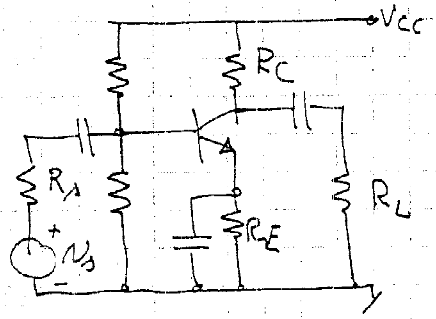
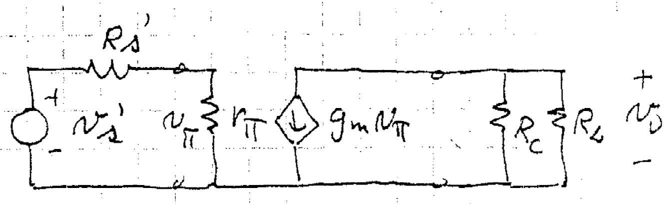
Udledning af max. $|A_v|$ i C.E. med givet R_S, R_L og V_{CC}.



$v_s' = v_s \cdot \frac{R_B}{R_s + R_B}$; $R_s' = R_s \| R_B$; $r_o >> R_C \| R_L$ antages



$$A_v = \frac{v_o}{v_s} = \frac{v_o}{v_s'} \cdot \frac{v_s'}{v_s} = A_v' \cdot \frac{R_B}{R_s + R_B}$$

$|A_v'|_{max}$ findes ved at variere R_C med fastholdt $V_{RC} = I_C \cdot R_C$.

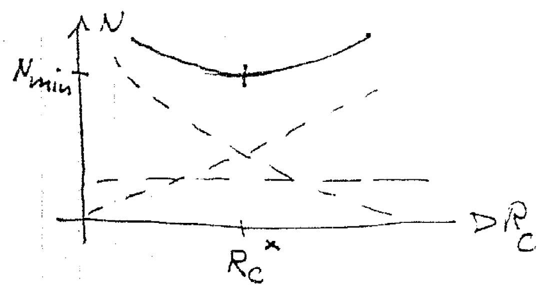
$$\left.\begin{aligned} v_o &= -g_m v_\pi \cdot R_C \| R_L \\ v_s' &= v_\pi + \frac{v_\pi}{r_\pi} \cdot R_s' \end{aligned}\right\} \underline{\underline{A_v'}} = -\frac{g_m \cdot R_C \| R_L}{1 + \frac{R_s'}{r_\pi}} = \underline{\underline{-\frac{R_C \| R_L}{\frac{1}{g_m} + \frac{R_s'}{\beta}}}}$$

g_m er afhængig af R_C: $g_m = \frac{I_C}{V_T} = \frac{V_{RC}}{R_C \cdot V_T}$ indføres:

$$A_v' = -\frac{1}{\left(\frac{R_C \cdot V_T}{V_{RC}} + \frac{R_s'}{\beta}\right)\left(\frac{1}{R_C} + \frac{1}{R_L}\right)} = -\frac{1}{\frac{V_T}{V_{RC}} + \frac{R_s'}{\beta R_C} + \frac{R_C \cdot V_T}{V_{RC} \cdot R_L} + \frac{R_s'}{\beta R_L}} = \frac{T}{N}$$

$|A_v'|_{max}$ fås ved N_{min}:

af $\frac{dN}{dR_C} = 0$ fås ved: $\underline{\underline{R_C^* = \sqrt{\frac{R_s' \cdot R_L \cdot V_{RC}}{\beta \cdot V_T}}}}$



en maksimal $|A_v'|$ på:

$$\underline{\underline{|A_v'|_{max}}} = \frac{1}{\frac{V_T}{V_{RC}} + \sqrt{\frac{V_T \cdot R_s'}{\beta \cdot V_{RC} \cdot R_L}} + \sqrt{\frac{V_T \cdot R_s'}{\beta \cdot V_{RC} \cdot R_L}} + \frac{R_s'}{\beta \cdot R_L}} = \underline{\underline{\frac{1}{\left(\sqrt{\frac{V_T}{V_{RC}}} + \sqrt{\frac{R_s'}{\beta \cdot R_L}}\right)^2}}}$$

Hvis $r_o = \frac{V_A}{I_C}$ medtages i udledningen, bliver:

$$\underline{A_v' = -\frac{r_o \| R_C \| R_L}{\frac{1}{g_m} + \frac{R_s'}{\beta}}} \quad \text{og} \quad \underline{\underline{R_C^* = \sqrt{\frac{R_s' \cdot R_L \cdot V_{RC}}{\beta \cdot V_T}\left(1 + \frac{V_{RC}}{V_A}\right)}}}$$

En uafkoblet emittermodstand: R_e' $= R_E \| R_E$, dæmper $|A_v'|_{max}$ ned til:

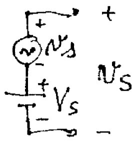
$$\underline{\underline{A_v' = -\frac{r_o \| R_C \| R_L}{R_e' + \frac{1}{g_m} + \frac{R_s'}{\beta}}}} \longrightarrow \underline{\underline{R_e' = \frac{r_o \| R_C \| R_L}{|A_v'|} - \frac{1}{g_m} - \frac{R_s'}{\beta}}} \; \cancel{=} R_E \| R_E$$

Metode til beregning af forvrængning (Harmonic Distortion) ud fra en given ulineær overførings funktion.

Overføringsfunktionen $i_O = f(v_S)$ opskrives som en Taylor-række ud fra arbejdspunktet: I_O, V_S:

$$i_O = I_O + f'(v_S - V_S) + \frac{1}{2!} f''(v_S - V_S)^2 + \frac{1}{3!} f'''(v_S - V_S)^3 + \cdots$$

hvor $f' = \frac{di_O}{dv_S}\Big|_{V_S}$; $f'' = \frac{d^2 i_O}{dv_S^2}\Big|_{V_S}$; $f''' = \frac{d^3 i_O}{dv_S^3}\Big|_{V_S}$



Med: $v_s = v_S - V_S = \hat{V}\cdot\cos\omega t$

$\cos^2\omega t = \frac{1}{2}(1 + \cos 2\omega t)$

$\cos^3\omega t = \frac{3}{4}\cos\omega t + \frac{1}{4}\cos 3\omega t$, fås:

Jævnleddet A_0: $I_O + \frac{1}{4} f''\cdot\hat{V}^2$

Grundfrekvens A_1: $f'\cdot\hat{V} + \frac{1}{8} f'''\cdot\hat{V}^3$

2. Harmoniske A_2: $\frac{1}{4}\cdot f''\cdot\hat{V}^2$

3. Harmoniske A_3: $\frac{1}{24} f'''\cdot\hat{V}^3$

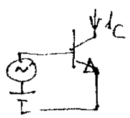
$$i_O = A_0 + A_1\cdot\cos\omega t + A_2\cdot\cos 2\omega t + A_3\cos 3\omega t + \cdots$$

Def.: $\text{T.H.D} = \sqrt{\frac{A_2^2 + A_3^2 + A_4^2 + \cdots}{A_1^2}} = \sqrt{HD_2^2 + HD_3^2 + HD_4^2 + \cdots}$, hvor:

$$2HD = \left|\frac{A_2}{A_1}\right| = \left|\frac{\frac{1}{4} f''\cdot\hat{V}^2}{f'\cdot\hat{V} + \frac{1}{8} f'''\cdot\hat{V}^3}\right| \simeq \frac{1}{4}\left|\frac{f''}{f'}\right|\cdot\hat{V}$$

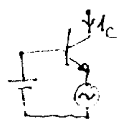
$$3HD = \left|\frac{A_3}{A_1}\right| = \left|\frac{\frac{1}{24} f'''\cdot\hat{V}^3}{f'\cdot\hat{V} + \frac{1}{8} f'''\cdot\hat{V}^3}\right| \simeq \frac{1}{24}\left|\frac{f'''}{f'}\right|\cdot\hat{V}^2$$, kan beregnes.

Eks: BJT uden generator modstand. $i_O \sim i_C$; $v_S \sim v_{BE}$



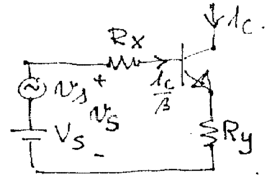
$i_C = I_S \cdot e^{v_{BE}/V_t}$; $f' = g_m = \frac{I_C}{V_t}$; $f'' = \frac{I_C}{V_t^2}$; $f''' = \frac{I_C}{V_t^3}$

$2HD = \frac{1}{4}\cdot\frac{\hat{V}}{V_t}$; (Da $4\cdot V_t \approx 100$mV ses at $HD_2[\%] \sim$ amplituden $\hat{V}$ i [mV])



$3HD = \frac{1}{24}\left(\frac{\hat{V}}{V_t}\right)^2$

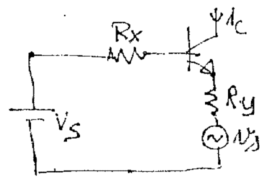
Reduktion af forvrængning i BJT med seriemodstande.



$i_C = f(v_S)$ søges $\to f'$ og f'' ved I_C

$v_S = \frac{i_C}{\beta}\cdot R_x + v_{BE} + i_C\cdot R_y$

$v_S = i_C\left(\frac{R_x}{\beta} + R_y\right) + V_t \ln\frac{i_C}{I_S}$



Hvor $f' = \frac{di_C}{dv_S}$ og $f'' = \frac{d^2 i_C}{dv_S^2}$ kan findes ved implicit differentiation:

$$1 = \frac{di_C}{dv_S}\left(\frac{R_x}{\beta} + R_y\right) + 0 + V_t\,\frac{1}{\frac{i_C}{I_S}}\cdot\frac{1}{I_S}\cdot\frac{di_C}{dv_S} + 0$$

$$1 = f'\left(\frac{R_x}{\beta} + R_y + \frac{V_t}{i_C}\right) \to f'(I_C) = \frac{1}{\frac{R_x}{\beta} + R_y + \frac{V_t}{I_C}}$$

og igen:

$$0 = \frac{d^2 i_C}{dv_S^2}\left(\frac{R_x}{\beta} + R_y\right) + \frac{d^2 i_C}{dv_S^2}\cdot\frac{V_t}{i_C} + \frac{di_C}{dv_S}\left(\frac{-V_t}{i_C^2}\right)\frac{di_C}{dv_S}$$

$$0 = f''\left(\frac{R_x}{\beta} + R_y + \frac{V_t}{i_C}\right) - f'^2\cdot\frac{V_t}{i_C^2} \to f''(I_C) = \frac{f'^2\cdot\frac{V_t}{I_C^2}}{\frac{R_x}{\beta} + R_y + \frac{V_t}{I_C}}$$

$$2HD = \frac{1}{4}\left|\frac{f''}{f'}\right|\hat{V} = \frac{1}{4}\cdot\frac{f'\cdot\frac{V_t}{I_C^2}}{\frac{R_x}{\beta} + R_y + \frac{V_t}{I_C}}\cdot\hat{V} = \frac{1}{4}\,\frac{\frac{V_t^2}{I_C^2}}{\left(\frac{R_x}{\beta} + R_y + \frac{V_t}{I_C}\right)^2}\cdot\frac{\hat{V}}{V_t}$$

$$2HD = \frac{\frac{1}{4}\cdot\frac{\hat{V}}{V_t}}{\left(\frac{I_C}{V_t}\left(\frac{R_x}{\beta} + R_y\right) + 1\right)^2} = \frac{\frac{1}{4}\cdot\frac{\hat{V}}{V_t}}{F^2}$$; hvor $F = \frac{I_C}{V_t}\left(\frac{R_x}{\beta} + R_y\right) + 1 = g_m\left(\frac{R_x}{\beta} + R_y\right) + 1$.

Vurdering: Med seriemodstande er forvrængningen faldet en faktor F^2, hvorimod forstærkningen, der er proportional med f', kun falder F gange.

$$\frac{A_V(m.R)}{A_V(u.R)} = \frac{f'(m.R)}{f'(u.R)} = \frac{\frac{V_t}{I_C}}{\frac{R_x}{\beta} + R_y + \frac{V_t}{I_C}} = \frac{1}{\frac{I_C}{V_t}\left(\frac{R_x}{\beta} + R_y\right) + 1} = \frac{1}{F}$$

Store modstande gør transistoren strøm-styret.

Ved yderligere differentiation kan udledes:

$$3HD = \left|\frac{3 - 2\cdot F}{24\cdot F^4}\right|\left(\frac{\hat{V}}{V_t}\right)^2$$