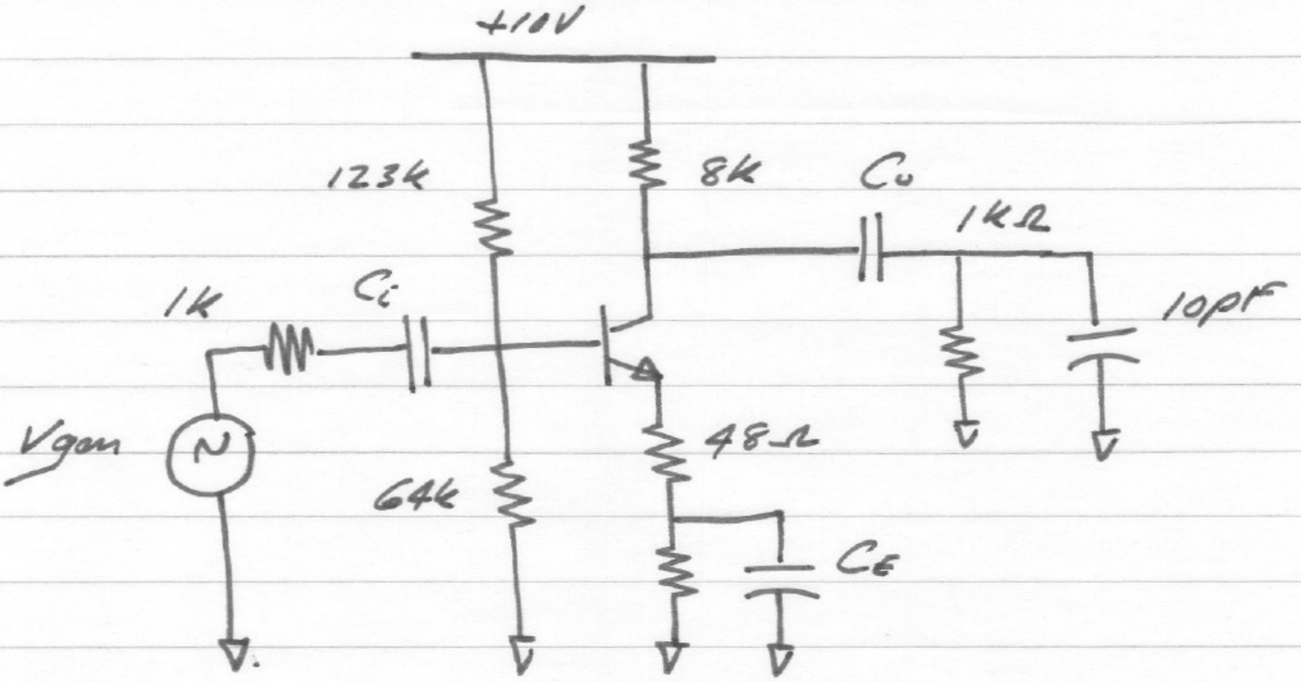
ECE137B Notes Set 4

Amplifier pulse response:



we had found earlier:

$$v_o/v_{gen}(s) = -8.9\frac{1 - s\cdot 1ns}{(1 + s\cdot 0.11\mu s)(1+s\cdot 2.1ns)}$$

Let us approximate:

$$v_o/v_{gen}(s) = \frac{-8.9}{(1+s\cdot 0.11\mu s)(1+s\cdot 2.1ns)}$$

Step response: $v_i(t) = 1V \cdot u(t) \rightarrow V_i(s) = 1V/s$

$$v_o/v_{gen} = \frac{A_o}{(1 + s\tau_1)(1 + s\tau_2)} \qquad v_i(s) = \frac{B}{s} \quad ; B = 1V$$

$$v_o(s) = \frac{A_o B}{s(1 + s\tau_1)(1 + s\tau_2)}$$

$$= \frac{K_1}{1 + s\tau_1} + \frac{K_2}{1 + s\tau_2} + \frac{K_3}{s}$$

let s approach $-1/\tau_1$:

$$\frac{A_o B}{(-1/\tau_1)(1 - \tau_2/\tau_1)} = K_1 = A_o B \cdot \frac{\tau_1}{\tau_2 - \tau_1} \cdot \tau_1$$

let s approach $-1/\tau_2$:

$$K_2 = \frac{A_o B}{(-1/\tau_2)(1 - \tau_1/\tau_2)} = A_o B \frac{\tau_2}{\tau_1 - \tau_2} \cdot \tau_2$$

let s approach zero:

$$K_3 = A_o B$$

$$v_o(s) = A_oB\left(\frac{\tau_1}{\tau_2-\tau_1}\right)\frac{\tau_1}{1+s\tau_1} + A_oB\left(\frac{\tau_2}{\tau_1-\tau_2}\right)\frac{\tau_2}{1+s\tau_2} + \frac{A_oB}{s}$$

$$V_o(t) = A_oB\left[u(t) - u(t)\frac{\tau_1}{\tau_1-\tau_2}e^{-t/\tau_1} - u(t)\frac{\tau_2}{\tau_2-\tau_1}e^{-t/\tau_2}\right]$$

$A_oB = -8.9V$ $\qquad \tau_1 = 0.11\mu s \qquad \tau_2 = 2.1ns$

$$V_{out}(t) = -8.9V\left[u(t)\right]\left[1 - 1.02\cdot e^{-t/0.11\mu s} + 0.02e^{-t/2.1ns}\right]$$

= this term, due to the 2^{nd} pole in the frequency response

1) Is really small if $\tau_2 << \tau_1$

2) Dies down much more quickly if $\tau_2 << \tau_1$

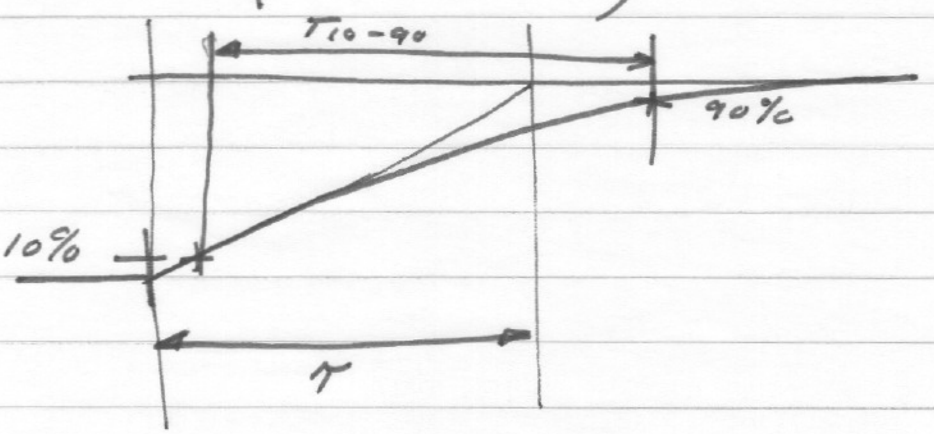
Conclusion: pulse response is dominated by the effect of the dominant pole so we could have done this more quickly:

$$v_o/v_{gen}(s) \cong \frac{-8.9}{(1 + s \cdot 0.11\mu s)}$$

2nd pole neglected:

$$V_o(s) = \frac{-8.9 \cdot 1V}{s \cdot (1 + s \cdot 0.11\mu s)} = -8.9 \left[\frac{1}{s} - \frac{0.11\mu s}{1 + s(0.11\mu s)} \right]$$

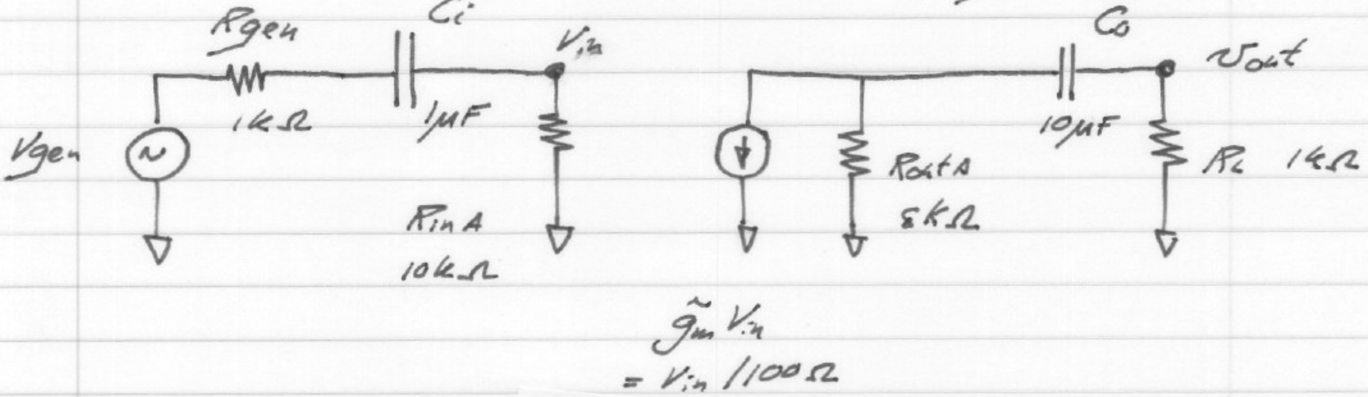
$$v_{out}(t) = -8.9 \cdot \left(1 - e^{-t/0.11\mu s} \right) \cdot u(t)$$



$$T_{10-90} = \tau \cdot [\ln 0.9 - \ln 0.1] = 2.2\tau = 230ns.$$

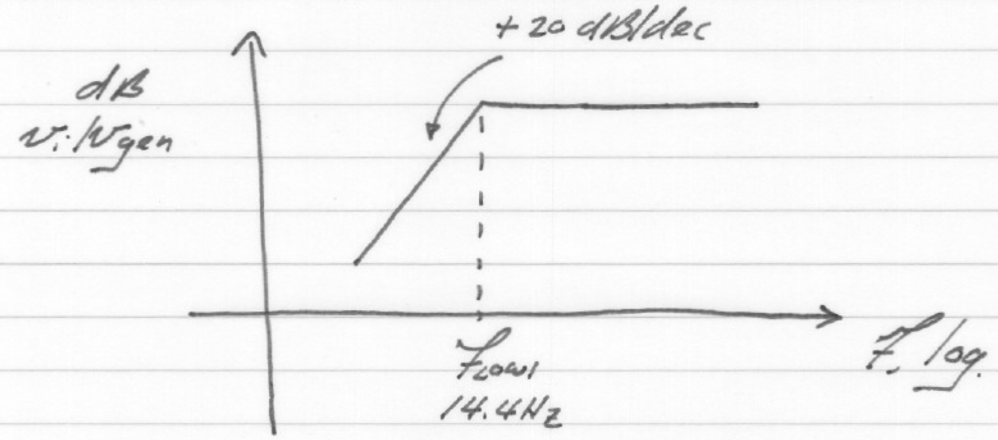
Low frequency response

Ignore C_E for now. This is not reasonable, but is necessary at present to simplify analysis.



$$\frac{v_{in}}{v_{gen}} = \left.\frac{v_{in}}{v_{gen}}\right|_{MB} \times \frac{s\tau_{in}}{1+s\tau_{in}} \quad ; \quad \tau_{in} = C_i(R_{gen} + R_{inA}) = 11\ ms$$

$$= \left.\frac{v_i}{v_{gen}}\right|_{MB} \frac{jf/f_{low1}}{1+jf/f_{low1}} \quad ; \quad f_{low1} = 1/2\pi\tau_{in} = 14.4\ Hz.$$

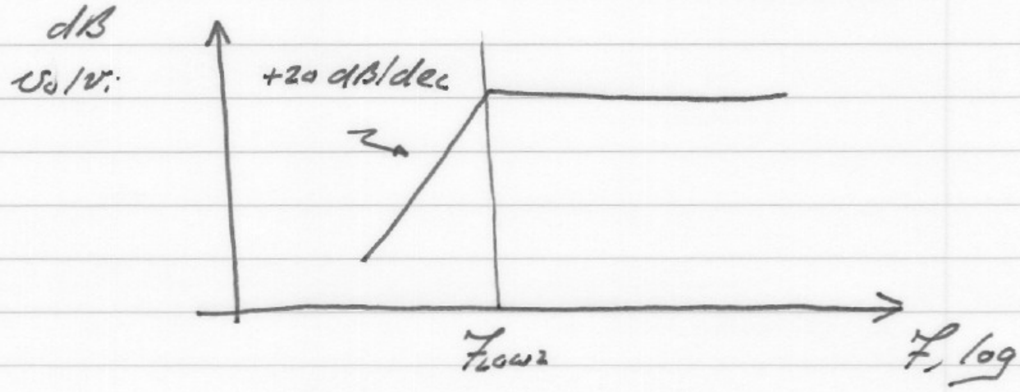


$$\left. v_i/v_{gen}\right|_{MB} = R_{inA}/(R_{inA}+R_{gen}) = 0.91$$

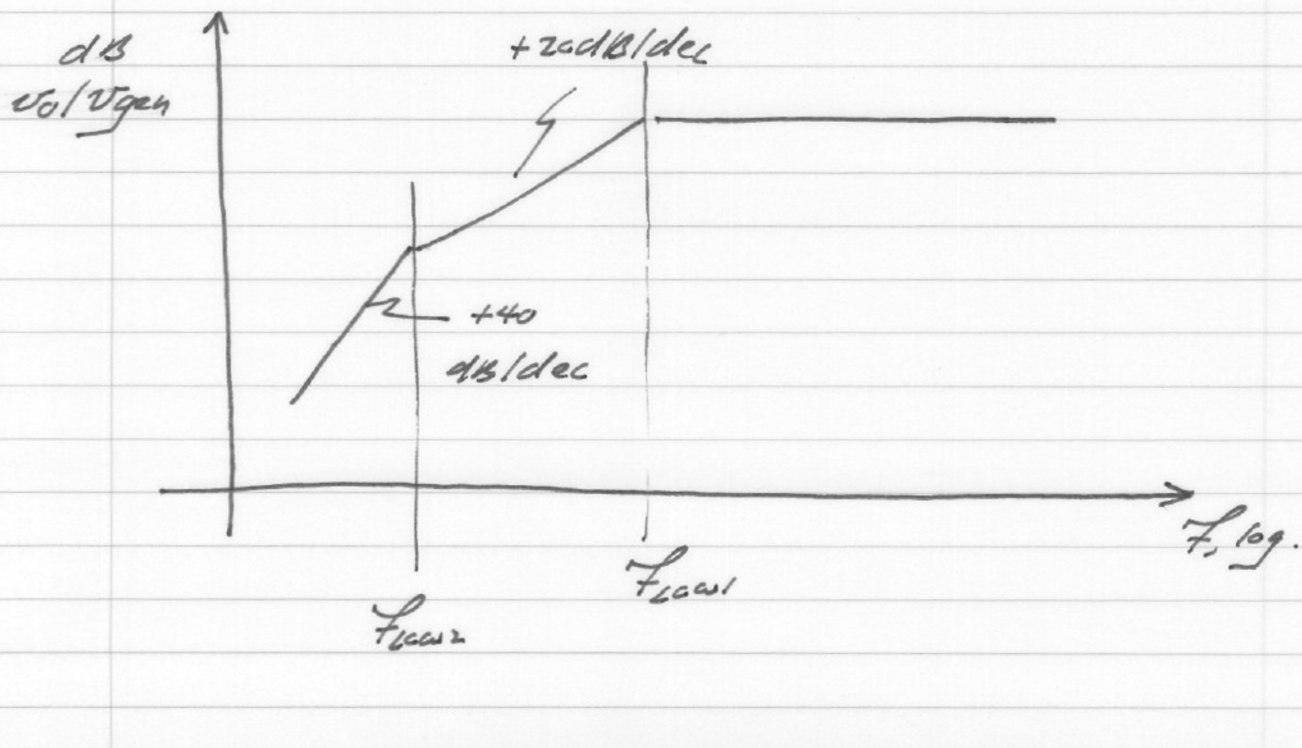
$$\frac{v_o}{v_i} = \left.\frac{v_o}{v_i}\right|_{MB} \frac{s\,\tau_{out}}{1 + s\,\tau_{out}} \quad ; \quad \tau_{out} = C_O(R_{outA} + R_L) = 90\ ms$$

$$\left. v_o/v_i \right|_{MB} = -g_m(R_{outA} \| R_L) = -8.9$$

$$\frac{v_o}{v_i} = \left.\frac{v_o}{v_i}\right|_{MB} \frac{jf/f_{LOW2}}{1 + jf/f_{LOW2}} \quad ; \quad f_{LOW2} = 1/2\pi\tau_{out} = 1.77\ Hz$$



overall low-frequency response



$$\frac{v_o}{v_{gen}} = \underbrace{\frac{v_o}{v_{gen}}\Big|_{MB}}_{\text{"Amb"}} \frac{s\tau_{in}}{1+s\tau_{in}} \frac{s\tau_{out}}{1+s\tau_{out}}$$

– this ignores the high frequency rolloff

Step Response of amplifier

$v_{gen}(s) = v_x / s$ e.g. $v_{gen}(t) = v_x \cdot u(t)$

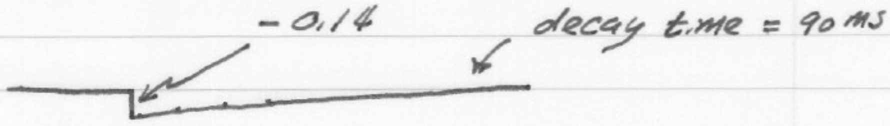
$$v_{out}(s) = \frac{\tau_o}{1+s\tau_o} \frac{\tau_i}{1+s\tau_i} \cdot s \cdot A_{MB} \cdot v_x$$

$$= A_{mb} v_x \left[\underbrace{\frac{\tau_{in}}{\tau_{in}-\tau_{out}}}_{-0.14} \cdot \frac{\tau_{out}}{1+s\tau_{out}} + \underbrace{\frac{\tau_{out}}{\tau_{out}-\tau_{in}}}_{1.14} \frac{\tau_{in}}{1+s\tau_{in}} \right]$$

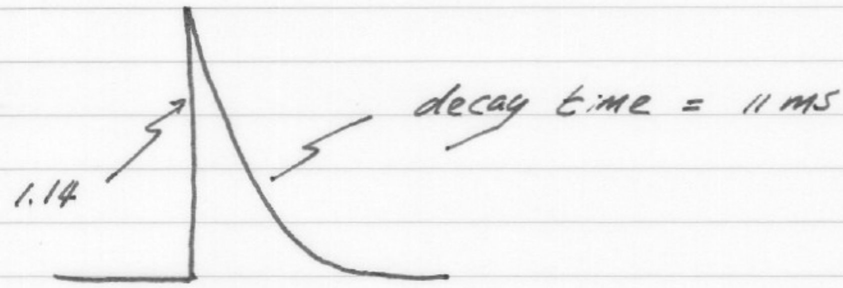
$$V_{out}(t) = A_{mb} v_x \left[\frac{\tau_{in}}{\tau_{in}-\tau_{out}} u(t) e^{-t/\tau_{out}} + \frac{\tau_{out}}{\tau_{out}-\tau_{in}} u(t) e^{-t/\tau_{in}} \right]$$

$\tau_{in} = 11\ ms$ $\tau_{out} = 90\ ms$

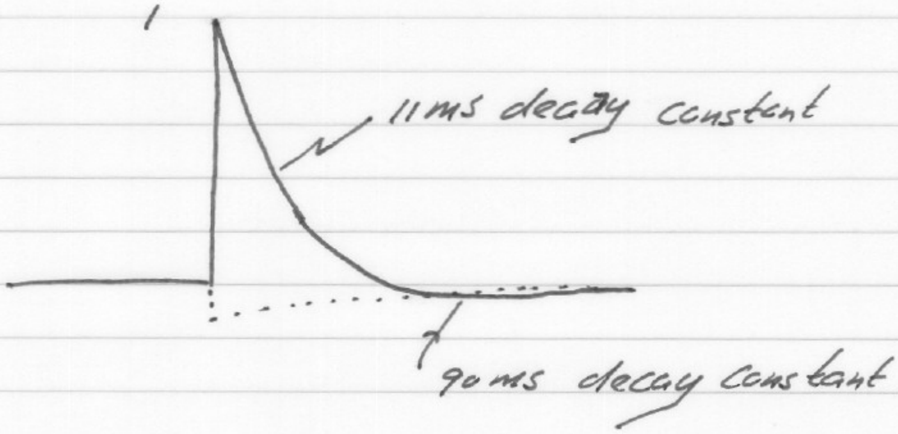
First term:



Second term



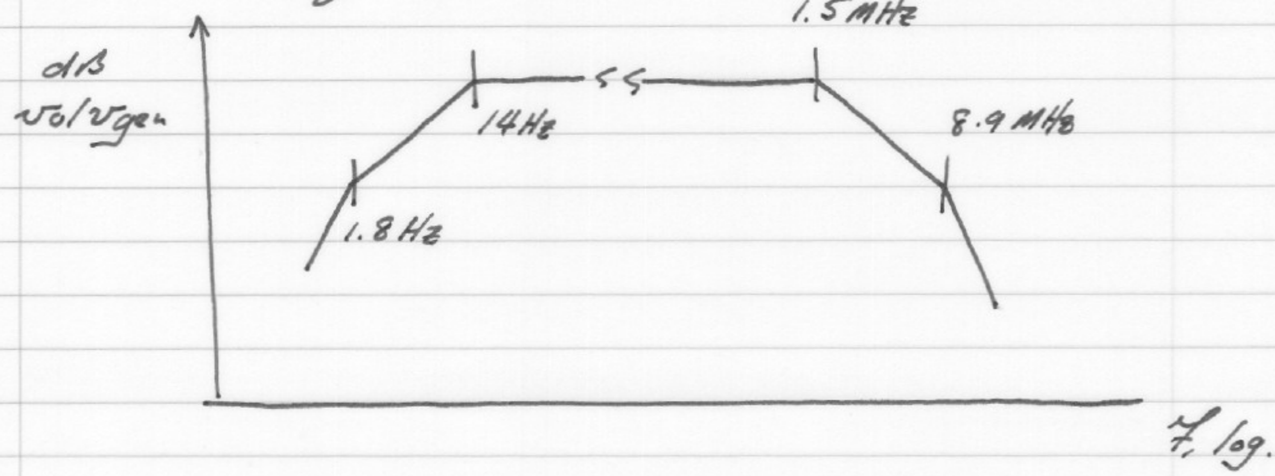
total response (normalized to $A_m b v_x$):



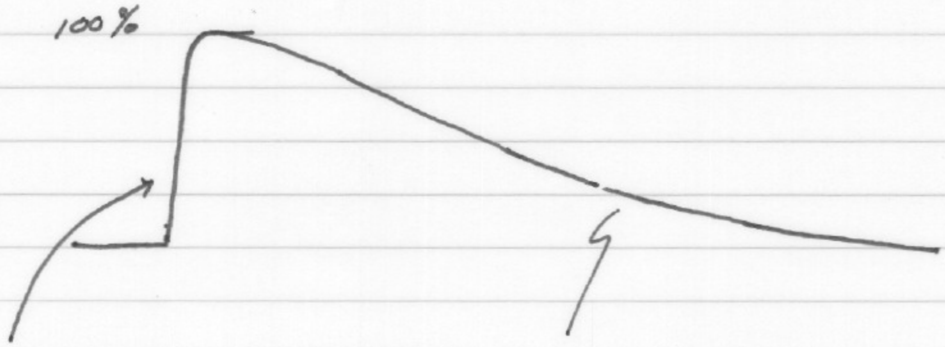
Again, the lower of the two low-frequency poles contributes only a small amount to the step response and decays away more slowly.

⇒ step response dominated by highest of high frequency poles.

overall frequency response



overall unit-step respons



initial rise of form

$\sim u(t)(1-e^{-t/\tau})$

$\tau = 103$ ns

$T_{10-90} = 226$ ns

slow decay of form

$\sim u(t)e^{-t/\tau}$

$\tau = 11$ ms