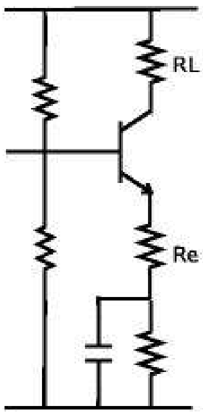
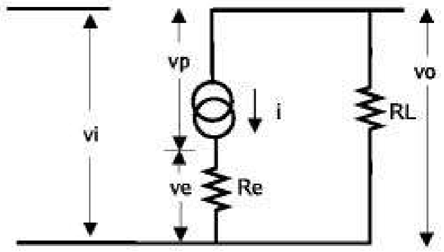
Small Signal THD Analysis of Preamplifier for THD

The preamplifier is based on the common emitter circuit with an emitter degeneration resistor.





From the small signal diagram we get the equations:

$$v_0 = -i R_L \qquad v_i = v_\pi + v_e \qquad v_e = i R_e$$

The small signal model of the transistor is a dependent current source of the following form:

$$i = g_m v_\pi - \delta v_\pi^2$$

where $g_m = I_e / V_T$ is the transconductance as used in the usual first order analysis, and we have introduced $\delta = I_e / V_T^2 = g_m / V_T$ which comes from the second term in the expansion of the exponential law of the BJT. We are ignoring higher order expansion terms. Substitute for *i*

$$v_i = v_\pi + R_e \left(g_m v_\pi - \delta v_\pi^2 \right)$$ Rearrange in terms of v_i (neglecting higher order terms)

$$v_\pi = \frac{v_i}{1 + R_e g_m} + \frac{R_E \delta}{1 + R_e g_m} \left(\frac{v_i}{1 + R_e g_m{}^2} \right)$$ Finally use v_π in *i* for v_o

$$v_0 = \frac{-R_L g_m}{1 + R_e g_m} v_i + \frac{R_L \delta}{(1 + R_e g_m)^3} v_i^2$$

Again some terms of order greater than 2 have been omitted. The last equation gives the output as the linear gain term (recognisable from textbooks) and a second order distortion term. If the input signal is $v_i = V \sin(\omega t)$ then THD is given by the ratio of the powers in the two terms:

$$THD = \frac{3}{4} \frac{(V^2 R_L \delta)^2}{(1 + R_e g_m)^6} \frac{(1 + R_e g_m)^2}{(V R_L g_m)^2} = \frac{3 V^2}{4 V_T^2 (1 + R_e g_m)^4} = \frac{3 V_T^2 V^2}{4 V_{RL}^4} G^4$$

Where G is the amplifier gain and the factor of 3/4 comes from the powers of the sine wave in v_i. In the last expression we have given THD in terms of gain *G* and a voltage V_{RL} which is the bias voltage across the load resistor R_L. Thus the THD increases with gain and input signal voltage, and decreases as we increase the bias voltage across the load resistor.