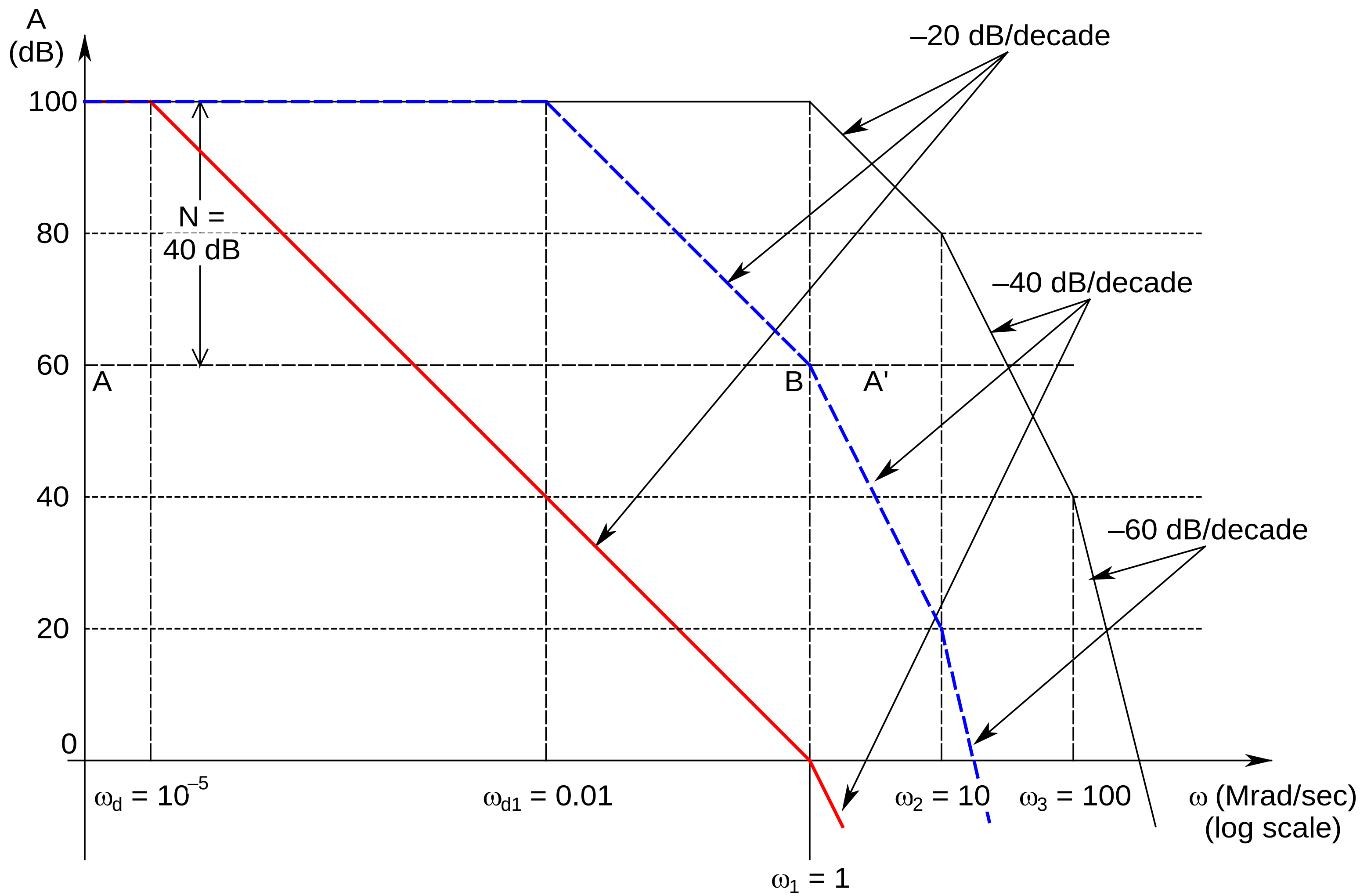


Normal Line: Open-loop system

Red Line: Compensated system for unconditional stability

Blue Line: Compensated system with conditional stability

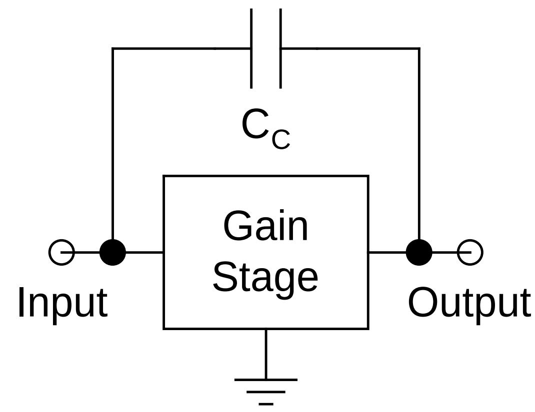
(till a feedback of 40 dB)

- Note that in order to achieve ***unconditional stability*** of the system, the ***bandwidth*** has ***reduced drastically*** from ***1 Mrad/sec*** to only ***10 rad/sec***!
- ***This is the most severe limitation of the DPC technique***

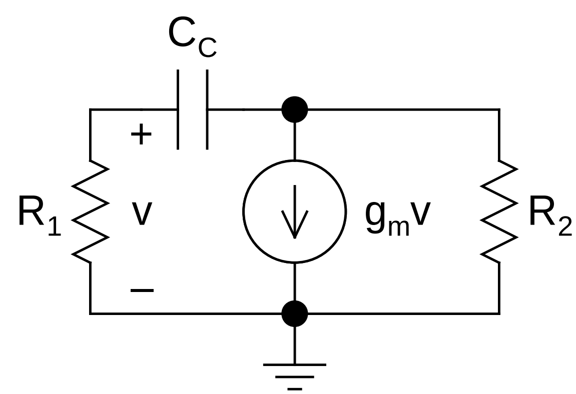
- ***For conditional stability***:
  - The ***previous compensation scheme*** ensured ***system stability*** for f all the way ***up to unity*** (corresponding to the ***amount of feedback*** of ***100 dB***, i.e., the ***entire output is fed back to the input***)
  - In some cases, it may be an ***overkill***, if it is known ***a priori*** that the ***entire output*** will ***NOT*** be ***fed back*** to the ***input***, ***rather only a part of it***
  - This is what is known as ***conditional stability***
  - Suppose that the ***maximum amount of feedback*** that the system would have is ***40 dB***

- ❖ For this system to be ***stable***, the ***DP frequency need not be at ω_d***, ***but at a higher value***
- ❖ To construct the ***compensation characteristic*** of this system, draw a ***horizontal line*** AA′, corresponding to the ***amount of feedback*** (***40 dB in our example*** $\Rightarrow$ ***A_f = 60 dB***)
- ❖ From the ***intersection point*** (B) of this ***line*** with the ***first pole*** (ω_1), ***go back 2 decades*** (40/20), to get the ***new dominant pole*** ω_{d1} at ***10 krad/sec*** (shown by the ***blue line***)
- ❖ This ***compensation scheme protects the system from any stability issues only till a maximum feedback of 40 dB***, ***by ensuring*** that ***from 0 to 40 dB of feedback***, ***no other pole will be encountered***, ***apart from ω_{d1}***
- ❖ Note the ***tremendous bandwidth improvement*** of ***1000 times*** (***from 10 rad/sec*** for ***unconditional stability to 10 krad/sec*** for ***conditional stability till a feedback of 40 dB***)

- ***Technique***:
  - ***Simplest way***: ***Attach a capacitor between the input and output of the gain stage*** (***similar to Miller Capacitor***)
  - ***This capacitor is labeled as the Compensation Capacitor*** (C_C)



Schematic



Equivalent Circuit

- ***By inspection***, the equivalent circuit can be identified as a ***Three-Legged Creature***:

$$\Rightarrow R_C^0 = R_1 + R_2 + g_m R_1 R_2$$

R_1 = ***Effective total resistance on the left of*** C_C

R_2 = ***Effective total resistance on the right of*** C_C

g_m = ***Transconductance of the gain stage***

- Thus:

$$\omega_d = 1 \big/ \left(R_C^0 C_C\right)$$

- ***From a knowledge of*** ω_d, ***we can find*** C_C

- ***Pole Zero Compensation (PZC)***:
  - In the ***DPC technique***, we observed a ***drastic reduction*** in ***bandwidth*** after ***compensation***
  - ***PZC technique alleviates this problem to some extent***
  - ***Novelty of this technique***:
    - ***It adds both a pole and a zero to the open-loop transfer function***, ***with the added zero canceling the first pole of the uncompensated system***

- Consider a ***three-pole uncompensated transfer function***:

$$A(s)\Big|_{\text{uncompensated}} = \frac{A_0}{\left(1+s/\omega_1\right)\left(1+s/\omega_2\right)\left(1+s/\omega_3\right)}$$

A_0: ***Low-Frequency Gain***

ω_1, ω_2, ω_3: ***Pole Frequencies*** ($\omega_3 > \omega_2 > \omega_1$)

- ***After adding the network for PZC***, the ***compensated transfer function*** will be:

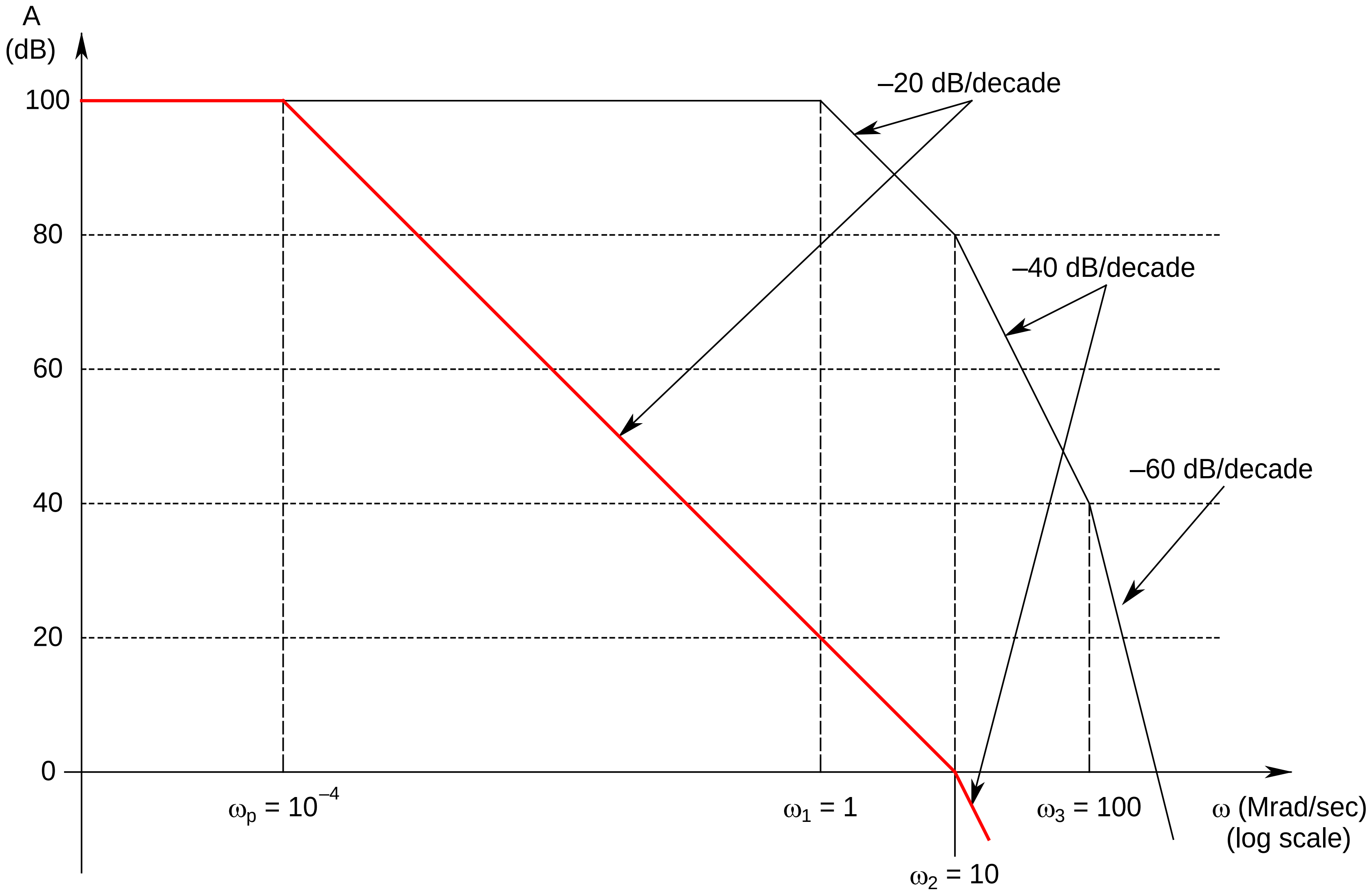
$$A(s)\Big|_{\text{compensated}} = \frac{A_0\left(1+s/\omega_z\right)}{\left(1+s/\omega_p\right)\left(1+s/\omega_1\right)\left(1+s/\omega_2\right)\left(1+s/\omega_3\right)}$$

ω_z: ***added zero***, and ω_p: ***added pole***

- ***By design***, ***ω_z is made equal to ω_1***

  $\Rightarrow$ ***They cancel each other***

- Thus, the ***compensated transfer function*** still has ***three poles***, but the ***first pole gets shifted from ω_1 to ω_p***
- ***The procedure for finding ω_p is the same as that for the DPC technique***
- We take the ***same example*** as that considered for the ***DPC technique***
- Refer to the next slide



Normal Line: Open-loop system

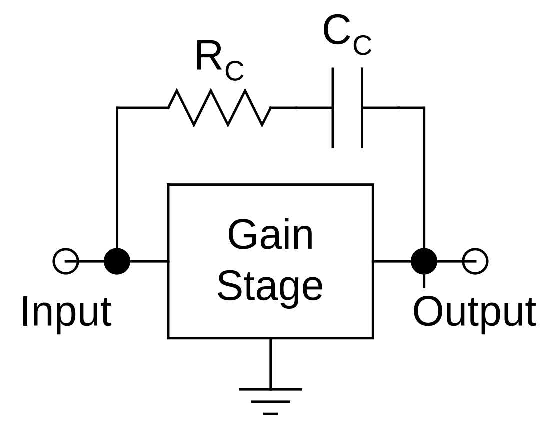
Red Line: Compensated system for unconditional stability

- Here, the ***added zero*** (ω_z) ***cancels*** the ***first pole*** (ω_1)
- Thus, we now ***start from ω_2*** and ***go back 5 decades*** to find ω_p, which comes out to be ***100 rad/sec*** (refer to the ***red line***)
- The ***compensated system*** will be ***unconditionally stable*** with ***PM of 45°***(***since ω_3 is ten times away from ω_2***)
- The ***increase in bandwidth***, ***as compared to DPC***, is ***10 times*** (***from 10 rad/sec to 100 rad/sec***: ***equal to the ratio of ω_2 and ω_1***)

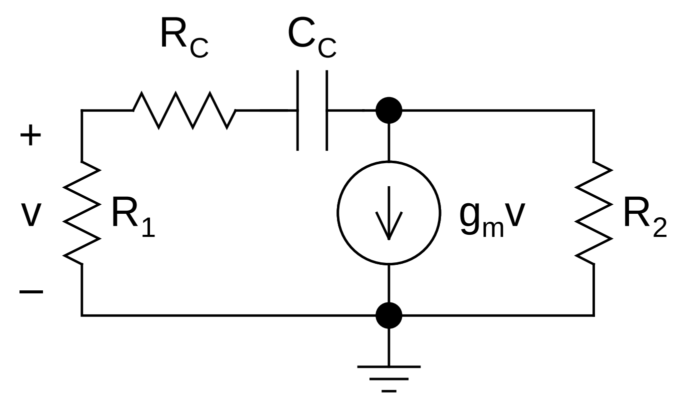
➢ ***Technique***:

- ***Just attach a resistor R_C with the compensation capacitor C_C***
- ***Put this R_C-C_C network between the input and output of the gain stage***
- Show that the ***transfer function*** of the ***compensated system*** is of the form:

$$A(s)\Big|_{\text{compensated}} \propto \frac{1+s\left(R_C - 1/g_m\right)C_C}{1+s\left(R_C + R_2\right)C_C}$$



Schematic



Equivalent Circuit

- Here

  $\omega_z = 1/[(R_C - 1/g_m)C_C]$

  $\omega_p = 1/[(R_C + R_2)C_C]$

- ***Choose R_C and C_C such that***
  - ***ω_z is equal to ω_1*** (***the first pole of the uncompensated system***)
  - ***ω_p is as found from the example given***