Chris Telford 07/03/2018
Codeup Lancaster

So you want to have a go at programming LEDs?

LEDs make for a great way to experiment with programming in the real world. They are cheap, easy to start programming and easy to get nice effects from. With a little bit of effort and creativity you can turn most simple LED circuits into an actually useful device such as a desk lamp, a torch, an artistic rainbow effect colour changing light fixture or else something like an electronic dice or some other creative project involving light. It's possible to start very simple and work your way up to more advanced projects.

This document isn't a 'how to' guide so much as an overview of what you'll need to get started, what you need to know, and where to get it and find out more. Other people have written detailed instructions on the different projects which I link to in this document.

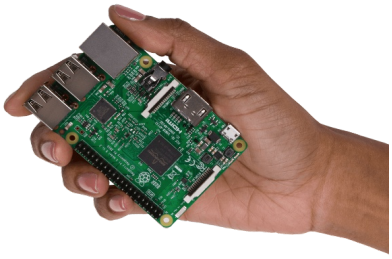
Short Version;

You need some LEDs, a power supply for the LEDs and something to control the LEDs with.

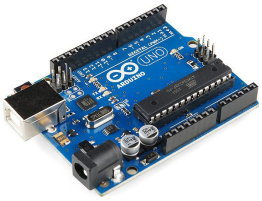
Controlling the LEDs

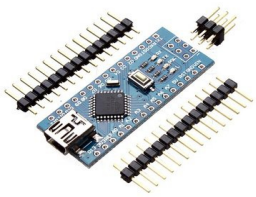
The LEDs can be controlled using a program running on a raspberry pi or an arduino. These are two very popular hobby grade devices which are easy to use for learning to program with. The Raspberry pi is a fully featured computer with a desktop that can also be used for physical computing. The arduino is a simple device running software in 'real time' that does not include an operating system or graphical user interface and which will only run the program it's been 'flashed' with (the user uploaded program) making it simpler and cheaper and in some ways easier to get started with, though less capable.

https://www.raspberrypi.org/ Raspberry pi



https://www.arduino.cc/ Arduino





I recommend the arduino for anyone on a budget as you can buy one for less than £3. I recommend the raspberry pi for anyone with a background in linux (or anyone that wants to learn) or anyone who wants to develop more involved projects that might later include running a website to control the LED or whatever hardware the user is playing with. Both are good options.

Both devices run software you can download or create yourself. Both devices have input and output pins that can be used to output signals to control things including LEDs or take inputs from things like buttons or temperature sensors. Neither device is good at powering high powered projects and you will need separate power supplies for the more powerful LEDs. The raspberry pi itself is powered by a USB / mobile phone style power adapter and the arduino is powered either by USB when plugged in to a PC or else by 5 volts or 7-12 volts input connected to the correct pins on the board.

There are plenty of tutorials and code examples available online for both these devices and I will link to some further down.

Powering the LEDs

Power (watts) = volts x amps.

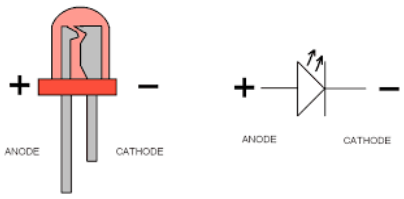
A single LED will require a given amount of current and will need to have a certain amount of voltage supplied across it. The current is usually limited by a resistor in the case of low powered LEDs and the voltage is set by the power supply in accordance with what the LED requires. In the case of a 3 volt LED the voltage should be a little above 3 volts (5 works well).

LED strings such as the addressable LEDs described below have built in resistors for current limiting and so only need the correct voltage supplied (usually 5 or 12 volts) and enough power in total.

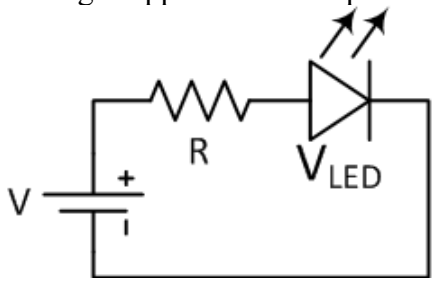
Power LEDs will need proper dedicated current limited power supplies in the form of specialised LED driver circuits which set the current through the LED. The supply voltage then needs to be what the LED specification requires + about 1.5 volts extra for the current limiting LED driver circuit.

Individual LEDs

These LEDs typically use about 10 to 30mA at around 3V. Exact specifications will vary based on the colour and type and LEDs will light up at less than the rated current.



Power requirements of individual low brightness LEDs are low enough that they can be driven using a simple low power voltage supply and resistor circuit. You can use Ohms law to work out the resistor required if you know the voltage supplied and the specifications of the LED;



If the voltage supplied is 5 volts and the LED needs 3 volts at 20mA then we use the following formula;

R = (V input – V led)/ I

R = (5 – 3)/0.02

R = 100 ohms

Here is a link to an online calculator that does the maths for you;

http://led.linear1.org/1led.wiz

If a 100 ohm resistor cannot be found then a higher value resistor will provide less current and a dimmer LED. A lower value resistor will provide more current and a brighter LED that will burn out after a much shorter amount of time than normal. Too low a value of resistor could damage the controller you are using as they are not rated to provide large amounts of power, so err on the side of caution with resistor values and aim a little high if in doubt.

The arduino has 5 volt and raspberry pi has 3.3 volt signal output pins that can be used for powering individual LEDs without blowing up the controller as long as you use the correct current limiting resistor and don't accidentally short circuit anything while setting the hardware up. Raspberry pi 'hats' that plug in to the pins on top of the pi itself can add safety by protecting the power supply and making it harder to accidentally short circuit pins that could damage the pi.

Project Ideas

A single LED and resistor can be wired to an arduino or raspberry pi's output pins. This LED can be blinked on and off using simple code as a visual equivalent of 'hello world'. Hello world is the simplest program written in every programming language by most new programmers. It just displays 'Hello World' on the screen as proof that something is happening. Making your LED blink is the first thing you'll want to do.

Here is an example using the arduino;

https://www.arduino.cc/en/tutorial/blink

Here is an example using the raspberry pi;

https://thepihut.com/blogs/raspberry-pi-tutorials/27968772-turning-on-an-led-with-your-raspberry-pis-gpio-pins

Going further

Once you've mastered blinking individual LEDs on and off you could look at creating a more involved project along the lines of the electronic dice demoed at the first codeup event in Lancaster on 06/03/2018. There are enough pins on both the raspberry pi and also the arduino that you can wire up half a dozen or so LEDs before you run out of pins and have to change approaches.

Here is the link to the electronic dice project page for more info;

https://github.com/highfellow/electronic-die

With the right software on your LED controller you can experiment with fading an LED instead of turning it on and off. This is called Pulse Width Modulation and involves turning the LED on and off many hundreds of times per second to create an average brightness effect that the human eye sees as a constant but reduced brightness. The average amount of 'on' vs 'off' time can be varied without changing the frequency in order to change the average or apparent brightness of the LED.

https://en.wikipedia.org/wiki/Pulse-width_modulation Pulse Width Modulation wikipedia article.

https://www.arduino.cc/en/Tutorial/Fading Arduino LED PWM example.

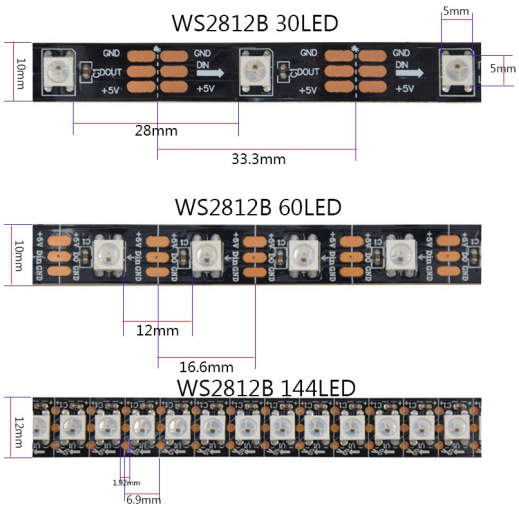
https://www.youtube.com/watch?v=uUn0KWwwkq8 Raspberry pi LED PWM example.

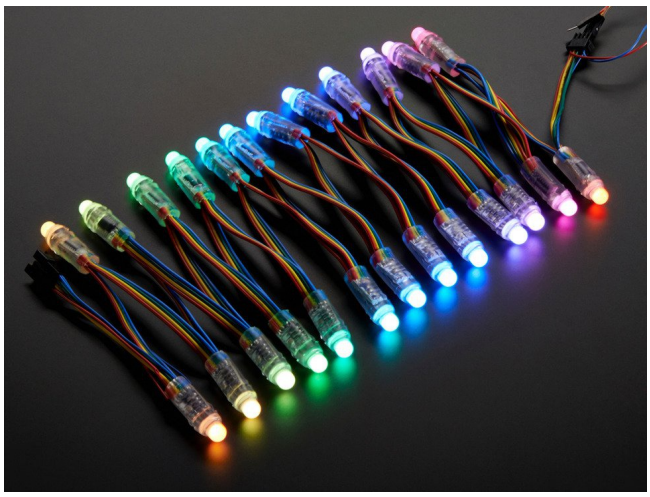
You can buy low powered RGB LEDs to experiment with colour mixing effects using PWM to vary the brightness of each colour channel. This could use the same code required to dim a single LED, only repeated 3 times, once for each colour.

https://learn.adafruit.com/adafruit-arduino-lesson-3-rgb-leds/overview or
https://playground.arduino.cc/Main/RGBLEDPWM for Arduino RGB LED examples

https://grantwinney.com/how-to-use-an-rgb-multicolor-led-with-pulse-width-modulation-pwm-on-the-raspberry-pi/ (raspberry pi RGB LED example)

WS2812 / WS2801 Addressable LEDs





Addressable / programmable LEDs are now available in lots of different form factors cheap on ebay. Usually they consist of a number of LEDs attached to something like a roll of sticky sided tape or in an actual string like christmas lights with 3 contacts. Power, Ground and signal. The LEDs are arranged in a line and are individually addressable. This means that there are little microchips attached to each LED that take in a signal generated by your controller which then set the brightness of the LED accordingly before passing the signal along to the next LED which can be set to completely different colours. Each LED is really three LEDs in one; a red, green and blue LED. The brightness can be varied on each individual LED so that you can create colour changing animated patterns that will run along the string and produce very nice effects. If you want the best christmas lights possible this is how you'd do it.

Please note that ws2812 LEDs tend to work better with the arduino and WS2801 LEDs work better with the raspberry pi for technical reasons associated with the way the timing works on each type of LED vs what the controllers can generate. WS2812 LEDs have a single signal wire whereas WS2801's have 2 signal wires. If you are copying a project you've found online make sure you buy the right type of addressable LEDs for the code used in the example.

Examples;
https://youtu.be/uvtrm7p7gh8
https://youtu.be/q9xgojR9X5U

This sounds much more complicated than individual LEDs but can actually be a simpler way of creating some very impressive effects. This is partly because you don't need to use more output pins if you want to run more LEDs. You just need to define the number of LEDs in the code which then sends all the signals for all the LEDs down the same wire.

Here is an example with the arduino;

https://randomnerdtutorials.com/guide-for-ws2812b-addressable-rgb-led-strip-with-arduino/

Here is an example with the raspberry pi;

https://tutorials-raspberrypi.com/connect-control-raspberry-pi-ws2812-rgb-led-strips/

In both cases you'll need to wire the LEDs up to a power supply and the signal pin to the relevant arduino or raspberry pi output pin. If your run of LEDs is short enough you may not need a separate power supply if using an arduino. If you want to make your LED string longer or use a raspberry pi then you'll need a suitable 5 volt power supply. Each LED uses about 50mA so a 1 amp 5 volt phone charger would allow you to power a string of 20 LEDs at full brightness before problems set in.

Going further

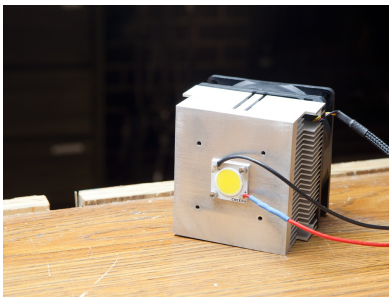
Once you've got the demo code installed and running with a suitable power supply hooked up, you'll need to think of something creative to do with it all. The simple demo codes look good enough that you could make yourself some christmas lights. With a bit of programming you could make a mood lamp or get sound activated effects working with a microphone attached. Try altering the demo code patterns to make them look nicer and / or remove the patterns you don't like if the code includes a sequence of different ones.

Example; http://www.instructables.com/id/Arduino-Controlled-Sound-Responsive-LED-Display/

If you really want to start a disco you can arrange your programmable LEDs into a grid then use one of the open source projects like 'glediator' and 'jinx' to build your own controllable LED matrix. You can create animated patterns on a PC that move and respond to music.

https://youtu.be/8EkmH5wEnvI
http://www.solderlab.de/index.php/downloads/category/4-glediator
http://www.live-leds.de/

Power LEDs



Power LEDs are less like addressable LEDs and more like the individual LEDs described earlier, only significantly more powerful. If you have LED bulbs in your house then this is probably what you've got.

Power LEDs do not include electronics, unlike addressable LEDs, and can be used exactly the same way with the same code as the individual LEDs.

The differences are that power LEDs use more power to produce a lot more light. This means they can't be current limited using a simple resistor circuit as the resistor would waste a lot of power and get very hot. You need a current limited power supply. You also need a heatsink for the LED itself as they will generate enough heat to burn themselves out in seconds otherwise. Old CPU heatsinks are ideal. A 10 watt power LED can run on a 100w CPU heatsink / fan with the fan disabled for quiet running or a smaller heatsink with a fan running.

The good news is that the power supplies are cheap and the heatsinks can be recycled from old computers (or bought cheaply from ebay).

Seach ebay for;

350 MA constant current LED driver with PWM control
or
700 MA constant current LED driver with PWM control

or similar, depending on the actual mA your LED requires.

More info on constant current LED drivers; https://youtu.be/E4D-odvmT1A

A 10 watt white LED will make a good table lamp or bright torch and can run from one of the

700mA constant current drivers. You may find the LED bright enough that it benefits from being dimmable which suggests an obvious project; a programmable dimmable table lamp, maybe with an on and off button and perhaps some other features you can think of programming in. With some extra thought and effort it could do something like flash if you get an email or similar, especially if you are going down the raspberry pi route.

A 10 watt RGB LED will use 350mA for each of the three colour channels and can be driven with three of the 350mA rated LED drivers. With a RGB LED you can make a table lamp or mood light that can be set to any colour you like. It's relatively simple to make an arduino take an input from three potentiomers to drive the three colour channels on a RGB LED.

https://playground.arduino.cc/Main/RGBLEDPWM

Both these constant current LED drivers take a PWM input which will control their output. This means that you can use the exact same code you wrote for the individual LEDs to drive the power LEDs using the output from your arduino or raspberry pi to drive the constant current LED driver via the PWM input. They will blink and dim and (in the case of the RGB LED) colour mix just as well as the low powered LEDs would.

Going further

A sound activated RGB LED could make for an interesting coloured strobe light or pulsating colour shifting light effect. If you use a Raspberry pi to control the RGB LEDs then you can create a website with a web interface that includes sliders instead of using potentiometers.

https://github.com/teslahed/interlight

Shopping list / how to get the bits you need.

I often use ebay to get bits cheap, either from the UK if I'm in a hurry or direct from China if I have the time to wait and want to save a bit of cash. Paypal tends to be enough to protect you from being ripped off in my experience.

If you search for the terms below you should find similar stuff to what I'm using at about the prices listed.

I am optimistically suggesting you can get the power supplies for free by looking through your old draws full of old electrical stuff. Check the current and voltages of whatever unused mains to DC power supplies you find. Otherwise you'll need to buy a power supply too.

If you have any old computer hardware lying around you may be able to get a heatsink for free. Failing that, a cheap cpu heatsink costs about £10-£15 on ebay.

I have recently acquired some RGB LEDs that I'd be happy to provide to anyone who wants one.

The raspberry pi may come with a power supply depending on where you buy it. If it doesn't you can use any mobile phone charger that's rated to 1 amp. Arduinos can run from USB input power so you can run those without a separate power supply as long as they are plugged in to a PC.

Controllers (arduino, raspberry pi)

Raspberry pi = £35

Arduino uno (large model with plugs for prototyping)		=	£6
Arduino nano (small model for soldering to stuff or breadboarding)		=	£3

Power supplies

Old mobile phone charger or similar @ 5 volts and at least 1 amp		=	Free / £5
Old mains to DC charger @ 12 volts and 1 amp or more		=	Free / £5
Old laptop power supply (for really high power stuff)		=	Free / ?

Constant Current drivers for power LEDs;

350 MA constant current LED driver with PWM control (x 3 for RGB power LED)		=	£2 / £6
700 MA constant current LED driver with PWM control		=	£2

LEDs

5mm coloured LEDs (low power)	x 50	=	£3
5mm RGB LEDs (low power)	x10	=	£2
WS2812 addressable LEDs		=	£3 - £50
WS2801 addressable LEDs		=	£3 - £50
(exact price depends on length and no. of LEDs)			
White Power LEDs 10W		=	£1.50
RGB Power LEDs 10W		=	£2
Resistors for individual LEDs		=	£1
Heatsinks for Power LEDs		=	Free / £10

I hope this document has given you some ideas. Please let me know if you have any questions or comments. christophertelford@yahoo.com