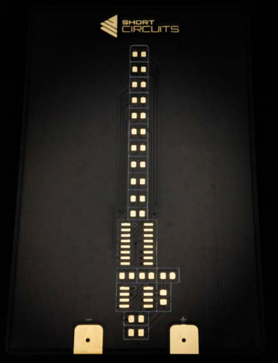
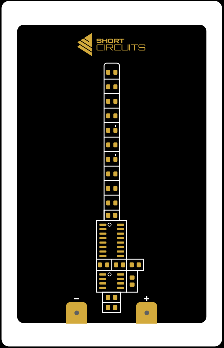
SHORT CIRCUITS

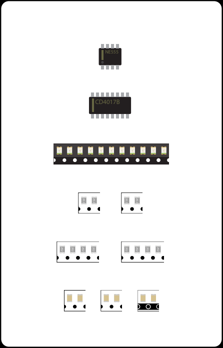


SABER CARD

INSTRUCTION MANUAL

The Kit





Printed Circuit Board

The Printed Circuit Board (PCB) is made of resin and fiberglass, with a layer of copper on the top and bottom. This is a 2 layer board, but boards with more layers are common. We can use PCB design software like the free KiCAD, or Eagle, Altium etc to lay out our circuit. The circuit is comprised of footprints that hold the various components, and traces which are copper connections between certain components.

When the finished design is sent to the manufacturer, they etch away the copper that isn't needed to form the circuit. The board is then coated in a coloured layer that protects the circuit. This is the mask. A different colour is then applied. This is the silkscreen layer, which is where the footprints, designations and other information are found. Short Circuit PCBs have the traces drawn on this layer, to help you follow the circuit.

Components

The kit comes with a variety of components. They make the circuit function. Designing circuits can be incredibly complicated. Our kits are designed to be simple to learn. They are not always the most efficient or effective way to design devices with these functions. They are designed to teach various concepts that can be applied in your own designs.

There is quite a lot of information in this manual, so here is a run down of each section and what you are likely to find.

The manual is a work in progress and we would appreciate your feedback. Please head to the forums if you have any ideas or constructive criticism. As the manual is digital, we will be updating it regularly.

Bill of Materials

The Bill of Materials (BOM) is a list of parts and their values. This can be used to find replacement parts or to check the datasheets for each component.

Component Layout

This will show you where each of the components, found in the BOM, will be soldered.

Schematic

The schematic shows the circuit design in it's simplest form. Each part of the circuit is shown separately. Connections within these sections are shown with white lines. You can find tags next to pins connected to other parts of the circuit. Each tag has a corresponding tag in the part of the circuit that it is connected to.

Circuit Explanation

The rest of the Circuit section of this manual explains how and why the circuit works. You can skip this bit and head straight to building your kit, then check back later to learn how it works. Or you can go head first into the how and why, then start building. It's up to you.

Assembly Instructions

This is where you can learn how to solder your components to the PCB. The tips at the start are very useful. They may prevent you from getting frustrated. The soldering iron can be hard to tame. Make sure to keep that tip tinned and shiny! The diagrams on the right pages show the components mentioned in the instructions. You can use this to match the components to the footprints on the board, and to make sure you are using the correct resistor in the correct place.

Testing for Faults

Be sure to go through this section to minimise any risk of breaking something. If you have a short and you connect the board to power, you might overheat a component, or burn out the power supply.

Component Index

The Component Index will give you details about each component (except some connectors). We've included information about how the component works, its construction, how to find out if it has failed and much more. You can use this as a reference when designing circuits or trying to fix them.

MOTHERBOARD

The SABER CARD kit is designed to teach you how to solder and desolder surface mount components without specialised equipment.

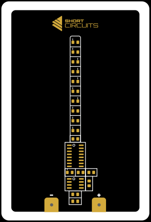
The circuit uses a 555 timer chip that can be set up to emit a clock pulse at a regular interval. This is fed into a decade counter that turns each of it’s outputs on sequentially. This circuit can run on 3-16V.

By changing a resistor or capacitor’s value, the clock pulse can be increased or decreased. When experimenting with the different values available, you will become familiar with replacing surface mount components.

A video tutorial showing the soldering technique and the build process can be found here.

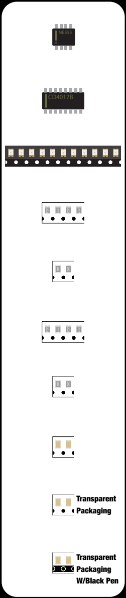
Contents

Kit Contents



1 x Printed Circuit Board

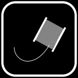
- 1 x NE555 Timer
- 1 x CD4017 Counter
- 11 x 0805 LEDs (Blue)
- 4 x 0805 Resistors (2K)
- 2 x 0805 Resistors (4.7K)
- 4 x 0805 Resistors (10K)
- 2 x 0805 Resistors (20K)
- 2 x 0.1uF Capacitors
- 2 x 1uF Capacitor
- 2 x 4.7uF Capacitor



Tools Needed

Soldering Iron
+ Thin Tip

Solder
0.3 - 0.5mm



Flux

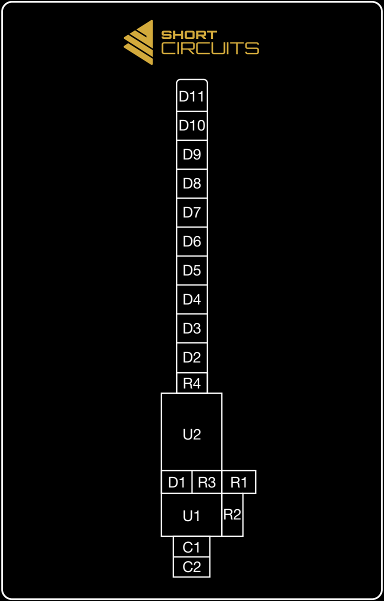
Circuit - Bill of Materials (BOM)

Designation	Value	Name	Footprint	Datasheet
C1	0.1uF	Ceramic Capacitor	0805	
C2	0.1uF/1uF/4.7uF	Ceramic Capacitor	0805	
D1-11	20mA, 2.5V, Blue	LED SMD	0805	
R1	10K, 1/4W	Resistor	0805	
R2	2K/4.7K/10K/20K	Resistor	0805	
R3, R4	2K, 1/4W	Resistor	0805	
U1	NE555	Timer	SOP8	
U2	CD4017	Decade Counter	SOP16	

Circuit - Identifying Components

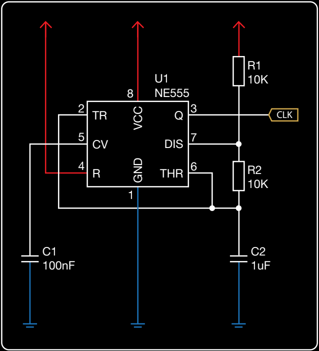
Designation	Value	Illustration	Packaging Description
C1, C2	0.1uF		White paper strip
C2	1uF		Transparent plastic strip
C2	4.7uF		Transparent with pen mark
D1-11	20mA, 2.5V, Blue		Black plastic strip
R1, R2	10K, 1/4W		White paper strip (1002)
R2, R3, R4	2K, 1/4W		White paper strip (202)
R2	4.7K		White paper strip (472)
R2	20K		White paper strip (2002)
U1	NE555		In black plastic
U2	CD4017		In black plastic

Circuit - Component Layout

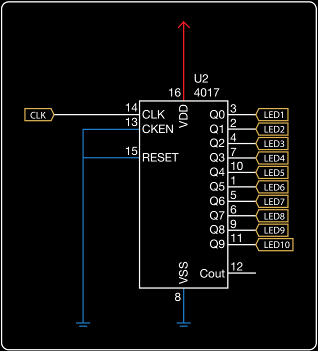


Circuit - Schematic

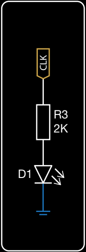
NE555 Clock Pulse Generator



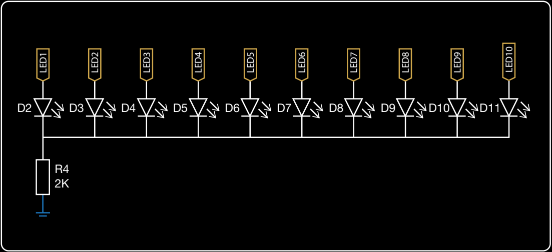
CD4017 Decade Counter



CLK LED



LEDs



NE555 Timer IC (U1)

The NE555 is a very versatile chip that has been around for 50 years. Some say the most popular IC ever made...

The chip has 2 main operating modes:

1. Astable

In astable mode, the chip acts as an continuous electronic oscillator. Common uses being LED flashers, logic clocks, tone generators, analog to digital conversion etc.

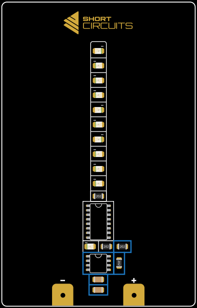
2. Monostable

In monostable mode, the chip produces one pulse instead of a continuous oscillation once triggered. The pulse ends when the capacitor's voltage reaches 2/3 of the supply voltage. Any change to the trigger input will have no effect on the output within the set timing interval. This can be used to remove bounce from switches, detect missing pulses, capacitance measuring etc.

To provide a clock signal for the 4017 decade counter, we are using the 555 timer in its astable mode.

Decoupling Capacitor (C1)

C1 is used to help smooth out variations in the power supply that may cause the circuit to malfunction. Capacitors take time to fill up and empty. A bypass capacitor provides a reservoir that adds voltage when some is missing and absorbs some when extra is available.



R1, R2 and C2

The values of R1, R2 and C2 will determine the frequency of the output clock signal.

The capacitor (C2) will charge up through R1 and R2 until it reaches 2/3 of the supply voltage. While this is happening, the output will be high. When it reaches 2/3 of the supply voltage it will start to discharge through R2 to the DIS pin of the IC. This will cause the output to be low. When the voltage of C2 reaches 1/3 of the supply voltage, it will start charging again, creating a continuous cycle.

Lowering the values of R1, R2 or C2 will increase the frequency (speeding up the clock pulse). Increasing their value will lower the frequency.

You can use the following formula to calculate the frequency:

$$f = \frac{1.44}{(R_1 + 2R_2)C_2}$$

Or head over to the Saber Card page on the website to find some helpful calculators.

To get the desired frequency you can experiment with the different value resistors and capacitors found in the kit. Removing and resoldering these will give you valuable soldering and repair experience.

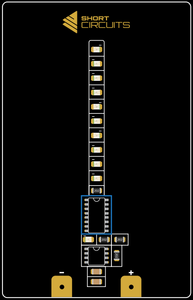
Circuit - Decade Counter Circuit

CD4017 Decade Counter

The CD4017 is a simple IC that turns on each of its 10 outputs sequentially. The counter advances one count when the input clock signal transitions to high. Each output will turn off when the next is turned on.

There are 3 input pins. The clock pin, the clock inhibit pin and the reset pin. The clock pin is used to advance the counter. The clock inhibit pin will ignore inputs from the clock pin if it is pulled high. The reset pin will reset the counter to 0 if it is pulled high. We have connected both to GND to prevent them from interrupting the sequence.

Each of the outputs is connected to the anode of an LED as the output is held high when on.



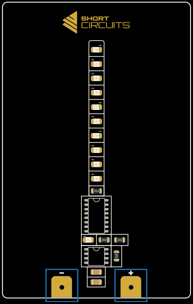
Circuit - Power

Power Pads

The 555 timer IC is rated for voltages between 4.5 and 16V. The 4017 decade counter IC is rated for voltages between 3 and 18V. This means we can apply any voltage between 4.5 and 16V to the power pads.

You can use clips that are connected to a desktop power supply, solder wires connected to a 9V battery, or snip a USB cable and solder the black and red wires to the - and + pads respectively. Breadboard (dupont) hookup wires fit perfectly into the holes, so you could use these for a non-soldered alternative.

You could also power this from a Motherboard kit. You could even wire the positive pad to an IO pin on the Motherboard so you can control when it turns on.



Circuit - LEDs

Main LED Strip (D2-11)

Each of the LEDs in the strip are connected to an output on the CD4017 decade counter. As the counter sends its outputs high when on, and we want our LEDs to turn on one at a time, we connect the outputs to the anodes of the LEDs. The cathodes of the LEDs are connected to GND via a current limiting resistor.

If we wanted all the LEDs to be on except the one that is connected to the output that is currently active, we can connect the outputs to the cathodes of the LEDs. The anode can then be connected to positive voltage through a current limiting resistor.

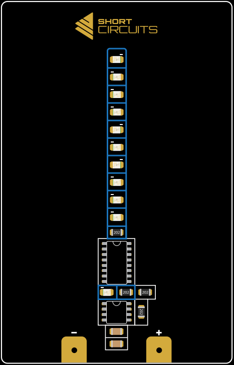
Clock LED (D1)

To give some added visual feedback, we have added an LED and current limiting resistor to the clock signal coming from the 555 timer. This is turned on when the clock signal goes high.

Current Limiting Resistors (R3, R4)

These resistors limit the current going through that part of the circuit. This protects the LEDs from burning out. The higher the resistance value, the lower the LED's brightness and the longer the LED will last.

Only one resistor is needed for the entire strip of LEDs. This is because our circuit is designed to turn one LED on at a time. If there were more than one LED on at a time, then we would need to use a resistor per LED.



To calculate the resistors minimum value, we can use the following equation:

$$R = \frac{V_{SOURCE} - V_{LED}}{I}$$

To find the voltage drop across the resistor, we need to take the voltage drop across the LED away from the total voltage from the supply.

Vsource is the maximum Voltage we will connect to the circuit. This will be 16V in our case.

Vled can be found in the LEDs datasheet. Check the datasheet link found in the BOM. The LEDs used in this kit have a typical forward voltage of 3.2V.

The current (I) will be the LED's recommended forward current. The datasheet states it's max forward current as 30mA. The value used in the datasheets measuring conditions can be used as a good safe current. This is stated as 20mA.

$$(16 - 3.2) / 0.02 = 640\Omega$$

640 is our minimum resistor value. After testing the brightness of the LEDs with different values above 640Ω, we settled on 2kΩ.

Check out the calculator on the website to find the LEDs forward current when using a 2kΩ resistor.

General Soldering tips

1. ALWAYS KEEP YOUR TIP CLEAN

To ensure the soldering iron can transfer enough heat from it to your solder/component leg you must keep the tip clean and shiny. A dull tip means the outside layer of metal has oxidise. This oxidised layer is a poor transferrer of heat. Because of this, you will have to hold the tip against the component for a longer period of time, which can result in the component failing. It's also very frustrating.

To keep your soldering iron tip clean, wipe it on a wet sponge or wire ball, then apply some solder to coat it, then wipe it again. Ideally, you should do this after every component. At the very least, do it after every 4 components.

2. CONTACT

When soldering, make sure the tip of your iron is making contact with both the leg of the component and the pad on the PCB. Apply heat to the area, then, within a second or two, apply the solder to the point of contact.

3. HEAT

It's better to be too hot than too cold. As mentioned earlier, when the iron tip isn't hot enough, you have to hold it on longer. This allows heat to transfer into the component and could cause a failure. It is better to set your soldering iron a little hot so the solder melts instantly and flows around the leg of the component with ease. You can start at around 350ºC and adjust from there. Too hot and the tip will oxidise too quickly,..

4. SOLDER

Leaded solder is much easier to work with, which makes it easier to learn with. It can be hard to find in some countries, but can often be ordered from China. There are potential health risks, but these are very low. Make sure you have a fan pointing away from your work area to blow the fumes away. Work in a well ventilated area.

Thinner is better. Working with a thick wire of solder can get messy. Use 0.4-0.5mm solder for more control. You will have to feed more into the solder joint, but you have more control when there are other pins close by that you want to avoid. This is essential when soldering surface mount components and Integrated Circuits.

5. SAFETY

350ºC is obviously very hot. Stuff catches fire at this temperature. Skin fries. Please be careful. Remember to turn it off when you are finished. This will prevent a potential house fire and also save your iron tip from continued oxidation.

6. ANGLE OF ATTACK

When soldering, make sure you position the board so that it is easy to access the area you are working on. It is easy to make a mistake when you are trying to maneuver your iron into position around some obstacle. You may have to spin the board 180 degrees, or make sure you have snipped the legs off the previous component. It's easy to be impatient so try to plan ahead.

Check the component position using the images opposite. To help identify the components please refer to the table on this page.

LEDs

The LEDs are polarity sensitive, so make sure the LED is soldered the correct way around. You will likely destroy the LED if you try and desolder it, so make sure you get this right. There are 4 extra LEDs in the kit, just in case.

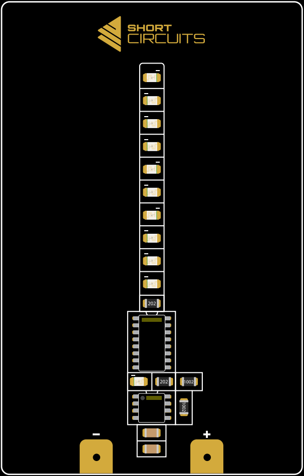
The negative side of the LED is indicated by a green mark on the top. There is also a symbol on the bottom that “points” to the negative side. This should line up with the “-” symbol on each of the LED footprints on the PCB.

Be careful you don't ping these tiny 0805 components across the room, finding them will be tricky.

To begin, we will first apply some solder to one of the pads of each of the LED footprints. This will enable us to solder the first pad of the LED without needing three hands. If you are right handed, solder the right pad as you are looking at the PCB. If you are left handed, solder the left pad.

We will be holding tweezers in our non-dominant hand (to hold the LED) and the soldering iron in our dominant hand. Orient the LED in the tweezers so it will be in the correct orientation when soldered to the PCB. Bring the LED towards its footprint on the PCB and get it into position next to the pre-soldered pad.

When ready, apply heat to the soldered pad with the soldering iron and simultaneously bring the LED towards the molten solder. When the LED is in position and the solder is covering the LED's terminal, while still holding on to it with the tweezers, pull away the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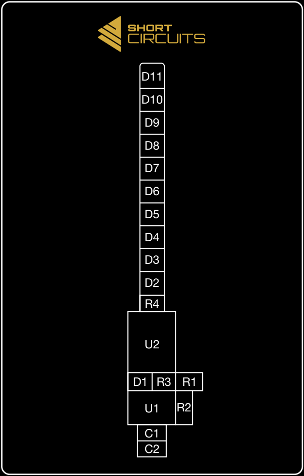
SHORT
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D4
D3
D2
R4
U2
D1
R3
R1
U1
R2
C1
C2

ASSEMBLY

soldering iron. If you pull away the soldering iron without holding onto the LED, the LED will likely come away with the iron.

If the LED is not flat with the PCB, you can apply downward pressure with the tweezers, while temporarily heating the solder. When you are happy with its position, solder the other pad to the LED. Do this by apply heat to the pad and the LED's terminal while feeding solder to the joint.

Repeat the procedure with all the LEDs. Again, pay attention to polarity.

To desolder a surface mount LED you can apply a lot of solder to the area and use that to heat up both pads at the same time, enabling you to scrape the LED off with the soldering iron tip. This will destroy the LED.

You can also try and heat one pad and wait for the heat to transfer to the other through the LED. This may take some time, and some heat. This will destroy the LED and potentially lift the pads on the PCB.

If you have a wide soldering iron tip, you can try and hit both pads at the same time and scrape the LED off like that. You can also use the thinner tip lying flat to achieve the same effect in a more awkward fashion.

Resistors

R1 = 10K, R2 = You choose, R3 and R4 = 2K

The resistors will be soldered in the exact same way as the LEDs but the polarity can be ignored. It is advised to keep all the writing the same way up to prevent the universe from imploding.

Capacitors

C1 = 100nF, C2 = You choose

The surface mount ceramic capacitors can be treated in the same way as the resistors and LEDs. They are not polarity sensitive.

When desoldering them, heat quickly conducts through the capacitor, so heating one pad and scraping the cap off when the heat has melted the solder on the other pad is a viable way to remove them with just a soldering iron.

NE555

This is an 8 pin IC in an SOP package. That means there is about a 0.7mm space between the pins. You should definitely be using a thin tip on your soldering iron. I use a 0.8mm tip.

All chips are polarity sensitive, so make sure you align the pin 1 symbol on the chip with the one on the PCB. SOP chips should have a circle next to pin 1 on the top of the chip. If not, the line and direction of the text can be used (pin 1 is the bottom left pin).

Just like the 0805 components, we will solder one pin to the PCB first, to hold it in place. To do this, add some solder to the pad closest to your soldering hand. With tweezers holding the chip in the right orientation, bring the chip towards the pad with solder on it while heating the solder. Remove the heat when you are satisfied with the chip's position. If it is taking a long time (>10 seconds), remove the heat and try again when the PCB and chip have cooled down.

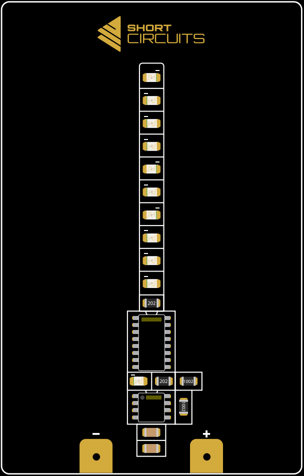
Now you can solder the pin diagonally opposite while slightly repositioning the chip if needed. Apply heat to the pin and pad while feeding a tiny amount of solder to the joint.

Now solder each of the other pins. If you create a bridge between two pins, make sure your tip is clean and shiny, then drag it towards you, between the two pins. This should part them. It may take a few tries. If the solder doesn't want to behave, you may need to add some flux.

CD4017

The CD4017 can be soldered in the same way as the 555 timer IC. This chip doesn't have the circle pin 1 indicator, so use the line on the top. It should be the same way around as the 555 IC.

To see a video of the assembly process including desoldering components, please watch the video here.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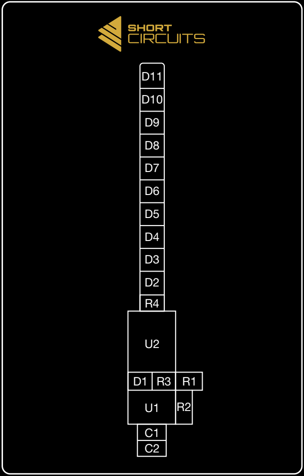
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D6
D5
D4
D3
D2
R4
U2
D1
R3
R1
U1
R2
C1
C2

ASSEMBLY

Testing for faults

Before you power on the board, there are a few things we need to do.

Visual Check

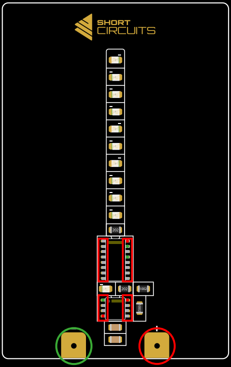
Firstly we need to do a visual check. We are looking for solder bridges that connect two pads that aren't meant to be connected. A magnifying glass is a good tool to have when doing this.

If you see any solder bridges, bring your iron up to temperature and drag it between the two pads. You may have to repeat this a few times. Make sure your iron is clean or the solder won't cling to it. Use flux if the solder bridge isn't parting.

Short Circuits

Now we need to check for short circuits (the bad kind). If we have a short circuit somewhere on the board and we apply power, you may destroy one of or both of the chips.

To check for shorts, get your multimeter and put it in continuity mode (🔊). Make sure the black cable is plugged into the common socket and the red cable into the red socket. Touch the probes together and make sure it makes a sound. Now press the black probe on one of the GND contact (green circle indicated in the diagram). Keep it held there while you press the red probe onto the Vcc(+) contact (the red circle indicated in the diagram). Making sure they are both making contact with metal, listen for a sound from your multimeter. If there is none, excellent, you don't have a short between Vcc and GND. You can jump over to the Power Test. If you here a constant sound from your meter when the probes are in contact with Vcc and GND then you have a short. Check the IC pins again for solder bridges. Focus on the areas marked with boxes on the diagram.



The green dot indicate a pin connected to GND and the red dots indicate a pin connected to Vcc. The closest GND and Vcc pins are pin 15 and 16 of the CD4017 IC.

Polarity

Check all the components that are polarity dependent. In this circuit, that would be the LED's and the ICs. The LED cathodes (faint green mark on top of LED) should be connected to the pad with a - symbol. If they are connected the wrong way around, the LED won't work when the circuit is active. The rest of the circuit should function though.

Make sure the ICs match the orientation in the picture. Getting these wrong may be fatal to the ICs.

Power Test

We can now connect the circuit to power. Connect anything from 5-16V. The positive lead/clip should be connected to the + pad and the negative lead/clip should be connected to the - pad.

If nothing happens, use a multimeter to check the power supply. Check the IC orientation again.

If one or a few LEDs don't work, then check their orientation.

Still having problems? Head over to the forums on our website for help and support. www.shortcircuits.cc

Component Index

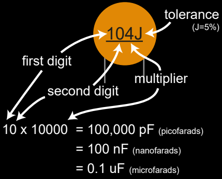
Here you will find information about each component that this kit includes. We have included some of the different sizes and shapes you may find out in the wilderness, different uses for each component, and important data that can be found in datasheets to help you design circuits around them. We have also outlined what happens when these components go pop and how to diagnose and replace them. This information can be used to fix your household appliances, rather than throwing them away. Make do and mend, as they used to say!

Capacitor - Ceramic

Overview

Capacitors are so named for their ability to store a certain capacity of electrical energy (Capacitance), measured in farads (F). A certain amount of capacitance exists between any two conductors that are in close proximity (this can sometimes be seen in an LED matrix in the form of ghosting, and can also cause problems in other sensitive circuits). Capacitors use this in a controlled manner, for various purposes. They usually consist of two conductors separated by a dielectric substance. A dielectric is an insulator (does not conduct electricity) that can be polarised (negative on one side and positive on the other) by an electric field. In this case, the dielectric material is ceramic. A dielectric substance increases the amount of electrical energy that can be stored compared to non-dielectric substances like air.

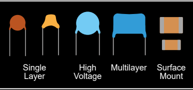
Identification



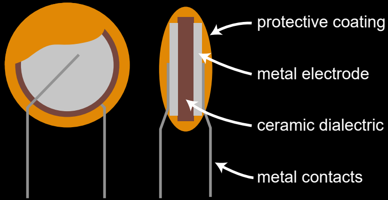
Quick Reference

Check Polarity	X
Positions	2
Type	passive
Schematic Symbol	
PCB Symbol	
Designator	C

Common Varieties



Physical Construction



Important Ratings

Parameter	Typical Values
Capacitance	0.5pF - 1uF (SL) 1pF - 470uF (ML)
Capacitance Tolerance	± 5 - 20%
DC Rated Voltage	10V - 20kV
Pitch	2.54 - 12.7mm

SL = Single Layer
ML = Multilayer

Capacitor - Ceramic

Troubleshooting

Unlike electrolytic capacitors, ceramic capacitors rarely fail in normal use. However, if the voltage exceeds the datasheet's recommended maximum values (breakdown voltage), they can and will produce magic smoke. If they look burnt, or smell burnt, then the charge may have arced across the dielectric layer and will have overheated considerably.

A simple test to see if the capacitor is functioning as it should is to measure it's resistance. As the capacitor charges, the resistance will increase. Before all tests make sure you discharge the capacitor by bridging the leads with a screwdriver. Set your multimeter to Ohms and attach your multimeter probes to each lead. If the resistance climbs to infinity, then the capacitor is functioning as it should. If the resistance reads 0 then the dielectric layer has been compromised and the capacitor will need replacing. This method unfortunately doesn't check its capacitance.

The only reliable way to test a capacitors capacitance is to remove it from the circuit and test it with a multimeter capable of reading capacitance. Set your multimeter to capacitance (Look for the -|(- symbol) and connect the multimeter to the legs of the capacitor. If the value is no longer within the stated tolerance, replace it.

Common Uses

Decoupling

Capacitors are often used to protect certain components from interference from other parts of the circuit. Most common applications are right next to any integrated circuit (IC). The capacitor acts as a storage reserve. If the voltage drops below the required voltage, the capacitor will use it's stored energy to make up the difference. If the voltage increases above the required voltage, the capacitor absorbs the excess voltage. The microcontroller, or other sensitive device will see a much more even voltage because of this. Decoupling capacitors are placed as close to the sensitive parts of the circuit as possible, for maximum effectiveness. To smooth higher frequencies, you would use a low value capacitor (like a 10nF - 0.1uF ceramic capacitor). To smooth the lower frequency noise, a higher value would be used (often a 1-10uF electrolytic capacitor). Decoupling capacitors feature in most of our kits.

ATMega328P's Decoupling Capacitors

Filtering

Unlike resistors, who's resistance stays constant no mater what frequency of signal that's passing through it, Capacitors are reactive devices that resist higher frequencies less and lower frequencies more. Because of this, they will block DC signals (very low frequencies) and allow AC signals (alternating at higher frequencies) through. This is useful when you need AC and DC in a circuit, but only want AC signals in a certain part. A common example of this is a microphone circuit. The microphone needs a DC signal to power the device, but records AC signals (sound) from the environment. When we pass the AC noise through to an amplifier circuit, we want the AC signal, but not the DC. Adding a capacitor in series will remove the unwanted DC signal. (See the Sensor Array for a working example of this)

AC Filter on the Sensor Array (electrolytic Capacitor)

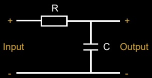
Capacitor - Ceramic

Another form of filter that uses capacitors is an RC filter. The most common RC filters are low-pass and high pass filters. As the name suggests, the low-pass filter lets low frequency signals pass but not high frequencies. High pass filters simply achieve the opposite. This is a passive filter as it uses passive components (resistors and capacitors). The following are the simplest of low-pass and high-pass filters, the equation that governs their properties and a graph to show the typical relationship between frequency (Hz) and amplitude (given in volts).

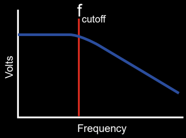
Time Delay

In an RC circuit, capacitors take time to reach their maximum store of electrical energy when exposed to a voltage source, and to deplete that store when the voltage source is removed. This can be used to create a time delay between turning on a voltage supply and a component receiving the voltage it needs to turn on, or read a logic level high for on a microcontroller for example. We can use a simple equation to work out how much time it will take the capacitor to reach approximately 63% of the supply voltage. This is refereed to as the RC time constant and uses the symbol tau (T). In the example circuit the LED will gradually get brighter until the capacitor reaches capacity, following the curve of the graph.

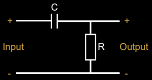
Low-Pass Filter



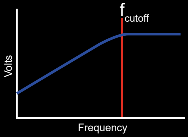
$$f_{cutoff} = \frac{1}{2\pi RC}$$



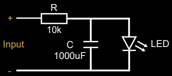
High-Pass Filter



$$f_{cutoff} = \frac{1}{2\pi RC}$$



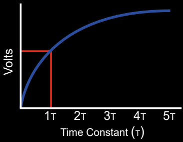
Time Delay Circuit



τ(seconds) = R(Ohms) x C(farads)

τ = 10,000 x 0.001

τ = 10 seconds



Integrated Circuit - NE555

Overview

The NE555 is a very versatile chip that has been around for 50 years. Some say the most popular IC ever made...

The chip has 2 main operating modes:

1. Astable

In astable mode, the chip acts as an continuous electronic oscillator. Common uses being LED flashers, logic clocks, tone generators, analog to digital conversion etc.

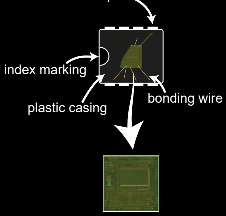
2. Monostable

In monostable mode, the chip produces one pulse instead of a continuous oscillation once triggered. The pulse ends when the capacitor's voltage reaches 2/3 of the supply voltage. Any change to the trigger input will have no effect on the output within the set timing interval. This can be used to remove bounce from switches, detect missing pulses, capacitance measuring etc.

Troubleshooting

Like any IC, checking for shorts between pins, especially Vcc and GND is a good start. If the 555 is set up in a circuit, you can measure the output pin with an oscilloscope to check it is operating correctly. The NE555 is a very common and cheap component, so replacement will be the easiest solution and swapping it out could be an easy way to diagnose the fault.

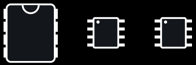
Physical Construction



Quick Reference

Check Polarity	✓
Positions	8
Type	IC
Schematic Symbol	
PCB Symbol	
Designator	U

Available Packages

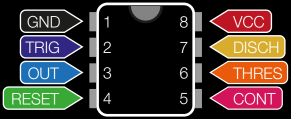


Integrated Circuit - NE555

Important Ratings

Parameter	Min.	Typ.	Max.
Operating temperature	0°C		70°C
Supply Voltage (V_{CC})	4.5V		16V
Output Current (I_O)			±200mA
Input Voltage (V_I)			Vcc

NE555 Pinout



Integrated Circuit - CD4017

Overview

The CD4017 is a simple IC that turns on each of its 10 outputs sequentially. The counter advances one count when the input clock signal transitions to high. Each output will turn off when the next is turned on.

There are 3 input pins. The clock pin, the clock inhibit pin and the reset pin. The clock pin is used to advance the counter. The clock inhibit pin will ignore inputs from the clock pin if it is pulled high. The reset pin will reset the counter to 0 if it is pulled high. We have connected both to GND to prevent them from interrupting the sequence.

Troubleshooting

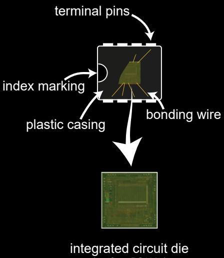
If the 4017 is in through hole format and easily removable, you can create a simple circuit to test the chip on a breadboard. Use a push button (and pull down resistor) connected to the clock pin, and LEDs connected to each output, then power the chip and press the button. If an LED doesn't light up (and it isn't defective), the output is fried. If nothing happens the chip is fried.

If the chip is surface mount, then you could test for continuity between pins, especially Vcc and GND. Check this against the pinout diagram. If something isn't right, then swap out the chip.

If there is no short circuit, try powering the circuit. You can Measure the voltage at the output pins to check it working correctly.

The 4017 is a common and cheap chip. Swapping it out is cheap and easy.

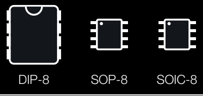
Physical Construction



Quick Reference

Check Polarity	✓
Positions	8
Type	IC
Schematic Symbol	
PCB Symbol	
Designator	U

Available Packages

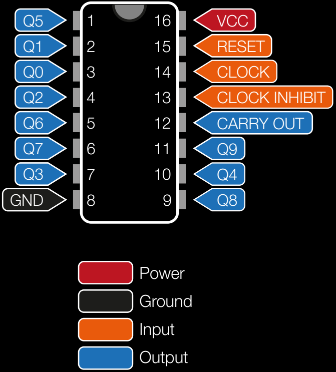


Integrated Circuit - CD4017

Important Ratings

Parameter	Min.	Typ.	Max.
Operating temperature	-55°C		125°C
Supply Voltage (V_{CC})	3V		18V
Clock Input Frequency (5V-15V)			2.5-5.5MHz
Quiescent Current	0.04µA		100µA
Input Low Voltage (5V-15V)			1.5-4V
Input High Voltage (5V-15V)	3.5-11V		
Output Current (5V-15V)		1-6.8mA	

CD4017 Pinout



Light Emitting Diode (LED)

Overview

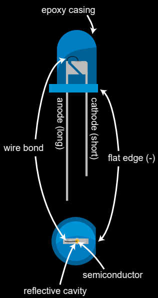
An LED is a Light Emitting Diode. Like all diodes, they are polarity sensitive. They are semiconductor light sources that emit light when current flows through them. Different semiconductor materials produce photons with different amounts of energy and so different colours. The structure of the LED is designed to emit light efficiently using a reflective cavity and shaping the case to act as a lens.

Troubleshooting

Fortunately it’s easy to know when an LED isn’t working to spec. If the polarity is correct, the voltage is sufficient, the series resistor is the correct value, and it doesn’t light up, it’s most probably toast. Here’s how to calculate the value for the series resistor, with an example:

$$R = \frac{V_{source} - VF}{IF} \qquad R = \frac{5 - 3}{0.02} \qquad R = 100\Omega$$

Physical Construction



Quick Reference

Check Polarity	✓
Positions	2
Type	active
Schematic Symbol	
PCB Symbol	
Designator	□

Common Varieties

Through Hole	Surface Mount

Important Ratings

Parameter	Typical Values
Forward Voltage (VF)	1.6 - 36V+ (typ)
Forward Current (IF)	30mA (max)
Reverse Voltage	5V
Power Dissipation	100mW
Luminous Intensity	0.4mcd - 700cd
Wavelength	280 - 800nm

Resistor

Overview

Resistors do exactly that, they resist the flow of electrons through them. This resistance, measured in Ohms (Ω), is fixed and can be relied on to compliment integrated circuits, divide voltages and protect other components from too much current. But due to the law of conservation of energy, this energy needs to go somewhere. In this case, it is converted into heat. This is why it is important to take note of the power rating of resistors, measured in Watts (W).

Resistors can be made out of many materials, but most commonly metal or carbon film. the film is wrapped around a ceramic core and the whole thing is protected by an insulated layer, usually cream, or blue in colour.

Troubleshooting

If a resistor is bad you can usually tell. It likely went up in a puff of grey smoke. as soon as you exceed the resistors power rating, it's going to get hot. Fortunately they are cheap and easy to replace. and easy to troubleshoot. Keep in mind that resistance cannot be measured in an operating circuit. Voltage and Current can however. So you could use Ohms law to calculate the resistance.

1. Remove one lead from the circuit
2. Turn your multimeter to its resistance setting
3. Set your multimeter to the lowest range that exceeds the value of the resistor
4. Place the multimeter's probes on each of the resistors leads (polarity doesn't matter) and note the reading.
5. If the value is outside the range of tolerance, then the resistor is bad and needs replacing.

Quick Reference

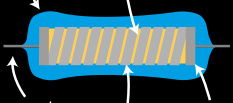
Check Polarity	✗
Positions	2
Type	passive
Schematic Symbol	
PCB Symbol	
Designator	R

Common Varieties

Through Hole

Surface Mount

Physical Construction



Important Ratings

Parameter	Typical Values
Resistance (R)	0Ω - 10GΩ
Power Rating (W)	0.1W - 250W
Tolerance (%)	±0.01% - ±10%
Temp Coefficient (ppm/°C)	±15 - 50ppm/°C
Max Voltage (V)	200V - 500V
Min Operating Temp (°C)	-70 - -25°C
Max Operating Temp (°C)	70 - 450°C

Reading Resistor Values

Surface Mount

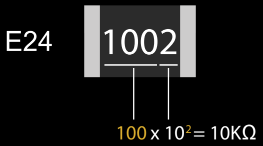
Surface mount resistors use a few coding systems. If you see just numbers, the resistor is probably using the E24 system. If it has a letter at the end then it is probably E96.

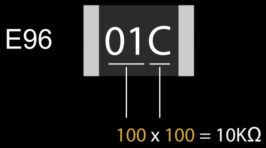
E24

The first two numbers of an E24 resistor represent the 2 most significant digits. The third number represents the magnitude (10 to the power of the third number).

E96

An E96 resistor starts with two numbers that can be looked up in the table, followed by a letter that can be looked up in the other table.





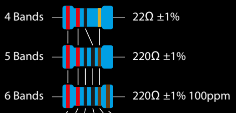
Code	Value	Code	Value	Code	Value	Code	Value	Code	Value	Code	Value
01	100	17	147	33	215	49	316	65	464	81	681
02	102	18	150	34	221	50	324	66	475	82	698
03	105	19	154	35	226	51	332	67	487	83	715
04	107	20	158	36	232	52	340	68	499	84	732
05	110	21	162	37	237	53	348	69	511	85	750
06	113	22	165	38	243	54	357	70	523	86	768
07	115	23	169	39	249	55	365	71	536	87	787
08	118	24	174	40	255	56	374	72	549	88	806
09	121	25	178	41	261	57	383	73	562	89	825
10	124	26	182	42	267	58	392	74	576	90	845
11	127	27	187	43	274	59	402	75	590	91	866
12	130	28	191	44	280	60	412	76	604	92	887
13	133	29	196	45	287	61	422	77	619	93	909
14	137	30	200	46	294	62	432	78	634	94	931
15	140	31	205	47	301	63	442	79	649	95	953
16	143	32	210	48	309	64	453	80	665	96	976

Code	Value
Z	0.001
Y or R	0.01
X or S	0.1
A	1
B or H	10
C	100
D	1000
E	10000
F	100000

Resistor

Through Hole

Through hole resistors have 4 to 6 coloured bands which represent digits, a multiplier, tolerance and temperature coefficient. Use the following diagram to work out the resistors value.



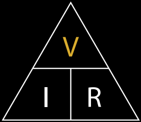
	digit 1	digit 2	digit 3	multiplier	tolerance	temp coefficient
Silver				0.01	±10%	
Gold				0.1	±5%	
Black	0	0	0	1		
Brown	1	1	1	10	±1%	100
Red	2	2	2	100	±2%	50
Orange	3	3	3	1K		15
Yellow	4	4	4	10K		25
Green	5	5	5	100K	±0.5%	
Blue	6	6	6	1M	±0.25%	
Violet	7	7	7	10M	±0.1%	
Gray	8	8	8		10M	
White	9	9	9			

Ohm's Law

Ohms law is the most basic and useful piece of maths used in electronics. We try to keep things maths free, but this one is unavoidable. It describes the relationship between Resistance (R), Voltage (V), and Current (I).

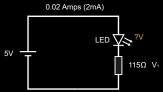
Ohm's law states that the current through a conductor between two points is directly proportional to the voltage across the two points. So, if the resistance stays the same, then as voltage increases, current decreases, and vise versa. If 2 of the three values (V, I and R) are known, you can easily work out the other using the following triangle.

Ohm's law can be used to calculate voltage drops across components, the current flowing through a circuit, the supply voltage, and the resistance across a component (although some components like an LED do not have a fixed resistance value). This can be useful when diagnosing problems in circuits. If the current is too high, maybe the resistance has dropped across a component for example.



$$V = I \times R$$

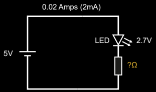
Finding the voltage drop across an LED:
(supply voltage = sum of all voltage drops in a series circuit)



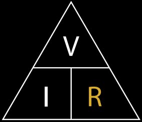
$$V_1 = 0.02 \times 115$$
$$V_1 = 2.3V$$
$$V = 5 - 2.3$$
$$V = 2.7V$$

$$I = \frac{V}{R}$$

Finding the value of a current limiting resistor:

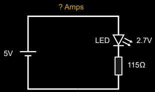


$$R = \frac{5 - 2.7}{0.02}$$
$$R = 115$$



$$R = \frac{V}{I}$$

Finding the current draw in a series circuit:
(the current that flows through the resistor is the same as the current that flows through the LED
because they are in series)



$$I = \frac{5 - 2.7}{115}$$
$$I = 115$$

This manual was written and designed by Martyn Evans.
The circuit designs are inspired by many different sources with hands on testing and experimentation.
If you recognise anything as your own, and think you deserve a mention,
please feel free to contact admin@shortcircuits.cc and let Martyn know.