# Duo.

Duo, a charging solution designed for smartphone users to combine both mains and portable charging in one simple modular device. It eliminates the need for multiple charging devices whilst addressing the restrictive nature of mains charging. Duo provides an ‘all-in-one’ flexible, streamlined, reliable and lightweight charging solution for the smartphone user.



Calum Warden - PDE

10 Page Summary

## The Problem

We are all bound to our phones on a daily basis, as they are vital to modern day living. This is now even more relevant during the coronavirus pandemic where everything has been digitalised due to the restrictions on human contact. As smartphones become more advanced, they are able to run more complex apps and software, which in turn drain the battery quicker. As smartphones become more progressive, we are still hindered by the **outdated charging** options we have, preventing us from having complete reliability and reassurance that our phone charge will last.

**Mains charging** is r**estrictive in nature** and forces users to be stationary when charging.

**Portable chargers** are an **extra device** to remember, charge and carry. And they are often bulky and provide only a **vague indication of charge**.



## The User Group

The majority of the UK population own smartphones. It is projected that by **2022** there will be well over **60 million** smartphone users. This demonstrates that **everyone** could be a potential user as we all face the daily challenge of maintaining phone charge.

In particular, business travellers are a select group of users who have specific dependencies on their mobile phones, which are critical to the performance of essential tasks whilst on the move e.g., emailing, connecting with clients and colleagues, navigation, accessing essential business documents, as well as storing travel documents, such as digital boarding passes. Consequently, running out of charge can result in **user stress**, and the potential to look unprofessional and unprepared in front of colleagues and clients if unable to access essential information to support business discussions. For this reason the target user group was initially selected as **business travellers.**



## The Market

The market currently provides various charging options: mains charging (plug and cable) and magsafe chargers which are stationary solutions, and back up charging via power banks, charging cases and solar powered portable devices. These existing solutions require business travellers to carry two charging devices, (A) a mains charger, (B) a backup power device. Business travellers like everyone prefer to **travel light** and look to carry as little as possible. The need to carry a plug and cable and a backup battery pack and cable and to remember to charge the backup battery pack is **inconvenient**, **cumbersome** and creates **stress** for travellers.

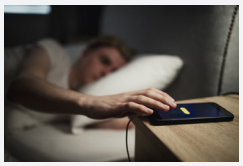
## The Opportunity/Brief

‘Design a charging solution which makes the process of maintaining charge on our smartphones **convenient**, **streamlined** and **seamless**’

# Initial key insights & analysis

After conducting two user surveys (n=50) I was able to identify problems with available charging solutions (as previously referenced). I then conducted one to one interviews with 25 users including school children and teenagers, students, working adults, retirees and sport people. From the surveys and the interviews, business travellers who were a sub group of working adults, were identified as facing the greatest number of challenges in maintaining smartphone charge.

## Key Insights



All users charge their phone **overnight** so they have full charge for the next day.

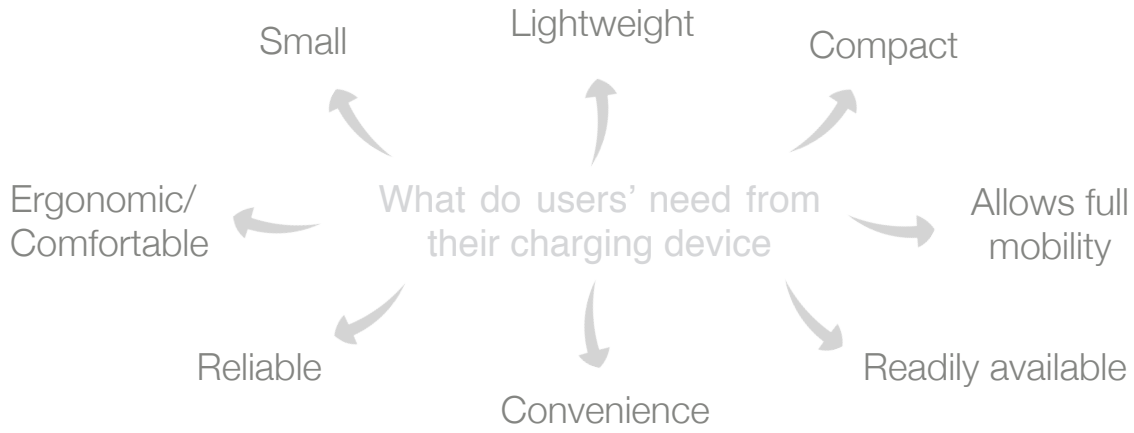
Users never let their phone **completely discharge.** The potential of having no mobile charge was a key problem that users consistently wanted to avoid.

Users dislike the **lack of mobility** they have when charging through the mains.

It is very **difficult to find** plug sockets when on the go, and often users don't often **don't have time** to stop and charge.

Portable chargers are an additional item to **carry** around and **charge** - they are inconvenient because users need to remember to charge them in advance and to carry them.


Charging cases are **annoying** as you have to swap between your normal case




## User Demands

When conducting interviews with all the users, at the end of every interview I asked what the users would improve or want from their current charging device. I let every interviewee know that their answer could be speculative and not to hesitate on answers which seemed unfeasible.

*'A charger that you didn't have to plug in, and didn't have to rely on mains power'*

*'A charger that picks up charge when you are moving, for example when your phone is sitting in your handbag it can pick up charge'*

*'Acts as a mains charger, portable charger and an adapter'*

*'thin, credit card size, QR code to charge'*

# Technology Evaluation

This evaluation was key to understanding which technologies would be viable for smartphones.

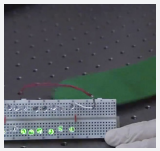
Kinetic charging - Inconvenient and won't produce enough power, as the user would need to be creating a great deal of kinetic energy to fully charge a smartphone - not feasible.

Inductive charging - Proven technology and currently on the market. Still not as efficient as users would like, but a viable option.

Solar Power -A proven technology and can produce enough power to successfuly charge, however is not convenient for the user group as it needs direct sunlight to charge itself.

Pyroelectric nanogenerators - Looking to use body heat as a source of energy, although temperature gradient between the human body and the environment is far too small to generate enough power.

Ultrasound - A technology currently being explored by companies such as Sonic Energy, and can charge wirelessly up to a distance of 1m, though still not a fully functional technology.



Piezoelectric nanogenerators - A technology which uses friction or pressure to create electricity. Unfortunately this technology again isn't close to being able to power a smartphone.

Charging using human breath - A very speculative consideration. Is an area being explored but again currently produces nowhere near enough power and would be very inconvenient for the user.

Wired charging - Charging through a USB or lightning cable is the charging method most familiar to all of us and is still the quickest method of charging our smartphones.

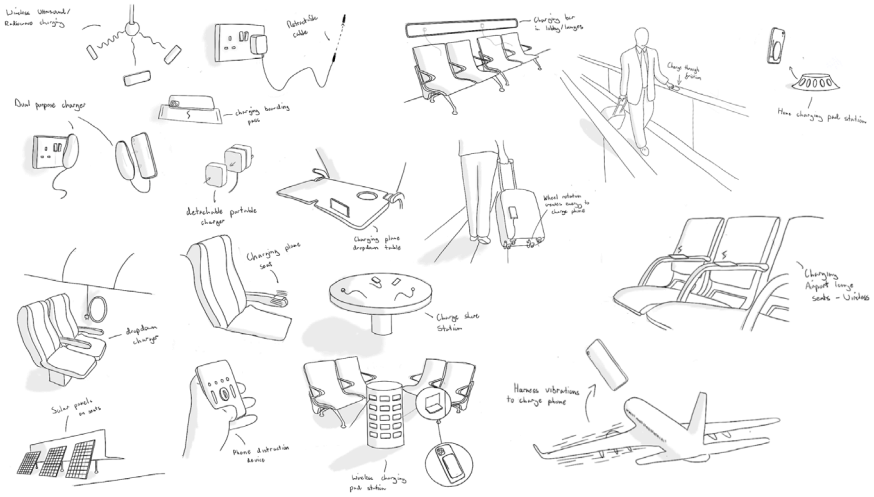
After consultation with experts in each of the available technology fields, I was able to conclude that the two technologies that would be most viable are basic wired charging and wireless charging using inductive coils. These technologies are already in use and therefore a thorough analysis had to be done when generating concepts to improve what is already out there.

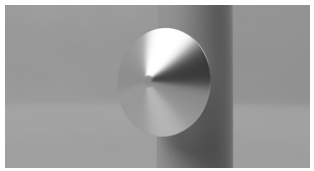
**Key Decision -Chosen Technologies for the Concept stage**

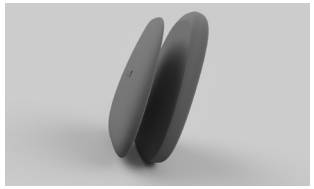
Wired Charging

Wireless/Inductive charging

Thanks to Scott Roy, Sandy Cochran, John Davies and Bryan Ehrenfreund







# Concept Generation

A range of concepts was developed, looking to meet the requirements of the brief, 'to design a charging solution which makes the process of maintaining charge on our smartphones convenient, streamlined and seamless'. Some concepts were very speculative to allow for the potential design to be stretched as far away from what currently is offered to users. As the target user group was business travellers, a lot of initial ideas were based around air travel.

After the initial concepts were generated, the strongest concepts were then taken forward and rough 3D models were made to understand the form they could potentially take. These models were then compared in a weighted matrix table to identify the best possible solution.

# Battery Evaluation

The battery is an integral component of the product as it takes up most of the space and will make up a large part of the weight. For this reason careful consideration had to be taken when selecting the right battery for the product. The three most commonly used batteries in electronic products are Lithium Ion, Lithium Polymer and Nickel Metal Hydride and therefore comparison tables were created in order to compare the different batteries and their properties. Lithium polymer was concluded as the best battery for the product due to it being lightweight, flexible in shape and more temperature tolerant which is a desirable feature as the product has the potential to be plugged into the mains for an extended period of time, and therefore overheating could arise.

**Key Decision** → Lithium Polymer

- Lightweight
- Flexible Shape
- Good Temperature Tolerance

| *Factor* | *Lithium-Ion* | *NiMH* |
|---|---|---|
| *Energy density* | 1 | 1 |
| *Flexibility (compatibility within different shapes)* | 0 | 1 |
| *Safety* | 0 | 1 |
| *Full Discharge ability* | 0 | 1 |
| *Self-discharge rate* | 1 | 0 |
| *Voltage output* | 1 | 0 |
| *Charge time* | 1 | 0 |
| *Temperature tolerance* | 1 | 0 |
| *Capacity* | 0 | 1 |
| *Cost to manufacture* | 1 | 0 |
| *Weight* | 1 | 0 |
| ***Total*** | **7** | **5** |

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| *Cost to manufacture* | 1 | 0 |
| *Weight* | 0 | 1 |
| ***Total*** | **6** | **7** |

# Interim Concept

The design proposed at the interim presentation was a pebble shaped charger, which functioned as both a mains and portable charger. The design incorporated fold down pins to allow for the device to sit flush to the back of the smartphone and charge wirelessly.

This design looked to reduce the inconvenience of users needing to charge both their smartphone, and their portable charger for backup power. The device would be plugged into the wall overnight and would charge itself and at the same time the smartphone would charge through a USB port. This would then allow the user to unplug their phone and the device the following day and the plug would be able to act as a wireless charging power bank.

Modelling of internal components

Working Prototype

Alternative form models

3D Model

To refine the design from the interim presentation, various prototypes were made to get feedback from the user group. Initially very rough models were made to understand the shape and form of the product. Then a working prototype was created and a 3D printed model to bring the idea to life. These were then tested with members of the user group along with a video prototype demonstrating a user scenario.

# Prototyping

## User testing/feedback

From the in-depth user testing of the prototypes there were a few key evaluations made about the current design. The first point that was raised was that it wasn't that obvious how the product should be used. The testing showed that users didn't know how it should be placed on the back of the phone, therefore highlighting that it was not intuitive enough. The main concern was based on the shape and size of the product. I was already aware of the design challenge around making the product small enough to be comfortable on the back of the phone, though this issue was made clear in the user feedback.

*'Personally, I would like something as small/light as possible. The shape of this adds bulk, could it be more in tune with phone (bigger but flatter). Most will carry phone in their pockets so is this the most ergonomic design?'*

Even though there was a lot of positive feedback for this design, the size concerns made it evident that there needed to be a **re-design** to make the product smaller and more ergonomic to hold when on the back of the phone.

**Key decision** → Design is **too big** and not an **ergonomic** shape → Need for **Redesign**

# Redesign

After deciding to redesign the product, I came to the conclusion that the best way to make the product smaller and more comfortable when attached to the back of the phone was to split the product into two components that could be coupled together but used independently. One part would be comprised of the mains charging device with fold down pins. The second part would the portable charger which would then attach onto the back of the mains device for being charged, or attached to the back of the smartphone when in charging mode.

This design allows for the same function as the interim concept, though when the user wants to use the portable charger component, they simply detach this component from the mains plug component. This means the portable charger component can be much lighter and smaller as it isn't having to house the folding pins mechanism or the mains circuit board.

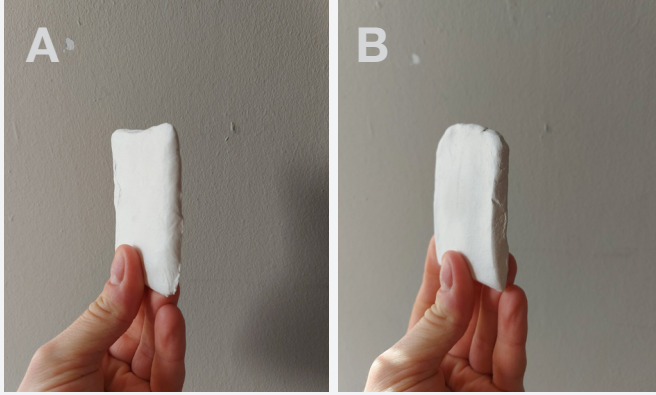
With the redesign, I decided to use wired charging instead of wireless charging between the backup power supply and the smartphone as wired charging is much more convenient because it is faster and more accessible for more phone models. I also concluded that this product extends beyond the reach of business travellers and would be attractive for everyone. It was then sensible to expand my user group to all smartphone users.

## This is a product for everyone.

As the portable charger was going to be able to attach to the back of the phone, considerations had to be made about the shape and size of this component, to allow it to be as comfortable as possible.

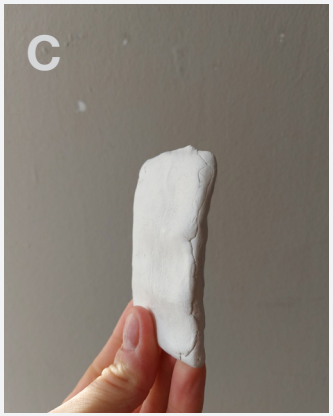
I tested different shapes with four members of my user group and got them to score the prototypes out of 10 for comfort.

The prototype which came back with the highest score was shape C, a rectangular shape with three grooves for the fingers to fit into when holding the charger on the back of the smartphone.











Once the new portable charger was modelled the mains charger component had to be modelled to match the dimensions of the portable charger, to create an exact fit between the two components. The face of the mains charger that would be in contact with the socket had to be lofted to prevent the component overlapping with the switch.

In order for the two components to attach, aluminium nickel magnets will be placed within both components to allow a snap fit between them.

After doing some further research into anthropometric data, I came to the conclusion that the grooves for the fingers may not be the best design. These grooves were modelled off my own hand and then tested on two 22-year-old males, therefore the testing was selective and not considerate of the general population. For this reason, instead of using the grooves as a design feature, there will be a slight dip in the centre to create a grip for the fingers, without forcing the users fingers into preset grooves.

Feedback on the final design demonstrated that the detachable feature of the portable charger was much more desirable as it was thinner and more lightweight, whilst still acting as a dual-purpose product,

# Product Overview

Arriving at the final design took longer than anticipated, although the additional time allowed for refining the design through numerous iterations. The final product name is **Duo.** which reflects its dual functionality. convenience and simplicity.

Duo comprises two component parts,

**Duo. Mains** – The mains plug component has fold down pins to allow the device to be made as small and compact as possible when not in use. Duo mains has two lightning ports, the first enables the charging of the smartphone, and the second enables the charging of Duo Porto.

**Duo. Porto** – A portable charger which attaches to the back of the Duo. Mains via the magnetic connectors.  Duo Porto can then be decoupled from the back of Duo. Mains and can be attached conveniently to the smartphone using the same magnetic connectors and charge the smartphone via the short lightning cable.

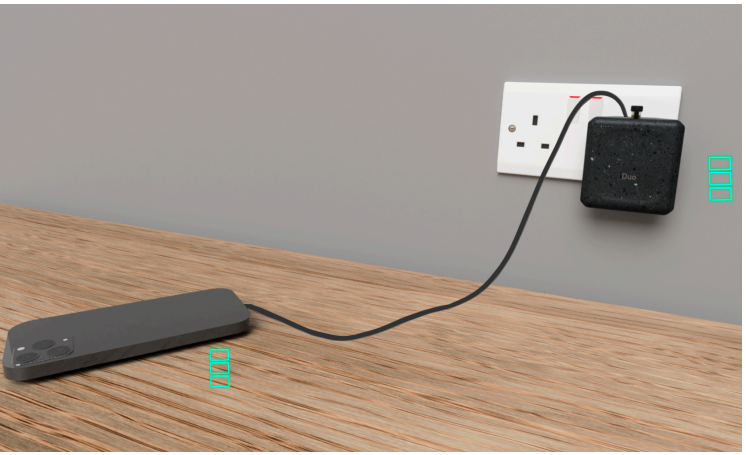
The product is designed to work with the iPhone X, iPhone 11 and iPhone 12 based on the dimensions of the product. It could be used for phone sizes which are bigger in width dimensions than these models although the comfort factor may be altered as the transition from the phone to the charger may not be as smooth. The 3200mAh battery capacity will also provide a full recharge for these three phone types. The product can be used on any smartphone , though the dimensions and battery size will affect its charging ability and ergonomics. The Product could have variations made for USB-C to allow it to be functional for android as well.

Made from recycled plastic and designed for disassembly at product end life

Provides full recharge for target phone models, without users having to think of recharging

Small, lightweight device, with the Duo. Porto only being 8.5mm thick and weighing 66g

# User Journey



The user charges their smartphone using Duo. Whilst the smartphone is charging through Duo Mains simultaneously the Duo Porto is being charged through a second lightning port, providing the user with an all-in-one streamlined, charging process for both smartphone and portable charger.

Once charged the user can unplug their smartphone and the Duo Porto from Duo Mains. This then provides the user with a full phone charge and full back-up.

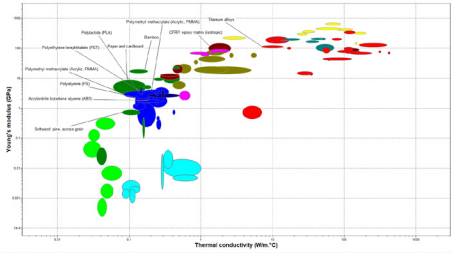
Duo Porto conveniently attaches to the back of their smartphone via magnetic connection. This connection works through the magnets inside the Duo Porto connecting to magnets pre-placed on the back of the phone or with a magnetic case accessory.

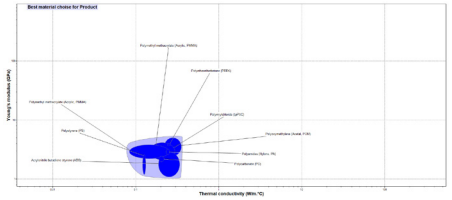
Then the user simply inserts the small lightning cable, which is housed inside the Duo Porto into the phone charging port.

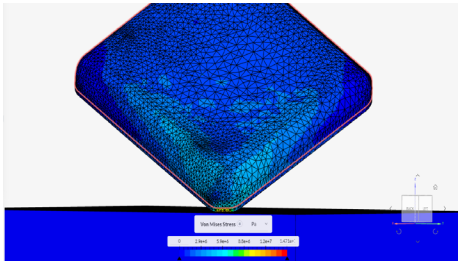
The user can then recharge their phone whilst using the phone as the slimline of the Porto allows for a comfortable fit when holding both Duo Porto and the smartphone.

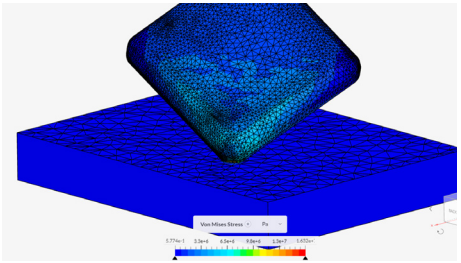
When the user is finished with the Duo Porto they can then recouple it to the back of the Duo Mains and it will recharge again.

# Material Choice





To distinguish the best possible material for the product shell, CEs Edu pack was used as it allowed the materials with the best properties to be highlighted. As the product is both a mains and portable charger, Youngs Modulus was plotted on one axis of the chart to demonstrate materials that would have higher durability. This was a necessary property as the product could be dislodged from the back of the phone and would need to be able to withstand the impact. The second material property was thermal conductivity, as in the event of a short circuit or loose wire, Duo Mains must be able to insulate the heat to protect the user from harm.

Once these properties were implemented further limits were put in place including electrical resistance, yield strength and optical properties. The two best materials after the limits were in place were ABS and PVC.

These two materials were then simulated In impact tests to see the stress distributions of both materials on impact and also to see if the 1.5mm wall thickness would withstand the impact. Both materials came back showing successful results, as neither material yielded. Though the final material decision from comparison was ABS due to its aesthetic opaque transparency and low density.

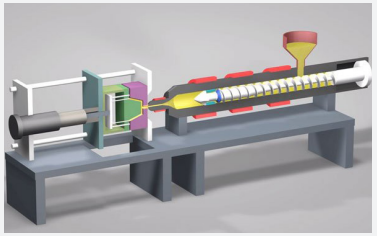
As this selection was not the best material when considering environmental factors, research showed that recyled ABS was easily manufactured and used in the automotive industry, therefore this then became the conclusive choice.

# Manufacturing

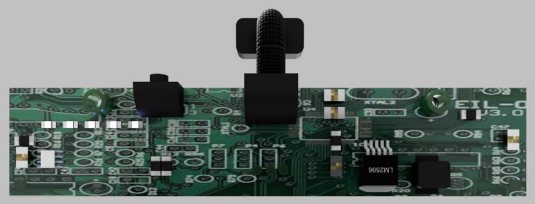
Various processes were considered for manufacturing the recycled ABS shell. As injection moulding is a fast, cheap and accurate process which can produce small plastic parts on a large scale it was deemed the best material process. There are a few key process variables that must be in place,

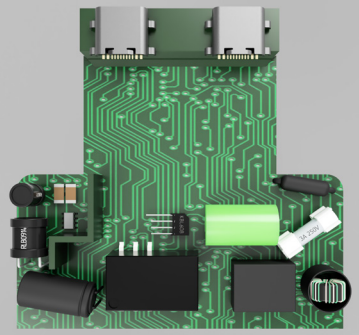
- ABS should be fully dried before injection moulded and preheated, as it is a very hygroscopic material and therefore has a tendency to absorb moisture; these measures can prevent the formation of bubbles and other inconsistencies.
- The melting temperature must be carefully monitered at different parts of the apparatus, as ABS is susceptible to melt marks and sink marks, if exposed to a variety of temperatures.

The manufacturing of other key components would best be achieved through external manufacturers. This would include the Lithium Polymer battery where the required capacity and dimensions would be specified and this information relayed to the specific manufacturer. The same would apply with the PCB and Circuit board which would have specific electrical components it needs to work and these would be implemented and comply with BS 1363.



Duo Mains will be assembled together using ultrasonic welding, as it contains high voltage parts which should not be accessed by the user, therefore the part will be sealed shut.





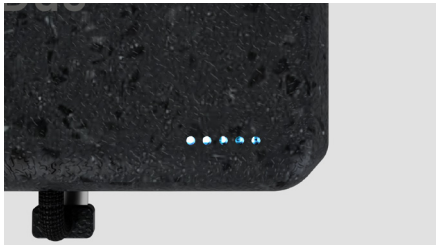
# Key Features

There are a few key electrical components required on both Duo Mains circuit board and Duo Porto PCB,

Duo Mains requires a flyback converter, which is a device similar to a transformer which allows the 230V coming from the mains to be dropped to the 5V required for charging the smartphone. It will also convert the current from AC (alternating current) to DC (direct current).

The Duo Porto PCB will need a buck/boost converter. This allows the 5V Duo Porto outlet to be dropped down to 3.7V to charge the battery and then be stepped up again to 5V to allow the battery to charge the smartphone when the Duo Porto is in use.

The PCB on the Duo Porto will also require protection from battery overcharging and over discharging, therefore a battery management chip will be present.



5 LEDs are placed on the PCB board to represent the charge of the battery. As LEDs use around 20mAh on full brightness, they will be brought down to 1/3 brightness as this still allows clear indication of charge but will not create intrusive light in a dark room when the charger is charging.

The wire that is housed within the Duo Porto allows for a simple connection to be made between Duo Porto and the Duo Mains and smartphone. As it is such a small distance required when connecting the wire into the phone or the Duo Mains, a normal wire would be very messy. Alternatively having a small wire that had to be connected into two ports every time would be a nuisance, and could also be easily lost.

# Assembly

As previously mentioned the ultrasonic welding process will seal the recycled ABS parts of Duo Mains together. The Duo Porto will not be designed with the same inaccessible nature.

Most portable charger devices are designed to remain sealed, making the recycling process of the product challenging. As the Duo Porto Device is intended to be disassembled at its end of life, it is held together by four round top screws at each corner of the device. This means that the product is easily taken apart when it is being disposed of, allowing the internal components to be removed and recycled. This feature along with the recycled ABS shell gives the product a huge selling point over other chargers, not only for its convenience but its sustainability.