompton. Only having two gears was not a problem, with the electric assist you can stay in one gear most of the time. Maybe the high gear could go up a bit, possibly change the front chain ring from 47 to 50 or 52, something to look at later.

The total weight this working eBrompton was **11.8Kg.**

So that looks promising, a better quality battery which would be smaller and lighter would need a smaller lighter bag. Then tiding up the cables and getting rid of all the slack will save a bit, so the finished weight should creep under **11.5Kg**, or **10.75Kg** plus battery.

Who needs Titanium ?

The stem catcher is what holds the handlebars in place when the Brompton is folded, a knob on the steer tube fits inside the catcher.

When I bought the bike, the standard Brompton stem catcher had been replaced with an H&H Titanium stem catcher. They cost around £30+.

However it did not really hold the handlebars firm enough, so I gave the arms a little squeeze, like you do. The catcher snapped, oh dear.

So I put the standard Brompton stem catcher on and the weight of the bike increased by a massive 16g, not good enough. So I ordered an Aluminium one costing as much as £6.25 from China. Fits just fine, hold the bars very securely. Its lighter that the titanium one.

Brake levers and sensors

The brake levers with built in switches as supplied with the TOPBIKEKIT could be used.

But for me that would be as a last resort. The conversion kit was only about £5 more expensive with the levers, so I thought they might be useful as spares. What I would much prefer is to keep the Aceoffix levers I had already fitted to the Brompton. The above lever weighs 112g, the Aceoffix levers are 78g lighter.

There are inline brake sensors that fit on the brake cable itself as on the Swytch kits. The 1 to 4 cable has 2 pin red Julet connectors for the brake sensors, so I bought one of the inline sensors with a 2 pin JST-SM plug.

I was not sure how the two wire brake sensors worked so I built some Julet to crocodile clip adapters so I could check. If the brake lever switch was just that, a simple switch, you would expect the resistance measured between the two wires with a multimeter to be the same when the multimeter leads were swapped around. If there was semiconductors involved in the switch\sensor then you would expect the resistance to change when you swapped the leads around.

The resistance across the two wires of the brake lever plug on the TOPBIKEKIT levers when the brake was applied was around 10ohm, and infinity when the brake lever was not active. The readings when the levers were the same when the connections were reversed. This suggests a mechanical switch.

I fitted the in-line 2 wire sensor (with the JST-SM connector on the end) to the front brake lever and carried out the same test. To fit the sensor you just pull back the brake outer at the lever and slip the sensor over the inner, so easy to fit (If they work). The similar 3 pin ones work well on my Swytchified Brompton. The test results suggested the in-line sensor was a mechanical switch also.

I cut the JST-SM connector off the in-line sensor and used one of the Julet to crocodile clip adapters I had made to connect the in-line sensor to the controller and the display did indicate brake when the lever was activated, success.

I cut the JST-SM connector off soldered on a 2 pin Julet connector.

I now have a fully working eBrompton at **11.8Kg** and there are still weight savings to make. The next decision is what battery to use. If a 10S1P 21700 5Ahr battery proves up to the job, that would be my preferred option, but it is likely going to be a couple of weeks before I get hold of one. The next option would be a 10S2P 18650 6Ahr which would be slightly bigger and heavier.

How to save 13.2g

The metal ring that you would normally use to hold the PAS disk together on a heavyweight eBike, weighs 13.3g. The PAS disk halves seem stiff enough when pushed together and to keep the halves together without the heavy ring, I used a bit of spectra cord.

Early trials

Fairly often when ordering stuff on eBay if they do ‘Click and Collect’ I will have it delivered to the Argos in Sainsbury's which is about a 5.5km journey each way and about 80m in height of hills to climb, or around 260 feet of climbing in units that most of us grew up with.

To give eBrompton a trial, whilst waiting for supplies of 21700 5Ahr cells to turn up, I bought a Hoverboard battery, its 10S2P @ 4.4Ahr of allegedly Samsung 18650 cells and cost £50 delivered, it arrived the next day too. It weighs 965g.

eBrompton has not been upgraded to shopping trolley mode, so when I arrived at the store I carried the folded eBrompton, with battery still in bag by its built in handle (the saddle nose) to the Argos outlet at the back of the store. I carried eBrompton about 75m. Would not want to carry it much further, but I could manage it. So for local trips such as to small shops if your ebike does not have shopping trolley mode, its quicker to fold up the bike and carry it rather than lock it up outside. I was going to say the same would apply when visiting the doctor or dentist, but most people wont remember what they are.

The route home to shop only has a couple of hundred meters of main road, the rest is about 50:50 quiet residential streets and cycle paths. I mostly rode on assist level 2, but on a couple of the steep bits I put it up to level 5. The motor and battery seemed to cope with this well enough.

When I got back to my house, I waited 60 seconds and made a note of the battery volts, it was 36.2V. When I get some ‘better’ batteries I can use this 11km hilly route as a standard to compare batteries against. If I get a battery that would do the route twice, that would be enough for my needs, for longer trips just carry another battery.

After I had upgraded eBrompton to shopping trolley mode I collected another ‘Click and Collect’ parcel with a freshly charged battery. Wheeling the folded Brompton through the store was heaps easier than carrying it. When I got back home I measured how many amp hours needed to be put back into the battery for it to be fully charged. It was, 2.34Ahr so approx 4.7km or 3 miles per amp hour. Thus a 5Ahr battery ought to be good for 23.5km which is longer than most all local trips I do on eBrompton.

A standard trip from house to Cardiff bay barrage car park is 11.4km there and the return is 12.3km, so 23.7km, but that route is mostly flat.

Something worrying discovered whilst in Hospital

I was visiting someone in the local Hospital and rather than do the 20minute walk from home, I rode there on eBrompton. Of course I left the battery behind so this was a simulation of riding the bike as if the battery or electrics had failed. The cycle was OK.

I arrived at casualty, folded eBrompton up and carried it in. No-one said anything, folded it hardly looked like an eBike anyway.

It was whilst I was sitting down in the ward that I noticed a problem with folded eBrompton. The PAS sensor disk on the left side interferes and is bent outward by the Brompton rear frame triangle, when its folded underneath the bottom bracket, see picture below;

That issue probably explains why the Swytch kit uses a PAS disk that attaches to the crank arm and not the bottom bracket axle.

Fortunately there looks to be plenty of room out on the right side, using the type of PAS sensor that fits between the frame and the bottom bracket securing sleeve.

So I removed the right crank and put the sensor in place. Spinning the PAS disk did make the front hub motor rotate the correct way, so I put the chainwheel back on.

The PAS disk was not as close to the PAS sensor as I would like, the gap was around 5.6mm.

With the chainwheel removed again I found that the sensor stopped working at around 6.5mm spacing, so its within 1mm of failing, not good. For potentially more reliable operation, I bent the sensor disk a bit and added a 2mm spacer to the bottom bracket mount to move the PAS disc out. With the chainwheel and crank back on it looks quite neat, works too.

Only annoying problem was that the cable on the right side PAS sensor was quite short, so there was a connector visible outside of the battery\controller bag.

I like to have spares to hand, so I now needed to buy another right side PAS sensor as a spare. I found an el-Cheapo one (£5), which had a long cable. Yes it had a JST-SM connector but it should be easy enough to wire a Julet to the end, see below.

What is maybe convenient about this sensor is that if the sensor part fails, you can easily access the single screw fixing it to the metal bracket and replace the sensor without removing the chainwheel and crank. I have had a PAS sensor fail on another eBike.

Portable repair stand

There is the problem that when out and about and you need to repair a puncture. Its easier, particularly if its the rear wheel to turn the bike over and prop it upside down on the ground. There is a problem with all bikes in that the stuff on the handlebar can get damaged, particularly in the case of an eBike which has a display to worry about. Break the display and the eBike goes no more.

I had seen the ‘Handlebar Jack’

https://www.handlebarjack.com/

Which is a pair of small tripods that you fit with elastics to each of the bar grips and then turn the bike over. You can buy them on eBay £40 and the pair is light at 90g. Neat idea.

However 90g is a lot to carry around all the time, so I had a think.

Expanded Polypropylene foam (EPP) is a foam I have used for making radio controlled planes. The foam is light and springy but stiff for the weight. It does not fall to bits like polystyrene. It sticks very well indeed with contact adhesive too.

I had a cut block about the right size so I cut a circular hole in it and then cut the block in half.

eBrompton is only around 12kg, so for a real test I placed the blocks on the handlebars of my much heavier eMountainBike, I held them in place with a bit of PVC tape.

I turned the bike over and it was quite stable and firm resting on the foam blocks with everything on the bars well clear of the ground.

Weight of the foam blocks, 6g plus 2g for the tape. Cost of foam, around £2.

Taking control of charging

The 10S1P of Samsung 21700 50S 5Ahr is on order, so with a test and comparison to be made with super el-cheapo hover board batteries, it was time to take control of charging. I wanted to be able to more closely monitor the charging process and add a bit of extra safety too. Later on I wanted to be able to measure the amount of charge applied to a battery and to be able to measure the batteries Ahr capacity in a controlled way.

Monitoring the charge process

I wanted to be able to control the charge cut off voltage for three reasons;

First there are indications if you mostly charge to 41V (for a 10S battery) then you may extend battery life.

Second if your not going to use the battery for a while it can be a good idea to charge only to say 38V for storage.

Third, if you could set a charge cut off voltage of say, 42.5V, you would have some protection against a charger failure potentially causing a battery fire.

However most all eBike chargers have a fixed charge limit of close to 42V, they are not normally adjustable, which in itself is maybe is a good idea for safety reasons.

There is a low cost device (£8.50) that will monitor the battery voltage with settable low and high voltage limits. This device is the XH-M602. It has a mains relay which allows it to turn on or off a connected battery charger according to the set limits.

So if you set an upper limit of 42.5V and something went wrong with the charger then the XH-M602 will detect the over voltage and remove the mains power to the charger, thus maybe preventing a battery overcharge and\or fire. If you do only want to charge the battery to 41V, then just set that as the upper limit.

The XH-M602 is a bare PCB with mains connections and it would not be safe to use it on the bench uncased. So a simple box was needed.

Clip top food containers, the good ones, are fairly solid, easy to work as project boxes and cheap. I decided to use a 680ml one from Tesco.

The switched mains output is connected to a twin mains socket, one socket for the charger and another for a timer light, etc. I suggest that only those with experience of working with and building mains equipment attempt such a build.

The mains leads are fixed in place with grommets from TLC Electrical and there is a pair of shrouded multimeter style sockets to tap into the battery voltage. The matching plugs are shrouded, since using bare plugs would be a considerable hazard, all too easy to accidentality short something out and many many amps could flow from our battery.

The XH-M602 was mounted on hex threaded nylon pillars to bring the display and switches closer to the lid. The switches were extended outside of the box by gluing and heat shrinking some short rods to the top of the switches on the PCB. The assembled charger controller is shown below. Easy to secure the lid with self tapping screws if you wish.

I needed a lead set to go between the battery and the charger which would allow the charger controller to monitor the battery voltage. The shrouded multimeter plugs in the picture above go in the sockets on the charger controller. There is a fuse in-line with the battery positive. If you wanted to check the accuracy of the XH-M602 voltage display then the shrouded plugs used have a 4mm socket on them allowing you to daisy chain and plug in additional leads such as for a separate multimeter. The battery leads are on the bottom left and the charger connects to the anderson powerpole connectors on the bottom right.

I discovered a problem however, the Swytch battery\controller pack does not appear to connect the battery to the charge socket unless there is a voltage present on the socket from the charger. So the XH-M602 does not see a battery voltage and leaves the charger mains off. To correct this problem you need to force the charger to initially switch on so its output voltage then turns on the battery and the XH-M602 is happy.

The circuit of the XH-M602 looks straightforward there is a 12V relay switching the mains for the charger with one end of its coil connected to +12V and the other end grounded by an open drain or open collector transistor. So all we need is a push to make switch with one wire to the open drain or open collector transistor (or the anode of the diode across the relay coil) and the other end to circuit ground.

I made the change and the charger, if needed, can now be forced on at the beginning of the charge cycle, hold the button down for a few seconds, release it and the charger should now stay powered, assuming the battery is not equal or higher than the stop voltage.

The XH-M602 is a low cost option that allows you to take control of the charging process and you can charge your batteries to the voltage you choose as long as its within the chargers limits.

Conversion to trolley mode

Bare bones eBrompton works just fine, but in its basic state whilst its light enough for lifting in and out of cars etc. For taking it into larger shops, rather than leaving it outside to make the thieves happy then you need to fold and push the Brompton in shopping trolley mode, you wont want to carry even eBrompton very far.

Shopping trolley mode requires that you have wheels on the bottom of the folded Brompton so you can push or pull it around, just like a shopping trolley. A standard Brompton will have small wheels around 6cm diameter fitted to the frame by the rear suspension block, just behind the seat post. Whilst the standard wheels are OK for pushing the Brompton around on the floor to store it in corners etc, the wheel base is fairly narrow at 14cm so the folded Brompton is not that stable. To make wheeling it around easier its common to fit an extendible wheel set that changes the wheel base up to 24cm or so. The wheel on the right side pulls out on an extension, if it were out all the time you would catch your foot on it.

The rest of the wheeling platform is provided by fitting a rear rack and then another set of wheels go in the mount points s at the end of the rack. The general arrangement of the rear rack is shown bellow.

There are two basic trolley modes, the first trolley mode is what I use and I leave the saddle up a bit and stand behind it and push and steer the Brompton with one hand on the saddle, see picture bellow.

In the saddle up mode be careful if you decide to lift the Brompton up by its handle (the saddle nose) as with the saddle up the Brompton is not locked in folded position. To prevent it unfolding when you do lift it with the saddle up fit a strap around the frame tube and rear wheel to keep it all together, see the red velcro strap in the picture above.

The second trolley mode is to leave the handlebars up and use the handgrips to push the Brompton it in front of you, or drag it behind. This mode can also be used if the Brompton does not have a rear rack with wheels but does have a rear mudguard fitted with a single wheel on it.

With the trolley mode added eBrompton is at a stage whereby its fully useable for local trips, going into shops and train stations etc. I have not fitted the carbon mudguards yet, waiting for some titanium button bolts to arrive.

Improvements to trolley mode

With the two sets of straight sets of wheels fitted the eBrompton is easy to push, but not so easy to steer and keep in a straight line. A suggested solution is Omni wheels.

The Omni wheels have rollers arranged so that one is always in contact with the ground, this means the wheels can move in all directions.

There are plastic Omni wheels that are cheap and light but they have plastic hinges for the rollers and they break quite easily when used on a Brompton in trolley mode. There are aluminium Omni wheels but they are not light. I was searching around and found a modified set of plastic Omnis wheels with metal hinges for the rollers that are advertised for the Brompton, no surprise really lots of stuff is made or modified for the Brompton.

These modified Omni wheels are a revelation, the folded eBrompton is very easy to push and steer, you can even spin it around on the supermarket floor. These modified Omnis wheels have a significant advantage over the normal straight wheels and a fair bit heavier, 78.7g versus 27.1g (for each wheel and bolt) but very much worth it.

Tanus airless rear tyre

I swapped out the rear Tanus airless tyre for a Continental Contact Urban air tyre with a Tubolito tube. Weight is around the same. The ride on the Continental Contact Urban is better, not so harsh.

Its a shame really, on normal cycle paths and good roads the Tanus is OK. The ride is not as good as an air tyre, but acceptable. With the Tanus there are no more punctures, no removing wheels when out and about nor the need to carry spares.

Many years ago when roads were kept in reasonable condition then Tanus airless tyres would have been OK in my locality. But in these modern times and with an overall national policy to apparently discourage cycling, road maintenance in my area seems to have been consigned to history.

Better tyres for front motor wheel

I previously had a problem with Continental Contact Urban tyres on the front motor rim. The rim appeared to be slightly different to a standard Brompton wheel rim and the Continental Contact Urban tyres would not hook into the rim properly. So I had fitted a Schwalbe Marathon plus on the front with a Continental Contact Urban on the back.

The Continental Contact Urban seems to have become the go for tyre on a Brompton, its light, apparently hard wearing and highly puncture resistant, see this video;

https://www.youtube.com/watch?v=3knxI7Q0qwk

“I tour a lot, not had a flat in two years on the Brompton, in the thousands of miles, commuted to work, gravel paths, off road”

I wanted to have a handy spare tyre and when I found that the Continental Contact Urban folding tyres (from Brilliant Bikes) were cheaper (£28) and lighter (-44g) than the wired version I bought one. The wired version is £30 and a Schwalbe Marathon would be £37.50.

I decided to test fit the folding version of the Continental Contact Urban to the front motor wheel of eBrompton to see if I had the same problem as the wired version where the tyre bead comes off the rim on inflation.

The folding tyre was easy peasy to fit by hand, no tyre levers needed. Easy to get off too without levers so minimal risk of pinching the tube.

I inflated it to 90psi and it fits very well, nice and clean and even. Looks secure. I marked the edge of the tyre where it met the rim with a black marker all the way round on both sides of the tyre and removed it from the rim. I could see from the markings that the bead was evenly under the rim hook all the way around the tyre, good job.

Its rides well, at least in the dry, a bit smoother than the Marathon plus.

The front tyre I had previously fitted to eBrompton was a Marathon plus weighing 480g. The Continental Contact Urban folding is a mere 213g, so if these tyres are really as puncture resistant as the Schwalbe Marathons, then there is an overall weight saving on a Brompton for two tyres of 534g, cheaper too. Lets see how they last.

Adding the mudguards

The titanium button bolts arrived so it was time to add the mudguards. Ever since I started using a cycle for commuting, local shopping and touring rides, I have used full mudguards. Back in the day, circa 1977 I was the

weirdo riding around on a custom Reynolds 531 double butted road racing cycle, fitted with full mudguards. I never have understood why so many cyclists go around on bikes that make them dirty when it rains.

The eBrompton mudguards are carbon, they don't save much weight versus standard Brompton guards but they do look cool. The front mudguard stay is a titanium version. The rear mudguard is held in place by the rear rack.

The added weight of the mudguards, including stays, flaps and bolts was 177g.

Next steps

I was hoping that by now I would have a 10S1P battery of 21700 cells to try, but delivery of the battery I ordered has been delayed, not sure when I might get it. I need the battery to see if it performs OK if it does then I can plan to use that, otherwise it will need to be a 10S2P of 18650. With the battery chosen I can select the best battery\controller bag and work out all that's needed to move the bag onto the Brompton front carrier block and shorten all the cables and tidy the conversion up.

The current weight of eBrompton, with added rear rack, extendible wheels, Omni wheels and front and rear mudguards is 12.9Kg. If the 10S1P battery works OK, and with the changes related to the battery\controller bag are carried out, the final weight should, hopefully, be in the region of 12.5Kg.

10S1P 21700 battery arrives

So finally the battery made from 10 x Samsung INR21700-50S, 5Ahr arrived. Its small, 125mm x 78mm x 45mm and light at 826g. See picture alongside one of the batteries from my eMountain bike;

But is it good enough ?

So I went for a trip, much longer than my normal shopping trips. The route was mainly flat on cycle paths and quiet roads. I went to the barrage in Cardiff bay, called in to see someone on the way back and popped into One-Stop to get some beers and returned home.

I was not hanging about doing 14mph mostly on assist level 1. There was actually quite a bit of assistance at that speed, I was not putting in a lot of effort. Total distance was 15 miles and I had about 25% battery left when I got home. Toward the end of the journey there is a 450m long hill and I went up that throttle only, battery voltage did sag down to 34V or so.

Ebrompton does have gears, 2 speed at the moment but will be upgraded to 3 speed. I don't normally use the gears on eBrompton in electric mode, the motor gives you the assistance needed on hills. You could argue that if the gears are not used then why not remove them and save more weight. Problem with that is that if the battery goes flat or the electrics fail then the gears are real handy for getting you home. Of course with a Brompton you could also just jump on a bus or train or call a taxi to get home.

The purpose behind eBrompton was to provide a light eBike that I could use for mostly local trips to shops, bank, doctor etc. Bromptons even in their basic form are not low cost and its not the sort of bike I would risk leaving locked up somewhere as you wander around town shopping. So I take it with me but for that to work it has to be light, easy to fold and easy to wheel around when folded.

If I want to go on longer trips or on off road tracks I would take my eMountain bike, that has a 17Ahr battery better tyres and front suspension. But its about twice as heavy as eBrompton and nowhere near so easy to get on and off.

I measured some of the typical trips I would use eBrompton for and the round trip distances were;

Bank and centre of town, 6.25 miles.

Doctor, 2 miles.

Tesco 2 miles.

Sainsburys click and collect, 6.6 miles

So most all of the trips I would do on eBrompton will use no more than around 33% of the battery capacity.

At this point I have a dilemma, the 10S1P is good enough for the intended purpose, but would a 10S2P of good quality 18650 and 7Ahr be better ? Such a battery would be maybe 250g or so heavier and a bit bigger at about 151mm x 106mm x 67mm, but it should provide more range and\or offer the potential for higher assistance levels. Choices, choices.

Motor Drag

I have ridden eBrompton with the electrics off and it fells not much different to having a non-motor front wheel. I though it would be good to know just how much drag there is from the motor when its not powered. Electrics can fail and you can forget to charge a battery, can you then still use the eBike without dying from exhaustion ?

I found a bit of road that was a hill followed by a long flat stretch at the bottom. The idea was to freewheel down the hill with the electrics on and off then repeat the test with a non-motor front wheel and compare how far eBrompton would roll before it stopped. For sure this is not measuring the exact amount of motor drag at a constant speed of 15.5mph, but it does provide an indication of the whether the motor drag in unpowered mode is significant.

I marked the kerb edge with a bit of chalk at the start point on the hill and first did the test with the motor wheel, first with the electrics on, but no power to the motor, then with the power switched off. I swapped the motor wheel for a standard no motor Brompton front wheel, and did a further two runs down the hill. The tyre type on the motor wheel was the same type as that on the non-motor wheel.

The nearest stopping distance was 55M, and the runs in sequence were;

Motor wheel, electrics on, 55M

Standard wheel, 57M

Motor Wheel, electrics off, 58M

Motor Wheel, electrics on, 60M

Standard wheel, 61M

Motor Wheel, electrics off, 66M

There is no indication that there is significant amount of motor drag, some of the runs with the motor wheel fitted are longer than those with a standard non-motor wheel.

Note: There was no wheel changing involved when out and about, I cycled back home so I could use my substantial and heavy torque wrench when swapping wheels and fitting the wheel nuts.

Measuring battery voltage sag

The amount of voltage sag the battery has under load is useful. Too much voltage sag under load means the available power is reduced due to overcoming the internal resistance of the battery that causes some of the sag.

The LCD4 display used on eBrompton will show the battery voltage. What would be useful is a simple standard test that I can repeat for various batteries (or bikes) and at different states of charge. So I identified a flat and quiet bit of local cycle track. The test run would be a short track of 250m only from standing with a few pedal strokes to start and then using max throttle up to the 25kmph limit. The voltage on the display would be noted as the end of the 250m run was passed. If I was testing multiple batteries in one session then I would wait a bit between tests to allow the motor and controller to cool down.

I first did some tests with fully charged batteries. The voltages recorded at the end of the 250m run were;

4Ahr Hoverboard battery, 10S2P of 18650 cells, 38.7V

4.4Ahr Hoverboard battery, 10S2P of 18650 cells, 38.0V

5Ahr Custom battery, 10S1P of 21700 cells, 39.4V

The next batch of tests will be over the same track but with an almost flat battery.

Monitoring battery and power usage

Its useful to be able to see what's happening with the battery, how much power and current is being used. I could fit an LCD3 display to eBrompton and that will show the power usage, but I would prefer to see the current being used.

I had earlier tried a power meter I had had some time, I used to use it to measure power\current used by electric radio controlled model planes.

But the display was not visible outdoors, especially in sunlight. For good outdoor visibility you need a transflective type LCD display. I could have replaced the LCD in the power meter above, but the display was around £9 to buy. So I had a hunt on eBay and the power meter below was only £8.61. The display did look like it was the transflective type.

The power meter arrived it tested out OK, so I took it to bits to replace the power in and out leads with longer ones. No additional flux was used or needed soldering the thick wires and XT60 connectors.

I cut two holes in the eBrompton battery bag and fitted the display in place.

As you can see its very clear and easy to read even in direct sunlight, nice big letters too. The amp hour used display option is useful.

I had been in the habit putting a bit of effort in and in assist mode 2 would often be doing max speed, 15.5mph. I noticed in that mode that the current used was around 12A, so I would only have about 25 minutes run time. If I held back a bit on the peddling speed I was travelling at around 11 – 12 mph, but the current used dropped to around 2A. So just small increase in speed of around 4mph would cut the distance I would get out of a charge from about 28 miles to 6.5 miles, on flat cycle tracks. I was surprised how much potential range increased by going just a bit slower.

Moving the battery and controller bag

To get the electrics working and test that the choice of batteries performed as required, I had used a temporary housing for the battery, controller and miscellaneous cables. This bag was handlebar mounted facing rearward. Unfortunately this position means that when eBrompton is folded the bag is poking out to one side. This increases the folded width quite a bit and the folded bike will tip over towards the bag.

The extendable easy wheels fitted to the hinged rear frame do mostly stop it falling over however.

If you ride the Brompton with the wheel extended, then your right heel will strike them when pedalling, that why you need to be able to pull the wheel in and out. Even with the extendable wheels in use the folded Brompton still tips over onto the right side wheel on the rear rack lifting the left wheel off the ground.

One solution to these rolling issues is to fit a front carrier adapter to the steel threaded block on the front of the Brompton steering tube and then mount the battery\controller bag on that. The Brompton carrier block is designed such that bags with a matching carrier plate can be easily attached and removed. The front carrier adapter I decided to use is below, its in two parts, the rear u shaped bracket is attached to the front part, that has the quick release catch, with a couple of M5 countersunk screws.

Using the carrier block for the battery\controller bag is the approach used by the standard electric Brompton, but then the battery controller is not left on the bike when its folded, its too big.

This is not the approach I wanted to take, I would much prefer that the battery\controller bag would be permanently fixed to the block and stays in place when eBrompton is folded, less to carry around and lose that way.

To hold the battery and take its weight I first thought to use the bracket below which weighed in at 102g.

I planned to cut a hole in the back of the bag to take the carrier block shown earlier and add a stiffener or liner if needed to the inside rear of the bag and screw the angled bracket and bag liner together with nylon screws and bolts. Some velcro straps would be fitted behind the angled bracket to allow the battery to be held in place. With the battery resting on the angled bracket all the bag itself would be supporting is the controller and the surplus cables.

However when I test fitted the bracket, it looked fine in cycling mode, but when folded the battery was rather high up, making it difficult to push the folded Brompton into a tight space such as under a desk.

The battery really needed to be lower down towards the mudguard.

So I made my own bracket out of 2mm aluminium and used some button head screws to secure the bracket to the front carrier adapter shown earlier.

I then melted two holes in the back of the chosen bag so the bottom of the aluminium bracket was at the very bottom of the bag and secured it to the front carrier adapter to check the fit;

Next, checking cable routing.

Checking cable routing

I needed to be sure the cables for display, brake and motor can be routed to the bag. On a non-folding bike this is not normally an issue, but on the Brompton the cables need to be routed in such a way that the rear wheel can fold underneath and the steering tube can fold backwards whilst being twisted forwards without damaging the brake, gear or electrical cables. Fortunately the front brake cable is fairly stiff and can keep the more flexible electric cables from flopping about.

If you look at this photograph you can see the smooth line that the yellow rear brake cable takes along the converted Brompton. The PAS wire from the bottom bracket can follow the yellow rear brake cable up to the handlebars and battery\controller bag. The cables for brake sensor, display and throttle are easy to route along the handlebars and are quite short. The motor cable can follow the route of the red front brake cable up to the handlebars.

However with the battery\controller bag lower down on the steering tube, just above the front mudguard the PAS cable has to jump across to the steering tube and there are now three cables for brake sensor, display and throttle to come down from the handlebars to the bag.

To test the layout I put the aluminium bracket in place on the block and removed the motor and PAS cables from the current handlebar bag and ran a test of the possible cable runs, including running the brake sensor, display and throttle cables from the handlebars.

It looks a bit of a mess, since some of the old cables are still in place. But nothing un-toward happened when the front wheel was turned either way and the fold looked OK with no cables catching so it was time to build up the battery\controller bag.

Building the bag

The back of the bag consisted of a thick nylon fabric outer, a stiff-ish PVC liner plate, a thin layer of white polythene foam and a very thin nylon fabric liner on the inside. I used the aluminium plate to make the positions of the needed mount holes in the back of the bag;

I fitted a plastic grommet in the back of the bag to thread to cables through. I then secured the aluminium plate to back of the inside of the bag back with 6 M5 Nylon screws (very light!). The bag was adequately secure and it would only be carrying the weight of the controller (276g) and a bit of spare cable. The cables on the handlebar, display and brake sensor were not long enough to reach the bag so I used Julet extension cables and fed all cables through the bag grommet. The controller went in the pocket at the front of the bag. At some point I will tidy up the cable install so the julet extension cable joins are not visible.

Assembled onto the block the inside of the bag looks looks like this;

So plenty of room for cables or a bigger battery. With the bag done up and the eBrompton ready to go, it looks like this;

The folded eBrompton now looks a lot better and is more compact, it hardly looks like an eBike at all, its Stealth eBrompton now.

Getting rid of the spare cables and visible cable joins

I had originally bought low rise carbon bars, but decided that leaning forward Manx Missile racing mode was not my riding style so bought some higher rise carbon bars (£30) which would provide a more upright riding position. The riser bars would need the brake and gear cables to be longer so I fitted the riser bars before starting to tidy up the cables. I did the brake and gear cables first and then checked the fold was OK.

With cables initially in place there was quite a bit of spare cable in the bag, the PAS, display, brake and throttle all had standard Julet style extension leads added to reach the battery\controller bag. I cut the these extension cables short and rejoined them with solder and heat shrink. I then covered most of the cable runs with nylon spiral wrap so the joins were not obvious.

I swapped the 120cm motor cable for a much shorter 60cm one which saved a fair bit of weight and cut down the 1-4 cable too, that saved quite a bit of cable as well.

This is what the cable layout looks like;

Rear Gears

I had fitted a 2 speed rear wheel to eBrompton and this saved a fair bit of weight over the 3 speed Sturmey Archer hub gear. The 2 speed cogs were 12 and 16 teeth and with 47 teeth on the front crank this was fine with the electrical assistance and the bike could just be used in get home mode if the electrics failed.

The 12/47 combination was perhaps a little high for normal non powered pedalling on the flat and 16/47 was a bit low. A simple modification to improve non electric mode is to replace the 2 rear cogs with 3 cogs. A couple of firms sell these cog sets which are thinner to fit in the gap and need an 11 speed chain. The standard 2 speed cog set weighs 42.3g and the 3 speed cog set weighs 50.01g for the 10, 14 and 17 set. That's a better spread than the 2 speed and the actual gearing can be fine tuned if needed by changing the front chain ring.

The crank set uses the 130BCD chain rings which are easy to find and low cost, around £12. I had already fitted a Sunrace M90 friction shifter (remember them from the 70s\80s ?) so there would be no index issues.

Pedals

The Aceoffix titanium shaft pedals, with a removable one on the left for neat folding, were OK and nice and light. I had bought the ones with two stick out bars in the pedal frame since this type could be fitted with reflectors. However I was constantly scarring my legs when walking with eBrompton and my leg hitting the pedal. So I devised a plan to fit a bendy bit of plastic to protect my legs from the pedal sticky out bits. Much money saved on plasters.

When all was done, eBrompton was eventually finished and the change to riser bars made it quite a bit more relaxing to ride.

With eBrompton done and working and with the battery bag in the final position, I stripped eBrompton back to the basics. I wanted to know just how light the eBrompton could be with no mudguards or rear rack for good rolling when folded.

The result for a 3 speed electric Brompton was **11.6Kg**. Without the rack and rolling wheels you cannot unfortunately push it around a supermarket. But you can definitely ride it, carry it and easily lift it into a car or stuff it under a desk. Here are some pictures;

The ultra light Electric Brompton, with no mudguards or wheels for rolling is an OK setup for a weight freak (?) but the basic handling and carrying of the folded Brompton is not so easy. The wheels themselves touch the ground and frame so the bike wont roll.

The easiest (and lightest ?) solution to this problem is to use the rear mudguard designed for the Brompton when its fitted without a rack, this is the L type mudguard. If you have a rack fitted then the read mudguard connects to the rack and no mudguard stays are needed, this is the R type mudguard.

Now I am definitely a mudguard person, so I wanted to see if the weight could be kept under 12kg, with the mudguards fitted. The rear mudguard on a Brompton (without rear rack) has a rolling wheel on it so it would be interesting to see if the folded eBrompton would be stable, as in not falling over, in this minimalist setup, so I set to work.

I attached a roller wheel to the rear mudguard on the Brompton and fitted the mudguard in place with the titanium stays. It looks like this;

The LitePro easy wheel extension bar (£11) which is the black aluminium bar just behind the seat post in the picture above, was needed to space the folded Brompton off the ground a bit. Without the easy wheel extension in place the front wheel of the folded Brompton touches the ground and you cannot roll it or easily push it under a desk. The other advantage of fitting the easy wheel extension bar is that when you pull the right wheel out the folded eBrompton does not fall over, which is good. See the pictures below;

You can now push the folded Brompton around on the floor on the easy and mudguard wheels. The rolling is not as good as having a rear rack with wheels on which is really needed for pushing the Brompton around a shop fully folded with the handlebars down. With the mudguard wheel setup you can however fold the handlebars up and push or pull the Brompton around like a cart whilst holding the handlebars.

Some more pictures;

This eBrompton conversion when setup for every day use which includes having the mudguards, weighs in at **11.95Kg** complete. Replacing the steel main tube and steering tube with titanium versions would cut the weight to around **11Kg**, maybe one day.

The Electric Brompton that Brompton sell is advertised as base **13.7Kg**, plus **2.9Kg** for the battery.

Conclusion:

The main advantage of this DIY conversion has been the significantly reduced weight, which for us older human types definitely makes handling the folded Brompton a lot lot easier. My previous Swytchified Brompton was about 6Kg heavier than this conversion, too heavy for me these days. The other main advantage is that the battery\controller remains attached to the eBrompton when folded and rolled.

Stuart Robinson

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