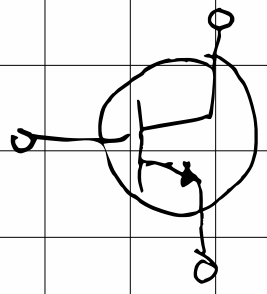
ME 133 Lecture 7 1/25/2022

Last time:

- BJT

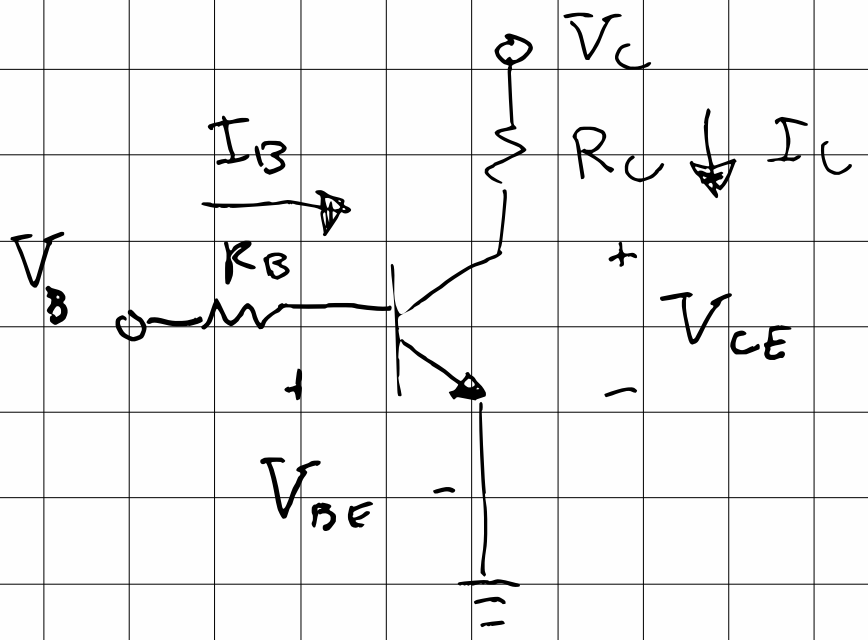


- Slight correction: NPN-BJT
  (NOT N-channel)
  PNP-BJT
  (NOT P-Channel)

Today:

1. Summerize BJT switch
2. FET overview

Summary for designing BJT switch



(1) $V_C > V_B > V_E$

collector must be more positive than base & emitter

(2) To turn ON $V_{BE} > 0.7\,V$ (Typically)

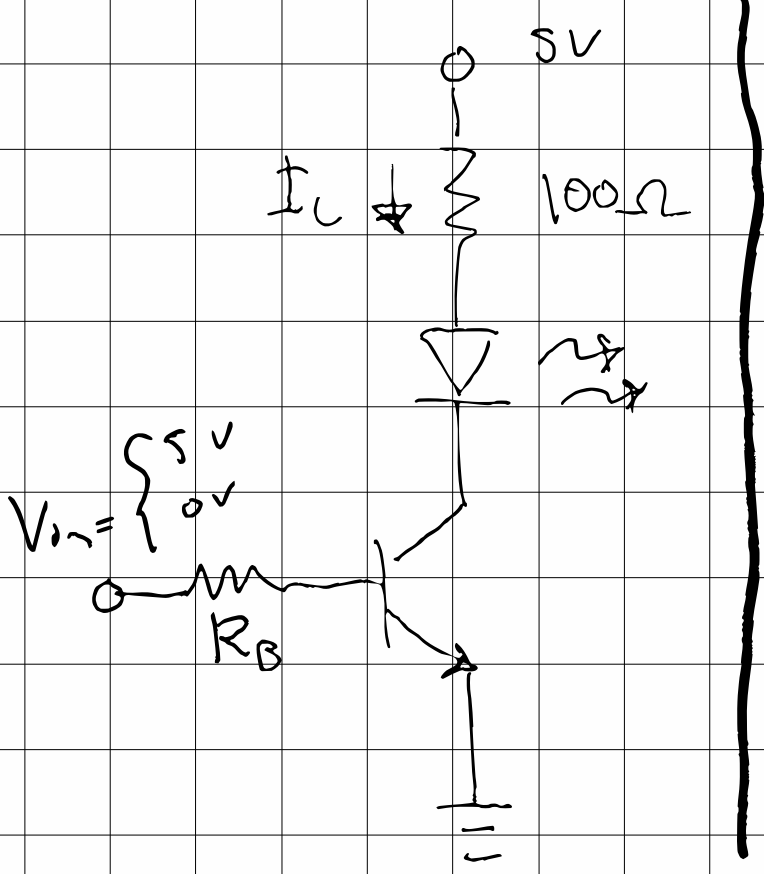
(3) I_C is independent of I_B when in saturation.

(4) Minimum base current I_B for saturation can be found $I_{B_{min}} \simeq I_C/\beta \rightarrow I_B = I_{B_{min}} \times 10$

Ex. 2.4

Goal: Design LED switch

PN2222



$V_{BE(sat)} = 0.6\,V$

$V_{CE(sat)} = 0.3\,V$

$\beta = 100$

$V_D = 2.0\,V$

Assumption about the voltage of the diode

$$I_C = \frac{V}{R} = \frac{5 - 2 - 0.3\ V}{100\ \Omega}$$

$$I_C = 27\ mA$$

$$I_{B_{min}} \simeq \frac{I_C}{\beta} = \frac{I_C}{100} \simeq 0.3\ mA$$

$$I_B = I_{B_{min}} \times 10 = 3\ mA$$

$$\frac{5\,V - 0.6\,V}{R_B} \simeq 3\,mA$$

$$\frac{4.4\,V}{3\,mA} = \boxed{R_B \simeq 1.5\,k\Omega}$$

Take away, we design R_B to ensure BJT is in saturation when turned ON.

Field-Effect Transistors (FETs)

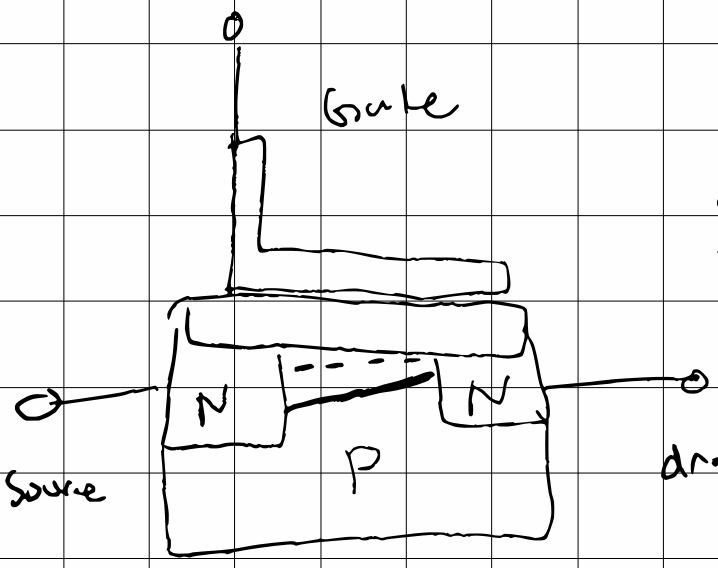
- Basic idea:

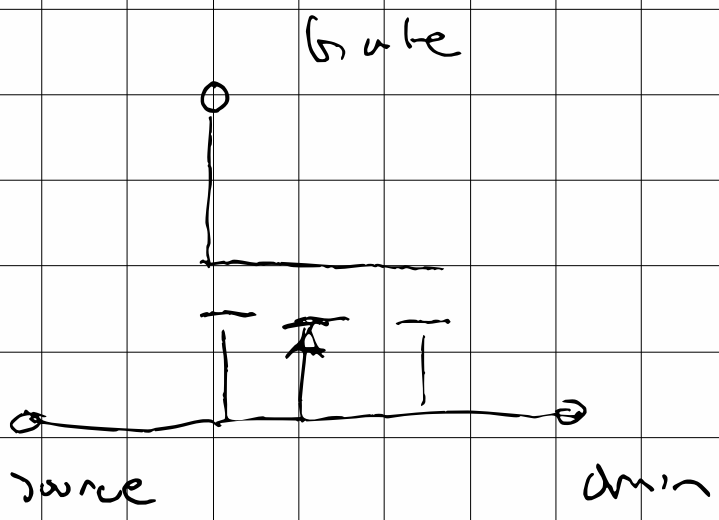
  Voltage on one electrode controls the charge carriers in a "channel"

  Channel: narrow region where current flows

- transconductance amplifier
  - → output current is controlled by input voltage

N-Channel





Analogy with BJT

gate → base

drain → collector

source → emmitter

Flavors

metal-oxide semiconductor (MOSFET)

Junction FET

✓ Enhancement mode : off $V_g = 0$

- common for switching

Depletion mode : on $V_g = 0$

- load resistors for logic circuits

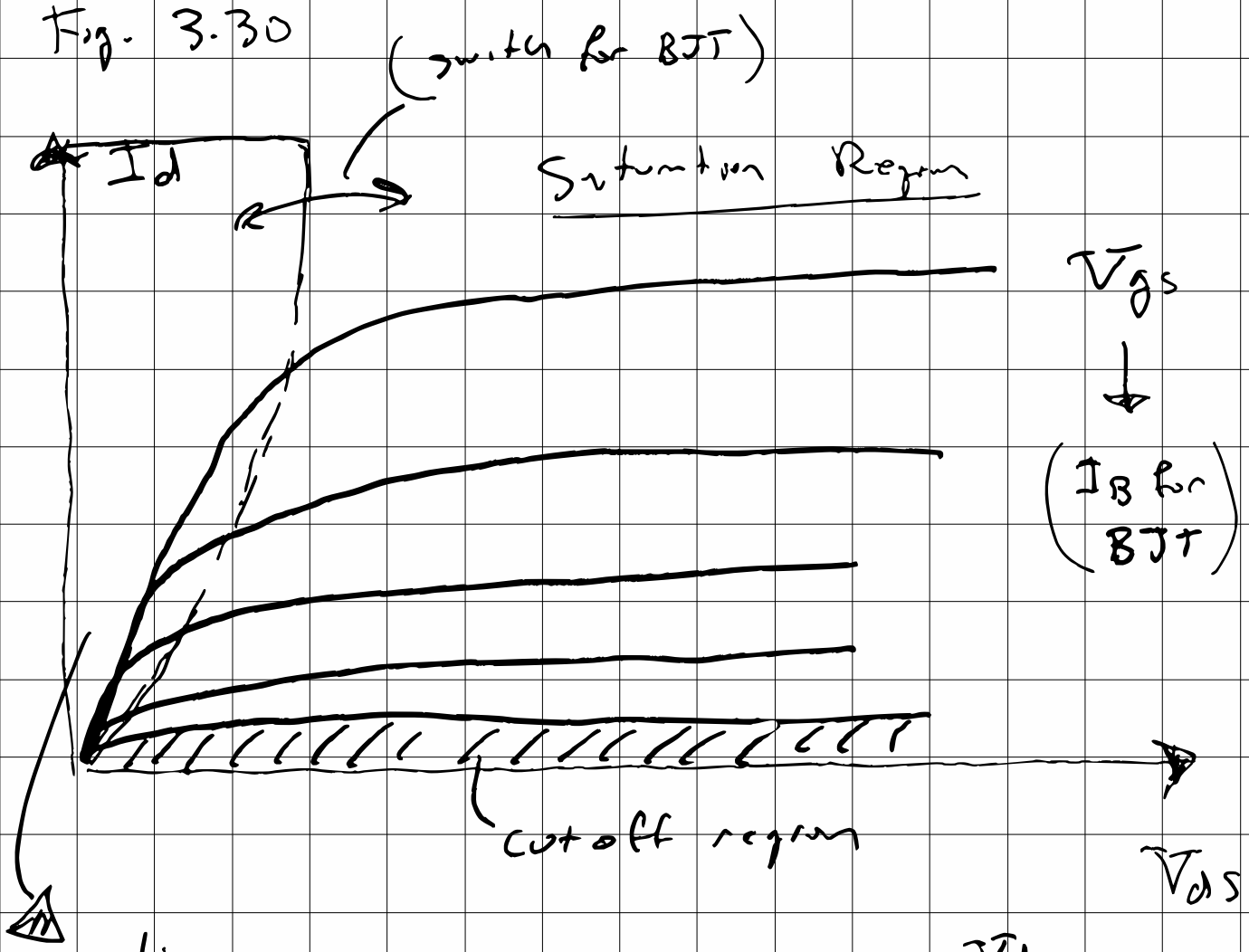
JFET are depletion

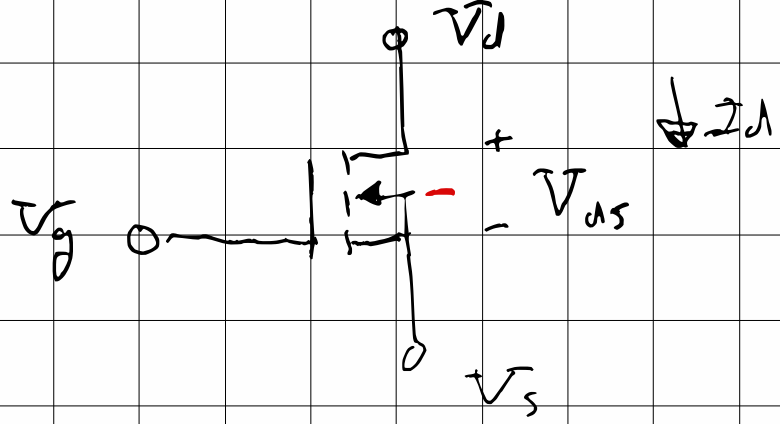
Which to use?

Case - by - case.

n-Channel enhancement Mode MOSFET

Fig. 3.30





* Saturation region of MOSFET corresponds to <u>active</u> region of BJT (roughly)

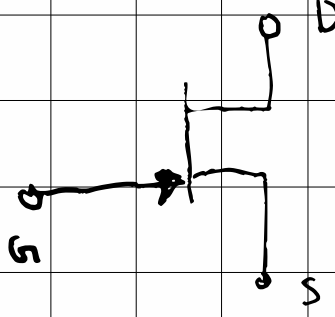
Symbols for FETS

Principle Characteristics

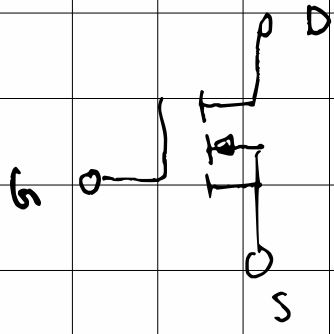
(1) Gate/substrate arrow distinguishes between p-channel (arrow out) & n-channel (arrow in)

(2.) A separation is shown between gate & source in MOSFET

(3.) Broken Line: enhancement mode
Solid Line: depletion mode

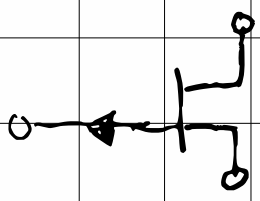


n-channel JFET

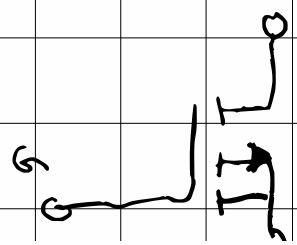


n-channel MOSFET

Fig. 3.33
(3.37 5th ED)



p-channel JFET



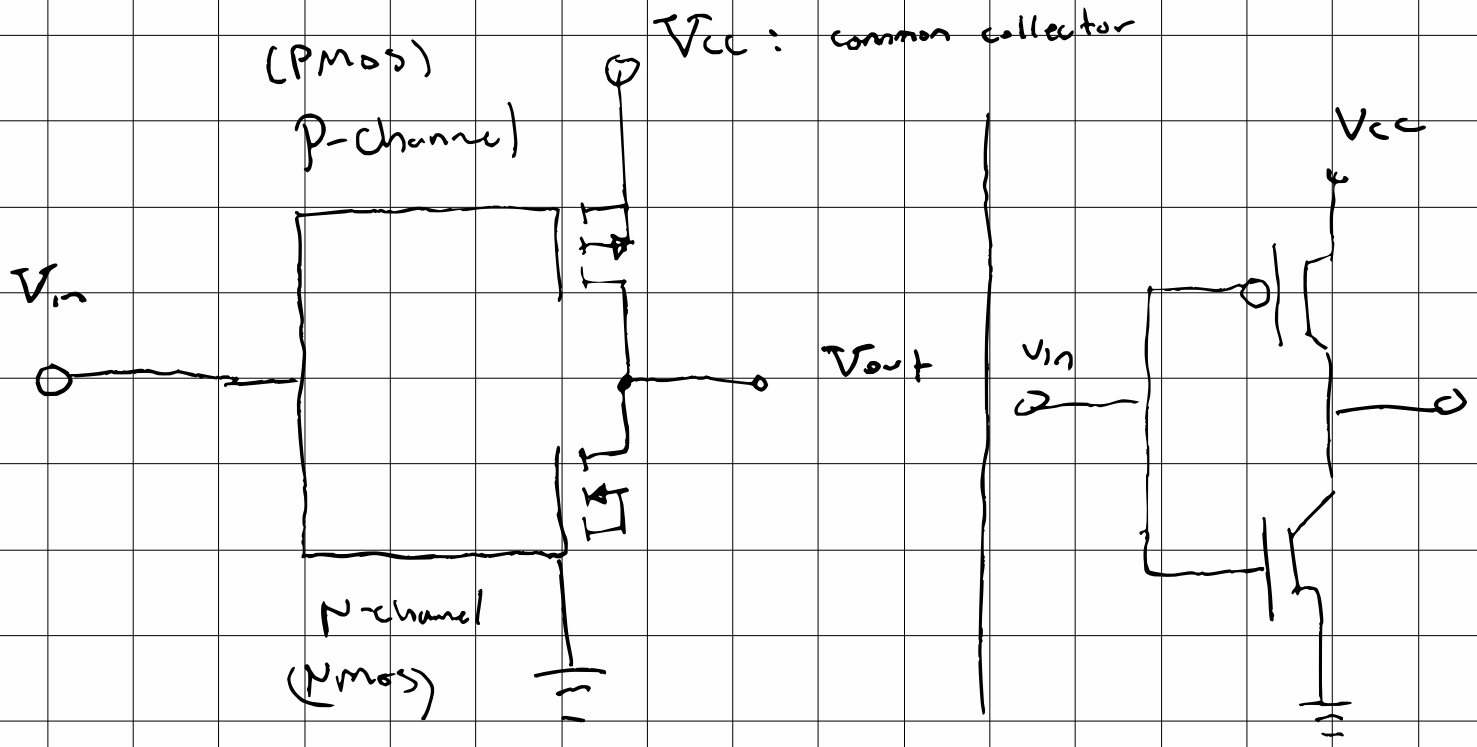
p-channel MOSFET

Applications

- switching power
  - → practically no current @ input!
  - → BJT we need to design R_B for saturation
- Analog switch
  - → pass analog signals
- memory: DRAM
  - ROM
  - RAM
- Sensors:
  - gas sensors (GASFET)
  - pressure sensors (PRESSFET)
  - .
  - .
  - .
- CMOS chips

CMOS

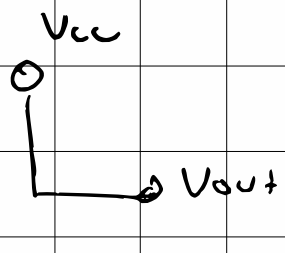
Complementary Metal-Oxide - Semiconductor



CMOS Inverter : V_{in} → common gate input

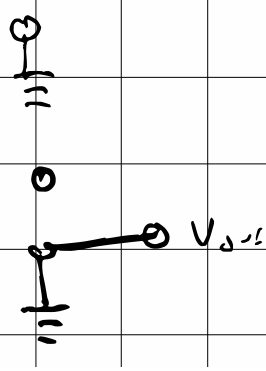
$V_{in} \approx 0\,V$, NMOS = OFF, PMOS = ON

$V_o = V_{cc}$ (HIGH - Logic 1)



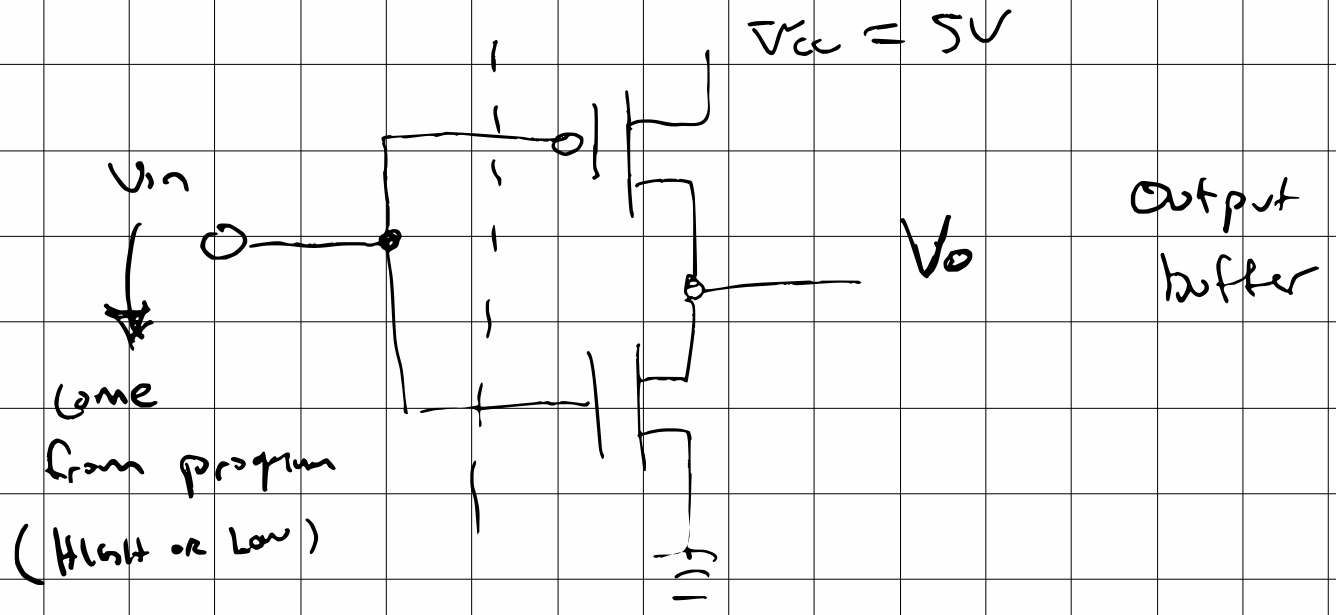
$V_{in} \approx V_{cc}$, NMOS = ON, PMOS = OFF

$V_o = 0$ (Low - Logic 0)



Logic circuits

Arduino output



Pin looks like when configure as output

Summary

Control

BJT: current controlled

FET: voltage controlled

Gain

BJT: larger current gain

FET: gain small

Size

BJT: large compared FET

FET: very tiny (Moore's Law)