2023

12. Polarity

R2: SCRAPY Guide

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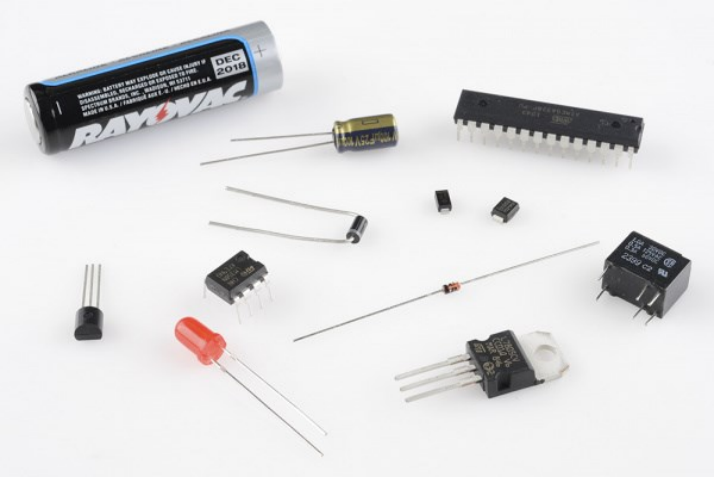
1 Introduction

In the realm of electronics, polarity indicates whether a circuit component is symmetric or not. A non-polarized component -- a part without polarity -- can be connected in any direction and still function the way it's supposed to function. A symmetric component rarely has more than two terminals, and every terminal on the component is equivalent. You can connect a non-polarized component in any direction, and it'll function just the same.

A polarized component -- a part with polarity -- can only be connected to a circuit in one direction. A polarized component might have two, twenty, or even two-hundred pins, and each one has a unique function and/or position. If a polarized component was connected to a circuit incorrectly, at best it won't work as intended. At worst, an incorrectly connected polarized component will smoke, spark, and be one very dead part.



An assortment of polarized components: batteries, integrated circuits, transistors, voltage regulators, electrolytic capacitors, and diodes, among others.

Polarity is a very important concept, especially when it comes to physically building circuits. Whether you're plugging parts into a breadboard, soldering them to a PCB, or sewing them into an e-textile project, it's critical to be able to identify polarized components and connect them in the correct direction. So that's what we're here for! In this lesson, we'll discuss which components do and don't have polarity, how to identify component polarity, and how to test some components for polarity.

2 Diode and LED Polarity

Note: We will be referring to the flow of current that is relative to the positive charges (i.e., conventional current) in a circuit.

Diodes only allow current to flow in one direction, and they're always polarized. A diode has two terminals. The positive side is called the anode, and the negative one is called the cathode.

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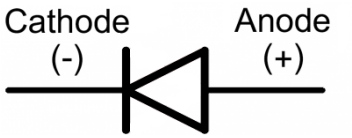
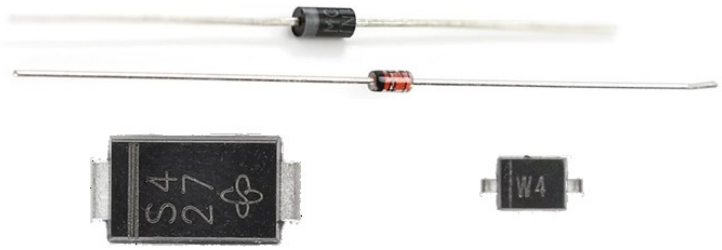


Diodes symbol

Current through a diode can only flow from the anode to the cathode, which would explain why it's important for a diode to be connected in the correct direction. Physically, every diode should have some sort of indication for either the anode or cathode pin. Usually, the diode will have a line near the cathode pin, which matches the vertical line in the diode circuit symbol.

Below are a few examples of diodes. The top diode, a **1N4001** rectifier, has a grey ring near the cathode. Below that, a **1N4148** signal diode uses a black ring to mark the cathode. At the bottom are a couple of surface mount diodes, each of which uses a line to mark which pin is the cathode.

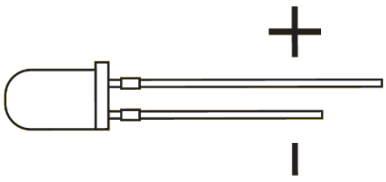


Notice the lines on each device, denoting the Cathode side, which matches the line in the symbol above.

3. LEDs

LED stands for light-emitting diode, which means that much like their diode cousins, they're polarized. There are a handful of identifiers for finding the positive and negative pins on an LED. You can try to find the longer leg, which should indicate the positive, anode pin.

Or, if someone's trimmed the legs, try finding the flat edge on the LED's outer casing. The pin nearest the flat edge will be the negative, cathode pin.



LEDs symbol

There might be other indicators as well. SMD diodes have a range of anode/cathode identifiers. Sometimes it's easiest to just use a multimeter to test for polarity. Turn the

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multimeter to the diode setting (usually indicated by a diode symbol) and touch each probe to one of the LED terminals. If the LED lights up, the positive probe is touching the anode, and the negative probe is touching the cathode. If it doesn't light up, try swapping the probes around.

The polarity of a tiny, yellow, surface-mount LED is tested with a multimeter. If the positive lead touches the anode and the negative touches the cathode, the LED should light up.

Diodes certainly aren't the only polarized component. There are tons of parts out there that won't work if connected incorrectly. Next, we'll discuss some of the other common polarized components, beginning with integrated circuits.

4. Integrated Circuit Polarity

Integrated circuits (ICs) might have eight pins or eighty pins, and each pin on an IC has a unique function and position. It's very important to keep polarity straight with ICs. There's a good chance they'll smoke, melt, and be ruined if connected incorrectly.

Through-hole ICs usually come in a dual-inline package (DIP) -- two rows of pins, each spaced by 0.1" wide enough to straddle the centre of a breadboard. DIP ICs usually have a notch to indicate which of the many pins is the first. If not a notch, the IC might have an etched dot in the casing near pin 1.

Integrated Circuit Polarity

An IC with both a dot and a notch indicates polarity. Sometimes you get both, sometimes you only get one or the other.

For all IC packages, pin numbers increase sequentially as you move counterclockwise away from pin 1.

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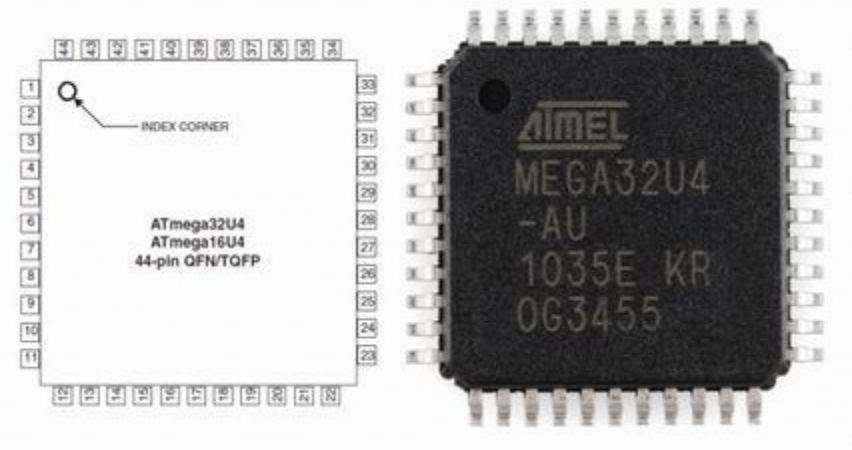
IC Pins

Surface-mount ICs might come in QFN, SOIC, SSOP, or several other form factors ICs will usually have a dot near pin 1.

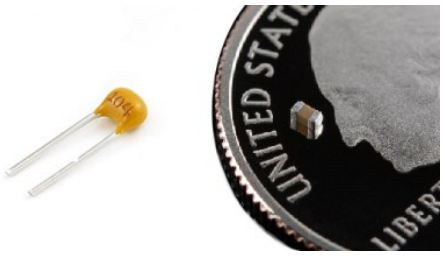


ATmega32U4 in a TQFP package, next to the datasheet pinout.

5. Electrolytic Capacitors

Not all capacitors are polarized, but when they are, it's very important not to mix their polarity up.

Ceramic capacitors -- the small (1µF and less), commonly yellow guys -- are not polarized. You can stick those in either way.



Through-hole and SMD 0.1µF ceramic capacitors. These are NOT polarized.

Electrolytic caps (they've got electrolytes), which look like little tin cans, are polarized. The negative pin of the cap is usually indicated by a "-" marking, and/or a coloured strip along the can. They might also have a longer positive leg.

Below are 10µF (left) and a 1mF electrolytic capacitors, each of which has a dash symbol to mark the negative leg, as well as a longer positive leg.

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10µF (left) and a 1mF (right) electrolytic capacitors

Applying a negative voltage for an extended period to an electrolytic capacitor result in a briefly exciting, but catastrophic, failure. They'll make a pop, and the top of the cap will either swell or burst open. From then on the cap will be dead, acting like a short circuit.

6. Other Polarized Components

Batteries and Power Supplies

Getting polarity right in your circuit all starts and ends with getting the power supply connected correctly. Whether you're project's getting power from a wall wart or a LiPo battery, it's critical to make sure you don't accidentally connect them backwards and apply -9V or -4.2V to your project accidentally.

Anyone that's ever-replaced batteries know how to find their polarity. Most batteries will indicate the positive and negative terminals with a "+" or "-" symbol. Other times it might be a red wire for positive and a black wire for negative.

An assortment of batteries. Lithium polymer, coin cell, 9V alkaline, AA alkaline, and AA NiMH. Each has some way to represent positive or negative terminals.

Power supplies usually have a standardized connector, which should usually have polarity itself. A barrel jack, for example, has two conductors: outer and inner; the inner/centre

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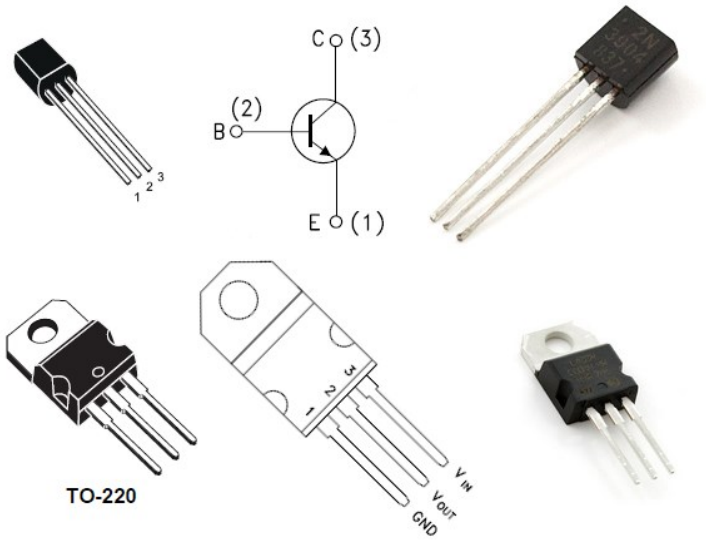
conductor is usually the positive terminal. Other connectors, like a JST, are keyed so you just can't connect them backwards.

A standardized connector

For extra protection against reversing power supply polarity, you can add reverse polarity protection using a diode, or a MOSFET.

Transistors, MOSFETs, and Voltage Regulators

These (traditionally) three-terminal, polarized components are lumped together because they share similar package types. Through-hole transistors, MOSFETs, and voltage regulators commonly come in a TO-92 or TO-220 package, seen below. To find which pin is which, look for the flat edge on the TO-92 package or the metal heatsink on the TO-220, and match that up to the pin-out in the datasheet.



Above, a 2N3904 transistor in a TO-92 package, note the curved and straight edges. A 3.3V regulator in a TO-220 package, note the metal heatsink on the back.

Etc.

This is just the tip of the polarized-component iceberg. Even non-polarized components, like resistors, can come in polarized packages. A resistor pack -- a grouping of five or so pre-arranged resistors -- is one such example.

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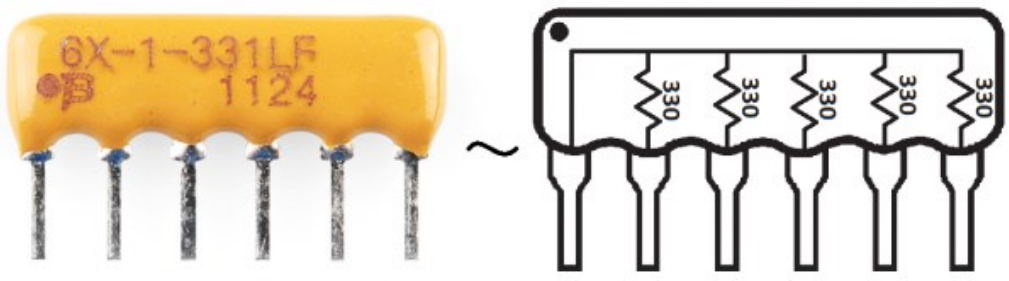

A polarized resistor packs. An array of five 330Ω resistors, all tied together at one end. The dot represents the first, common pin

7 Conclusion

Fortunately, every polarized component should have some way to inform you which pin is which. Be sure to always read the datasheets and check the case for dots or other markers.

Now that you know what polarity is, and how to identify it, why not check out some of these related lessons:

- **Connector Basics** - There are several connectors which have polarity of their own. Usually, this is a great way to make sure you don't apply power or some other signal backwards.
- **Diodes** - Our shining example of component polarity. This lesson goes further in-depth on how diodes work, and what types of diodes are out there.

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