Solid State Devices (2)

Daniel Kohn
University of Memphis
Department of Engineering Technology
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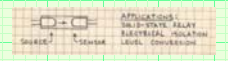
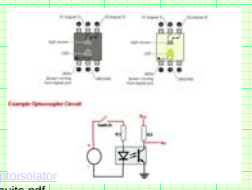
Opto Isolators

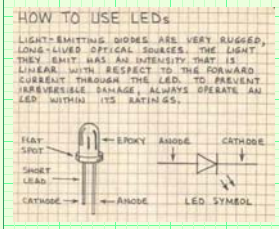
- An optoisolator (also known as optical coupler, optocoupler and opto-isolator) is a semiconductor device that uses a short optical transmission path to transfer an electrical signal between circuits or elements of a circuit, while keeping them electrically isolated from each other.

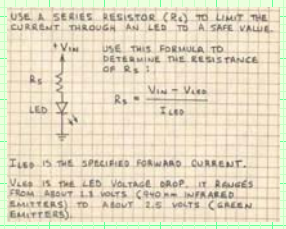




http://searchcio.techtarget.com/definition/optoisolator
Mims/vol01_03_Forrest_Mims_optoelectronics_circuits.pdf
http://www.resil.co.uk/Optocouplers.htm

- Current Limiting resistor for LED's or Opto-Isolators





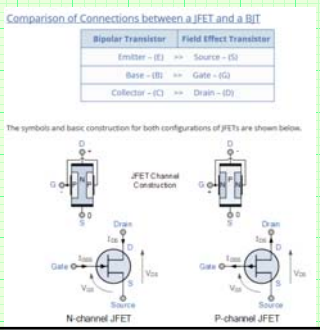
Mims/vol01_03_Forrest_Mims_optoelectronics_circuits.pdf

MOSFETs

- **Field Effect Transistor (FET)**, uses the voltage that is applied to their input terminal, called the Gate to control the current flowing through them resulting in the output current being proportional to the input voltage.

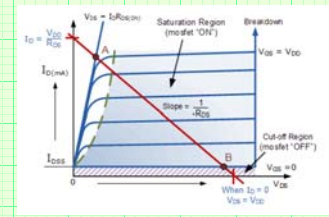
- Field effect transistors
  - smaller than an equivalent BJT transistor
  - have low power consumption and power dissipation
    - lower resistance
    - Do not heat up as much
  - High input impedance (when compared to BJT)
  - Sensitive to Electro-Static Discharge (ESD)

Pins

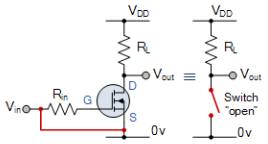


MOSFETs as a Switch

- Just like BJT's MOSFETs can be used as an amplification device and also as a switch (ie the "Saturation" and "Cut-off" Regions)

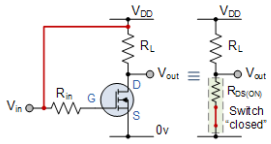


Cut-off



- The input and Gate are grounded (0v)
- Gate-source voltage less than threshold voltage $V_{GS} < V_{TH}$
- MOSFET is "OFF" (Cut-off region)
- No Drain current flows ($I_D = 0$)
- $V_{OUT} = V_{DS} = V_{DD}$ = "1"
- MOSFET operates as an "open switch"

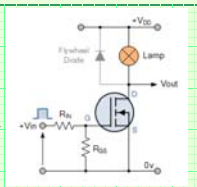
Saturation



- The input and Gate are connected to V_{DD}
- Gate-source voltage is much greater than threshold voltage $V_{GS} > V_{TH}$
- MOSFET is "ON" (saturation region)
- Max Drain current flows ($I_D = V_{DD} / R_L$)
- V_{DS} = 0V (ideal saturation)
- Min channel resistance $R_{DS(on)} < 0.1\Omega$
- $V_{OUT} = V_{DS} = \approx 0.2V$ due to $R_{DS(on)}$
- MOSFET operates as a low resistance "closed switch"

MOSFET Relay Driver

- gate resistor use to protect whatever is sourcing the current.
- Much like a discharged capacitor, the gate will initially look like a short to ground when voltage is first applied. A MOSFET with a very large gate capacitance can sink a very large amount of current for a short period of time.
- If you're driving the gate with, say, a MCU pin, it's usually a good idea to put a small resistor to reduce that current surge to a value the MCU can handle. If your MCU pin can handle, say, 20mA and you're driving 3.3V into the gate, then you choose a resistor that limits the current to 20mA at 3.3V:

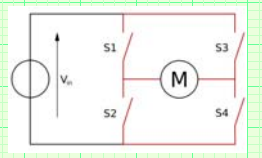


$$R_{gate} = \frac{V}{I} = \frac{3.3V}{20mA} = 165\Omega$$

H-Bridge

H Bridge

- A H-bridge is an electronic circuit that enables a voltage to be applied across a load in either direction. These circuits are often used in robotics and other applications to allow DC motors to run forwards and backwards.



https://en.wikipedia.org/wiki/H_bridge

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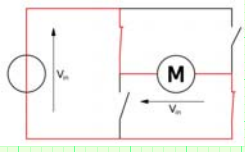

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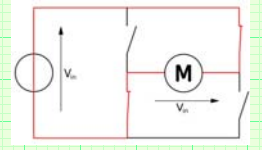
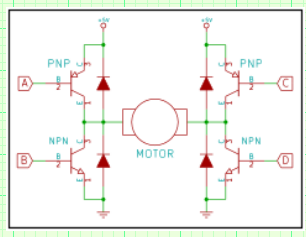
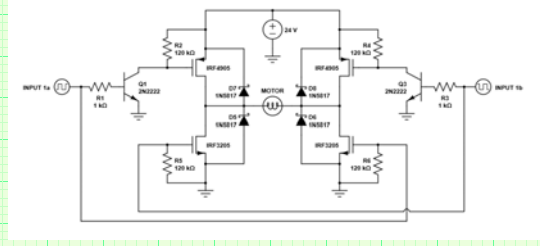


H-Bridge with Transistors



http://www.nathankumont.com/blogh-bridge-tutorial

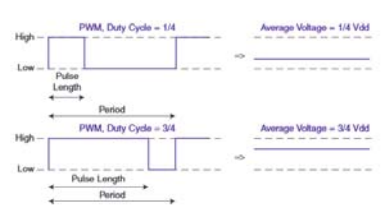
MOSFET H-Bridge



https://www.circuitlab.com/

Pulse Width Modulation

- **Pulse Width Modulation**, or **PWM**, is a technique for getting analog results with digital means. Digital control is used to create a square wave, a signal switched between on and off.



1- https://www.arduino.cc/en/Tutorial/PWM
2- IEEE Potentials Magazine Jan/Feb 2006

IGBT

- Insulated-Gate Bipolar Transistor (IGBT)
- Three-terminal power semiconductor device primarily used as an electronic switch
- combines high efficiency and fast switching
- Commonly used in variable-frequency drives (VFDs)
- Pulse repetition rates well into the ultrasonic range
- The IGBT combines the simple gate-drive characteristics of MOSFETs with the high-current and low-saturation-voltage capability of bipolar transistors.
- The IGBT combines an isolated gate FET for the control input, and a bipolar power transistor as a switch, in a single device.

https://en.wikipedia.org/wiki/Insulated-gate_bipolar_transistor

IGBT

- The IGBT is used in medium- to high-power applications like switched-mode power supplies, traction motor control and induction heating.

- Large IGBT modules typically consist of many devices in parallel and can have very high current handling capabilities in the order of hundreds of amperes with blocking voltages of 6000 V, equating to hundreds of kilowatts.

Small IGBT module, rated up to 30 A, up to 900 V

IGBT

- IGBTs have been the preferred device under these conditions:
  - Low duty cycle
  - Low frequency (<20kHz)
  - Narrow or small line or load variations
  - High-voltage applications (>1000V)
  - Operation at high junction temperature is allowed (>100°C)
  - >5kW output power
- MOSFETs are preferred in:
  - High frequency applications (>200kHz)
  - Wide line or load variations
  - Long duty cycles
  - Low-voltage applications (<250V)
  - < 500W output power

IGBT

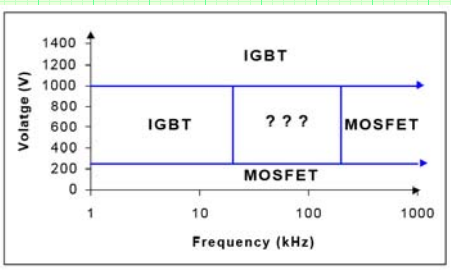


Figure 3. Where MOSFETs and IGBTs are preferred, not counting output power.