ECE 523/421 – Analog Electronics

Lecture 28: CMOS Operational Amplifier Circuits

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Review of Last Lecture

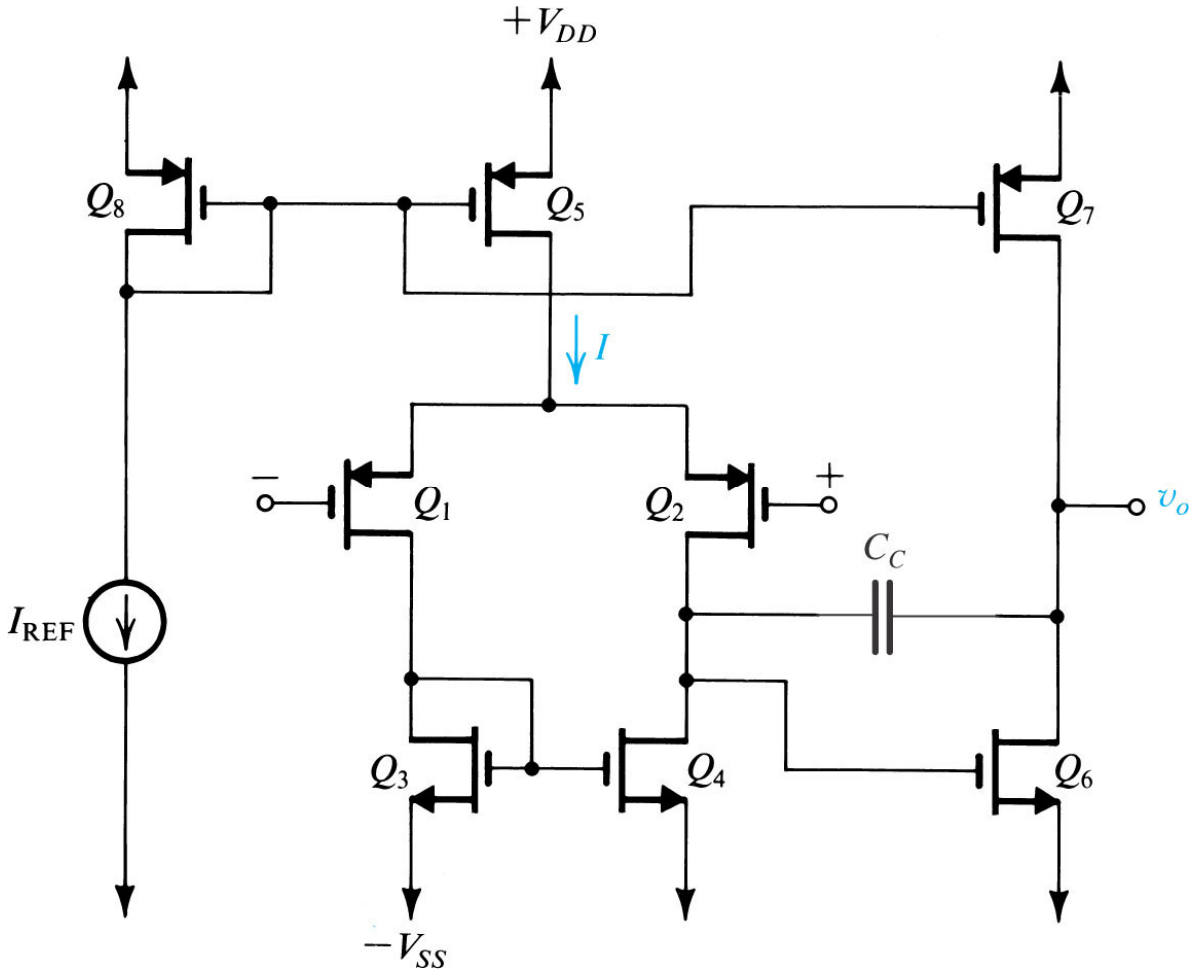
- **Basic Digital to Analog Converters**
- **Basic Analog to Digital Converters**

Today's Lecture

- **CMOS OPAMPs**

Courtesy of Prof. Philip Allen

Importance of Data Conversion



Input & Output Swing

$$-V_{SS} + V_{OV3} + V_{tn} - |V_{tp}| \leq V_{ICM} \leq V_{DD} - |V_{tp}| - |V_{OV1}| - |V_{OV5}|$$

$$-V_{SS} + V_{OV6} \leq v_O \leq V_{DD} - |V_{OV7}|$$

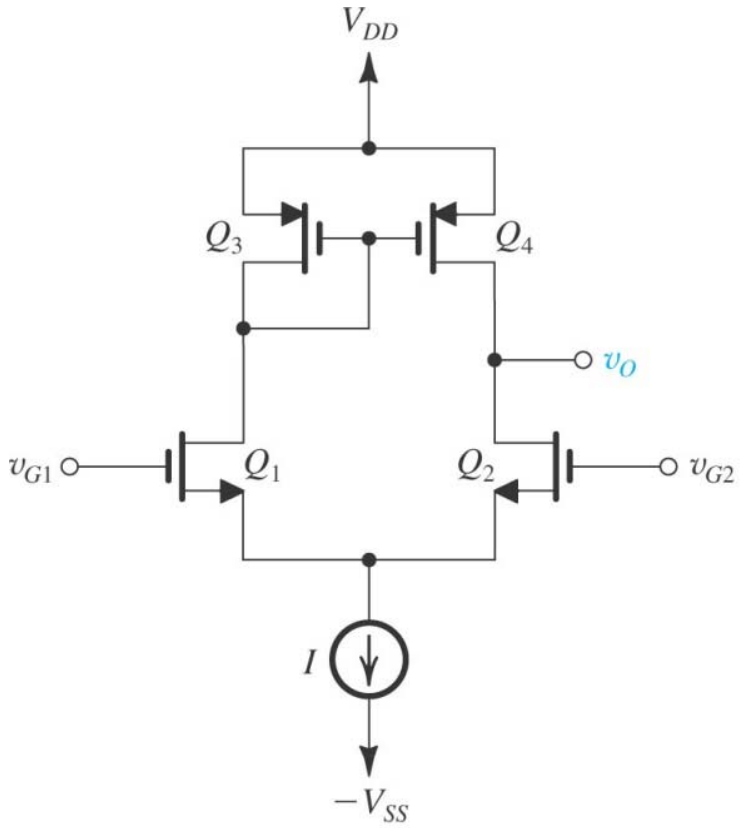
Voltage Gain

$$A_v = A_1 A_2$$

$$= G_{m1} R_1 G_{m2} R_2$$

$$= g_{m1}(r_{o2} \| r_{o4}) g_{m6}(r_{o6} \| r_{o7})$$

Common-Mode Rejection Ratio CMRR



$$CMRR = \frac{A_d}{A_{cm}} \approx (g_m r_o)(g_m R_{SS})$$

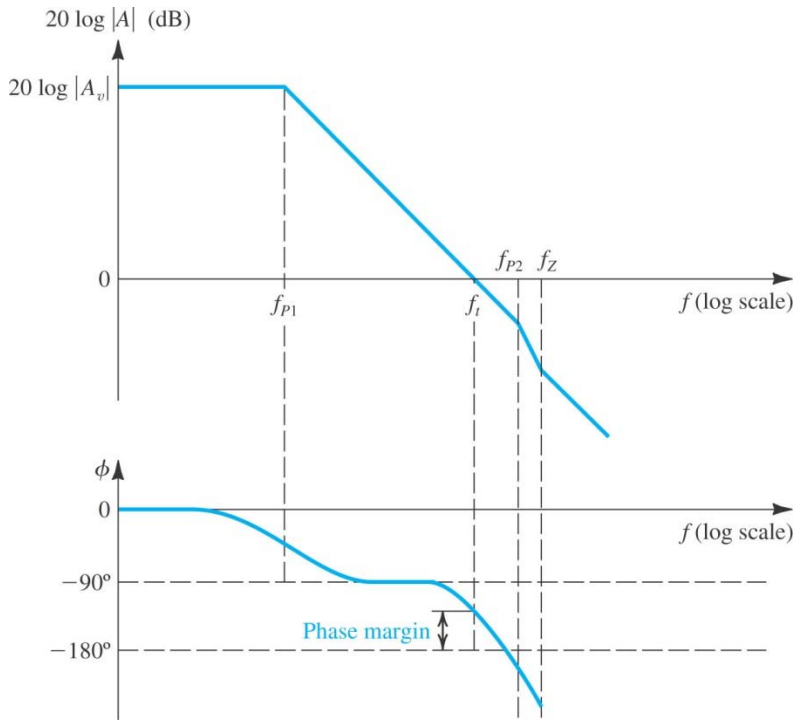
Frequency Response

$$f_{P1} \simeq \frac{1}{2\pi R_1 G_{m2} R_2 C_C}$$

$$f_{P2} \simeq \frac{G_{m2}}{2\pi C_2}$$

$$f_Z \simeq \frac{G_{m2}}{2\pi C_C}$$

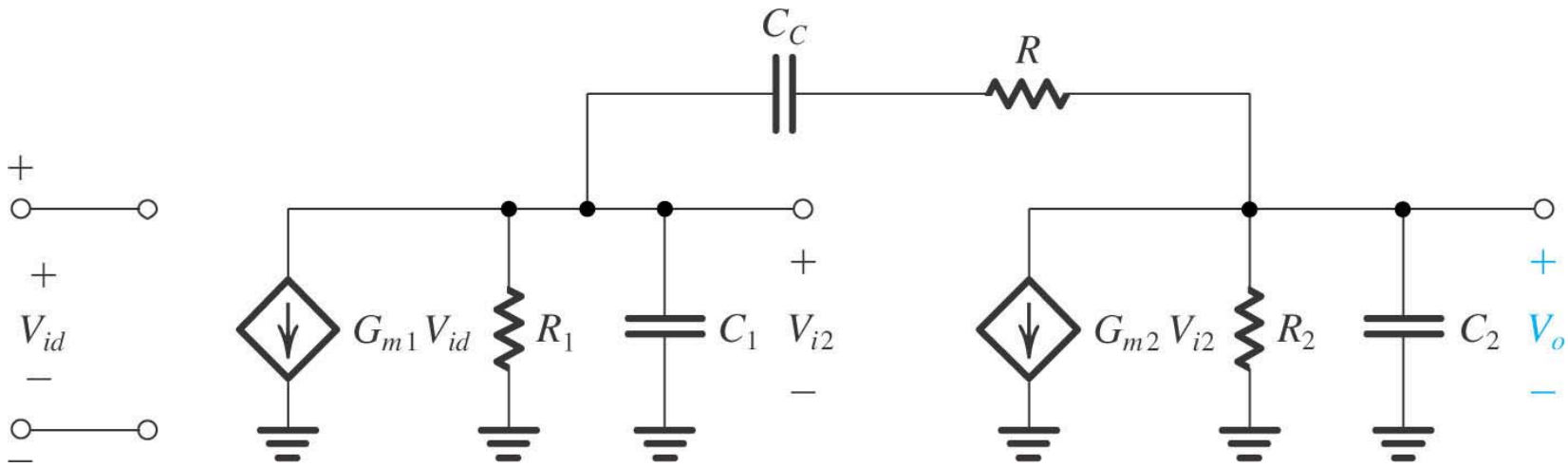
$$f_t = |A_v| f_{P1} = \frac{G_{m1}}{2\pi C_C}$$



$$\text{Phase margin} = 180° - \phi_{\text{total}}$$

$$= 90° - \tan^{-1}(f_t/f_{P2}) - \tan^{-1}(f_t/f_Z)$$

Frequency Response with RC Compensation



$$s = 1/C_C\left(\frac{1}{G_{m2}} - R\right)$$

Slew Rate

$$v_o(t) = \frac{I}{C_C} t$$

$$SR = \frac{I}{C_C}$$

Internal Circuit Diagram for 471