EE112 - Fall 2016
Analog Integrated Circuits I

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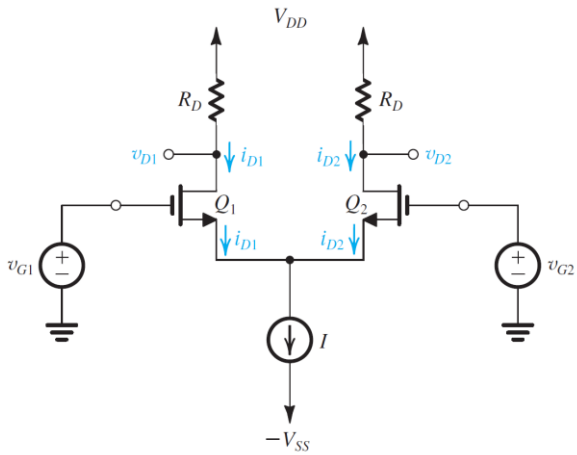
Why Differential?

- Differential circuits are much less sensitive to noises and interferences
- Differential configuration enables us to bias amplifiers and connect multiple stages without using coupling or bypass capacitors
- Differential amplifiers are widely used in IC's
  - » Excellent matching of transistors, which is critical for differential circuits
  - » Differential circuits require more transistors-not an issue for IC

MOS Differential-Pair

Basic Configuration



- Two matched MOS transistors Common current bias.
- "Differential signals" applied to v_{G1} and v_{G2} (equal amplitude but opposite sign).
- "Differential outputs" are produced at v_{D1} and v_{D2}.
- Note: in differential configuration with 0 differential input, V_{GS} is fixed for both Q_1 and Q_2.

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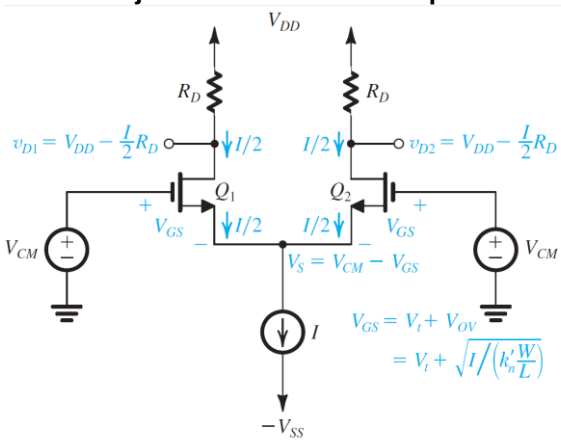
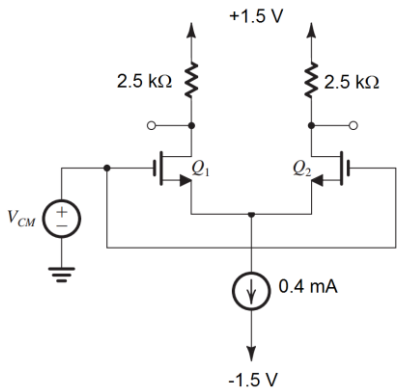
Differential Pair
Rejects Common-Mode Inputs



- The common voltages applied to both Q_1 and Q_2 are referred to as common mode, V_{CM}.
- Common mode inputs usually come from noises or interferences.
- Differential pair should reject V_{CM}:
  - » Since $V_{GS1} = V_{GS2} = V_{tn} + \sqrt{I/k_n}$ is fixed in differential pair,
  - » V_{CM} simply changes the voltage at Source, V_S.
- The drain currents remain fixed:

Example

- $V_{DD} = V_{SS} = 1.5V$, $I = 0.4mA$, $R_D = 2.5k\Omega$. Minimum voltage across current source $V_{CS} = 0.4V$. For Q_1 and Q_2: $k_n = 4\ mA/V^2$, $V_{tn} = 0.5V$.
- Find V_S, I_{D1}, I_{D2}, V_{D1}, V_{D2} for 3 different V_{CM} below:



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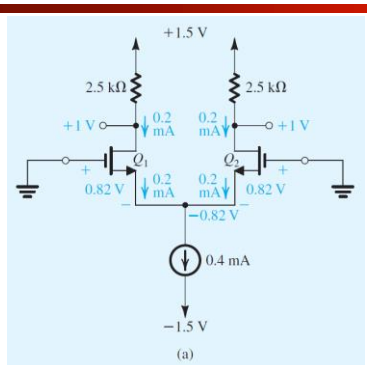
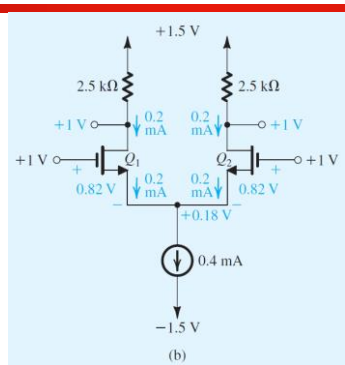
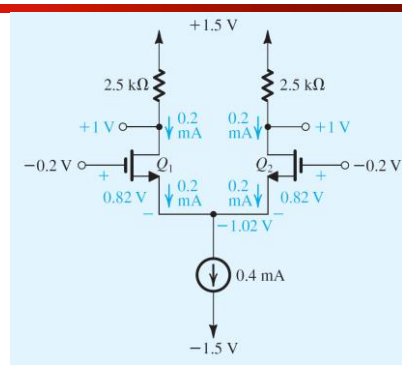
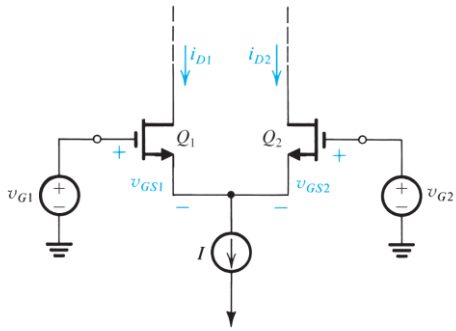


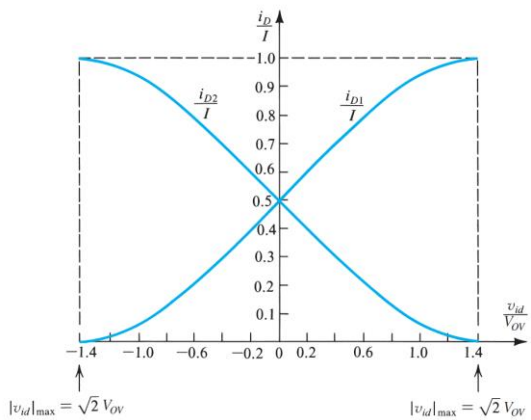




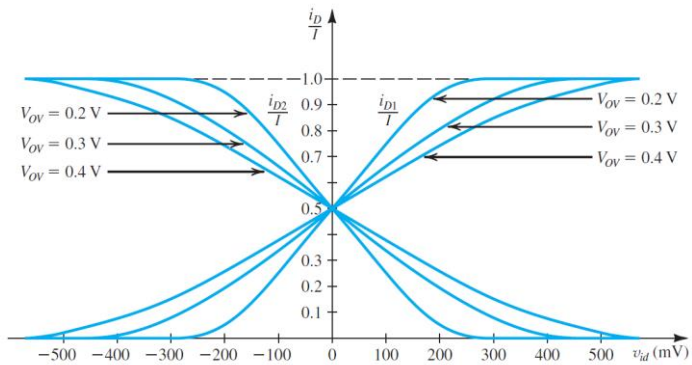
Operation with Differential Input Voltage



Operation with Differential Input Voltage

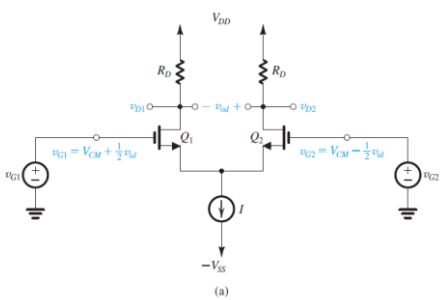


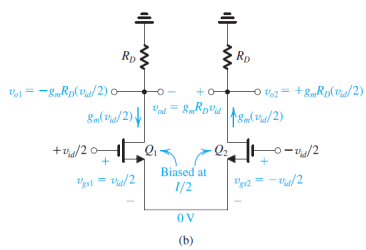
Current of Differential Pair for Various Overdrive Voltage

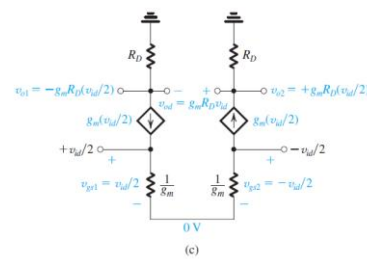


- The linear range of operation of the MOS differential pair can be extended by operating the transistor at a higher value of V_{OV}

Small Signal Operation



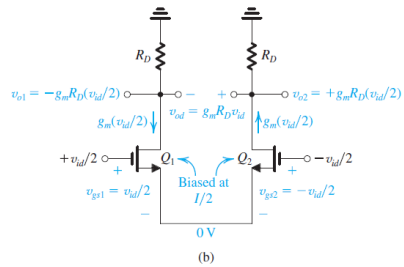


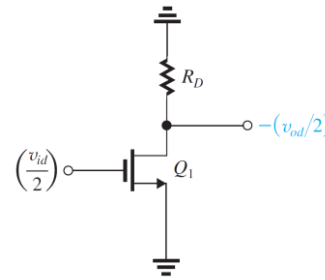


For differential AC small signal, the differential pair is “anti-symmetric”. The potential at the mid point (Source) is zero. This is called “Virtual Ground”

This virtual ground is obtained without using a large bypass capacitor -> much smaller area and better frequency response

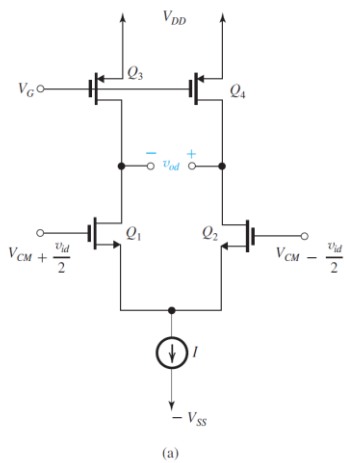
Differential Half Circuit

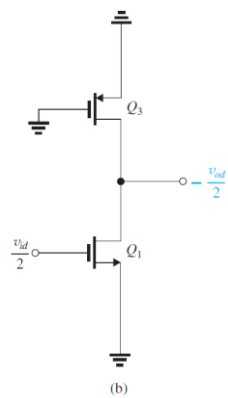




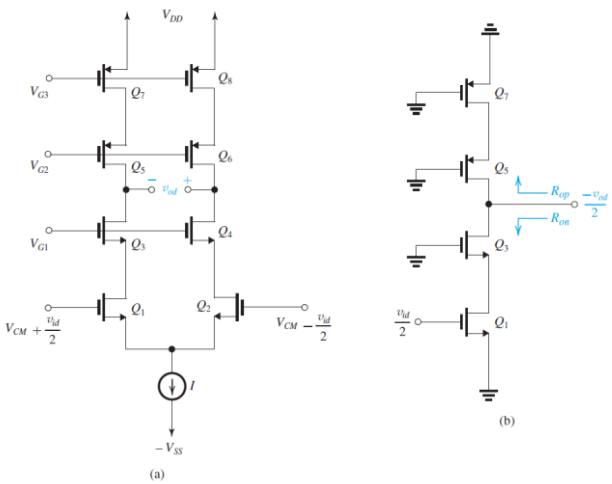
- Because the two halves of the circuits are anti-symmetric, and Source is at virtual ground, we can simplified and just analyze the "half circuit"

Differential Amplifier with Current-Source Loads





Cascode Differential Amplifier



- Cascode configurations for both amplifying transistors and current source loads.