Active electronic-MEC100x-Lectures 5

Energy, Power and Intelligent Control
School of Electronics, Electrical Engineering and Computer Science
Ashby Building
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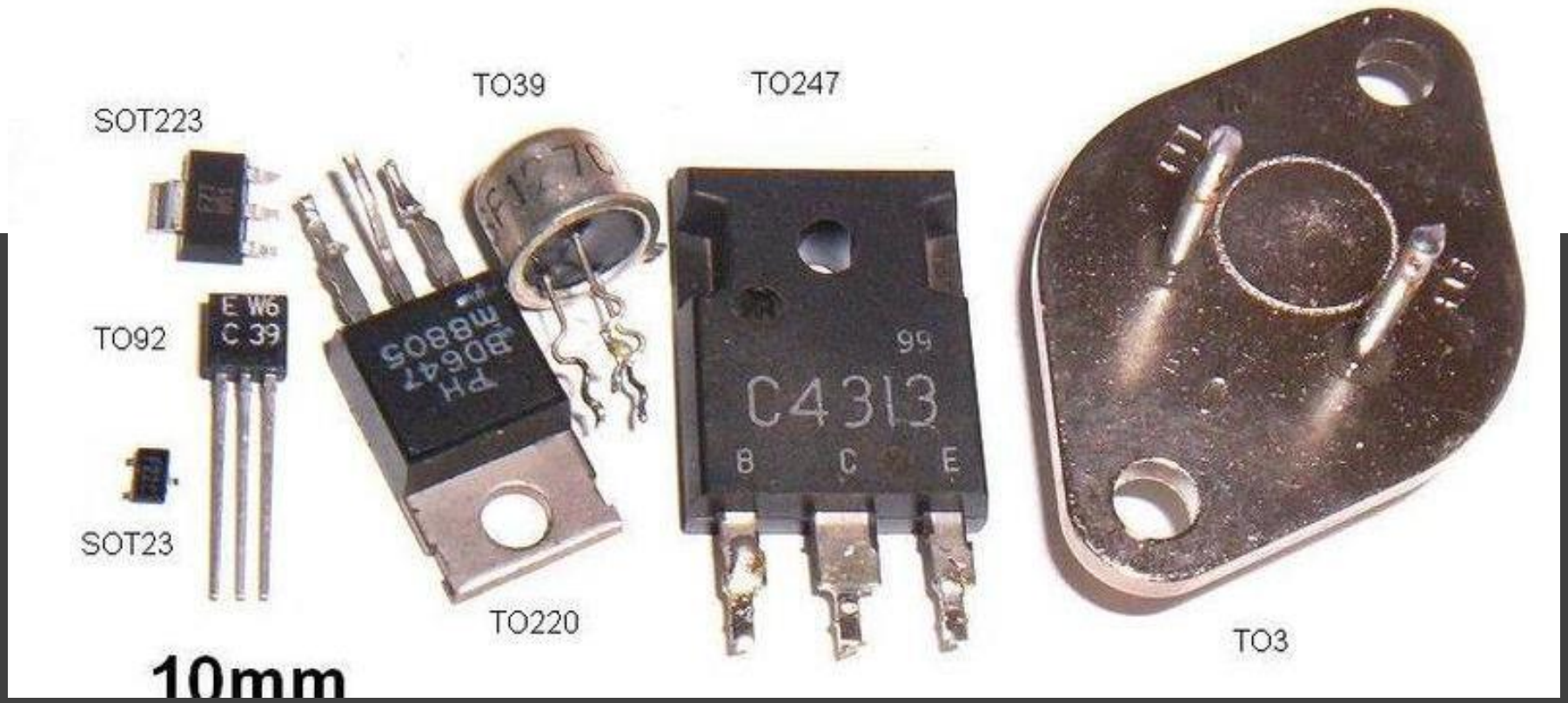
Aims

1. Electro-mechanical switches (Relay)
2. Solid state relay (SSR)
3. FET/MOSFET as ON/OFF switching

Active electronic (Transistors)



Amplification:

Magnify a signal (Voltage-Current) by transferring energy from an external sources.

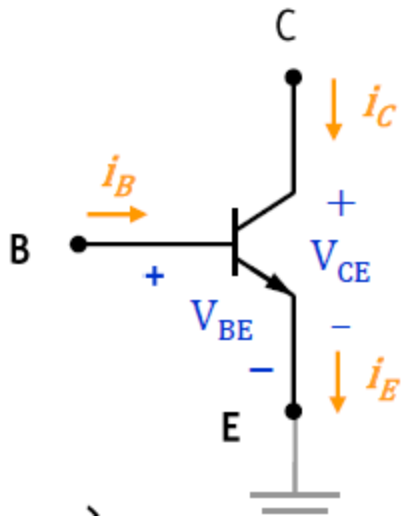
Switching:

Controlling a relative large current between or voltage Across two terminals using a small control current or voltage.

In Cut-off and Saturation Regions, BJT acts as a Switch

Cut-off: Open Switch

Voltage V_{CE} can be viewed as a open switch.



$$i_B = 0; \quad i_C \approx 0; \quad V_{BE} < V_F; \quad V_{CE} \geq 0$$

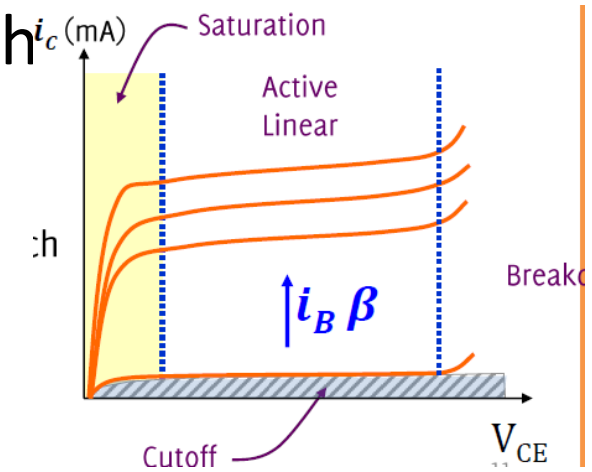
Saturation:

Closed Switch: Max collector current

Voltage V_{CE} can be viewed as a open switch

$$i_B > \frac{i_C}{\beta}; \quad V_{BE} = V_F;$$

$$V_{CE} = V_{SAT} \approx 0.2\,V$$



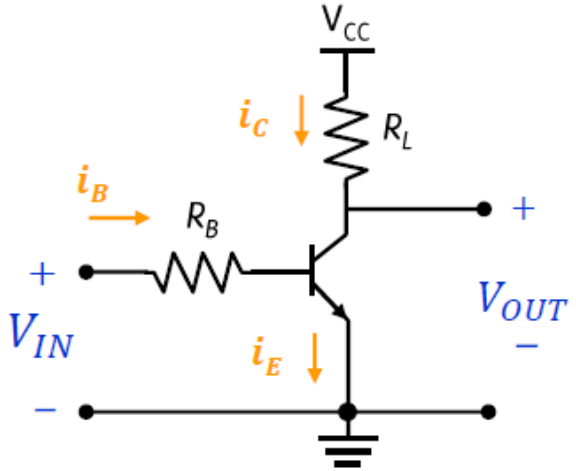
Point A:

$iB \approx 0$ or small VIN < 0.6 V

Transistor is cut-off

$iC \approx iE \approx 0 \Rightarrow$ VOUT $\approx$ VCC

Switch is Open!



Point B:

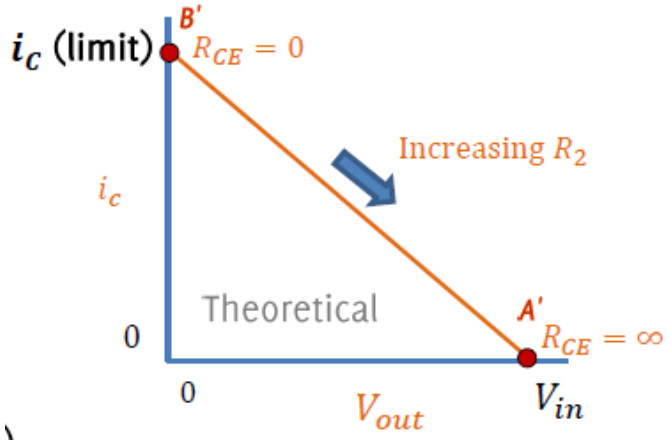
$iB > iB(sat)$ or large VIN > 0.7 V

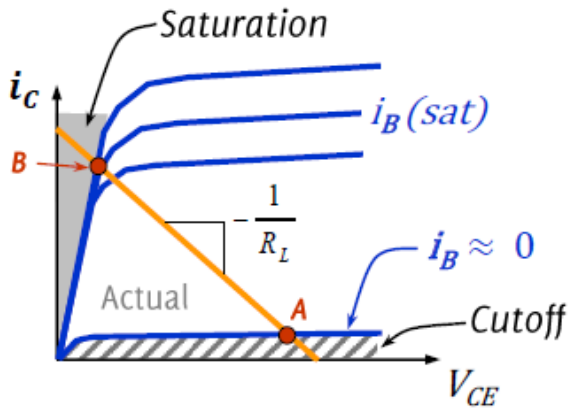
Transistor is saturated.

$VOUT = VCE(sat) \approx 0.2$ V (very small)

Switch is closed!

$iB = VIN - VBE(SAT) \,/\, RB$;
$iC \approx VCC - VCE(SAT) \,/\, RL$

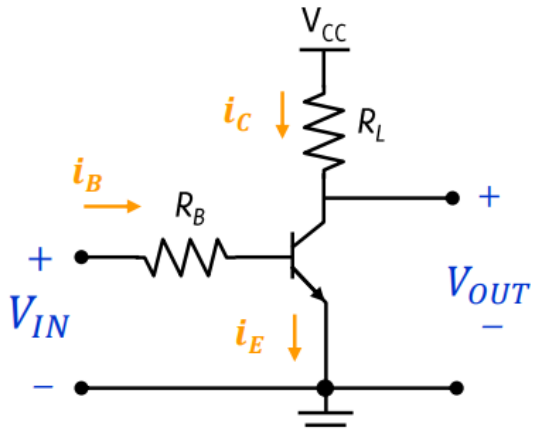


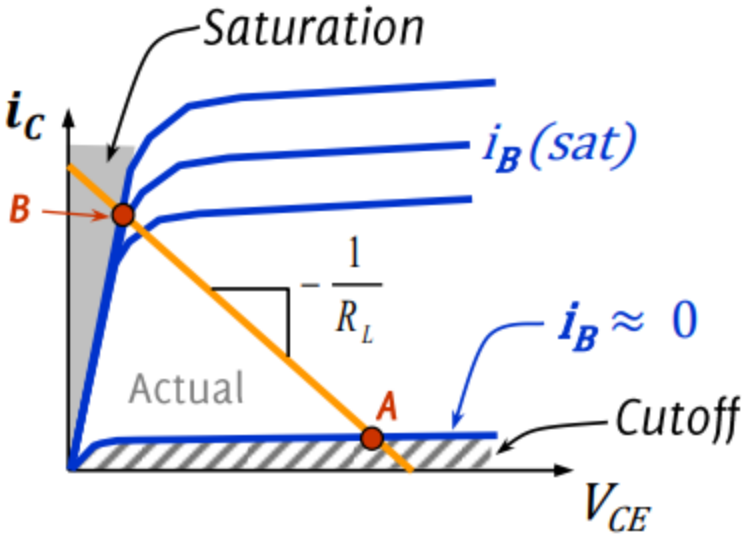


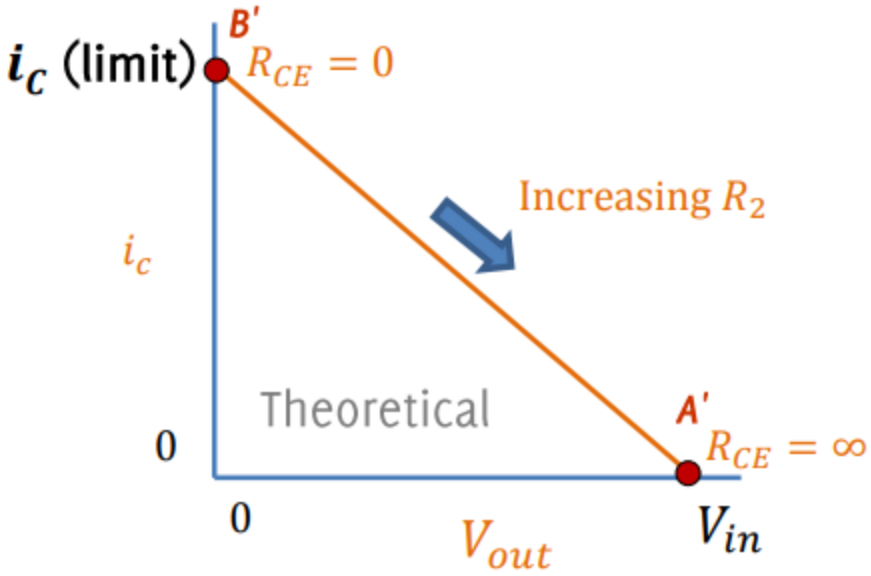
Based Current can toggle BJT Switch;

Choose circuit values such that, when Vin goes High;

$iB > iC(\text{limit})\ /10$







BJT Switch is not immediate and instantaneous;

t_D (Delay time)

When we apply ON-Voltage to Base of transistor. Transistor remains OFF after input current (Base Voltage-VB) is applied, the required time for this happening is T_D.

t_R (Rise time)

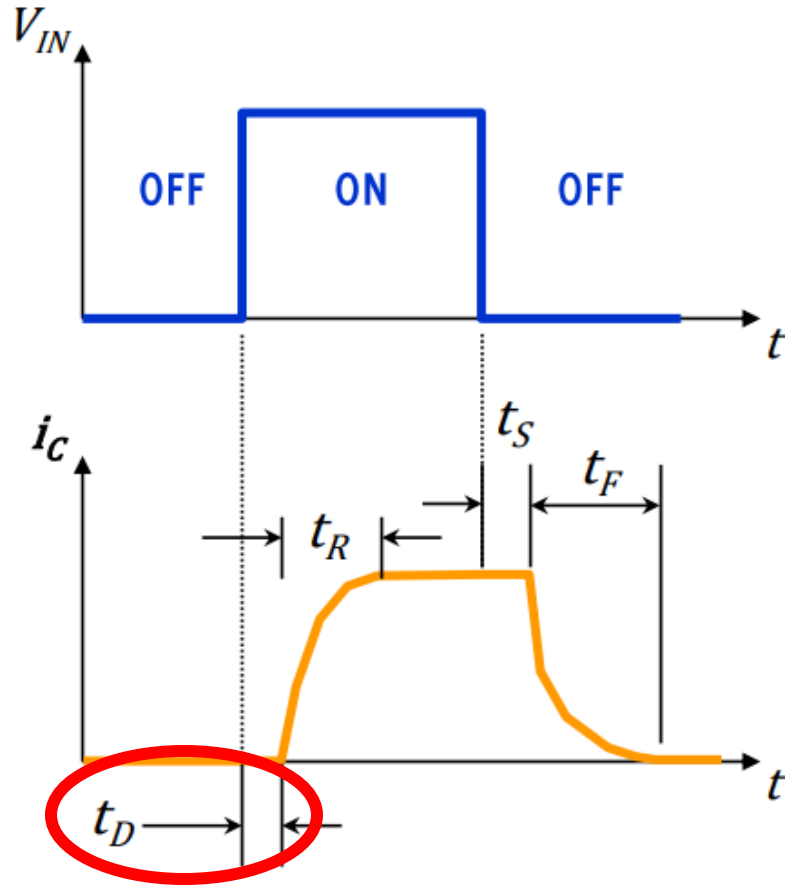
Required Time to reach 90% of final voltage value.

t_S (Storage time)

Required Time remains close to the maximum value after input current is removed.

t_F (Fall time)

Required Time to fall the signal to below 10% of final voltage value.



BJT Switch is not immediate and instantaneous;

Turn-ON Time:

$t_{on} = t_r + t_d$

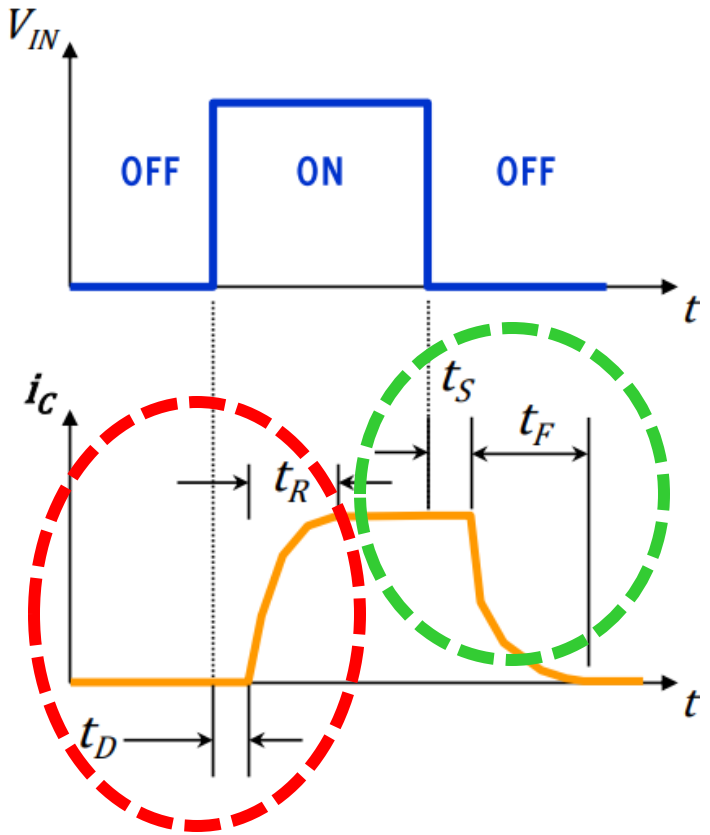
Turn-OFF Time:

$t_{off} = t_s + t_f$

Typical values for 2N3904 transistor:

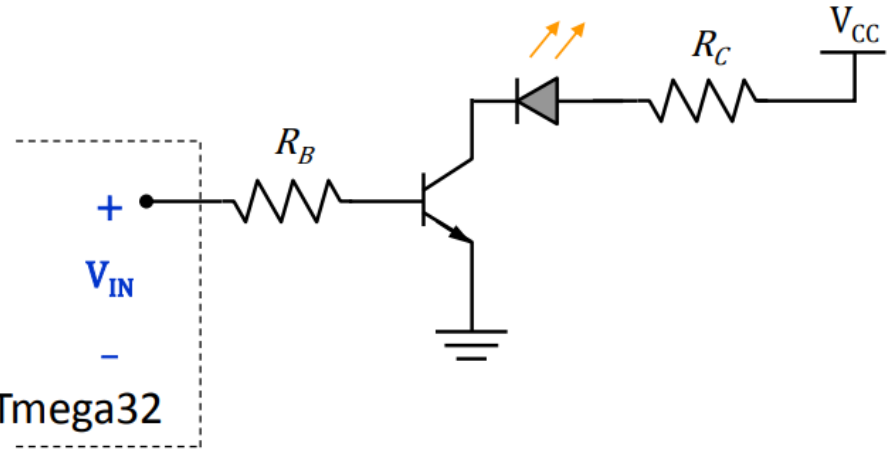
- t_d = 35 nsec
- t_r = 35 nsec
- t_s = 200 nsec
- t_f = 50 nsec

turn-ON time = 70 nsec
turn-OFF time = 250 nsec



Example: BJT as ON/OFF switch;

LED Driver:



Select RB to protect logic control circuit:

5 V: High level
0 V=Low level

Here; I going to calculate R_B (Base resistance):

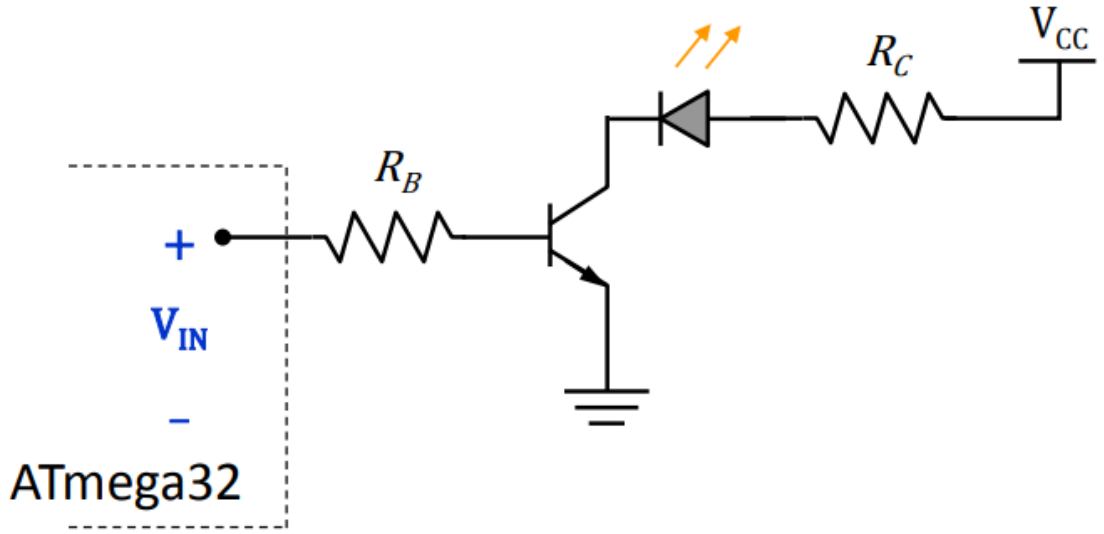
$R_B > (V_{IN} - V_F) / I_{DO,max} = 4.3\ \text{V} / 40\ \text{mA} = 107.5\ \Omega \approx 110\ \Omega$

$I_{DO,max}$; Is current can draw from Microcontroller and goes to the Base of transistor.

- Digital output can supply 40 mA when Vin is high.

Example: BJT as ON/OFF switch;

LED Driver:



How we can calculate Rc (collector resistance)? Select RC to protect LED:
VCC=5V

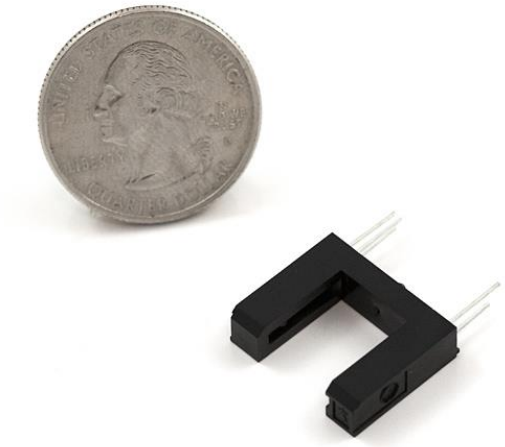
- (Maximum collector current: i_C (max))= Pmax /V_{LED} = 80 mW /2 V = 40 mA
- Rc (collector resistance) > $VCC - V_{LED} - V_{CE}(sat)/i_C$(max) = (5 − 2 − 0.2 V)/40 mA = 70 Ω
- To maintain hard saturation, $i_B > 4$ mA ⟹ $R_B < 1075$ Ω

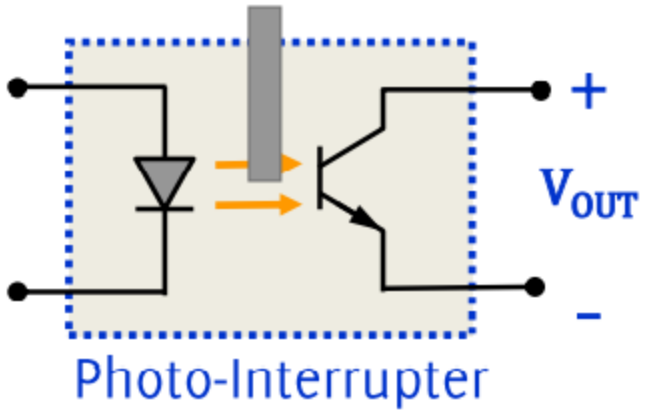
➢ we explained completely about calculation of i_C (max) , Rc (collector resistance) and RB

A photo-interrupter acts as an optical switch ;

Photo-interrupter: Pair of LED + Phototransistor

Can be used to detect **the presence of an object** that may partially or completely interrupt the light between LED and phototransistor.

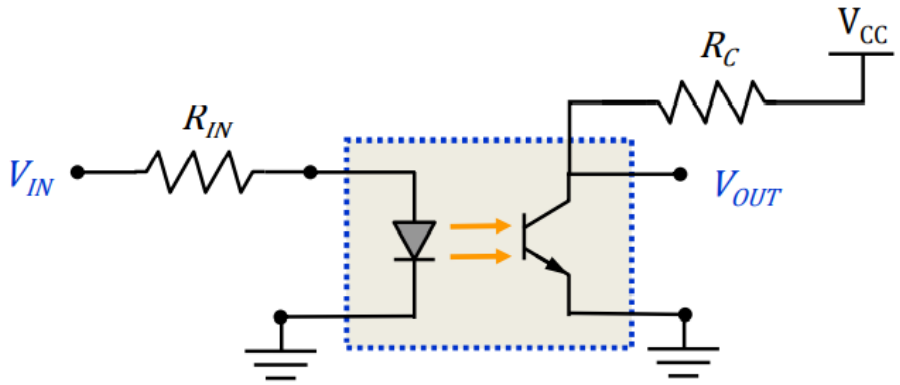


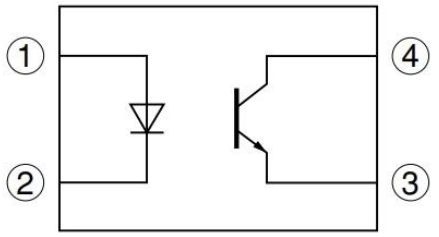


https://www.sparkfun.com/products/9299

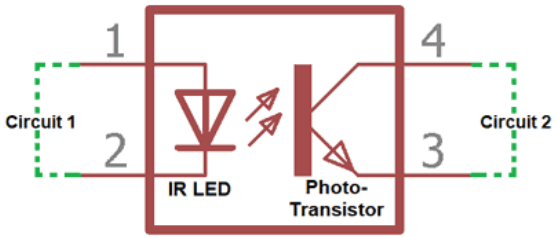
Opto-Isolator provides circuit separation;

Opto-coupler: Pair of LED + Phototransistor

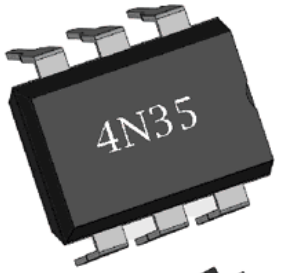


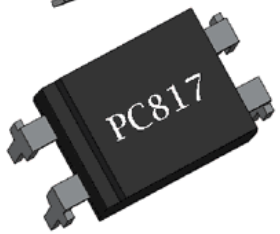


① Anode
② Cathode
③ Emitter
④ Collector



Opto-coupler





easybom™

https://www.easybom.com/blog/a/pc817-optocoupler-datasheet-pinout-circuits-arduino-examples

Electro-mechanical switches (Relay)

RELAY SWITCHES
ELECTRO-MECHANICAL Component

- A **very important component** in an Electrical Circuit.
- A relay is a simple electromechanical switch made up of an electromagnet and a set of contacts.

<u>Relay Construction</u>

Relays are amazingly simple devices.

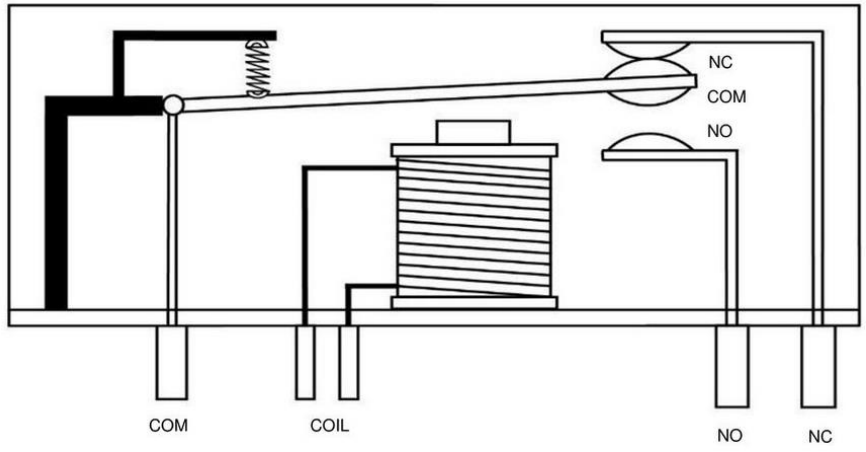
There are **four parts** in every relay:

1. Electromagnet

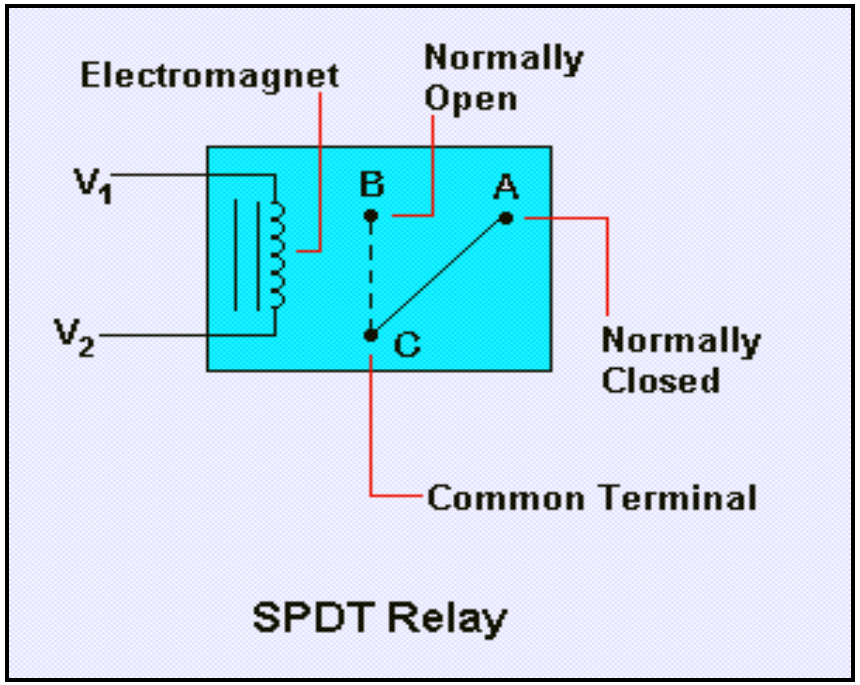
2. Armature that is attracted by the electromagnet

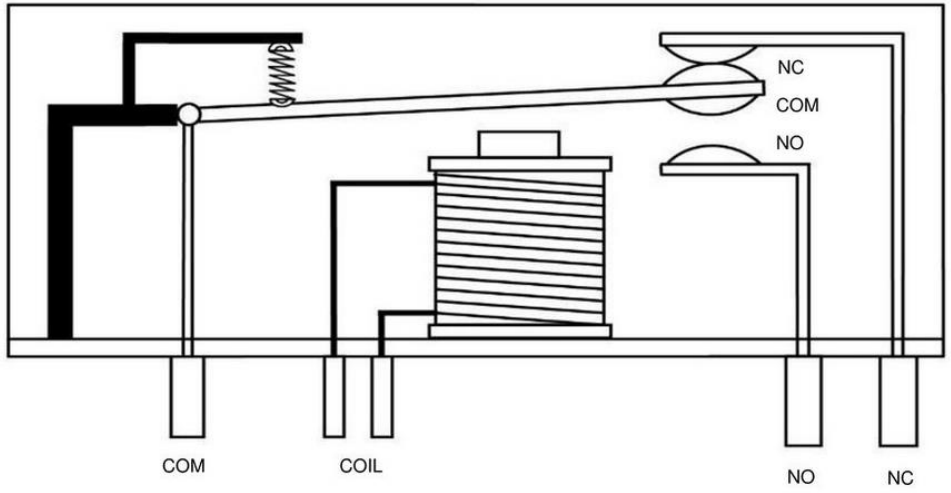
3. A **Spring**

4. A Set of **electrical contacts**



Relays





https://slideplayer.com/slide/16515619/

Factors when looking at a relay

We must pay attention to it:

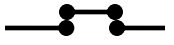
- Coil terminals
- Number of switching contact sets
- Rating of **the coil voltage**
- Rating of **the contact voltage and current**
- Structure of the **pin layout**

Contacts

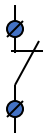
Symbol schematic of N.O and N.C

Normally Open Contact

Normally Closed Contact

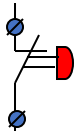


Normally Open Contact with terminals



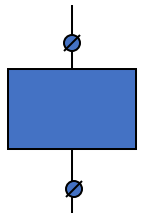
Normally Closed Contact with terminals

.Start Push Button (N.O Contact)

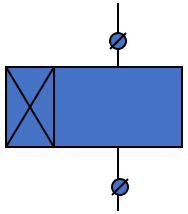


Stop Push Button (N.C Contact)

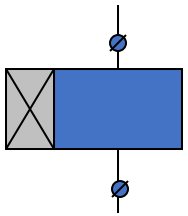
Relays & Coils



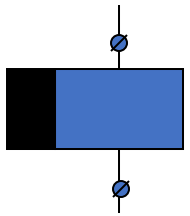
Relay coil / Contactor Coil



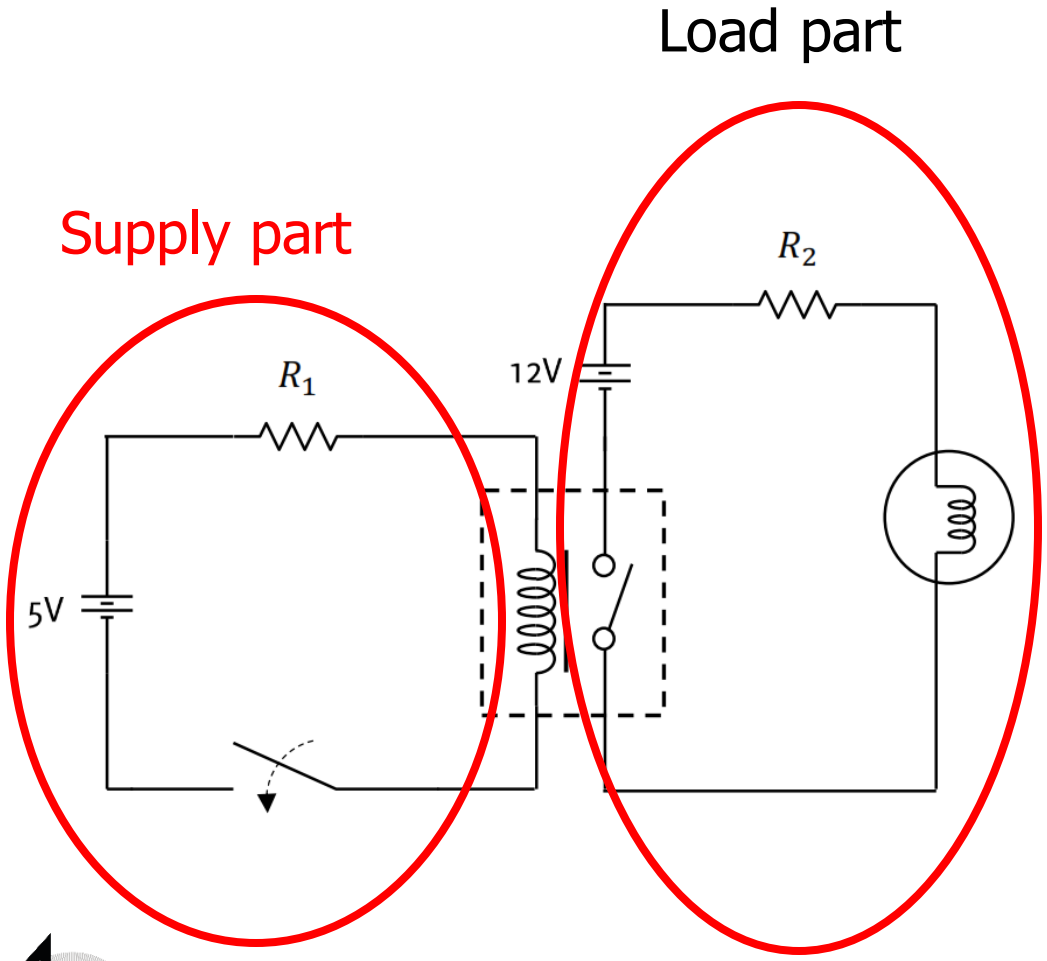
Timer Relay Coil (on Delay)

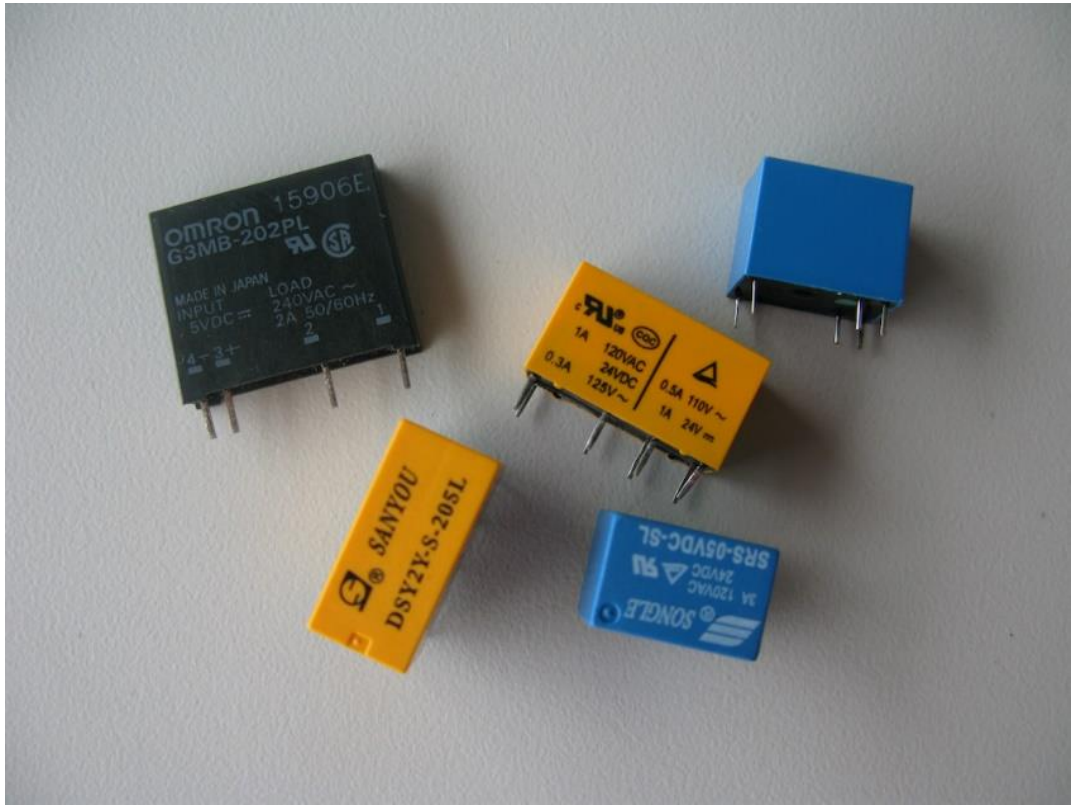


Timer Relay Coil (off Delay)



ELECTRO-MECHANICAL
RELAY SWITCHS can isolate electrical circuits



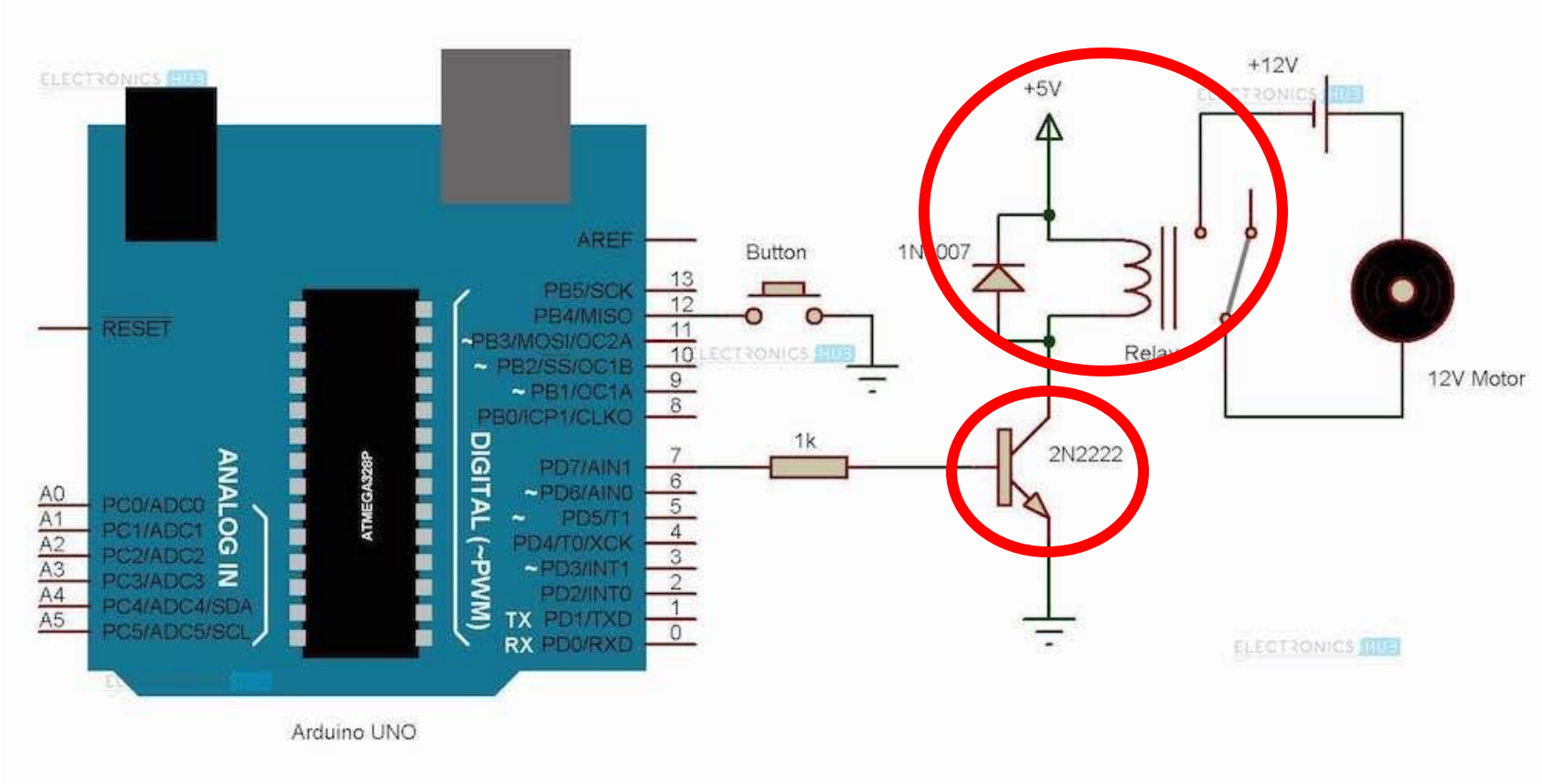


https://slab.concordia.ca/arduino/relays/

Interfacing ELECTRO-MECHANICAL, RELAY SWITCHS with Micro-Controllers

When Arduino sends High (1) command to BJT- BJT switch will be ON ---- Relay will br ON--- DC Motor will be ON.

When Arduino sends Low(0) command to BJT-BJT switch will be OFF ---- Relay will be OFF--- DC Motor will be OFF.



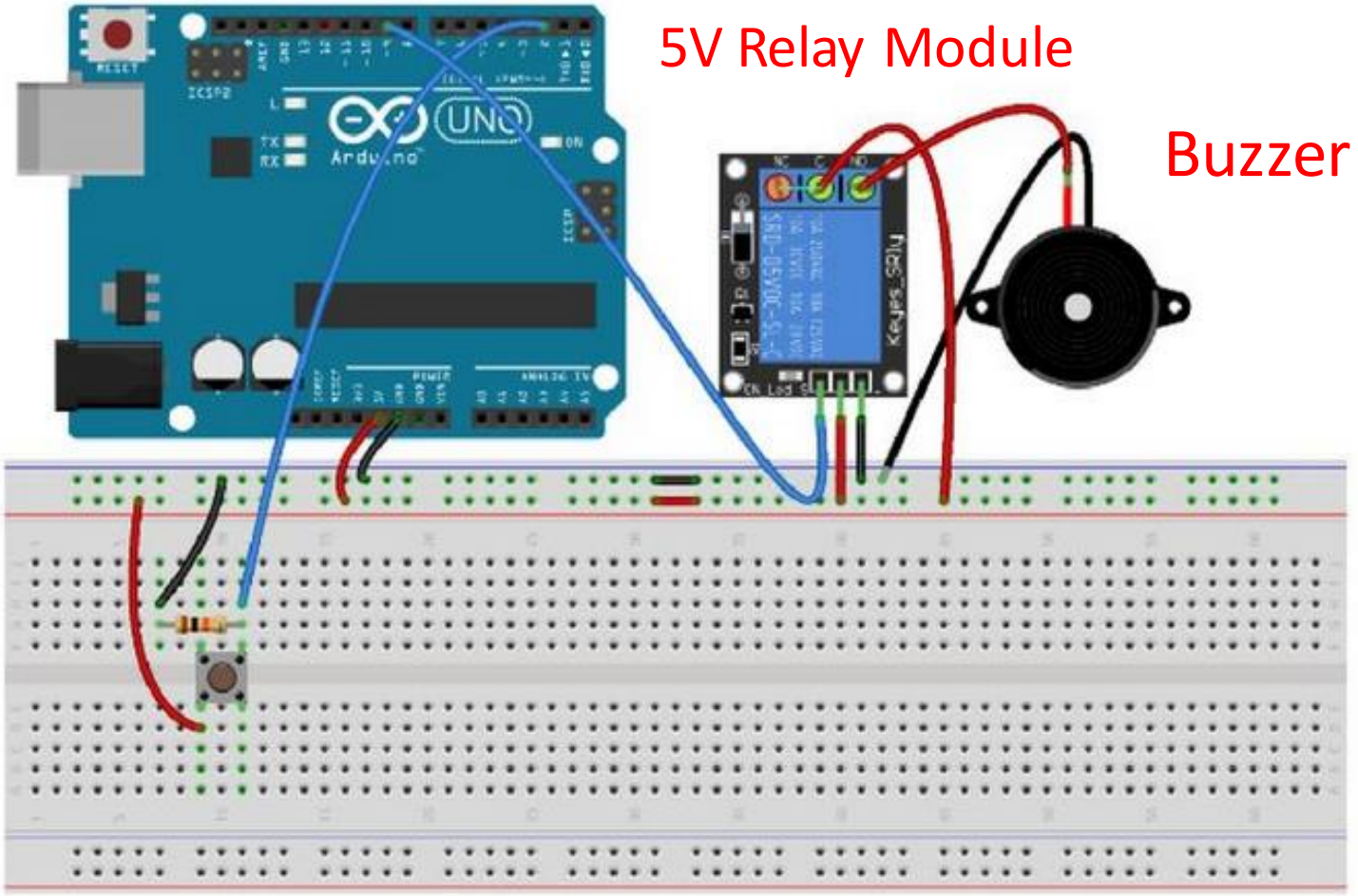
https://www.electronicshub.org/arduino-relay-control/

5V Relay Module

- The module provides all the required components (Protection diode- Transistor switch and current- limiting resistor) and an indicator LED.

ELECTRO-MECHANICAL Relay Exercise

- When the relay is ON then Buzzer should sound.



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ELECTRO-MECHANICAL Relay

- **Pros**
- Inexpensive
- Large selection
- Resistant to electrical surge

- **Cons**
- Bulky
- Slow (5 to 15msec) switching time
- Limited cycle rate

Solid State Relays (SSR)

- **What is Solid State Relay (SSR)?**

❑**Solid state relay (SSR)** is an electronic switching device made of **semiconductors** that switch (On & Off) a high voltage circuit using a low voltage at its control terminals.

❑Unlike **EMR (Electromagnetic relay)** that has a **coil & mechanical switch (physical contacts),** the SSR relay uses Optocoupler to isolate the control circuit from the controlled circuit.

Difference between SSR & EMR

The operation of **SSR (Solid State Relay)** and **EMR (Electromagnetic Relay)** or contact relay is same while the main different between SSR and EMR is that:

- **1- There are no mechanical parts and contacts in SSR relay.**
- 2- Other different between Solid State Relay and Electromagnetic relay are that **there is no surge and noise during the operation of SSR.**
- 3- There is a chance of leakage current about few µA to mA in SSR **relay while the value of leak current is Zero (0) in EMR.**
- 4- On the other hand, SSR switch OFF AC loads at the point **of 0 load current which leads to eliminate the noise,** contact bounce and electrical arcing in case of inductive load as compared to EMR relays.

Solid State Relays(SSR) with terminal designations Visible

1: 1,2 load terminal- load voltage can be vary between 24-380 VAC.

2: [+]: 3, is control logic input(can be High and Low) logic high can be up to 32V or as low as 3 V.

3: [-]: 4, is control logic ground

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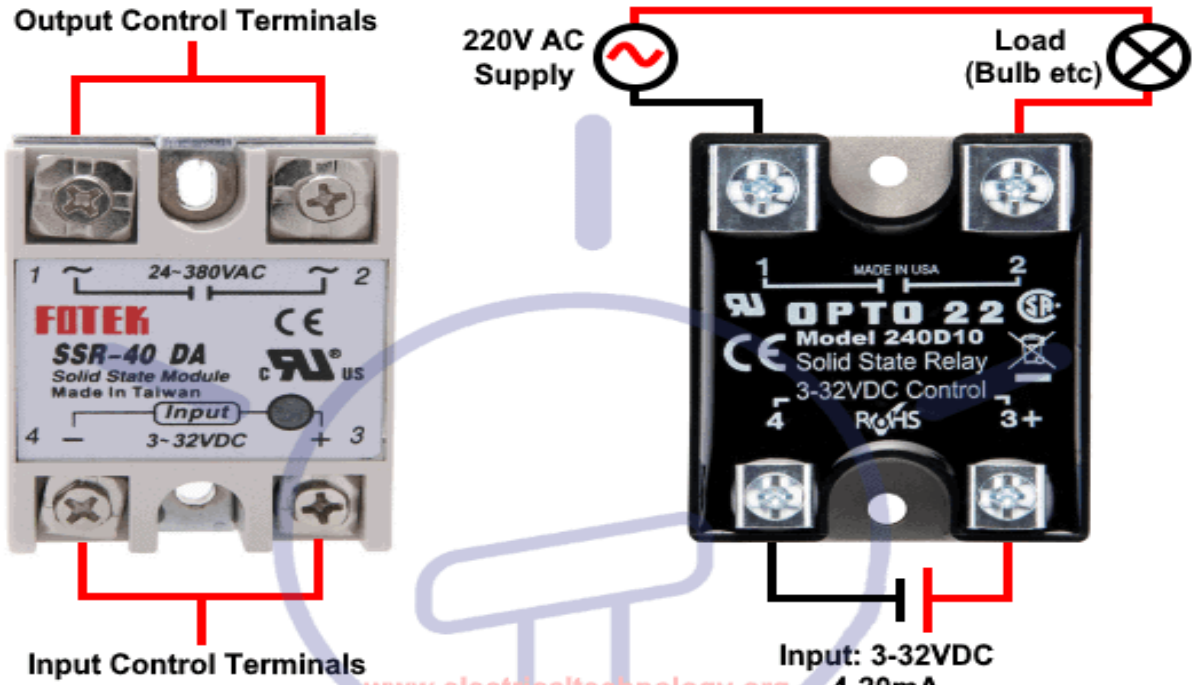
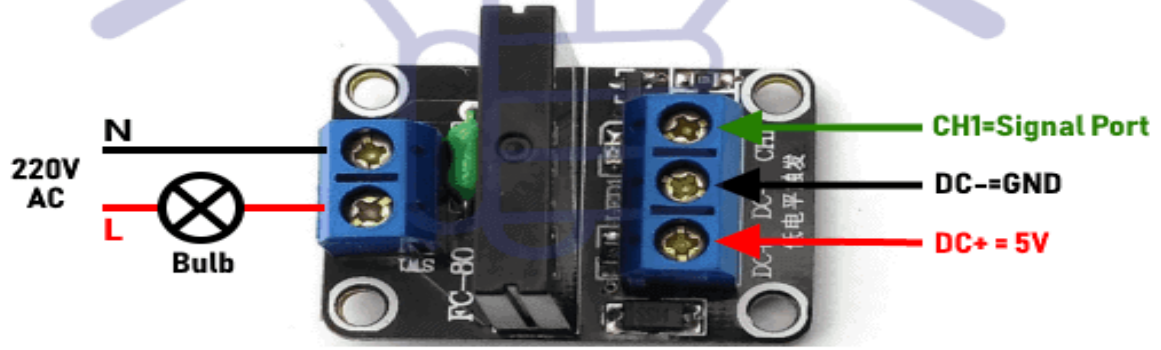
Solid State Relays(SSR)



SSR Relay Terminals & Connections

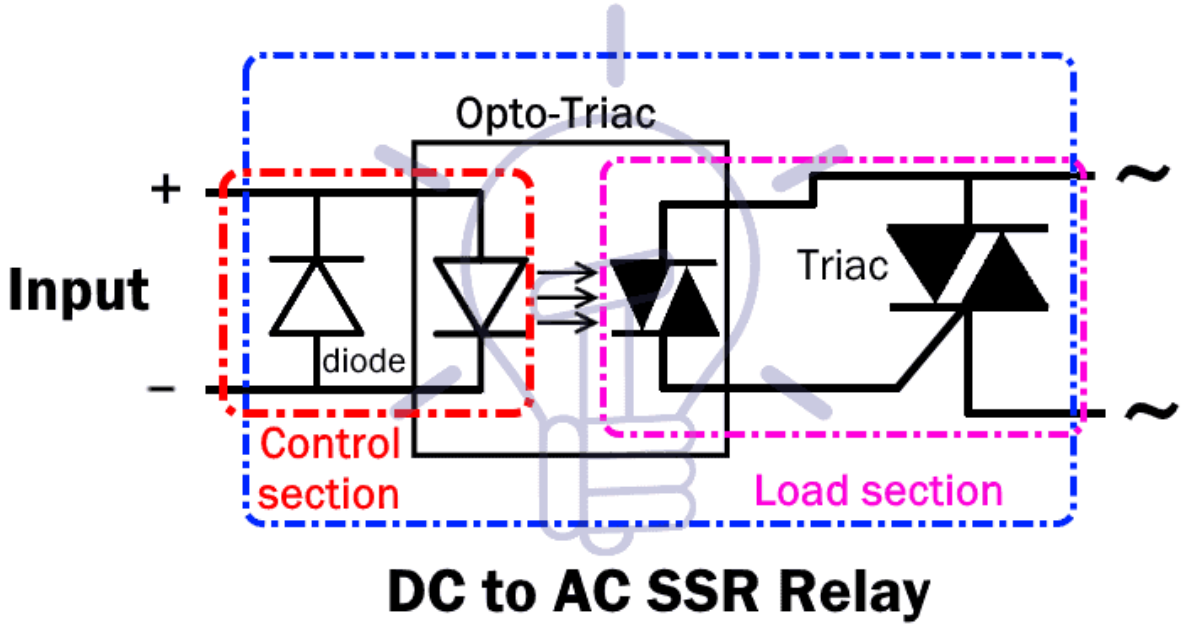


1-Channel 5V SSR Relay Connection

https://www.electricaltechnology.org/2019/01/solid-state-relay-types-of-ssr-relays.html

Schematic Model of SSR Relay

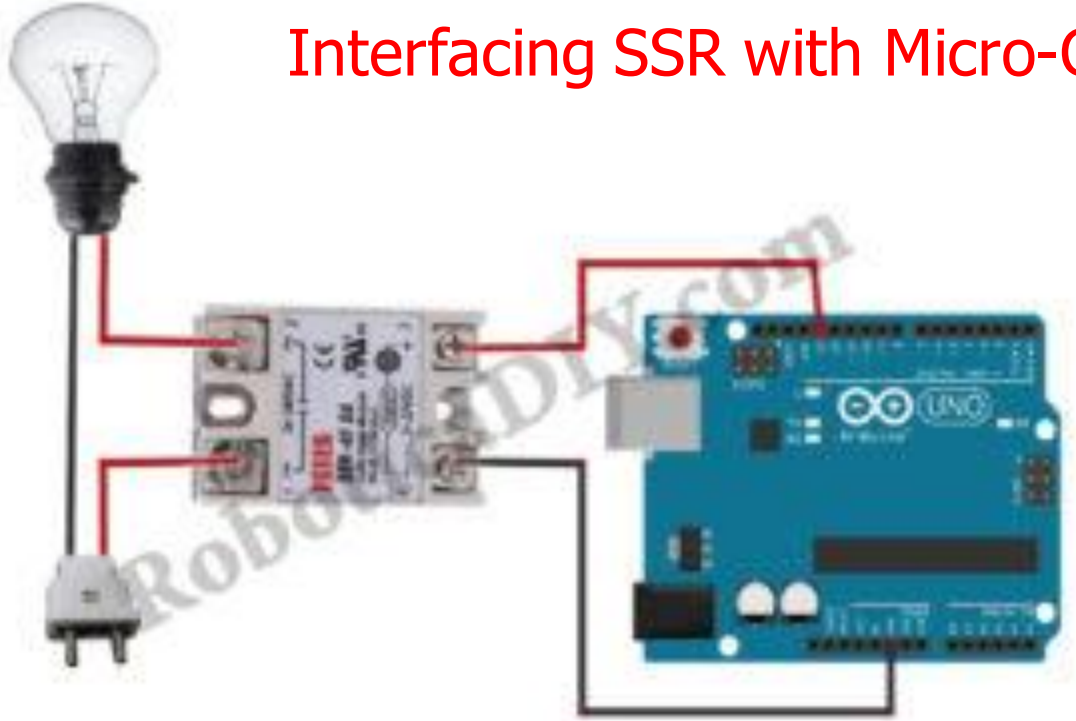
A general schematic for the operation of a **DC to AC SSR** relay's operation with model schematic is given below:



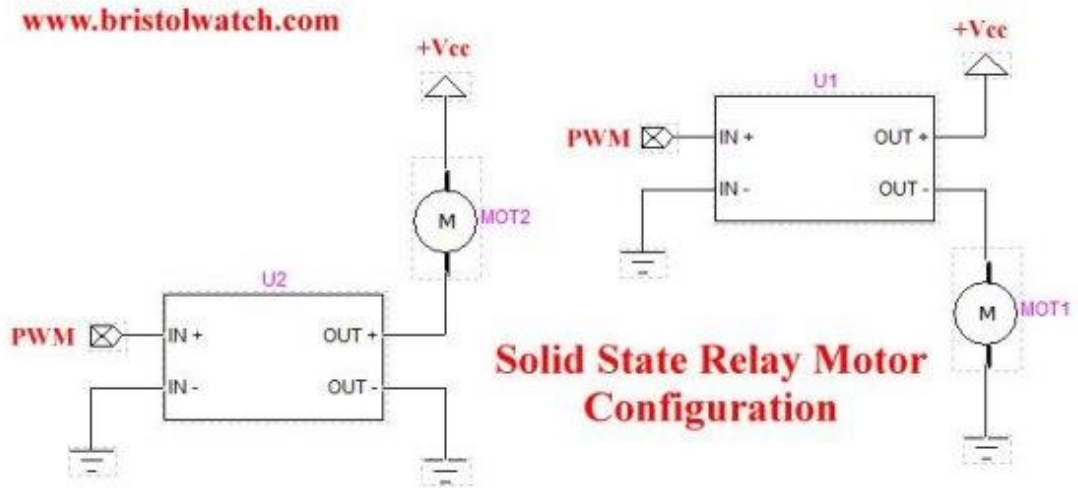
DC to AC SSR Relay

https://www.electricaltechnology.org/2019/01/solid-state-relay-types-of-ssr-relays.html

Interfacing SSR with Micro-Controllers

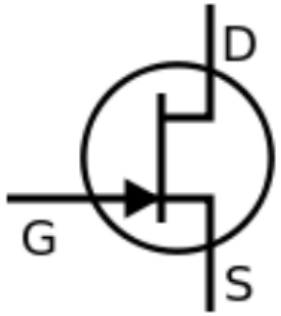


https://roboticadiy.com/how-to-use-solid-state-relay-to-control-240v-120v-with-5v-arduino/

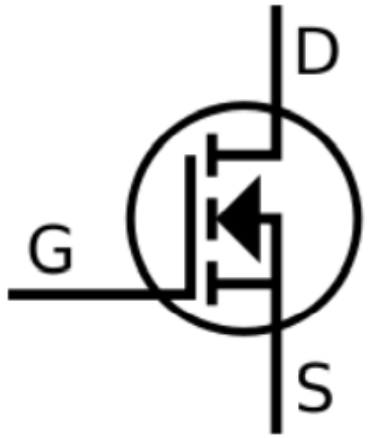


Field-Effect Transistors(FET) are usually either JFET or MOSFET

JFET = Junction FET



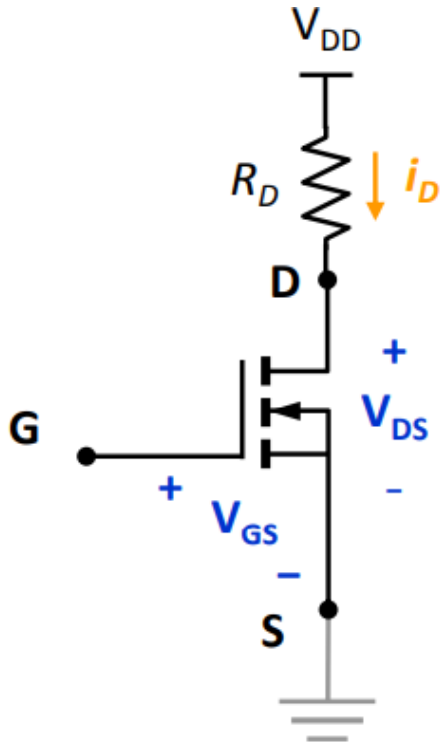
MOSFET = Metal- Oxide-semiconductor FET



Threshold Voltage defines MOSFET operation.

1- Threshold voltage(V_T) is the voltage between gate and substrate when N-channel begins to form.

2- Threshold voltage *(VT)* may be denoted as $VGS(\text{on})$ and is typically between and 5 V.



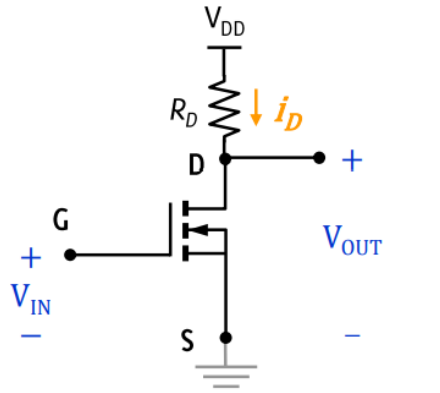
Gate Voltage can toggle MOSFET Switch.

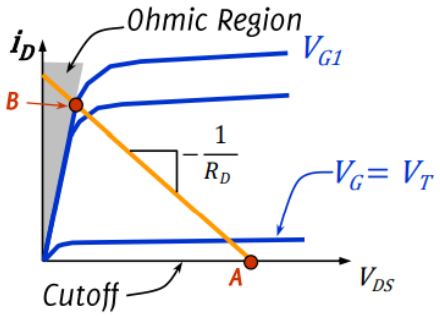
Point B ($V_{IN} > V_T$)

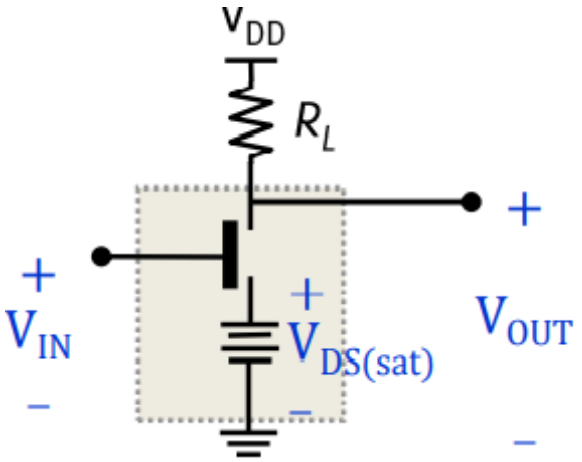
- transistor is in Ohmic region
- $V_{OUT} = V_{DD} - V_{DS} = V_{DD} - i_D(V_{G_1}) \cdot R_D$
- Switch closed!

Point A ($V_{IN} < V_T$)

- transistor is cutoff
- $i_D \approx i_S \approx 0 \Longrightarrow V_{OUT} \approx V_{DD}$
- Switch open!







Thank You For Your Attention!

Any Question?