AERO ASTRO

16.682 - Prototyping Avionics
Spring 2006

LECTURE 6

February 27, 2006

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

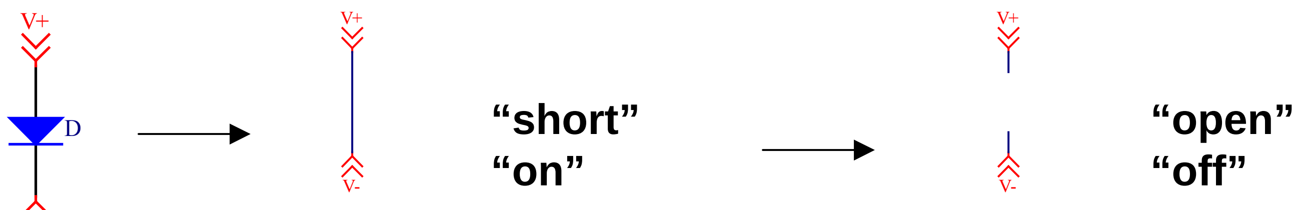
Alvar Saenz-Otero

Outline

- **Transistors**
  - **Introduction**
  - **NPN/PNP**
  - **MOSFETs**
- **Digital Logic Introduction**

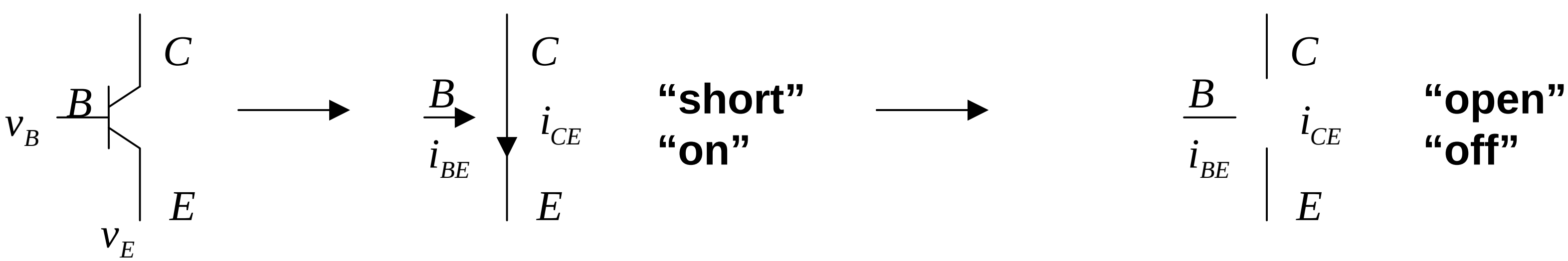
Transistor Introduction

- **We want an electronic switch which allows us to open or close a circuit…**
  - **The diode could do that if we reversed voltage:**



$v^+ > v^-$ $\qquad$ $v^+ < v^-$

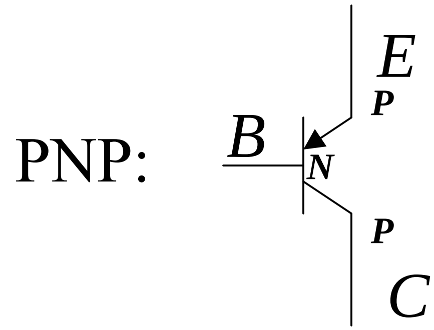
  - **But can we do it by commanding a separate voltage, instead of the input voltage?**
    - **That is what a transistor is for:**

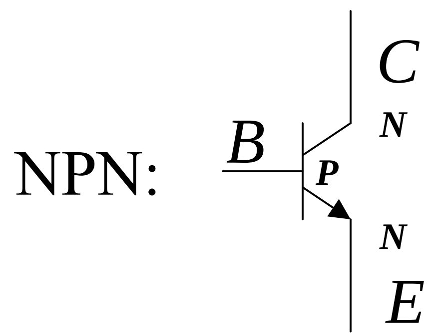


$v_B > v_E \rightarrow i_{CE} >> i_{BE}$ $\qquad$ $v_B < v_E \rightarrow i_{CE} = i_{BE} = 0$

Bipolar Transistors

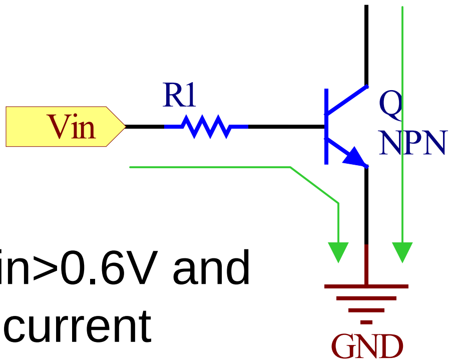
- **PNP and NPN *Bipolar* Transistors**
  - **Current "amplification" components**
    - $i_C = \alpha i_B$ **α ~ 40-200**
  - **Have three connections:**
    - **Base - he "control" of the transistor**
    - **Emitter - the connection that *emits* current**
    - **Collector - the connection that *collects* current**
  - **Have a "diode" between the <u>Base and the Emitter</u>**
    - **Determines polarity: PNP or NPN**
    - **Turns "on" when <u>current</u> can flow through the diode**
    - **The <u>current is amplified</u> between the collector and the emitter**





Bipolar Transistors

- **Example with an NPN transistor:**

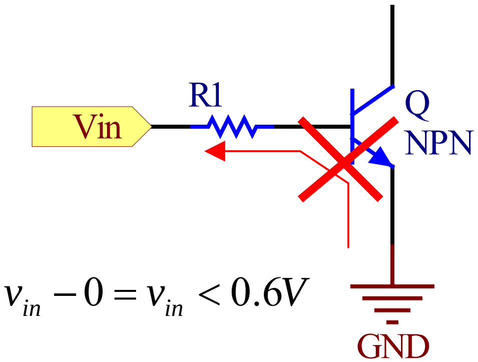


If Vin>0.6V and the current source can provide enough i_{BE}, then...

$$v_{BE} = 0.6V$$

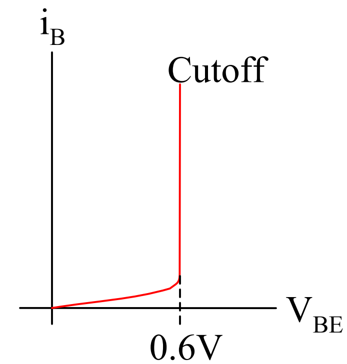
$$i_{BE} = \frac{v_{in} - 0.6V}{R_1}$$

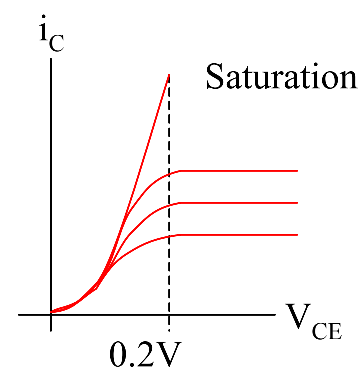
$$i_{CE} = \alpha \cdot i_{BE}, v_C \sim 0$$



$$v_{BE} = v_{in} - 0 = v_{in} < 0.6V$$

But if the current tries to flow the wrong way, the transistor is "off"



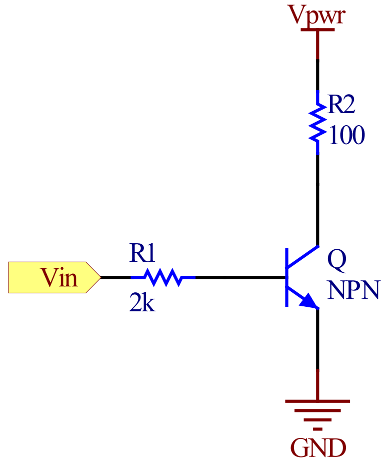


- **Notes:**
  - **The diode dictates a maximum een *B* & *E* of 0.6V**
  - **The voltage drop between *C* and *E* is usually 0.2V**
  - **The current amplification is usually determined by specific parts**

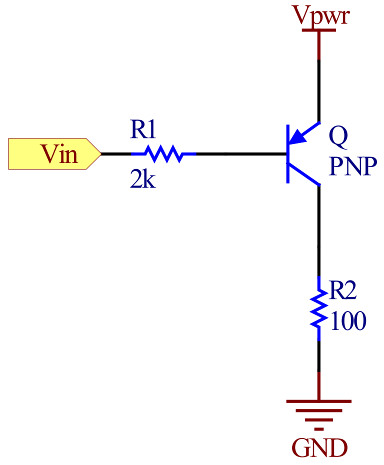
Transistor Use

- **Driving a high-current, separate voltage load**
  - **Vin does not have to be the same as Vpwr**
  - **A large Vin saturates V_{BE}**

$$v_E = 0$$
$$v_{in} = 3.3\text{V}$$
$$i_B = (3.3V - 0.6V)/2k = 1.35\text{ma}$$
$$i_C \approx 100\text{ma}$$

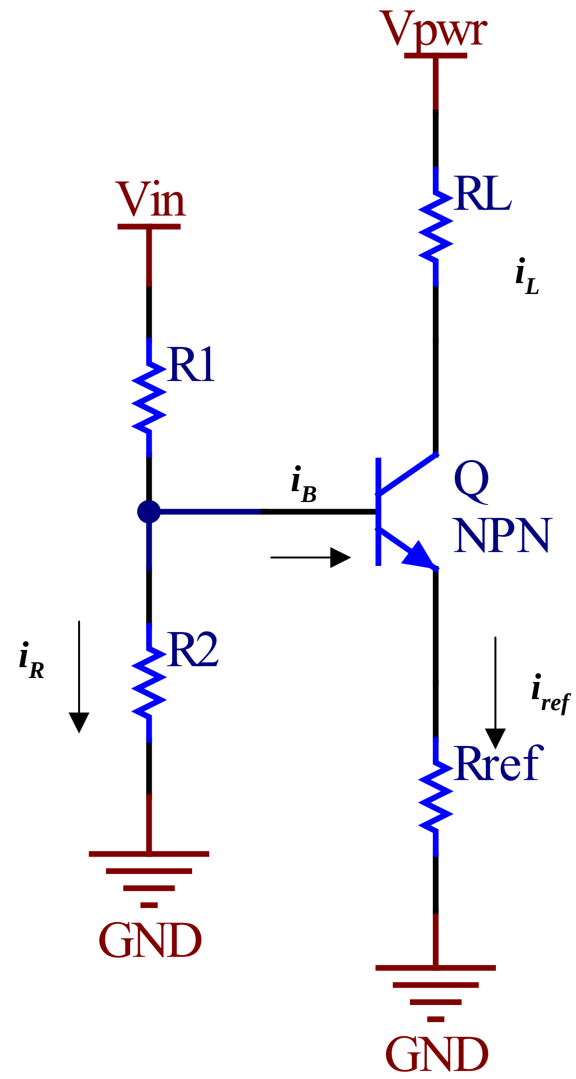


- **Negative input (inverse signal)**
  - **Must be able to drive V_{in}@ V_{pwr}**
  - **V_{in}= V_{pwr}means transistor is OFF**
  - **V_{in}= 0V means transistor is ON**



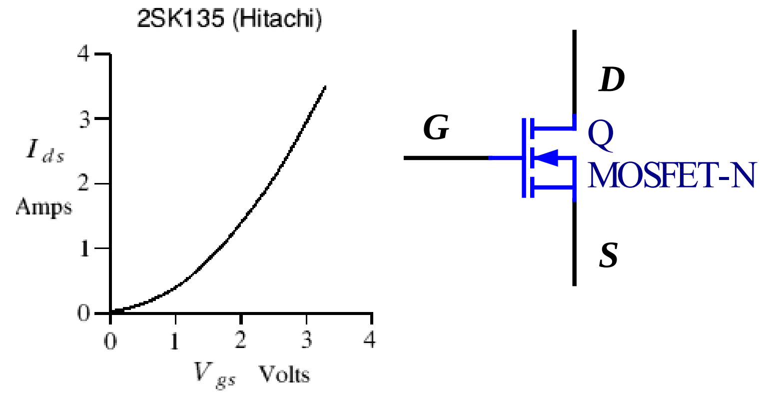
Transistor Use

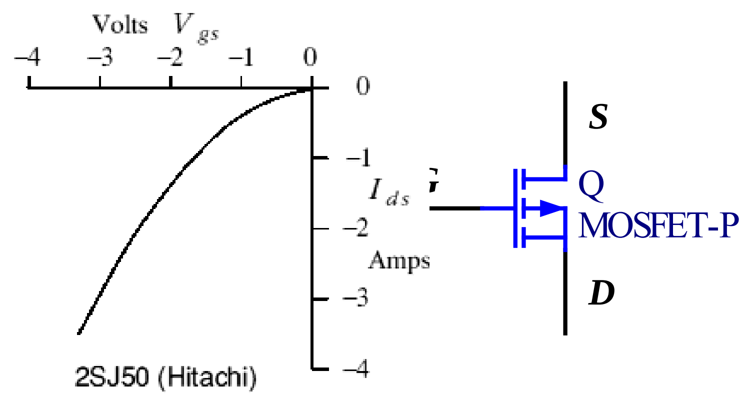
- **Current Source**
  - $$v_B = V_{in}\left(\frac{R_2}{R_1 + R_2}\right)$$
    $$v_E \cong v_B - 0.6V$$
    $$i_{ref} = \frac{v_B - 0.6V}{R_{ref}}$$
    $$\text{if } i_B \approx 0\ (\alpha = 100) \rightarrow i_L = i_{ref}$$
  - **Example: R_{ref}=10Ω, V_B=1.6V**
    $$v_B = 1.6V$$
    $$v_E \cong 1.0V$$
    $$i_{ref} = \frac{v_B - 0.6V}{R_{ref}} = \frac{1}{10} = 100mA$$
    $$i_B \approx 1mA\ (\text{Need R1 \&R2 such that } i_B \approx 0 \text{ WRT } i_R)$$
    - **Note limits: V_B=10.6V then i_B=100mA, too large!**



MOSFET Transistors

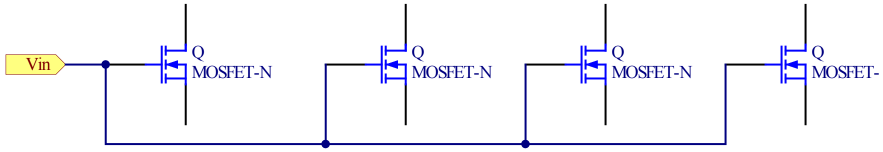
- "Voltage" Transistors
  - FET = Field-effect transistor = "voltage" transistor
  - Gate/Source/Drain instead of BCE
  - Voltage turns transistor on/off
    - $i_{SD} = \alpha v_{DS}$
    - Need very small current (almost 0) at the gate
  - V_{GS}= 1 -> ON
  - V_{GS}= 0 -> OFF





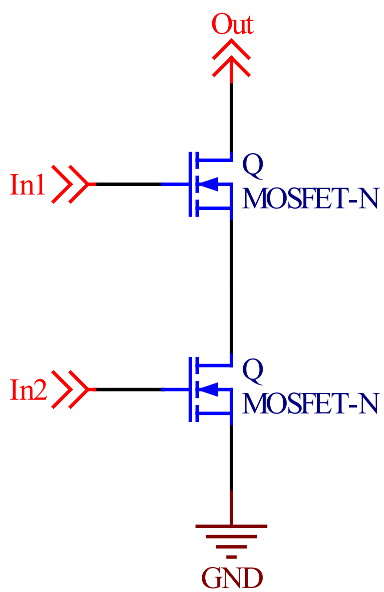
MOSFETS in use

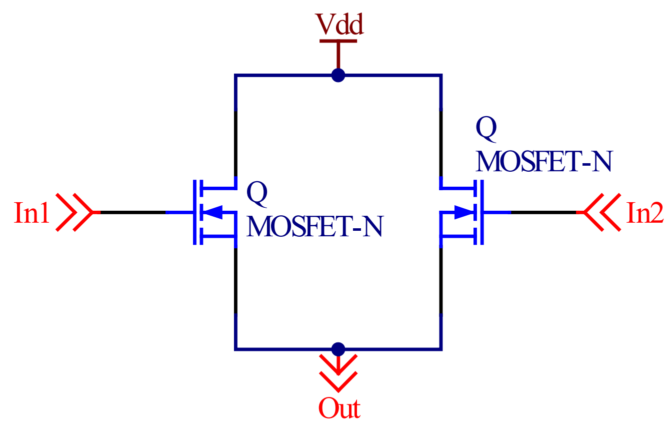
- **Driving many "lines" from a single voltage**
  - **Use small current**
  - **Same ground, may change power**



- **"CMOS" logic (Complementary MOS)**
  - **Example to create AND and OR circuits:**

In1	**In2**	**i**
0	0	Off
V	0	Off
0	V	Off
V	V	On



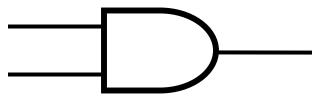


In1	**In2**	**i**
0	0	Off
V	0	On
0	V	On
V	V	On

Digital Logic

- **Basic Gates**
  - **AND**

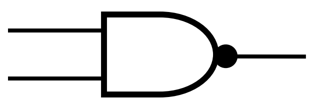
A	B	Q
0	0	0
1	0	0
0	1	0
1	1	1



- **Both inputs must be true**

  - **NAND**

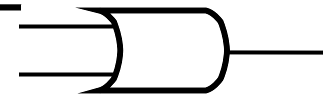
A	B	Q
0	0	1
1	0	1
0	1	1
1	1	0



- **Neither input must be true**

  - **OR**

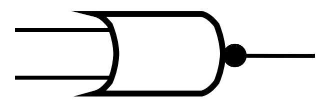
A	B	Q
0	0	0
1	0	1
0	1	1
1	1	1



- **Any input is true**

  - **NOR**

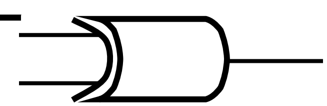
A	B	Q
0	0	1
1	0	0
0	1	0
1	1	0



- **Neither input is true**

  - **XOR**

A	B	Q
0	0	0
1	0	1
0	1	1
1	1	0



- **The inputs are different**