Spring 2019 Purdue University

ECE 255: L36

High Frequency Wrap Up

(Sedra and Smith, 7th Ed., Sec. 13.1)

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Announcements

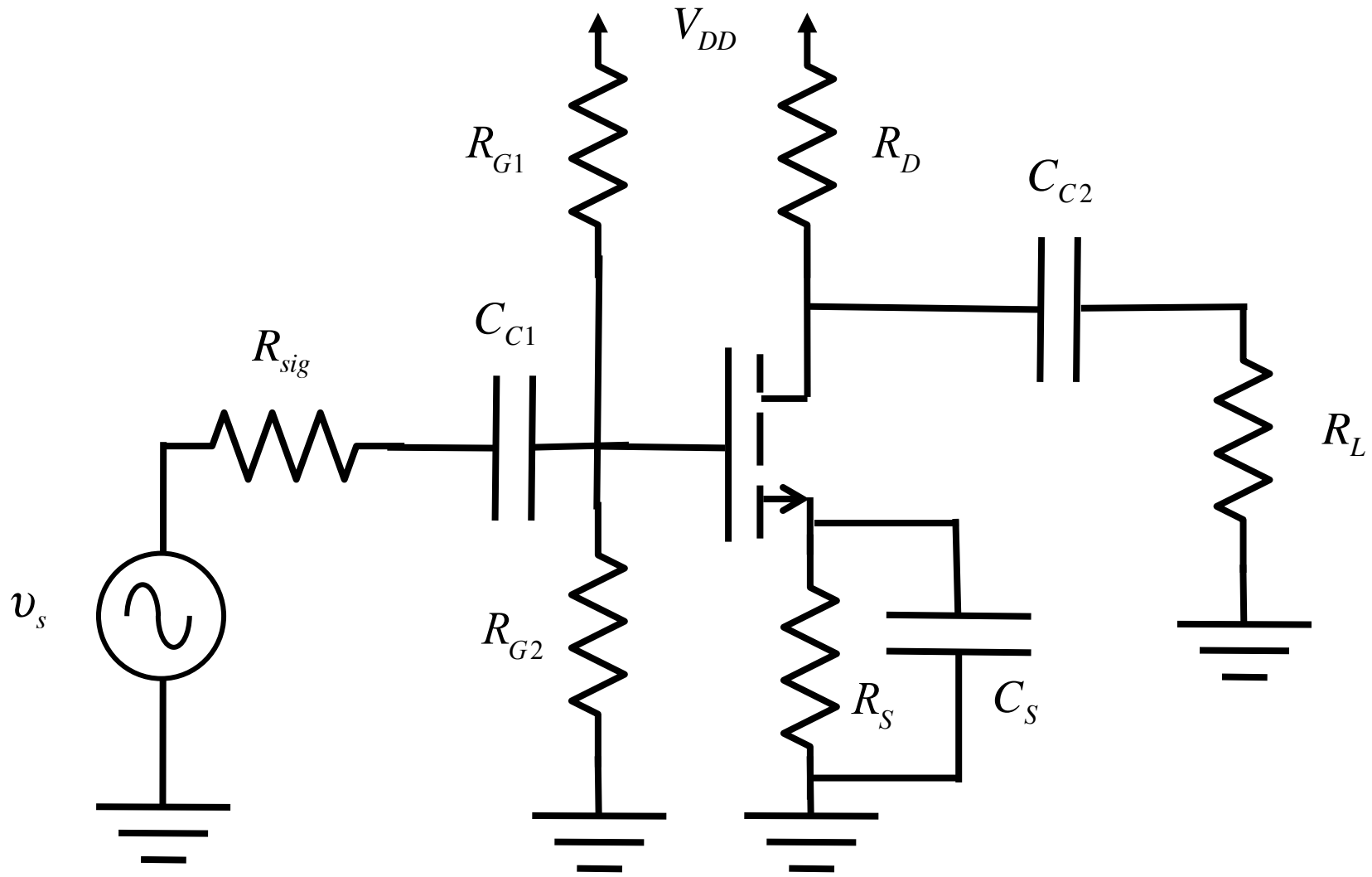
Final Exam: Thursday, May 2, 7:00 − 9:00 PM, CL50

HW11 Due 5:00 PM Friday, April 26 in EE-209 dropbox (note submission sheet)

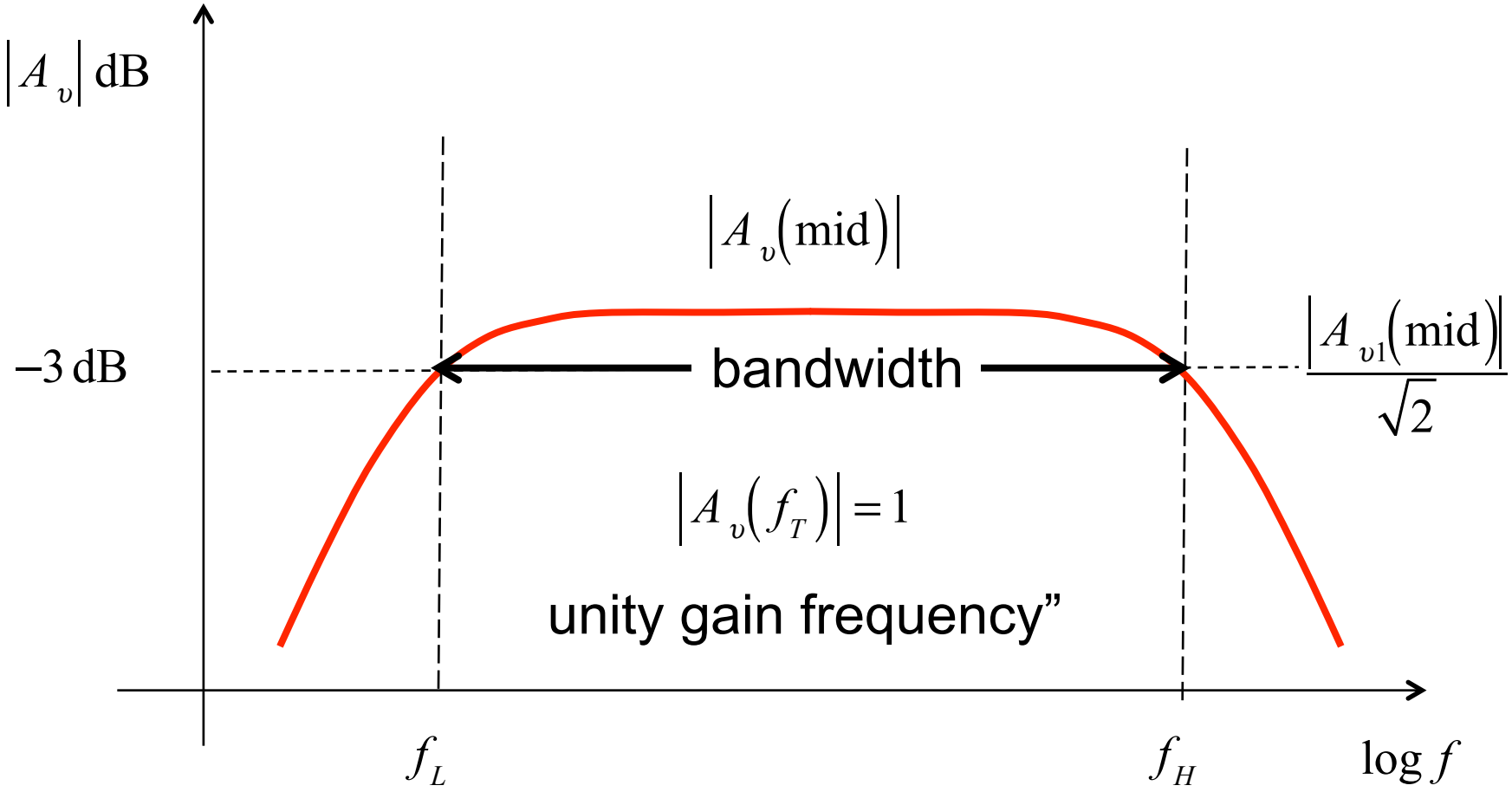
Please complete the online course evaluation

No class on Friday, April 26!

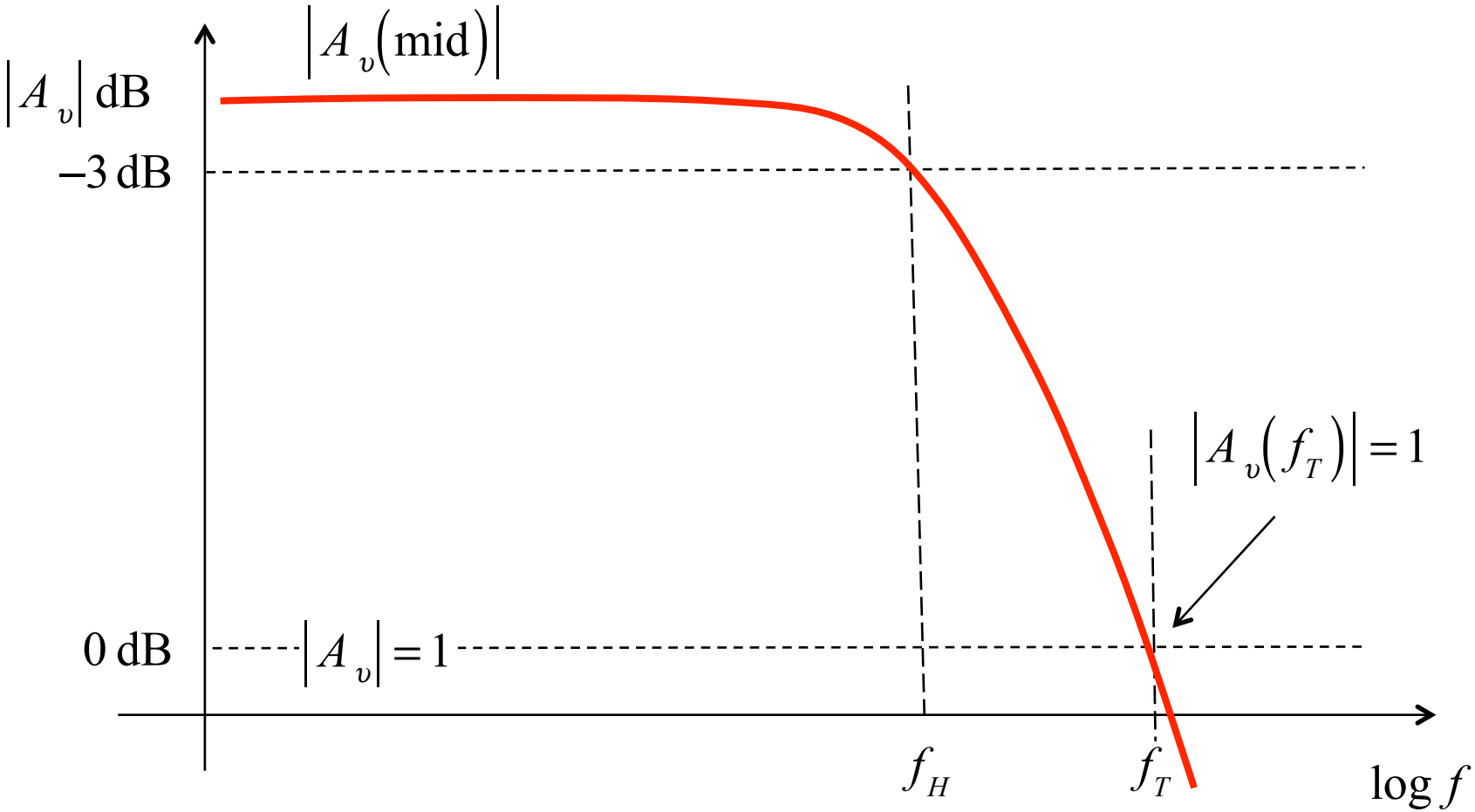
Discrete CS Amplifier



Bode plot

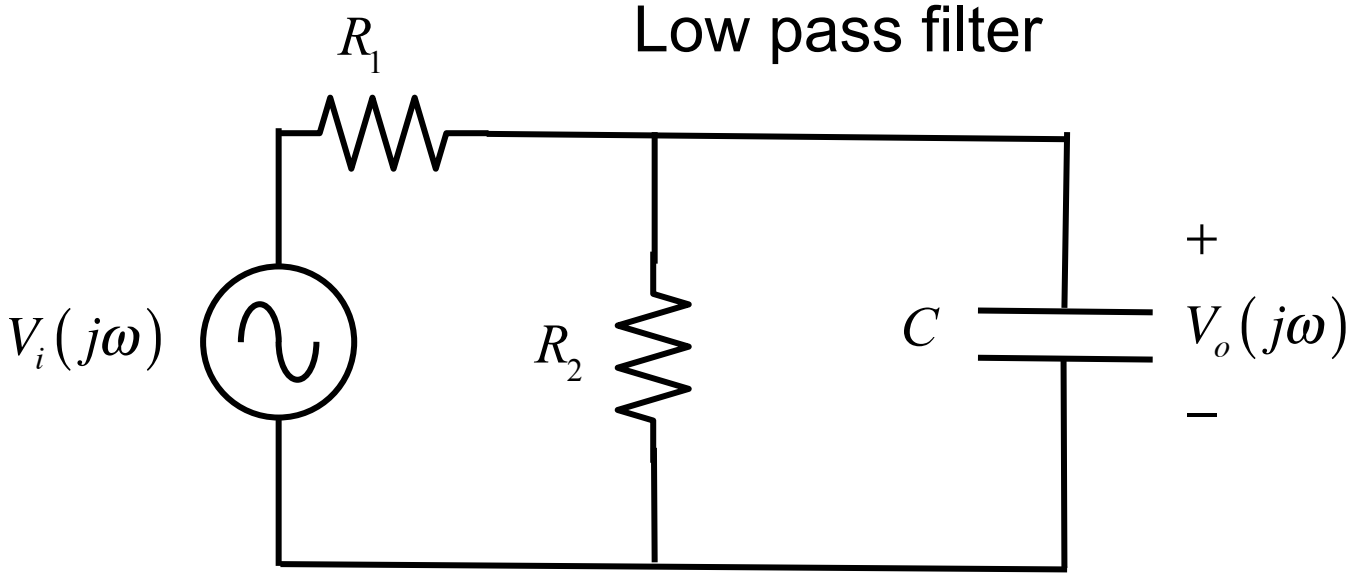

$|A_v|$ dB
$|A_v(\text{mid})|$
-3 dB
bandwidth
$\frac{|A_{v1}(\text{mid})|}{\sqrt{2}}$
$|A_v(f_T)| = 1$
unity gain frequency"
f_L
f_H
log f

Bode plot for op amp



Recall the STC circuit

Low pass filter

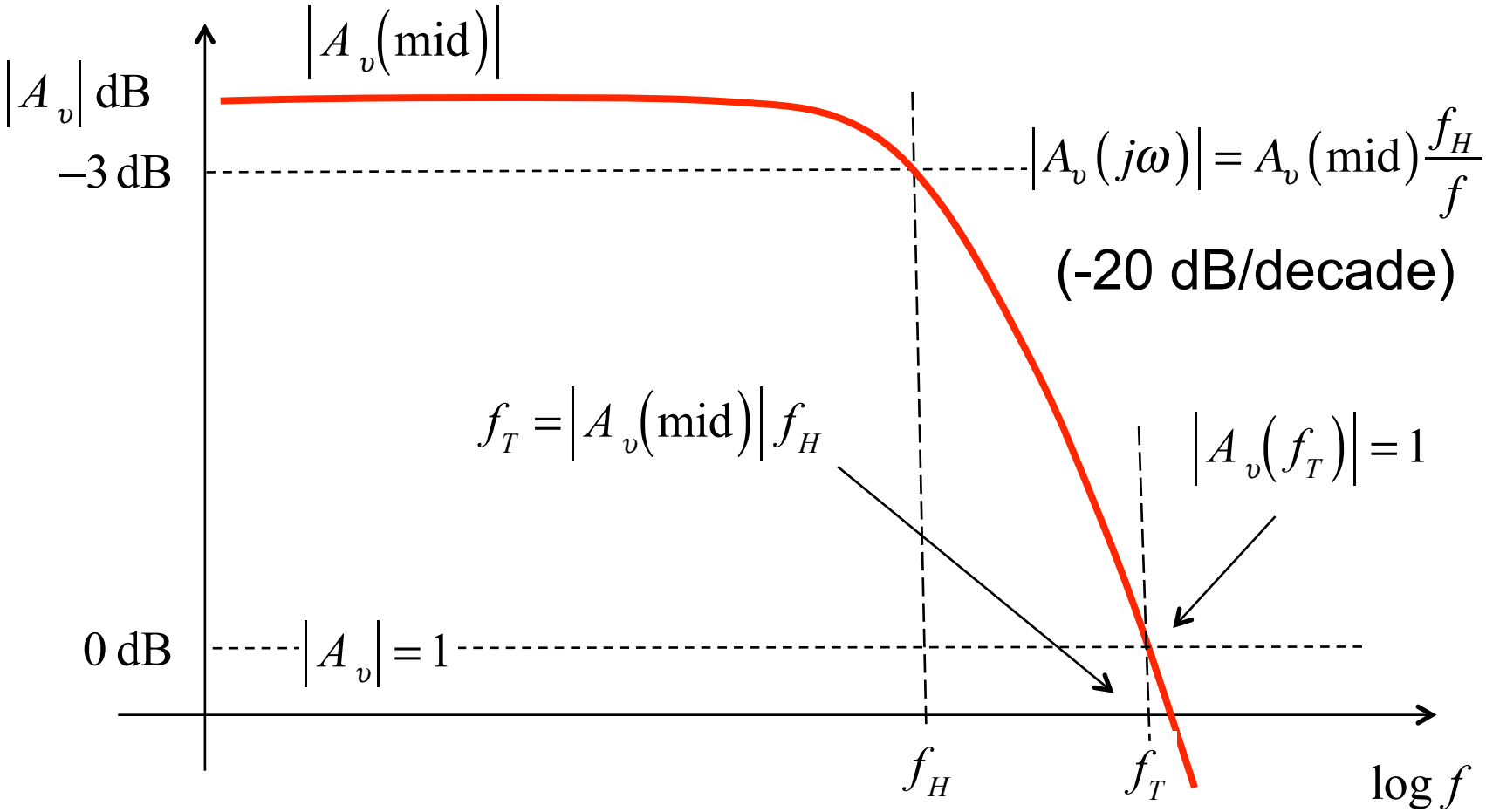


$$T(j\omega) = \frac{T_{mid}}{1 + j\omega/\omega_H} \qquad \left|T(j\omega)\right| = \frac{T_{mid}}{\sqrt{1+\omega^2/\omega_H^2}} \qquad \left|T(j\omega)\right| = 1 = T_{mid}\frac{\omega_H}{\omega_T}$$

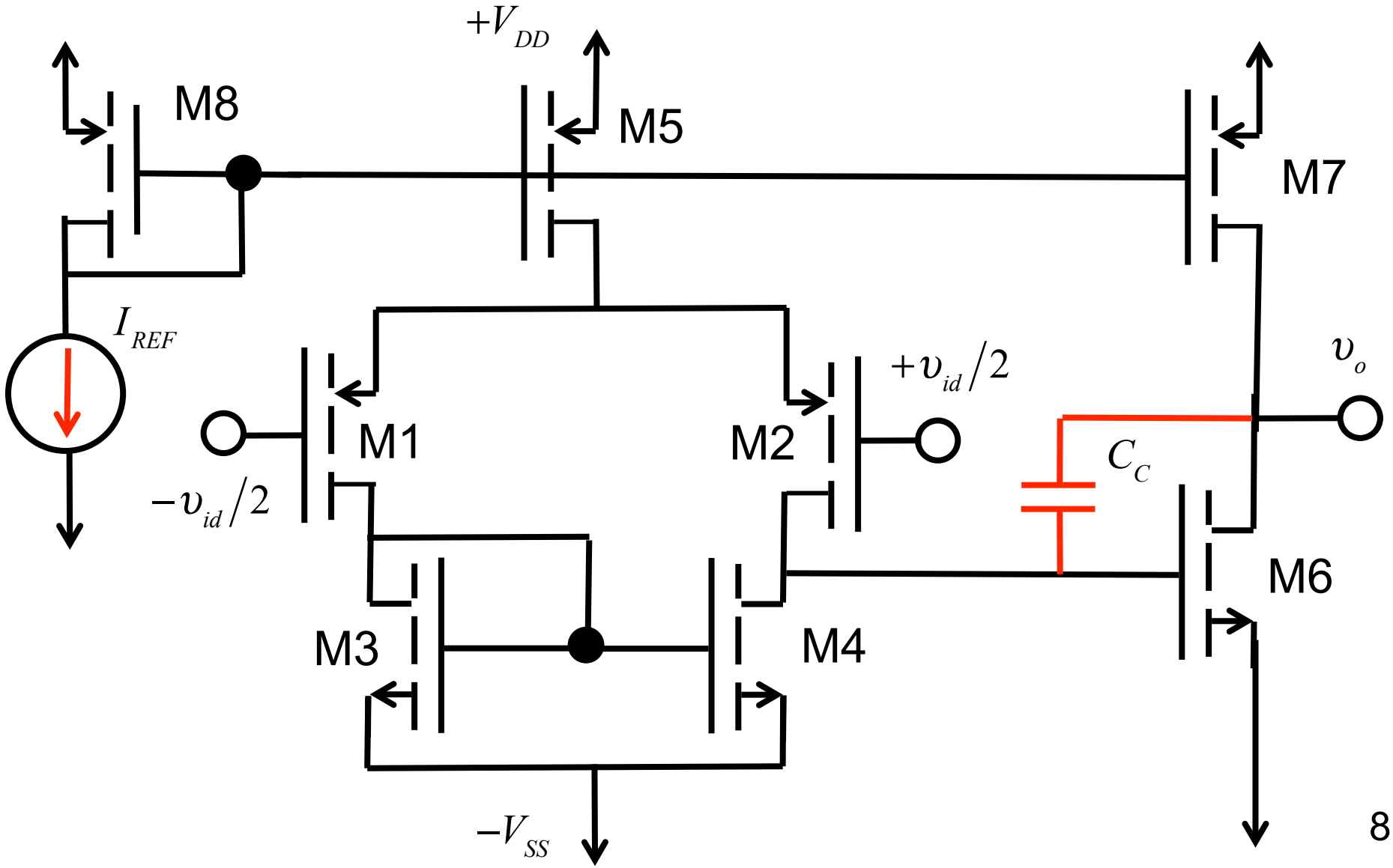
$$\omega_H = \frac{1}{R_{th}C} \qquad \left|T(j\omega)\right| = T_{mid}\frac{\omega_H}{\omega} \qquad \omega_T = \omega_H T_{mid}$$

$$\omega >> \omega_H$$

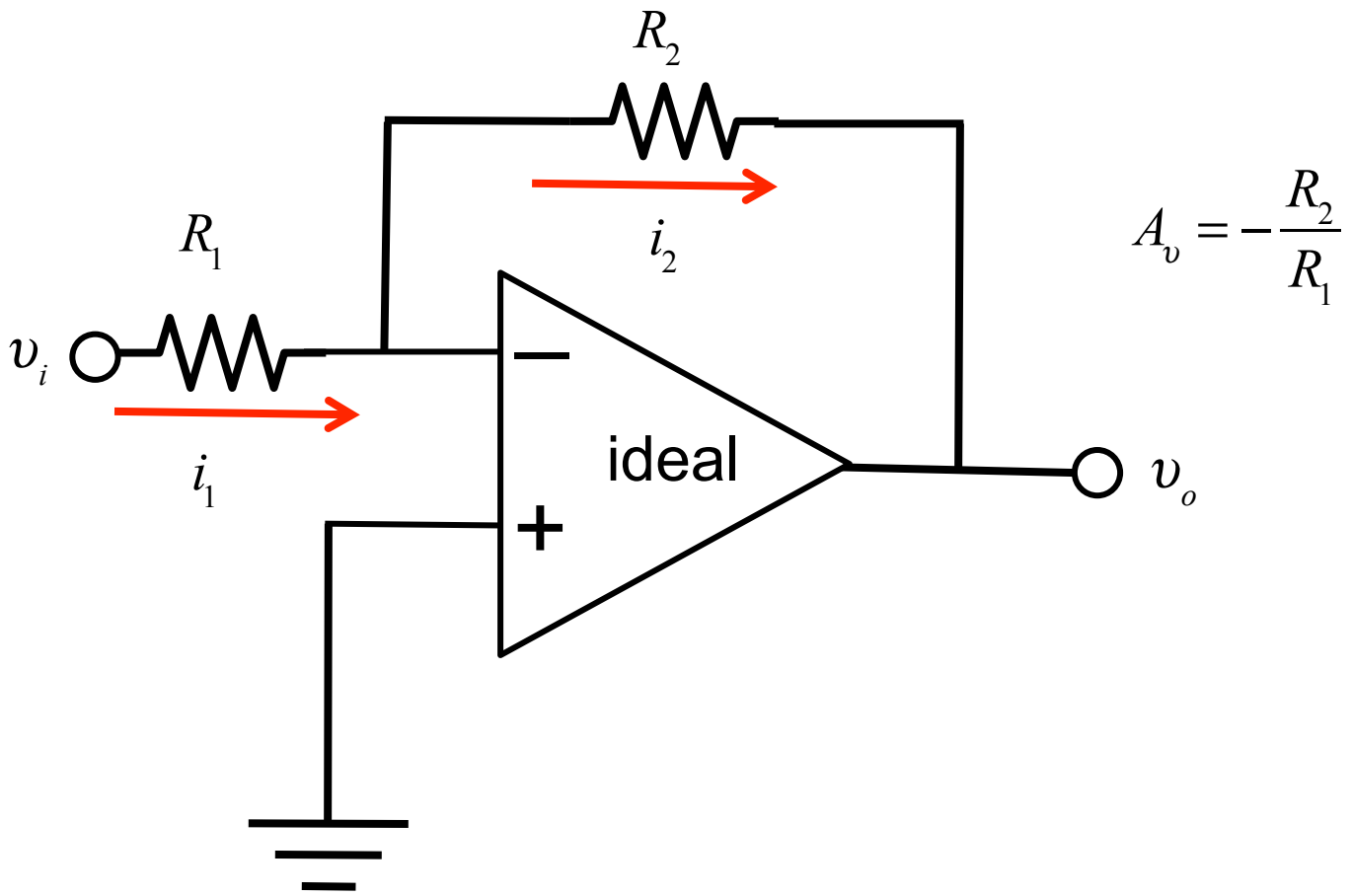
Bode plot for op amp



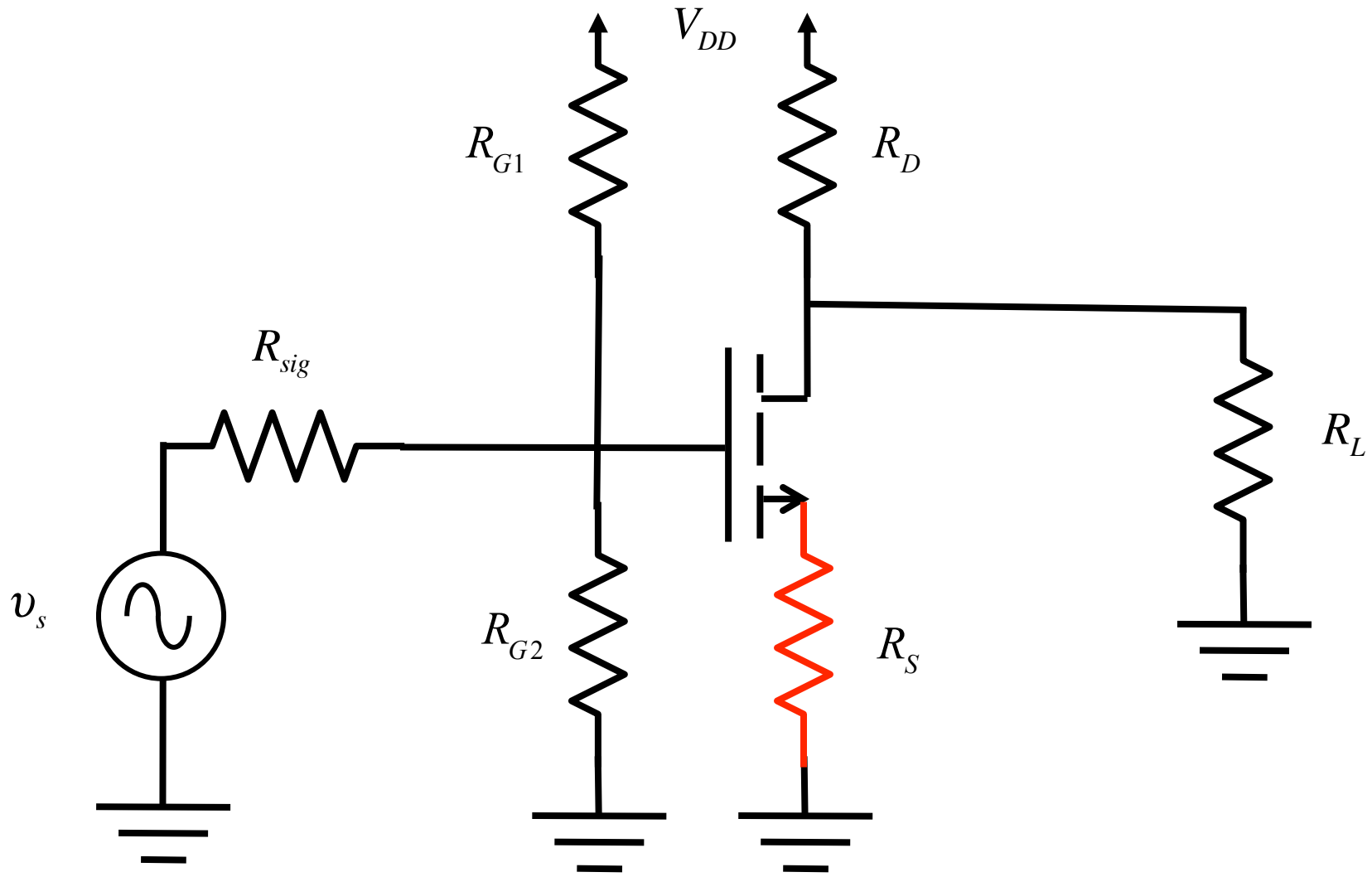
Two-stage CMOS Op Amp



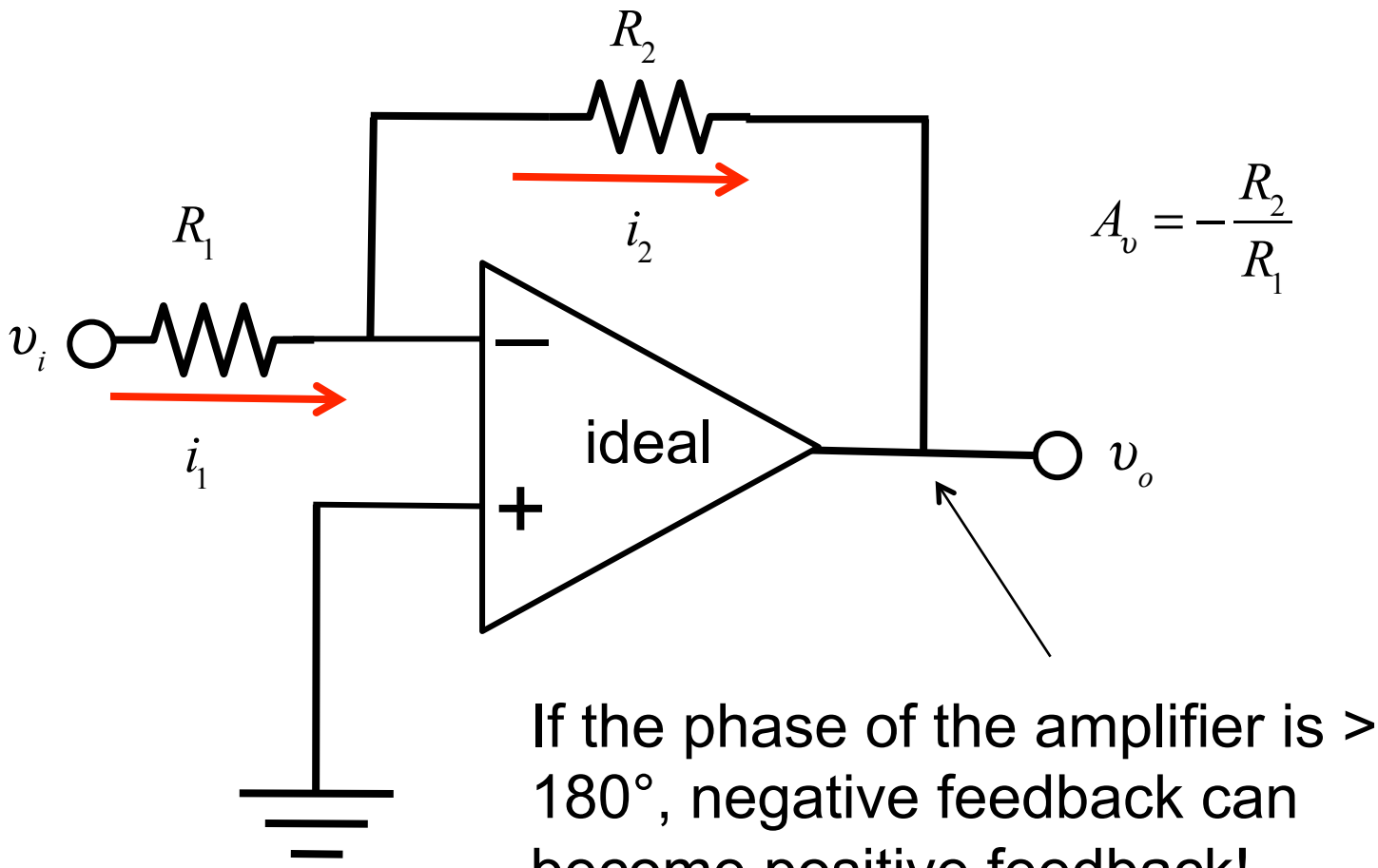
Op amps with feedback



CS Amplifier with **negative** feedback

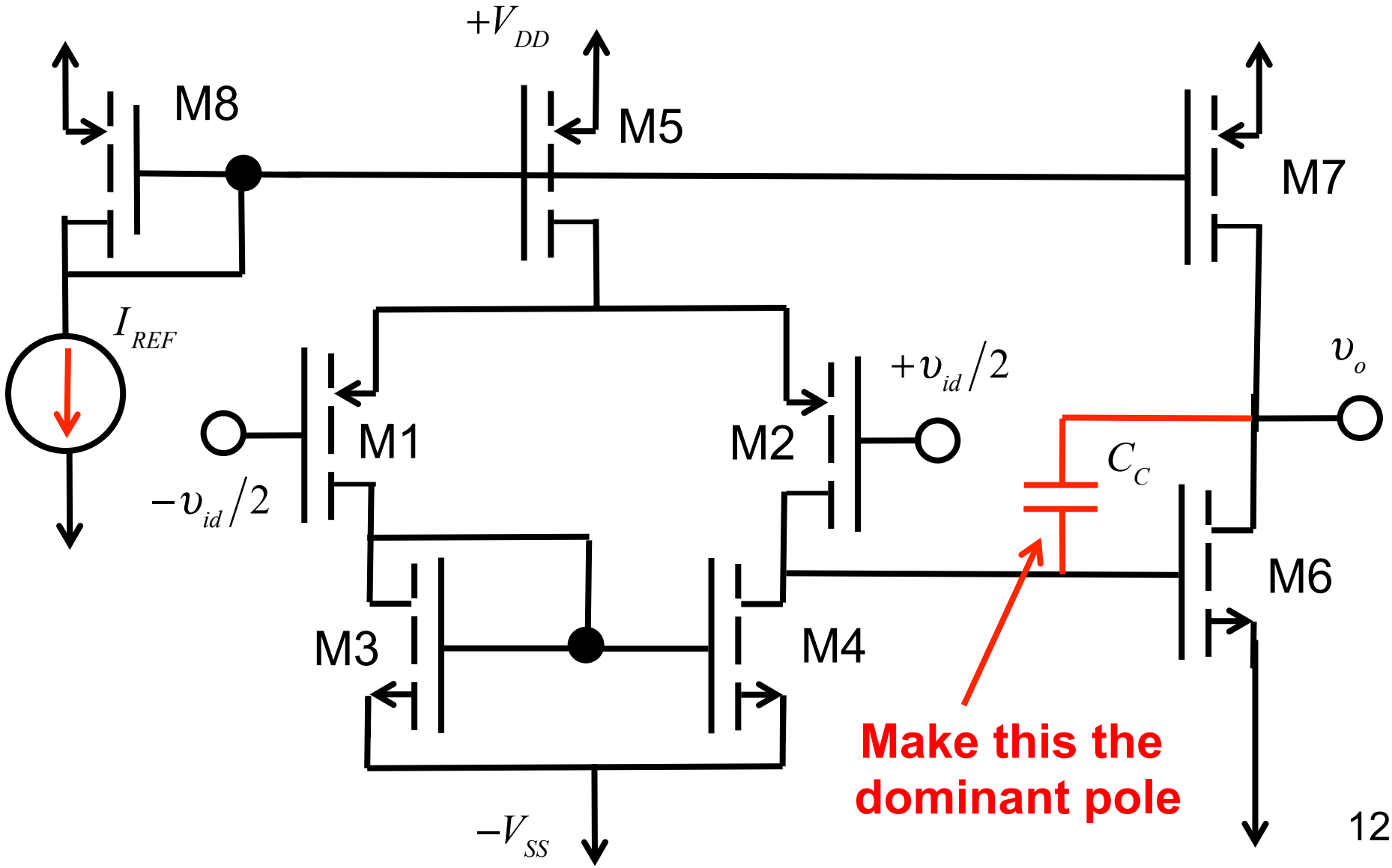


Op amps with feedback

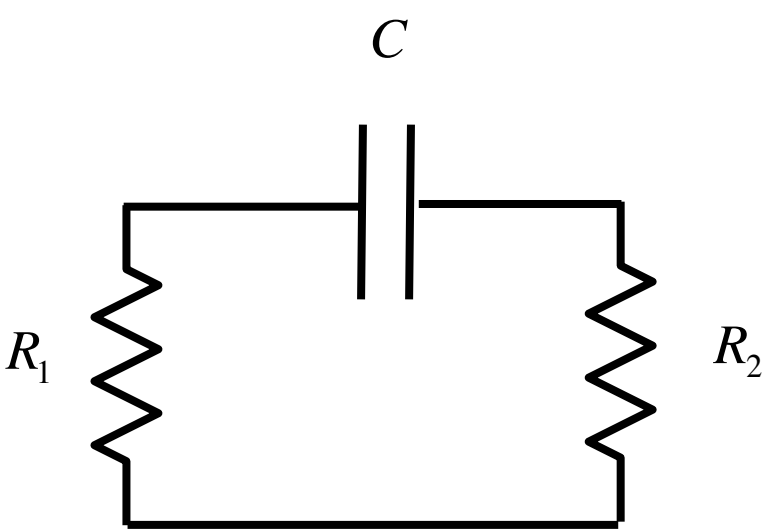


If the phase of the amplifier is > 180°, negative feedback can become positive feedback!

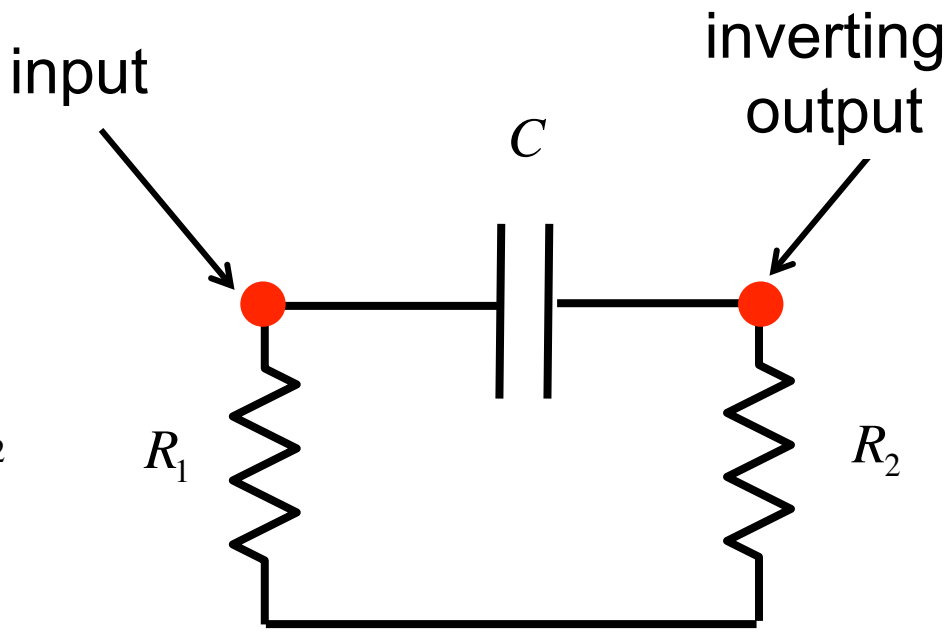
Two-stage CMOS Op Amp



The RC time constant



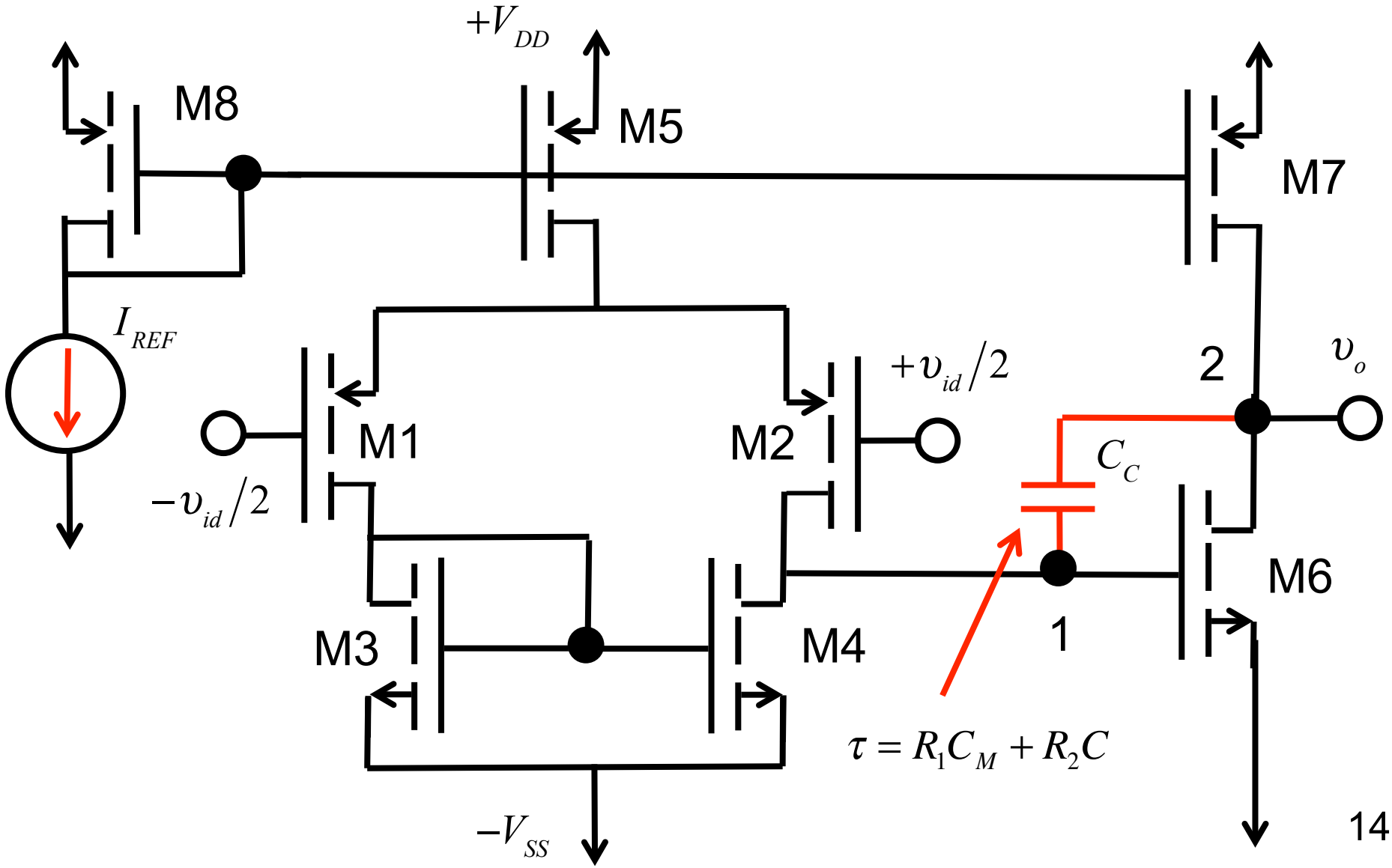
$$\tau = R_1 C + R_2 C$$



$$\tau = R_1 C_M + R_2 C$$

$$C_M = \left(1 + |A|\right) C$$

Two-stage CMOS Op Amp



Dominant pole

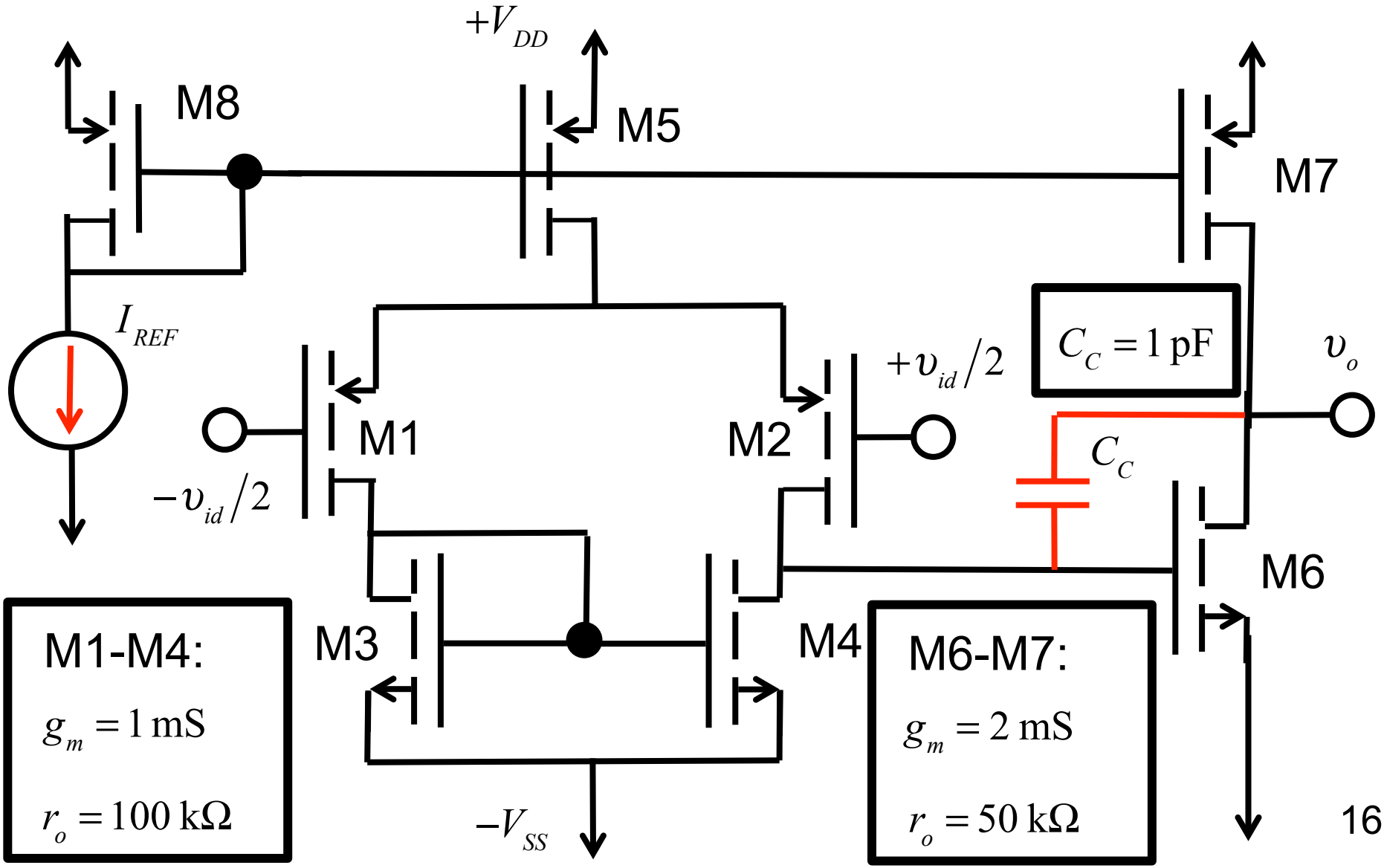
$$\tau = R_1 C_M + R_2 C_C$$

$$\tau = \left(r_{o4} \parallel r_{o2}\right) C_M + \left(r_{o6} \parallel r_{o7}\right) C_C$$

$$C_M = \left[1 + g_{m6}\left(r_{o6} \parallel r_{o7}\right)\right] C_C$$

$$\omega_H = \frac{1}{\tau}$$

Example: Two-stage CMOS Op Amp



Mid frequency gain

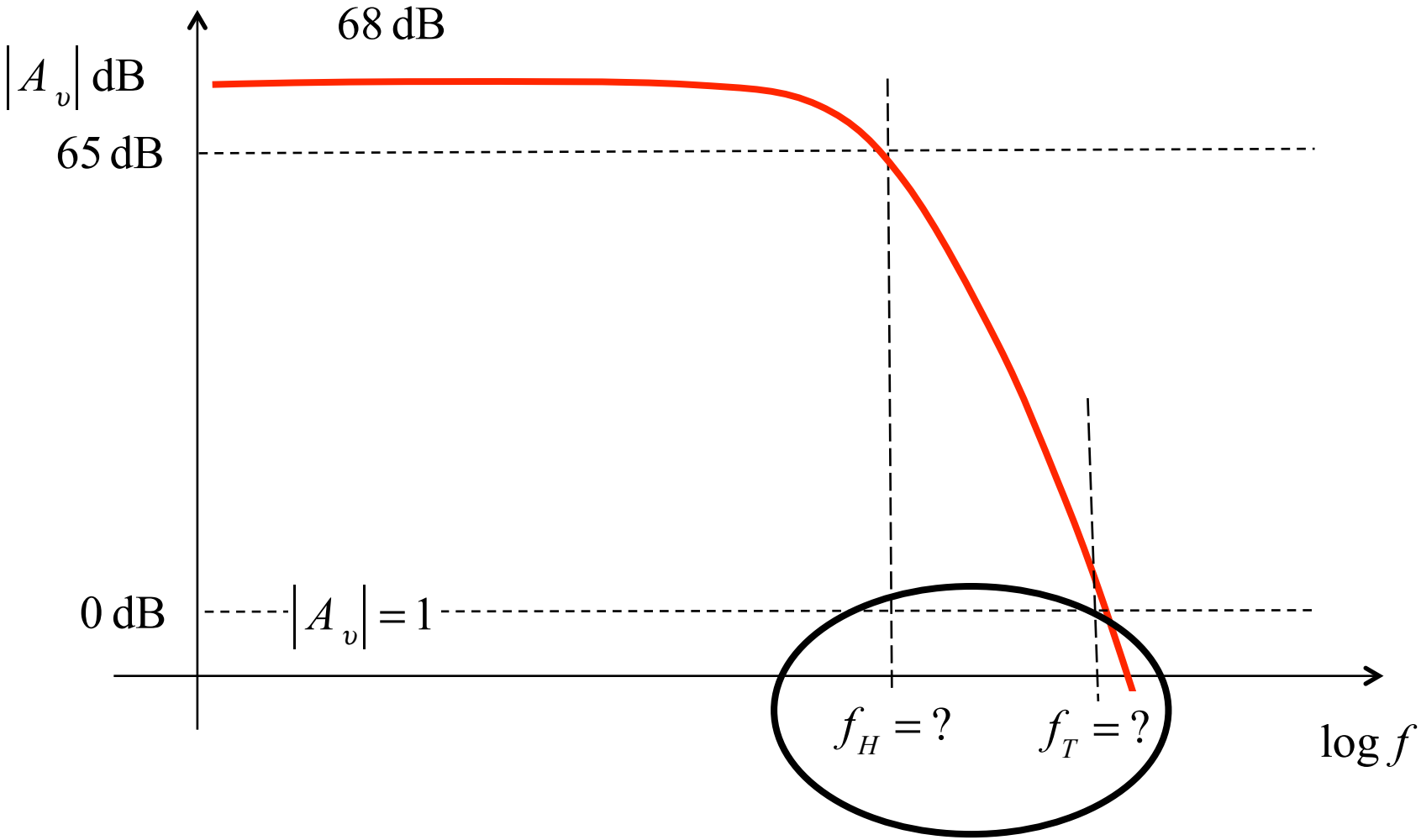
$$A_{dm} = -g_m\left(\frac{r_o}{2}\right) = -1 \times 50 = -50$$

$$A_{v2} = -g_m\left(\frac{r_o}{2}\right) = -2 \times 25 = -50$$

$$A_v = A_{dm} \times A_{v2} = +2500$$

$$A_v = A_{dm} \times A_{v2} = 68 \text{ dB}$$

Bode plot for op amp



Corner frequency

$$\tau = R_1 C_M + R_2 C_C$$

$$\tau = 2.6\ \mu\text{s}$$

$$\tau = \left(r_{o4} \parallel r_{o2}\right) C_M + \left(r_{o6} \parallel r_{o7}\right) C_C$$

$$\tau = \left(50\ \text{k}\right) 51 \times 10^{-12} + \left(25\ \text{k}\right) 1 \times 10^{-12}$$

$$C_M = \left[1 + g_{m6}\left(r_{o6} \parallel r_{o7}\right)\right] C_C$$

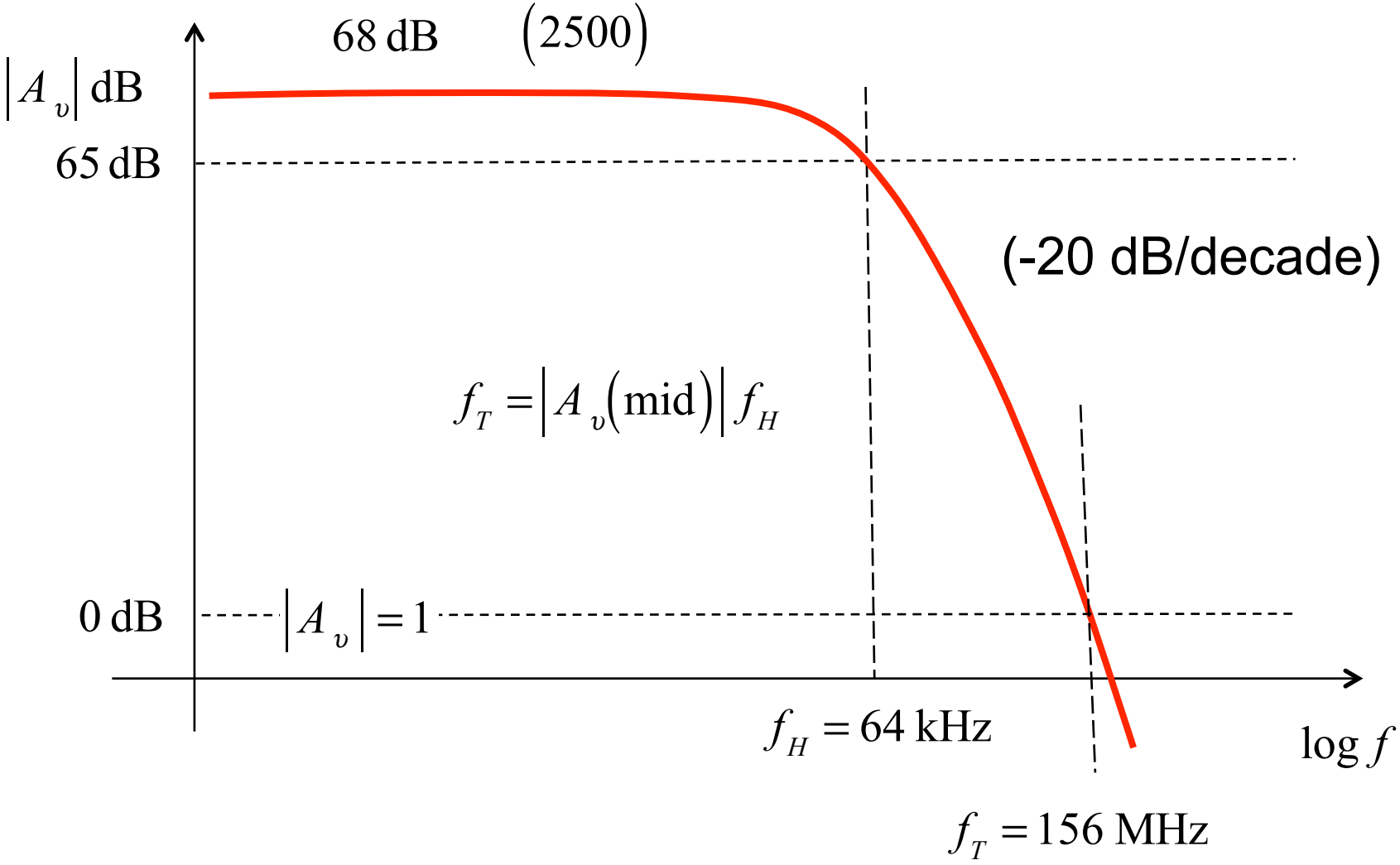
$$C_M = \left[51\right] C_C = 51\ \text{pF}$$

$$\omega_H = \frac{1}{\tau}$$

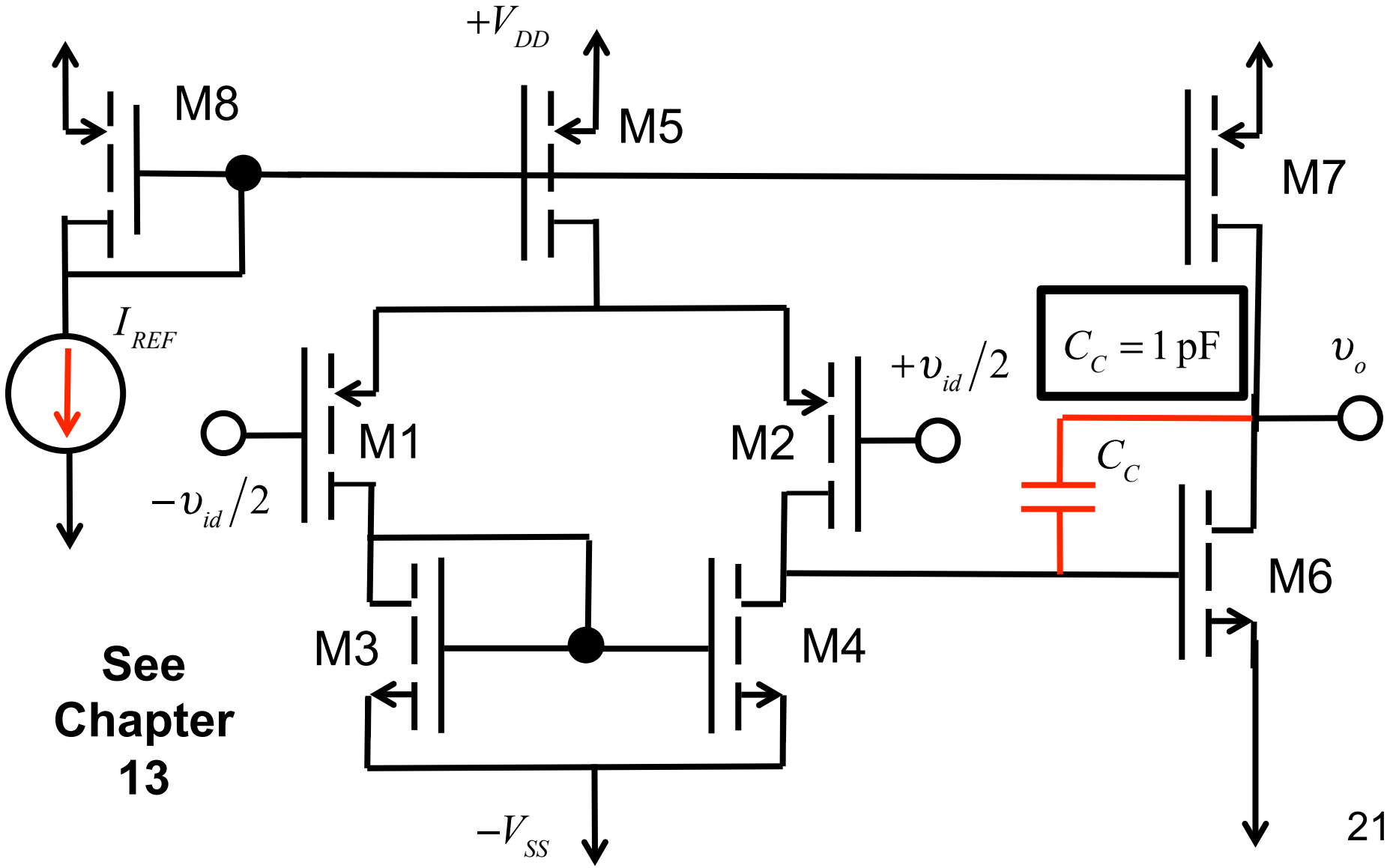
$$\omega_H = 3.9 \times 10^5 \qquad f_H = 64\ \text{kHz}$$

$r_{o4} = r_{o2} = 100\ \text{k}\Omega$ $\quad$ $r_{o6} = r_{o7} = 50\ \text{k}\Omega$ $\quad$ $C_C = 1\ \text{pF}$ $\quad$ $g_{m6} = 2\ \text{mS}$

Bode plot for op amp



Two-stage CMOS Op Amp



See Chapter 13