The World of Electronics

A New Builder Guide

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V1.0

Welcome!

Hello there! Welcome to the next guide in what is now becoming a series of New Builder Guides. As the title says, this guide will cover Droid Electronics, covering various different electronics in many different droids. Electronics is one of those subjects that will make some new as well as experienced builders quake in their boots. The aim of this guide is to give you a more detailed look at what electronics go into droids. We briefly covered Electronics in the Becoming A Droid Builder Guide which you can read here if you haven't already.

Continuously Evolving

A side note that I wanted to include, whilst all of the guides I write will be kept up to date for the foreseeable future, the Electronics Guide in particular will be the most frequent one I update. This is because there is so much to cover the guide would take too long to complete and release as well as the fact it would be one of the longest guides I've written if I attempted to include every possible thing surrounding Droid Electronics.

Electronics in Droids

The more droids you build, the more you will learn about the electronics that go into them. You will often find similarities between the electronics, after all technology is mostly recycled from what has already been done and turned into something new, the same can be said for Droid Building. Did you think they reinvented the wheel when it came to BB-8's logic lights for example? No chance! They took R2's dome lights and created BB-8's lights off that.

The more you look into Droid Electronics and how things work, the more comfortable you will become and the more similarities you will see between them. When it comes to designing and building something for a new droid, a lot of the time you just need to look at things that already exist and rework it to fit your idea.

Most droids consist of similar types of electronics:

- Lights
- Audio
- Movement
- Servo Controlled Parts
- Batteries

Lights could be an Astromech Droid Logic Lights, a BB Units Holo Projector, Flashing LEDs on a Gonk Droid's faceplate or the eyes on a T3-M4. There are different lights on all droids, some you might be aware of and some you might not.

Audio is self explanatory, they are sounds of the droids and differ from droid to droid (usually). Sometimes, sounds and lights can work together. In the Padawan360 Control System for example, there is the ability to alter the logic lights when certain sounds play. If

you’re feeling brave you can also program your own so certain lights could show in a pattern when a certain sound is played.

Movement, whilst common in most droids, isn’t always used. Everything about your droid is down to your own personal preference. Servo controlled parts would be things such as moving arms, opening and closing body panels, pie panels on the dome etc.

Safety

Usually people tend to skip over the safety sections, but I implore you to read this. Many Builders fear the electronics part of a droid build, and whilst you are not working with the Nation Grid here, droid electronics can do some serious damage if you are not careful. The most common form of error is user error: we can forget to connect a cable, upload the latest sketch or even turn it on. When dealing with electronics, some of the components can get very expensive so to be careless when plugging them in and setting things up could be damaging both to your droid and your wallet.

While it is rare, you do simply get bad components from the manufacturer. In which case, after troubleshooting the problem, you should get in touch with the manufacturer.

Make sure that you follow the instructions of the components and come up with a plan. Pay attention to the wiring diagrams and remember: if you are unsure, ask questions! The community would rather answer the same question a hundred times than see a post of somebody's droid that has caught fire.

Make sure any equipment you use is safe, and the right equipment for the job. Avoid cutting corners to save money or time, the vast majority of the time you will find yourself going back to redo things multiple times.

Asking Questions

Regardless of what you may see in some groups, questions are always welcome. I cannot stress this enough, especially when dealing with electronics. If you make a mistake in your 3D Print, for example, you can always print it again, if you make a mistake during the painting process, you can always paint it again. While both of those examples cost money and are fairly annoying, they are not nearly as frustrating as spending £100+ on a circuit board and blowing it up.

As I advise in all of these guides, be proactive and do some research beforehand. This is to maximise the total amount of information you can get about the question. Also, the same question could have been answered in a lot more detail elsewhere which could be much better suited to you.

Another place you can ask questions and get help other than the Astromech.net and Facebook Groups would be the Droid Builder Discord Server. You can find the link here - http://discord.gg/4ZV9DmY

Do I really need to learn electronics?

Of course not! Many builders have made some fantastic creations as either static models or purchased pre-made electronics kits from BC Approved Parts Runs on the forums. If you go down this route, you may still have to do a few things since there is no single kit that has everything already put together: you will have to connect a few wires here and there but, compared to doing all the work yourself, this is most certainly the easiest option.

For some of you, that might sound perfect and you may have even decided, that is what you want to do as you may fear you don't have the skills, tools or knowledge to make anything yourself and that is perfectly understandable and quite common within the community. We have many builders who are professionals in the electronics and engineering industry. We also have many builders who aren't and one of the best things about the community is the help you can receive.

Nobody expects you to become an expert. I would even go so far as to say people working in the industry probably wouldn't classify themselves as "experts" but you should always be willing to learn. Most builders find themselves wanting to learn about electronics but for various reasons they put it off. My first piece of advice I can give you is to discipline yourself and set yourself realistic goals.

There are so many reasons why you should learn and understand the electronics going inside your droid. The key reasons would be:

- You can fix your own electronics if / when they break.
- Quite often, the public asks about how your droid works, it's always great to be able to explain how your droid functions instead of telling them you haven't got a clue.
- You become a lot closer to being able to create new things to put in your droid. By understanding how it works you will be able to think more on the level of "If I swapped this component for that component, I could achieve this".
- You will have another achievement you can be proud of.
- Anything you learn here can be applicable in other un-related electronics projects.

What electronics should I learn?

In the Becoming a Droid Builder Guide and the Control System Guide, we talked about various things you should take a look at. Just to reiterate, nobody is telling you to become an expert here, so a basic understanding of things is perfectly fine. Try not to go into learning complicated circuits straight away, you should start with simple things such as learning the names of the components. Being able to identify what components are used in any form of circuit is a great first step.

Alongside learning the names of the components, discovering what they do and how they are used in a circuit will also help you. You will find that you have already seen many of these components before. Once you feel more confident in knowing what the components do, it then becomes easier to understand wiring up your droid. I have provided some links to YouTube Tutorials below, these are some good beginner tutorials that should give you plenty of information.

Basic Electronics for Beginners - The Organic Chemistry Tutor

Essential Electronics Components - GreatScott!

The Learning Circuit - element14 presents

Electronics Playlist

I have also created a playlist on my Youtube Channel that I will keep up to date with various videos of electronics that I think are handy to watch. They will be droid related but I would suggest keeping an eye there to see if a video I save there could help you.

https://youtube.com/playlist?list=PLuglvkyfYnUbv1k94rgJVVNFyIpI7oI1Q

Be Warned

A word of caution: do not attempt to master this task quickly. Most builders fear electronics for various reasons and, whilst we are not working with electronics that would vapourize you into atoms, it is still rather frustrating when things go wrong. Rushing, not using the right components or simply using the wrong tools for the job will cause you problems in the end. Electronics, in my opinion, should not be cheated. By this I mean: do not attempt to cut corners to get it completed quicker, do not attempt to save money by using unsuitable components or cheap knockoffs that are not tried and tested. Sometimes, they will work and you can get a great bargain; however, when they don't work, they cause you problems that will cost you time and money.

Basic Electronics

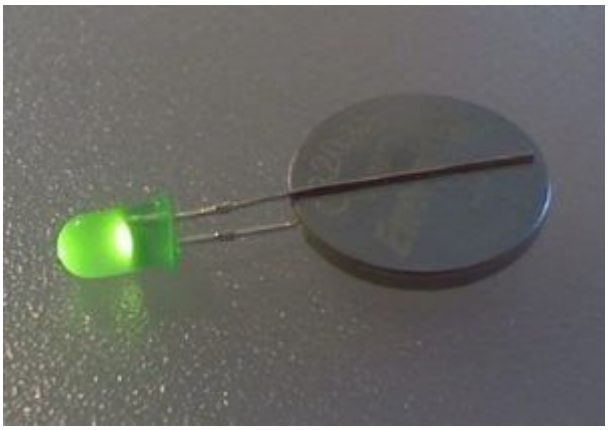
Electronics come in many different shapes, sizes and levels of complexity. More often than not, new builders get rather anxious about electronics and putting them in their droids and whilst electronics for the inexperienced builder can be somewhat nerve racking, there is really no need to panic.

If you plan to have a droid that moves, makes sounds and lights up like a Christmas tree, then Electronics is something you will have to learn. Just to reiterate that nobody expects you to be an electronics genius and as long as you are willing to learn, the knowledge will fall into place. The majority of electronics for your droid can be found in parts runs, as a pre-made BC Approved item that you can purchase or are simple enough that any beginner can do it themself.

Let us begin with the basics for those who are brand new to electronics. If you already know the basics, you can skip ahead to the section that talks about the specific electronics in droids.

Batteries and Load

First, let's talk about Batteries and load. A battery is fairly obvious: they come in many shapes, sizes and voltages and they provide the power for a circuit to work. Without batteries, all of your electronics gadgets would need to be plugged into a dedicated power source all of the time. Load is an electrical component or a part of your circuit that consumes power which within a typical electronic circuit, could be almost everything. The most basic example of this is shown in the image below.



(Image courtesy of Oliver Steeples)

In this simple example, a battery supplies power and the LED acts as a load. Droid electronics is just an extension of this with motors, more LEDs and servos for a basic set up. If you want to go into more depth on the basics of electronics, components, circuits and how it all works I have included a link to a very good tutorial that can take you through the basics.
Click Here to watch on YouTube

Battery Types

Once you get to the electronics part of your build, you should look back at your research and read through all of the functions that you want to include in your build. Sometimes, this is where a lot of builders suddenly realise the amount of work that goes into these functions. One thing you will have to give plenty of thought to is how you are going to power these wonderful electronic gadgets, as without the correct amount of power they will not work!

Researching batteries can be time consuming because there are so many different versions of batteries available. Technically there are two types, Rechargeable and Non-Rechargeable. Just in case it isn't already obvious, you need rechargeable batteries for a droid, otherwise, once they die, you will need to buy more and keep replacing them, which is not a good thing for your wallet and it can be a huge pain to constantly do.

It is also important to note that not all batteries are able to be charged the same way. Some may require a dedicated charging unit whereas others may only charge a certain way. For example, SLA Batteries are best charged with a Trickle Charger. These chargers prevent the battery from losing enough charge to stop them working. Make sure that you research how you should be charging your battery of choice before you buy it.

We now look at the types of batteries you should buy, some of which you may already be familiar with.

- SLA (Sealed Lead Acid) - Commonly found in cars and occasionally older intruder alarm systems.
- Li-Po Batteries - Can be found in gadgets such as remote control cars.
- Li-ion Batteries - Commonly found in smartphones, smaller compact cameras, power tools and laptops.

People have experimented with other types of batteries, but the most common type of batteries used in a droid has been the Lead Acid (SLA) batteries which are now getting replaced by the LiPo batteries by most. Your battery choice should also take into account the type of droid you are making: size and Weight are key here. For example, a Mouse Droid doesn't typically have an SLA battery because the droid itself is small and lightweight, so a large and heavy battery would not be a very good choice and, instead, a Li-Po battery could be more suited. A heavier droid will require more power in order to make it move. This also means you should consider the strain on the battery.

SLA Batteries

Pros:

- Cheap
- Can provide a large amount of current if needed
- Readily available from most stores

Cons:

- Weight
- Shorter lifespan - Around 200 cycles
- Low density

Li-Po Batteries

Pros:

- Lightweight
- High output
- Considerably great life span
- High density

Cons:

- Expensive
- Likely to cause a fire if damaged
- The batteries can start to fail after a couple of years
- Lifespan of around 400-500 cycles

Li-ion Batteries

Pros:

- A lot safer than LiPo
- Increased popularity through using power tool batteries
- Low maintenance
- Capacity begins to fail between 500-1000 cycles

Cons:

- Density is less than LiPo Batteries

Charging Batteries

Charging your droids batteries might not be a simple case of plugging in a power cable and walking away: different batteries have different charging requirements. Some batteries can be placed in their own charging unit, which will take care of everything for you, whereas other batteries would need to have an eye kept whilst they charge.

There is quite a bit of theory you can read up on about charging batteries, the charging cycle, the pros and cons to different charges etc which I will link below for anyone interested in reading. Whilst they are handy and interesting to know, there are plenty of chargers out there that you can buy, plug in and either they turn off automatically so as not to overcharge the batteries or you would come back to check on them.

This section will be short but I will provide various links for you to do your own research in more depth.

Battery Charging Theory

Charging a battery is often done in stages. Usually, these are three stages regulated charging however two stages or four stages are not uncommon. The stages depict the different things that happen during the charge cycle. The first stage is BULK, which involves about 80% of the charge and is responsible for actually charging the battery. The second stage is ABSORPTION which involves the remaining 20% and is where the charge holds the voltage at the chargers absorption voltage and decreases the current until the battery is fully charged. The third stage is FLOAT and this is where the charge voltage is reduced to just below the batteries maximum charge level and held constant whilst the current is reduced to less than 1% of the battery capacity. This is to keep the battery fully charged without it overcharging.

Link to more information of Battery Chargers and Charging Methods -
https://www.mpoweruk.com/chargers.htm

Battery Universe - Charging
https://batteryuniversity.com/learn/article/all_about_chargers

SLA Charging

The recommended charger for a SLA battery is a trickle charger. A trickle charger is designed to charge your battery slowly over a period of time and not overcharge it. Some trickle chargers can be safely used over a period of a few days and others are designed to stay connected over the course of a few months. Standard Trickle Chargers should charge your droids batteries fairly quickly.

(A SLA Trickle Charger)

Li-Po Charging

Li-Po batteries charge differently to other kinds of batteries: they require a regulated charger that starts the charging cycle by applying a constant voltage that is slightly higher than the battery's current resting voltage. Once the battery is charged, the current flow slows and eventually stops. Li-Po batteries cannot be trickled charged and do not have a safe saturation point like SLA batteries, for example, where they will no longer accept charge. Overcharging a Li-Po battery will lead to an explosion.

You should always use a good LiPo battery charger, such as a Turnigy Charger which is designed specifically for LiPo batteries. This charger can usually charge other types of batteries such as Li-Ion, NiCd and Lead Acid however you should always remember to make sure the charger is in “LiPi Mode” before charging your LiPo batteries, failure to do so will almost certainly result in battery failure and fire.

(A LiPo Balance Charger)

Li-Ion Charging

Different Li-Ion Chargers work with different types of batteries, most depending on whether the battery is lead and lithium based, nickel based etc. Different batteries also use different charging methods which is one important factor when choosing a charger for your batteries. You will want to remember that Li-Ion Batteries need to be charged at a specific voltage and with less current. Overcharging a Li-Ion Battery can result in damage to the cells, which can lead to exploding batteries. Float Charging is a useful option for Li-Ion batteries since, due to the chemistry of this battery type, trickle charging doesn't work and most other charging methods run a high risk of overcharging.

(A common Lithium Ion Battery Charger)

R/C

Droid Electronics remain the same regardless of the droid you are building. The components may differ, but the principles of the electronic circuits and what they do are all the same. In this section, we will take a look at some of the similarities between the different droid electronics.

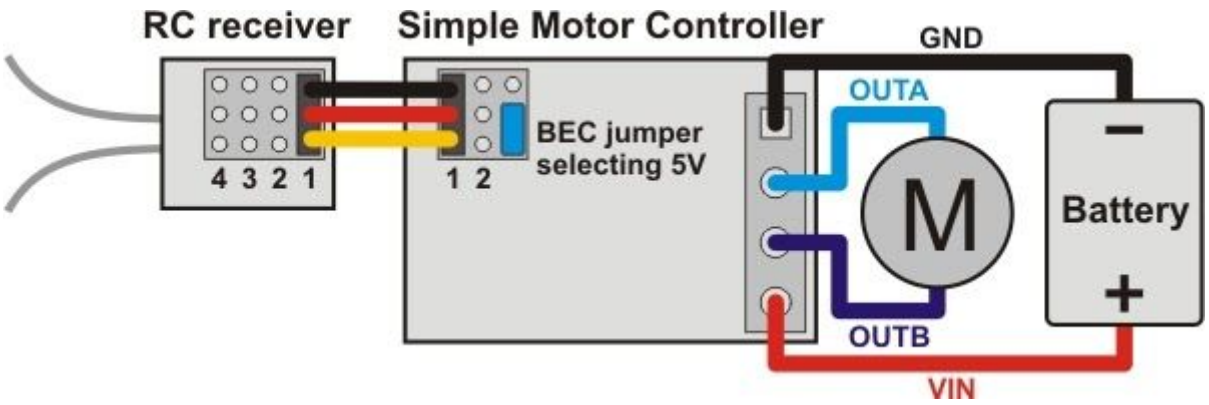
Drive Systems - Every droid has a drive system. There are many different drive systems and some are entirely tailored to that particular droid however, in this example, we will use an R/C Drive system since that is easily adaptable across many droids.

R/C stands for Radio Control and, as the name suggests, it allows you to control your droid through the use of radio waves. This is where the frequency comes in: most of the time, you will see R/C systems on 2.4Ghz. It works by the transmitter (your controller) emitting a certain amount of electrical pulses on that frequency to the receiver. Once the receiver has received those pulses, a circuit board translates the pulses into actions which are then performed by a motor, usually.

We now know what R/C is, it is a very common and reliable form of control for robots, cars, model planes alike, and currently is a requirement in most countries for official work such as film or some events so, as a new builder, you should take that into consideration if that is a goal for your droid.

RC has been around since the 70’s and technology has improved greatly with frequencies changing from 27MHz to the current 2.4GHz range. As the technology evolved, it went from analogue to digital, with signal loss detection and other improvements. The cost of transmitters has also decreased while the number of channels has increased, which has added to the popularity of RC systems amongst builders.

The next thing to know is an ESC (Electronic Speed Controller), a device that regulates the power of an electric motor. You may have heard of two terms: Brushed and Brushless. These are types of motors that an ESC would control.



(Image Courtesy of Oliver Steeples)

The above shows the main battery supplying power to the speed controller and this drives the motor from the RC signal supplied from the Receiver. The ESC also provides power to the receiver via a BEC (Battery Eliminator Circuit)

BECs/UBECs/DC buck converters are very handy to have in your circuits, they typically convert high input voltage into a lower filtered output voltage. By using an external UBEC in front of expensive electronics, it reduces the risk of damage.

All components/ modules have different voltage and current requirements and may need to be stepped up or down. The Speed Controller supplies the power to the motor and something to think about wherever you are connecting components together is the gauge of the wire you are using. Incorrectly sized wires can result in fires.

Controller Types

You will see different builders with different types of controllers. There are various types of transmitters you can purchase however the two popular types amongst builders are the Pistol Grip transmitters and the Stick Grip transmitters.

(A Pistol Grip Transmitter)

You may have guessed why it has it's name from the image. It has a handgun style layout to it and the trigger operates as the throttle, allowing you to control the speed of your droid whilst the wheel mounted on the side is used for steering. There are a couple of good reasons to use this controller type, the first one being the self centering wheel which means once you let go of the wheel, it returns back to the center meaning your droid would then be going in a straight line. In theory this should prevent your droid from drifting away from a straight line when driving forwards. It is also rather compact meaning travelling with it can be easier than most other controller types.

(A Stick Grip Transmitter)

Another popular choice is the stick grip. This operates in a similar way where one joystick would control your throttle and one would control the steering. Some forms of controlling your droid with a transmitter such as this allows you to have throttle and steering on one joystick whilst having dome rotation on the other.

The range of these transmitters can vary and you can buy specialist long range transmitters, however some of the more tried and tested transmitters would be the FlySky, Traxxis, Turnagy and Spektrum. There are no doubt more brands of transmitters that builders use which could be found in groups and the forum.

A standard range for an RC transmitter is around 200 meters (600 feet) but this can depend on what you choose to go for. You should read the instructions of your transmitter to make sure you know the range. There are also built in fail-safes in the majority of RC systems where if the connection between the receiver and transmitter is interrupted either through travelling out of range, batteries falling, damaged transmitter etc the receiver will return the signals to the ESC and servo to neutral, effectively stopping the droid from moving.

Failsafes such as this are required for the droid to pass the UK MOT Test. You can read more about RC Transmitter Types here.

LEDs and LED Types

As a beginner to the world of electronics, you will find that a lot of things are rather common across droid building. There are various types of LEDs and, as you progress and dive deeper into droid building, you may consider looking at the different kinds for different purposes. LED stands for Light Emitting Diode and is one of the most common components found within a droid. Using R2 as an example, LED's are found in dome lights such as the Teeces Kit, the Process State Indicators (PSIs), Holoprojectors, Various body electronics such as the Charge Bay Indicator and the Data Panel etc. Those are just naming a few of the more common settings, builders often adding some more custom options.

You may ask why we use LEDs, the answer has many reasons:

- Low Power Consumption compared to standard light bulbs
- More Robust
- Various colours available
- Fast Switching
- Long Lasting

There are many different types of LED such as:

- Through Hole LEDs - The most common type these LED have legs that slot through the holes in the circuit board and get soldered from beneath;
- Flanged/ Flangeless LED - The flange is useful if you are mounting the LED within a panel, it helps to keep the LED in place;
- Surface Mount LEDs - Extremely small - these are not designed to slot into holes but instead get soldered directly on the top of the circuit board;
- Bi-Colour LEDS - As the name suggests, this single LED can emit two colours;
- RGB LEDs - These LEDs are becoming more common within droid building due to their ability to emit multiple colours. This would allow you to use one LED instead of three different LEDs;
- High Power LEDs - These produce a power rating equal to or greater than 1 Watt. Commonly used in newer car headlights and flashlights.
- Neopixel LEDs - These are becoming more popular within general electronics as well as droid building. They are surface mounted RGB LEDs with an integrated driver allowing them to be individually addressable. A common use is the neopixel strips that allow people to program custom light shows.

LEDs require a certain voltage in order to light up in your circuit. Like everything else, not enough power and it will not light up, too much and it will blow. Resistors are used to limit the current going through the LED and some LEDs even have resistors built into them.

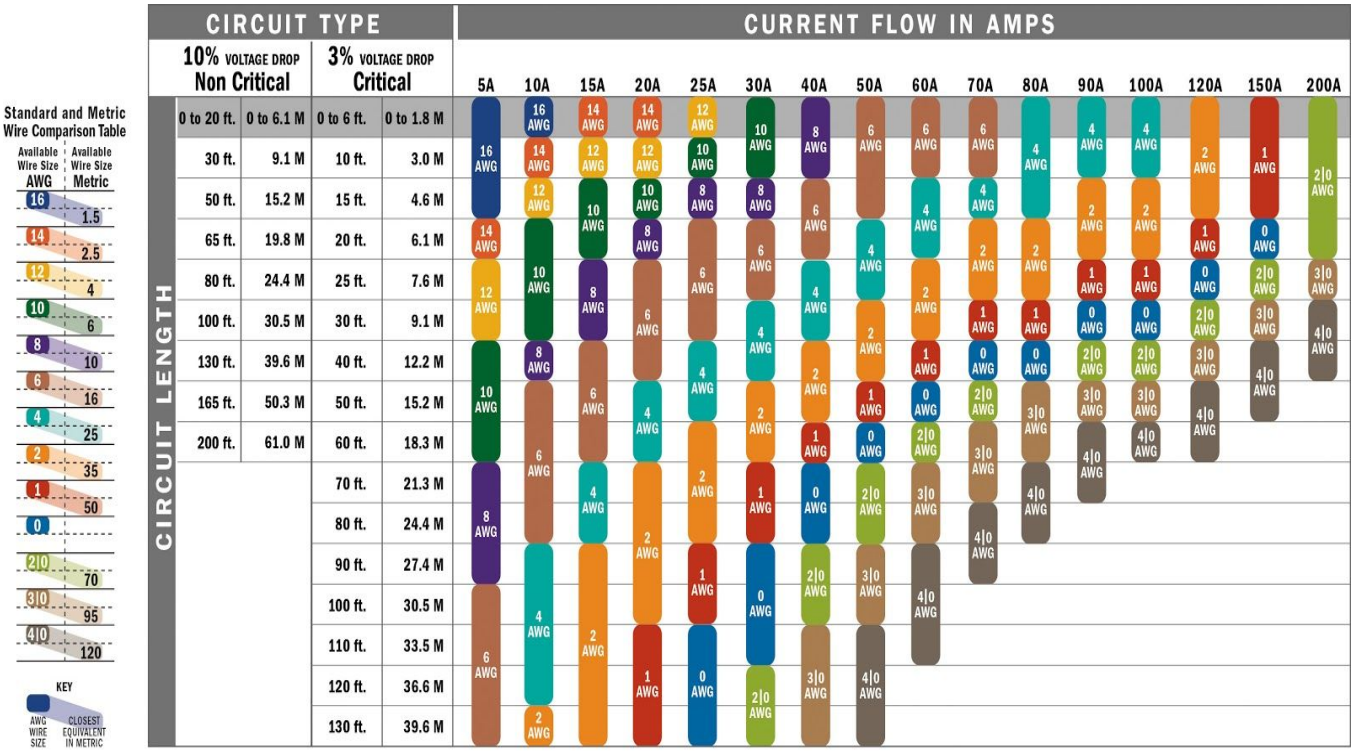
Wire Gauges

I felt it would be wise to include a section about Wire Gauges since I have found myself asking these questions a few times. The Wire Gauge or the size of the wires connecting your components is something that I found is not greatly explained in tutorials for the most part. What we do know is that we need wires to connect the components together in order for the current to flow from the batteries around the circuit. We also know that different components require different voltages and currents in order to function.

What exactly is a Wire Gauge? The gauge of a wire indicates the thickness of the conductor that carries the electron flow. There are many factors that come into play when calculating what wire gauge to use and, unless you are trying to reinvent the wheel, you would not need many different sizes for your droid.

To calculate the correct gauge of your wire, you need to know the total amount of current flowing through that circuit. Wires offer resistance and, over longer distances, the voltage decreases due to the resistance of the wire. This is called voltage drop and it is when the voltage at the end of a cable is less than at the beginning, it mostly occurs when you are sending voltage across long distances. Alternatively, if your wire is undersized, it cannot handle the current flowing through it which generates heat, and often leads to fire. Within Droid Building there isn't much distance between most components since most of the electronics are located within one small area.

It is common to use different gauge wires in different areas of your circuit. The wire gauge between your battery and fuse box, for example, would be different to the gauge of the wire between components.



http://assets.bluesea.com/files/resources/newsletter/images/DC_wire_selection_chartlg.jpg

Regulators

Voltage Regulators are a wonderful thing to have, I would class them as an essential item myself, without them you would have to have multiple power sources for the different components and circuits that do not all run on the same voltage.

A voltage regulator generates a fixed output voltage of a preset (or sometimes adjustable) size which remains constant. Providing you supply it with the required voltage in order to operate, the output would remain constant regardless of any change in the input voltage. There are different kinds of regulators that you will come across, some of which you may not use in your build, but it helps to know about them and which ones are the preferred to use and why.

Linear Regulators

Linear Regulators (such as the ones used in the teeces logic lights) are regulators where a linear component is used to regulate the output. Linear Regulators are considered by most to be old fashioned and wasteful. They are poor in terms of efficiency and have considerable heat generation. Not to mention they only have a step down operation, not an ability to step up a voltage.

(A Linear Regulator)

Buck Converters

Buck Converters or step-down converters have one simple job: they step down voltage from the input to it's output. These switched converters provide much greater power efficiency than linear regulators. The switching ability is controlled by a Field Effect Transistor (FET) which is turned on and off by a switching controller IC that monitors the output of the switching regulator in a feedback control loop. This makes sure that it maintains a constant output under normal usage.

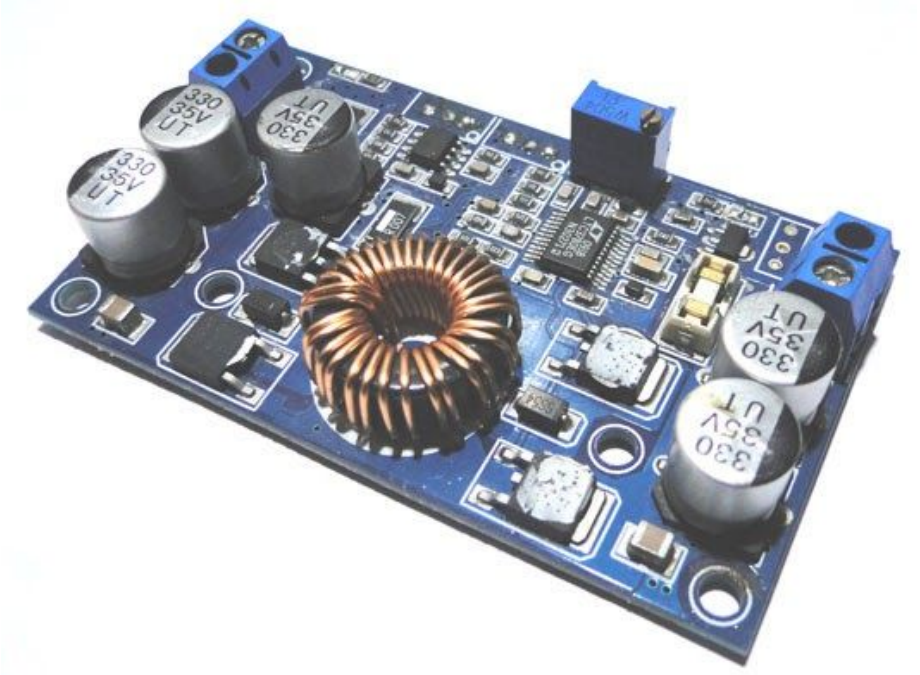
Where would you use these within your droid build? That would depend on how many components are required for the voltage to be stepped down, however you can expect to use a number of these for sections such as dome/ body lights, servos controlling panels etc. This is due to them requiring a lower voltage than what you are supplying. The Charge Bay Indicator and Data Panel Logics, for example, that are supplied by Glyn Harper require only 5V in order to run, if you push 12V, 24V or whatever you are running in your droid to the board, you will do some expensive damage.

(A Buck Converter)

Boost Converter

A boost converter is one of the simplest types of switch mode converters. As you could guess from the name, it takes an input voltage and boosts it. This means that the output voltage would be greater than the input voltage. It uses an inductor, a semiconductor switch (these days it would be a MOSFET), a diode and a capacitor.

Where would you use a Boost Converter? You would use one of these converters if you have a component that requires a higher voltage than what you are supplying.



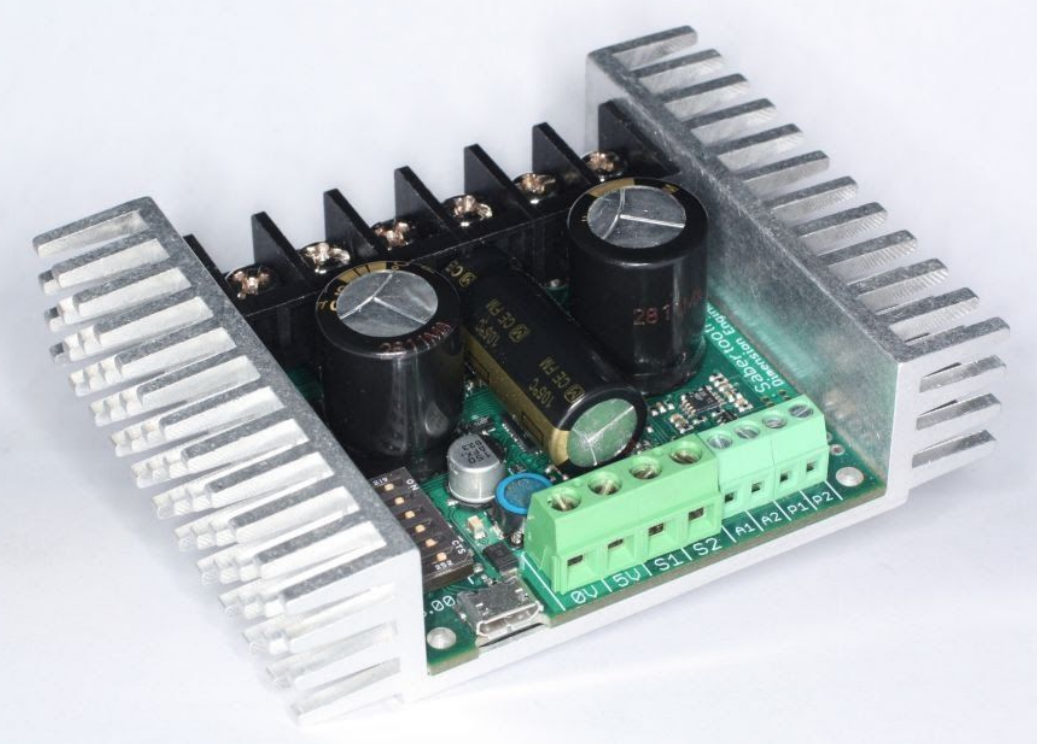
(A Boost Converter)

Motor Controllers

If you want your droid to move, then you will need a Motor Controller so it would be handy to know exactly what one is and how it works as well as some suggestions. What is a motor controller? A motor controller is a device that acts as a “middle man” between the microcontroller (in most cases this would be an arduino), the batteries and the motors. We require motor controllers because we need the ability to flip the polarity of power to the motors in order to make them spin in both directions. Flipping polarity requires a large amount of current. Alos, a microcontroller can typically provide roughly 0.1 Amps of current whereas most motors require several Amps in order to work so this would be another reason to use a motor controller. Motors are often the biggest consumers of current within your entire droid so the general rule of thumb would be if you have enough power for them, you should be fine for the rest of your droid but you shouldn’t take that assumption as fact.

Sabertooth

The Sabertooth is the go-to Motor Controller for Droid Builders to use with the foot motors. It is tried and tested with multiple Control Systems and is very reliable. There are different versions of the Sabertooth but the most common one that is suggested would be the Sabertooth 2x32. Usually this is purchased from Dimension Engineer and it is recommended because it gives you up to 32A to two motors. This would be more than enough to drive, for example, some E100 Razor Scooter Motors which are common for builders to use in droids such as R2.



(A Sabertooth 2x32)

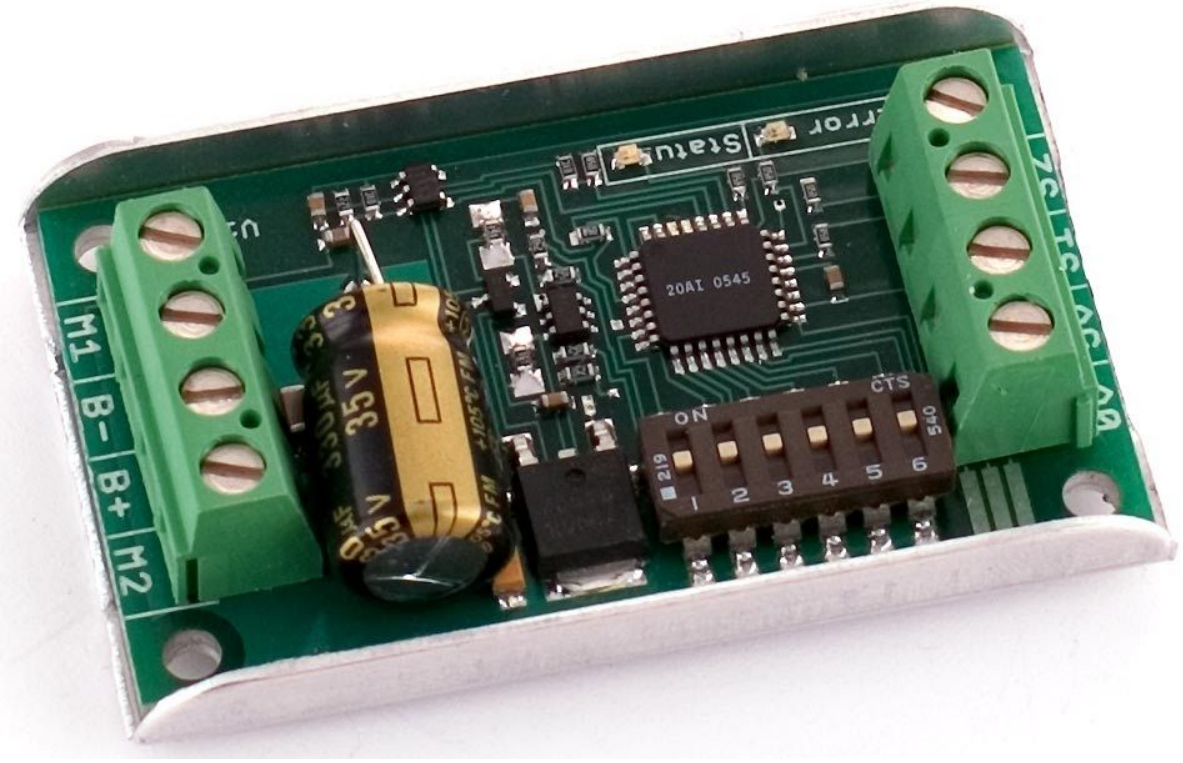
The biggest issue that many new builders have with the Sabertooth is that, at first, it can be confusing on how to set it up since it is not entirely a plug and play device. Fortunately, Dimension Engineering offers a program and instructions on how to set it up. You can even plug the Sabertooth into your computer directly to update firmware or run any tests you choose on the board as well as perform tweaks such as Ramp Speeds. The program allows you to select exactly what you're using the Sabertooth for and returns the correct dip switch settings that you should use which is often a common mistake for builders to make..

Another negative that people find with the Sabertooth is its cost. At the time of writing this guide, the Sabertooth retails at £100 which is very expensive, especially for a new builder who may be on a budget. As I have previously stated, with electronics, I have found it is worth spending the extra money and buying correctly the first time instead of trying to find bargains and buying cheap alternatives only to find you are regularly having to replace them.

Syren10

The Syren10 is another go-to Motor Controller. However, this one is specifically for the dome motor. Originally, my first question was “Why can’t we just use the Sabertooth for all of the motors?” and there are a couple of reasons that I will detail. Firstly, the Sabertooth will only take up to two motors which are the two foot motors. Secondly, the motor that we fit inside the dome is usually a Pittman motor and the dome motor usually is less powerful than the feet motors because it does not have the same demand as the feet motors.

The dome motor only has to spin a dome that sits on top of a lazy susan, it doesn’t have to move a whole droid around, which means it doesn’t require as much current compared to the feet motors. For this reason, the Sabertooth is rather overkill for the dome motor and for most, an expensive overkill. The Syren10 however was found to be a good substitute being just as reliable, providing enough current (10A) for a single dome motor and is roughly half the price of a sabertooth.



(A Syren10)

Roboteq

For those of you using brushless motors such as the Q85s, you will want to take a look at the Roboteq SBL-2360 Controller. Brushless motors are harder to control than brushed and, because of this, need a specific controller. The reason they are trickier to control is because whilst DC motors have two wires and are easy to wire up, brushless motors have three wires which can also be fairly easy to wire up. However, if you are using a sensored speed controller such as the Roboteq, then you also need to wire up the hall sensors which gets slightly more complicated as you then have 8 wires to the motor. A hall-effect sensor varies its output voltage in response to a magnetic field and they are used as proximity sensors for positioning, speed and current detection. They are very useful items if this is the road you choose to go down however there is quite a learning curve so you should be prepared.

You can view the correct controller here. The biggest issue I have found about the Roboteq controller is the price of it which comes down to what sort of drive system you want and whether you can justify the cost of it.

(A Roboteq SBL-2360 Controller)

Motors

We have talked about some motor controllers but what about the motors themselves? It is a common question that I have seen in various groups and threads, “What motors should I buy?”, “Can I use these for my droid?” etc.

For R2-D2, the most commonly used motors are the E100 Razor Scooter Motors. There are two versions you can purchase: a belt version or a chain version. Builders are evenly split in regard to their preferred motors, with some preferring one over the other. The reason they are preferred is because they are easier to obtain as well as being a lot cheaper. Moreover they are a nice fit into most of the drive systems being able to be fitted in without major reconstruction of the drive system and they remain easily covered by the battery boxes.

(Left: Chain Motor - Right: Belt Motor)

These motors come in 12V or 24V version however the 24V are the suggested choice for most builders since it will future proof your droid if you replace any parts or change parts of your droid which would add to the weight. How do you choose between a belt and chain? Is one better than the other? It depends who you ask. Below is a quick list of pros and cons to using either:

Chains:

- Adjustable, will give a bit over time and need adjusting
- Noisy
- Oily and can pick up crud on the chains

Belt:

- Not adjustable
- Quieter than chains
- More likely to snap the belt rather than a chain

It is down to personal preference. Attending a couple of events where people are running both would give you a good idea of which one you might swing towards. You may not like either which is perfectly fine because there is another option.

The Q85 Motor is a recent addition to the list of tried and tested parts for Droid Builders. Q85s were introduced at Celebration Anaheim by Lee Towersy and Oliver Steeples. Brushless Q85s were introduced for many reasons, some of which are that they provide a huge amount of torque and that they are very controllable as the motors don't have any left/ right handing so you will avoid any of the left to right drift when you are driving your droid. Also, they are very good at low speeds and only draw a few amps under normal operation which are far better than the current motors commonly used which can draw in excess of 6A.

The downside to the motors is firstly the cost of them which would put them out of reach for most builders on a budget with a price tag of £722.00 plus shipping (at the time of writing) from an Astromech Parts Run. They also need good mountings to cope with all of the torque that they put out.

(Image courtesy of Oliver Steeples)

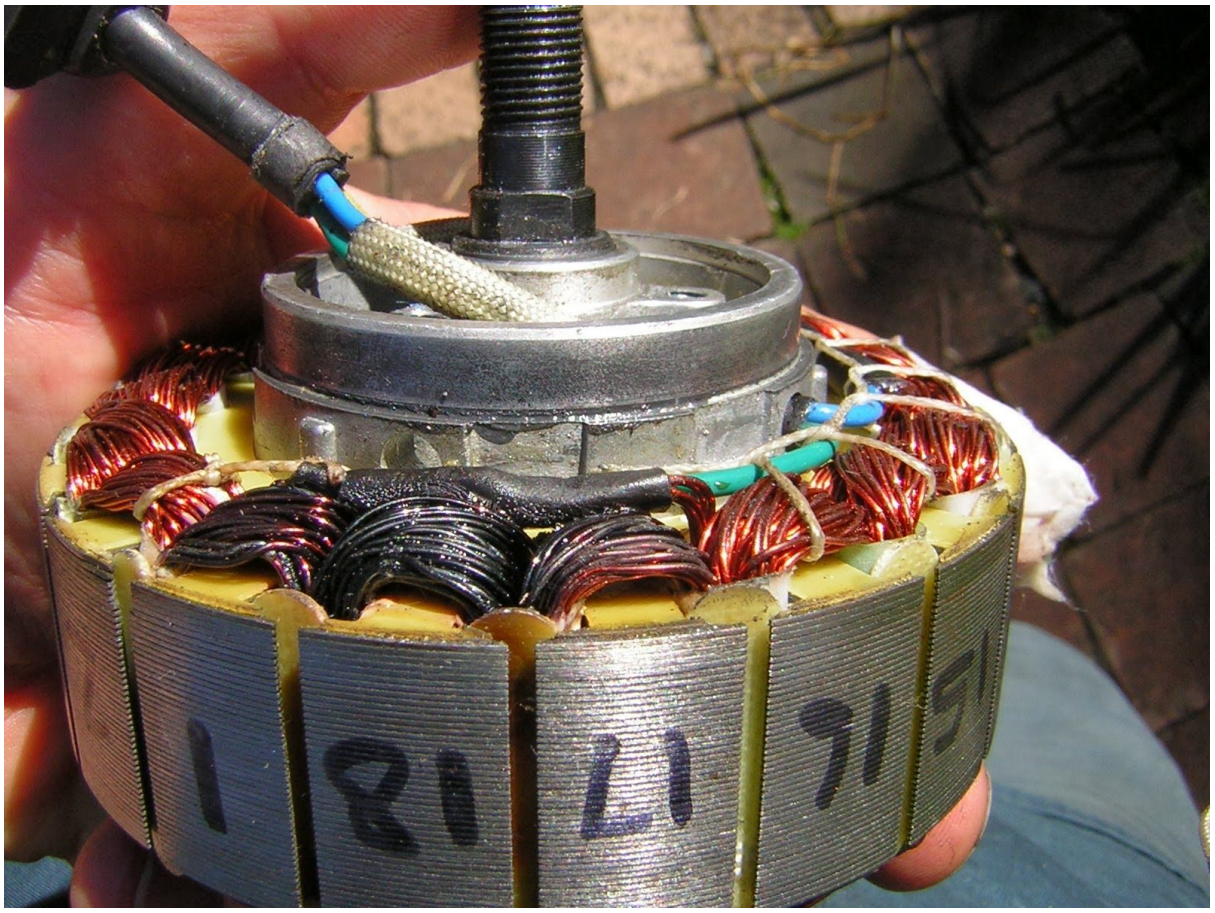
Brushed / Brushless

You will hear these terms mentioned a lot when you are discussing motors. Since I have found many are unsure what the difference is between them, I believed it to be worth putting a section here to explain.

Brushed Motors came about in the late 1800s. They are one of the simplest types of motors: they use a configuration of wound wire coils which act as a two-pole electromagnet. The direction of the current is reversed twice per cycle by a mechanical rotary switch. The E100 Razor Scooter Motors would be a good example of a brushed motor.

(A Brushed Motor)

Brushless Motors utilizes a permanent magnet as its external rotor, it also uses three phases of driving coils and a specialized sensor that tracks the rotor position. As the sensor tracks the position of the rotor, it sends signals to the controller which activates the coils in a structured way. The Q85 Motors would be a good example of a brushless motor.



(Insides of a Q85 Motor)

Now you know what the difference is between the two types of motors, which should you choose? Say it with me… It Depends! The brushed motors are perfectly fine to use within a build, as are the brushless. I have compiled a small list below of some key features of either to help you make your mind up.

Brushed:

- Low overall costs
- Can be rebuilt to extend life
- Simple and inexpensive controller
- Ideal for most environments

Brushless:

- Less overall maintenance
- Operates effectively at all speeds with rated load
- High efficiency and high output power to size ratio
- Reduced size with superior thermal characteristics
- Higher speed range and lower electric noise generation

Most builders I spoke to who have made the switch to brushless motors, specifically the Q85s, have said they wouldn't switch back to brushed motors if they built another droid. The price is also something to take into account when looking at the motors. Whilst a single E100

Brushed Razor Scooter Motor can be purchased from eBay for usually under £30, the brushless Q85 motors can be more around £100 plus.

Taking Care

Black Sand, Dust, Debris, Dirt. These are all things that can cause you a few problems with your motors. Outdoor events or indoor events, there are little things that your motors will collect overtime. Black Sand is a common problem due to its composition being made up of many types of different ferrous metals which are attracted to the magnets within the motors.

Other kinds of problems, such as dust and dirt, are collected over time and require taking time to keep your droid clean (figuratively speaking) and make sure you keep all of the parts of your droid as well kept as you can. Eventually, you will need to replace parts, you should also check how to clean your motors, when the best time to remove them from your droid and give them a good clean would be to prevent the buildup of dirt and debris which can stop your motor from spinning and cause a whole range of other problems.

(Image of Black Sand inside a motor)

Droid Electronics

Since you now have a good understanding of the components and LEDs no longer resemble tiny magical fairies that produce light upon the call of a switch, looking at some Droid Electronics should not look as intimidating! With that said, remember that some builders love electronics and have done some wonderful things in their droids. However, do not be deterred by this: they are simply a number of levels above you at this point, you have the chance to get to that level as well if that's what you want to do.

We can now move on to some more electronics, this is where we look at some specifics to droids.

MP3 Trigger

Would a droid really be a droid if it did make the boops, beeps, whistles and play the Cantina music all day long? We usually enjoy making our droids talk to each other and members of the public by allowing them to output sounds. This is done through the use of an MP3 Trigger.

An MP3 Trigger is a small low powered embedded audio unit that plays MP3 Tracks from a microSD card through a 3.5mm (⅛") headphone jack. In the case of droid building, depending on what control system you are using, it will take its trigger from a 12/15 channel R/C Remote or from serial via Arduino if you are using something such as the Padawan360.

By putting the correct audio files on the microSD card, you can trigger a particular sound to be played and the more sounds you have, the more chance you have of playing random sounds on random buttons that you have assigned.

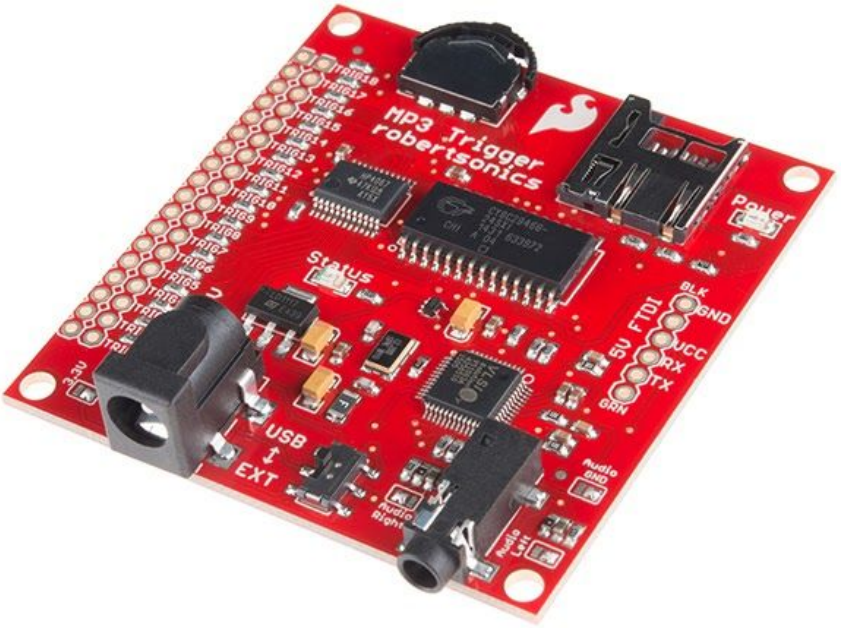
The most common MP3 Trigger used in droids is the Sparkfun MP3 Trigger.

There are various different things that you can do with the MP3 Trigger to incorporate it within your build and it would entirely depend on what you wanted to do. Whilst this is not a guide that simply lists every possibility, the aim would be to give you an overview of the common components and provide plenty of resources for you to delve deeper into the research.

Pre-Amp

Also suited with the MP3 Trigger would be a Pre-Amp. The MP3 Trigger is only able to drive earphones, not speakers like you would have in your droid. The signal generated from the trigger is weak in terms of output and, if you tried to play it though a speaker, it would be extremely quiet. A pre-amp goes between your Trigger and your speakers and amplifies the signal to give a loud output signal through the speakers.

There are various threads in the groups and forums regarding which pre-amp you should use, my advice would be to make sure you get a good one. I have found that, with this hobby, you get what you pay for.



(The Sparkfun MP3 Trigger commonly used by Droid Builders)

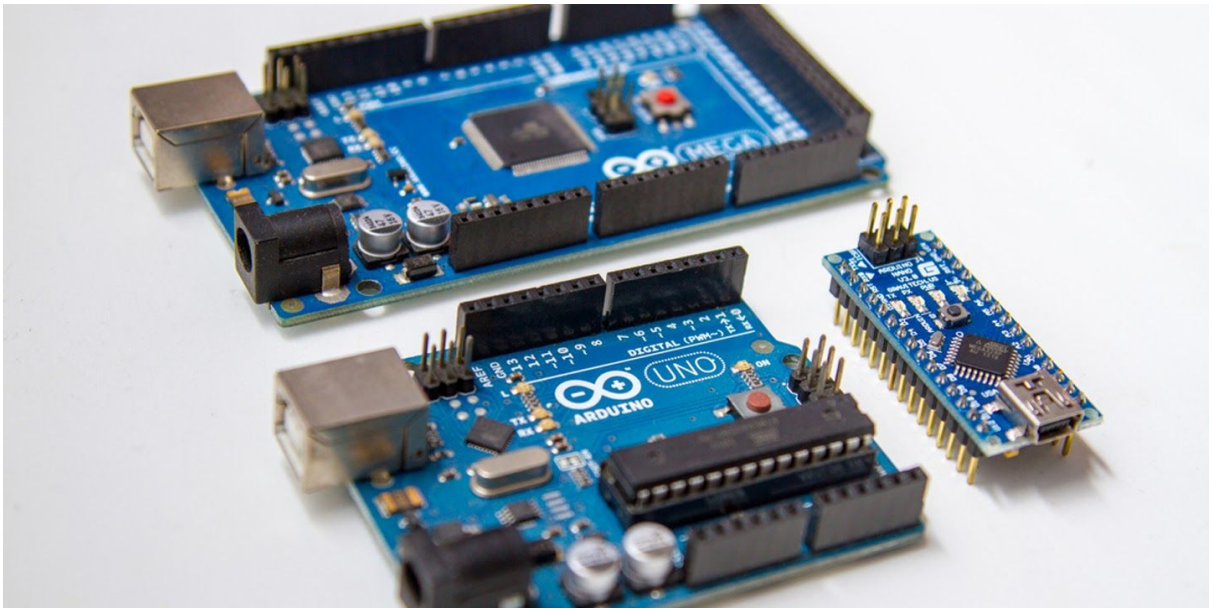
Arduino

I would be surprised if you have not already heard of Arduino. It has become the center of electronics in the Droid Building Community and remains an extremely popular component of droid builds. Arduino is an open source electronics platform based on easy to use hardware and software. There are different types of Arduino boards that are more suited for different things but a modern droid could easily have a couple of Arduino boards doing various things.

You can read more about Arduino on their website.

Within a Droid, an Arduino can be used in various situations. Dome lights could be one example. A standard astromech such as R2 has plenty of lights in his dome, logic lights and PSI. For ease, I will discuss the JoyMonkey Teeces since they are one of the most common.

Created by Astromech.net user JoyMonkey, the Teeces have had a few different versions over the years, with the latest being the R-Series using Fibre Optic lights. The standard Teeces uses an Arduino Pro Mini, Micro or Pro Micro (builders preference) which are small and compact compared to an Arduino Uno for example.



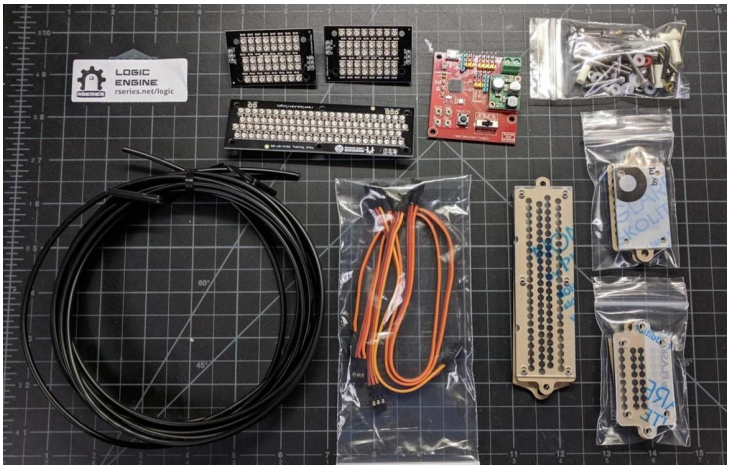
Dome Lights

Following from the previous section, lighting within your droid specifically Dome Lights can be achieved in multiple ways. The most common is the JoyMonkey Lights either Teeces or the R-Series. The Teeces use 3mm flangeless LEDs that are coloured the various colours and are programmed using an Arduino. These are a very common light setup for builders since there are many options to either purchase the boards and components yourself and attempt to build them by hand or you can buy completed sets from various BC Approved Parts Runs.

You can find the Parts Run for these lights here.

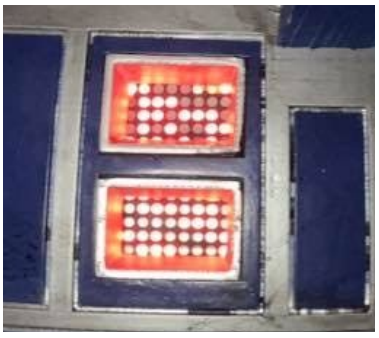
(Image courtesy of MisterFubar)

The R-Series was a great step further in terms of the Dome Lights, moving from standard LED's to Fibre Optic Lights. The R-Series are more accurate to the screen used Logic Lights and there have been a number of alterations from the previous Teeces system. Instead of using two drive boards, it now uses a single Arduino Zero board. The boards are more compact after being able to use smaller LED's, and support more modern ways of controlling such as the Jawalite, R2Touch and Marcduino, as well as being easier to assemble and mount. You can find the Parts Run for these lights here.



(Image courtesy of JoyMonkey)

There are also other ways people have created their logic lights such as using some 8x8 Dot Matrix Displays and even Christmas Lights. If you are not able to afford the more expensive parts, this is a great chance for you to get inventive!

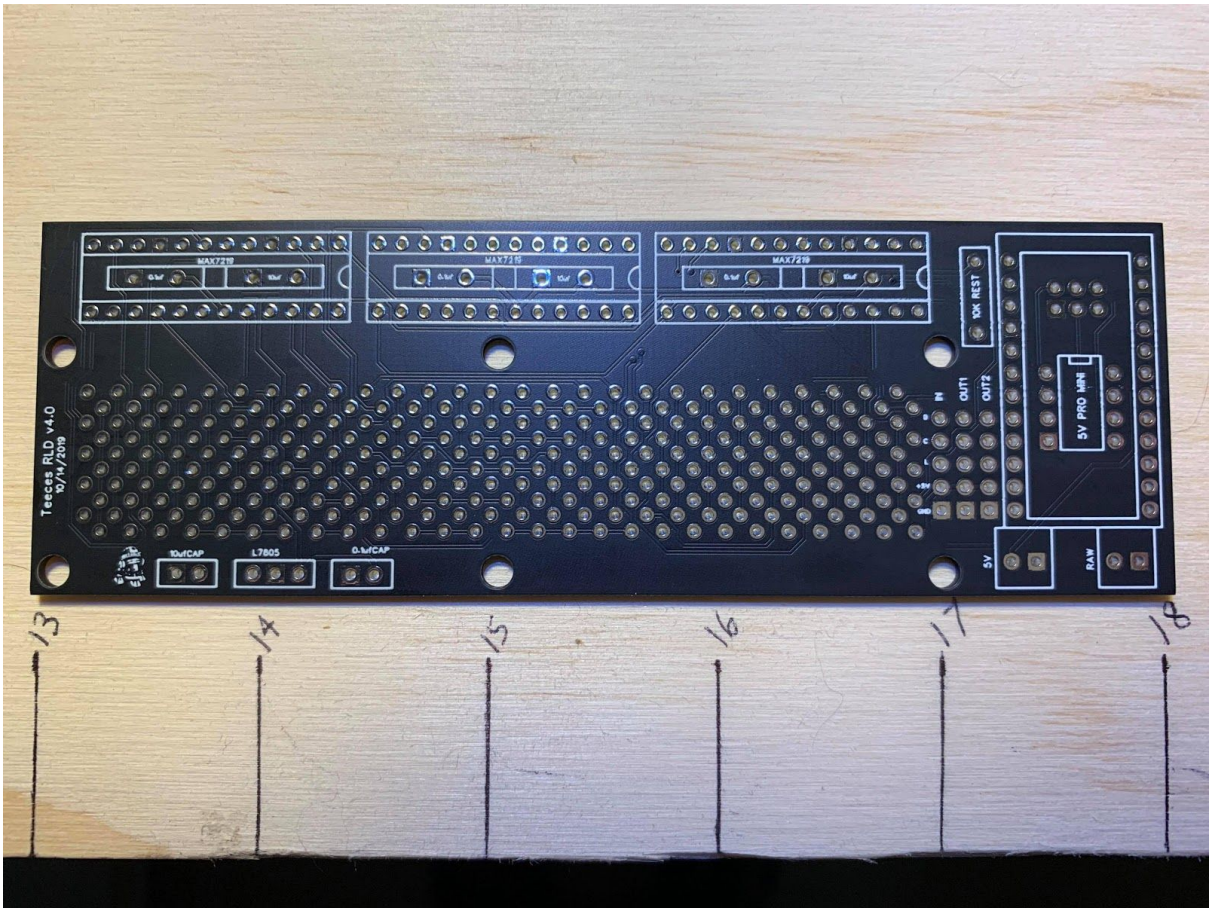


(Image courtesy of Rob Howdle)

As always, there are pros and cons to almost everything. Whilst the Teeces, to this day, remain the ever popular choice for builders around the planet, they are prone to blowing the MAX chips by supplying them with too much voltage. The Teeces do have an onboard regulator (a linear 7805) however, if this fails, you will need new chips and possibly other components. Another reason to have a device such as a UBEC in front to provide a clean voltage.

Something to note is that the Teeces Light Boards are openly sourced from Osh Park, meaning if you wanted to have a go at creating your own light boards, you can! You can find the boards here and a list of components needed here.

Another factor to note is, with special thanks to Devin Olsen, he has kindly revised the Teeces Boards. The reason for this was that there were a number of issues found with the boards which caused some to not work or have a lot of problems whilst others seemed unaffected. The results were a much neater board with a lot of cleaned up traces and tracks.



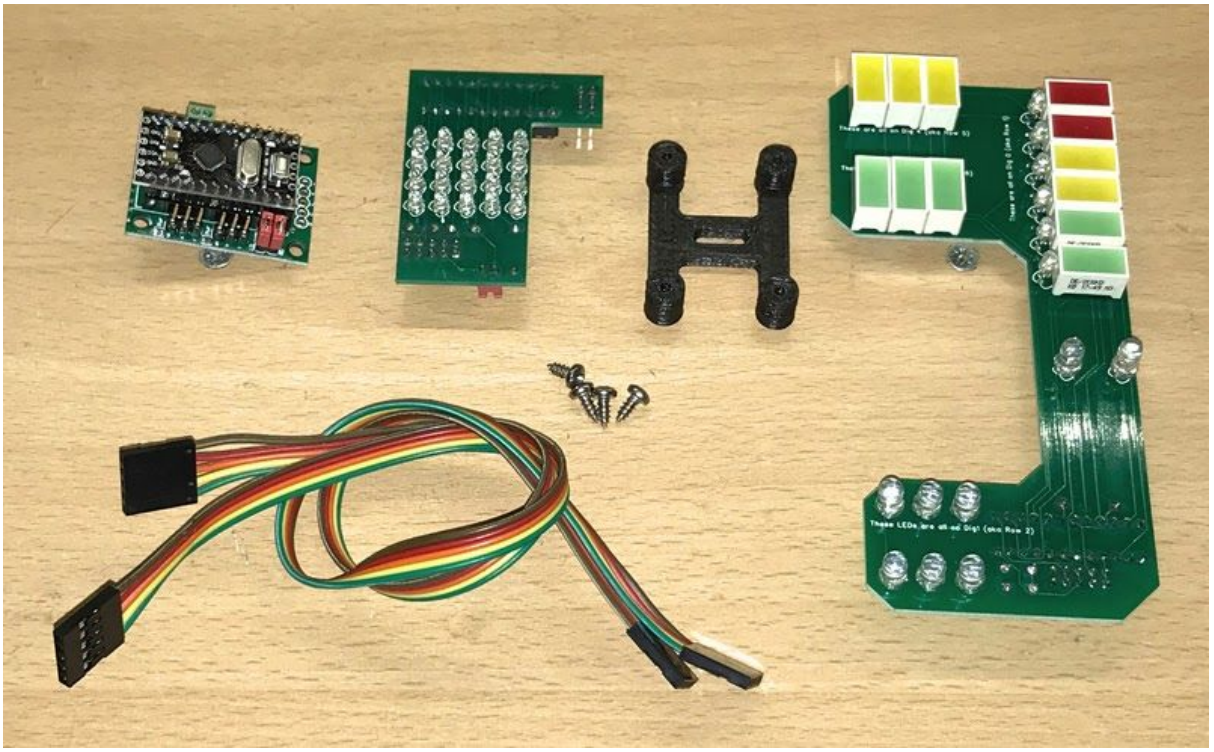
(Image courtesy of Devin Olsen)

Body Lights

Moving down from the dome, there are many different things a builder can do in the body of your droid. Glyn Harper, a UK Builder provides BC Approved Runs of the Dataport Logics and Charge Bay Indicators which can be found here.

These circuits utilise 5mm and 3mm through hole LEDs, an arduino and also Bar LEDs. These logics offer random LEDs sequences that simulate things such as data processing etc. This is another small thing that helps make your droid seem alive thus adding to the magic witnessed by the public and other builders alike.

These particular circuits require 5V and, should you not have a 5V supply, you can always use a voltage regulator which will take an input voltage and reduce it. Many builders have also customised their Charge Bay Indicators and Data Panels to suit their droids.

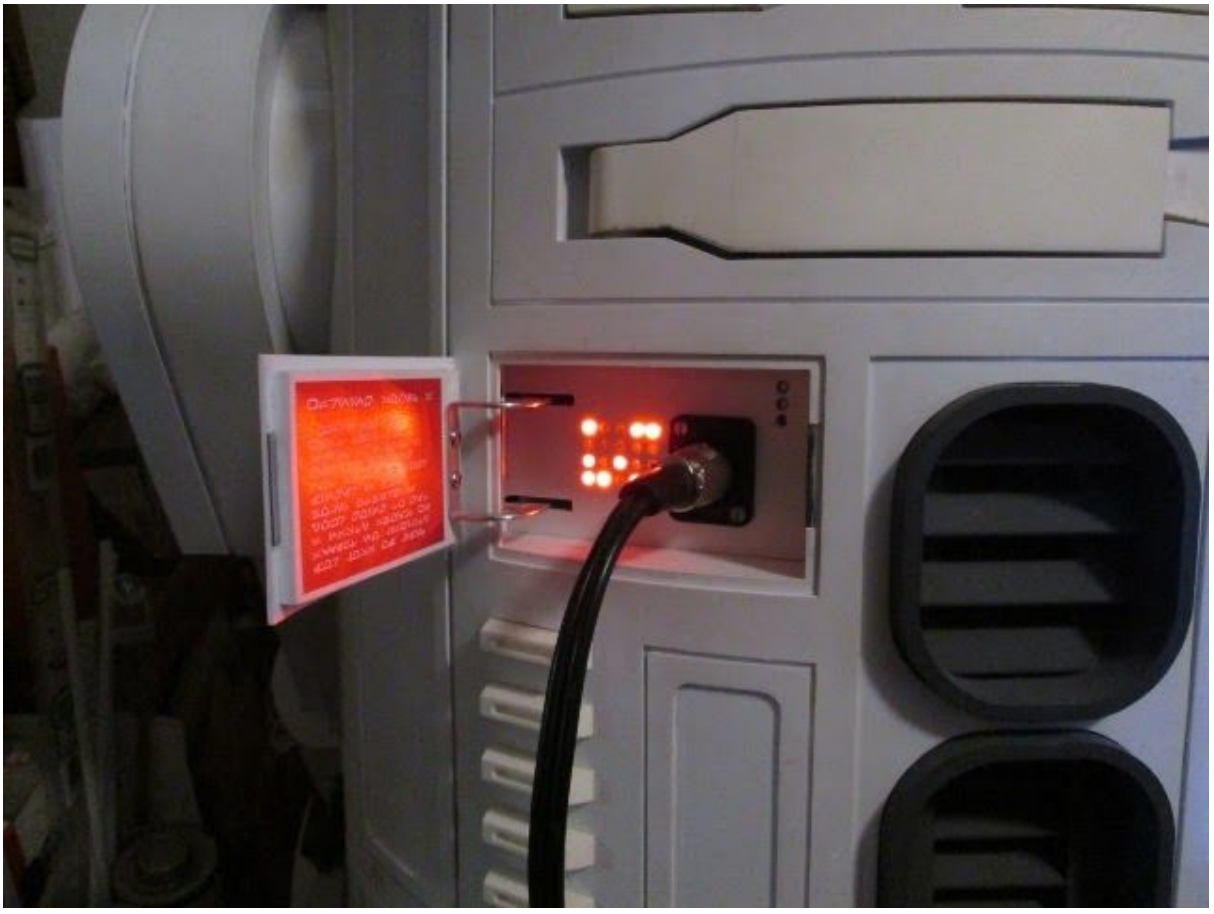


(Image courtesy of Glyn Harper)

Charge Bay Indicator

Many builders have been able to turn their Charge Bay into a functioning circuit for charging their droid, as seen in Empire Strikes Back. There is a debate between builders about whether you should charge batteries within your droid or not, if not then perhaps this would not be a functioning feature for you to have, or you may be able to adapt this to allow this port to perhaps charge a mobile device, a programming port or even as non functioning but you could build the Fusion Furnace (Droid Charger) as seen in Empire Strikes Back and have it look the part.

Many Builders often have their Charge Bay Indicators reflect their battery status giving a real time three coloured LED display of how much charge their batteries have, Green, Yellow and Red.



(Image courtesy of Chewbakken)

Data Panel Logics

Data panel logics are often optimised to provide useful information to the builder if done correctly. There are various places on the Data Panel itself (the plate, not the circuit) for you to mount various displays and many builders take this opportunity to mount some displays to show them things such as how many Amps their droid is drawing, some may have a separate display for the foot motors to measure them separately etc.

Builder Modifications

Something I feel is certainly worthy of mentioning here, if only to prove that it can be done is a modification I was made aware of by a builder. This was achieved by Trevor Zaharichuk and this isn't necessarily a modification as such, in fact Trevor describes it as more of a full redesign. To begin with he replaced all the LEDs with addressable SMT (Surface Mount LEDs, of course you already knew that since we spoke about them not too long ago!) This means that each LED has an integrated driver and can be controlled individually for example you can control the brightness of the individual LEDs instead of one brightness for them all.

Incorporating a Teensy 4 board (a complete USB-based microcontroller development system, in a very small footprint, capable of implementing many types of projects), voltage gauges, spectrum bars (you will have seen these previous in things such as audio equipment, they can often pulse and light up based on volume or frequency), the addition of a DFPlayer (a mini mp3 player) and also some connectors for servos. The reason for this is so the data panel can be used as a central control board.

Naturally this might seem like I am now speaking Huttese but the inclusion of this was to prove just how much customisation you can do within Droid Electronics and that you are highly encouraged to attempt something new.

(Image courtesy of Trevor Zaharichuk)

2-3-2 (3-2-3)

For those of you who may already be familiar with electronics, you might be interested in this section. Flashing lights, opening doors and whistle noises are not the only things a droid can do. With Astromech droids, some builders were very clever in the way they constructed and developed what is known as the 2-3-2 '3-2-3' function. This function allows your droid to transform from three legged mode, to two legged mode and back. Many astromechs can be seen doing this in the movies and it is a wonderful addition to be able to achieve. This feature makes use of components such as linear actuators to tilt the droid into the correct position.

The 2-3-2 is a complicated yet exciting feature to have within your droid. It is a widely known feature yet there are not many droids with the 2-3-2 functionality. The reason for this is firstly it's quite a complicated function to put into a droid which can be enough to deter most builders who may not be up for the challenge. Another reason this feature is not very common is that it does not leave you much space within your droid for other features. While it is certainly possible to have a 2-3-2 function and other parts within your droid, it doesn't leave much space to work inside without removing skins and taking your droid to bits.

There is an interesting thread on astromech.net by KevinHolmes that I'd suggest you read if you are considering adding the 2-3-2 functionality to your droid. You can find it here. There is also a wonderful video by long time UK Builder Brad Oakley showing off the 2-3-2 Movement in his R2-BHD Droid. I think this is a good video to show how things work because in the video, his droid's back plate is off and you can visibly see the various parts moving. You can watch that here.

This feature, whilst it is a great challenge for somebody looking for one, is one that requires a lot of planning, a lot of research and patience. It is a case of trial and error for the most part and should not be rushed. Currently 2-3-2 features only exist in builds made from aluminium, wood and some cases even styrene. As a new builder, you will have been introduced to 3D Printing by now and whilst one or two people have made 3D printed droids that can do the 2-3-2 function, there is no official way to do it since at the time of writing this, there is no single way that has proven to be a safe and structurally secure way of completing this task. Currently the only 2-3-2 capable droid that is 3D Printed that I am aware of is Troy Flinns which uses his own files for the 2-3-2 function compatible with Michael Baddeley's R2 file. These can be found in the Printed Droid Facebook Group.

Other Droids

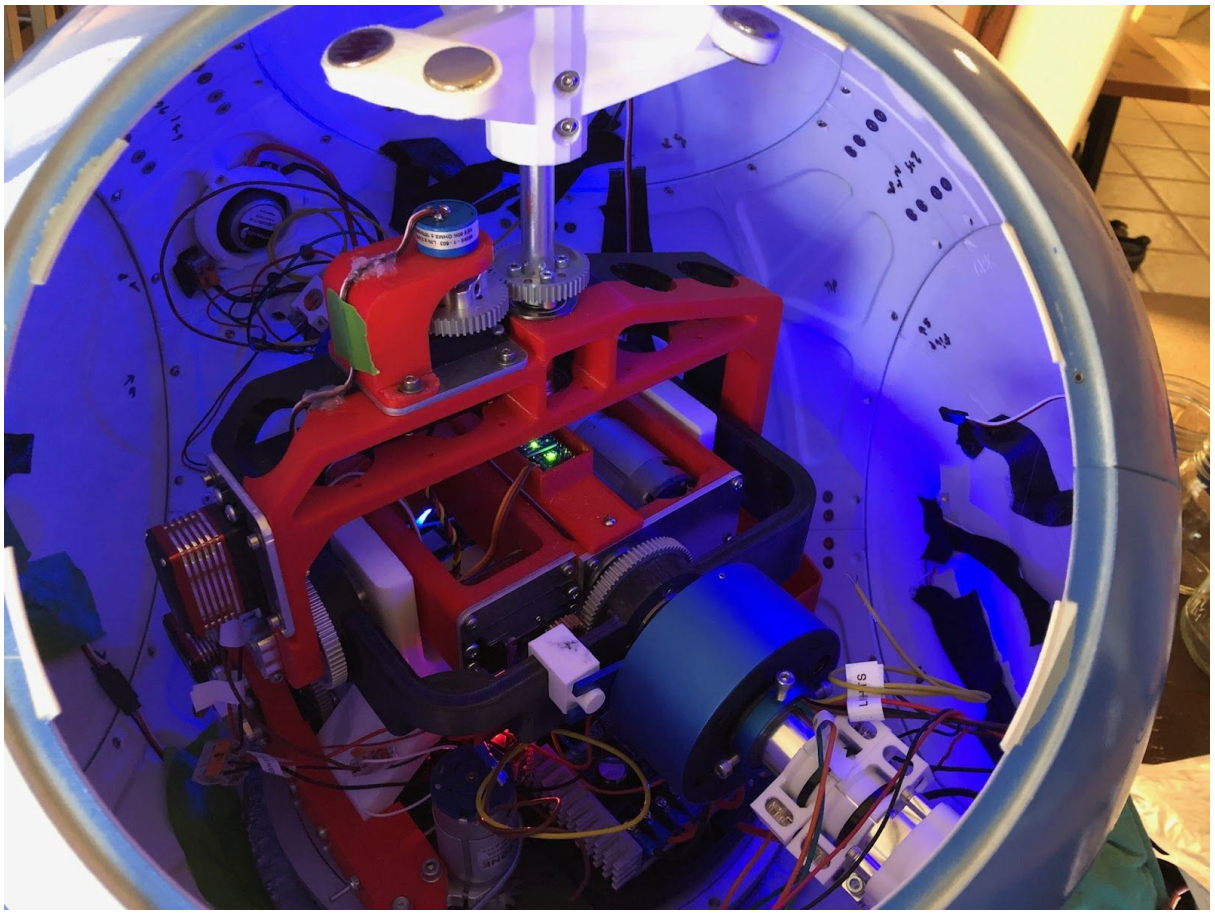
R2-D2 is not the only droid in town these days. We have so many more droids being shown in movies and tv shows that more and more unique droids are appearing. Below, we will discuss some specifics for other droids you might be interested in building. You will notice that, even though the droids are different and what you see as the end result may look different, quite often the electronics used are the same, however slightly altered. At the very least, the principles of electronics used in droids are the same: since technology progresses all of the time it should come as no surprise that you can achieve the same things in different ways.

Below we will take a look at some of the various and unique electronics found in different droids.

BB-8

BB-8 is quite new compared to R2-D2 but he is equally fun to build! The BB-8 Builders have done a fantastic job of creating everything for this droid and the technological challenges they overcame with this droid are outstanding. The Drive System in BB-8 is the result of a lot of hard work and careful planning. The following write up is courtesy of a BB-8 Builder - Luke Schumacher.

> When building a BB-8 drive system, there are several engineering challenges you will face. Starting with how the main sphere moves. Unlike R2-D2, where we can hide motors in the feet, BB-8 doesn't have any feet. Again, since people are used to building droids like R2 which have a type of tank drive system where the left and right motor spin in the same direction to go forwards and backwards and then both in opposite directions to turn, BB-8 was quite different. This means builders had to figure out how to control turning, spinning on the spot, as well as how to get the dome to stay on top of the main sphere without falling off.
>
> Starting with the main drive and how the system can roll forwards and backwards: it is designed like a pendulum. A fixed point is created at the center of the sphere, this is the main drive shaft. The main drive shaft will be attached on both sides at the exact center of the sphere and will act as a datum. From the main drive shaft, a weight is attached at a known distance and will be located as low as possible inside the sphere, without touching the bottom. The weight is important because this will create the potential energy needed to move the sphere forwards and backwards. The weight will be controlled by a motor attached to the main drive shaft. When this motor spins forward, the weight will move forward inside the sphere, and create the energy needed to move the entire system forward. It is important to have enough weight to create this reaction but not too much that it is uncontrollable. The weight is also important to balance the dome and make the droid stable. This is the first key to understanding how BB-8 can move forwards and backwards.



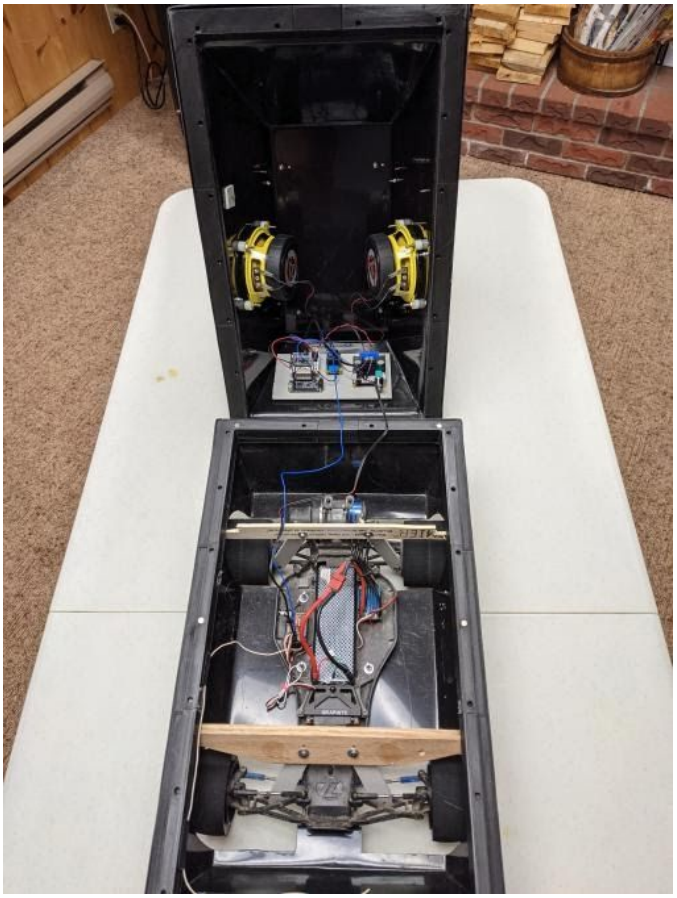
(Image Courtesy of Tosin Onafowokan)

Mouse Droid

Mouse droids have been around just as long as R2 himself. First seen in A New Hope these little droids caught the eye of quite a few builders and have become a fan favourite due to the smaller size of the droid, cheaper cost to build and simplicity in comparison to droids such as R2. We will take a look at the drive system electronics which may surprise you in terms of how they operate.

Mouse Droids are great builds, especially for new builders who don't feel confident taking on the larger droids straight away. You might be surprised to learn that Mouse Droids are quite simply RC Cars sandwiched between two custom shells. The most common RC car used in this build is the Traxxas Bandit Car which has all of the electronics you need in terms of the drive system. These electronics might look slightly different to the others in terms of the lack of circuit boards. Realistically, having large circuit boards and other electronics in a small car would make for a very good product.

Other than that, the only other electronics you might want to install into your mouse droid is an MP3 Trigger which will allow you to play sounds. Some builders add some wonderful additions to their mouse droids, such as Matt Hobbs! You can watch the video here for more details.



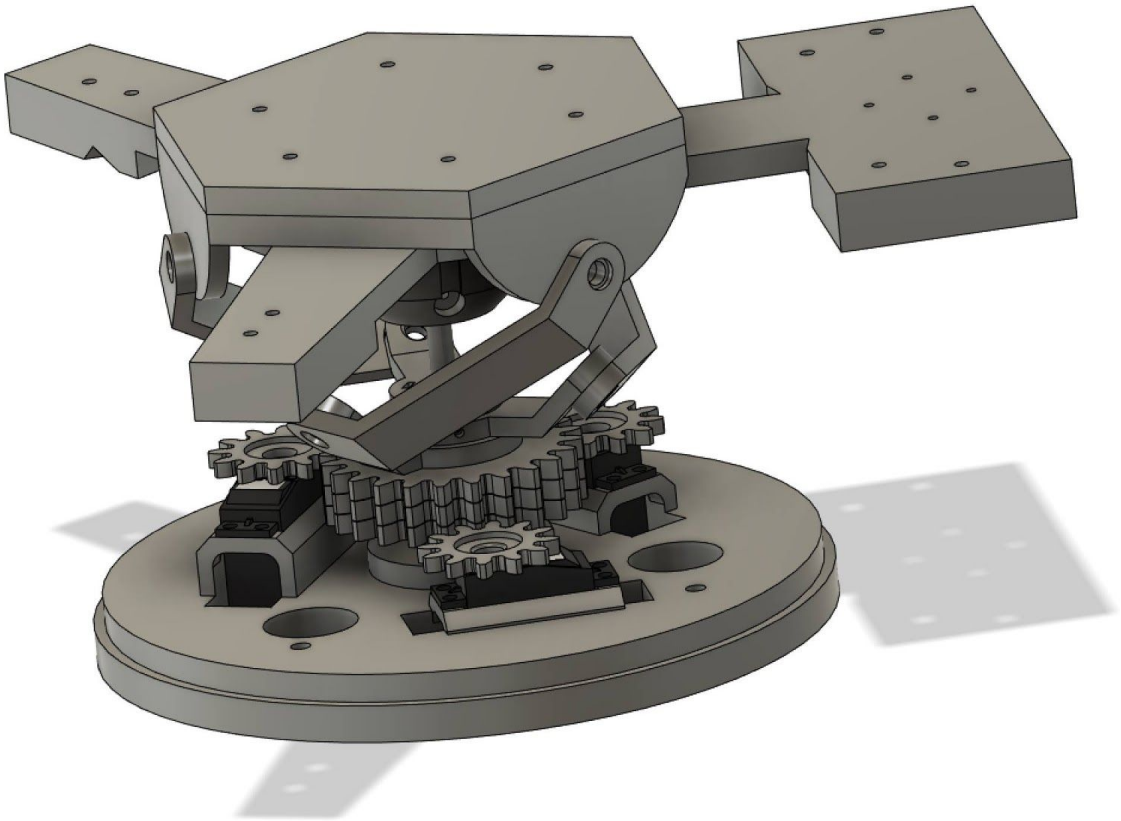
(Image courtesy of Patrick Ryan)

T3-M4

T3-M4 is a new droid to the community. Possibly more challenging to make work than the other droids because T3 is being built from the Knights of the Old Republic video games and, as most of us know, video game logic and real world logic usually are not the same.

T3 has many challenges in terms of electronics. The neck mechanism was the biggest to date and we were able to devise a couple of solutions to tackle this. T3-M4 does not have a dome like R2 does, it has a head which can rotate the same as R2 however this head can also perform tilts and rolls, meaning he can look up and down as well as tilt the head left and right. Instantly, we realised that if we wanted this functionality we would have to come up with something new.

Luckily, the group has some clever builders who did just that. Doug Olson created a neck mechanism based off a Spherical Parallel Manipulator which is 3D Printable, and long time Droid Builder Oliver Steeples created another version which has a similar rotation method to the classic R2 but is based on a standard Universal Joint arrangement with servos positioned to control the pitch and tilt along with a motor located at the bottom which controls the rotation.



(Image courtesy of Douglas Olsen)

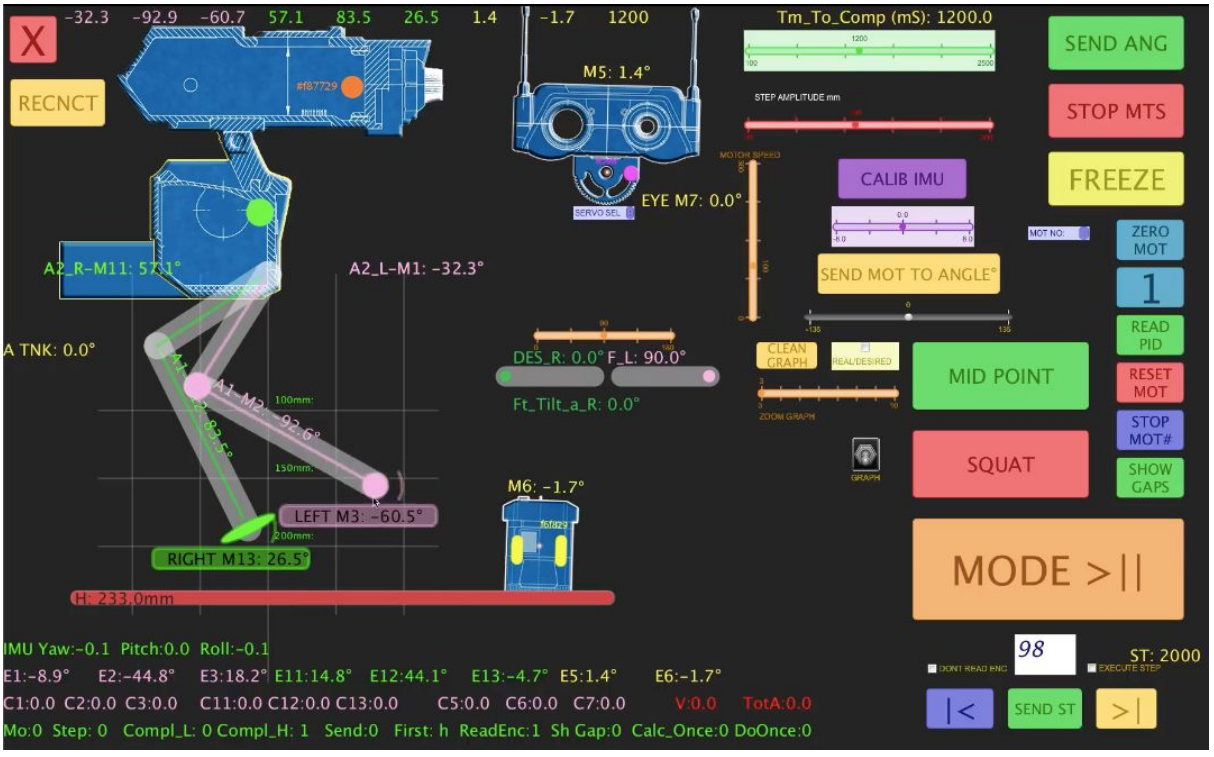
(Image courtesy of Oliver Steeples)

BD-1

BD-1 has become a fan favourite since the release of the Jedi Fallen Order game, a bi-pedal droid with a lot of functionality. Whilst there have been many 3D attempts at this droid the biggest drawback is that a real life droid has to be stationary (so far!) due to the difficulty to replicate game physics but also that making a bi-pedal droid at this size presents many challenges. Luckily, the Droid Building Community is not short of innovative people and many felt up to the challenge.

One example of this innovation is from Mitch Anderson who has worked on developing the first walking BD-1. It works by having multiple motors and servos in the various joints. He created a Graphical Interface which allows him to control the droid and put him in various positions. His BD-1 walks by recording various positions in terms of waypoints and then repeating those waypoints.

Mitch has done some incredible work with BD-1 and there is a lot more to the droid than what I have detailed, you can find more information in the [BD-1 Facebook Group.]



(Image courtesy of Mitch Anderson)

Another alteration to the BD-1 droid I wanted to mention was the modification made by Darren Serool. He made some fantastic modifications and I specifically wanted to detail them here to inspire you and to remind you that you are not limited to what everyone else is doing. Below is a description of Darren's droid, DS-72.

> After printing the files which Michael Badelley produced, DS-72 was then assembled and airbrushed using semi gloss black, gun metal grey and chrome. He also includes the BD-1 rear panel designed by Trevor Zaharichuk. Several pieces were modified to fit, look and work better. The tiles used for the base were 20mm x 20mm and meant to be used for making a diorama of the Death Star. The Imperial base was designed in Fusion360 by randomly inserting tiles into place on a sketch, and then extruding the rear of the sketch to join them. After printing all necessary pieces, they were cleaned and epoxied together. The base design includes a trench run from Episode 4. The base paint job is a simple primer, semi gloss sealer followed by a dark wash. Turbo lasers were included for good measure. Because of the trench run, changes had to be made to the leg mechanism to allow movement.
>
> Dual 20kg servos were used by straddling them across the trench and connecting them to a custom bar between the legs. Springs were added to reduce the weight on the servos. The software originally written by Andrew Donatelli has been modified to fit my purpose and several dance routines have been added. The dance routines contain movements which are timed to the music. Listening to the song several times I had to plot the movements with the beat and then play with the delays and loops to create the desired effect. An infrared sensor has also been added to detect movement to create a sense of autonomy.

(Image courtesy of DS-72 Builder Darren Serool)

How should I plan the electronics for my droid?

Is there a single kit of electronics I should use?

A very good question that is asked constantly in almost every group meaning it gets its own section in the guide. Many people ask whether there is a single wiring diagram for connecting up electronics, if there is a single list of components and links where to buy them from, if there is just one way to do things. The answer is simply no. One of the best things about the Droid Building Community and building the droids that we do is that there are many ways to do things, which means that the hobby is open to so many more people.

There are multiple ways. For example, for the logic lights in R2's dome: you can create your own lights, some use Christmas lights, use BC approved parts runs such as the Teeces, and some find other creative ways to replicate the lights. If this hobby was limited to only one way then it would become much more closed off to certain people due to experience, demand for parts and even availability or budget. For obvious reasons, this would not be good.

Since there are multiple ways of doing the same thing, one single set of instructions or a single wiring diagram simply does not work. You do not set up the Teeces the same way you would set up some christmas lights. Plenty of builders have created various documents, guides and videos that you can follow, however the work must initiate from you, the builder. Even with electronics that are already made, you still need to understand how they work so you can connect them into your droid and make them function with other circuits! What good is having a bunch of electronics ready to go into your droid if you don't know what the power requirements are? Not enough and they will not work, too much and you could get the Magic Smoke achievement...

Availability

Availability is something that in this day and age one would assume wouldn't be a big problem, you would be rather surprised that it is one of the biggest reasons people cannot get certain parts. Many people around the planet are constantly developing new technologies for droids. In order for them to develop things, they need to find the items, put them together and make sure they work as intended. The problem with this is that what might be available to one person in one country might not be available at a reasonable price or even at all in another country, does that mean that people in those countries simply cannot have it? Of course not!

Builders are nothing if not resourceful. Many builders will come together and do a bulk order and have a member in that country ship the items or they'll group together and buy X amount of parts for multiple people to help spread the cost and, occasionally, members actively go and find alternative parts that are easily found in their countries. For those reasons and more, there is no single list of materials or single wiring diagrams etc.

Research

It's that word again! Research, as always, is key. Bad research or no research will cause you many problems further down the road, electronics research is just as important. You might have already researched what electronics you want in your droid, which is great! You're already ahead of the game but do you know exactly what your electronics will consist of other than perhaps a few flashing LEDs and an arduino? You may have decided you want your body panels to open and close but do you know which servos you need?

You should also check what parts are available to you in your country. Sometimes, it can be quite costly to get some electronics imported to your country if you don't have somebody locally that might do runs of them. Nobody is asking you to become some Electronics Guru in order to put a few lights into a robot but you will be expected to at least have a read up so you know what you are talking about. You are less likely to get assistance from other builders if you refuse to help yourself. After all, the biggest part of the journey is learning new things, figuring out problems etc. If you don't want to do that, you might get by or you have a string of good luck with builders who will help but that is not what building a droid is about.

Just like when researching your droid in general, getting background information about electronics and what goes into them is also an important step, do not skip it! The vast majority of droids these days use Arduinos however builders are always on the lookout for new things for example incorporating the ESP32 Module in . Questions to ask yourself to see if you already have some background knowledge would be things like:

- What language is Arduino Code written in?
- Do I have the Arduino Program installed on my computer?
- Do I know how to install libraries and set up the project?
- Can I search for the basic Arduino Errors that might come up such as board errors, compiling errors, library errors etc?

Those are just some of the very basic things related to Arduino Programming that you should know before starting, if you are using any arduinos. When it comes to helping people with electronics, many builders will jump at the chance to help fix a problem or give their advice. One of the issues that can be quite common when builders ask questions in forums and groups is when the builder does not know what they want their droid to do. They know they want it to do something but, sadly, we cannot give you specific advice when you do not even know what you want.

One further thing: sometimes, builders will release BoMs (Bill of Materials) which are very handy. These are lists of required components for a particular part of the build or sometimes the whole build. The biggest issue with the list is keeping it updated with what is available, as well as the fact a particular part available to one builder may not be available to another. You should pay close attention to these lists, I have seen numerous builders purchase parts which are either not right or the wrong type. Usually this happens when builders do not follow a Bill of Materials or when they attempt to purchase all parts from a single source that

may not stock the correct parts. This also happens when builders try to substitute untested alternatives.

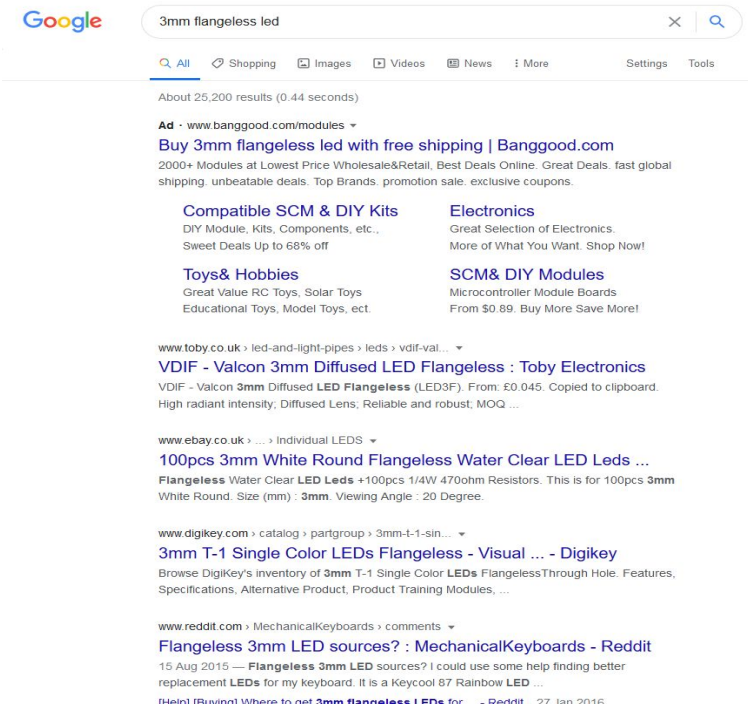
Components and where to get them

As mentioned earlier, different countries stock different parts. Most companies and sellers will ship almost anywhere. However, there unfortunately are cases where the parts you need either cost a fortune to get into your country or they are simply not available. The first thing I would suggest is contact the company if you're unsure and ask about shipping to your country.

You can also post on forums or in the facebook groups as to whether anyone has been able to get parts shipped to your country: you could be in luck and a local builder might have exactly what you want! Sometimes, other builders can ship you the item, again cost depending and whether you can physically ship the item.

In the modern day, you can find almost anything you need on either Amazon, eBay or both when it comes to finding components and use of that fantastic tool "Google" will save you so much time over asking in various groups and waiting for a response and, many times, you'll find a lot of answers can suggest different things and contradict each other. If you add up how much time you have spent before ordering, a lot of the time you will find you have spent more time waiting for a solid answer than you would have finding it yourself.

3mm Flangeless LEDs, for example, which are used in the JoyMonkey Teeces kit I have demonstrated below. There are no secret tricks when it comes to finding components and occasionally I see some builders both new and old make mountains out of finding some components which can be very easy to source. The issues come when you need a specific part that is not available to you in your country. This is where you would ask in groups or contact companies etc. Usually, your local area will have well known local companies where you can also purchase components from if you struggle with any of the other options.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Flangeless Water Clear LED Leds +100pcs 1/4W 470ohm Resistors. This is for 100pcs 3mm White Round. Size (mm) : 3mm. Viewing Angle : 20 Degree.
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Alternative Parts

Cost is something that plays a large part in Droid Building and some people simply cannot afford to spend certain amounts on components, which is perfectly understandable. However, alternative products can cause problems. The biggest reason I have found is that the clever builders who have come along and written various sketches and programs to make R2 work used certain components and not all components can be swapped out with other components. The code which tells these components what to do was written using a certain type of component. Once you begin changing these components, things like the programming code that should tell that component what to do, no longer understand what the component is so it simply doesn't work.

Some alternatives have worked in a few builds however this has usually required some custom coding. Another point to make is the wiring: when you read wiring guides such as the one for the Padawan360, it offers a couple of different ways to wire it depending on the arduino you use. However, if you change a component such as the MP3 Trigger to something else, you may not have the same pins that are required in order to trigger your sounds.

The final point to make would be the Tried and Tested argument. The components that are suggested are tried and tested by many builders. I am certainly not going to tell you that you cannot do something new, in fact I encourage you to do new things, but you should be mindful that, when doing something new, you are entering uncharted waters for the most part and there would be little support to offer since you may be the first to try something.

Basic Equipment

We talked a little bit about a similar topic in the New Builder guide: around costs. Electronics Equipment varies greatly depending on what you are doing, some people make do with a basic tool kit whereas others go to great lengths, having some very high tech gear and, when you ask about what electronics equipment you need, both are perfectly fine answers. We have listed below some basic tools you need to begin doing electronics work in droids:

- Adjustable Temperature Soldering Iron - Some components are more delicate than others and they will need a lower/ higher temperature.

- Flux - A chemical agent used before and during the soldering process. It prepares the metal surfaces by cleaning and removing any oxides and impurities.

- Flush Type Cable Cutters - These are angled cutters with a flat side allowing you to snip things close to the board/ components.

- Helping Hands - These come in different shapes and sizes but are perfect for holding your circuits and components whilst you work on them!

- Tweezers - Some components you will come across are very small and especially if you have larger hands, it can be very tricky to place components on the boards, tweezers help a lot when dealing with smaller components.

- Solder - Something obvious yet it always gets left out of any lists!

Power for Droids

Unlike The Emperor, droids do not have ‘Unlimited Power’. They run from batteries, as KevinHolmes once said “*because an extension cord would just look silly.“* A common question in various groups and forums that I see is “What are people using to power their droids?” Can you guess what the first answer we will give? It depends! Builders use different types of batteries for their droids for various reasons. Some simply because they might have better access to one kind over another, a type of battery might provide more current suiting their needs over other batteries. Space is another issue builders face, compare the difference in sizes from a SLA (Sealed Lead Acid) battery to a LiPo battery as well as the weight difference, then try to find a secure spot for them that is easily accessible for charging. For some builders this is quite difficult therefore using different batteries is their only option.

Speaking of KevinHolmes, he wrote a fantastic thread about the basics of power for your droids on the astromech.net forum and wiki. You can find the forum post here and the wiki entry here.

The advice I would give to any new builder when you arrive at the electronics part is to make sure that you have thought about what you want electronics wise at the beginning because, sometimes, it can be very difficult to install electronics after you have finished building and painting. Whilst it is still possible, many builders have ended up having to pull apart glued pieces, repaint parts, drill new holes etc and, if this guide can save you the hassle of doing that, then I hope you will follow the advice.

You might envision your droid having lots of gadgets and features, which is wonderful and highly encouraged. However you need to make sure you know how much power you’re going to need for them which means a bit of research to see if firstly, it has already been done. If so, this will make your research easier because somebody else has usually already done all the tough calculations and worked out what is needed etc but, secondly, you need to make sure that what you have will be suitable. If not, you need to find something that is suitable.

Calculating Power Requirements

Before you think about buying expensive components, 3D Printing some great custom circuit board holders and making wonderful flashing lights, you need to know how much power you will need. You have probably thought about it a couple of times by this point, “What batteries do I need?”, “Can I just buy a really big battery and plug it in?”, “If I just plug everything in and turn it on, will it work?” and more questions along those lines.

Your electronics are nothing without power, so you must understand how to calculate it, if you are going to understand how to build it. If this seems a daunting task, have no fear, we shall take it one step at a time.

Step One would be to get a list of everything you would like in your droid. You need to know what is going inside of your droid before you can calculate what sort of power you need. Usually, this is where the majority of you stop because you find you don’t know exactly what you want, which isn’t a bad thing!

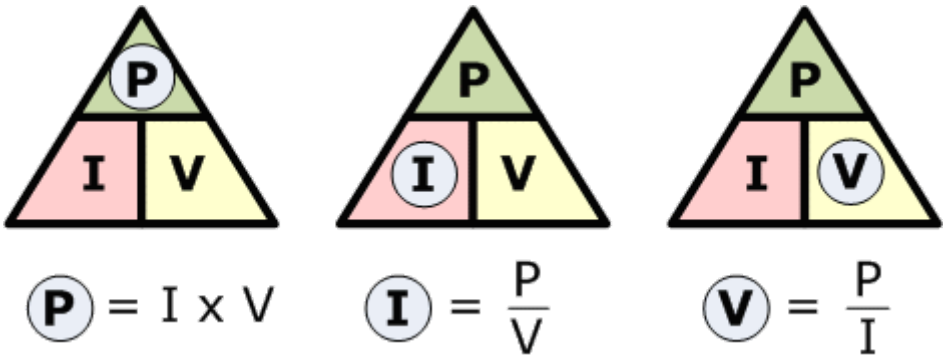
Step Two would be to work out what makes up the functions that you want. This means that, if you want your droid to play sounds, there is no “single” piece of kit that will make that happen in a way that you might want, it is most likely going to be connected up in multiple parts.

In the sound example, in the Padawan360 Control System, there is an arduino that detects what controls you are pressing and works out what sound needs to play, that also sits inside a USB host shield in which the Xbox 360 receiver is connected to. From there, it goes into a Sparkfun MP3 Trigger which reads the input and sends the audio file. After that, it goes into a preamp, then speakers or sometimes you might get speakers with a preamp built in.

The above is what makes up the Sound Functions. You need to be able to identify what makes up the functionality that you want before you can implement it in your droid. For building droids such as R2-D2, Mouse Droids etc, people have already done the hard work of figuring all of this out and documenting it, it is one of the main reasons all members are constantly advised to register on Astromech.net to research because that is where everything is. All you have to do, as a builder, is find the information and then read it.

Depending on what droid you are building, you may need to do some digging into alternative components due to different availability, costs and also requirements. Some components are not within some builder's budget, other components they may not be able to get and then others simply may not be enough or may be overkill for what you want ultimately.

Step Three would be to think about how you are going to power it. Now you have discovered what you want, you know how it’s all made up and from that information you know how much power these individual components need. To work this out, you need some basic electronics theory which hopefully you have learnt after reading the other guides or simply by learning as you go.



Above is an image which should help you work out which formula you need for any situation. The one we will focus on is the one on the left: Power (watts) = Current (amps) x Voltage (v). You need to make sure that you calculate these correctly, if not you could have big, expensive problems.

Let's talk about Voltage. If all of your voltages are the same for example if everything you ran inside your droid required 12V, then you don't really need to worry about anything as long as you are supplying 12V. It is very unlikely that you will only have one voltage however. This goes back to step one of finding out exactly what you want.

Sometimes, it is easier to split up your components into sections based on their voltages to help you understand them better. You may have a 5V section, a 12V section and a 24V section. I'll reiterate, it is very important to make sure this is right. If you supply the incorrect voltage to a component you risk damaging them. We would use a step down converter, or a buck converter to step down the voltage where required. This could take 24V from your fuse box and step it down to 5V if you have power going directly to your dome for example.

Current is the next big thing, it is the flow of an electric charge within a circuit. Devices will only draw the current that they need so we do not need to worry too much about having to work this out, although it is handy to know, especially for troubleshooting.

When is the right time?

One of the most frequent questions I see asked in various groups from new builders is whether they can do the electronics later. I did cover this in the New Builder Guide but it is something I believe that is worth explaining here also.

At the end of the day, this is your build and you will build it however you see fit. As a new builder you can take advice, or you will not. Not all advice is good advice and yet sometimes one would be foolish to not follow some pieces of advice and experience plays a part in knowing which is which.

You can start working on your electronics from Day One if you choose. After all, a lot of builders find this part of this build easier than others and electronics might be just that in your case. Alternatively, you could find the electronics very difficult and want to give yourself as much time as you can to understand it. I would highly suggest that you put a lot of thought into your initial research. To make sure you have explored all of the available options you can and you know what you need to make it work.

Knowing that you want the droid to light up and move sadly isn't enough. You need to look at how you want it to work, what do you want to make your droid light up with? What parts of your droid do you want to put lights into etc. You'll find each question you ask will open the door to two more questions. You should start thinking about your electronics at the beginning during your researching phase. This paves the way for actually beginning the electronics later because you should already know what you want by this point.

If you have decided to get some building done before you tackle the electronics, that is perfectly fine! It is a path builders commonly take, the best piece of advice I could give a new builder on that particular path would be that, before you glue parts together, fill and sand and then eventually paint, have a good think to be sure the parts you are sticking together do not have any electronic parts or wires going through them first. This would be something that one might see as obvious but it happens when builders get rather excited to start putting their droid together, and sometimes we forget.

It is very disheartening when you put a lot of effort into something only to have it scuffed, scratched, damaged or ruined completely because you need to drill a hole or take it back apart to run some wires, mount a servo etc. Patience is key and it is harder than it seems to hold back from assembling everything in one go, but this is where dry fitting comes in!

For those who don't know, dry fitting is where you roughly assemble parts without fixing them or gluing them into place to ensure it goes together correctly and you can identify any potential problems early.

I forgot the electronics!

There will probably be one or two of you at least who have already started gluing things together and painting and have probably forgotten that you needed to put some electronic components in first. The first thing I would suggest is to reach out to other builders, use the forums and the various groups, take pictures of the part in question and ask for advice. There are some extremely clever people in this community who may just save you having to redo the part entirely with a clever trick!

Troubleshooting Electronics

I have stressed this many times in various guides and in different groups but I will say it once again, to make sure people get the idea: everyone is happy to help you but they will not do it for you. You will never learn if you don't give it a go. Most people find they have to troubleshoot things more often than others and that could be for various reasons, faulty components, incorrect wiring diagrams, or simply a lack of experience.

Electronics can be a complicated game often leaving you scratching your head with more questions than you originally had and troubleshooting something that is not working can be even more challenging. In this section, I am going to take you through some basic troubleshooting that you should be able to do yourself. These require patience and the assumption that you know what the circuit should be doing. If you simply bought a kit, plugged it in and hoped for the best without attempting to learn anything then this will be even more difficult for you. This is even more beneficial because by doing this basic troubleshooting can help you narrow down where the fault is as well as saving time if you need to ask for help.

1) Turn it off and on again.

Something that has become a joke amongst IT Support and other industries. This option can fix quite a lot of problems for many different reasons. One reason being that, as your device runs, it has many processes running in order to be able to function correctly. Sometimes, these processes require too many resources from the device itself which can cause it to crash or just not perform very well at all, a restart can often fix this problem. Another reason this could fix your issue is, if any process fails to execute, it could prevent another device from functioning correctly.

2) Use your senses

We have eyes and they are great tools for spotting things. A very helpful part of troubleshooting is to physically see if there are any problems. Checking your wiring is always a good place to start, have any of your wires popped out? If they are not soldered in or if you are using jumper cables this could quite easily happen. Look at your components, do you see anything there that shouldn't be there? Is something missing that should be there? Can you see a popped capacitor or a burnt out chip? Is the board dirty and may have something conductive shorting out components?

Using your ears, can you hear anything when the circuit is turned on? Fizzing, popping and sizzling are usually sounds that mean there is a problem, you should identify where these sounds are coming from as quickly as possible and then turn the circuit off.

This can be a strange one but if you use your nose: if components have blown or shorted out, sometimes, they will emit a distinct smell. Most of the time it would probably smell of burning but other times it may not.

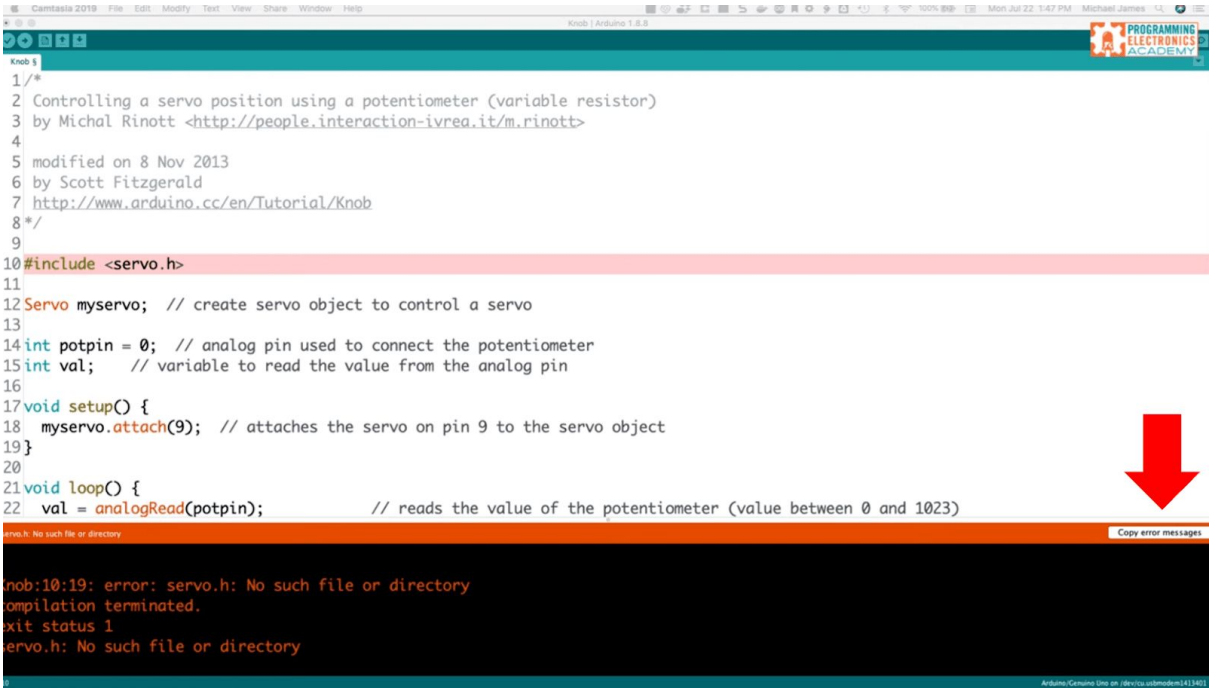
Sometimes, you can physically feel a component to find problems but this can be quite dangerous at times.

3) Have a search!

It is very unlikely that you are the first person to have this problem. Quite often using Google, Facebook Group Search, the Forum Search or the Discord Server will bring you your answer. It can be easier said than done but it is not impossible. Many people have documented so many things using forum build logs, facebook posts, discord messages, youtube videos etc.

4) Read the error messages

More related to programming, but quite often when there will be an error message or an error code etc. If you read the message, you can often google that error code or message to find that somebody has already posted a solution. I have posted below an example of one of the most common errors that people inquire about and I intend to talk you through just how simple it can be to troubleshoot and fix. Bare in mind, it isn't always simple or easy to fix!



The above image shows an Arduino Sketch that a user is trying to upload to their board. We can see an error has been flagged when the sketch was compiled. The error says “servo.h: No such file or directory” (last line of the error message, bottom of the picture, in the black square). File is self explanatory and, for those who may be interested, directory is another name for a folder. Servo.h is a file within a library that the user has told the sketch to include. What this error message is telling us is that the Arduino IDE is looking in the Library folder and it cannot find this library.

5) Back to basic!

When in doubt, strip your circuit back to basics. With the various electronics that connect together inside of your droid, it can become quite confusing as to what may be causing the problem. Sometimes, we have things connected that have no direct connection to another circuit. For example, Dome Lights have nothing to do with the Foot Motors but, down the line, they are connected together. Anything has the ability to cause a problem and, by removing anything that is not relevant to the circuit in question (the one you’re troubleshooting) and only having what is required for that circuit to work is a good and sensible approach to troubleshooting.

There are many other ways to troubleshoot and often it depends on what the problem is. You should give any of the above steps a try and see if you can work the problem first. You will not understand the huge feeling of self accomplishment and satisfaction of working something out like this until it happens. It is truly a wonderful feeling.

Final Thoughts

Electronics can be difficult, daunting and quite simply scary. They can also be inviting, exciting and quite simply wonderful. This topic is not one you can take on a whim and hope for the best, there is too much that can go wrong and the problems can be endless. There is a lot to learn when it comes to electronics and many find that off putting in itself, because most builders just want to get on with their build and get it finished. You should remember that this is not a race! I would urge all builders reading this to slow down: there is a reason the Droid Builds can take over a year or two to complete. It is only recently, with the addition of 3D Printable Droids, that people have suddenly been able to create droids in less than a year, realistically.

I'd advise that you do plenty of research and make sure you document exactly what you want, when a builder says they want "everything" what exactly does that mean? Failure to successfully plan is planning to successfully fail. Electronics can open the door to so many other things, you start to see things from a different angle and it makes you realise just how things can work together and what is possible.

Electronics are just one of the many things that constantly change. The way we operate and control droids is different now than how they were originally controlled (for the most part). Builders are constantly trying to come up with new ways of doing things, finding lighter, smaller and more powerful batteries, creating circuits that recreate parts of a droid in which a whole new droid was made for the movie just for that one feature and overall trying to put as much from the movies as physically possible into one droid.

You have to remember why we do what we do: I think sometimes it is easy to get lost in it all and forget why we do it. First and foremost, we are building droids because we enjoy it. We love the droids so much that we would put ourselves through the process of learning to create one for real. We love the challenge, nobody ever said that droid building was a simple and easy process and if anybody ever does, I would question whether they've ever built one themselves. We love to learn: you will learn so much when you get into electronics and there are many people who will help you along your way. There is so much content out there in the form of PDFs, Books, YouTube Videos, Forum Posts, Facebook Posts, Tutorial Wikis and even Podcasts. The answers are out there, you just have to be willing to look.

Credits

There are always many people who help me write these guides. I write the guides and do the research myself however I greatly rely on the assistance of other builders to make sure that what I have learnt is correct. There are always many ways to do things and it can often be tricky to identify what things are correct.

I would like to thank the following people for proof reading of the guide, offering various suggestions for additions and the structure of the guide:

- Oliver Steeples
- Patrick Ryan
- Bobtaculer
- Patrick Ryan
- Devin Olsen
- Darren Poulson
- Josh Kelley
- Darren Serool

Once again I would like to give a huge thank you to Marine Domarchi for the proof reading, grammar checking and spell checking. Marine has checked over all of the New Builder Guides and has been a huge help in ensuring they are readable and laid out in the best way.

Other Guides

I have written a number of guides designed to help new builders find their way in this community, figure out where to start and to attempt to take as much information from this community as possible and give the reader a more organised and simplified overview. I have detailed the various other guides I have written below, they can all be found on my website.

https://www.robsrobots.co.uk/guides.php

New Builder Guide
Control System Guide
The World Of Electronics

Updates

I created this page to track updates and changes to the guide.

V1.0 - Initial Release