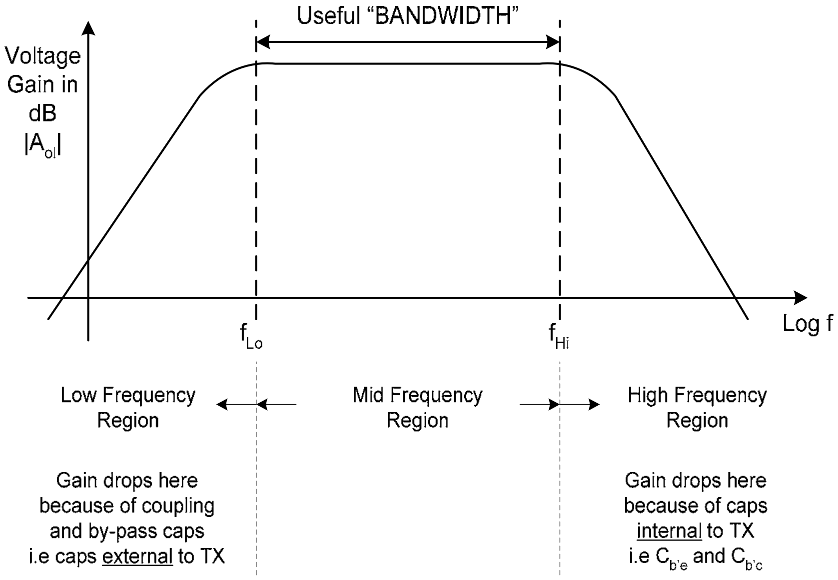
Part 19: Effect of Negative Feedback on Amplifier Bandwidth

Bandwidth of transistor amplifiers is determined by **CAPACITORS:**



What happens when we apply feedback? How is bandwidth affected?

We can see what happens by considering frequency dependence of the loop gain T

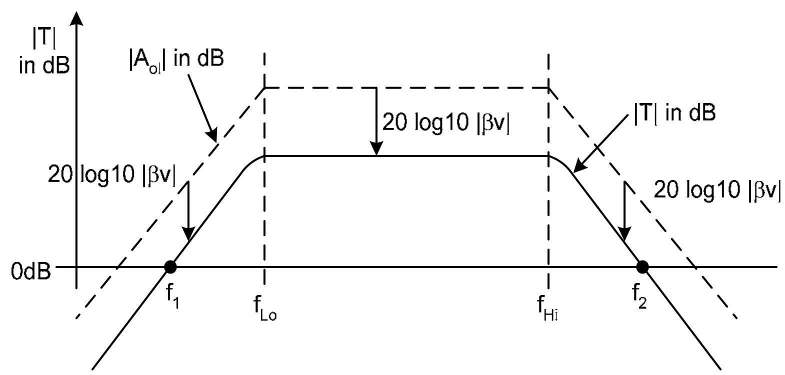
Now |T| in dB = $20\log_{10}|A_{ol}\,\beta_v|$

$$20\log_{10}|A_{ol}| + 20\log_{10}|\beta_v|$$

This is 1st graph

Since $0<|\beta_v|<1$, then $20\log_{10}|\beta_v|$ is **negative**; eg. if $|\beta_v|=0.1$, then $20\log_{10}|\beta_v| = -20dB$

So we can construct $|T|$ vs. frequency curve by **shifting down** $|A_{ol}|$ curve:
Note points where $|T| = 0dB \rightarrow f_1, f_2$

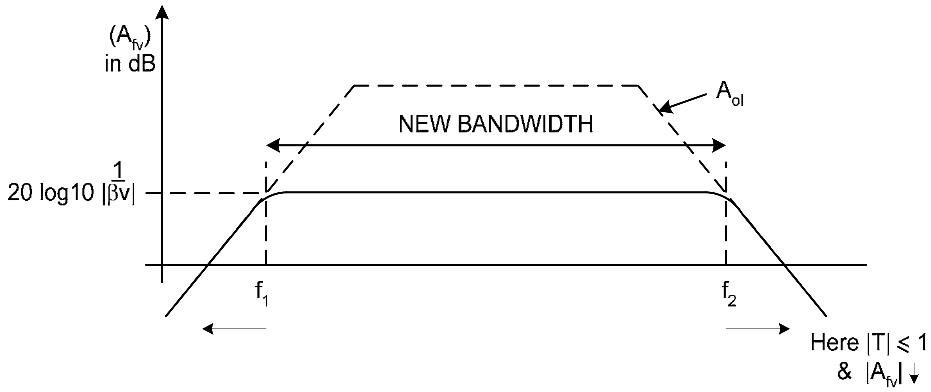


The new amplifier having feedback has a gain (closed loop gain)

$$|A_{fv}| = \frac{1}{|\beta_v|}\left|\frac{T}{1+T}\right|$$

and as usual, if $|T| >> 1$ that is, $|T| >> 0dB$ then $|A_{fv}| \approx \frac{1}{|\beta_v|}$ INDEPENDENT of $|A_{ol}|$

So we can sketch $|A_{fv}|$ in dB as:



OLD Bandwidth = $f_{Hi} - f_{Lo}$

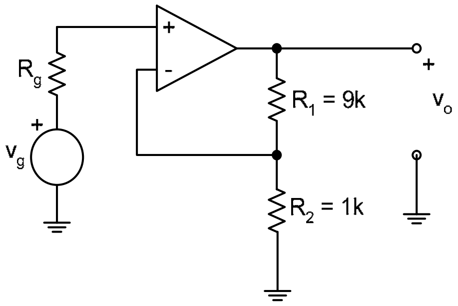
NEW Bandwidth = $f_2 - f_1$ which is > $f_{Hi} - f_{Lo}$

NEG Feedback has **increased** bandwidth by **trading-off** open loop gain.

How much bigger is the bandwidth?

Need to have an analytic expression or a measurement of $|A_{ol}|$ to decide this

Particular Example



For this NON-INVERTING AMP,

$$\beta_V = \frac{R_2}{R_1 + R_2} = \frac{1k}{1k + 9k} = \frac{1}{10}$$

So that ideally $\frac{v_o}{v_g} = A_{fv} = \frac{1}{\beta_v} = 10$

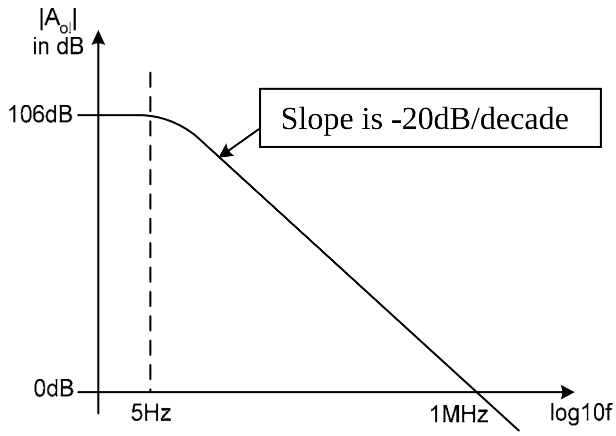
What is bandwidth?

Manufacturer specification sheet gives open loop gain magnitude vs. Frequency (Fig. below)

ie. $|A_{ol}| = 2 \times 10^5$ = 106dB at 5 Hz and below

but = 1 = 0dB at $1MH_z$

Let us plot, on the same graph, the variation of $\frac{1}{|\beta_v|}$ with frequency.

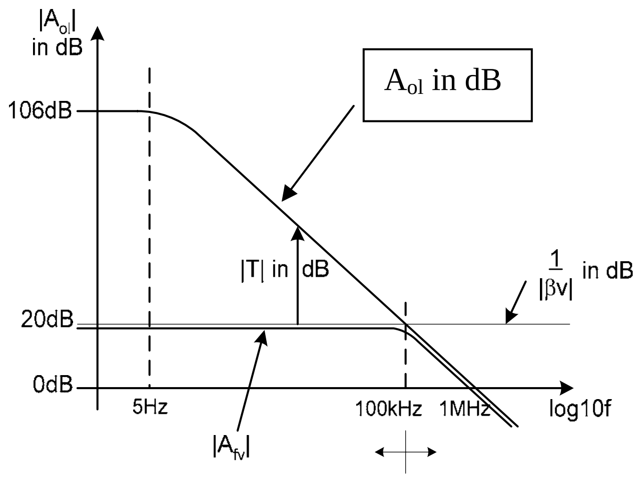


Let us plot, on the same graph, the variation of $\frac{1}{|\beta_v|}$ with frequency.

Since $\left|\frac{1}{\beta_v}\right| = 10, \left|\frac{1}{\beta_v}\right| in\, dB = 20\log_{10} 10$

$= 20\text{dB}$

Independent of frequency- so $\frac{1}{\beta_v}$ vs freq is a horizontal straight line!



Now notice that the vertical distance between $|A_{ol}|$ and $\frac{1}{|\beta_v|}$ curves is the value of $|T|$ in dB at that frequency.

To see this: $20\log_{10}|A_{ol}| - 20\log_{10}\frac{1}{|\beta_v|} = \text{vertical separation}$

$= 20\log_{10}|A_{ol}\,\beta_v| = |T| \text{in dB}$

At point where $|A_{ol}|$ and $\left|\frac{1}{\beta_v}\right|$ cross, $|T| = 0\,dB \equiv 1x$

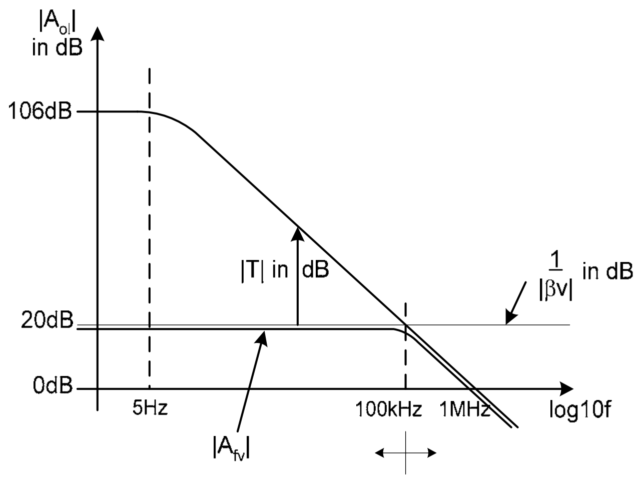
So from previous argument $|A_{fv}| = \frac{1}{|\beta_v|}$ below $100\,kHz$ where $|T| >> 1$

and above $100kH_z$ we have to use the more accurate expression:

$$|A_{fv}| = \frac{1}{|\beta_v|}\left|\frac{T}{1+T}\right| \qquad = \left|\frac{A_{ol}}{1+A_{ol}\beta}\right| \rightarrow |A_{ol}| \text{ when } |T| << 1$$

The conclusion is that $|A_{fv}|$ follows $\frac{1}{|\beta_v|}$ curve up to 100kHz and then follows $|A_{ol}|$ curve.

Clearly bandwidth is now 100 kHz



So original gain $= 2\times10^5\,x$

new gain $= 10x$

Original bandwidth = 5 Hz New bandwidth = 100kHz

Gain reduction is by 2×10^4 **times**

Bandwidth increase is by $\dfrac{100kHz}{5Hz}$ = 2×10^4 times

In fact **product** of gain and bandwidth is a ***constant*** for this type of non-inverting amplifier;
product = "gain-bandwidth product" – **GBW**

Op-Amp has $2 \times 10^5 \times 5\text{Hz}$ = 1MHz GBW

Op-Amp **circuit** has $10 \times 100\text{kHz}$ = 1MHz GBW

The same !

Why is it that all non-inverting op-amp circuits built with a given op-amp have same GBW?

Because of SHAPE of $|A_{ol}|$ curve

A slope of -20dB/decade $|A_{ol}| \alpha \dfrac{1}{f}$ that is $A_{ol} \times f = \text{Const}$

$\therefore$ All points on the slope have $|\text{A}_{\text{ol}}| \times \text{f} = \text{Const} = \text{GBW}$

So wherever $\dfrac{1}{|\beta_v|}$ intersects $|A_{ol}|$,the frequency at the intersection $\times \dfrac{1}{\beta_v} (= \text{gain}) = \text{GBW}$