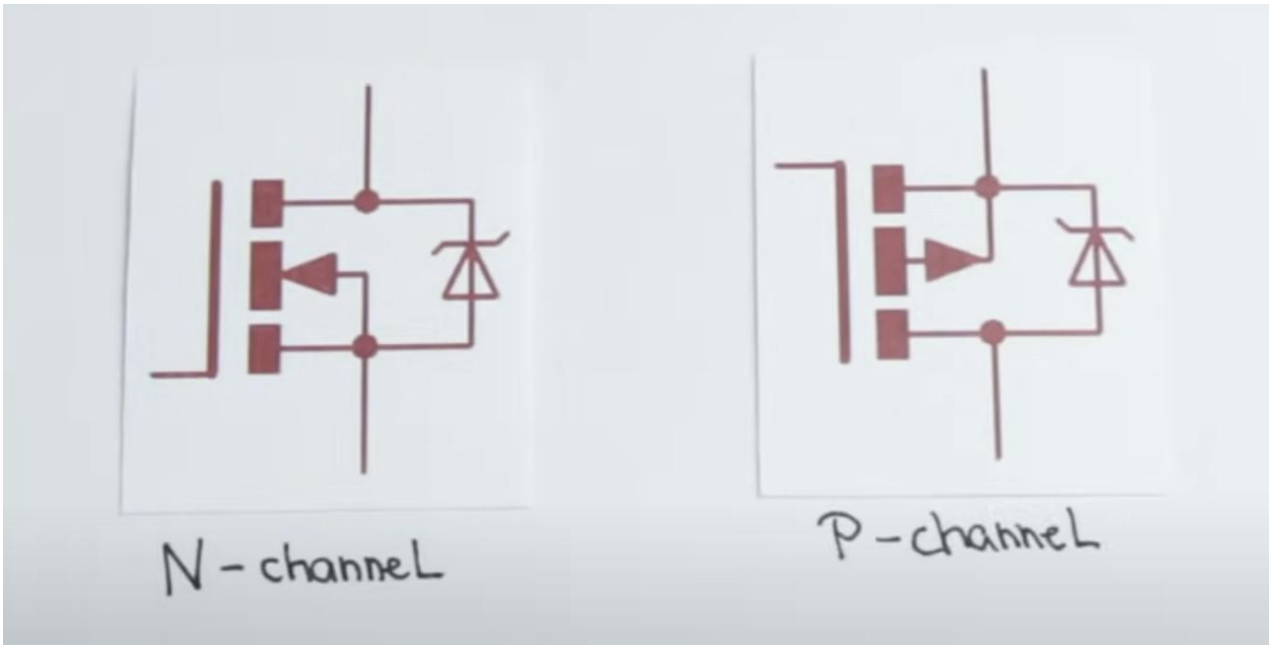
VIDEO#23: Electronic #23:Transistor (MOSFET) as Switch

Introduction

Bipolar Junction Transistors (BJTs) can be used as switches, but they have significant energy losses due to heat dissipation in the collector-emitter path. To improve efficiency, MOSFETs (Metal-Oxide-Semiconductor Field-Effect Transistors) are used. MOSFETs have lower energy loss and can increase circuit efficiency up to 97%, making them a better choice for many applications.

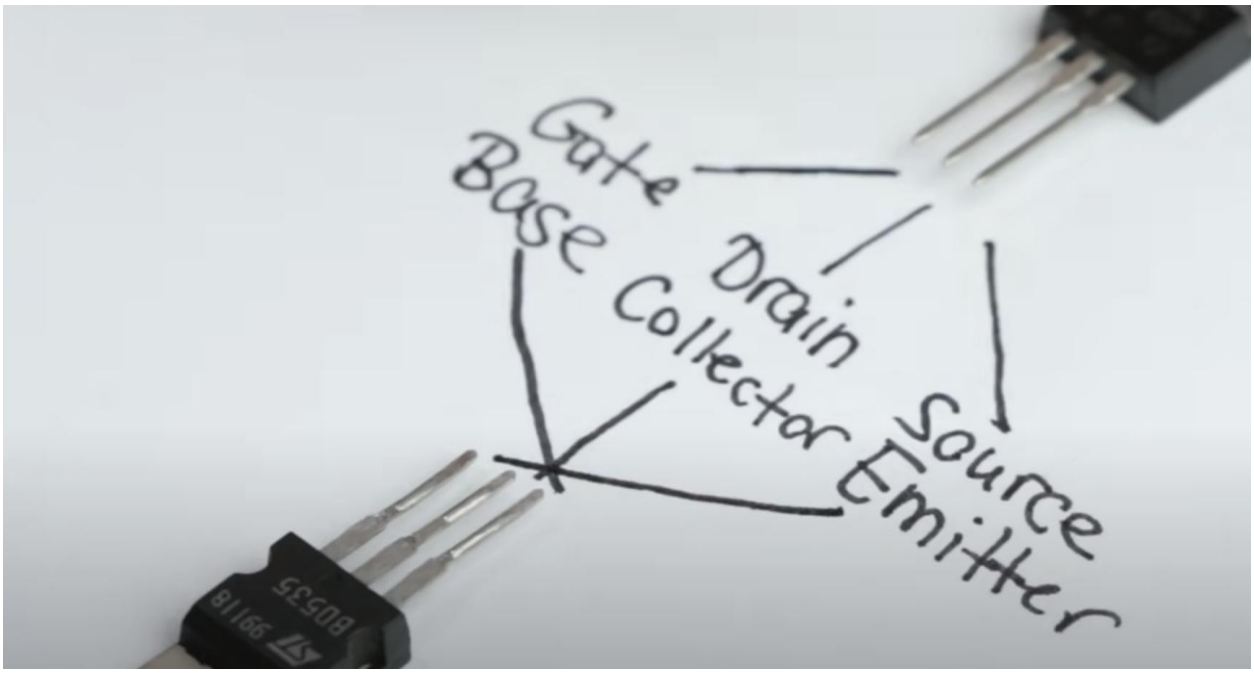
Types of MOSFETs

There are two main types of MOSFETs: N-Channel and P-Channel. N-Channel MOSFETs, such as the IRLZ44N, are more commonly used. P-Channel MOSFETs are less common but can be useful in specific applications where an N-Channel MOSFET may not be ideal.



MOSFET Pins and Operation

A MOSFET has three terminals: Gate (G), Drain (D), and Source (S). These are equivalent to the Base, Collector, and Emitter of a BJT, respectively. Unlike BJTs, MOSFETs require voltage at the gate rather than current to switch on. The voltage applied to the gate must be higher than the threshold voltage mentioned in the datasheet but must remain below the maximum rated gate-source voltage to prevent damage.



MOSFET as a Switch with Arduino

To use a MOSFET as a switch with an Arduino, the Source is connected to Ground, the Drain is connected to the cathode of an LED, and the anode of the LED is connected to the power supply. A 10kΩ pull-down resistor is placed between the Gate and Source to prevent accidental switching. The PWM (Pulse Width Modulation) signal from the Arduino is then applied to the Gate to control the MOSFET.

When the Arduino output is HIGH, the drain-source voltage is LOW, turning the LED ON. Conversely, when the Arduino output is LOW, the drain-source voltage is HIGH, turning the LED OFF. By incorporating a potentiometer with the Arduino, we can create an LED dimmer.

Bootstrapping and P-Channel MOSFETs

If the load voltage is higher, a simple 5V gate signal may not be sufficient to turn on the MOSFET. One solution is bootstrapping, which involves using specialized ICs to increase the gate voltage. A simpler alternative is to use a P-Channel MOSFET instead of an N-Channel MOSFET. In

this case, a pull-up resistor is used instead of a pull-down resistor, and +5V turns the MOSFET OFF while 0V turns it ON.

Oscillations and Gate Drive Considerations

Large loads may cause parasitic capacitances that lead to oscillations. For example, when switching off, a MOSFET can experience voltage spikes of up to 64V. These oscillations are caused by parasitic capacitances within the MOSFET, inductance from wiring, and rapid current changes (high di/dt).

Reducing Oscillations

To limit oscillations, a series gate resistor can be used to control the peak gate current. For instance, using a 1.15Ω resistor results in a peak gate current of 113mA. By increasing the resistance to 470Ω, the peak gate current is reduced to 11mA, slowing down switching and reducing oscillations.

Switching Losses and Frequency Considerations

As switching frequency increases, the required gate current also increases. High-frequency operation can lead to switching losses. For example, at 490 Hz (Arduino PWM frequency), losses are negligible, but at 1 MHz, switching losses can reach 80mW. To address this, MOSFET driver ICs can be used to ensure efficient high-frequency switching.