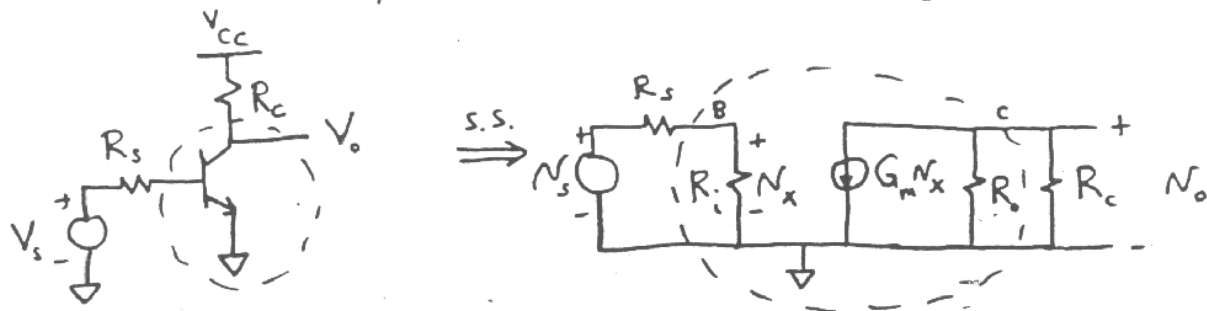


Single Transistor Amplifier Models

P. Hurst

(r_c, r_{ex} assumed negligibly small, r_{μ} assumed negligibly large - with some exceptions)

C.E.



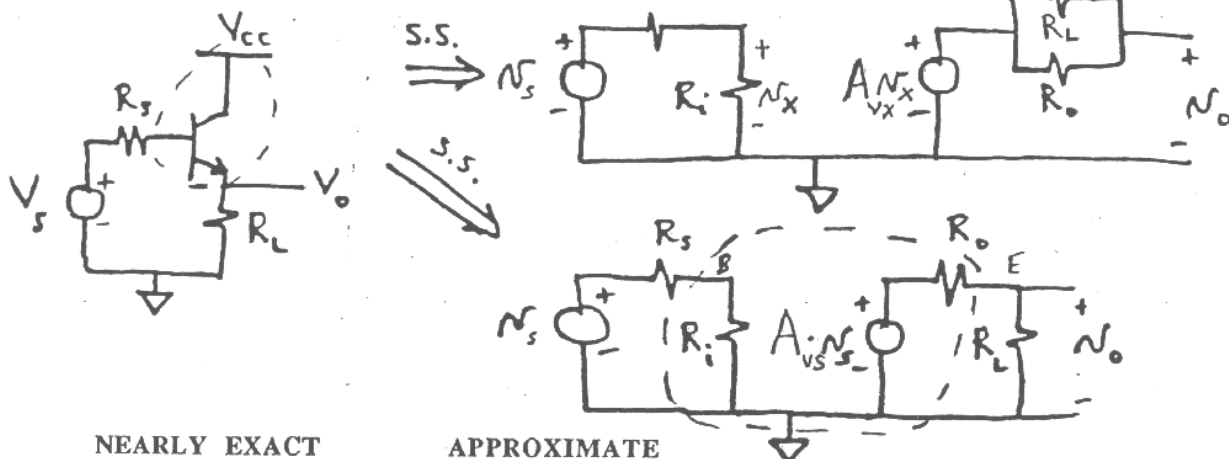
PARAMETER	NEARLY EXACT EXPRESSION	APPROXIMATE EXPRESSION	ASSUMPTIONS
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$R_i =$	$r_{\pi} + r_b$	$\approx r_{\pi}$	$r_b \ll r_{\pi}$
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$R_o =$	$r_o \parallel \left[\frac{r_{\mu}}{\beta} \left(\frac{1 + \frac{r_{\pi}}{R_s + r_b}}{1 + \frac{1}{g_m(R_s + r_b)}} \right) \right]$	$\approx r_o$	term in $[] \gg r_o$
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$G_m =$	$g_m \left(\frac{r_{\pi}}{r_{\pi} + r_b} \right)$	$\approx g_m$	$r_b \ll r_{\pi}$
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C.C.



PARAMETER	NEARLY EXACT EXPRESSION	APPROXIMATE EXPRESSION	ASSUMPTIONS
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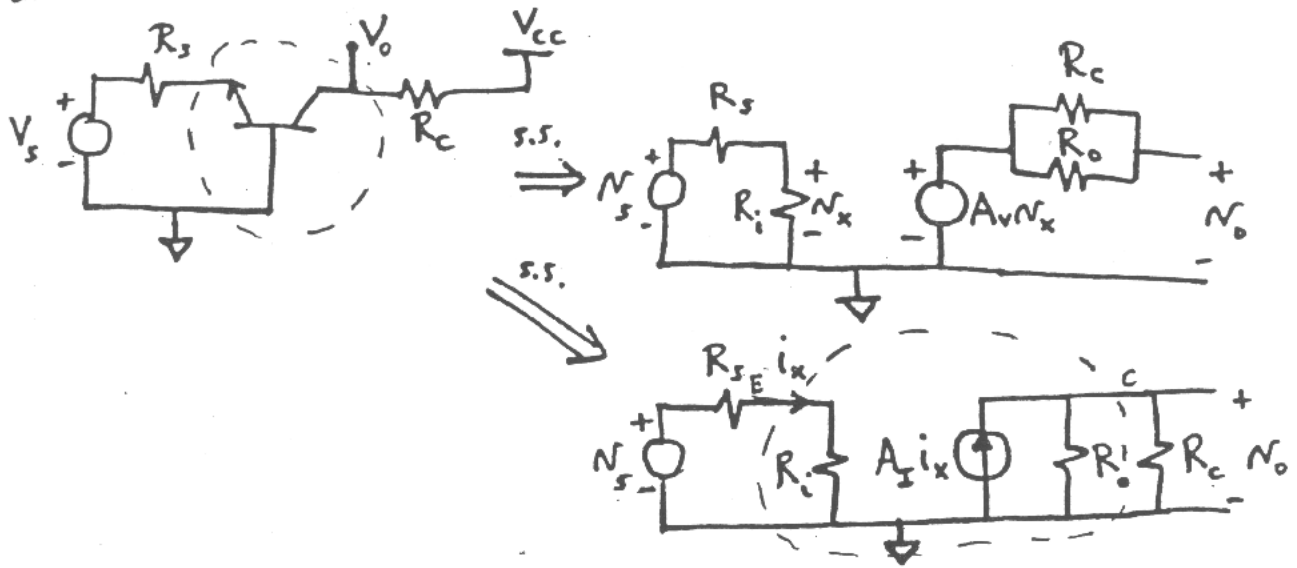
$R_i =$	$r_b + r_{\pi} + (\beta + 1)(R_L \parallel r_o)$	$\approx r_{\pi} + (\beta + 1)R_L$	$r_b \ll r_{\pi}, R_L \ll r_o$
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$R_o =$	$\left(\frac{r_b + r_{\pi} + R_s}{\beta + 1} \right) \parallel r_o$	$\approx \frac{r_{\pi} + R_s}{\beta + 1} \approx \frac{1}{g_m} + \frac{R_s}{\beta + 1}$	$r_b \ll r_{\pi} + R_s, r_{\pi} + R_s \ll (\beta + 1) r_o$
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$A_{vx} = \frac{v_o}{v_x} =$	$\frac{R_L \parallel r_o}{R_L \parallel r_o + \frac{r_b + r_{\pi}}{\beta + 1}}$	≈ 1	$\frac{r_b + r_{\pi}}{\beta + 1} \ll R_L \parallel r_o$
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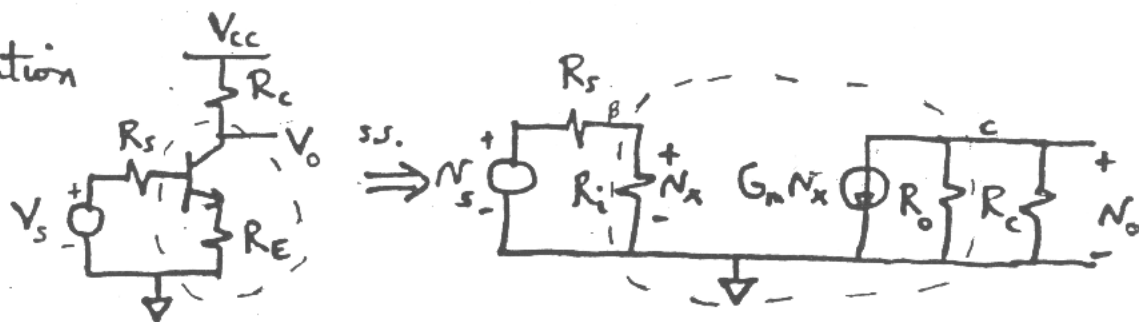
$A_{vs} = \frac{v_o}{v_s} \Big _{R_L = \infty} =$	$\frac{\frac{r_b + r_{\pi} + R_s}{\beta + 1} + R_L}{\frac{r_b + r_{\pi} + R_s}{\beta + 1} \cdot \frac{r_o}{r_o + R_L} + R_L}$	≈ 1	$R_L \ll r_o \text{ or } R_L \gg \frac{r_b + r_{\pi} + R_s}{\beta + 1} \cdot \frac{r_o}{r_o + R_L}$
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C. B.



PARAMETER	EXACT EXPRESSION	APPROXIMATE EXPRESSION	ASSUMPTIONS
$R_i =$	$\frac{(r_{\pi} + r_b)(r_o + R_c)}{(\beta + 1) r_o + R_c}$	$\approx \frac{r_{\pi}}{\beta + 1} = \frac{\alpha}{g_m} \approx \frac{1}{g_m}$	$r_b \ll r_{\pi}, r_o \gg R_c, \alpha \approx 1$
$R_o =$	$r_{\mu} \parallel \left[r_o \left(1 + \frac{\beta R_s}{r_{\pi} + r_b + R_s} \right) \right]$	$\approx (\beta r_o) \parallel r_{\mu}$	$R_s \gg r_{\pi} + r_b$
		$\approx r_o$	$\beta R_s \ll r_{\pi} + r_b, r_{\mu} \gg r_o$
$A_v =$	$\left(g_m + \frac{1}{r_o} \right) (R_c \parallel r_o \parallel r_{\mu})$	$\approx g_m (R_c \parallel r_o)$	$g_m r_o \gg 1, r_{\mu} \gg r_o$
$A_i =$	$\frac{r_{\pi} + r_b + \beta r_o}{r_{\pi} + r_b + (\beta + 1) r_o + R_c} \cdot \frac{R_c}{R_o \parallel R_c}$	$\approx \frac{\beta}{\beta + 1} = \alpha \approx 1$	$r_{\pi} + r_b + R_c \ll \beta r_o, R_o \gg R_c$

C.E. w/ degeneration



PARAMETER	NEARLY EXACT EXPRESSION	APPROXIMATE EXPRESSION	ASSUMPTIONS
$R_i =$	$r_b + r_\pi + (\beta + 1)R_E$	$\approx r_\pi (1 + g_m R_E)$	$r_b \ll r_\pi, \beta \gg 1$
$R_o = (r_\pi + r_b + R_s) \parallel R_E + r_o \left(1 + g_m R_E \cdot \frac{r_\pi}{r_\pi + r_b + R_s + R_E} \right) \approx r_o (1 + g_m R_E)$			$r_\pi \gg r_b + R_s + R_E$
		$\approx r_o \left(1 + g_m R_E \frac{r_\pi}{r_\pi + R_s + R_E} \right)$	$r_b \ll r_\pi + R_s + R_E$
		$\approx \beta r_o$	$R_E \gg r_\pi + r_b + R_s$
$G_m =$	$\frac{g_m}{1 + \frac{r_b + (\beta + 1)R_E}{r_\pi}}$	$\approx \frac{g_m}{1 + \frac{(\beta + 1)R_E}{r_\pi}} \approx \frac{g_m}{1 + g_m R_E}$	$r_b \ll (\beta + 1) R_E$
		$\approx \frac{1}{R_E}$	$r_b \ll (\beta + 1) R_E, g_m R_E \gg 1$

GENERAL EXPRESSIONS

$R(\text{looking into base}) \approx r_b + r_\pi + (\beta + 1) \cdot R_{\text{EMITTER}}$

$R(\text{looking into collector}) \approx r_o \left(1 + g_m R_{\text{EMITTER}} \cdot \frac{r_\pi}{r_\pi + r_b + R_{\text{BASE}} + R_{\text{EMITTER}}} \right)$

$R(\text{looking into emitter}) \approx \left(\frac{r_b + r_\pi + R_{\text{BASE}}}{\beta + 1} \right)$

where: $R_{\text{EMITTER}} = R(\text{from emitter to ac ground})$ and $R_{\text{BASE}} = R(\text{from base to ac ground})$