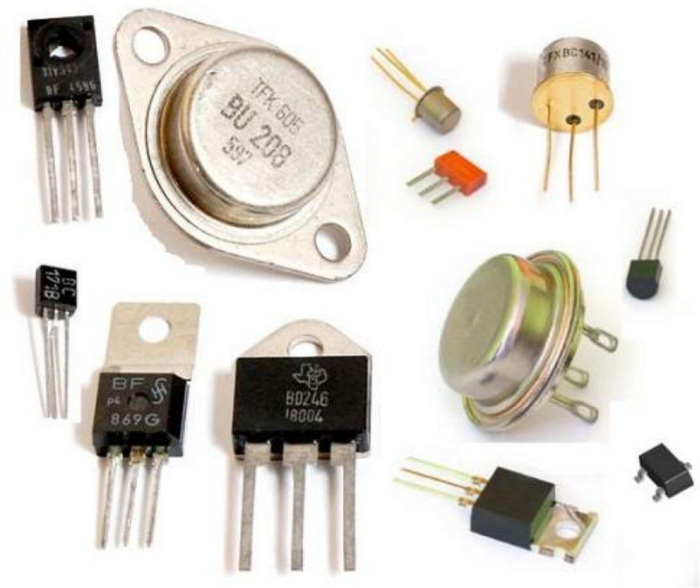
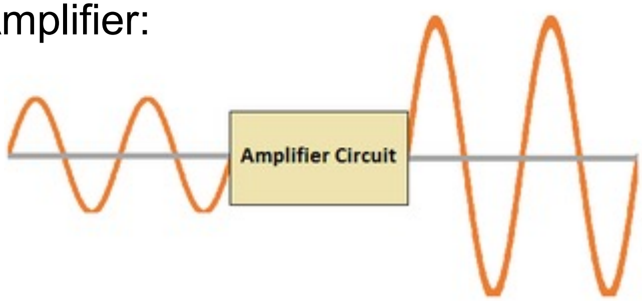
Challenge 2
CS-EEE

Introduction to
Transistors

What is Transistors?



- Amplifier:



- Switches:

It comes in various forms and packages but

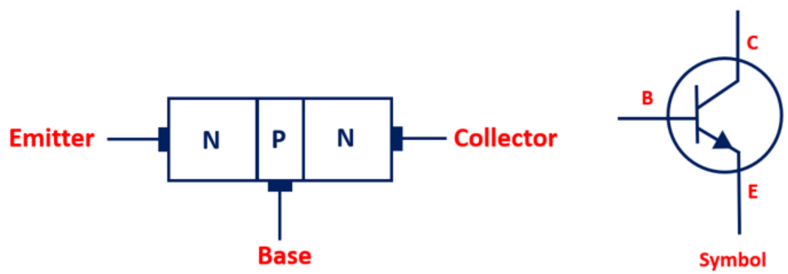
- It has three terminals
- Two types: BJT and MOSFET

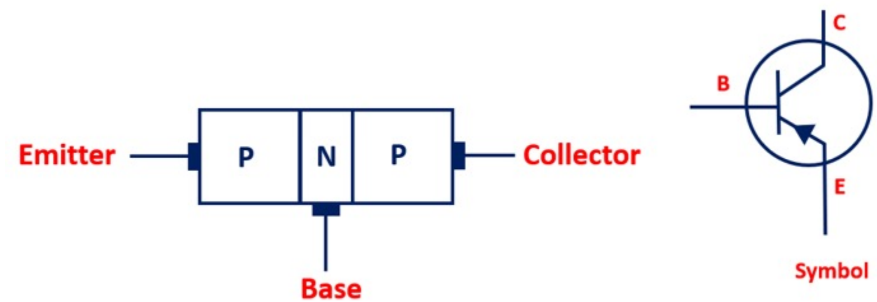
A semiconductor device used to:

- amplify signal
- switch electrical signals and **power**.

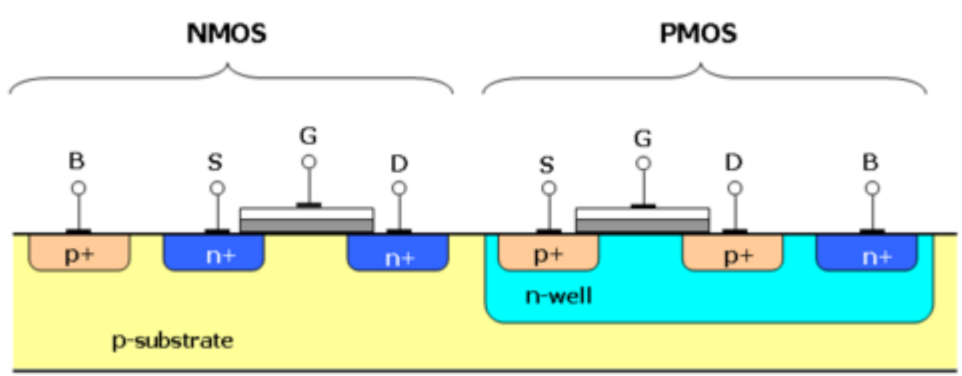
Transistor Types

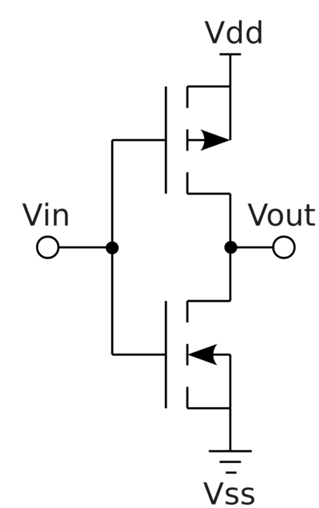
Bipolar Junction Transistor





Complementary metal–oxide–semiconductor (CMOS)





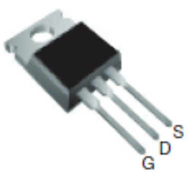
Transistor Types

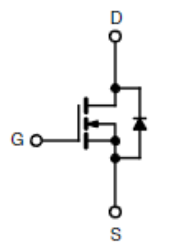
Characteristic	MOSFET	BJT (NPN/PNP)
Transistor Types	N-Channel (e.g., IRF520, IRF740), P-Channel (e.g., IRF9530, IRF9630)	NPN (e.g., 2N3904, BC547), PNP (e.g., 2N3906, BC557)
Input Control	Voltage-controlled device	Current-controlled device
Input Impedance	Extremely high	Moderate to low
Switching Speed	Very fast (e.g., nanoseconds to microseconds)	Fast to moderate (e.g., microseconds to milliseconds)
Voltage Rating	low to high voltage	low to moderate voltage
Current Rating	low to high current	low to moderate current
Applications	Digital and analog applications	Amplification, switching, signal processing

How do they work? At entry level

- **Symbol of MOSFET**

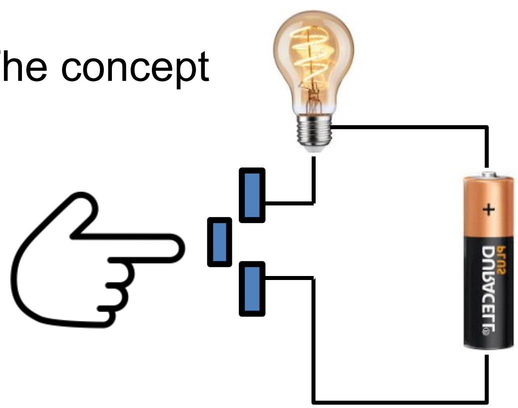
TO-220AB





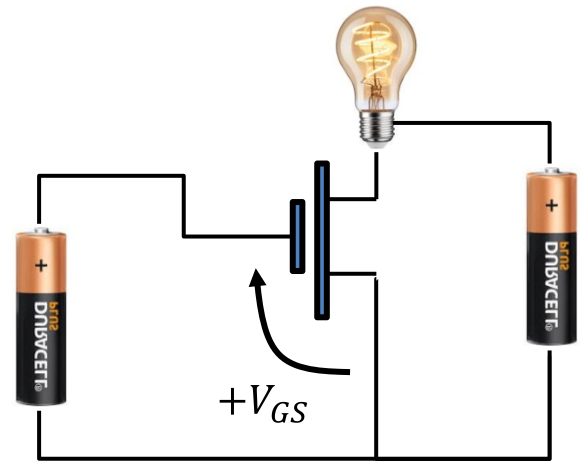
N-Channel MOSFET

- The concept



- Functions as a switch with a control terminal

- The circuit implementation



- A positive V_{GS}
- Drain (D) and Source (S) are connected like a switch!

- The V_{GS} must be large enough to turn on the switch, hence larger then a V_{TH}

- Control the gate voltage to control the current flows through the light bulb

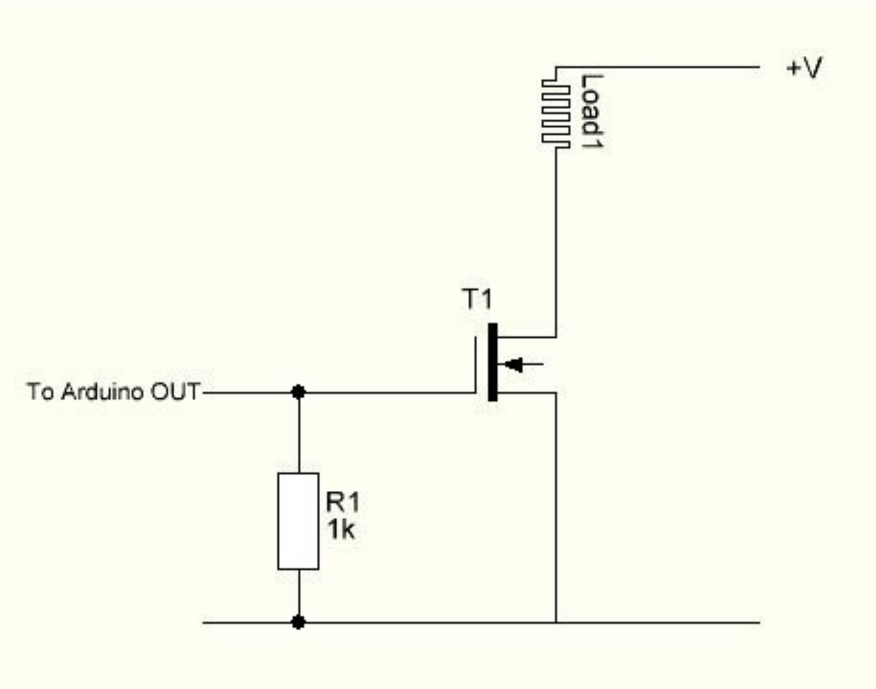
How to use it?

- The transistor in serial with the load
- The gate of the transistor is connected to the selected IO pins from Arduino.
- R1 is called a pull-down resistor
- When the IO pin is high, 5V is connected to the transistor, and turn it on
- Current flows from supply +V to the Load.

If +V = 5V, can we use IO pin to connect to the load?

Can we connect the load on the other side of the transistor?

Circuit schematics



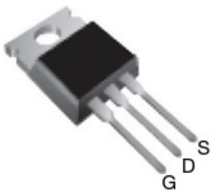
More about transistors

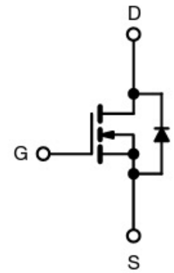
IRF520

www.vishay.com

Vishay Siliconix

TO-220AB





N-Channel MOSFET

PRODUCT SUMMARY		
V_{DS} (V)	100	
$R_{DS(on)}$ (Ω)	V_{GS} = 10 V	0.27
Q_g max. (nC)	16	
Q_{gs} (nC)	4.4	
Q_{gd} (nC)	7.7	
Configuration	Single	

ABSOLUTE MAXIMUM RATINGS (T_C = 25 °C, unless otherwise noted)

PARAMETER			SYMBOL	LIMIT	UNIT
Drain-source voltage			V_{DS}	100	V
Gate-source voltage			V_{GS}	± 20	
Continuous drain current	V_{GS} at 10 V	T_C = 25 °C	I_D	9.2	A
		T_C = 100 °C		6.5	

Gate-source threshold voltage	$V_{GS(th)}$	$V_{DS} = V_{GS}$, I_D = 250 μA	2.0	-	4.0	V

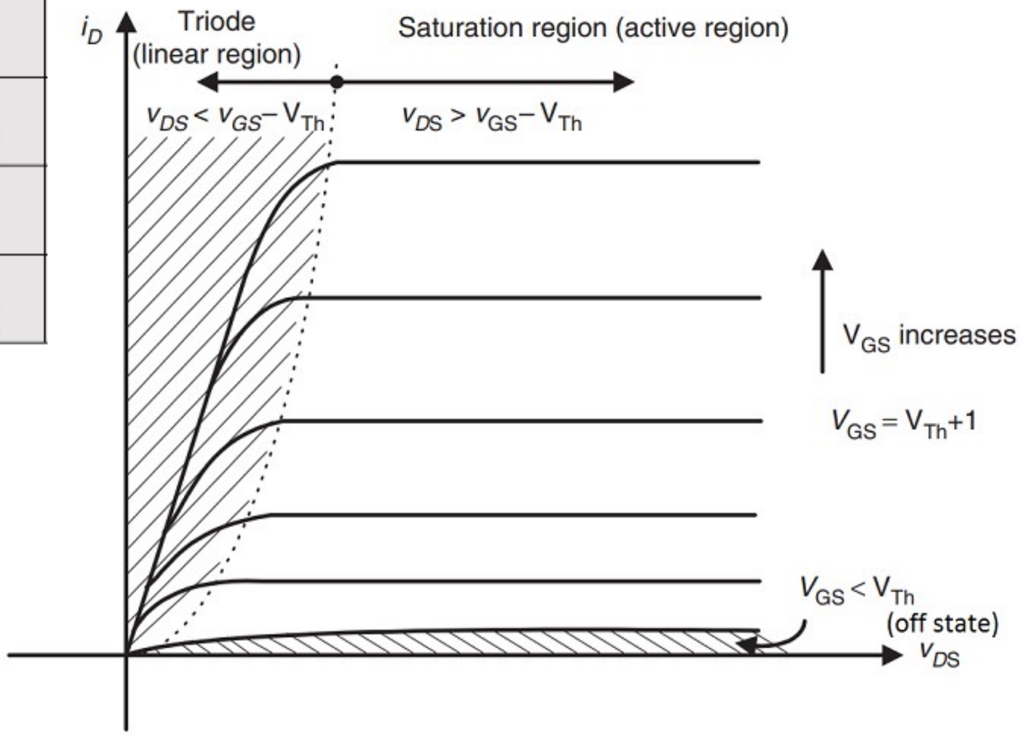
IRF520

Vishay Siliconix

www.vishay.com

Regions of operations of MOSFET

Operation Mode	Type	Condition
Cut-Off	NMOS	$V_{GS} < V_{TH}$
	PMOS	$\lvert V_{GS}\rvert < \lvert V_{TH}\rvert$
Linear	NMOS	$V_{GS} \geq V_{TH}$ $V_{DS} \leq V_{GS} - V_{TH}$
	PMOS	$\lvert V_{GS}\rvert \geq \lvert V_{TH}\rvert$ $\lvert V_{DS}\rvert \leq \lvert V_{GS}\rvert - \lvert V_{TH}\rvert$
Saturation	NMOS	$V_{GS} \geq V_{TH}$ $V_{DS} \geq V_{GS} - V_{TH}$
	PMOS	$\lvert V_{GS}\rvert \geq \lvert V_{TH}\rvert$ $\lvert V_{DS}\rvert \geq \lvert V_{GS}\rvert - \lvert V_{TH}\rvert$



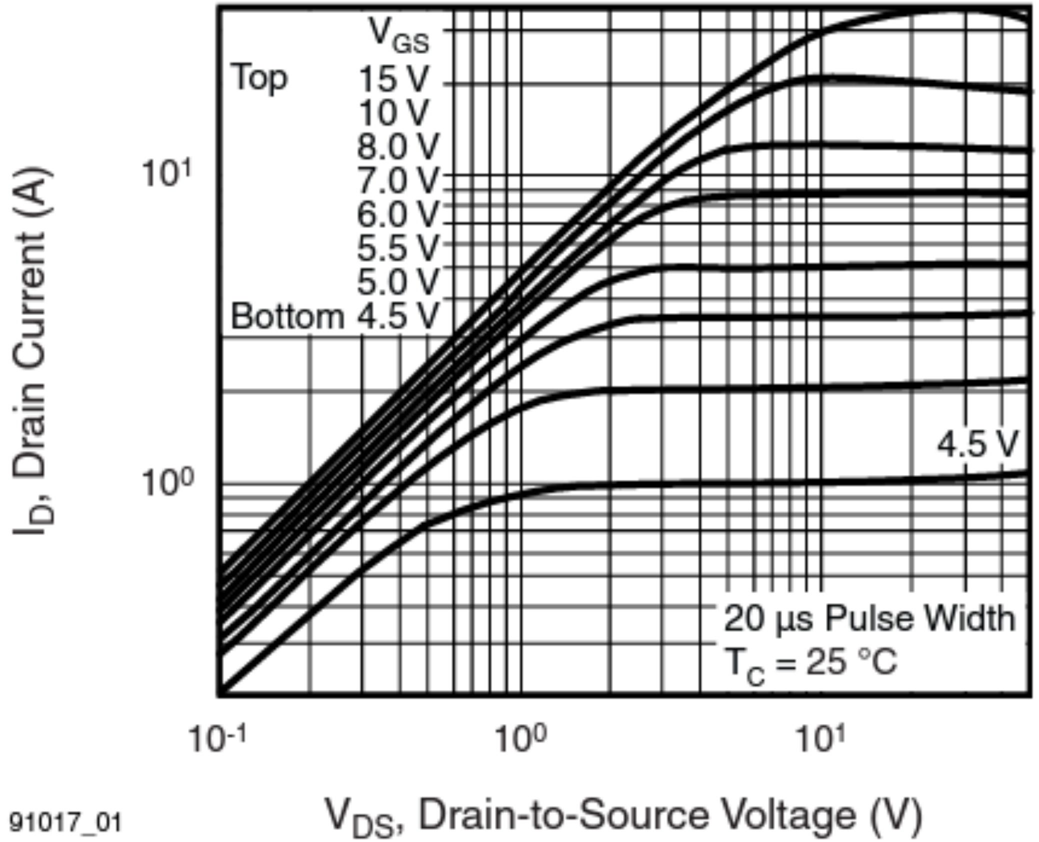
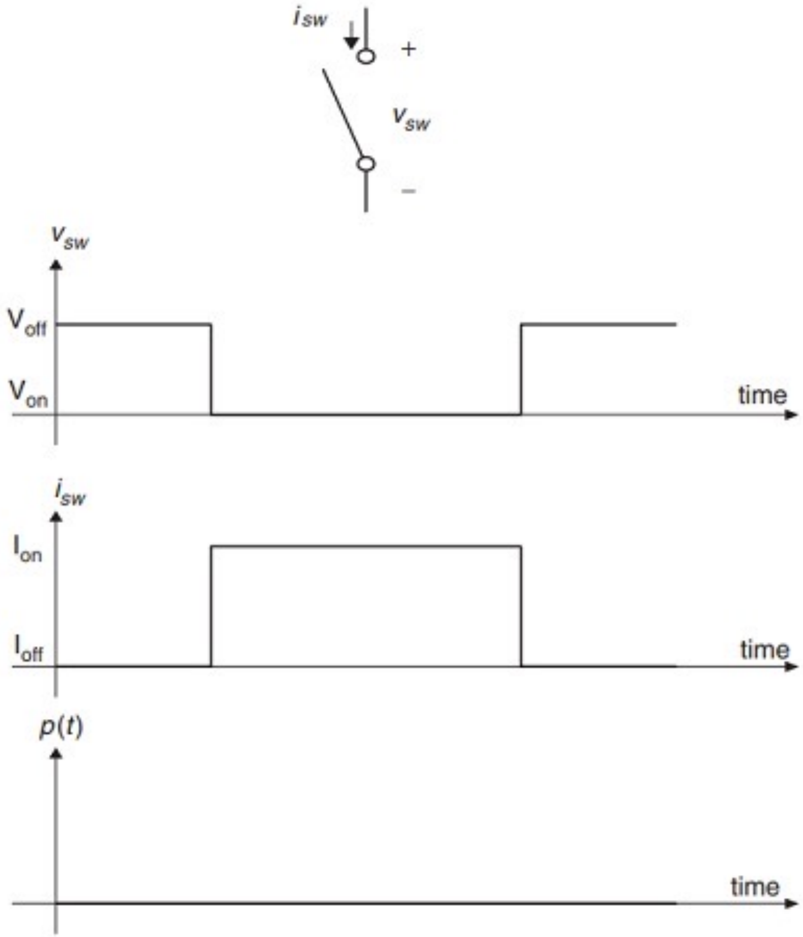


Fig. 1 - Typical Output Characteristics, $T_C = 25$ °C

Ideal Switch vs. Practical Switch



ON state:

- No limit on the current it can carry.
- Zero voltage drop.

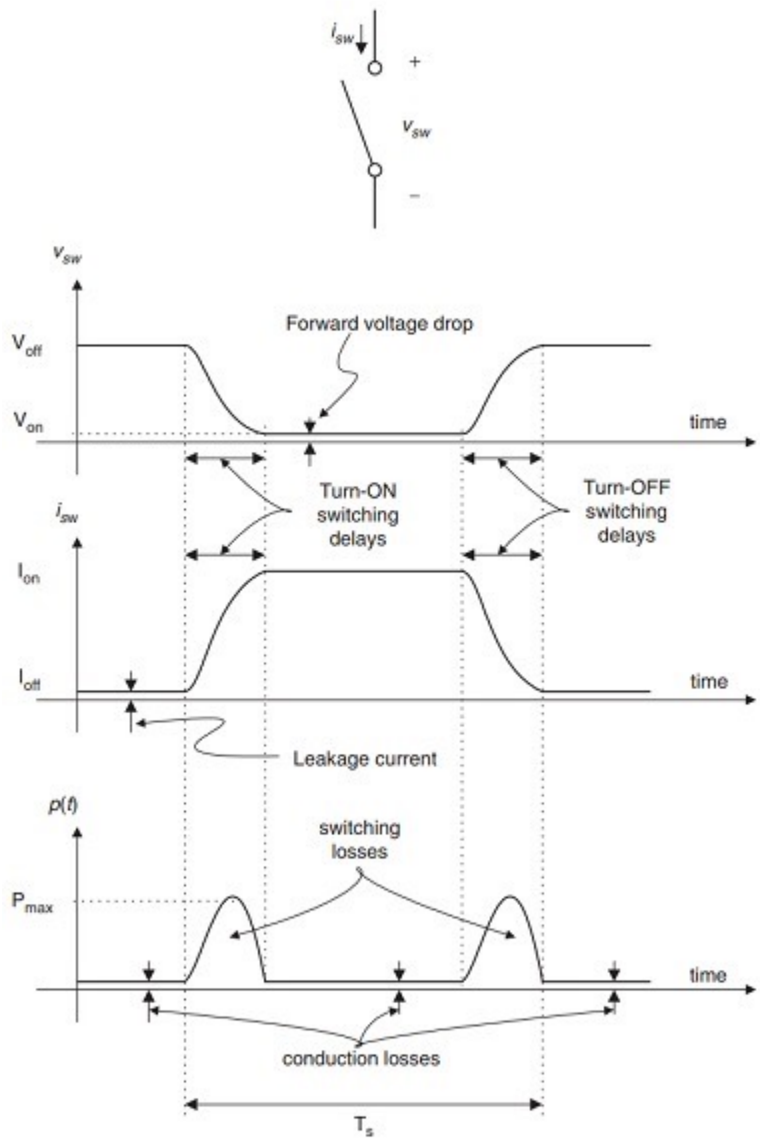
OFF state:

- No limit on the blocking voltage.
- OFF state resistance should be infinite.

The operating speed of the device has no limits.

Ref: https://www.electronicshub.org/mosfet-as-a-switch/

Reality Check



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Power handling capabilities

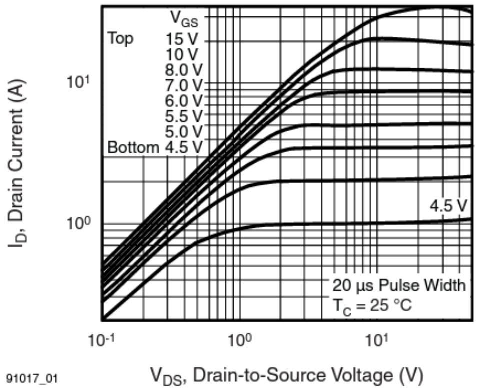


Fig. 1 - Typical Output Characteristics, T_C = 25 °C

Finite on-state resistance

$R_{DS(on)}$ (Ω)	V_{GS} = 10 V	0.27

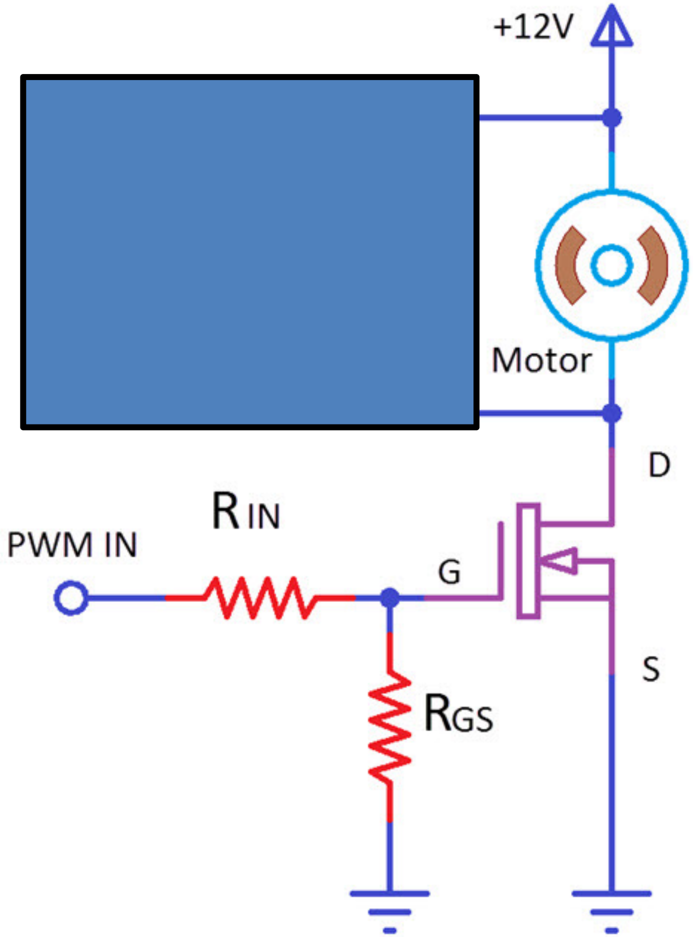
Finite off-state resistance, which results in a reverse leakage current and 100V max V_{DS}.

Limited speed of operation

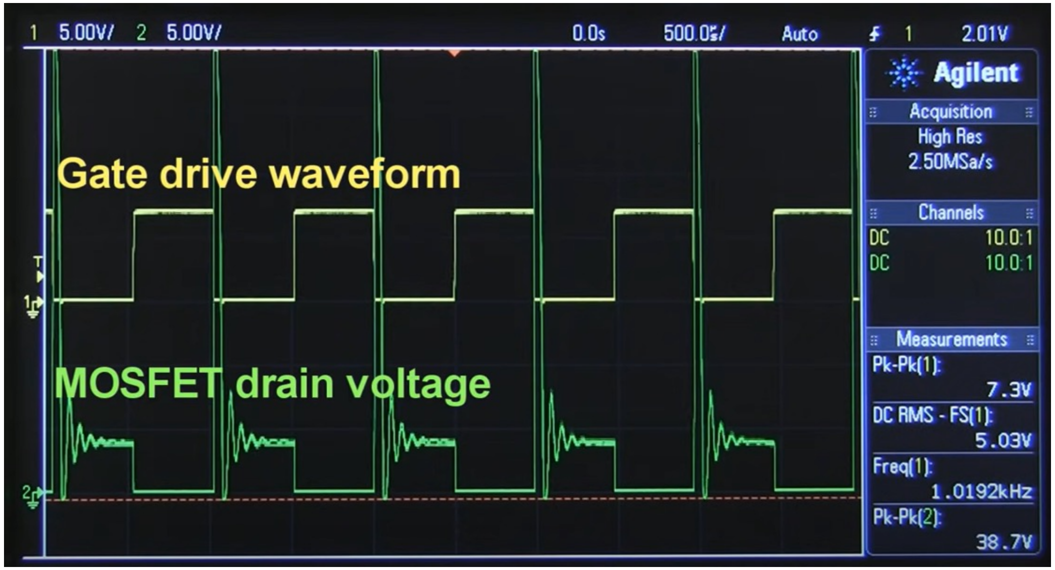
Power losses during the transition of states.

One more thing

Back EMF and flyback diode



Look at those spikes! And there is a limited on Vds



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https://youtu.be/LXGtE3X2k7Y?si=Y35UGmVnJL8Plsqc