University of California
Berkeley

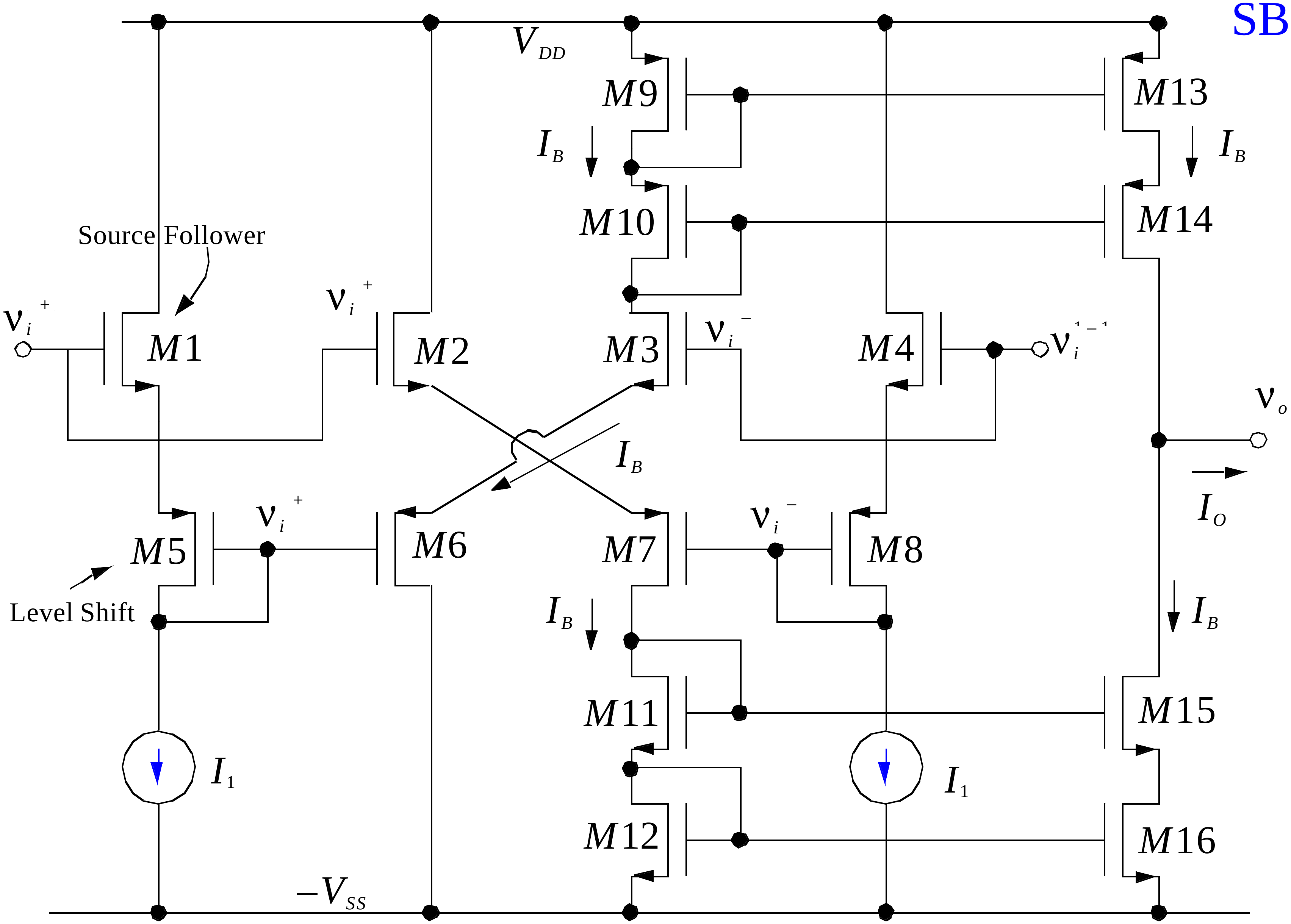
College of Engineering
Department of Electrical Engineering
and Computer Science

Robert W. Brodersen
EECS140

Analog Circuit Design

Lectures on STABILITY (continued)

SB-40


V_{DD}
M9
M10
M13
M14
I_B
Source Follower
v_i^+
M1
M2
M3
M4
v_i^-
v_o
I_O
M5
M6
M7
M8
Level Shift
M11
M12
M15
M16
I_1
$-V_{SS}$

Class AB Input Stage Cross Coupled Differential Pair

Calculating currents :

$$V_{GS1} + V_{SG5} = V_{SG6} + V_{GS3} \qquad v_i = 0$$

$$\cancel{V_{Tn}} + V_{DSAT1} + \cancel{V_{Tp}} + V_{DSAT5} = \cancel{V_{Tn}} + V_{DSAT1} + \cancel{V_{Tp}} + V_{DSAT3}$$

Let All

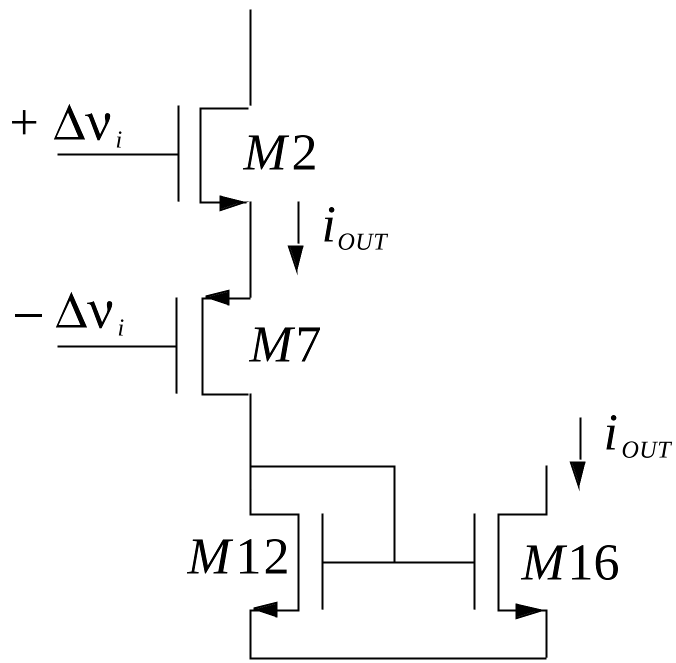
$$\left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right)_3 \qquad \left(\frac{W}{L}\right)_5 = \left(\frac{W}{L}\right)_6$$

$$\left(\frac{2 \cdot I_1}{\left(\frac{W}{L}\right)_5 \cdot k_p'}\right)^{\frac{1}{2}} + \left(\frac{2 \cdot I_1}{\left(\frac{W}{L}\right)_1 \cdot k_n'}\right)^{\frac{1}{2}} = \left(\frac{2 \cdot I_B}{\left(\frac{W}{L}\right)_5 \cdot k_p'}\right)^{\frac{1}{2}} + \left(\frac{2 \cdot I_B}{\left(\frac{W}{L}\right)_1 \cdot k_n'}\right)^{\frac{1}{2}}$$

$$I_1 = I_B$$

Class AB Input Stage Cross Coupled Differential Pair (Cont.) SB-42

Transistor $M2$ has $M7$ as its source resistance.



If g_m's are all equal = g_m

$$\frac{g_{m2} \cdot v_i}{1 + g_{m2} \cdot \left(\frac{1}{g_{m7}}\right)} = \frac{g_{m2}}{2} \cdot \Delta v_i = \frac{g_m}{2} \cdot \Delta v_i$$

Class AB Input Stage Cross Coupled Differential Pair (Cont.) SB-43

As Δv_i increase i_{OUT} continues to increase.

If Δv_i decreases M2 & M7 cutoff.

But then current comes from M3 & M6.

So for Small Signals

$$GM = \underbrace{\frac{i_{ds3}}{v_{in}}}_{g_m/2} + \frac{i_{ds7}}{v_{in}} = g_m$$

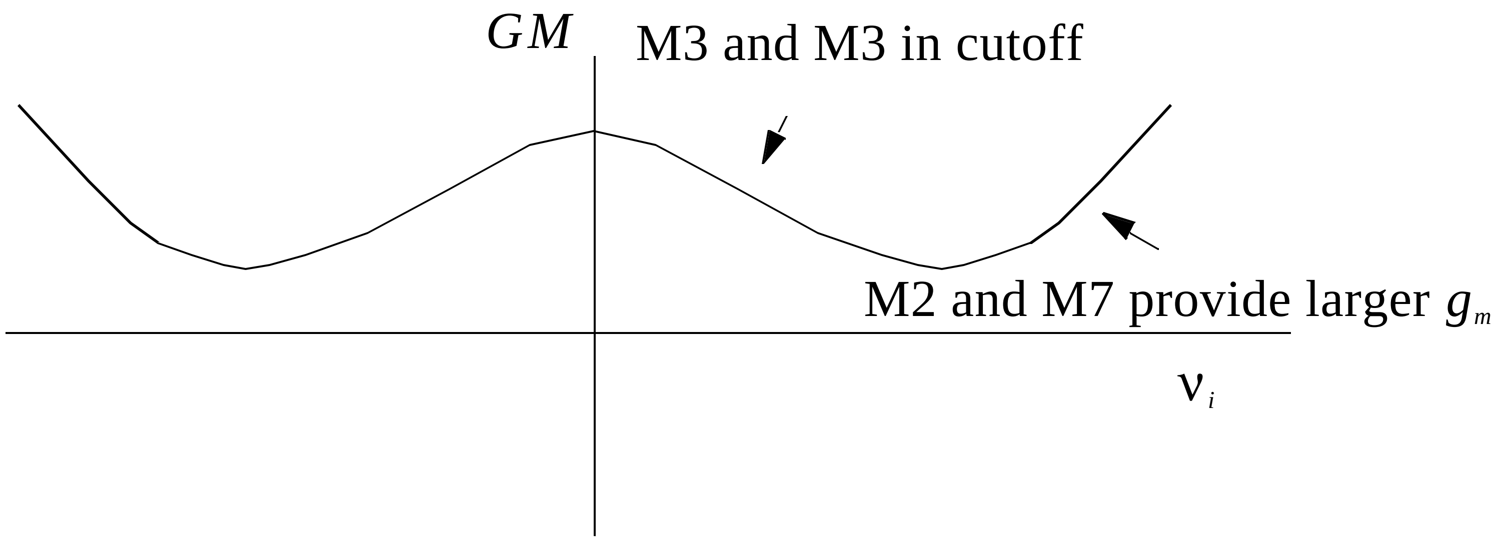
$$R_{OUT} = g_m \cdot r_o^2 \parallel g_m \cdot r_o^2 = \frac{g_m \cdot r_o^2}{2}$$

$$A_v = \frac{g_m^2 \cdot r_o^2}{2}$$

Class AB Input Stage Cross Coupled Differential Pair (Cont.)

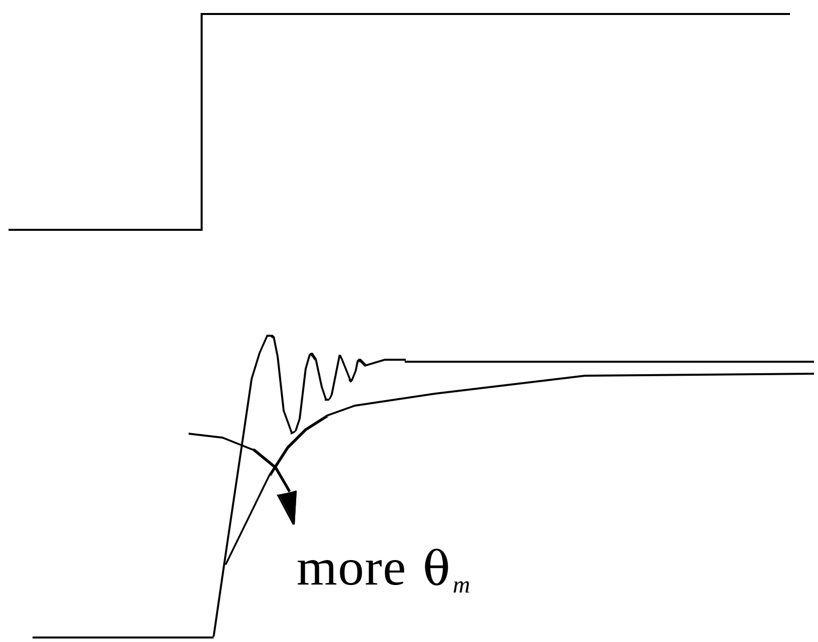
For Large Signals either M2, M9 or M3, M6 cutoff so the

g_m drops, but since the current is increasing it increases again.



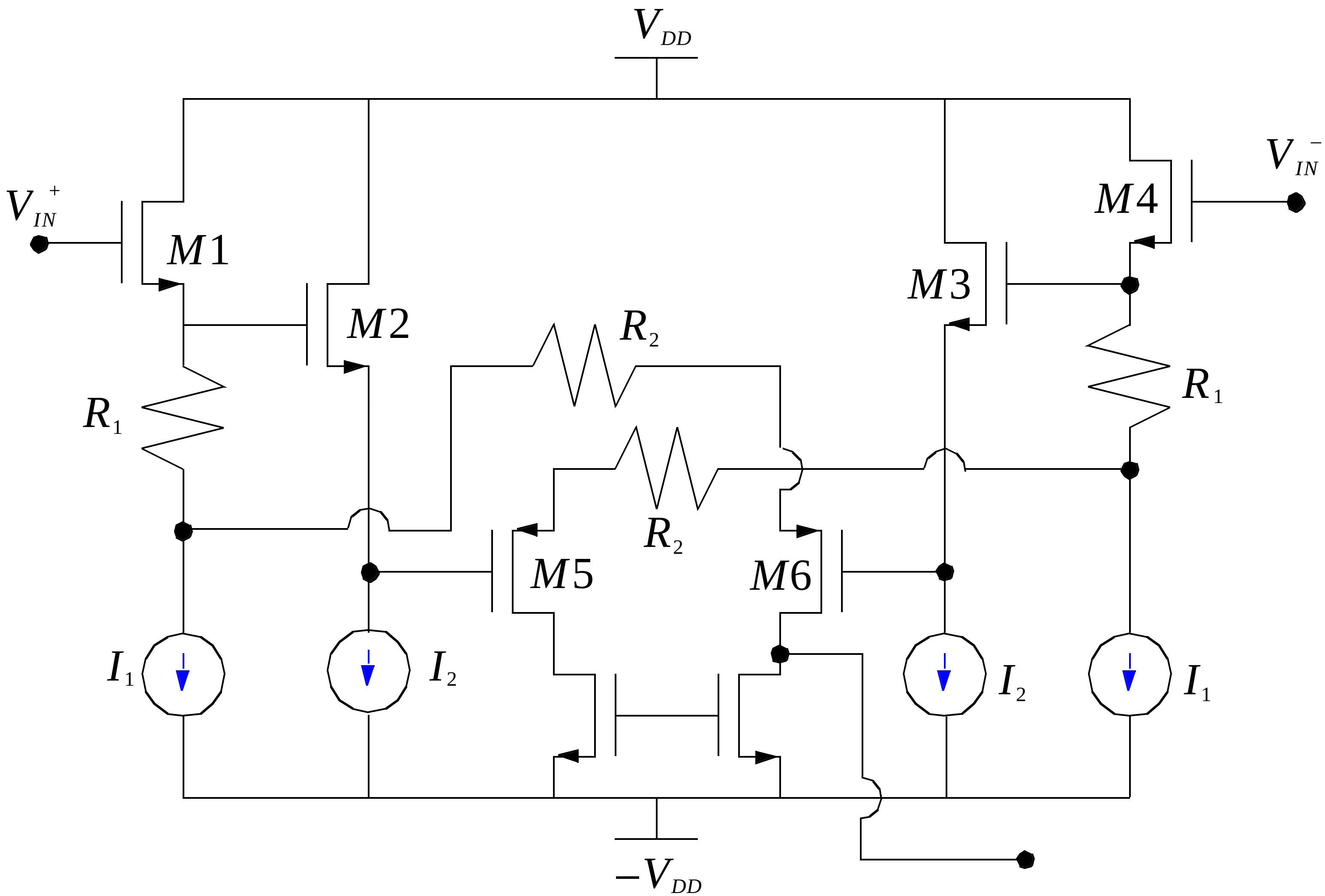
Class AB Input Stage Cross Coupled Differential Pair (Cont.)

Slew Rates can be very high since they are independent of the Bias Current $\Rightarrow$ Bigger Signal gives more current to drive the next stage.



SB-46

Another Class AB



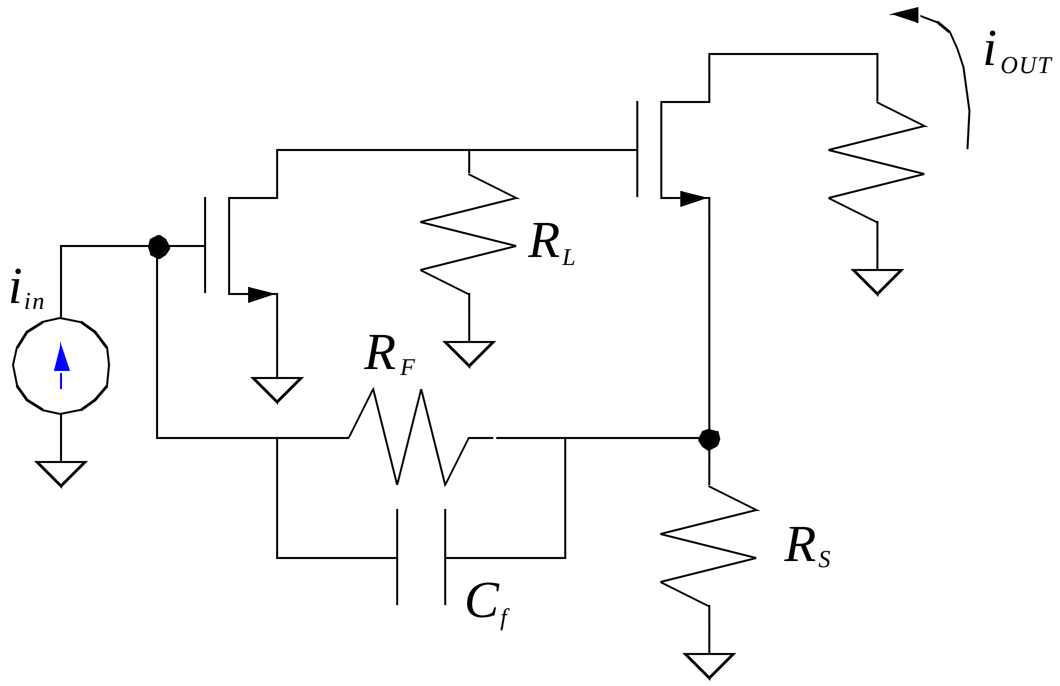
Another Class AB (Cont.)

Small Signals M5 & M6 are degenerated by R_1 & R_2

But for Large Signals the INPUT appears across $R_1 + R_2$

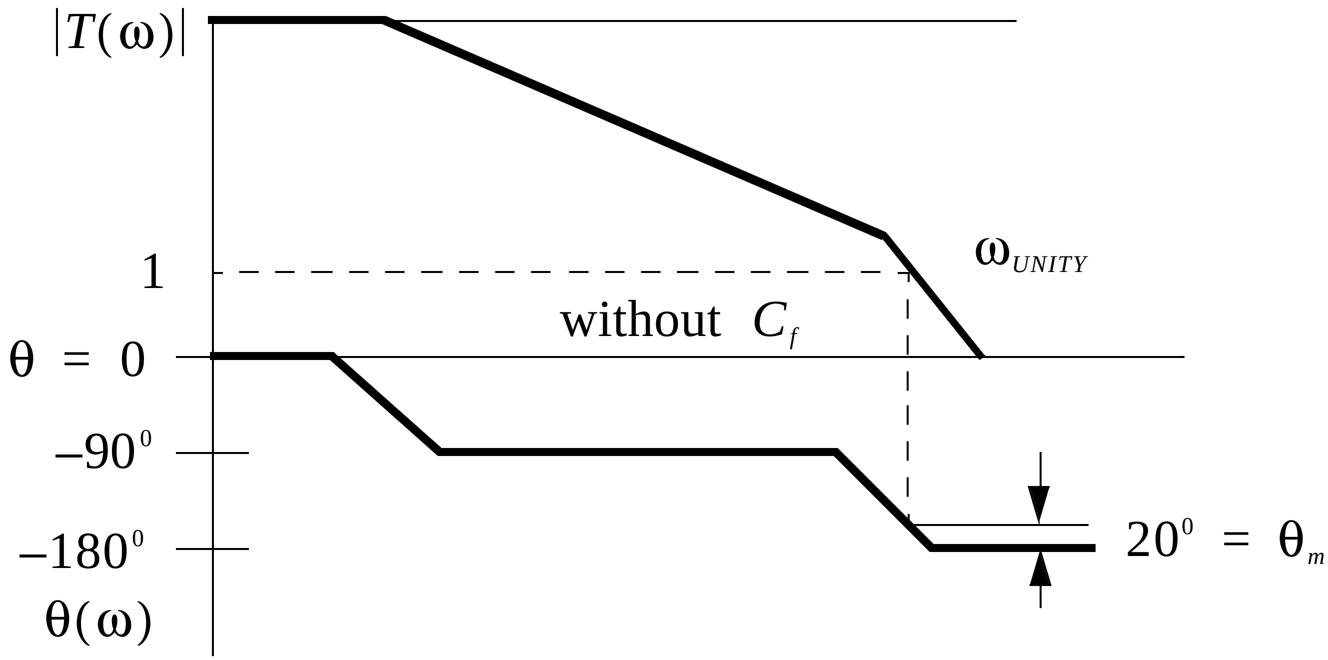
$$I_{OUT} = \frac{V_{IN}^{+} - V_{IN}^{-}}{R_1 + R_2}$$

Feedback Zero Compensation

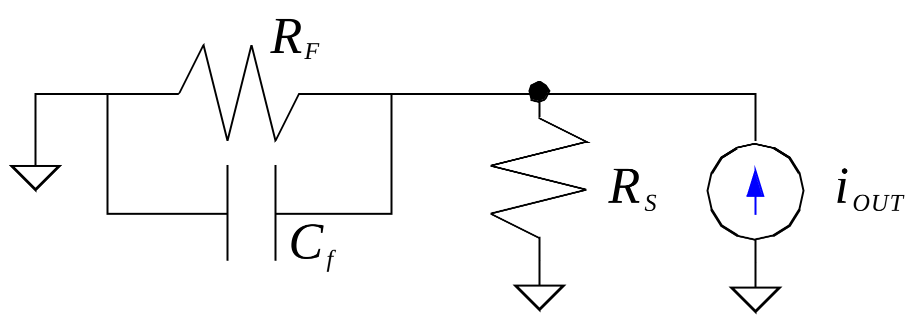


Shunt - Series Feedback

Feedback Zero Compensation (Cont.)



But we want 45^0 of θ_m so we add C_F



Feedback Zero Compensation (Cont.)

$$f = \frac{R_S}{R_F + R_S} \cdot \left(\frac{1 + R_F \cdot j \cdot \omega \cdot C_F}{1 + (R_S \| R_F) \cdot j \cdot \omega \cdot C_F}\right)$$

If $R_S \ll R_F$

$$f = \frac{R_S}{R_F} \cdot \left(\frac{1 + j \cdot \omega \cdot R_F \cdot C_F}{1 + j \cdot \omega \cdot R_S \cdot C_F}\right)$$

$$\omega_Z = \frac{1}{R_F \cdot C_F} \qquad \omega_P = \frac{1}{R_S \cdot C_F}$$

Since $R_S \ll R_F$ $\omega_Z \ll \omega_P$

$$T = a(\omega) \cdot f(\omega)$$

Feedback Zero Compensation (Cont.)

We can add positive phase shift from the zero at ω_{unity} and as long as the contribution is $< 45°$ There is no change in the magnitude of $f(\omega)$ and thus $T(\omega)$

$$\tan(\omega_{UNITY}(R_F \cdot C_F)) = 25°$$

or,

$$C_F = \frac{1}{R_F \omega_{UNITY}} \cdot arc\tan(25^0)$$