Microelectronics Devices and Circuits

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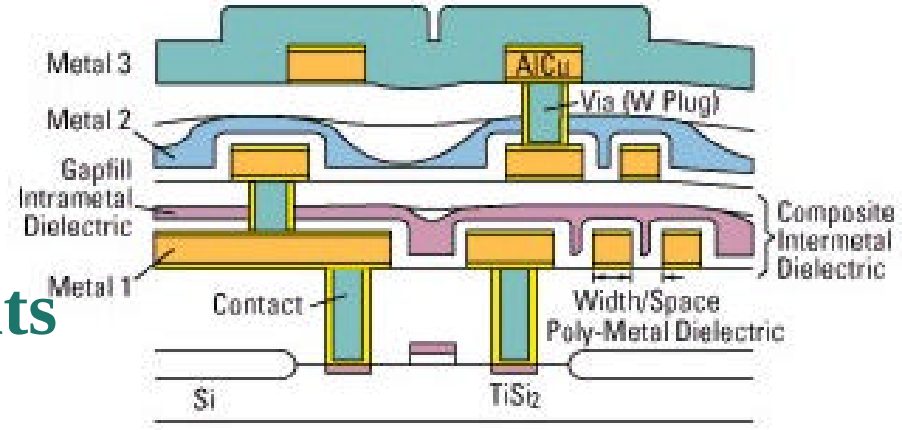
Lecture 2



Value Added by Circuits

How Does a Digital Camera Work?

- Physics (semiconductor junction)
  - » **Photons => charge => voltage**
- Analog Circuits
  - » **Amplify, gray level conversion**
- Digital Circuits
  - » **Encode, store, move, play**
- Analog Circuits
  - » **Display drivers**

Model for Photo Detector

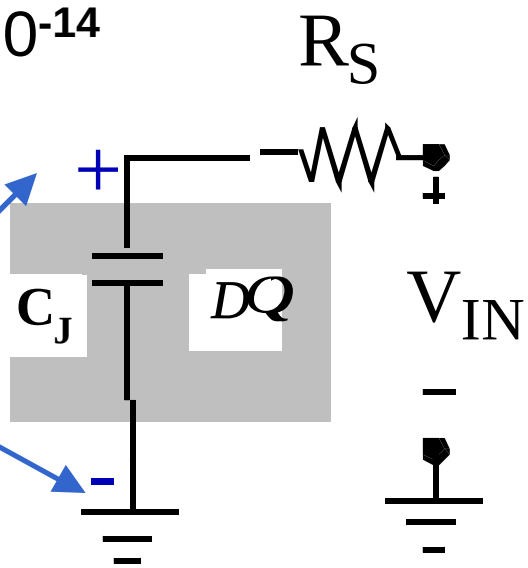
- Film sensitivity ~ $3x10^4$ photons

  $\Delta Q_S = 3x10^4$ electrons
- Junction capacitance $C_J \sim 30$ fF
- $\Delta V_S = \Delta Q/C_J = 3x10^4 x 1.6x10^{-19}/3x10^{-14}$

  $\Delta V_S = 160$ mV
- Series resistance $R_S = 200$ Ohms

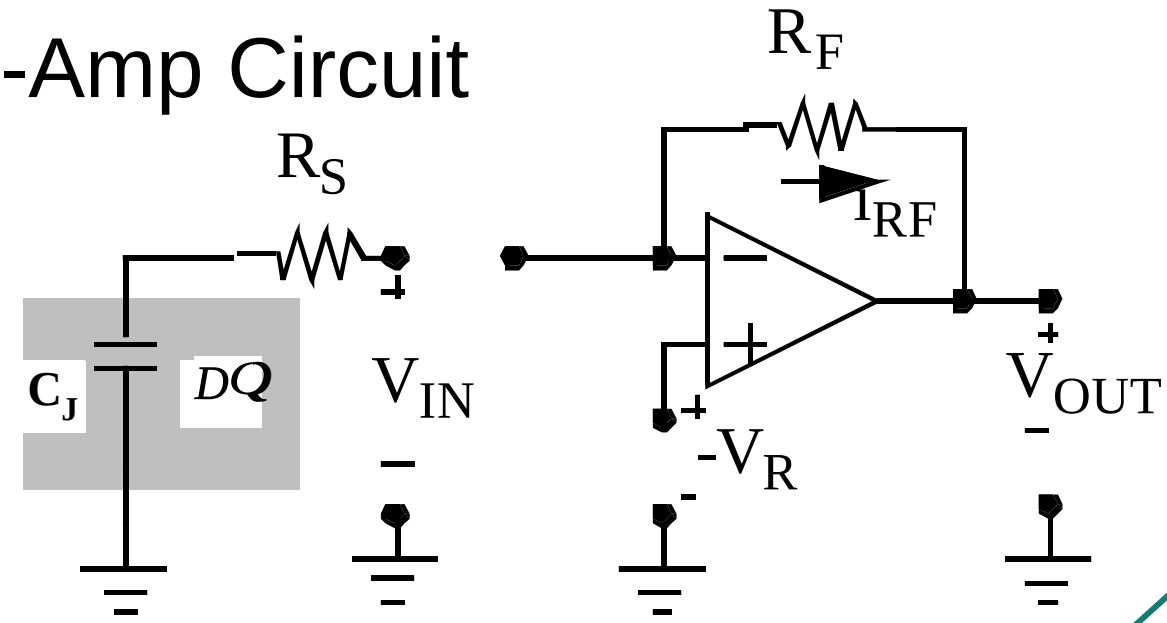
$V_{SOURCE} = V_{BIAS} + \Delta V_S$

$= V_{BIAS} + \Delta Q/C_J$



Current to Voltage Conversion

- Op-Amp Circuit



Remove Bias

$$V_{OUT} = V_R - R_F\{(V_{BIAS} + \Delta V_S - V_R)/R_S\}$$

Current

Op-Amps are Ideal but EE 105 is Not

- **Ideal Op-Amp properties**
  - » **No input current (Infinite R_{IN}!)**
  - » **$V_- = V_+$ (Infinite voltage gain! With feedback)** ← **Topic for EE 140**

How do we get these?

- **Circuit configurations give the leverage to build nearly ideal circuits from devices with les than idea properties.**

Don't forget about Op-Amps from EE 40 as in EE 105 we will use Op-Amps to study circuit concepts like frequency-response.

Back to the Future

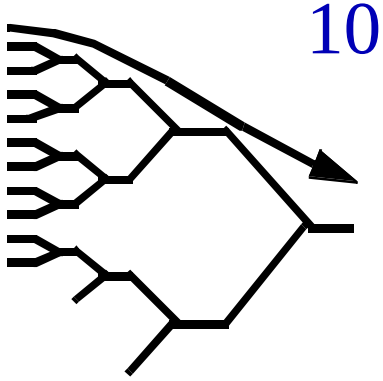
- 3 MegaPixels with 3 colors requires nearly 10M Op-Amps.
- If each draws 100 μA, the battery must supply 1000A.

A car battery would last only 3 minutes!

- Solution: Analog switch array of 10 levels and 2^{10} – 1024 factor of sharing.

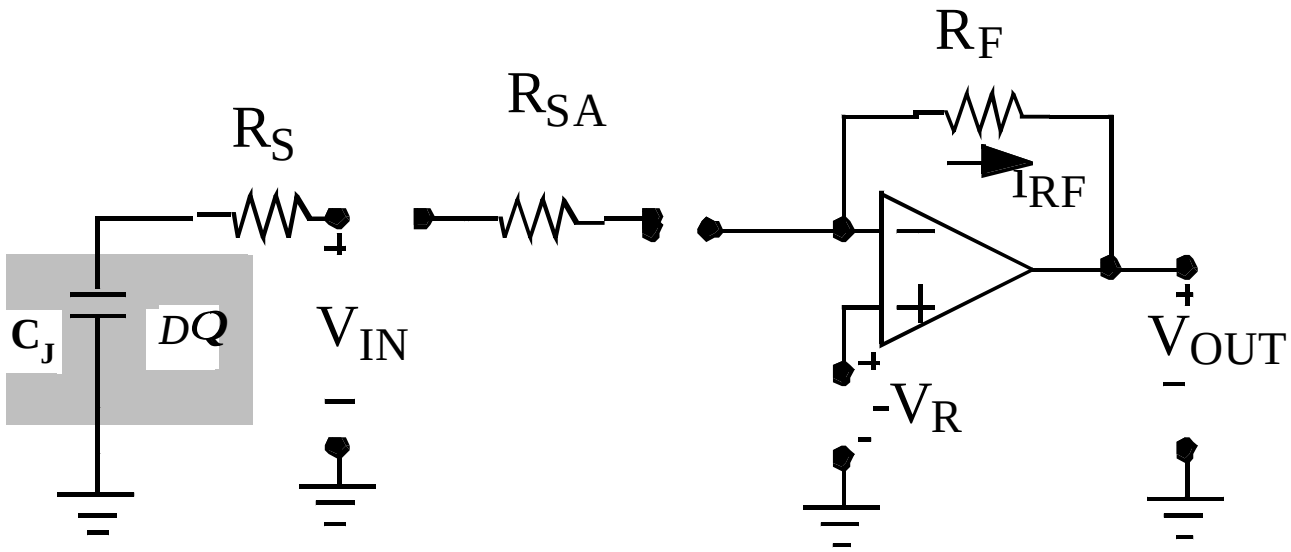
Resistance and Capacitance of 10 analog switches in series

1024 Photodiodes



R_{SA} **= 10*10 kOhms = 100 kOhms**

Model For Switching and Amplifier



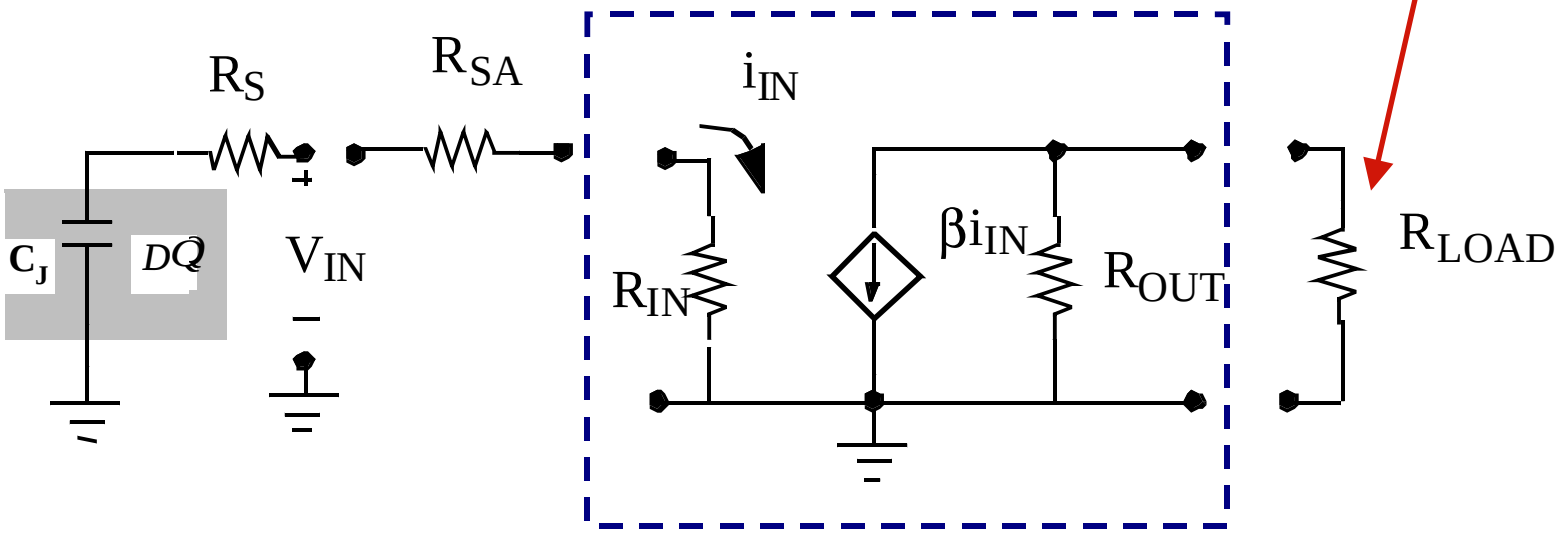
$$V_{OUT} = V_R - R_F\{(V_{BIAS}+\Delta V_S - V_R)/(R_{S+}R_{SA})\}$$

ΔV_S is 10 times smaller due to C_{SA}

From 200 Ohms to 100,200 Ohms => 500X smaller signal!

Simple EE 105 Amplifier

R_{IN} = 30 kΩ β = 100 R_{OUT} =Infinite R_{LOAD} = 10 kΩ



$$V_{OUT} = [\Delta V_S / (R_S + R_{SA} + R_{IN})](-\beta)R_{LOAD} = 115\text{mV}$$

$$\Delta V_S = 15\text{ mV}$$

i_{IN}

Circuit to Hold the Charge Longer

- Problem C_J Discharges Quickly

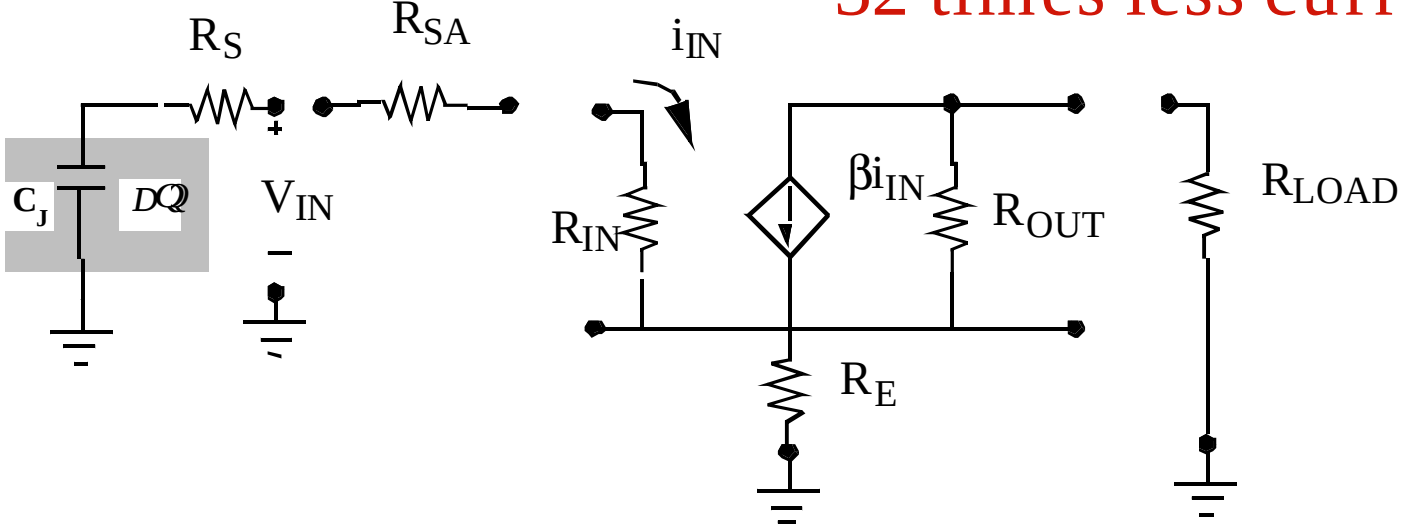
$T = C_J * R_{SA} = 30fF * 100k\Omega = 3*10^{-10}$ Sec

- Solution: Add Value Through Circuit Design of High Input Resistance Amplifier

High Input Impedance Circuit

$R_E = 30\ k\Omega \quad R_{IN\ EQ} = R_{IN} + (\beta+1)R_E = 3.06\ M\Omega$

32 times less current

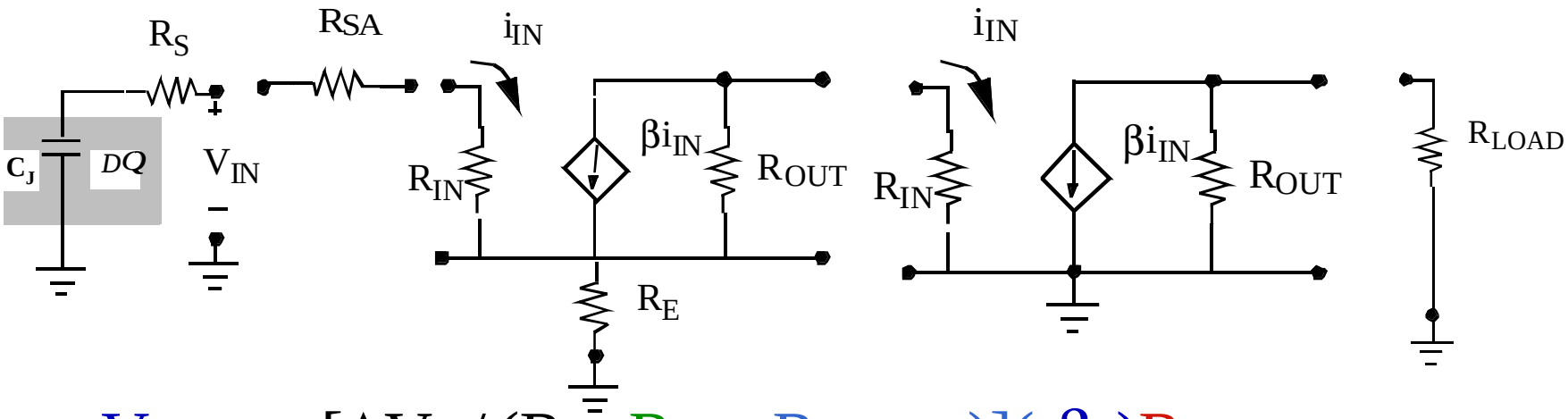


$V_{OUT} = [\Delta V_S / (R_S + R_{SA} + R_{IN\ EQ})](-\beta)R_{LOAD} = 33\ mV$

37 times smaller gain

Adding a Second Stage

Switch First Stage Second Stage

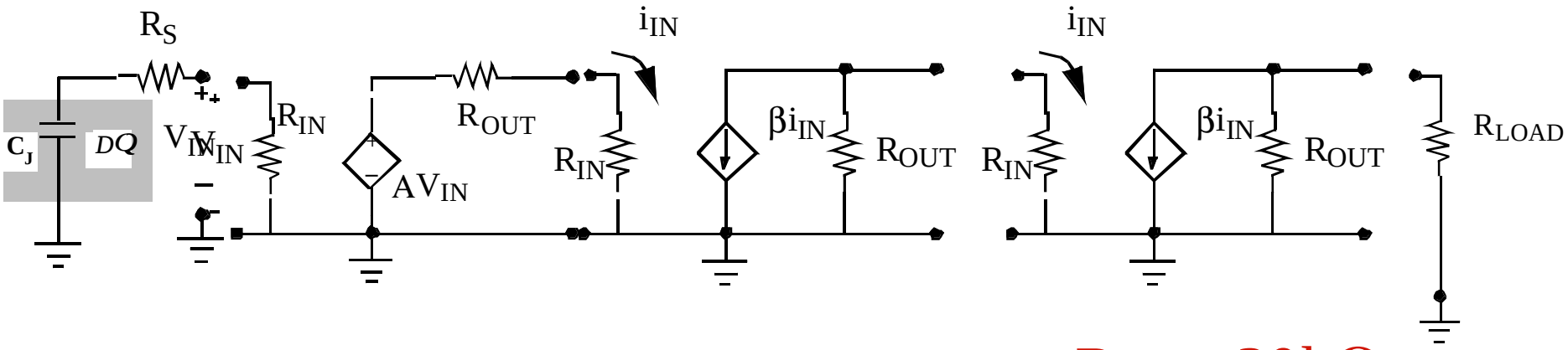


$$V_{OUT} = [\Delta V_S / (R_S + R_{SA} + R_{IN\ EQ1})](-\beta_1)R_{in2}$$

$$(1 / R_{in2})(-\beta_2)R_{OUT} = 490\ \text{mV}$$

Visualizing as a Multistage Amplifier

Switch First Stage Second Stage

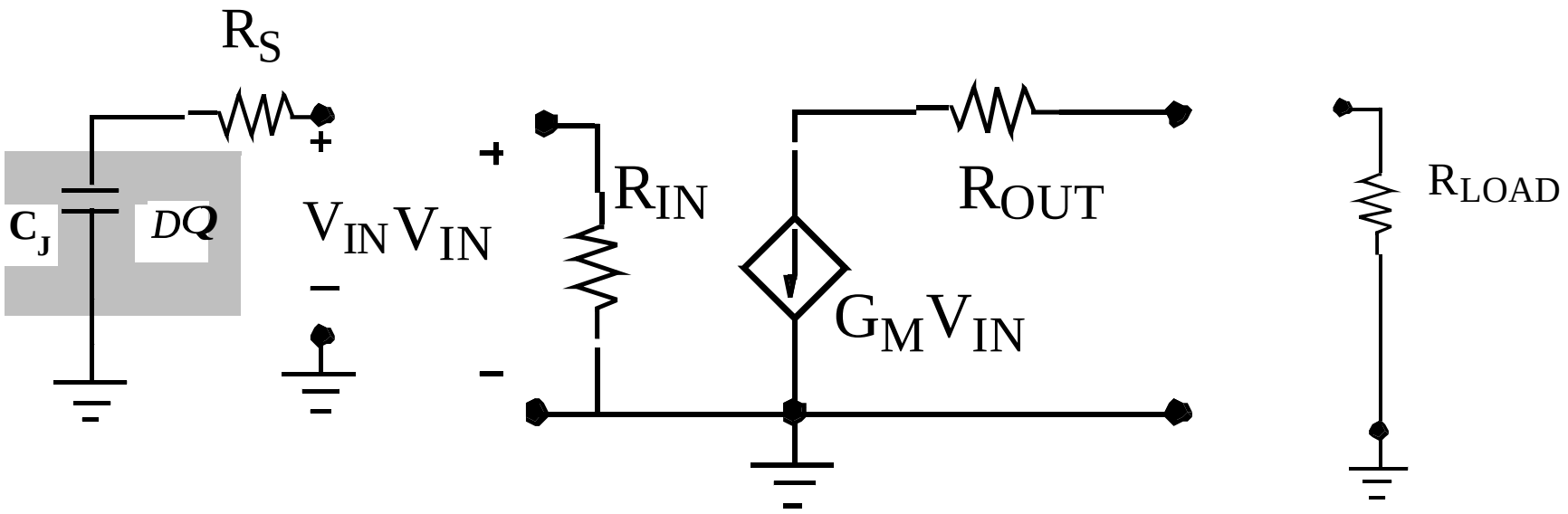


$R_{IN} = R_{SA}$ $R_{IN} = 2.06M\Omega$ $R_{IN} = 30k\Omega$

$A = 1$ $\beta = 100$ $\beta = 100$

$R_{OUT} = R_{SA}$ $R_{OUT} = \text{infinite}$ $R_{OUT} = \text{infinite}$

Visualizing as an Equivalent Two-Port

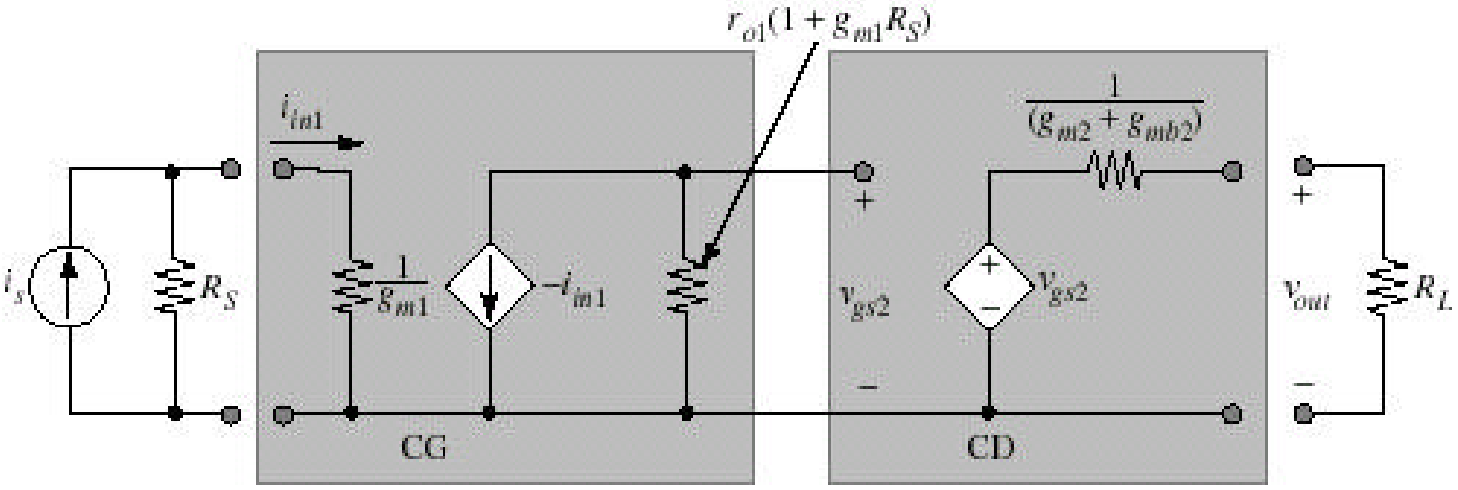


$$R_{IN} = R_{SA} + R_{IN\ EQ1}$$

$$G_M = [1/(R_S + R_{SA} + R_{IN\ EQ1})](-\beta_1)R_{in2}(1/R_{in2})(-\beta_2)$$

$$R_{OUT} = \text{Infinite}$$

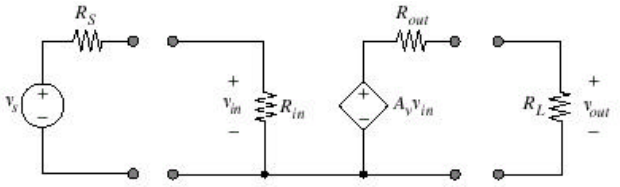
Multistage Amplifiers



This example from the reading in Chapter 8 this week.

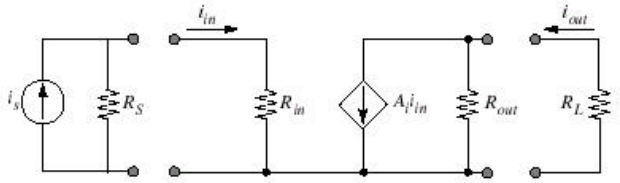
Classification of Two-Port Amplifiers

Voltage Amplifier



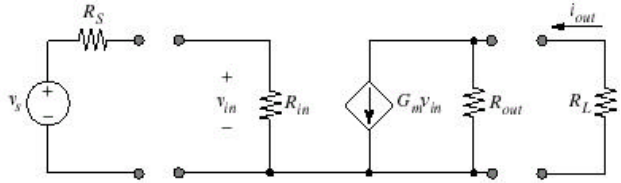
Voltage

Current Amplifier



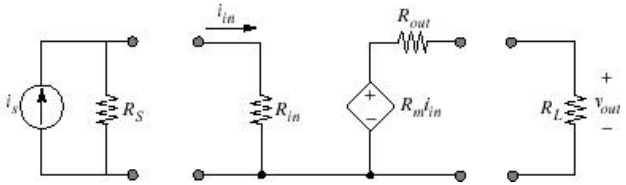
Current

Transconductance Amplifier



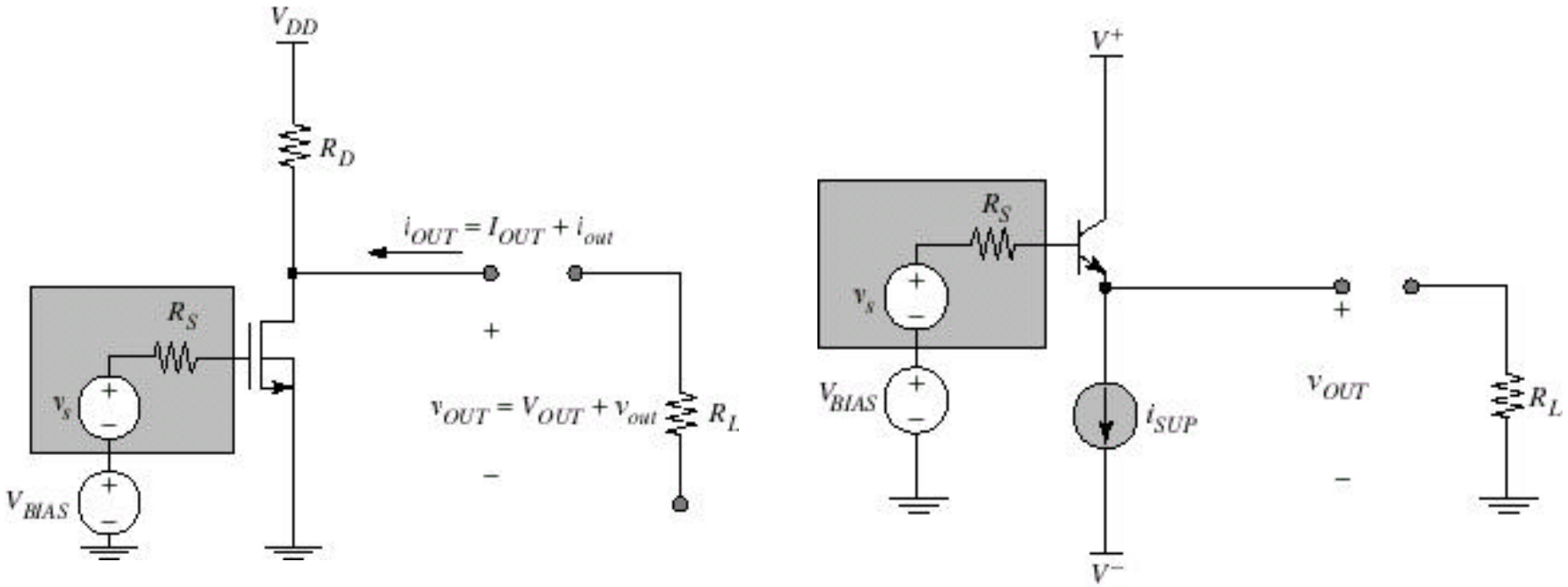
Transconductance

Transresistance Amplifier



Transresistance

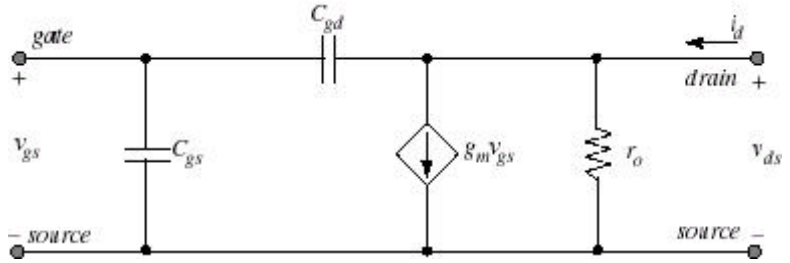
What Goes in the Amplifier Box



MOS BJT

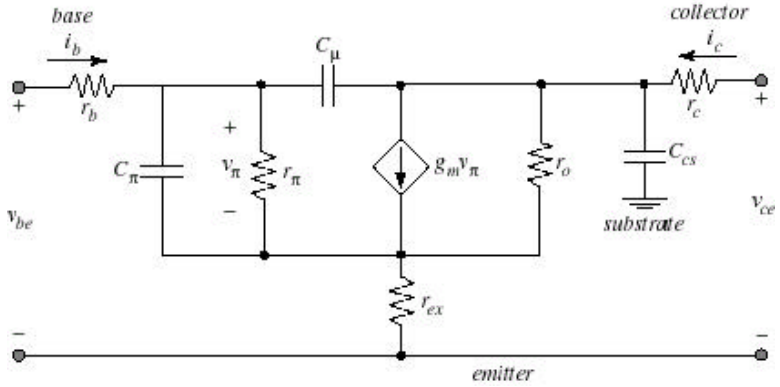
Material from Chapter 8 from week 11.

Small Signal Models for Transistors



MOS

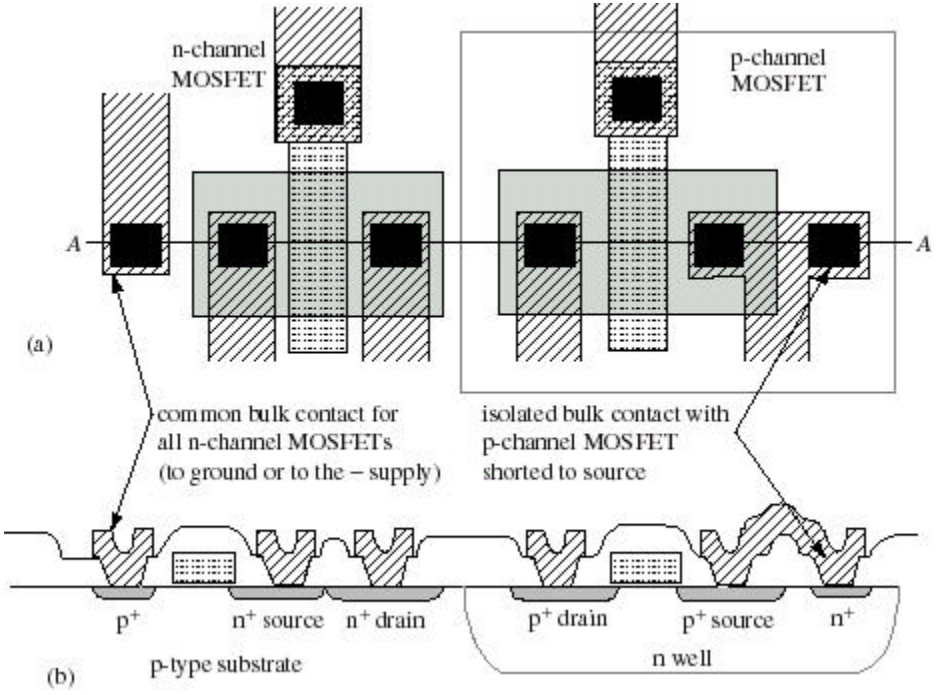
Week 5



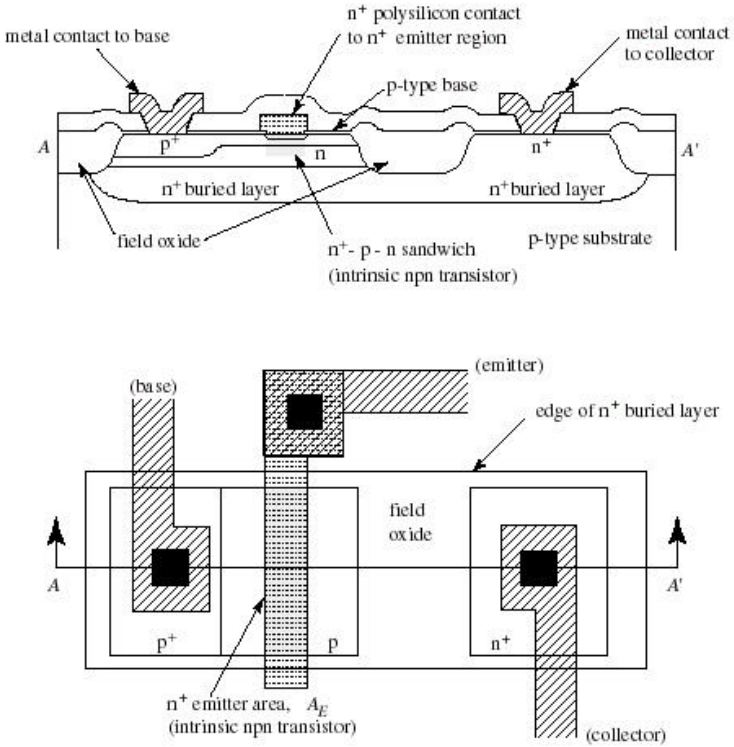
BJT

Week 8

Layout of Transistors



Week 2



Week 8