ECE 523/421 – Analog Electronics

Lecture 13: Differential Amplifiers: BJT Differential Pair

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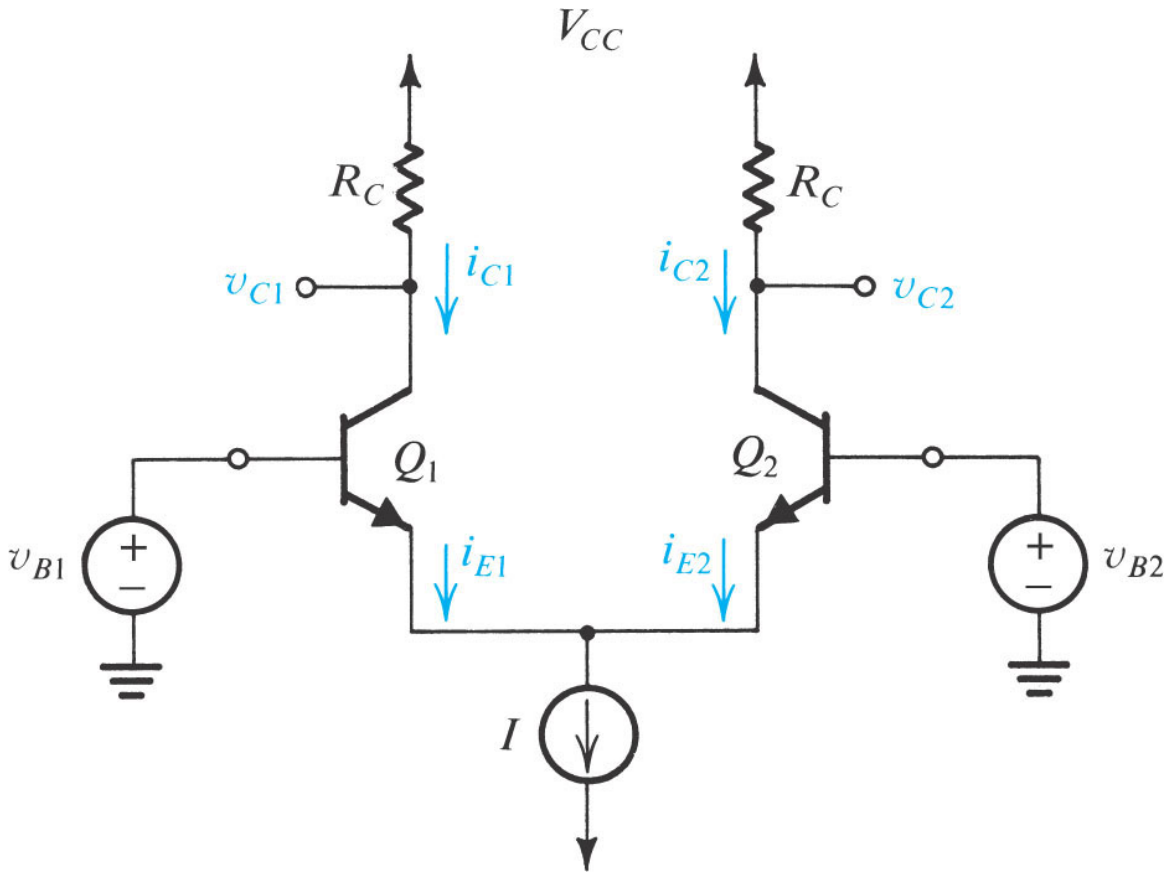
Review of Last Lecture

- **MOS Small Signal Differential Amplifier**
- **Half-Circuit Differential Mode**
- **Half-Circuit Common Mode**
- **Active Load Differential Amplifier**
- **CMRR**

Today's Lecture

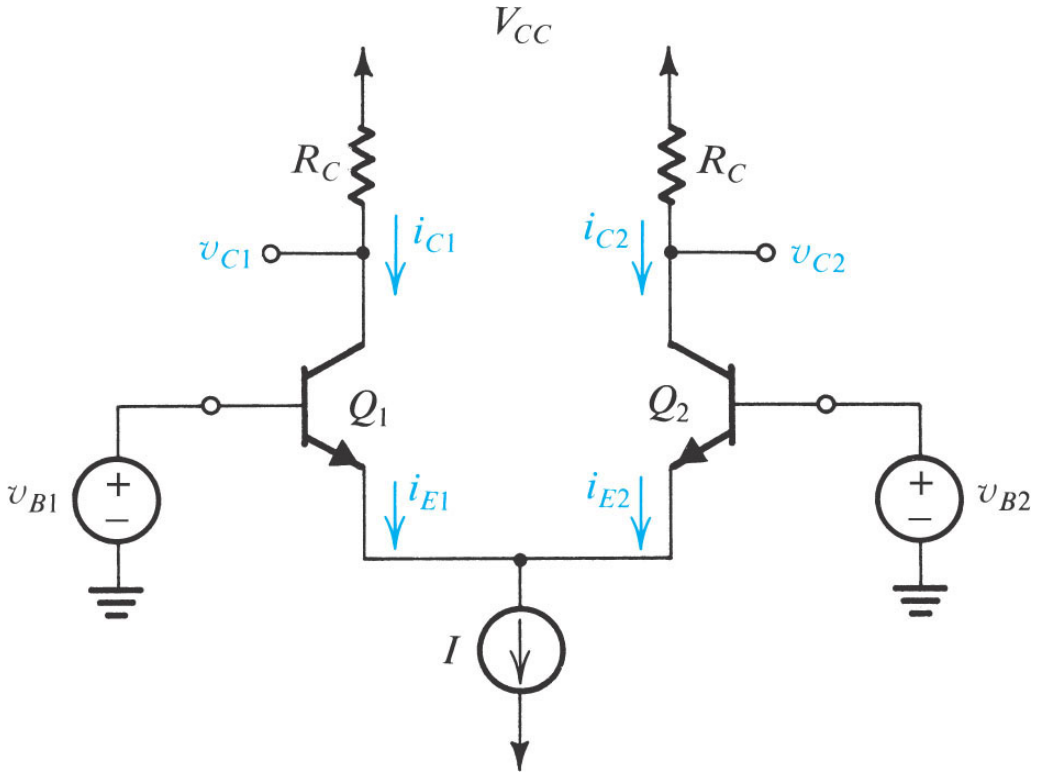
- **BJT Large Signal Differential Amplifier**
- **Half-Circuit Differential Mode**
- **Half-Circuit Common Mode**
- **CMRR**

Operation With Differential Mode Input



$$-4V_T \leq v_{id} \leq 4V_T$$

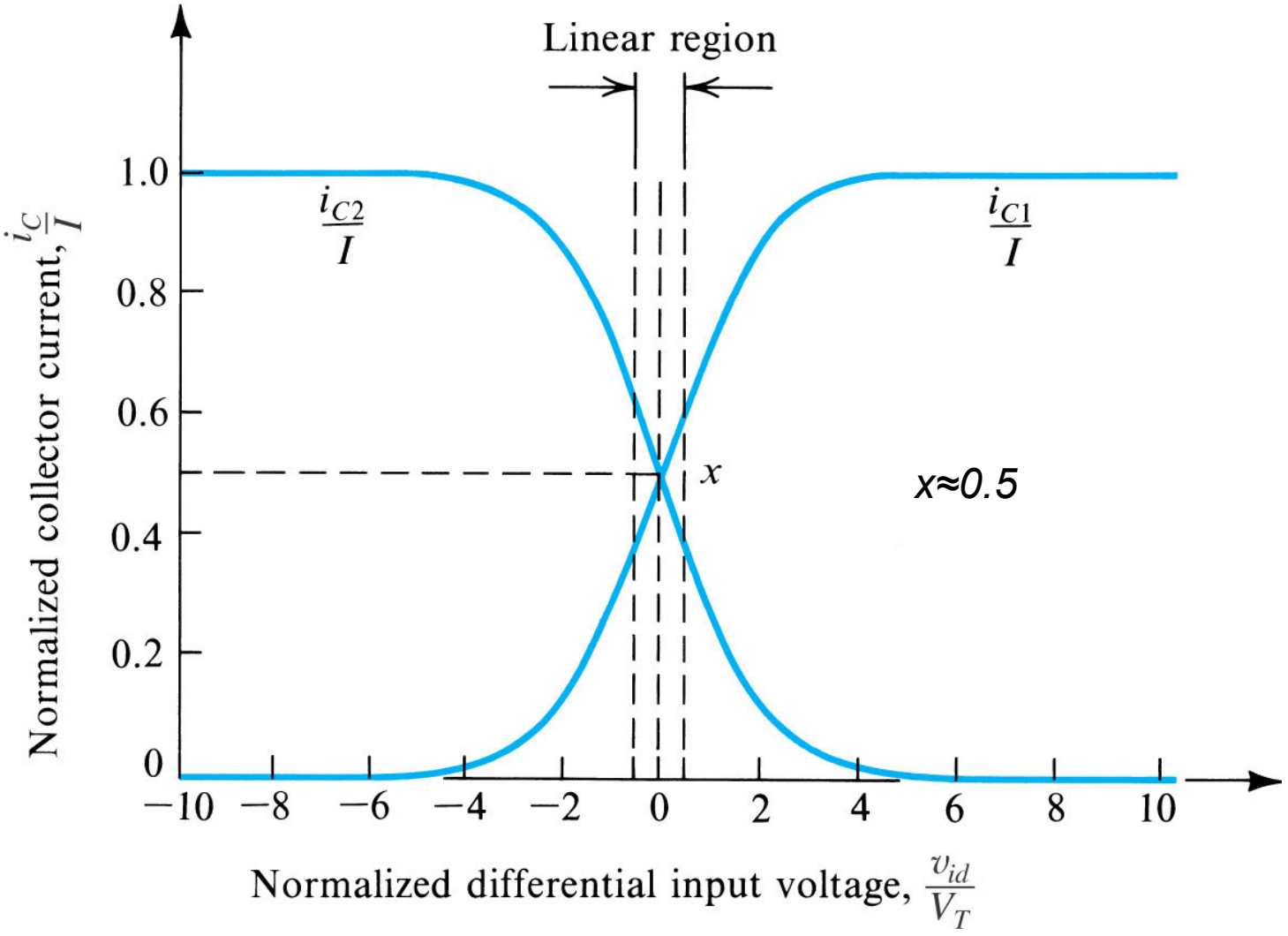
Large Signal Operation



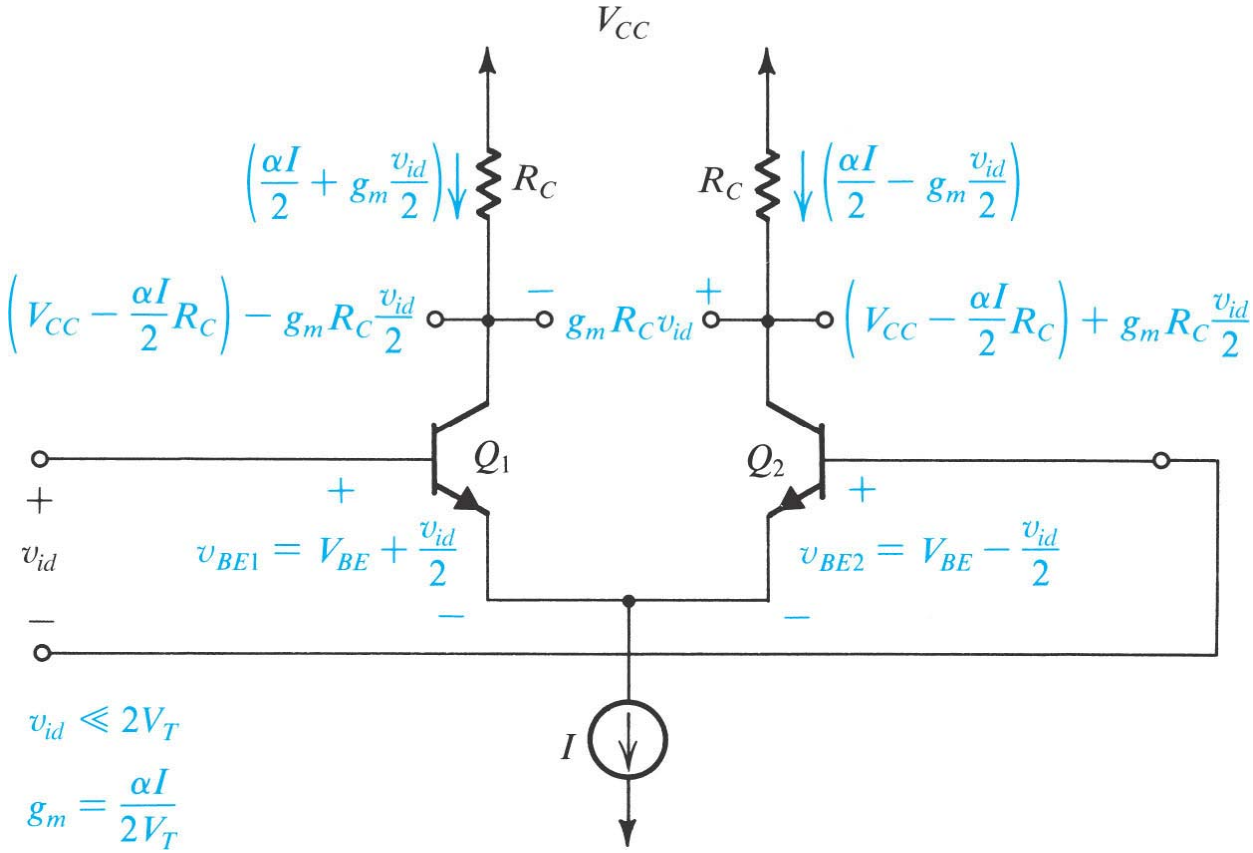
$$i_{C1} = \frac{\alpha I}{1 + e^{-v_{id}/V_T}}$$

$$i_{C2} = \frac{\alpha I}{1 + e^{v_{id}/V_T}}$$

Large Signal Operation

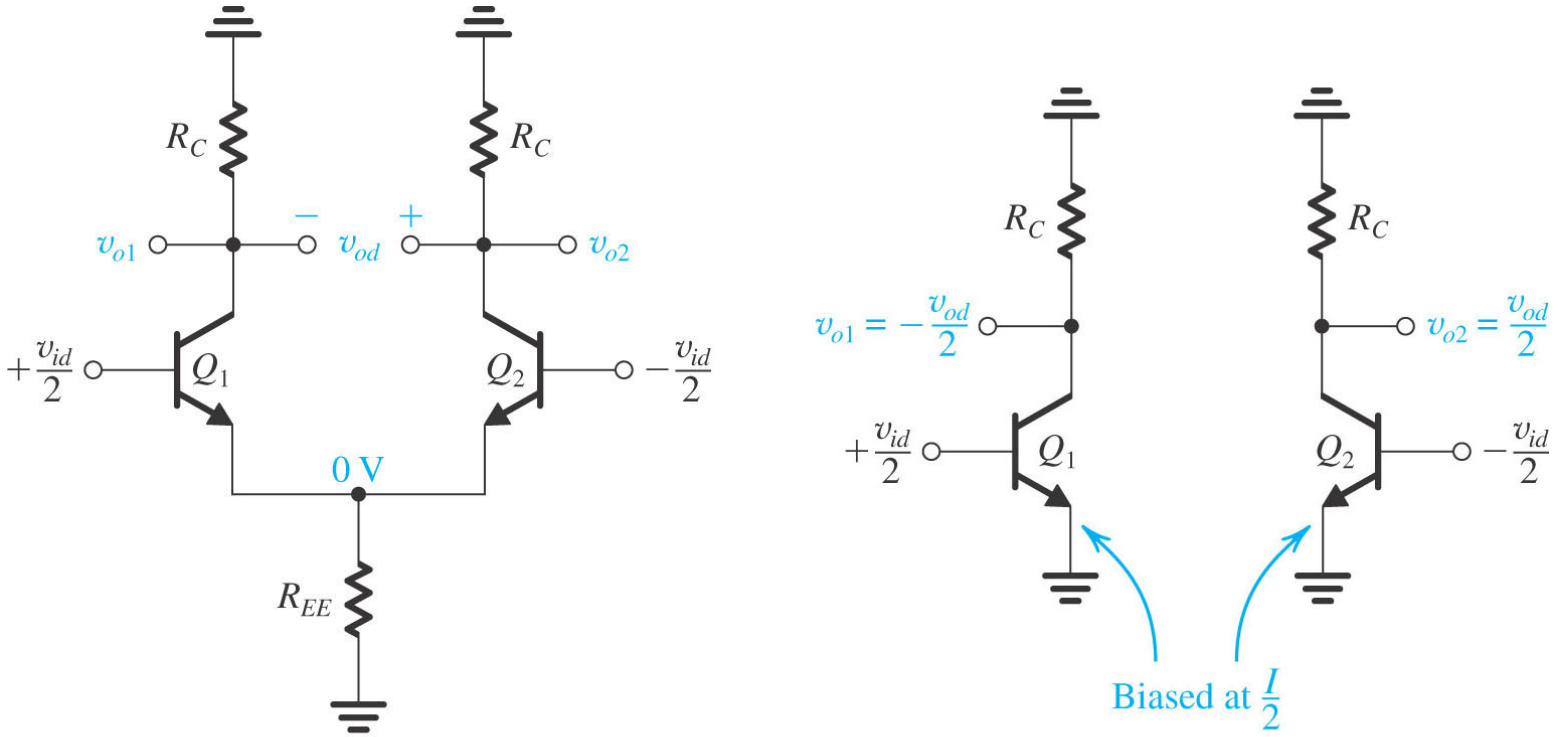


BJT Differential Gain



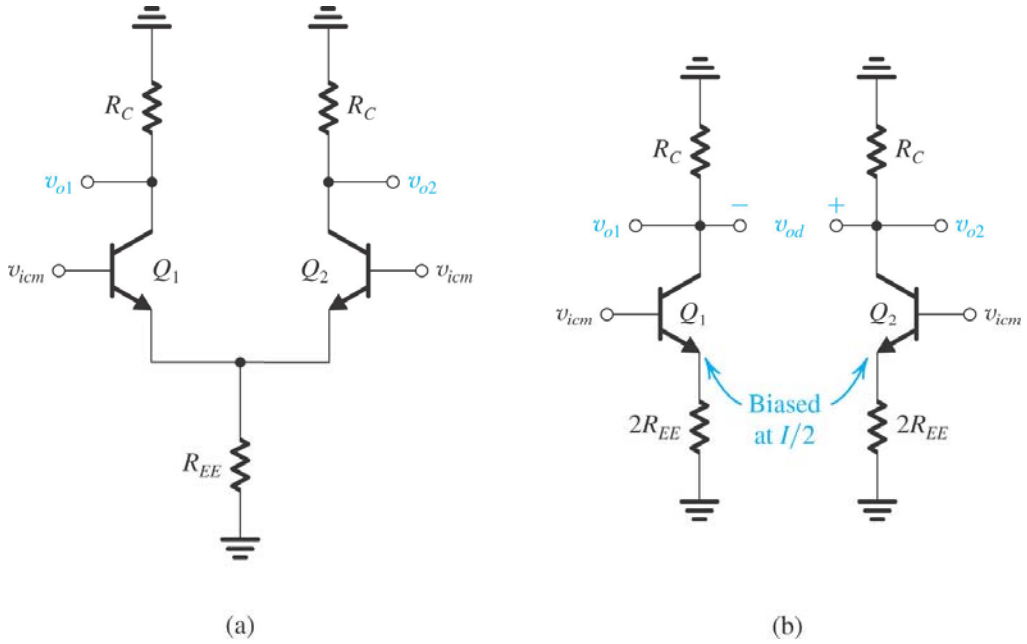
$$g_m = \frac{I_C}{V_T} = \frac{\alpha I/2}{V_T} = \frac{I/2}{V_T} \qquad A_d = \frac{v_{od}}{v_{id}} = g_m R_C$$

Differential Half-Circuit



$$A_d = \frac{v_{od}}{v_{id}} = g_m\left(R_C \| r_o\right)$$

Common Mode Gain



$$\frac{v_{o1}}{v_{icm}} = \frac{v_{o2}}{v_{icm}} = -\frac{R_C}{1/g_m + 2R_{EE}}$$

$$v_{od} = 0$$

**** Assuming differential output***

R_C Mismatch and Common Mode Gain

Ideal Case

$$\begin{cases} \dfrac{v_{o1}}{v_{icm}} = \dfrac{v_{o2}}{v_{icm}} = -\dfrac{R_C}{1/g_m + 2R_{EE}} \\ v_{od} = 0 \end{cases}$$

R_C Mismatch Case

$$A_{cm} = \frac{v_{od}}{v_{icm}} = -\frac{R_C}{1/g_m + 2R_{EE}}\left(\frac{\Delta R_C}{R_C}\right)$$

**** Assuming differential output***

Common Mode Rejection Ration

$$CMRR = \frac{|A_d|}{|A_{cm}|} \qquad CMRR(dB) = 20\log\left(\frac{|A_d|}{|A_{cm}|}\right)$$

Examples:

R_C Mismatch Case

$$CMRR = \frac{1 + 2g_m R_{EE}}{(\Delta R_C / R_C)}$$

**** Assuming differential output***

Example: BJT Differential Amplifier

1) Let β=100. Find R_{id} and v_{od}/v_{sig}.