DREAMINO CYBER LEARNING SYSTEM

David Ray Electronics and More LLC

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<u>Book One</u>

Section 1: Introduction to Electronics

Let's get started. We need to go over a few fundamental concepts of electronics so that you can better understand the concepts that we will cover through this series.

1.01: Atomic Structure and Electron Theory:

You may remember from science class that an atom is made of two major parts. The nucleus is in the center and is made of protons and neutrons. Outside the nucleus are electrons. Each of these particles have different charges. The proton has a positive charge, while the neutron has a neutral charge. The important part of this is the electron though. The electron has a negative charge.

While the nucleus is tightly packed together, the electrons are not and move around the nucleus. This means it is much easier to move an electron from one atom and have it jump to another. Normally a stable atom will have an equal number of electrons and protons, but when one electron is removed from an atom then that atom become unbalanced and is positively charged. The opposite is true when an atom gains an electron, it becomes negatively charged. When you have movement of electrons that creates a current. Since most atoms are stable and electrons don't move from atom to atom to create a current naturally, we have to apply an outside force to make the electrons move. This force is called voltage.

Some materials can conduct a current of electricity better than others. If something can conduct a current it is called a 'conductor', if it normally can't conduct a current it is considered an 'insulator'. Most metals conduct electricity. Items like silver, gold, aluminum, copper, and mercury are great conductors. And things like glass, rubber, air, and wood are great insulators.

1.02: Current (Unit of measure: Amperes, Amps, A) – Current is a measure of how many electrons pass through a point in your circuit at a given time. Electrons are measured in a unit called Coulombs. One Coulomb is 6.241×10^{18} or 6,241,000,000,000,000,000 electrons. In comparison, there are 7.5 x 10^{18} grains of sand on earth. One ampere is considered as one Coulomb of electrons passing through a point per second. That means that if your circuit has 1.25 amps, then more electrons are passing through your circuit per second than grains of sand on Earth. Isn't that cool? In your circuit the electrons flow from the negative terminal to the positive terminal.

1.03: Special Note - Differences Between DC and AC Current – There are two conventional ways that current flows in modern electronics, direct current and alternating current. The terms direct current and alternating current describe how the current flows through the circuit. In a direct current circuit, electrons will flow from one point (the negative terminal) to another (the positive terminal). An alternating current circuit will have the electronics oscillate, or move back and forth, very fast. In the USA they move back and forth roughly sixty times a second or 60Hz. You will find that batteries will provide a direct current source, while things like standard wall outlets provide an alternating current source.

1.04: Voltage (Unit of measure: Volts, V) – Voltage is the force that physically pushes electrons through your circuit. When a circuit has no voltage applied to it then the electrons are not being pushed through the circuit and sit attached to the outer shell of the atoms they are resting at. Sometimes people will use the phrase 'electro-motive force', while describing voltage. This is because voltage is a physical force that is applied to the electrons.

1.05: Resistance (Unit of measure: Ohms, Ω) – Resistance is a measure of a materials ability to resist the flow of electrons. Everything has some level of resistance, even things like wire and solder. Yes, you read that right and even though wire and solder have resistance it is so small that it is not usually considered. The best way to think of resistance is cars on the road. When you have a four-lane highway traffic moves smooth, but if there is construction on the highway and two lanes are closed then all of the sudden traffic slows down quite a bit. On the other hand, if the four-lane highway turns into an eight-lane highway then all of the sudden the cars can move a lot faster and more freely. In most cases you regulate the flow of electrons with a resistor. Keep in mind, when you add resistance and it slows down the current it can generate some heat. Therefore resistors have a wattage specification.

1.06: Capacitance (Unit of measure: Farad, F) – Capacitance is a measure of a system's ability to hold a charge. Capacitance is measured in farads. A Farad is a charge of one coulomb storing a potential of one volt. The farad is named after the English physicist Micheal Faraday.

1.07: Inductance (Unit of measure: Henry, H) – Inductance is a measure of a device's ability to induce voltage with a change of current. Inductance is measured in Henries. A Henry is the ability to induce one volt over a change of one ampere. Most of the earliest work on inductance was published by Micheal Faraday, but the henry is named after the American scientist Joseph Henry. Joseph Henry was able to independently derive many of the same rules and observations that Faraday made at roughly the same time.

1.08: Frequency (Unit of measure: Hertz, Hz) – Frequency is a measurement of cycles per second. One cycle is usually when a signal or a current measurement goes from a neutral or zero point to a maximum, then a minimum, and then back to the neutral point. There is a lot more that we can talk about when it comes to things like frequency, but those are things for a future class. The unit hertz is named after the German physicist Heinrich Hertz.

1.09: Units of measure - Whenever noting values, always use the units of measure while noting it. For example, when you are talking about resistance you should always mark it with Ohms instead of just putting down a number. This will help you later and it will help others when reading your notes. This a best practice and should be followed.

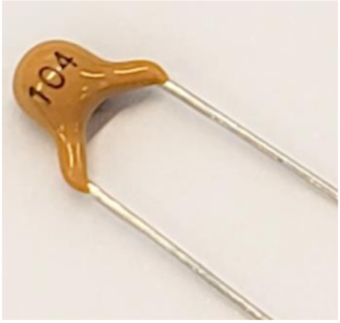
Section 2: Components

2.01: Resistors (Ohms, Ω) – Resistors are components that are designed to oppose and limit the passage of current. They usually have two types of measurements. The first is the value of resistance. This is, as we covered earlier, measured in ohms (Ω). The other is the value of power dissipation or how much heat it is rated to take before it stops working. This is measured in watts.

2.02: Resistor Color Code – Standard resistors will normally have four different bands on them that each have a color. These are used to distinguish the value of the resistor. The first two a bands together signify a number, the third band signifies a multiplier (..or how any zeros to add after the number), and the fourth band shows the resistor's tolerance. Let's go over an example. We have a resistor that is marked brown, black, red, gold. The first two bands make the number 10. The third bad, red, tells use how many zeros to put after than number. So, in this case, the resistor's value is 1000 ohms. The fourth band is gold and shows the tolerance of 5%. This means that the actual value of the resistor will be within 5% of 1000 ohms. So, the value is between 950 ohms and 1050 ohms. A tolerance of 5% is fine in most cases, but if you are doing precision measurements or calibration tasks, you can buy resistors that are made to be very high precision and will have a tolerance of 0.1% or better.

First Three Bands				Fourth Band	
Color	Value	Color	Value	Color	Value
Black	0	Green	5	Silver	±10%
Brown	1	Blue	6	Gold	±5%
Red	2	Violet	7	Brown	±1%
Orange	3	Grey	8		
Yellow	4	White	9		

2.03: Capacitors (Farad, F) –
Capacitors are devices used to store energy, like an inductor, but it does it in a very different way. Inductors store energy in a magnetic field, while capacitors store energy in an electric field. Often capacitors are used to block DC and filter out noise.



Capacitors are constructed with two different ‘plates’ that are separated by a type of insulator material. One plate attracts electrons, while the other repels electrons. Since the two plates never actually touch each other, direct current will not flow through the capacitor, but alternating current can. Therefore these types of capacitors are often used to filter out noise in the circuit, instead of holding a charge. Noise can cause undesired effects and can damage your circuit. In this configuration they are called ‘decoupling capacitors’.

There are many other types of capacitors and some do need to connect a specific way. The term used for these is ‘polarized capacitors’. If you ever work with electrolytic capacitors, they are polarized and must be connected the correct way.
There are three physical factors that affect a capacitor's capacitance value:

1 – The type of material used as an insulator.
2 – The area of the two plates.
3 – The distance between the two plates.

2.04: Inductors (Henries, H) – An inductor is a device that temporarily stores energy in the form of a magnetic field. It resists changes in current flow. They are usually just coils of wire, with something in the center. Often, the center is just air, but an iron-core or ferrite-core is very common as well. When a current passes through a coil it creates a magnetic field. The inductor will not pass the full amount of current going through it until it builds its magnetic field. That field then stores a charge, so when the current changes through the inductor the field collapses and as it collapses it induces current flow back into the inductor. This means that if you decrease the current going through an inductor, it will not immediately reflect that change as the magnetic field will collapse back into the inductor inducing current. If you are using an inductor in a DC circuit then it will only act like a very low-ohm resistor once the magnetic field is built, but when you are using an inductor in an AC circuit, where the current changes periodically, the inductor's magnetic field will affect your circuit. Remember, the current in an inductor cannot instantly change. It will always take a certain amount of time to store and release the energy in an inductor.

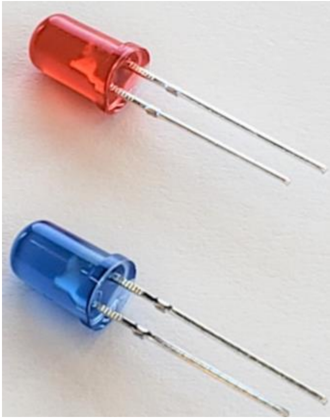
Inductors have two main forms of measurement. The first is the measurement of Henries, which is often noted as nano-Henries (nH) or micro-Henries (µH). The second, like with resistors, is a measure of power dissipation in watts. Other major measurements exist for inductors, but that is outside the scope of this course.

There are four physical factors that affect the inductance value of an inductor component. These include the following:

1 – The number of turns in the coil.
2 – The diameter of the coil.
3 – The length of the coil.
4 – The material that is used inside the core of the coil.

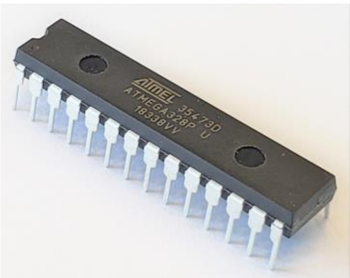
There are other factors, but those are well outside the scope of this course.

2.05: Light Emitting Diodes (LEDs) - Light Emitting Diodes or LEDS are considered semi-conductor devices. They use special forms of silicon or germanium, along with a few other things, to help control the flow of electrons and, in this case, create light. LEDs and other diodes do care what direction they are connected to the board. There are two leads, the <u>longer lead</u> needs to go through the hole marked with a '+' (positive) symbol and the shorter lead must go through the hole marked '-' (negative). Place the LEDs through the board and solder them on. It is important to place the LED on the board correctly, if installed backwards it will not work.



2.06: Crystal Oscillator - A crystal oscillator is a device that can generate an oscillating signal at a very specific frequency. In this case, it will be the clock of the Micro-Controller. It is encased in a metal housing to shield it from outside noise and interference. The one we use in the kit is 16MHz. The Micro-Controller has a built in clock that is 8MHz , but we want it to be faster, so we are going to use this to clock it at 16MHz.

2.07: ATMEGA328P Micro Controller – The ATMEGA328P MCU is the computer for the DREAMINO kits. That's right. It's a computer. It may not be as fancy as complicated as the ones you are used to.



Section 3: The Math of Electronics

3.01: Ohm's Law

Ohm's Law is named after the German mathematician Georg Ohm. It is a way to show that voltage and current are proportional. It is often written as V = I x R where V is the voltage, I is the current, and R is the resistance. I know that current doesn't start with I, but the practice of using I for current comes from the French physicist André-Marie Ampère and it actually stands for intensity. Okay, enough about history for now. Since Ohm's Law is V = I x R that would mean that one volt is equal to one ampere of current going through one ohm of resistance. Let's try some math here. We have already covered that 1A x 1Ω = 1V. So, let's try to figure out what happens when we change some of these values.

How many volts would you get from half an amp going through 5 ohms of resistance?

.5A x 5Ω = ??V

Okay, this would should be pretty easy. You just multiply the .5 by 5 and get 2.5. There would be 2.5 volts. Now, let's change it up some. If you have twelve volts and you want to have .25 amps what resistance would you need to use?

.25A x ??Ω = 12V

To make these types of calculations easier there are different forms of this formula that make it easy to calculate both resistance and current. Here are the main three formulas used with Ohm's Law. So, to find the desired resistance value we would want to divide the given voltage by the desired current.

$$\boxed{\begin{aligned} V &= I \times R \\ I &= V / R \\ R &= V / I \end{aligned}}$$

12V / .25A = ?? Ω

By doing this math, we see the needed resistance is 48 ohms. Super easy. Now, don’t worry, 48 ohms is not a standard resistor value, but 47 is. You can use a 47 ohm resistor in place of a 48 ohm resistor in most cases and it will be fine. Let’s see how much our desired current will change if we use a 47 ohm resistor instead of a 48 ohm resistor.

12V / 47Ω = ?? A

You may need to pull out your calculator for this one, it’s okay, I don’t judge. If you divide 12 by 47 you will find that the answer is .255. So, instead of the .25 amps that we wanted, we get .255 amps. This isn’t always an issue with most basic electronics projects. Most components have some tolerance for these kinds of things.

3.02: Engineering Notation - You don’t often see people write about current as .255 amps, but instead people use 255 milli-amps. People don’t write .000001 farads, they write 1 micro-farad. Now, we need to go over how calculate these things. It can be tricky, but we can do this.

We want to rewrite .255 amps in milli-amps to make it easier to write and easier for other to understand. All we need to do is take the number .255 and divide it by the factor listed on the right for ‘milli’.

Prefix	Description	Factor
milli (m)	One Thousandth	0.001
micro (u)	One Millionth	0.000 001
nano (n)	One Billionth	0.000 000 001
pico (p)	One Trillionth	0.000 000 000 001

.255 A / .001 = ??? mA

There you go, easy. .255 amps is 255 milli-amps. Milli-amps is the most common units of measure for current. I’m going to let you try this a few more times. Don’t worry if you get it wrong, it’s okay. It can take some practice, but over time you will be able to do more of this in your head with ease. Until then, you should double check your work.

Going the other way, people don't write 470,000 ohms, instead they would use 470 kilo-ohms. Now let's talk about how to deal with big numbers.

In the kit you get three 1,000 ohm resistors. This can be re-written as 1 kilo-ohm or 1 kΩ. To do this you divide the number you have by the factor in the table to the right. So, 1000 ohms divided by 1000 makes 1 kilo-ohm. It is also important to note that when dealing with 'Mega' notation you must use a capital 'M' because the lowercase 'm' is used for 'milli' notation and that is very different than 'Mega'. Let's try this in a few exercises.

Prefix	**Description**	**Factor**
kilo (k)	One Thousand	1 000
mega (M)	One Million	1 000 000
giga (G)	One Billion	1 000 000 000

Review Questions:

1. What does the ‘I’ in Ohm’s Law stand for?
A) Intensity
B) Current
C) Both A and B
D) Impedance

2. What is the formula
for Ohm’s Law?
A) E = C x R
B) V = E x K
C) V = I x R
D) E = I x A

3. What is a resistor and what does it do?
A) Only used for making voltage measurements.
B) Only used for making current measurements.
C) It resists the flow of current.
D) Only used for making resistance measurements.

4. If you know the voltage and the current, how would you find the resistance?
A) You don’t have enough information to find the resistance.
B) Resistance is current divided by voltage.
C) Resistance is the voltage divided by the current.
D) None of the above.

5. When using a multimeter, you find that the value of a resistor is slightly different than the value it is called. Is this a bad thing?
A) Yes
B) No
C) I don’t know.

6. 5A x 5Ω = V

7.	12V / .25A	=	Ω
8.	12V / 47Ω	=	A

9. What is ‘electric current’?
A) Water running through a pipe
B) The amount of atoms that flow through a point
C) The flow of electrons
D) The time it takes for a charge to take place

10. What direction do electrons flow through a circuit?
A) From the low-pressure system to the high-pressure system
B) To the negative terminal from the positive terminal
C) From the negative terminal to the positive terminal
D) All of the above

11.	0.5 A	=	mA
12.	0.000 03 F	=	µF
13.	0.000 01 H	=	µH
14.	0.000 000 02 F	=	µF
15.	0.000 000 02 F	=	nF
16.	0.003A	=	mA

Section 4: Soldering

Soldering is a great skill to have, but it can also be very dangerous if you are careless. In this chapter I want to cover how you can solder safely and be successful while doing it.

4.01: Safety Rules for Soldering:

1 – Always keep your work area clean and organized.

Soldering can be dangerous. Keeping your work area clean will help prevent accidents from happening and keep you safe.

2 – Only solder in a well-ventilated area.

You can use a fan to pull the fumes away from your face. You can also buy special fans that have a filter built in to absorb the fumes. The visible fumes that you see when soldering is the flux or rosin from the solder. This stuff can make you sick. Be mindful of ventilation when soldering.

3 – Use care while soldering.

You should know that soldering irons are **HOT**! That means you will get burned. It’s okay, everyone gets burned a few times when starting out, but just be careful. You may also need to use tweezers or clamps to help hold things in place while you’re working. Also, when you’re not using the iron always place it back into the stand.

4 – Never leave your soldering equipment on when you’re not there to watch it.

When you leave your work area make sure you turn your soldering equipment off. It does take a minute or two to warm back up when you come back to work on it, but it’s a lot easier to do that than to have your place burn down. (See rule 2.)

5 – If you use a cleaning sponge, keep it wet.

While soldering you need to regularly clean your iron. If you use a sponge to clean it (which is a great way to clean it), you really need to keep it wet.

6 – Always wear eye protection.

Solder can fly off your soldering iron pretty easily. If that 400°C solder gets in your eye, you will have bigger problems in your life than soldering.

7 – No matter what you do, wash your hands.

Soldering includes things like lead and flux. Both aren’t the best for you when they get in your body. Whenever you get up from your work area, take a moment and wash your hands with warm water and soap.

8 – Do not use soldering equipment that has obvious damage.

If you see damage to the iron, cable, or plug either repair it or replace it. Do not use damaged equipment. It can cause very serious injury.

9 – Always try to manage your waste in one place.

When you cut leads from your components or other things place them in a bin together. Leaving little pieces of metal on the floor can stab you in terrible ways. Trust me on this one.

4.02: Building an Excellent Soldering Toolkit

Here is what you need to know to piece together a basic soldering toolkit that will help you through almost every situation.

Soldering Iron: Your first soldering iron is an important decision. Here are some things to look for and some things to avoid.

1 – A Soldering Gun Is Not A Soldering Iron: A soldering gun is just what it sounds like. It is shaped like handgun. It has a hand grip and is pretty bulky. This is not made for board level repair. Do not use a soldering gun to solder on boards. It is too clumsy of a tool for precision work. While I am at it, avoid battery or butane powered irons. They are not intended for bench work.

2 – Power: Do not buy an under-powered iron. I recommend getting an iron that is rated 25 watts or more. Anything less than that may not get hot to the point where you can melt your solder the way it needs to in order to make a solid connection. 13 watt irons are popular by some vendors, but I have had a lot of issues with those and I can not recommend anyone use those for board level soldeirng.

3 – Adjustable Irons: I mostly use adjustable irons. It's just an iron with a stand that has a knob on it. The knob allows me to turn it down lower for more sensitive components, like some semiconductors, or to just turn it off with ease. Having an off switch on an iron make safety a lot easier to maintain.

4 – Tips: When buying an iron you have to worry about the tips it uses. How easy is it to get replacement tips? Does it use a standard tip? Does the store you are buying from sell replacement tips? I recommend always buying one or two extra tips when buying a new iron. There are lots of different types of types too. Flat tips, blunt tips and pointed tips. It all depends on what you're trying to do.

I mainly use a flat tip. There are times where a pointed tip might make one specific task easier, but it isn't much harder to just use a flat tip. Not enough to merit turning my iron off, letting it cool down all the way, changing my tip, and heating it back up for just a few minutes.

Solder: I always have a small assortment of solder on my bench. I have thin solder, that I use for surface mount soldering and for soldering where components are tightly packed, and thicker solder, for tinning wire and soldering ground buses down. I mostly buy 'rosin core' solder. The rosin (sometimes called flux) in the center of the solder is used to aid in the heat conduction of the solder to your components. When I first learned to solder I didn't have 'rosin core' and I had to apply the rosin separately with a small paint brush. It was a huge pain. The rosin helps wet the area and prime it for the solder to take it's place. Also, keep in mind that rosin can make you sick if you ingest it, so having to apply it separately makes it easier to get on your hands and on your food later in the day. It is a little more expensive, but I almost always buy 'rosin core' solder.

You can also find solder with differing lead content. 60/40, 63/37, etc. Generally, in the U.S. solder is a mix of lead and tin. The amount of lead affects the melting point of the solder. You can also find RoHS compliant solder. RoHS stands for the 'Restriction of Hazardous Substances'. Since lead is considered a hazardous substance, it is banned in many countries for use in manufacturing. RoHS compliant solder is lead-free solder. It is a little harder to work with, but works similar to the other packs of solder you can find.

I recommend buying lead free 0.8mm rosin core solder for your projects. It will cost a little more, but it is better for you and it is the new industry standard.

Solder Wick: This is a copper braid. It is often wet with rosin or flux. It is effective in pulling solder off a component or a board. You place the braid over the solder, apply heat to the braid with your iron and the solder will be pulled into the copper braid and away from your board. If your braid is dry, adding a little rosin to it before using it will make it so much easier to use.

Desoldering Pump: These are sometimes called solder suckers. It is a type of desoldering tool. You use it by heating up the solder and then using the tool to 'suck' the solder right out of the joint. It can be tricky to use, but when used in combination with solder wicking braid it can be very effective.

Soldering Tweezers: These are sometimes called jeweler's tweezers or cross locking tweezers. Basically, they are spring loaded to be shut when in the rest position. It allows you to grab a component or a wire and keep a good mechanical grip on it while working. You must apply a squeeze to the tweezers in order for them to release the part.

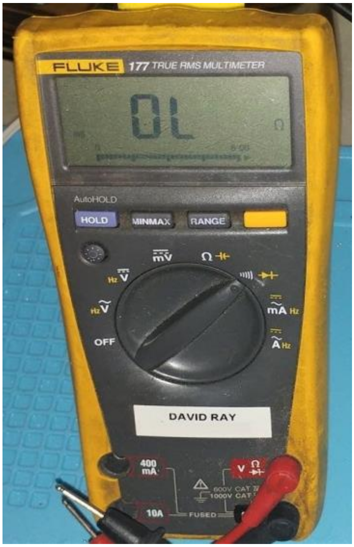
Heat Shrink: Heat shrink is something that you can use to put a jacket on bare wires, group wires together, or isolate components. You place the wire or component inside the heat shrink and apply heat. The material will shrink to half of it's former size and create a jacket around what was inside. It is important to consider what size of heat shrink to use though. If you use heat shrink too big then it will not be able to get small enough to make a good jacket around your parts.

Small Needle Nose Pliers: Having a very small pair of needle nose pliers is super helpful on the bench. It allows you to reach between components to grab a lead or wire and put it in a better position or to pull it tight for soldering down.

Diagonal Cutters: Diagonal cutters are handy for many situations. For soldering you will want to use mini or precision cutters. These are normally spring loaded and are made for cutting the small leads off of components after you solder them down. These are a must-have for any bench.

Brass Sponge Tip Cleaner: Keeping the tip of your iron clean is super important. Your tip should always be clean and shiny for good heat conduction to take place. That is why I try to keep a brass tip cleaner in my kit. Most versions of this is made up of a little metal cylinder with an open top. Inside it is something similar to a kitchen scrubber, but it is tougher than that. You use it to scrape your tip clean in between uses. If you're caught without one, a normal damp kitchen sponge will work fine. Just make sure you keep some water near by so that your sponge never gets dry. If you do use a sponge, you can never use it to clean your dishes again, it now belongs to your soldering kit.

Multi-meter: This is one of the most important tools you can keep in your kit. A multi-meter can measure almost everything that you may need. One of the more handy things in soldering is the 'continuity test'. This test allows you to make sure you have a solid connection from one point to another. When you use it, the meter will beep if it has good continuity. Many budget meters do not have this test, so instead you can use the meter's resistance test. When you have good continuity, it should read a resistance very close to zero ohms.



There you go. There are all kinds of other things you can add to your kit to make it better for you. Small water bottles, flux cleaner, hot glue guns, magnetic trays, and electrical tape make awesome additions to your kit, but this is the minimum I feel that you should try to put together to get started.

4.03: Tips and Tricks for Soldering:

Apply Heat to the Board, not the Component - When soldering it is best practice to apply heat to the pad on your board and not the component. Then you apply solder to another part of the pad. The idea is that you allow the pad itself to melt the solder.

The Three Second Rule for Heat - You should try to never apply heat to your board more than 3 seconds at a time. You can melt the bonding agent that holds the copper layer to the rest of the board. When you do that, your board will be damaged, and it will be difficult to repair. Instead, apply heat and if it has been more than 3-5 seconds remove the heat, wait a few moments, and try again.

Your Iron Might Be Too Hot - Solder with the lowest temperature that works. If you have an iron that has a dial that reads from 1 to 5, maybe start at 3 and wait a few minutes for it to warm it up. Check to see if it works and if it doesn't, increase the heat some and try again. I know it is tempting to just turn your iron up to 5 and use it, but this will cause damage to your tip and significantly cause it to need to be replaced sooner than otherwise.

A Shiny Tip is a Good Tip - Your tip should be shiny when you clean it. The shiny parts of the tip are the parts that will make it possible to hold solder to your tip. If your tip won't hold solder, then it will be very difficult to effectively solder.

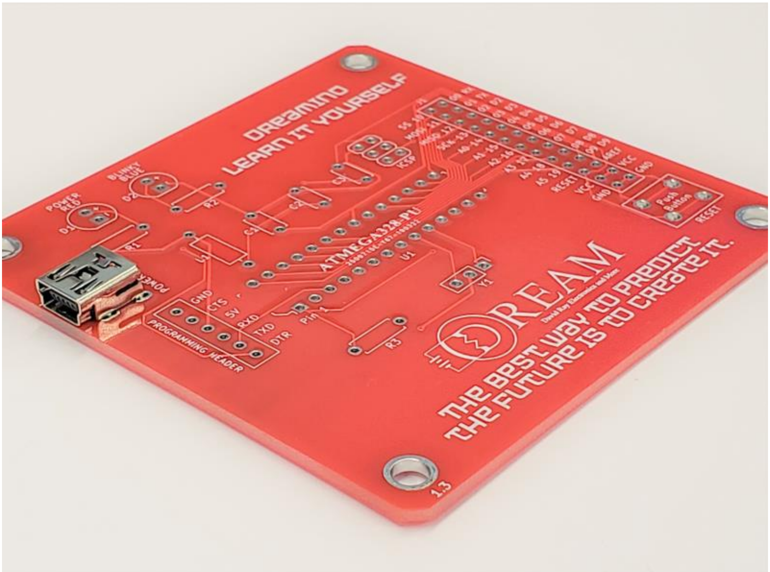
Keep a Clean and Tinned Tip - When soldering it is best practice to clean and tin your tip each time you pick up your iron from the holder and when you put it back. To tin your iron's tip all you need to do is apply a small amount of solder to the tip. Tinning your tip before using it makes it more effective and makes it easier to apply heat to your board or components. Tinning your tip when you put it back in the holder helps keep the tip from oxidizing while it is sitting in the holder. Doing this will add a significant amount of life to your tips.

Section 5: Building the Kits

The DREAMINO Learn It Yourself Starter Kit

This is the first kit that the whole DREAMINO Learning System is built around. It uses the Atmega328p Micro-Controller Unit and perfectly emulates the Arduino Uno.

Grab that board and the envelopes marked 1, 2, 3, and 4.



5.01: Starter Kit Parts List

The Starter Kits comes with four different part envelopes. It is important that you don't open the envelopes until they are needed. This will make it easier to not get parts mixed up or lose parts.

Envelope 1 - Basic Parts Kit:
C1, C2, C3: 0.1 µF Capacitor (104)
R1, R2, R3: 1,000 Ω Resistor (Brown Black Red)
L1: 10 µH Inductor
SW1: Push Button
D1: Red 5mm Diffused LED
D2: Blue 5mm Diffused LED
1 x 28 Pin Socket for Micro-Controller
1 x 6 Pin Right Angled Header
1 x 26 (2×13) Pin Header

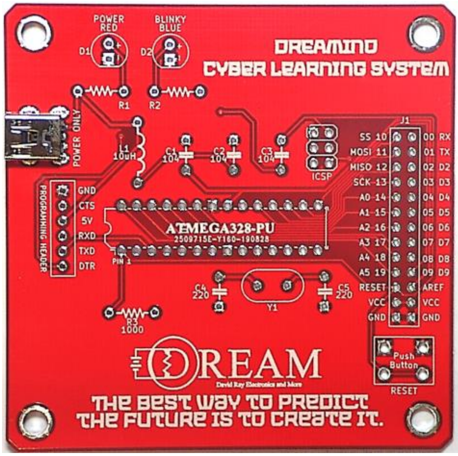
Envelope 2 - Micro-Controller (16 MHz):
U1: ATMEGA328P

Envelope 3 - USB Adapter:
1 x USB to TTL (FTDI) Programmer
1 x USB Mini Cable

Envelope 4 - 16 MHz Clock Kit:
Y1: 16MHz Crystal Resonator
C4, C5: 22 pF Capacitor

Normally, when building something you will want to put the lower profile parts that sit closer to the board on first. Each step will tend to have larger and larger parts as we go. This is not always the case though. Just something to keep in mind.

5.02: About the Printed Circuit Board (PCB)



PCBs are often made of a type of fiberglass hardened with an epoxy. The 'traces' that connect the components together are a type of copper foil that is printed on to the board.

PCBs have a few different layers. We can generalize most boards with just four different layers. Let’s go over then from the top to the bottom.

On the very top, the first thing you see on the board, is the 'silkscreen' layer. This is the text and graphics on the surface of the board. This is normally white, but some manufacturers use different colors.

The second layer is called the solder mask. This is a thin protective coat that helps keep the copper traces below from oxidizing, short-circuits, or solder bridges. The traditional color for this is green, but most manufacturers today can use several different colors.

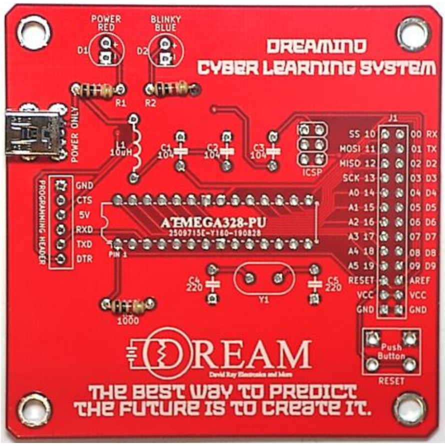
Below that is the copper layer. This is where the copper traces are printed on the board. This part is the most important to get right. Many manufacturers have guidelines on how the copper traces have to be places, including things like how far apart traces have to be from each other, what the minimum width of a trace is, distance between pads, etc.

The fourth layer is called the substrate. This is what everything is built on. It is often made of a type of fiberglass and epoxy. It comes in varying types of thickness and, in most conditions, non-conductive.

This is how most 'single layer' boards are. The boards we are using in the kit are 'two layer' boards. That means that the layers are on the bottom too, allowing traces to be routed on the top and bottom. Some products are built with even more layers. For example, today's smartphones often have 10 or more layers on their main board.

5.03: Envelope 1

Step 1: Resistors

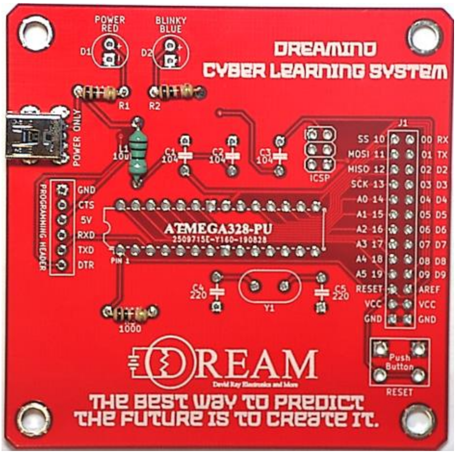


Resistors are components that are designed to oppose the passage of current. They usually have two types of measurements. The first is the value of resistance. This is, as we covered earlier, measured in ohms (Ω). The other is the value of power dissipation or how much heat it is rated to take before it stops working. This is measured in watts. The resistors in the starter kit are 1000 Ω 1/4 watt resistors. This means that they can reliably take 0.25 watts of power going through them and will affect current with the value of 1000 Ω. You can use Ohm's Law to determine how these affect your values.

Bend the leads of the resistors down, like the picture below, and push them into the pads marked R1, R2, and R3. Resistors do not have a specific way they need to be installed, but for the sake of aesthetics I recommend placing them all the same direction on the board.

Before you solder them on, pull the leads so that the resistor sits flat on the board and then bend the leads against the back of the board so that the resistor is less likely to shift as you're working with it. After you solder it on, if it has shifted then heat the pad up again, and use your tweezers or pliers to pull the lead tight against the board. Also, do not forget the 'Three Second Rule for Heat.'

Step 2: Inductors



An inductor is a device that temporarily stores energy in the form of a magnetic field. They are usually just coils of wire, with something in the center. Often, the center is just air. Inductors have two main forms of measurement. The first is the measurement of Henries, which is often noted as milli-henries. The second, like with resistors, is a measure of power dissipation in watts. Other major measurements exist for inductors, but that is outside the scope of this course.

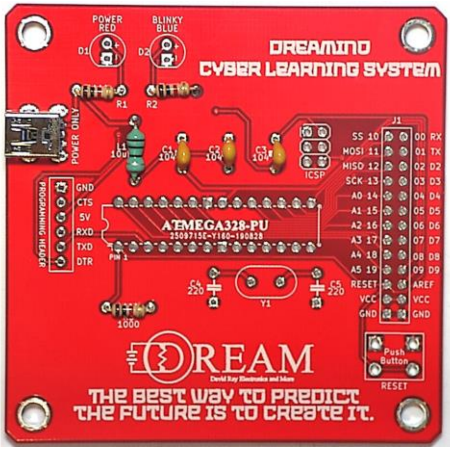
There are several physical factors that affect the inductance value of an inductor component. These include the following:

1 - The number of turns in the coil.
2 - The diameter of the coil.
3 - The length of the coil.
4 - The material that is used inside the core of the coil.

There are other factors, but those are well outside the scope of this course.

The inductor looks like the resistors, but it is not the same type of component. Again, bend the leads like in the picture above and place the component through the pads for L1 and solder it in place.

Step 3: Capacitors



Capacitors are devices used to store energy, like an inductor, but it does it in a very different way. Capacitors are also often used to filter out noise. Capacitors are built with two different 'plates' that are separated by a type of dielectric material. One plate attracts electrons, while the other repels electrons. Since the two plates never actually touch each other, direct current will not flow through the capacitor, but alternating current can be affected by capacitors. Therefore, these types of capacitors are often used to filter out noise in the circuit, instead of holding a charge. Noise can cause undesired effects and can damage your circuit. In this configuration they are called 'decoupling capacitors'.

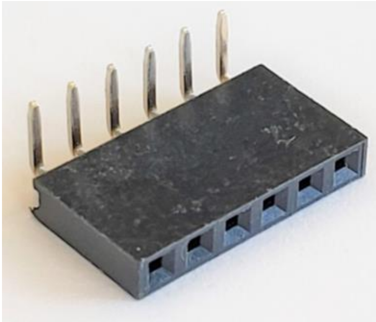
There are many other types of capacitors and some do need to connect a specific way. The term used for these is 'polarized capacitors'. There are several factors that affect capacitance in a capacitor.

1 - The area of the plates inside the capacitor.
2 - The distance between the plates.
3 - The type of material that is between the plates.

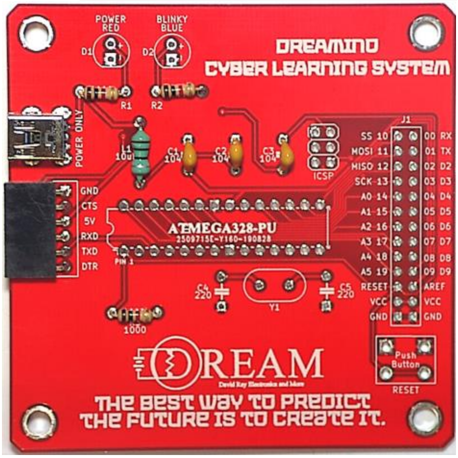
There are other factors that affect capacitance, but that is outside the scope of this course.

Place these capacitors through the board where the pads are for C1, C2, and C3. This capacitor is called a monolithic ceramic capacitor and it does not care which direction you install them on the board, just like the resistor and the inductor.

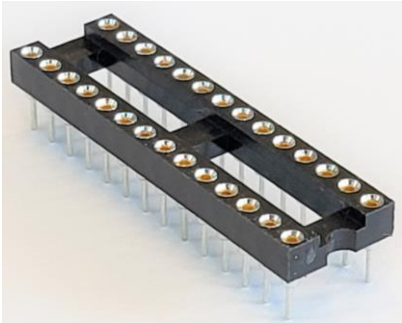
Step 4: 6 Pin (1 x 06) Right-Angle Header



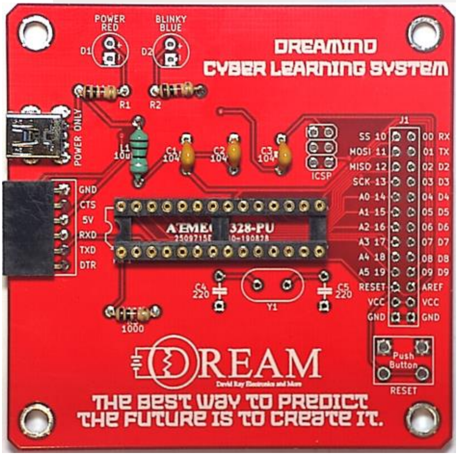
This is the six-pin header that lets you plug in the USB to serial adapter to your board. Place it in the six holes. Headers like this can be a little tricky when soldering on your board because you want it to be as flat to the board as it can be, but it moves around some when you're soldering. The best way I have found to handle this is to solder only one end of the connector on first and then see if it is sitting flat against the board. If it isn't, then heat the pin up again and push the header back down. Then solder the pin on the other side and check again. If it's right, then go ahead and solder the rest of the pin down. Make sure that you don't 'bridge' any of the connections. If you do, clip the pins and then place some solder wicking braid over the 'bridge' and heat it up with your soldering iron. This will pull the excess solder into the braid and fix it for you.



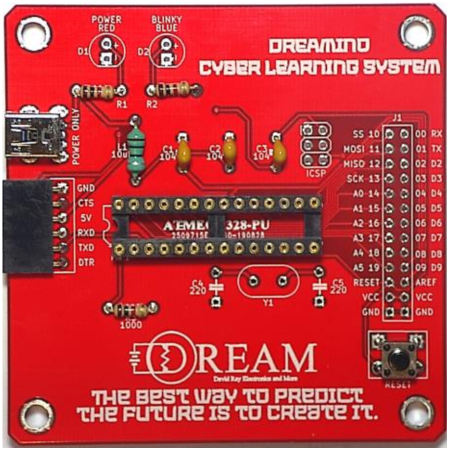
Step 5: 28 Pin Dual In-Line (DIP) Socket



When soldering ‘through-hole’ integrated sockets (IC) to a board it is best practice to use a socket. This is because some ICs can be damaged by direct heat. You solder the socket down first, then later you can install the IC into the socket. We don’t need to install the IC yet though. That’s going to be much later. The direction of this part does matter. If you look you will see a notch on the side of the socket. This goes on the side of the board where it says Pin 1. It is there so we know what direction to install the IC later. When soldering a socket to the board we want to use a similar technique that we used for the six pin header. Solder only one corner down first, adjust it, solder the opposite corner down, adjust as needed, and then solder the rest of the pins down. Again, try not to create bridges, but you likely will. If you do, just use your solder wicking braid.

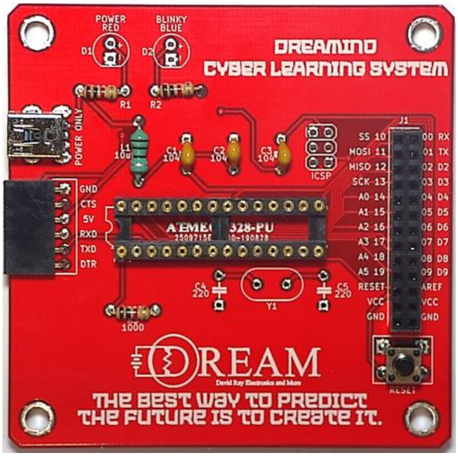


Step 6: Push Button



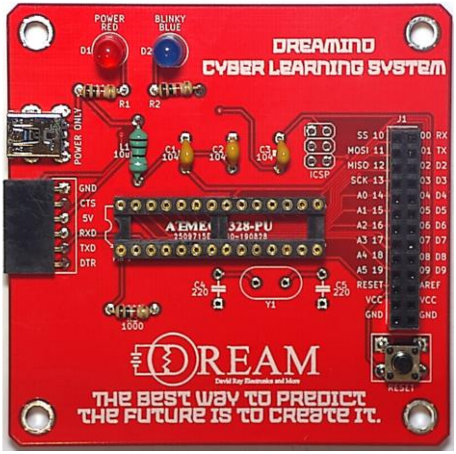
The reset button is used to restart your Arduino program whenever you need to. Place the button on the board where it is marked ‘Push Button’ and then fold the connections toward the center of the button. Afterwards the button should be held to the board only by the pins being bent in. Then, solder the connections to the board.

Step 7: 26 Pin (2 x 13) Header



This is the main interface for projects that can be built with the board. You can use it to plug jumper wires to a breadboard or to install an add-on board to this kit. Install it onto the board and only solder one corner and check the position. Then solder the opposite corner and check again. Once you’re happy with it, go ahead and solder the rest of the pins. You likely will bridge some of the connections. It’s hard not to do. Just make sure you have good solder connections and then use the wicking braid to clean up the connector.

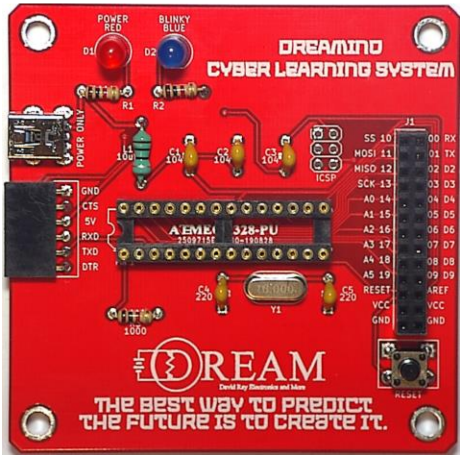
Step 8: Light Emitting Diodes (LED)



Light Emitting Diodes or LEDS are considered semi-conductor devices. They use special forms of silicon or germanium, along with a few other things, to help control the flow of electrons and, in this case, create light. LEDs and other diodes do care what direction they are connected to the board. There are two leads, the longer lead needs to go through the hole marked with a '+' (positive) symbol and the shorter lead must go through the hole marked '-' (negative). Place the LEDs through the board and solder them on. It is important to place the LED on the board correctly, if installed backwards it will not work.

5.04: Envelope 4

Step 9: 16 MHz Crystal Oscillator Kit

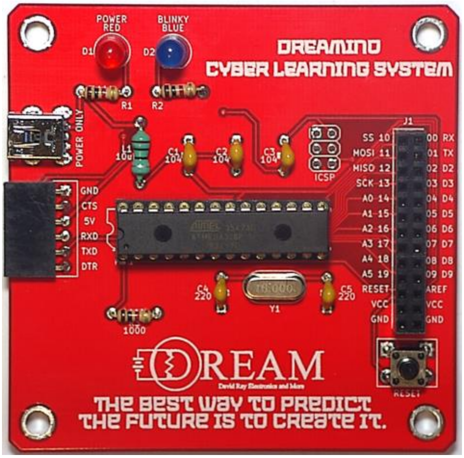


The crystal kit comes with two 22 pF (220) capacitors. These are decoupling capacitors used to shunt unwanted noise or interferon to the ground of the circuit. These capacitors look very similar to the other capacitors, but they are very different. The ones we used earlier are marked '104' while these are marked '220.'

Place the crystal on the board, it does not have a specific way that it needs to go on, and solder it in place. Next, do the same for the two capacitors.

5.05: Envelope 2

Step 10: ATMEGA328p Micro-Controller



This is the Micro-Controller Unit (MCU). Use care with this part. This plugs into the DIP socket. If you look, you will see a notch on the MCU. This helps note the direction that Pin 1 is on. It is super important that you don't put this on backwards. The pins on the MCU may not be straight up and down. You may need to place the IC on its side to help push the pins against your table, so that they may fit in the socket better. Do this to both sides. When installing the IC into the socket, use care and slowly push it in. Look on both sides of the socket and make sure that the pins are in the holes. If you need to, remove the MCU, make adjustments, and try again. Do not push the MCU all the way into the socket until you are certain all of the pins are in the socket.

5.06: Envelope 3

FTDI Programmer and USB Cable

This is how we connect the board to your computer in order to program the Micro Controller. It uses an USB to serial converter made by a company called FTDI Ltd. You may need to install drivers for your computer to recognize it. The drivers can be downloaded directly from the FTDI website. When connecting the adapter to your board, it needs to be installed in a way that the on-board electronics of the board are facing towards the front.

Section 6:
6.01: Installing the Arduino IDE

You may need to download the Arduino IDE from the Arduino website.

The version of the firmware on the Micro-Controller is running at 16 MHz and is called the ‘Arduino Uno’. It comes with the Arduino Board Manager. To set your Arduino IDE to work with this board, change these settings.

- Tools -> Board -> Arduino/Genuino Uno
- Tools -> Port -> What Com Port your computer is using for your FTDI interface

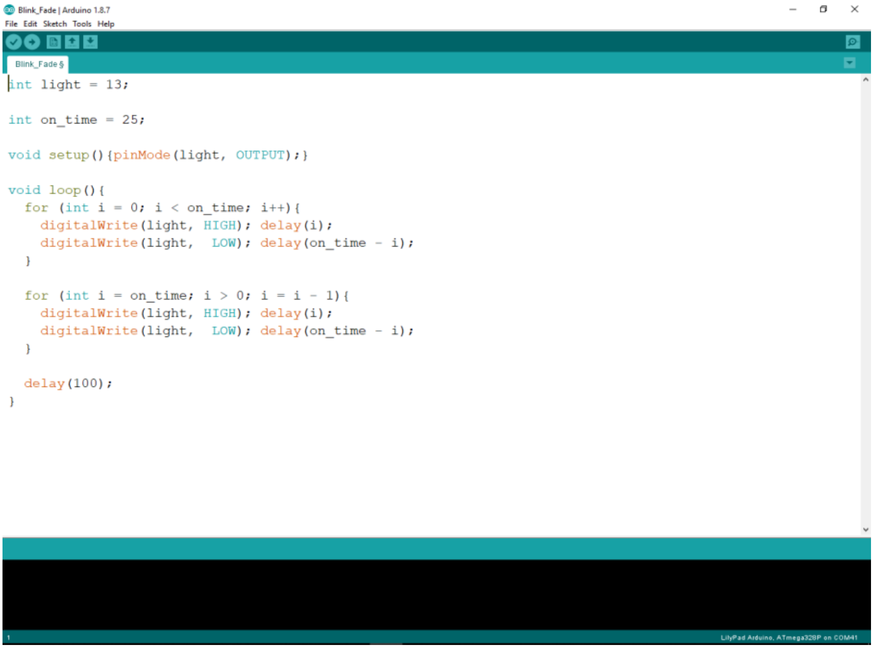
6.02: Loading you First Program

To test your new board, we're going to blink the light on the board. Connect the FTDI adapter to the board and then, using the USB cable, connect it to your computer. Now load the example program called 'Blink'. To do this, follow these steps in the Arduino IDE.

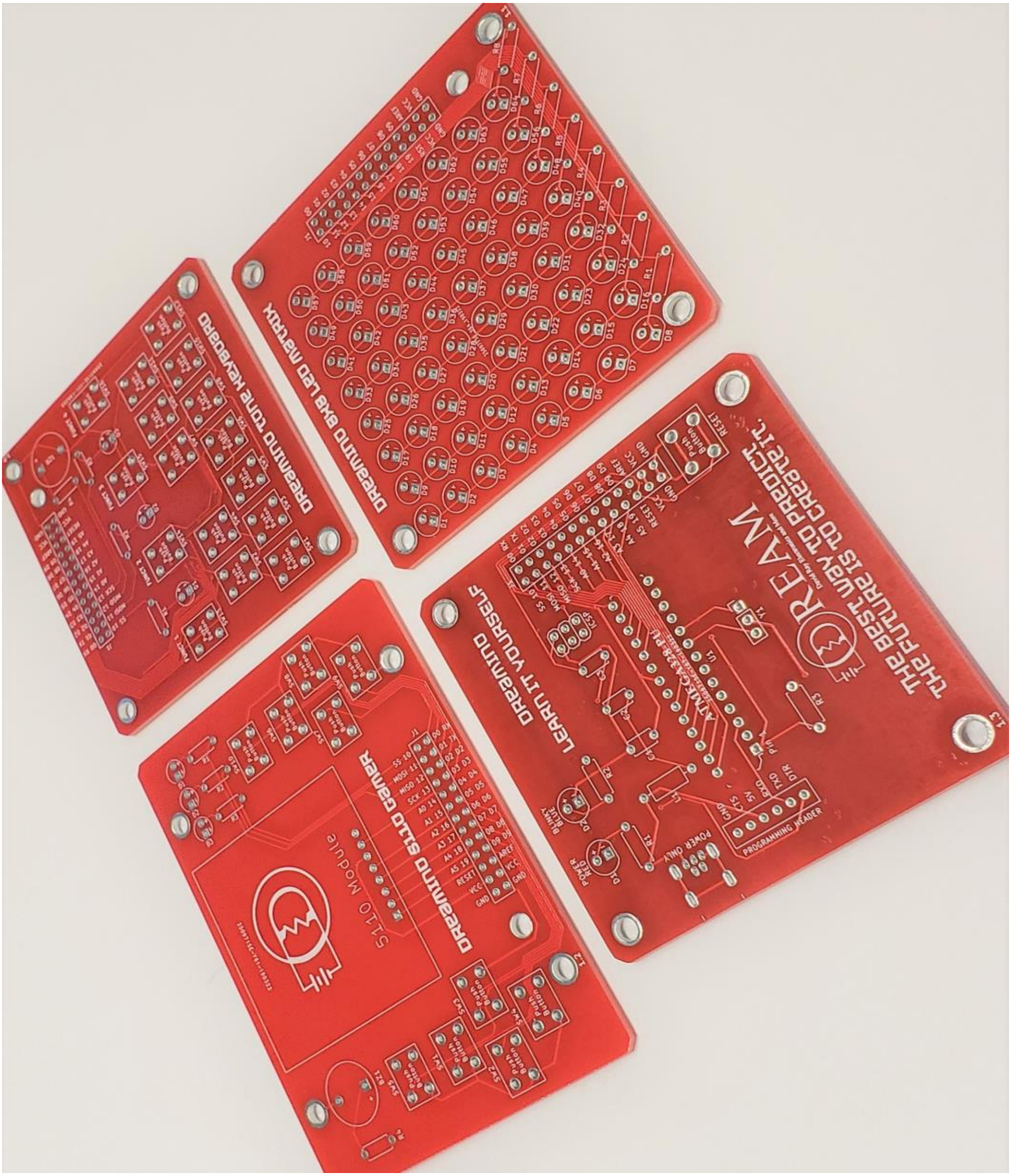
- File -> Examples -> 01. Basic -> Blink

Once, it is on your screen we're going to push that program to your board.

- Sketch -> Upload



You should see a few things happening on the bottom. If it gives you an error or gets stuck, try again a couple of times. If that doesn't work, maybe you have it set to the wrong com port. Try changing the com port under the Tools menu and then trying again. If you continue having issues, re-seat the USB connections, check the soldered connections on your board, and make sure your components are installed correctly. If after that you are still having issues, please turn your computer off and back on again. If you continue having trouble, post your question on http://class.DREAM-Enterprise.com.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