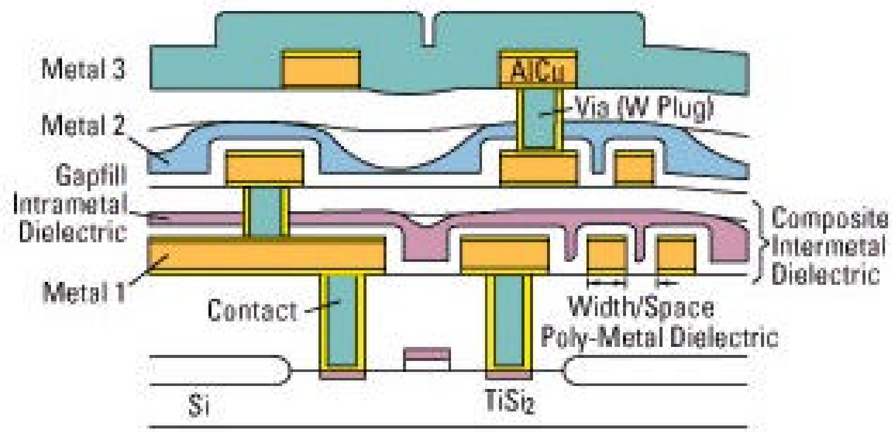
Lecture 2, February 19, 2001

EECS 105 Microelectronics Devices and Circuits, Spring 2001

Andrew R. Neureuther



Topics:
Value Added by Circuits

Reading: (review of EE 40), HS 1, 8.2.2, 9.1

Revised 1/21/01

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**

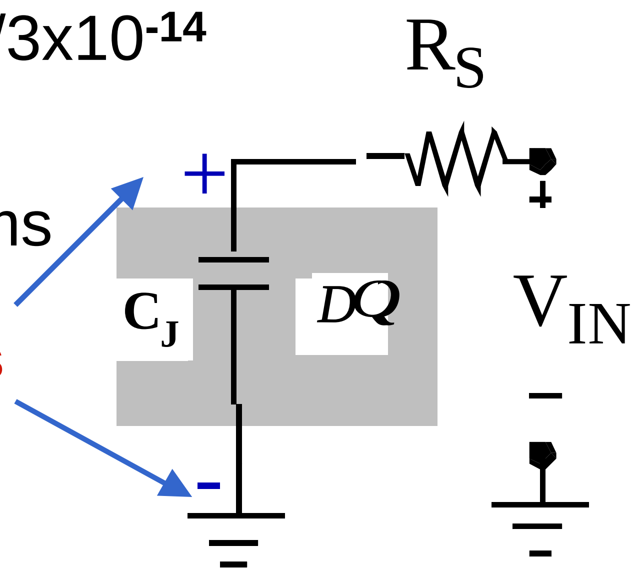
Model for Photo Detector

- Film sensitivity ~ 3×10^{4} photons

  $\Delta Q_S = 3\times10^{4}$ electrons
- Junction capacitance C_J ~ 30 fF
- $\Delta V_S = \Delta Q/C_J = 3\times10^{4} \times 1.6\times10^{-19}/3\times10^{-14}$

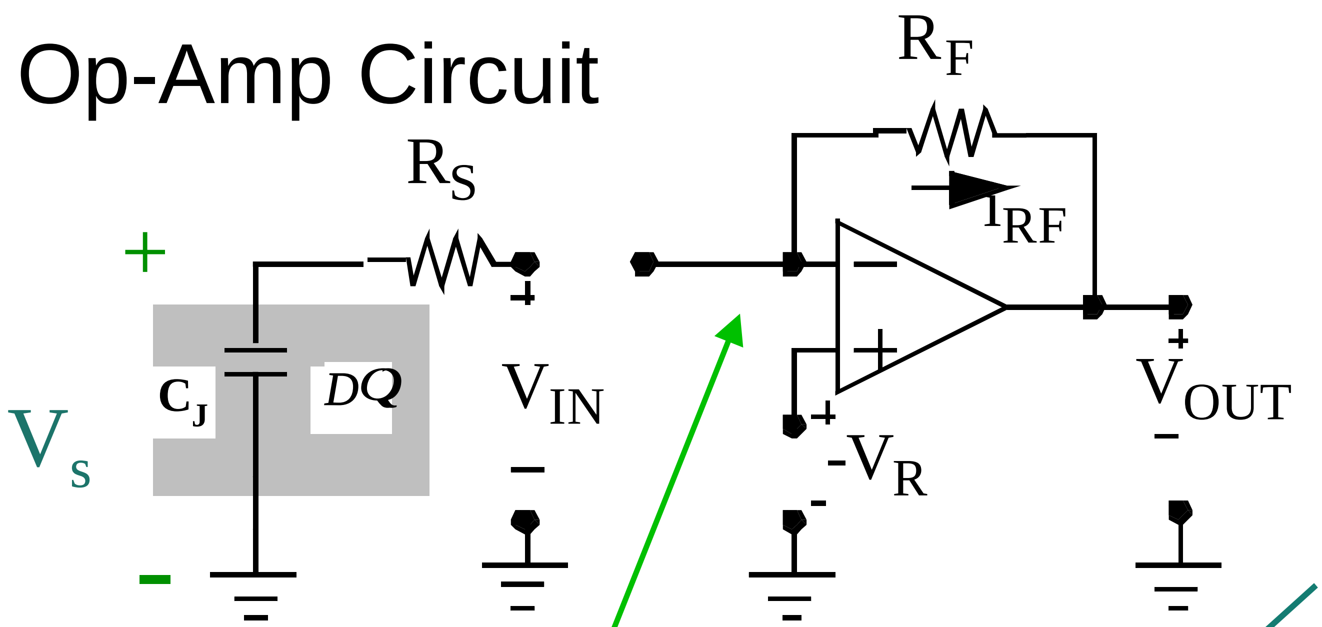
  $\Delta V_S = 160$ mV
- Series resistance R_S = 200 Ohms

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



Current to Voltage Conversion

- Op-Amp Circuit



KCL => $\Sigma I_i = 0$

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

Remove Bias

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 less than ideal 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.

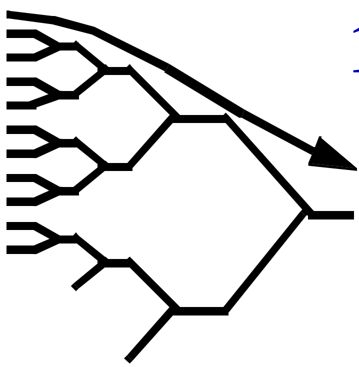
Back to the Future

- 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.

1024 Photodiodes



Resistance and Capacitance of 10 analog switches in series

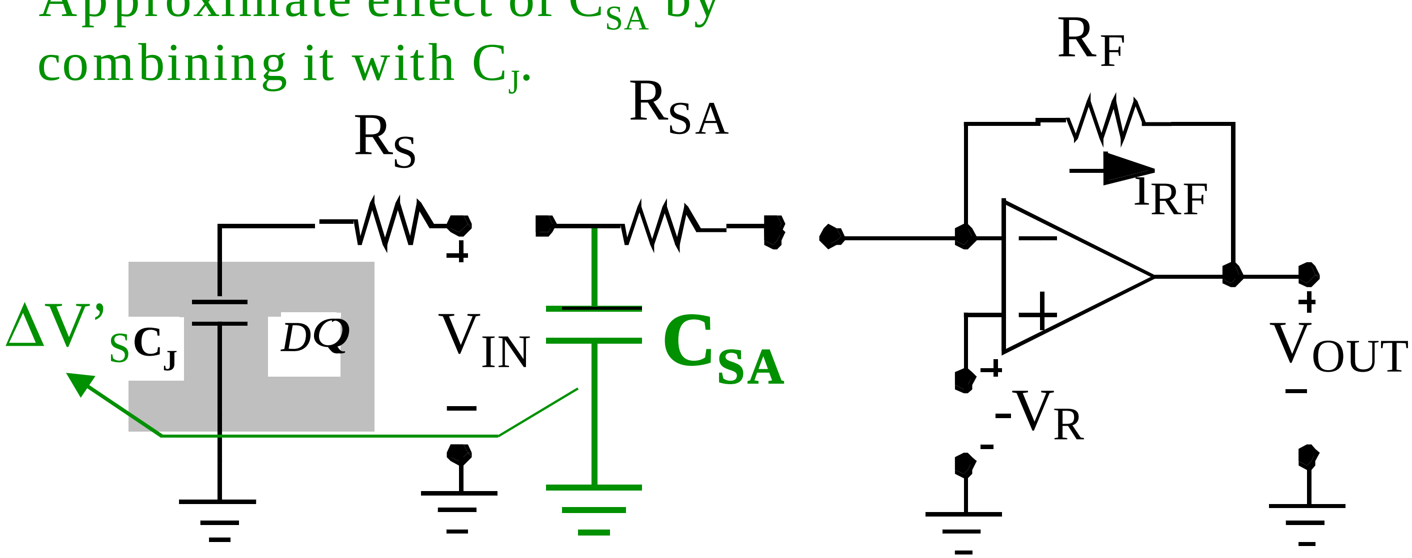
Amplifier

$$\mathbf{R_{SA} = 10*10\ k\Omega = 100\ k\Omega}$$

$$\mathbf{C_{SA} = 10*30fF = 300\ fF}$$

Model For Switching and Amplifier

Approximate effect of C_{SA} by combining it with C_J.



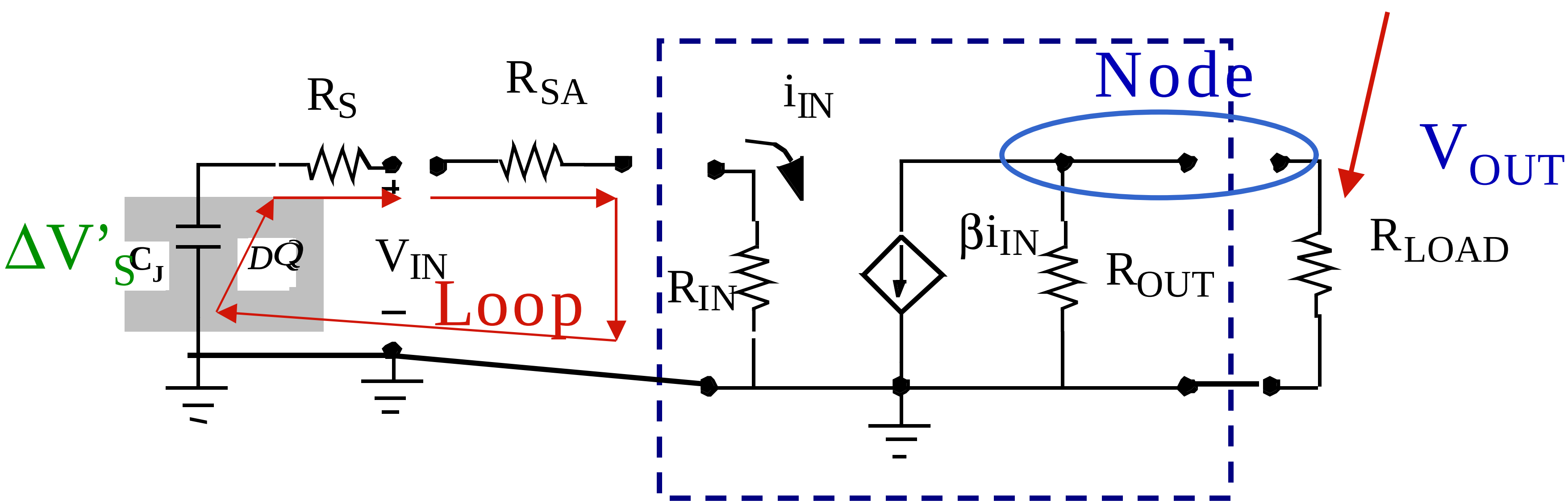
$$V_{OUT} = V_R - R_F\{(V_{BIAS} + \Delta V'_S - V_R) / (R_{S+}R_{SA})\}$$

$\Delta V'_S$ is 10 times smaller due to C_{SA} and is now about 15 mV

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



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

$\Sigma V_i = 0 \Rightarrow i_{IN}$ $\Delta V'_S = 15$ mV

$\Sigma I_i = 0$ with R_{OUT} =Infinite =>

Circuit to Hold the Charge Longer

- Problem C_J Discharges Quickly

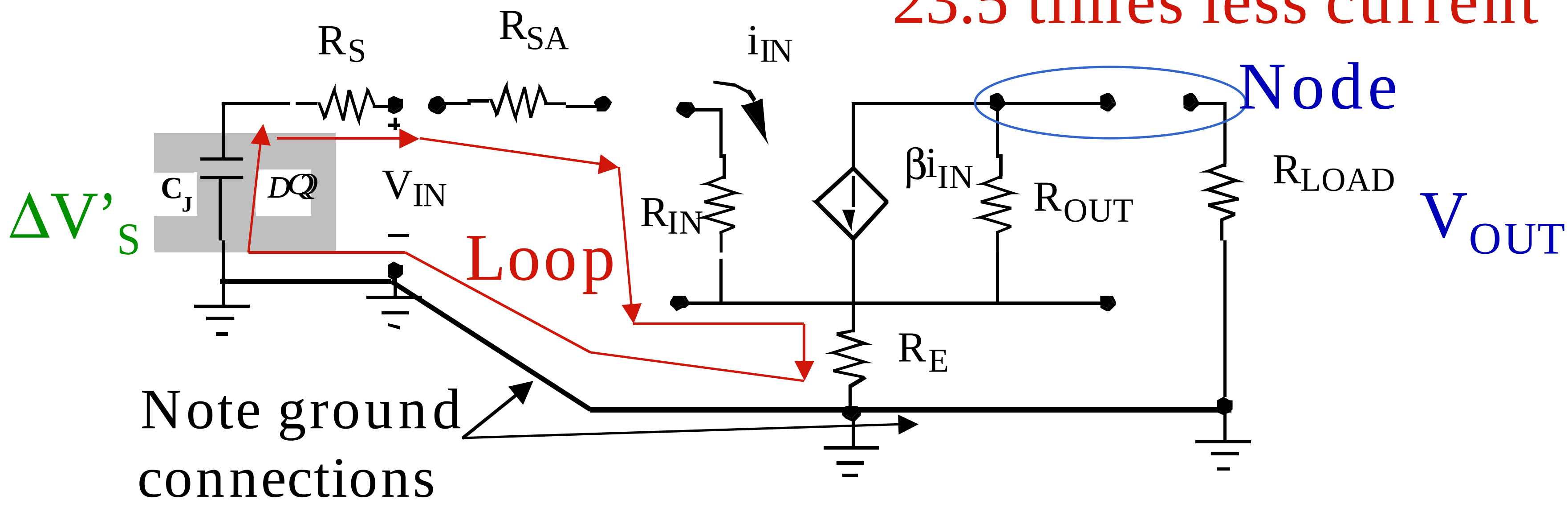
$T = C_J * R_{SA} = 30fF * 100k\Omega = 3*10^{-10}$ Sec

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

High Input Impedance Circuit

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

23.5 times less current

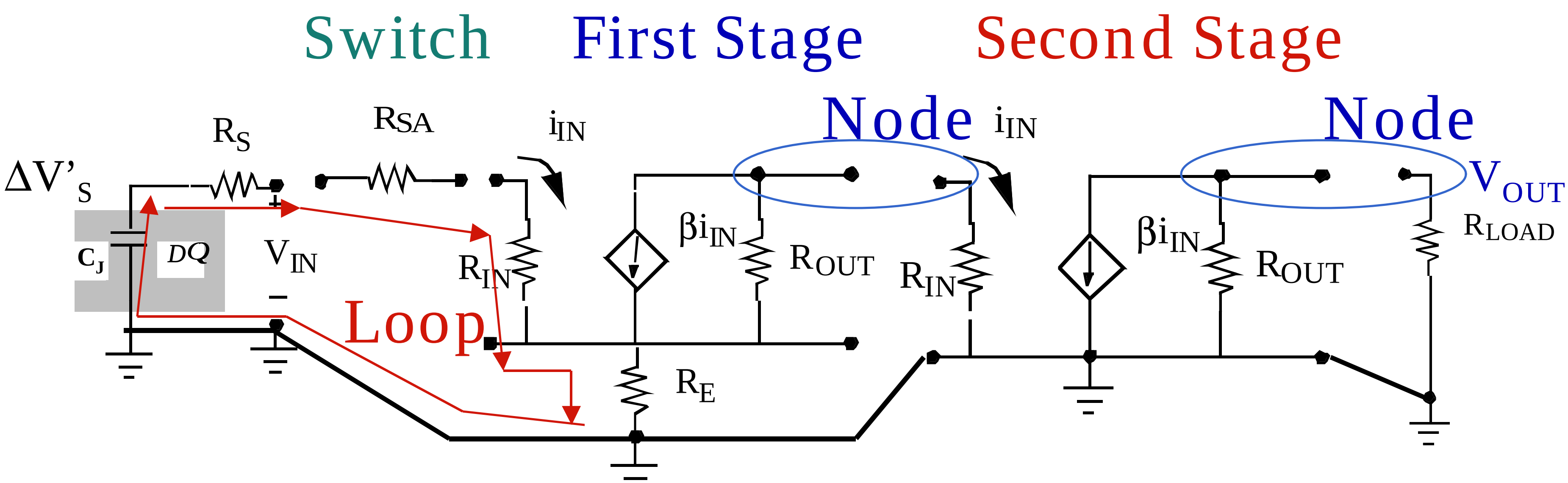


$V_{OUT} = [\Delta V'_S / (R_S + R_{SA} + R_{IN\ EQ})](-\beta)R_{LOAD} = 5\ mV$

$\Sigma V_i = 0 \Rightarrow i_{IN}$

23.5 times smaller gain

Adding a Second Stage



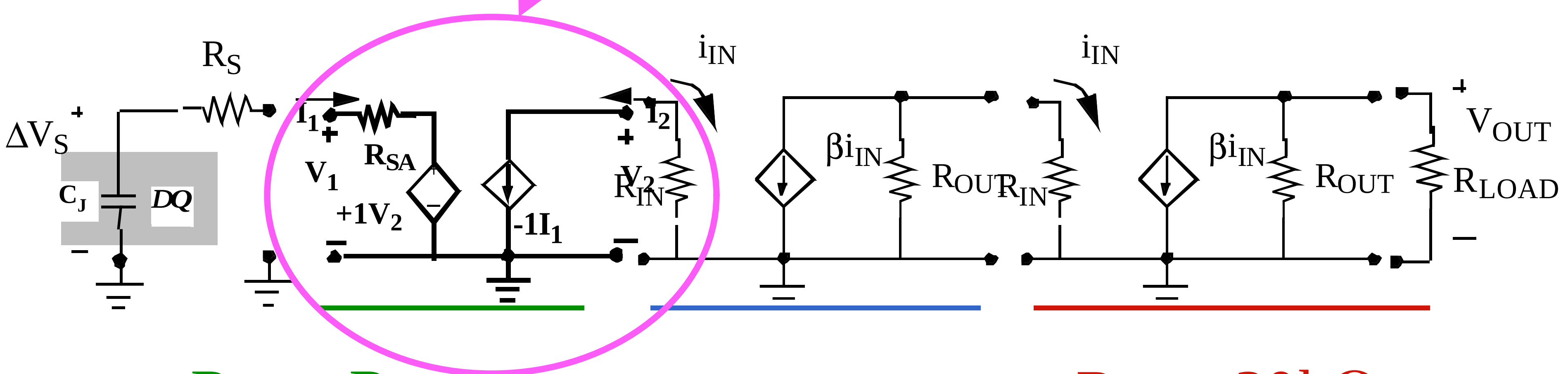
$$V_{OUT} = [\Delta V'_S / (R_S + R_{SA} + R_{IN\ EQ1})](-\beta_1)R_{in2}$$

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

Visualizing as a Multistage Amplifier

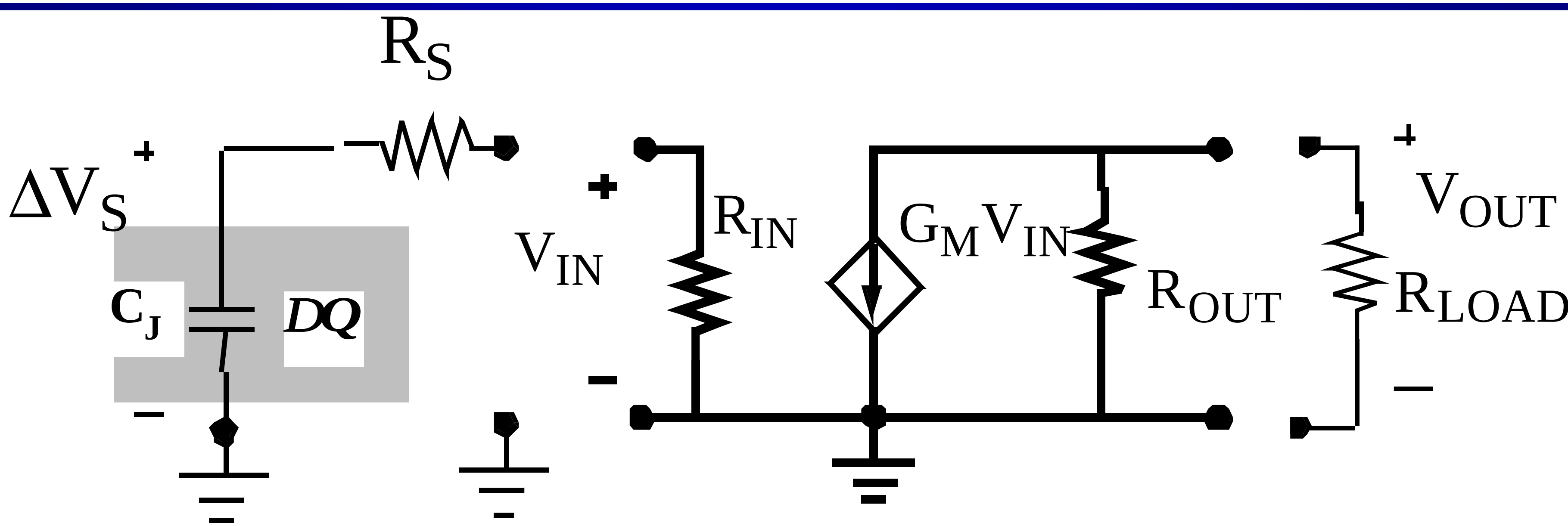
Error fixed 1/21/00

Source Switch First Stage Second Stage



$R_{IN} = R_{SA}$	$R_{IN} = 3.06\text{M}\Omega$	$R_{IN} = 30\text{k}\Omega$
$A_I = 1, A_O = 1$	$\beta = 100$	$\beta = 100$
$R_{OUT} = R_{SA}$	$R_{OUT} = \text{infinite}$	$R_{OUT} = \text{infinite}$

Visualizing as an Equivalent Two-Port

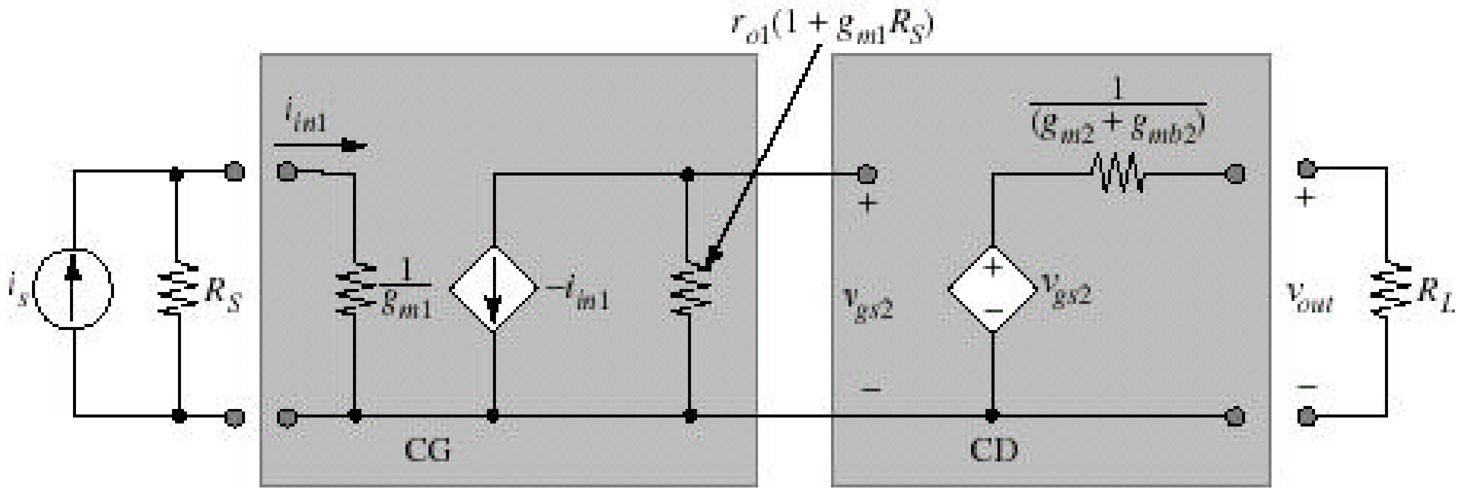


$R_{IN} = R_{SA} + R_{IN\ EQ1}$

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

R_{OUT} = Infinite (Assumed Initially)

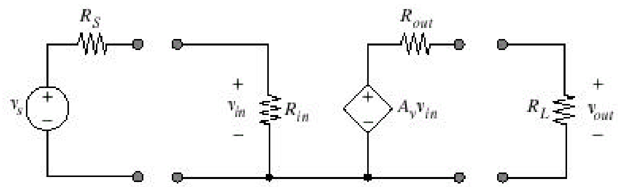
Multistage Amplifiers



This example from the reading in Chapter 8 this week.

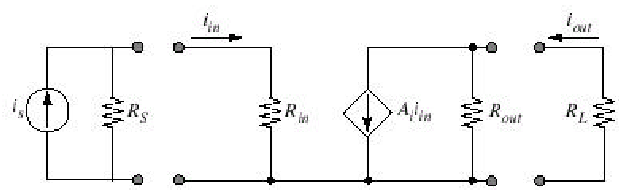
Classification of Two-Port Amplifiers

Voltage Amplifier



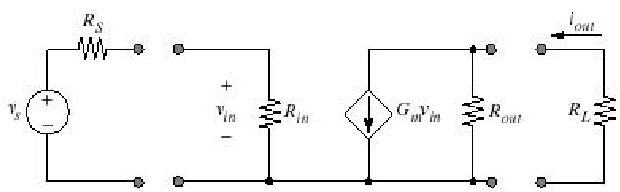
Voltage

Current Amplifier



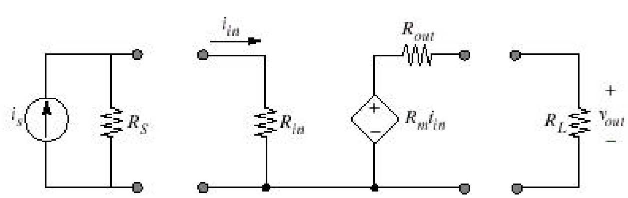
Current

Transconductance Amplifier



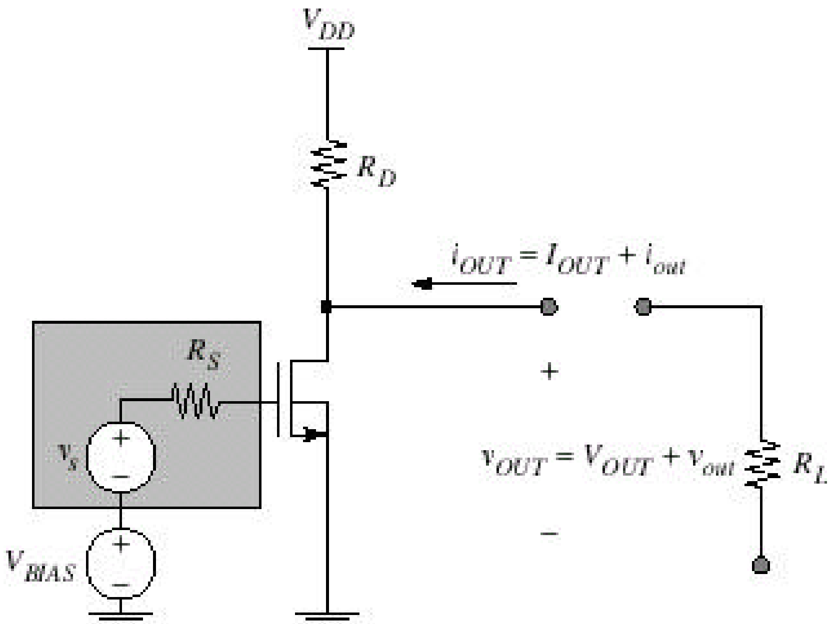
Transconductance

Transresistance Amplifier

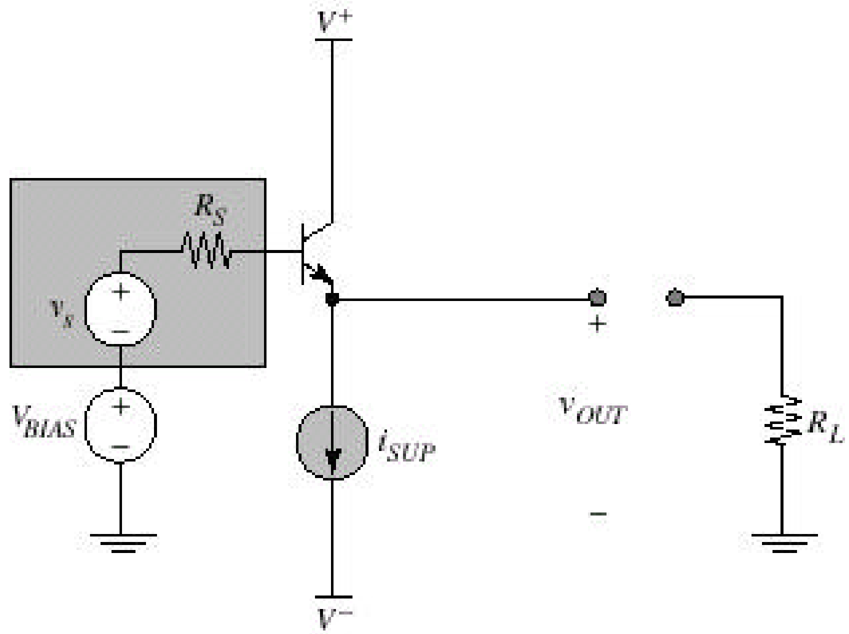


Transresistance

What Goes in the Amplifier Box



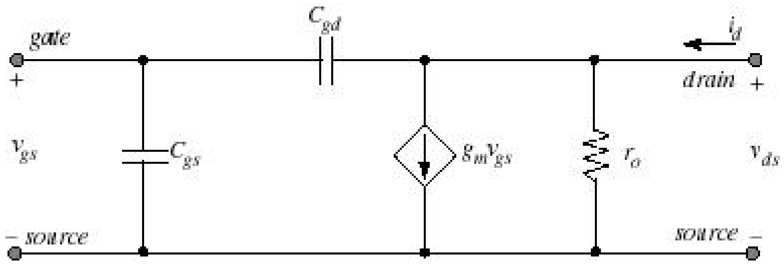
MOS

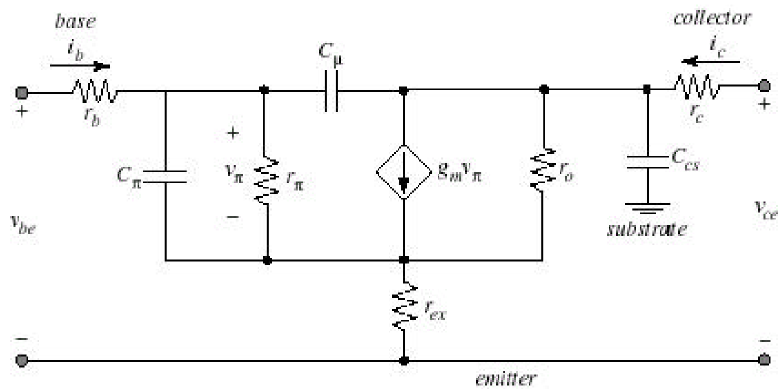


BJT

Material from Chapter 8 from week 11.

Small Signal Models for Transistors





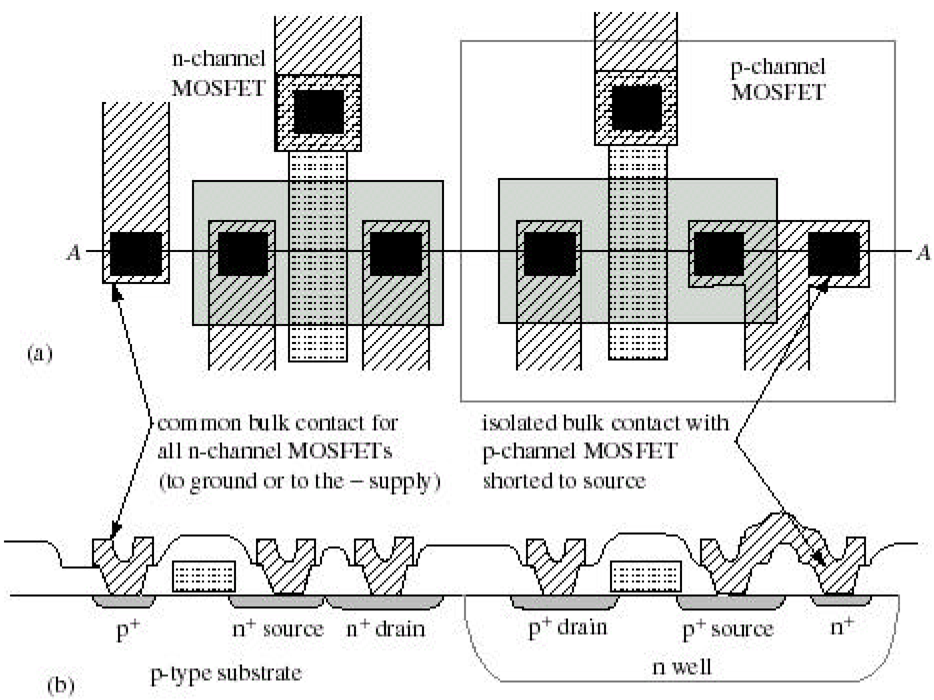
MOS

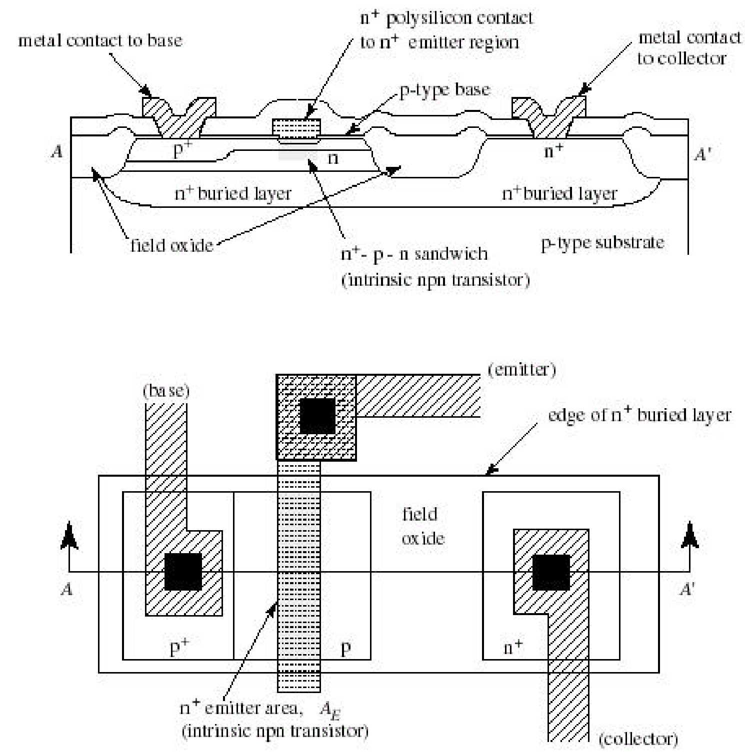
Week 5

BJT

Week 8

Layout of Transistors





Week 2

Week 8