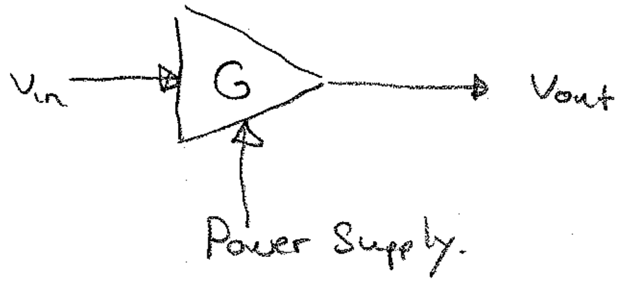
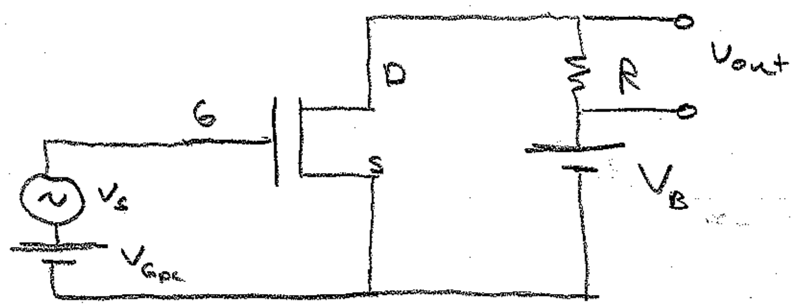
Amplifier 1 dB compression Pt & 3rd Order Intercept.

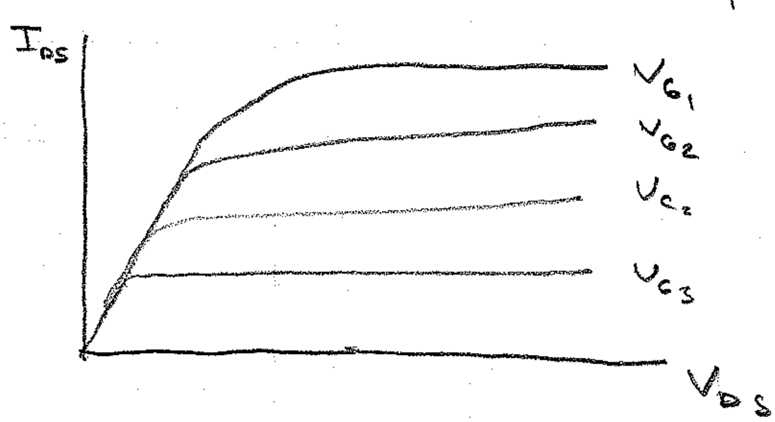


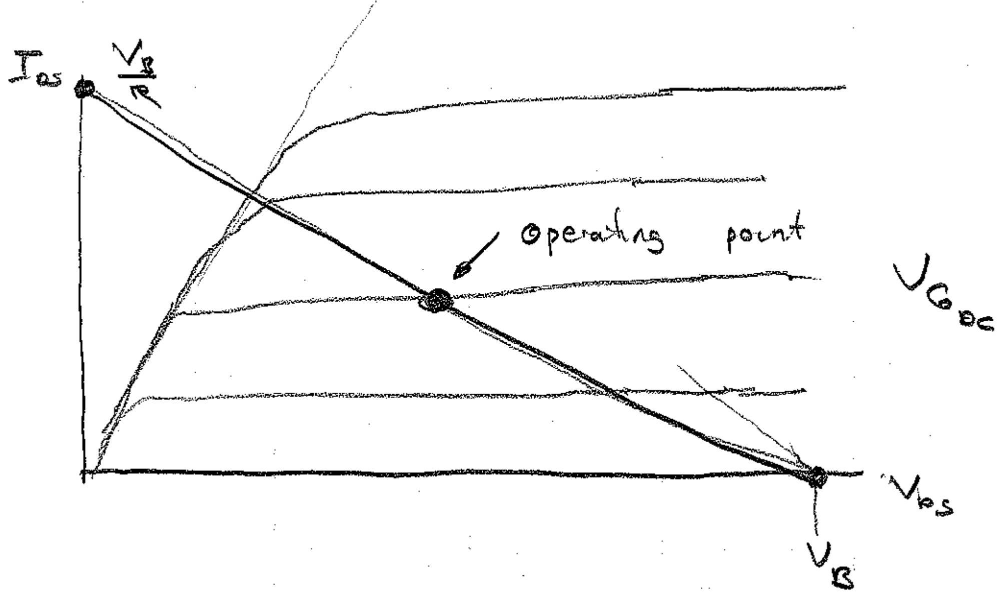
If there is a finite amount of power available from the power supply then there are limits to how large V_{out} can be.

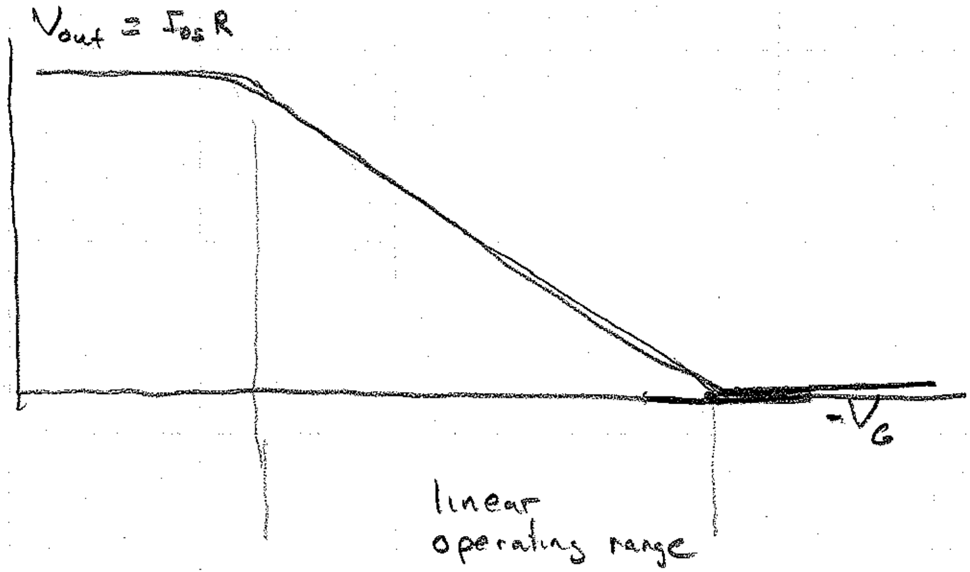


$$V_{DS} = V_B - I_{DS} R$$

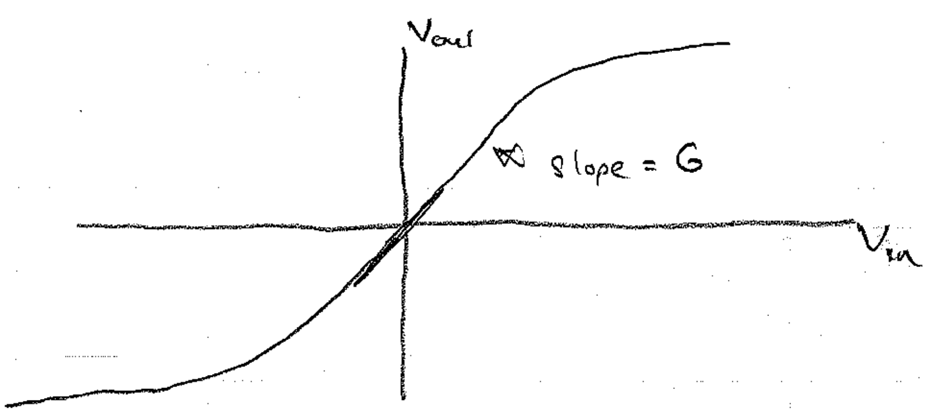
FET V-I curve







Remove the bias for the time being.
We can model a gain curve as



We can expand gain curve as a taylor series

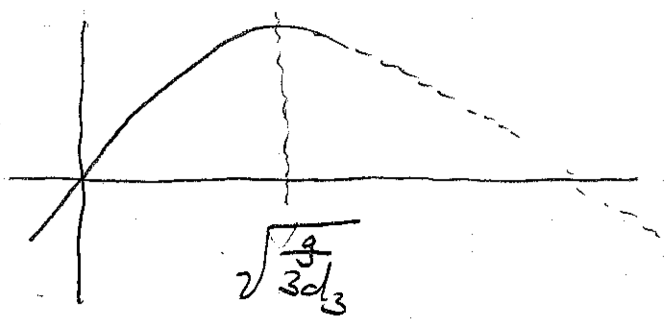
minus sign gain rolls over

$$V_{out} = \cancel{V_B} + g\,V_{in} - \cancel{d_2}\,V_{in}^2 - d_3\,V_{in}^3 \;\cdots$$

AC coupled odd about V_{in}

For the time being, ignore $d_n > d_3$

$$V_{out} = g\,V_{in} - d_3\,V_{in}^3$$



$$V_{in_{max}}^2 = \frac{g}{3d_3}$$

$$V_{max}^2 = \frac{g}{3d_3}$$

$$d_3 = \frac{g}{3V_{max}^2}$$

$$V_{out} = g\left(V_{in} - \frac{V_{in}^3}{3V_{max}^2}\right)$$

Let $V_{in} = v_i \cos \omega t$

$$\cos^3 x = \cos x \cdot \cos^2 x$$

$$= \cos x \left(\frac{1}{2} \cos 2x + \frac{1}{2} \right)$$

$$= \frac{1}{2} \cos x \cos 2x + \frac{1}{2} \cos x$$

$$= \frac{1}{2} \left(\frac{1}{2} \cos x + \frac{1}{2} \cos 3x \right) + \frac{1}{2} \cos x$$

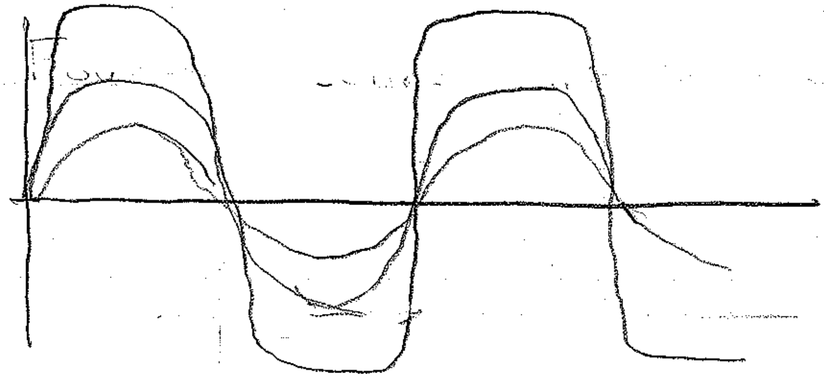
$$= \frac{3}{4} \cos x + \frac{1}{4} \cos 3x$$

$$V_{out} = g\, v_i \cos \omega t - \frac{g}{3V_{max}^2} v_i^3 \left(\frac{3}{4} \cos \omega t + \frac{1}{4} \cos 3\omega t \right)$$

$$V_{out} = g \left(1 - \left(\frac{v_i}{2v_{max}} \right)^2 \right) v_i \cos \omega t$$

$$- \frac{g}{3} \left(\frac{v_i}{2v_{max}} \right)^2 v_i \cos 3\omega t$$

Non-linearities generate harmonics!!



$$f(t) = \sum_{n=1}^{\infty} c_n \sin n\omega_0 t$$

$$c_n = \frac{4}{T}\int_0^{T/2} f(x) \sin n \frac{2\pi}{T} t \, dt$$

for square wave

$$c_n = \frac{4}{T}\int_0^{T/2} \sin \frac{2\pi n}{T} t \, dt$$

$$= -\frac{4}{T} \frac{T}{2\pi n}\left(\cos \pi n - 1\right)$$

$$= \frac{4}{\pi n} \quad \text{for } n \text{ odd}$$

$$= 0 \quad \text{fo } n \text{ even.}$$

$$f(t) = \sum_{n=1}^{\infty} \frac{4}{\pi(2n-1)} \sin(2n-1)\omega_0 t$$

1 over n

n odd

1 dB compression point.

Gain at the fundamental at low power

$$g_{low} = g$$

Gain at the fundamental at high power

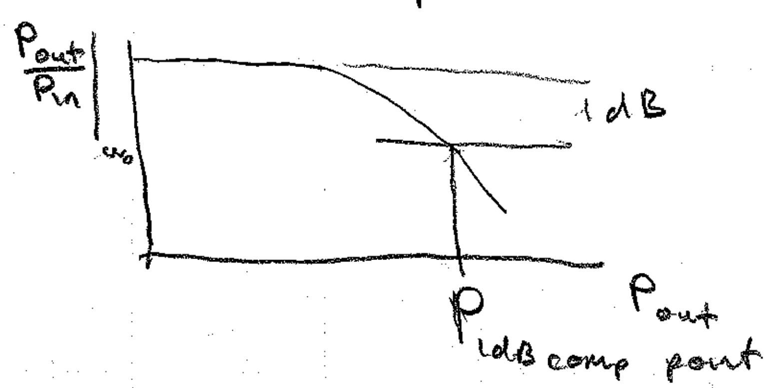
$$g_{high} = g\left(1 - \left(\frac{v_i}{2v_{max}}\right)^2\right)$$

$$\frac{g_{high}}{g_{low}} = \left(1 - \left(\frac{v_i}{2v_{max}}\right)^2\right)$$

$$10 \log\left(\left(\frac{g_{high}}{g_{low}}\right)^2\right) = -1\,dB$$

is defined as the 1 dB compression point

Power at which the power gain at the fundamental at high power is 1 dB lower than the power gain at zero power



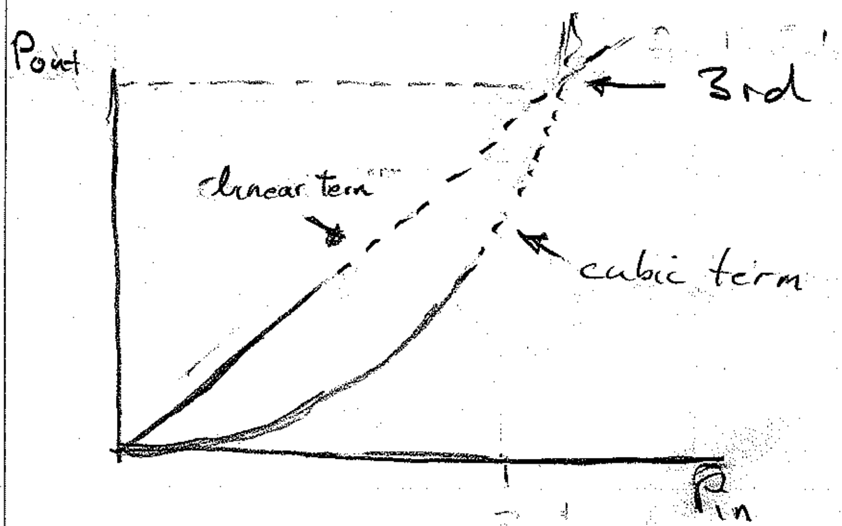
$$-1\ \text{dB} \Rightarrow \quad 10^{-\frac{1}{10}} = (.794)$$

$$\left(\frac{V_{out}}{V_{in}} - \left(\frac{V_i}{2V_{max}}\right)^2\right)^2 = .794$$

$$\left(1 - \left(\frac{V_i}{2V_{max}}\right)^2\right) = .891$$

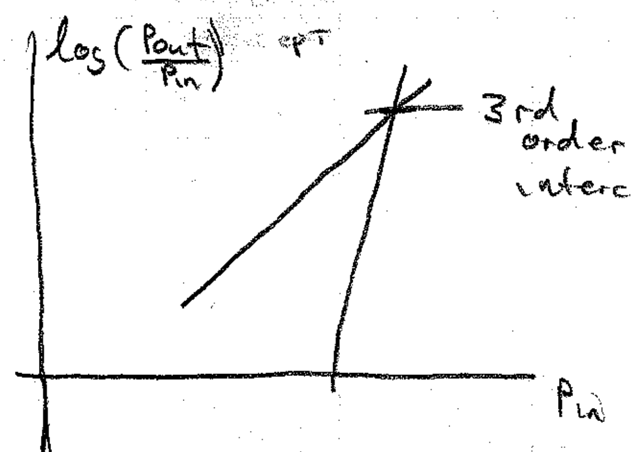
$$v_i = .66\, v_{max}$$ (for our simple model)

3rd Order Intercept



place when fundmental Dsappears!

Or log Plot



Never really go to the 3rd order intercept ⇒ usually past the destroy level of the amplifier

<u>3rd order intercept</u>

$$1 - \left(\frac{v_i}{2v_{max}}\right)^2 = 0$$

$$v_i = 2v_{max}$$

$$20\log_{10}\left(\frac{V_i\big|_{intercept}}{V_i\big|_{-1dB\,comp}}\right) = 9.63\ dB$$

∴ 3rd order intercept ≃ 10dB greater than the 1dB compression point.

3rd order Intermodulation Distortion.

$$v_{in} = v_1 \cos((\omega_0 + \Delta\omega)t)$$
$$+ v_2 \cos((\omega_0 - \Delta\omega)t)$$

$$v_{out} = g\left(v_{in} - \frac{v_{in}^3}{3V_{max}^2}\right)$$

$$(v_1 + v_2)^3 = v_1^3 + 3v_1^2 v_2 + 3v_1 v_2^2 + v_2^3$$

$$v_1^3 = \frac{3}{4}\cos((\omega_0+\Delta\omega)t) + \frac{1}{4}\cos(3(\omega_0+\Delta\omega)t)$$

$$v_2^3 = \frac{3}{4}\cos((\omega_0-\Delta\omega)t) + \frac{1}{4}\cos(3(\omega_0-\Delta\omega)t)$$

$$v_1^2 v_2 = \frac{1}{2}\left(1 + \cos 2(\omega_0+\Delta\omega)t\right)\cos((\omega_0-\Delta\omega)t)$$

$$= \frac{1}{2}\cos((\omega_0-\Delta\omega)t)$$

$$+ \frac{1}{4}\cos((3\omega_0+\Delta\omega)t) + \frac{1}{4}\cos(\omega_0+3\Delta\omega)t$$

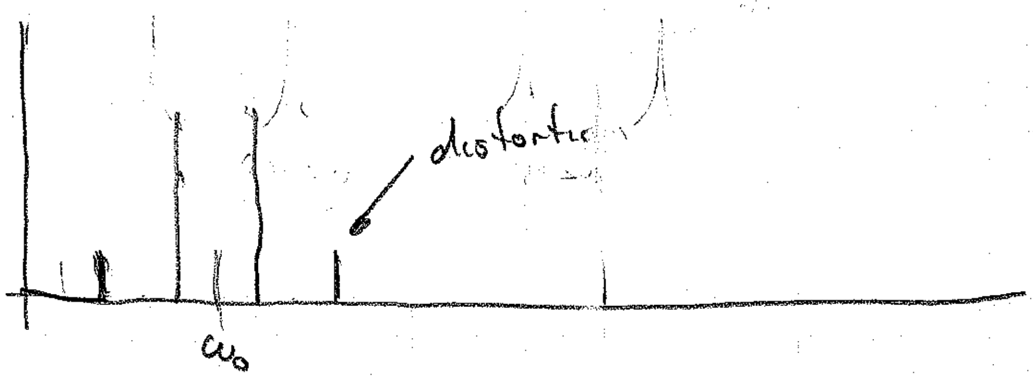
$$v_1 v_2^2 = \frac{1}{2}\cos((\omega_0+\Delta\omega)t)$$

$$+ \frac{1}{4}\cos((3\omega_0-\Delta\omega)t) + \frac{1}{4}((\omega_0 - 3\Delta\omega)t)$$

Let

$$v_{in} = v_o \cos\left((\omega + \Delta\omega)t\right) + v_o \cos\left((\omega - \Delta\omega)t\right)$$

Assume $\Delta\omega'$ small



Amplitude of distortion products

$$= \frac{g}{3V_{max}^2} \frac{3}{4} (v_o)^3$$

$$= g V_o \left(\frac{v_o}{2 v_{max}}\right)^2$$

When $v_o = 2v_{max}$, the amplitude of the distortion products match the linear power

To measure 3rd order intercept

1) Create two tones of same amplitude but different frequencies

2) Increase tone amplitude & measure distortion product compared to tone amplitude on a spectrum analyzer

3) Extrapolate when distortn products will match linear signal