Circuit Playground: M is for MOSFET

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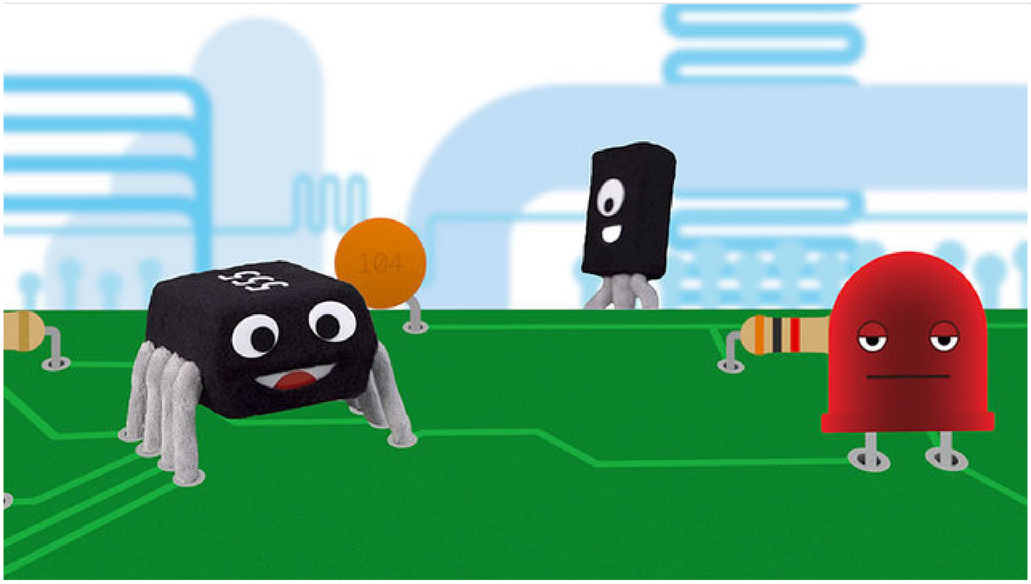
Guide Contents

Video

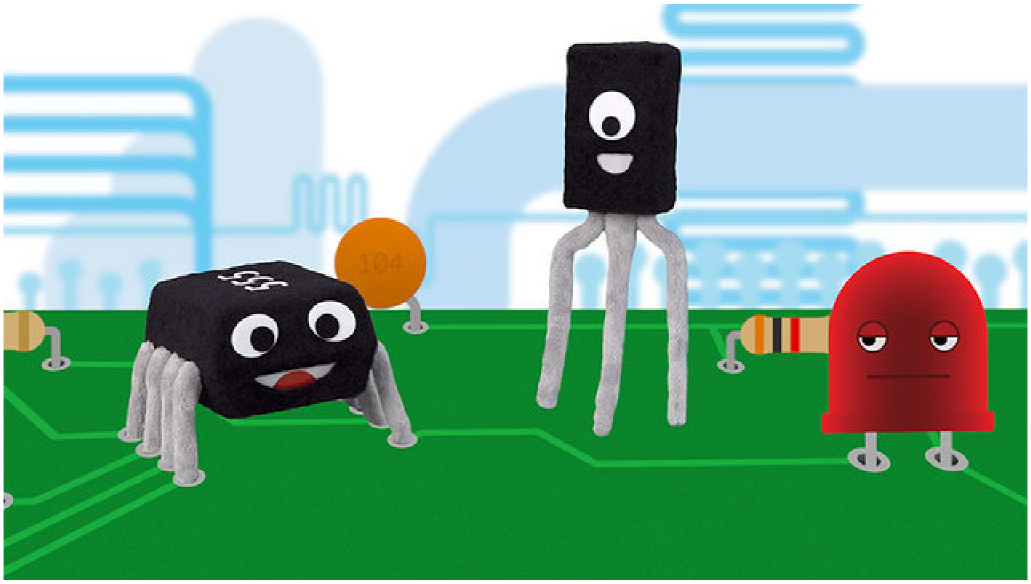
Hans could use some help. Luckily, Connie is here to save the day! Join them at Circuit Playground and learn how MOSFETs can use small signals to control high powered devices.

Transcript



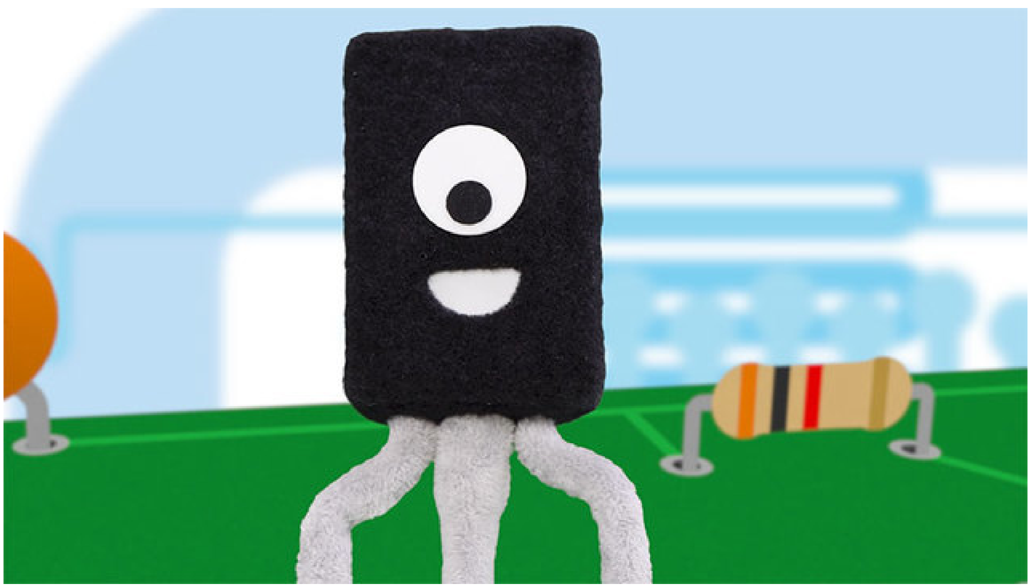
Connie: Hey Hans, what are you doing?

Hans: Hi, Connie. Well, as you know I am a 555 timer IC, so I'm pretty good at sending pulses of electricity in perfect time. Normally, I can blink an LED once per second but for some reason, I can't make this high power LED flash.



Connie: Oh - you probably just need to give it more electrical current.

Hans: Hmm - you may be right. but I can only supply a bit of current from my pins here, my integrated circuit was not designed for driving a lot of current.



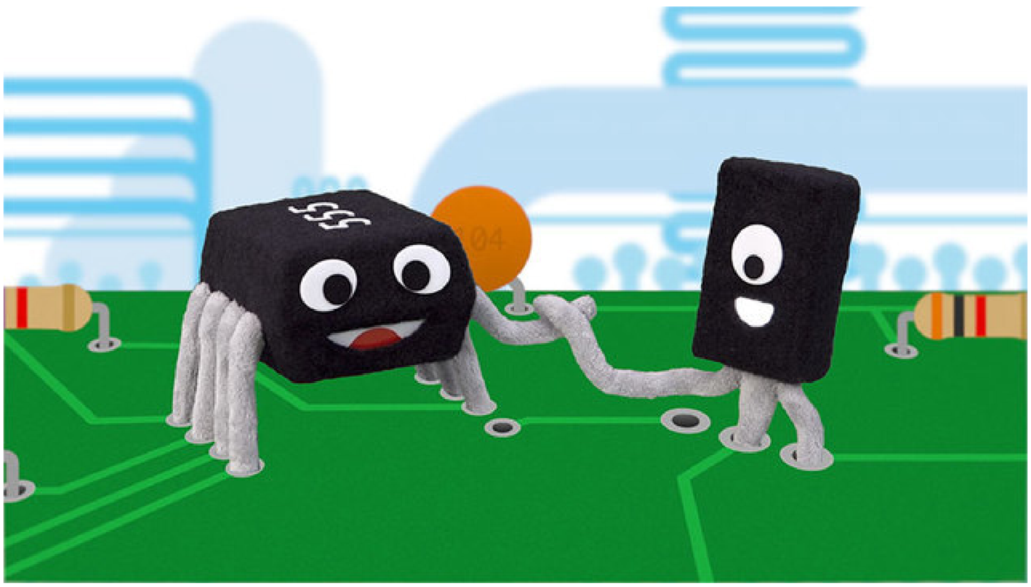
Connie: Well, you are mighty lucky I came along — I can help you!

Hans: Really? How?

Connie: I may be small, but I'm pretty strong! I can push and pull ten times as much current as you can, and manage enough power to light this big LED - I just need you to tell me when to turn it on.

Hans: Oh? how do I do that?

Connie: Grab my hand like this –



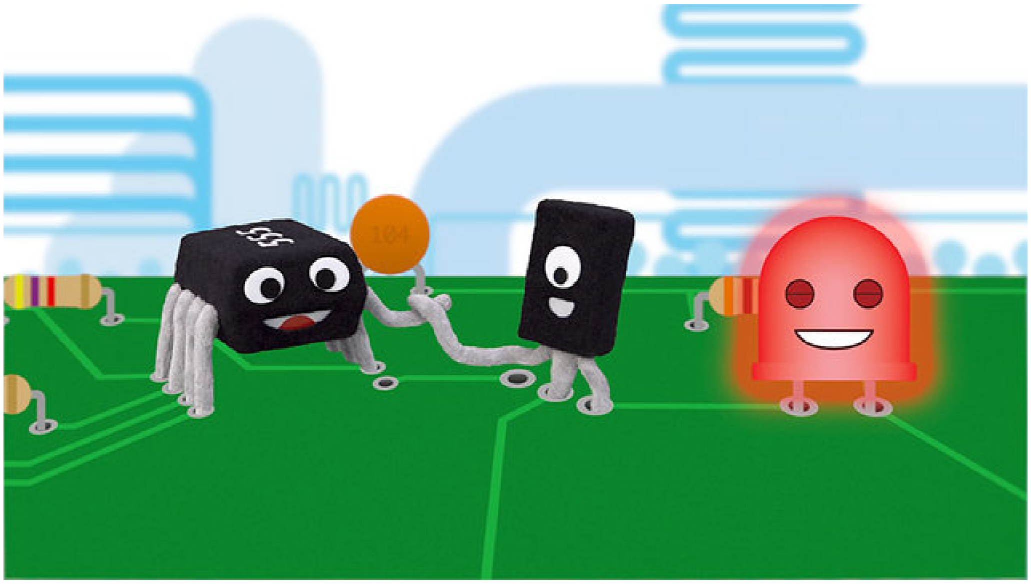
Connie: So now, you just send electrical pulses through your output pin like you were doing before.

Connie: My other pin is connected to the positive leg of the LED, and all three of us are connected to ground.

Connie: Whenever you send an electrical pulse to my left pin, i'll know you want me to do the same on my right pin. What I mean to say is - when you turn your pin on, I'll turn the high power to the LED on. And when you turn your pin off, I'll turn power to the LED off.

Connie: You ready?

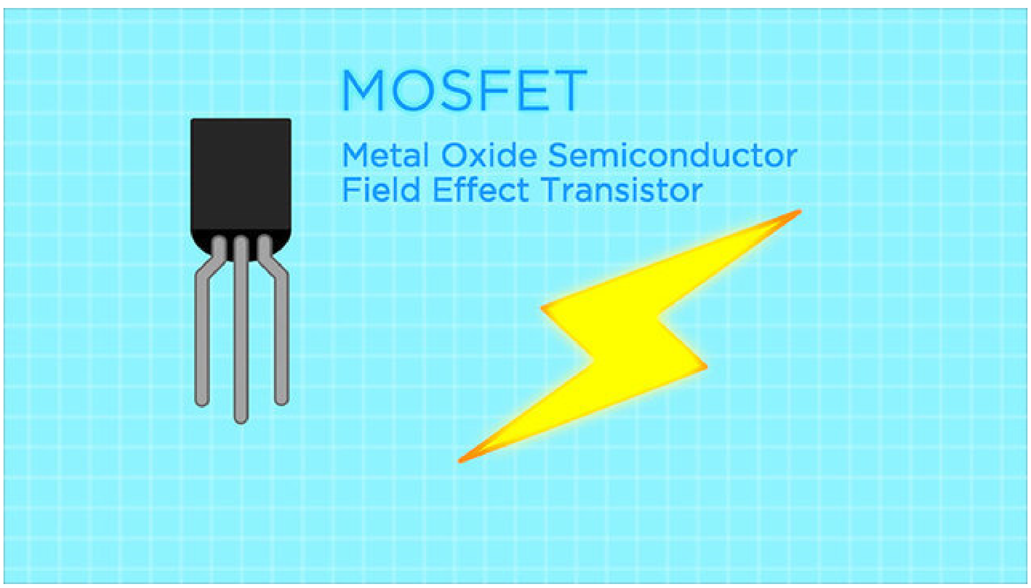
Hans: Ok, ya - let's give it a go!



Hans: It’s working! Connie - you *are* very strong!

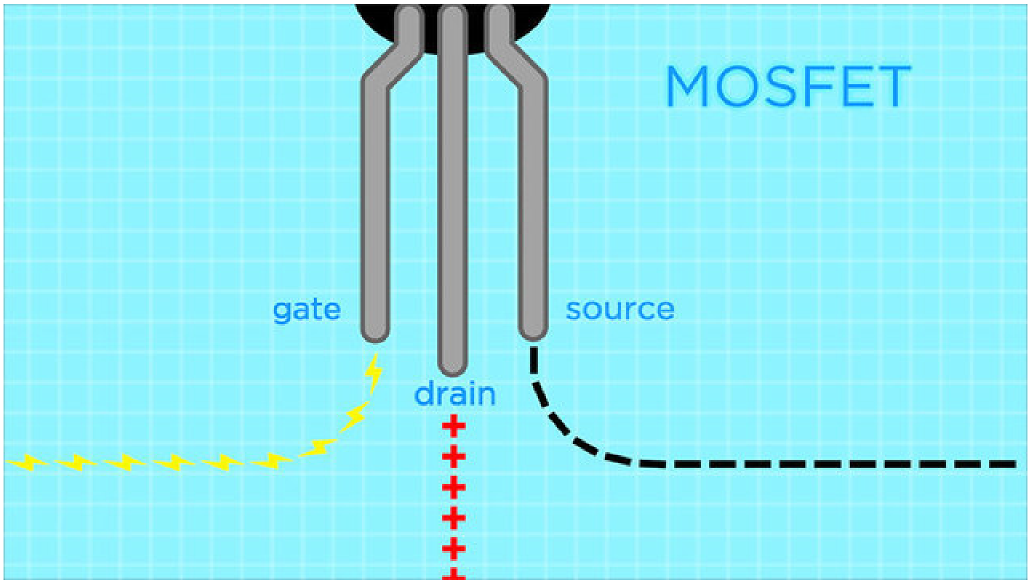
Connie: Ha - just doing my job! I’m a MOSFET :)

Hans: You have Mossy Feet? What in the wide world of sports is that?



Connie: Oh, no Hans - a MOSFET. That stands for Metal Oxide Semiconductor Field Effect Transistor.

Connie: I can take weak electrical signals and *strengthen them*. Those small signals can then control much larger amounts of current.

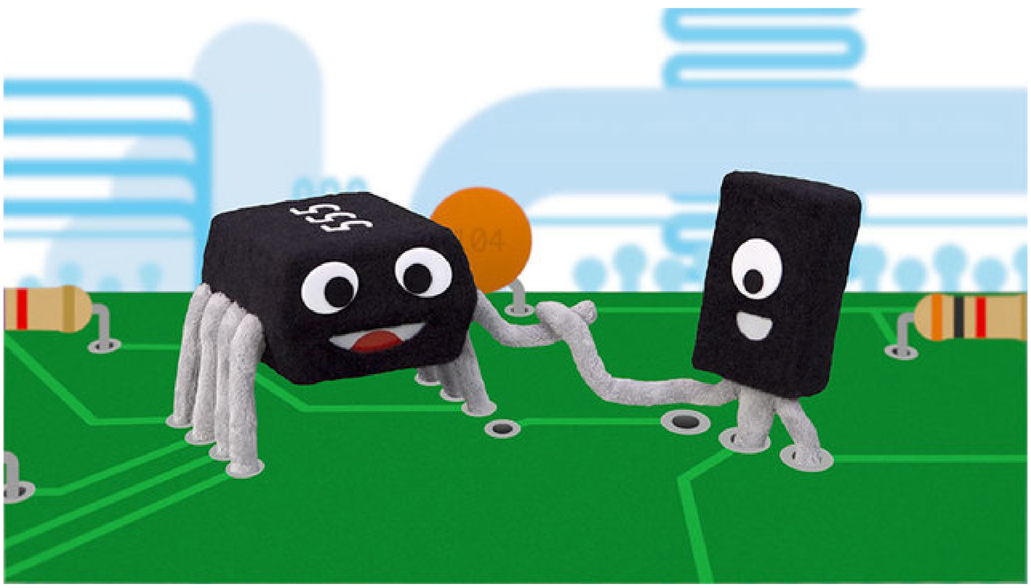


Connie: I use three connections to make that happen.

Connie: My Source pin connects to the source electrons I want to control the flow of, such as ground or negative connection on a power supply.

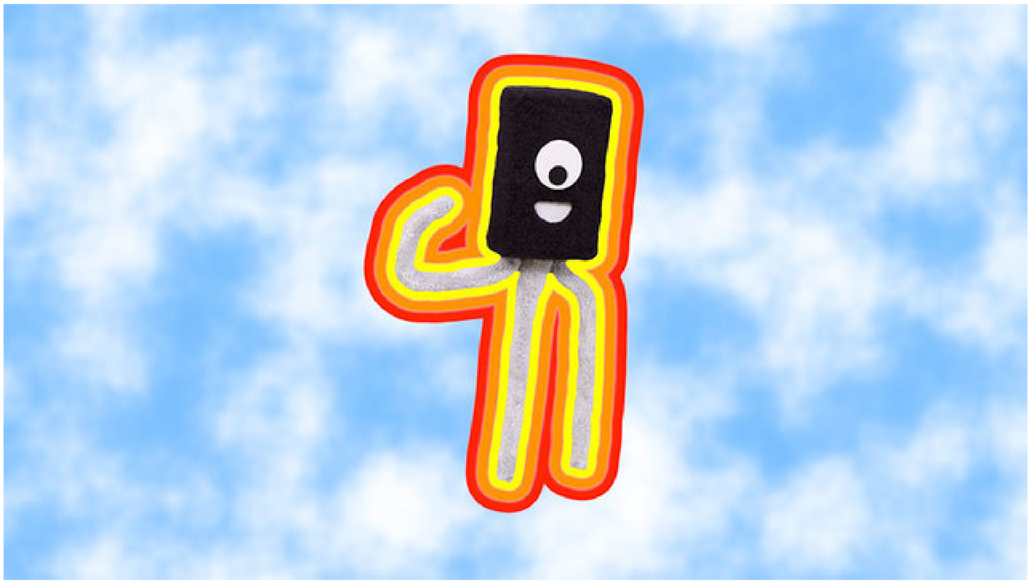
Connie: My Drain pin connects to a positive power

Connie: ... and my gate pin connects to the signal which tells me when to turn the higher current connection on or off.

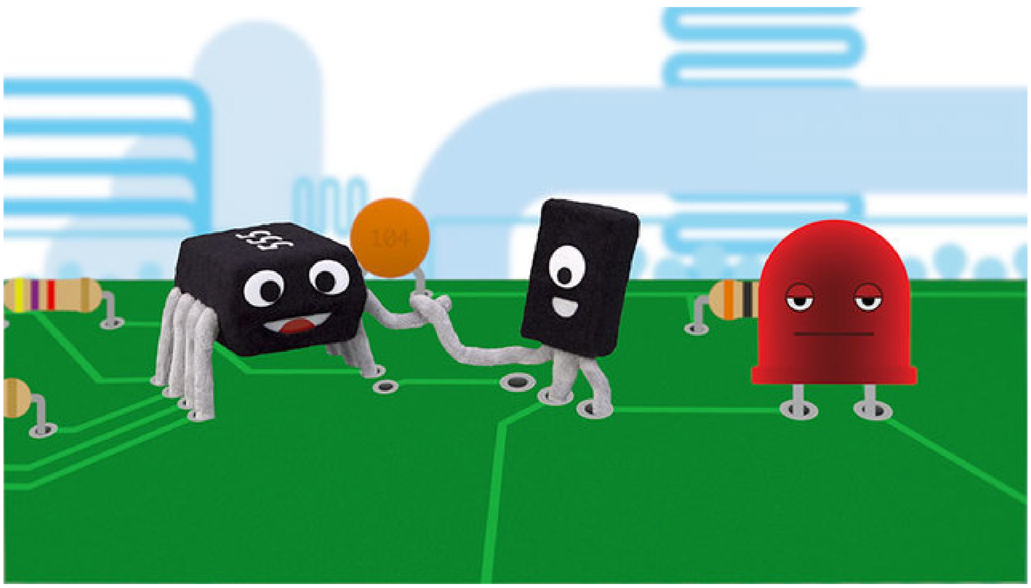


Hans: So, you empower smaller electrical signals to make them bigger!

Connie: That's true! You know - some folks even call me an amplifier.



Hans: Connie, the amplifying MOSFET - sounds like a superhero!

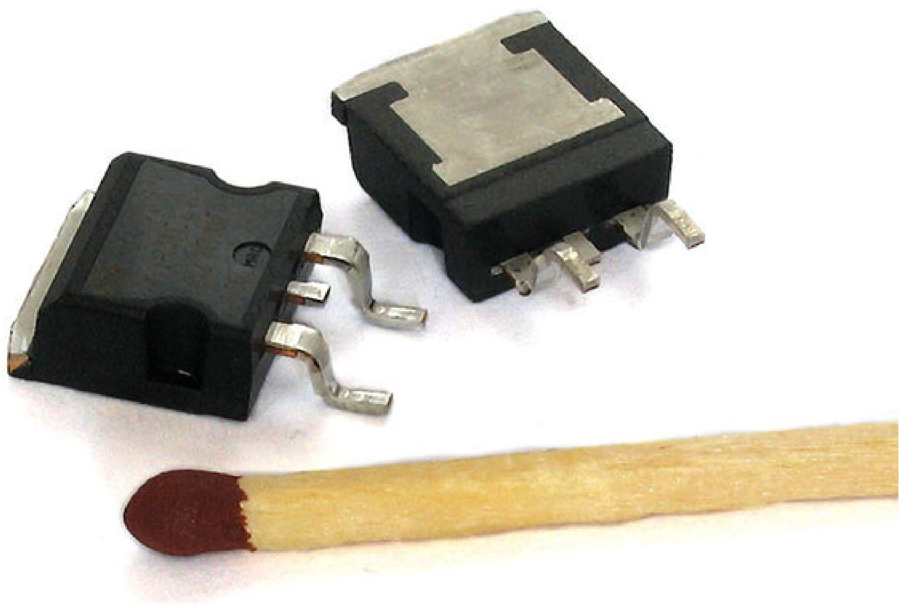


Connie: Ha - thanks, Hans. Well, I told Cappy I'd meet him at an audio circuit around 2:30. He wants help to make his stereo speaker louder. Sooo - how long do we have to flash this LED for?

Hans: Oh - just like another 400,000 milliseconds. So, you should be fine.

Connie: Ohh ... OK.

Learn More



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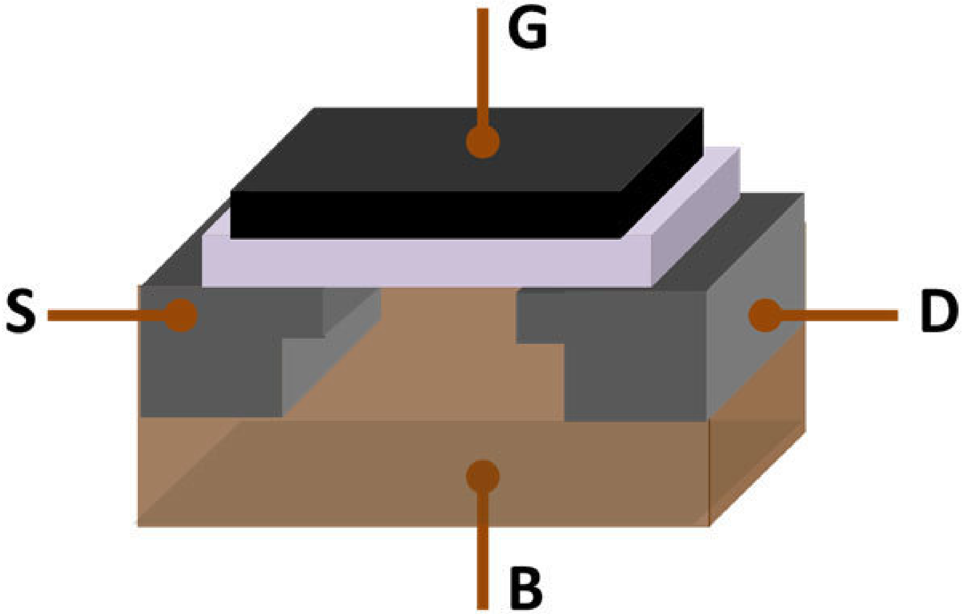
From Wikipedia (https://adafru.it/Chx)

> The **metal–oxide–semiconductor field-effect transistor** (**MOSFET**, **MOS-FET**, or **MOS FET**) is a type of field-effect transistor (https://adafru.it/Chy) (FET). It has an insulated gate, whose voltage determines the conductivity of the device. This ability to change conductivity with the amount of applied voltage can be used for amplifying or switching electronic signals (https://adafru.it/Chz). A metal–insulator–semiconductor field-effect transistor or MISFET is a term almost synonymous with MOSFET. Another synonym is IGFET for insulated-gate field-effect transistor.
>
> The basic principle of the field-effect transistor (https://adafru.it/Chy) was first patented by Julius Edgar Lilienfeld (https://adafru.it/ChA) in 1925[1] (https://adafru.it/Chx).
>
> The main advantage of a MOSFET is that it requires almost no input current to control the load current, when compared with bipolar transistors. In an "enhancement mode" MOSFET, voltage applied to the gate terminal increases the conductivity of the device. In "depletion mode" transistors, voltage applied at the gate reduces the conductivity.[2] (https://adafru.it/Chx)
>
> The "metal" in the name MOSFET is now often a misnomer (https://adafru.it/ChB) because the gate material is often a layer of polysilicon (https://adafru.it/ChC) (polycrystalline silicon). "Oxide" in the name can also be a misnomer, as different dielectric materials are used with the aim of obtaining strong channels with smaller applied voltages. The MOSFET is by far the most common transistor in digital (https://adafru.it/ChD) circuits, as hundreds of thousands or millions of them may be included in a memory chip or microprocessor. Since MOSFETs can be made with either p-type or n-type semiconductors, complementary pairs of MOS transistors can be used to make switching circuits with very low power consumption, in the form of CMOS logic (https://adafru.it/ChE).

Composition



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> Usually the semiconductor (https://adafru.it/ChG) of choice is silicon (https://adafru.it/ChH), but some chip manufacturers, most notably IBM (https://adafru.it/ChI) and Intel (https://adafru.it/ChJ), recently started using a chemical compound (https://adafru.it/ChK) of silicon and germanium (SiGe (https://adafru.it/ChL)) in MOSFET channels. Unfortunately, many semiconductors with better electrical properties than silicon, such as gallium arsenide (https://adafru.it/ChM), do not form good semiconductor-to-insulator interfaces, and thus are not suitable for MOSFETs. Research continues on creating insulators with acceptable electrical characteristics on other semiconductor materials.
>
> To overcome the increase in power consumption due to gate current leakage, a high-κ dielectric (https://adafru.it/ChN) is used instead of silicon dioxide for the gate insulator, while polysilicon is replaced by metal gates (see Intel announcement).
>
> The gate is separated from the channel by a thin insulating layer, traditionally of silicon dioxide and later of silicon oxynitride (https://adafru.it/ChO). Some companies have started to introduce a high-κ dielectric and metal gate combination in the 45 nanometer (https://adafru.it/ChP) node.
>
> When a voltage is applied between the gate and body terminals, the electric field generated penetrates through the oxide and creates an "inversion layer" or "channel" at the semiconductor–insulator interface. The inversion layer provides a channel through which current can pass between source and drain terminals. Varying the voltage between the gate and body modulates the conductivity (https://adafru.it/ChQ) of this layer and thereby controls the current flow between drain and source. This is known as enhancement mode.

Links to more info

- A Beginner's Guide to the MOSFET (https://adafru.it/ChR)

- MOSFET facts for kids (https://adafru.it/ChS)
- What is a MOSFET? (https://adafru.it/ChT)
- How MOSFETs and Field Effect Transistors Work (video) (https://adafru.it/ChU)
- MAKE Presents: The Transistor (https://adafru.it/ChV)