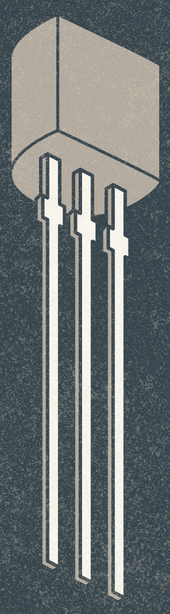
FIELD GUIDE TO TRANSISTORS

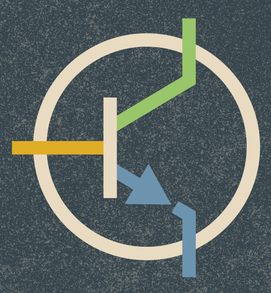
The humble transistor is a device that can control the flow of electricity automatically – it's triggered by the electrical current itself, like a switch. Transistors can be used to create more sophisticated circuits, amplify an electrical signal and even serve as the fundamental building block of a modern computer. The transistor is arguably one of the most important inventions of the 21st century.



SEMICONDUCTING

The most common type of transistor in hobby electronics is the carbon film transistor. Carbon film transistors use silicon that's been treated, or "doped," with other elements – typically phosphorus or boron. These additives manipulate the way electrons flow through the silicon. In a P-type or NPN transistor, a small flow of current from the **BASE** will trigger the transistor high or "on." In an N-type or PNP transistor, a small flow of current from the **BASE** will turn the transistor off or "low." In computing, a "high" signal is represented by a 1 and "low" with a 0.

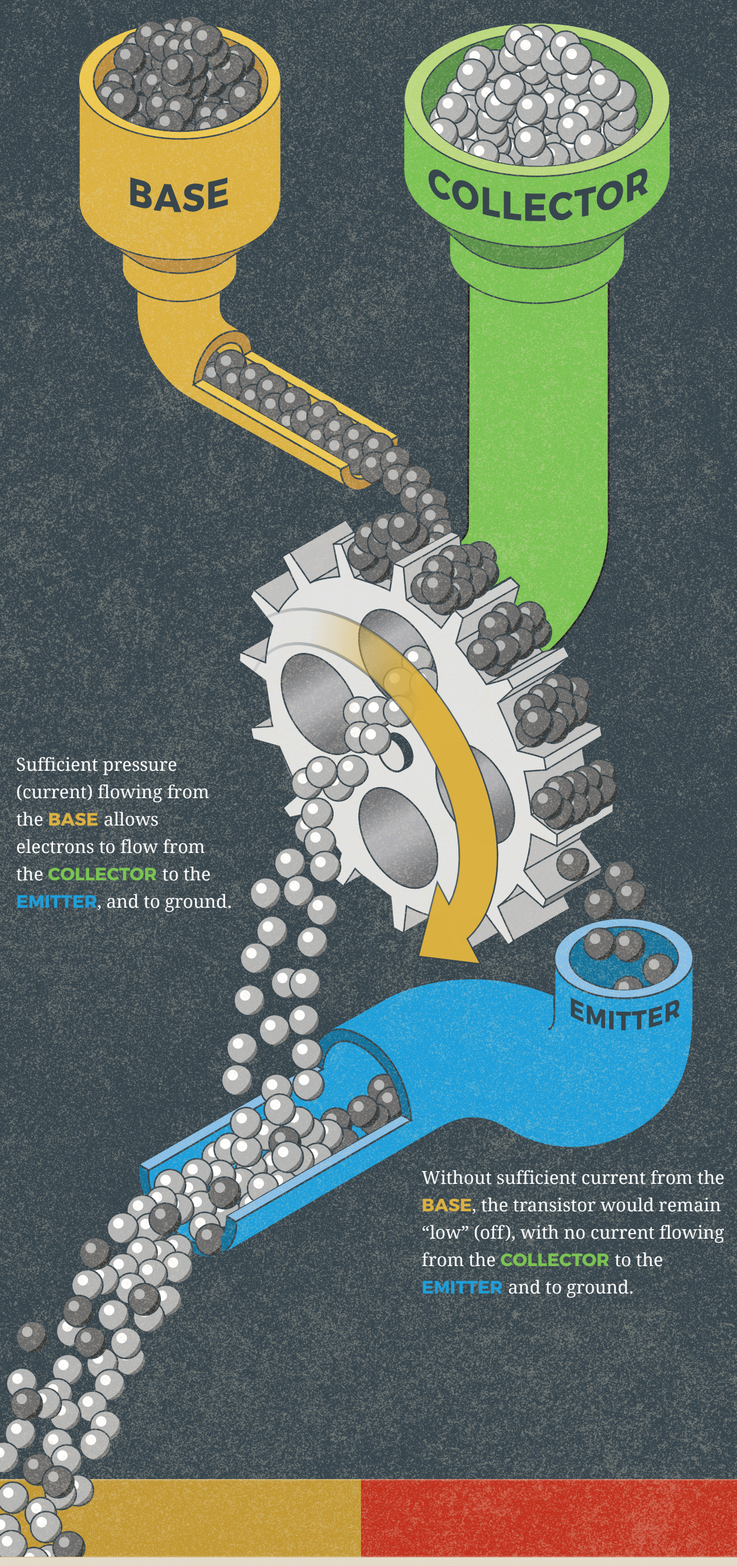
NPN



BC546
2N3903
2N2222

With an NPN transistor, voltage at the **BASE** of the transistor is required to trigger the transistor "high" (on).

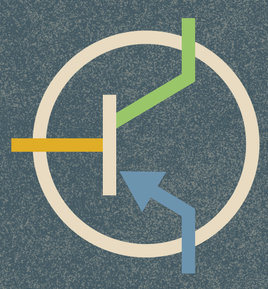
Voltage from the **COLLECTOR** will not flow to the **EMITTER** unless there is sufficient current flowing from the **BASE**.



Sufficient pressure (current) flowing from the **BASE** allows electrons to flow from the **COLLECTOR** to the **EMITTER**, and to ground.

Without sufficient current from the **BASE**, the transistor would remain "low" (off), with no current flowing from the **COLLECTOR** to the **EMITTER** and to ground.

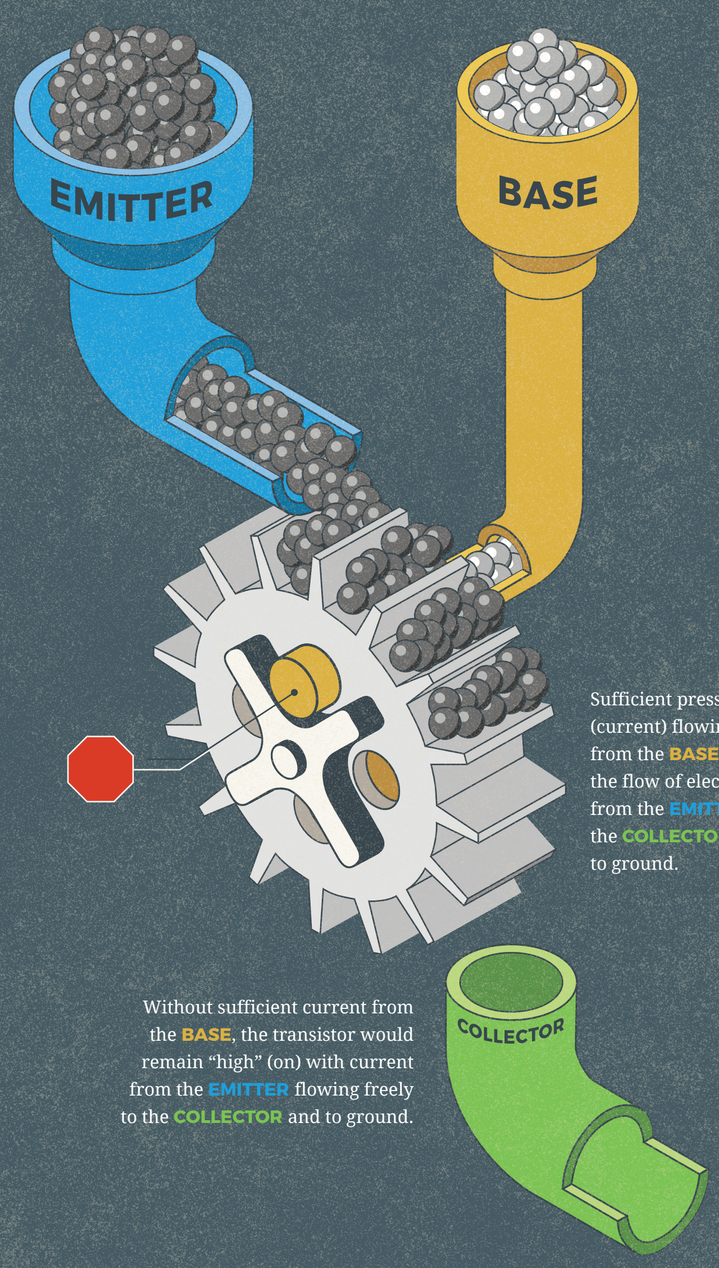
PNP



BC556
2N3906
2N2907

With a PNP transistor, voltage from the **EMITTER** will naturally flow to the collector unless there is sufficient current flowing from the **BASE**.

Voltage at the **BASE** is still required to trigger the transistor, but in this case, it triggers it "low" (off) instead.

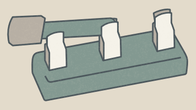


Sufficient pressure (current) flowing from the **BASE** halts the flow of electrons from the **EMITTER** to the **COLLECTOR** and to ground.

Without sufficient current from the **BASE**, the transistor would remain "high" (on) with current from the **EMITTER** flowing freely to the **COLLECTOR** and to ground.

TRANSISTORS THROUGH HISTORY

Transistors are all around us – they are the foundational element of every computational event taking place in the world at any given moment – but where did they come from?

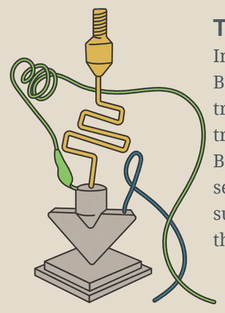


PHYSICAL SWITCHES

Early circuits used physical switches to redirect the flow of electricity. These circuits relied on physical operation, either by a human operator or environmental factors.

VACUUM TUBES

A vacuum tube acts like a valve that can allow current flow in one direction by introducing a smaller electrical charge. Their introduction allowed for more sophisticated circuits that could operate with more automation than those using manually-operated switches.



THE FIRST TRANSISTOR

In the late 1940s, scientists working for Bell Labs developed the solid-state, trans-acting resistor – what we now call a transistor. Shockley, Bardeen and Brittain's invention used the concept of semiconductivity (a semiconductor is a substance that allows electricity to flow through it at a specific rate).

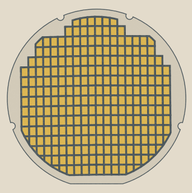
CARBON FILM TRANSISTORS

Modern transistors use silicon mixed with specific quantities of other elements to manipulate the flow of electricity through them. By applying specific inputs at low voltages, a transistor can trigger a circuit "on" or "off" depending on the type of transistor it is.

If you interpret an "on" value as 1 and an "off" value as 0, you have a bit – the smallest unit of data in computing! If you build an array of tiny transistors, the circuit can be programmed to generate of string of ones and zeroes. Now we have binary code.

FIELD EFFECT TRANSISTORS

Field Effect Transistors, or MOSFETs, allow better high current applications and use less power to activate, marking a major advance in the digital world. Breakthroughs in material sciences have had a huge effect on MOSFET transistors, making them smaller, less expensive and more efficient.



THE BUILDING BLOCK OF COMPUTERS

Modern transistors are the lowest common denominator of modern computers. As our knowledge of space-age materials advances, we continue to discover new methods of making transistors better and faster. In the examples below, the higher the transistor density, the more powerful the processor.

APOLLO GUIDANCE COMPUTER
12,300 TRANSISTORS

NINTENDO NES PROCESSOR
(MOS 6502) **3,000+ TRANSISTORS**

ARDUINO/ATMEGA328
~800,000 TRANSISTORS

MODERN SMARTPHONE
(SNAPDRAGON 835)
~3 BILLION TRANSISTORS

– HTTPS://EN.WIKIPEDIA.ORG/WIKI/TRANSISTOR_COUNT

LOOKING INTO THE FUTURE

Transistor technology is the driving force behind advances in modern computers. Nanomaterials like carbon nanotubes and graphene, breakthroughs in microscopic manufacturing, and even a return to miniaturized vacuum technology could make computers even more capable than they are today.

Learn More

KEEP GOING! If you want to learn more about transistors, circuits and how to use them effectively in your next project, you can find plenty of tutorials and guides at **learn.sparkfun.com.**

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START SOMETHING