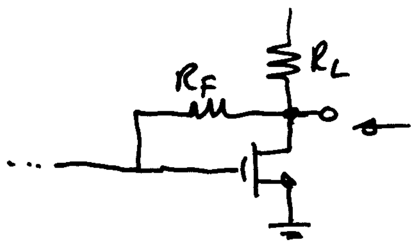
Next week Dr. Sengupta will lecture

APPLICATIONS OF FEEDBACK

1.) Removal of amplifier nonlinearity
(see notes on web site)

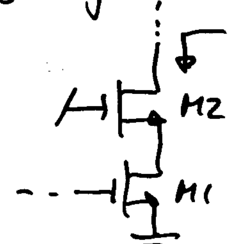
2.) Change Resistance Levels

Shunt neg. fb. → $\dfrac{R_{in}}{1+\text{Loop Gain}} = \dfrac{R_{in}}{1+AF}$



→ $\dfrac{R_L \| R_F}{1+\text{Loop Gain}}$

Series neg. fb. → $R_{in}(1+\text{Loop Gain}) = R_{in}(1+AF)$

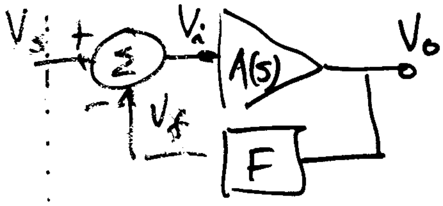


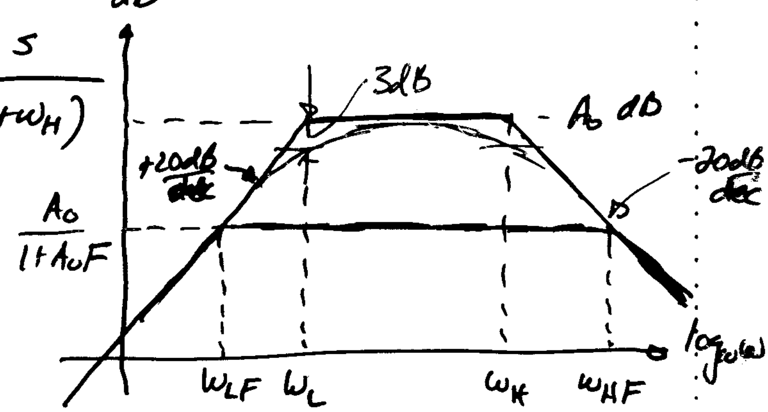
$r_{ds1}(1+\text{Loop Gain}) \simeq r_{ds1} g_{m2} r_{ds2}$

3.) Increase the bandwidth of an amplifier.

Wideband Amplifier -

$$A(s) = \frac{A_o \omega_H s}{(s+\omega_L)(s+\omega_H)}$$





$\dfrac{V_o}{V_s} = ? = \dfrac{A}{1+AF} = A_F$ Assume F is not a function of frequency.

1.) Low frequency ($\omega << \omega_H$)

$$A(s) \simeq \frac{A_o s}{s+\omega_L} \qquad A_F = \frac{A}{1+AF} = \frac{\frac{A_o s}{s+\omega_L}}{1+\frac{A_o F s}{s+\omega_L}}$$

$$A_F(s) = \frac{A_o s}{s+\omega_L + A_o F s} = \frac{A_o s}{s(1+A_o F) + \omega_L}$$

$$= \left(\frac{A_o}{1+A_o F}\right)\left(\frac{s}{s+\frac{\omega_L}{1+A_o F}}\right) = A_{oF}\frac{s}{s+\omega_{LF}}$$

$$\therefore \boxed{\omega_{LF} = \frac{\omega_L}{1+A_o F}}$$

2.) High Frequency ($\omega >> \omega_L$)

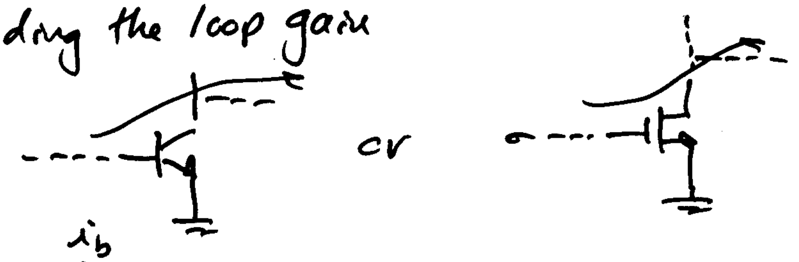
$$A(s) \cong \frac{A_o \omega_H}{s+\omega_H} \rightarrow A_F(s) = \frac{\frac{A_o \omega_H}{s+\omega_H}}{1+\frac{A_o F \omega_H}{s+\omega_H}}$$

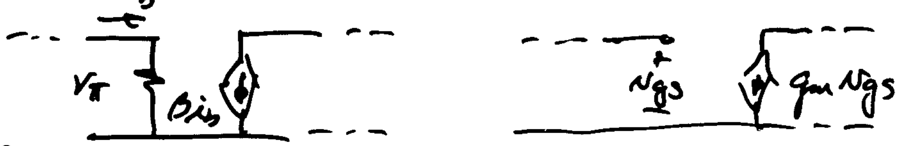
$$A_F(s) = \frac{A_o \omega_H}{s+\omega_H(1+A_o F)} \times \frac{1+A_o F}{1+A_o F} = \left(\frac{A_o}{1+A_o F}\right)\left(\frac{\omega_H(1+A_o F)}{s+\omega_H(1+A_o F)}\right)$$

$$A_F(s) = (A_{oF})\left(\frac{\omega_{HF}}{s+\omega_{HF}}\right) \qquad \therefore \boxed{\omega_{HF} = \omega_H(1+A_o F)}$$

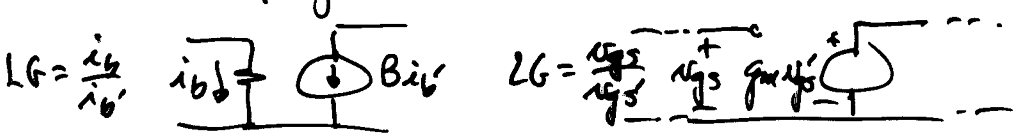
Next Topics

1.) Finding the loop gain



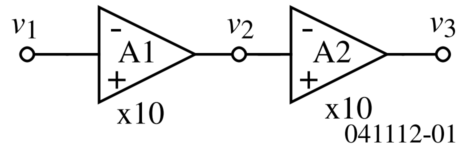


To find loop gain -



USE OF FEEDBACK TO REMOVE DISTORTION

In many circumstances of electrical engineering, feedback can be used to improve the performance of a system by removing distortion. As an example, consider Fig. 1. Let us assume tha A2 is similar to the power output stage and that A1 is similar to the pre-amplifier stage of a hi-fi amplifier. Because A2 is a power amplifier, it is subject to distortion. A plot of v_3 versus v_2 may look like that in Fig. 2.



041112-01

However, since A1 is a low level amplifier, its transfer function may be represented by Fig. 3. The overall transfer curve of the amplifier will be the product of Figs. 2 and 3 which is represented in Fig. 4.

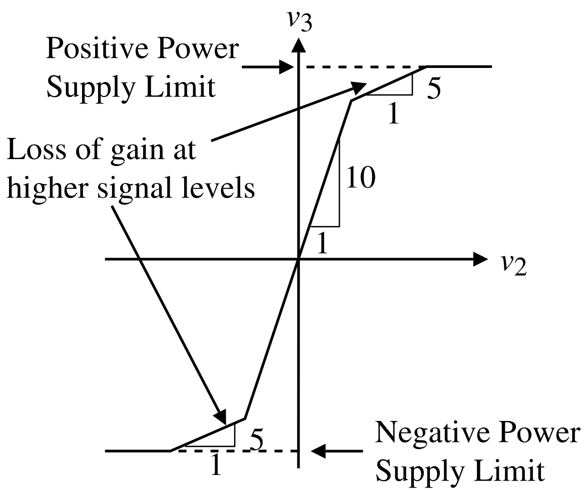


Figure 2 041112-03

We now have the situation where feedback can be used to improve the performance of the circuit by reducing the distortion caused by the loss of gain at high signal levels. Let us apply feedback (F) around stage 2. Since feedback will reduce the gain let us make the gain of the second stage two and increase the gain of A1 to 50.

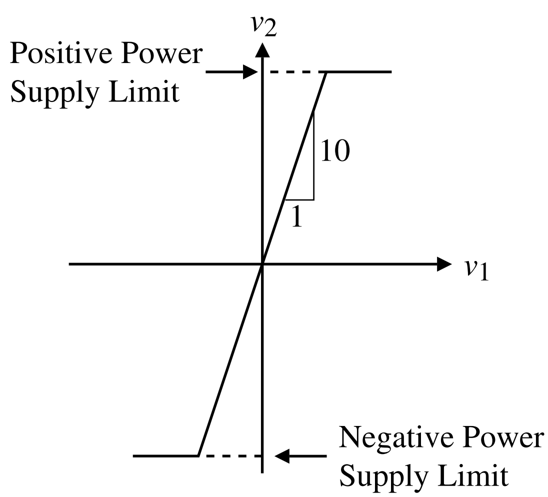


Figure 3 041112-03

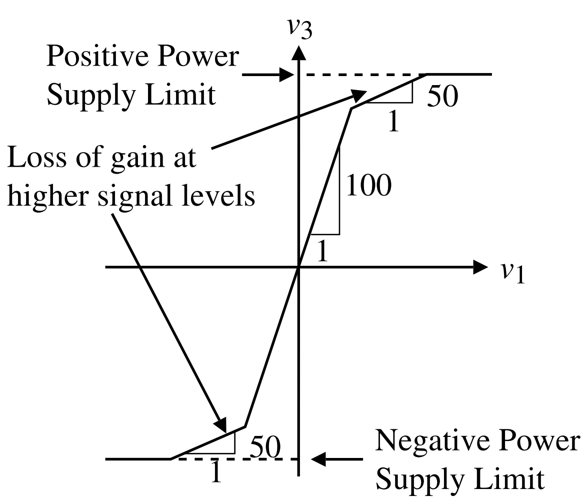


Figure 4 041112-04

The result is shown in Fig. 5. In order to find the correct value of F, we solve the standard feedback equation which is given in this case as

$$\frac{v_3}{v_2} = \frac{A_2}{1+A_2\beta} \qquad (1)$$

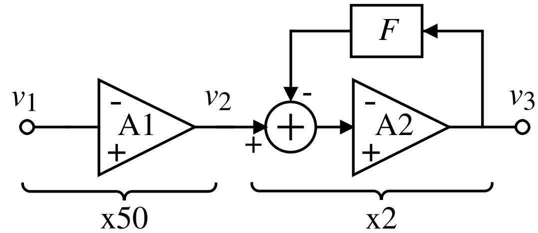


Figure 5 041112-05

Solving this equation for β when $A_2 = 10$ and choosing $v_3/v_2 = 2$ results in $F = 0.4$. Thus we need to attenuate the amount of v_3 being fed back to the input of A_2 by 0.4. The resulting overall transfer function is given in Fig. 6. The slope in the high signal level region is found by substituting $A_2 = 5$ and $\beta = 0.4$ into Eq. (1) and multiplying by 50, the gain of A_1. The slope in this region turns out to be 250/3 = 83.3/1. Comparing this with the slope in the high signal region of Fig. 3 shows that the slope more closely matches that of the small signal region, i.e. 100.

While this demonstration may seem artificial it is in fact a very realistic situation. The reason is that distortion such as that shown in Fig. 2 can be caused by current as well as voltage. For example, the load seen by A_2 may be an 4 or 8 ohm speaker. When the output of the amplifier (v_3) is 8 volts then the amplifier A_2 must provide 1 ampere of current. However, the input resistance to the second stage can easily be in the vicinity of say 10kΩ. If we assume for simplicity that the second stage has a gain of one rather than the two used in this demonstration, it is seen that A_1 only has to provide 0.8 mA at 8 volts. At this lower current level, A_1 is still free of *high signal level distortion caused by large signal currents*. Consequently, using feedback to decrease the distortion in A_2 and making up the loss in gain with A_1 represents a good solution to a difficult problem.

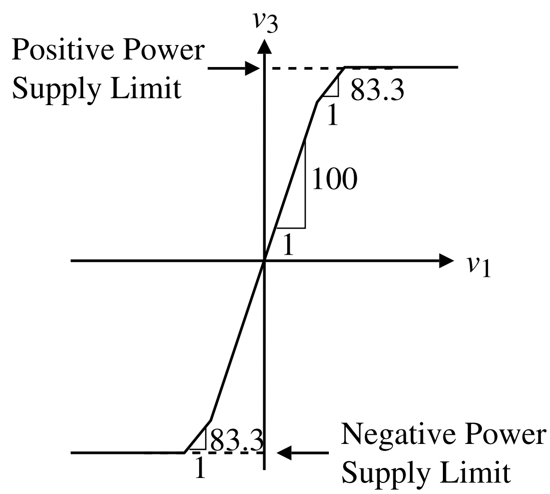


Figure 6 041112-06

If you would like to physically demonstrate this circuit to yourself, the circuit in Fig. 7 will do so very nicely.