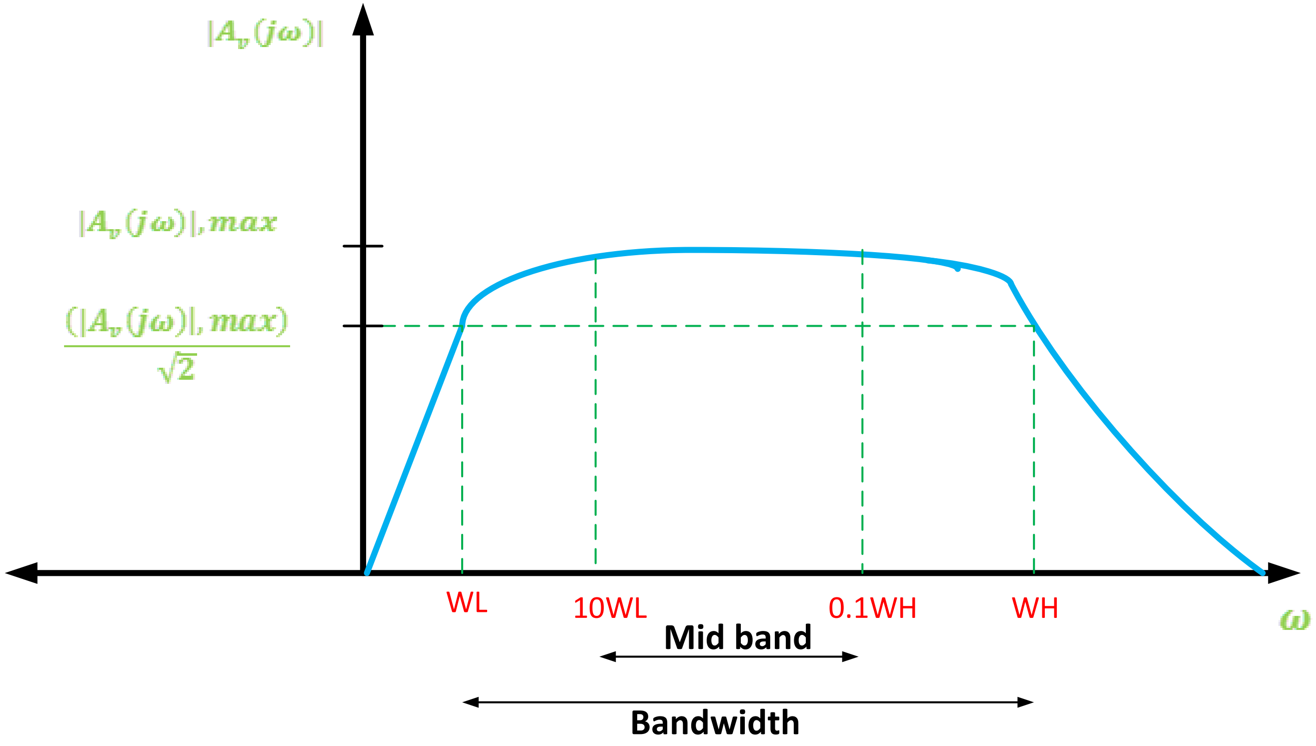
Frequency Response

Frequency Response



ω_L **Lower cut off frequency**

ω_H **Upper cut off frequency**

$$|A_v(j\omega)|_{\substack{\omega=\omega_L \\ \omega=\omega_H}} = \frac{|A_v(j\omega)|,_{max}}{\sqrt{2}} = \frac{|A_v|,_{mid}}{\sqrt{2}}$$

Bandwidth $= \omega_H - \omega_L$

Mid band range = $0.1\omega_H - 10\omega_L$

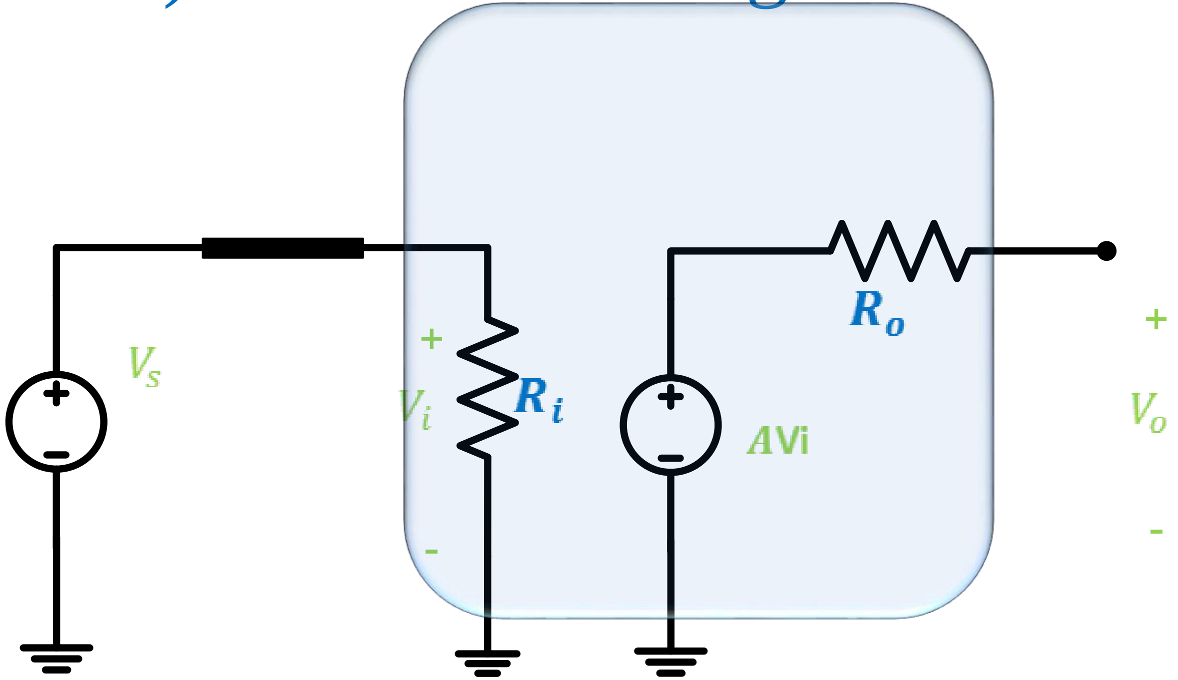
Frequency Response

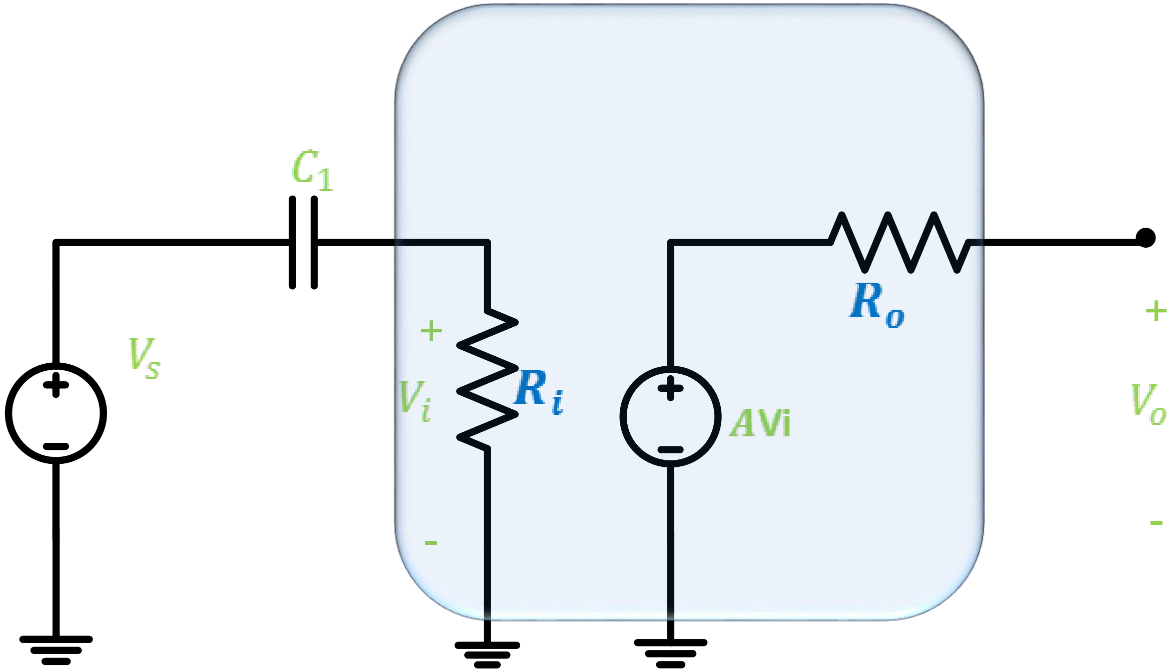
- **The signal passed through an AC amplifier is usually a complex waveform containing many different frequency components, rather than a single frequency sine wave.**
- **For example, audio- frequency signal such as speech and music are combination of many different sine waves accruing simultaneously with different amplitude and different frequencies in the range from $20H_z$ to $20kH_z$.**
- **In order for an output to be an amplified version of the input, an amplifier must amplify every frequency component in the signal by the same amount.**

- **Bandwidth must cover the entire range of frequency components if undistorted amplification is to be achieved.**

Series Capacitance and low-frequency Response

1) at mid band range





$$V_o = AV_i$$
$$V_i = V_s$$

$$\therefore \; \frac{V_o}{V_s} = A = A_{v(mid)}$$

Series Capacitance and low-frequency Response

2) At Low Frequency

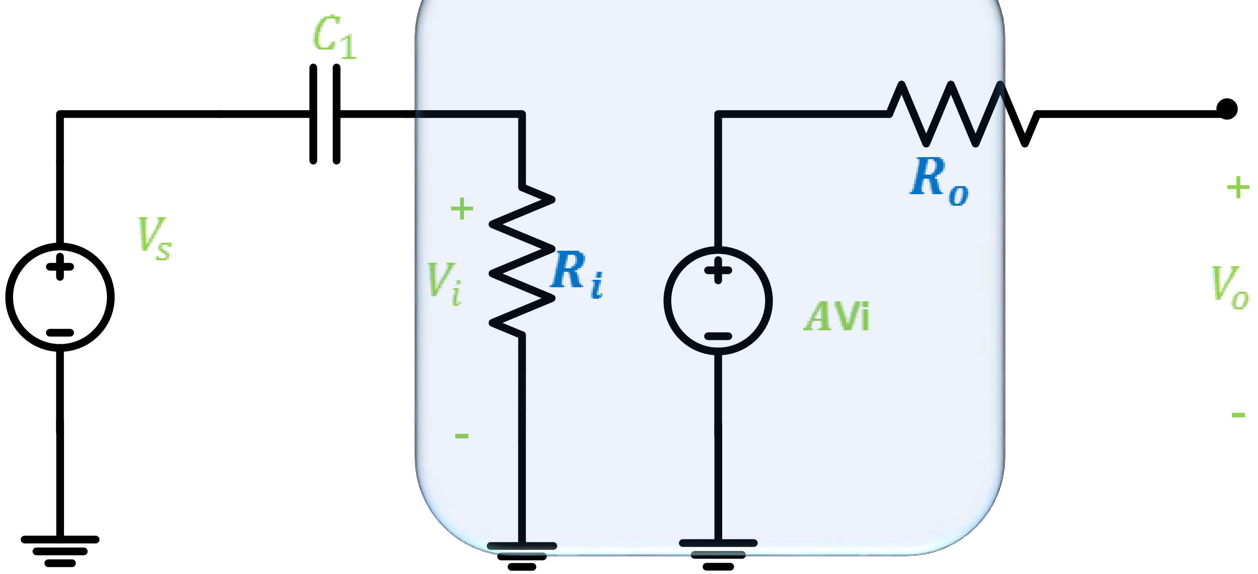
$$V_o = AV_i$$

$$V_i = \frac{R_i}{R_i + \frac{1}{jwc1}} V_s$$

$$\frac{V_o}{V_s} = A_v(j\omega) = A\frac{R_i}{R_i + \frac{1}{jwc1}}$$

$$A_v(j\omega) = A\frac{1}{1 + \frac{1}{jR_iwc1}}$$

$$|A_v(j\omega)| = A\frac{1}{\sqrt{1 + (\frac{1}{R_iwc1})^2}}$$



a) $If \ \ \omega \to 0 \, ; |A_v(j\omega)| \to 0$

b) $If \ \ \omega \to \infty \, ; |A_v(j\omega)| \to A$

c) $If \ \omega = \frac{1}{R_iC1} \, ; |A_v(j\omega)| \to \frac{A}{\sqrt{2}}$

Series Capacitance and low-frequency Response

$$\therefore\ \omega_L = \frac{1}{R_i C_1}$$

Let $\omega_{c1} = \frac{1}{R_{TH} C_1}$

Where ω_{c1} is the corner frequency of c_1

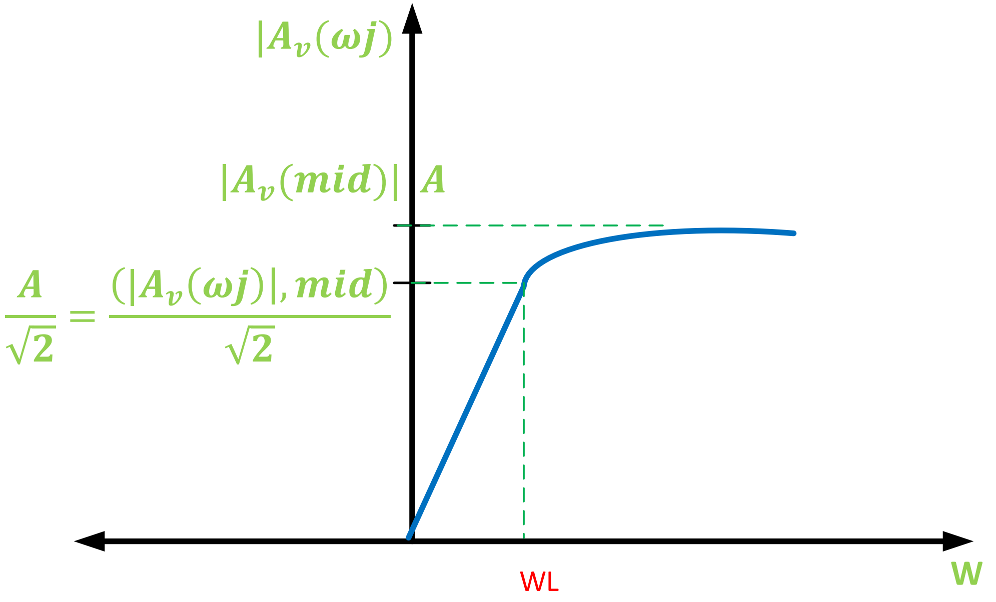
$$\omega_{c1} = \frac{1}{R_i C_1}$$

$$\therefore\ \omega_L = \omega_{C1}$$

a) $If\ \ \omega \to 0\,;|A_v(j\omega)| \to 0$

b) $If\ \ \omega \to \infty\,;|A_v(j\omega)| \to A$

c) $If\ \omega = \frac{1}{R_i C1}\ ;|A_v(j\omega)| \to \frac{A}{\sqrt{2}}$



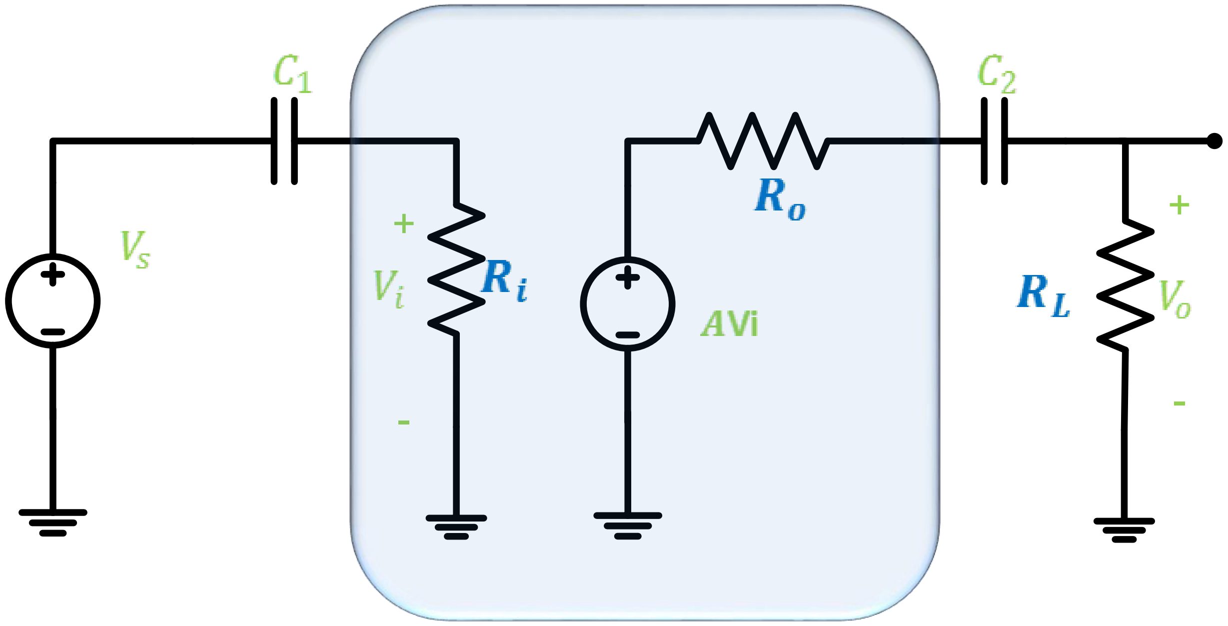
Input and output coupling capacitors

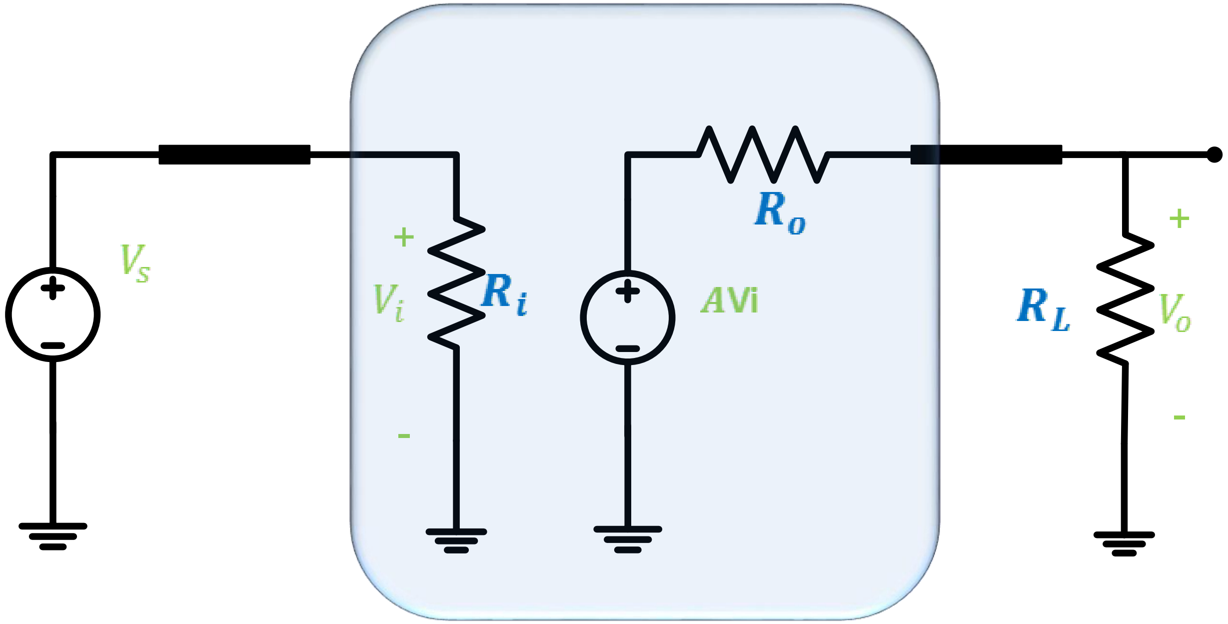
1. At mid band range

$$V_o = \frac{R_L}{R_L + R_o} A\, V_i$$

$$V_i = V_s$$

$$A_{v(mid)} = \frac{V_o}{V_s} = A \frac{R_L}{R_L + R_o}$$





Input and output coupling capacitors

2. At low frequency:

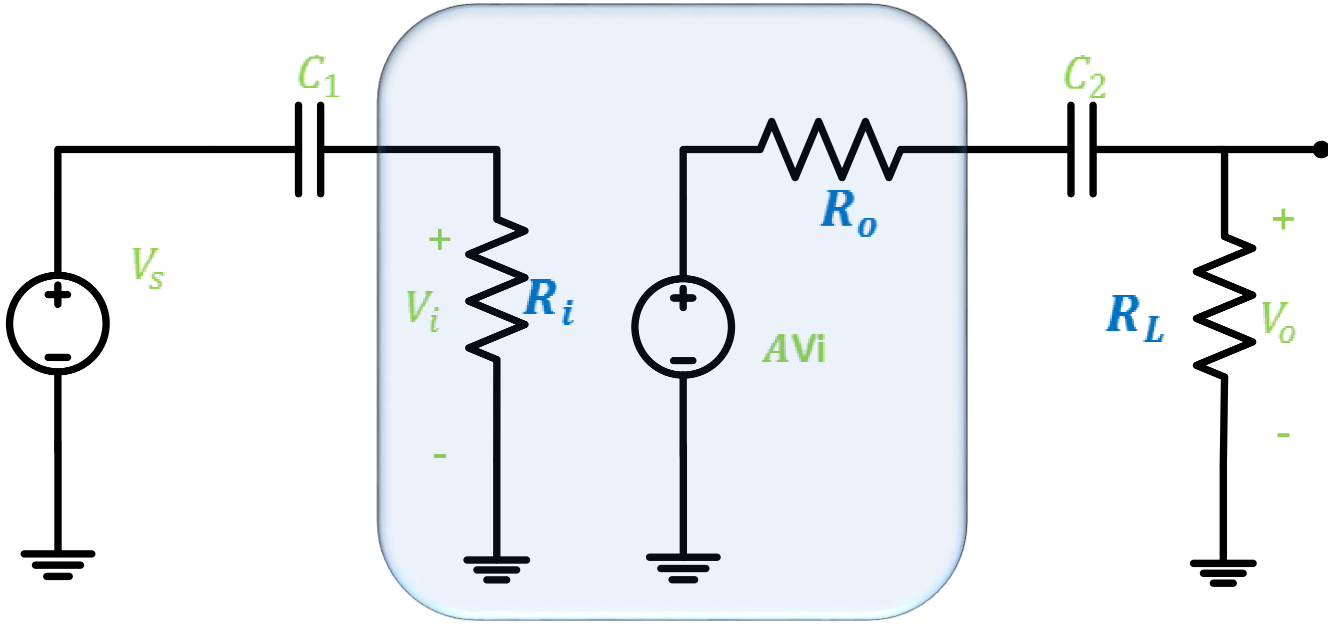
$$V_o = \frac{R_L}{R_L + R_o + \frac{1}{j\omega c_2}} A\,V_i$$

$$V_i = \frac{R_i}{R_i + \frac{1}{j\omega c_1}} V_S$$

$$A_{v(j\omega)} = \frac{V_o}{V_S} = A\frac{R_L}{R_L + R_o}\left(\frac{1}{1+\frac{\omega_{c1}}{j\omega}}\right)\left(\frac{1}{1+\frac{\omega_{c2}}{j\omega}}\right)$$

$$\therefore A_{v(j\omega)} = A_{v(mid)}\left(\frac{1}{1+\frac{\omega_{c1}}{j\omega}}\right)\left(\frac{1}{1+\frac{\omega_{c2}}{j\omega}}\right)$$

$$|A_v(j\omega_L)| = \frac{A_{v(mid)}}{\sqrt{2}}$$



Where

$$\omega_{c1} = \frac{1}{R_i c_1}$$

$$\omega_{c2} = \frac{1}{(R_o + R_L)C_2}$$

Input and output coupling capacitors

$$|A_v(j\omega_L)| = \frac{A_{v(mid)}}{\left|\left(1+\frac{\omega_{c1}}{j\omega_L}\right)\left(1+\frac{\omega_{c2}}{j\omega_L}\right)\right|}$$

$$\therefore \left|\left(1+\frac{\omega_{c1}}{j\omega_L}\right)\left(1+\frac{\omega_{c2}}{j\omega_L}\right)\right| = \sqrt{2}$$

$$\therefore \omega_L^2 = \frac{\omega_{c1}^2+\omega_{c2}^2}{2} + \frac{\sqrt{(\omega_{c1}^4+\omega_{c2}^4+6\omega_{c1}^2\omega_{c2}^2)}}{2}$$

$$\therefore A_{v(j\omega)} = A_{v(mid)}\left(\frac{1}{1+\frac{\omega c_1}{j\omega}}\right)\left(\frac{1}{1+\frac{\omega c_2}{j\omega}}\right)$$

$$|A_v(j\omega_L)| = \frac{A_{v(mid)}}{\sqrt{2}}$$

- **A) Let** $\omega_{c1} = 616\ r/s$

  $\omega_{c2} = 17.86\ r/s$

  $\therefore \omega_L = 616.517\ r/s$

- **B) Let** $\omega_{c1} = 200\ r/s$

  $\omega_{c2} = 750\ r/s$

  $\therefore \omega_L = 798\ r/s$

  $\therefore if\ \ \omega_{c1} > \omega_{c2} > \omega_{c3}$

  $\therefore \omega_{c1} + \omega_{c2} + \omega_{c3} > \omega_L > \omega_{c1}$

$$A_{v(j\omega)} = A_{v(mid)} \frac{1}{(1+\frac{\omega_{c1}}{j\omega})(1+\frac{\omega_{c2}}{j\omega})}$$

Let $\omega_{c1} > \omega_{c2}$; $\omega_L > \omega_{c1}$

$$|A_v(j\omega_L)| = \frac{A_{v(mid)}}{\left|(1+\frac{\omega_{c1}}{j\omega_L})(1+\frac{\omega_{c2}}{j\omega_L})\right|}$$

$$|A_v(j\omega_L)| = \frac{A_{v(mid)}}{\sqrt{2}}$$

$$\therefore \left|(1+\frac{\omega_{c1}}{j\omega_L})(1+\frac{\omega_{c2}}{j\omega_L})\right| = \sqrt{2}$$

Since $\omega_{c1} > \omega_{c2}$ and $\omega_L > \omega_{c1}$

$$\therefore \quad \frac{\omega_{c1}}{\omega_L} < 1 \quad and \quad \frac{\omega_{c2}}{\omega_L} \ll 1$$

$$\therefore \left|(1+\frac{\omega_{c1}}{j\omega_L})(1+\frac{\omega_{c2}}{j\omega_L})\right| \approx \left|(1+\frac{\omega_{c1}}{j\omega_L})\right|$$

$$\therefore \left|(1+\frac{\omega_{c1}}{j\omega_L})\right| \approx \sqrt{2}$$

$$\sqrt{1+(\frac{\omega_{c1}}{\omega_L})^2} = \sqrt{2}$$

$\therefore \omega_{c1} = \omega_L$ (Lower limit)

To find the upper limit

$$\left|(1+\frac{\omega_{c1}}{j\omega_L})(1+\frac{\omega_{c2}}{j\omega_L})\right| = \sqrt{2}$$

$$\left|1+\frac{\omega_{c1}+\omega_{c2}}{j\omega_L}-\frac{\omega_{c1}}{\omega_L}.\frac{\omega_{c2}}{\omega_L}\right| = \sqrt{2}$$

But $\frac{\omega_{c1}}{\omega_L} < 1\ and \quad \frac{\omega_{c2}}{\omega_L} \ll 1$

$$\therefore \frac{\omega_{c1}}{\omega_L}.\frac{\omega_{c2}}{\omega_L} \lll 1$$

$$\therefore \text{let } \frac{\omega_{c1}}{\omega_L}.\frac{\omega_{c2}}{\omega_L} \to 0$$

$$\left|1+\frac{\omega_{c1}+\omega_{c2}}{j\omega_L}-\frac{\omega_{c1}}{\omega_L}.\frac{\omega_{c2}}{\omega_L}\right| \cong \sqrt{(1+\left(\frac{\omega_{c1}+\omega_{c2}}{\omega_L}\right)^2}$$

$$\sqrt{(1+\left(\frac{\omega_{c1}+\omega_{c2}}{\omega_L}\right)^2} = \sqrt{2}$$

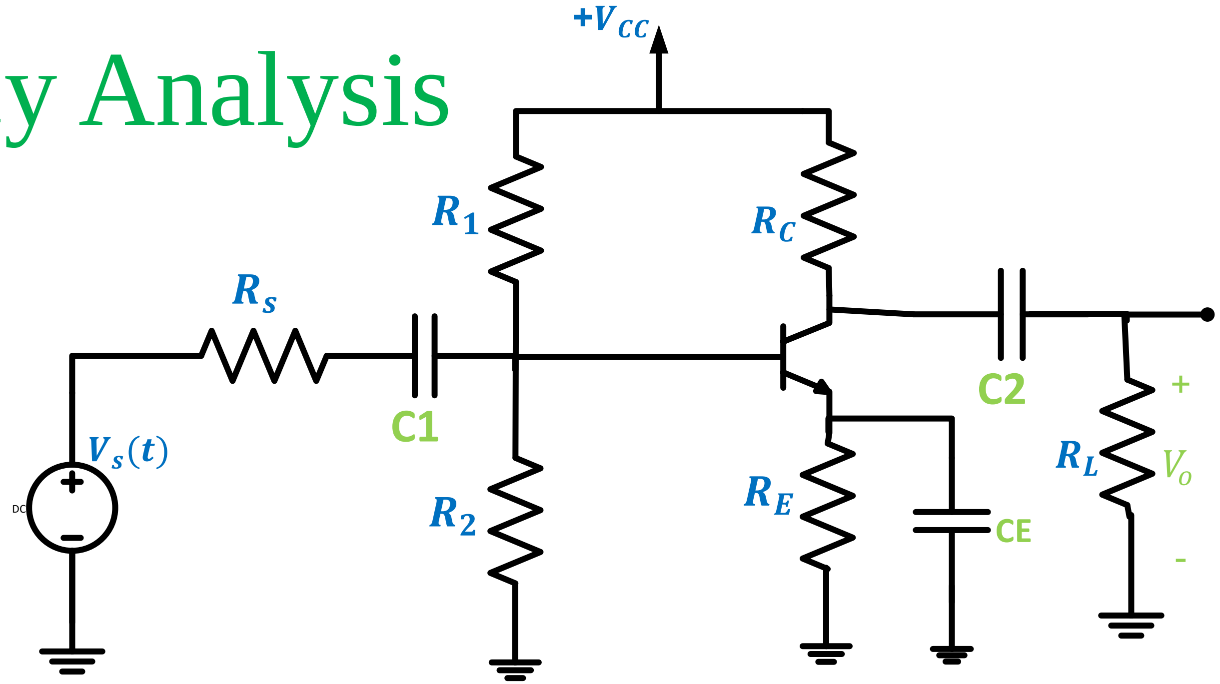
$$\therefore \frac{\omega_{c1}+\omega_{c2}}{\omega_L} = 1$$

$\therefore \omega_L = \omega_{c1}+\omega_{c2}$ Upper limit

$$\therefore \text{if } \omega_{c1} > \omega_{c2}$$

$$\omega_{c1}+\omega_{c2} > \omega_L > \omega_{c1}$$

CE Amplifier low-frequency Analysis



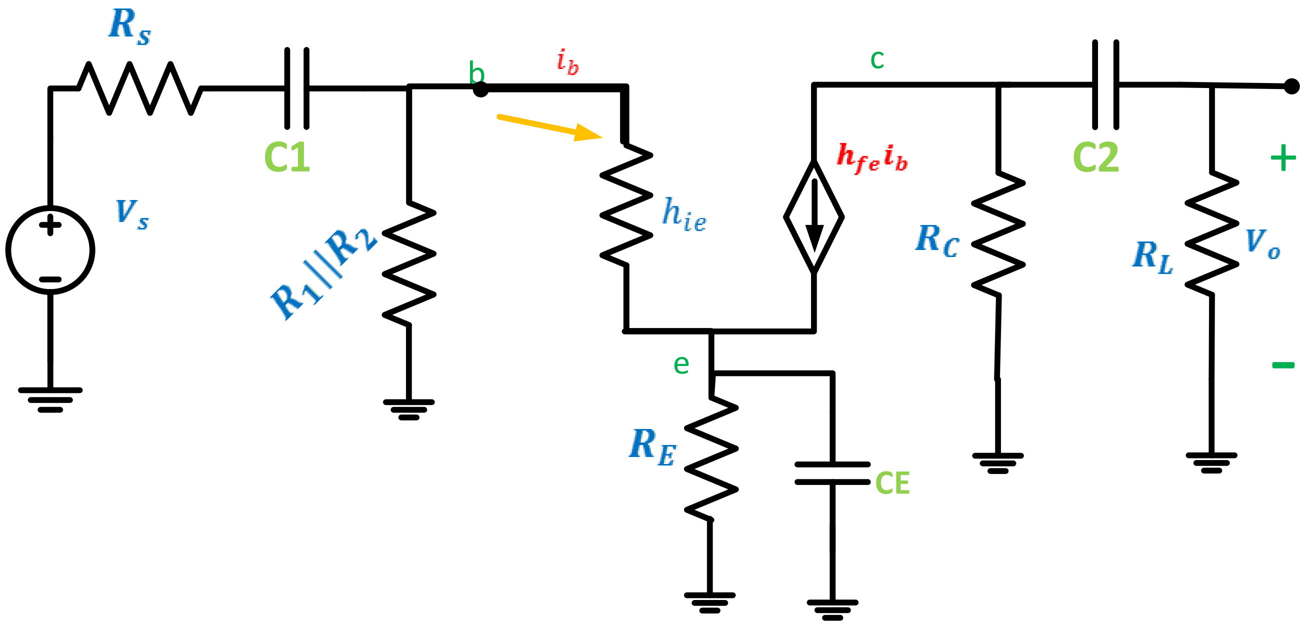
$h_{ie} = 10.45k$, $h_{fe} = 350$, $R_1 || R_2 = 16.67k$

$R_c = 5k$, $R_L = 2k$, $R_E = 5k$, $R_s = 1k$

$C_1 = 3\mu F$, $C_2 = 8\mu F$, and $C_E = 50\mu F$

Estimate ω_L

Ac small signal low- frequency equivalent C_{KT}



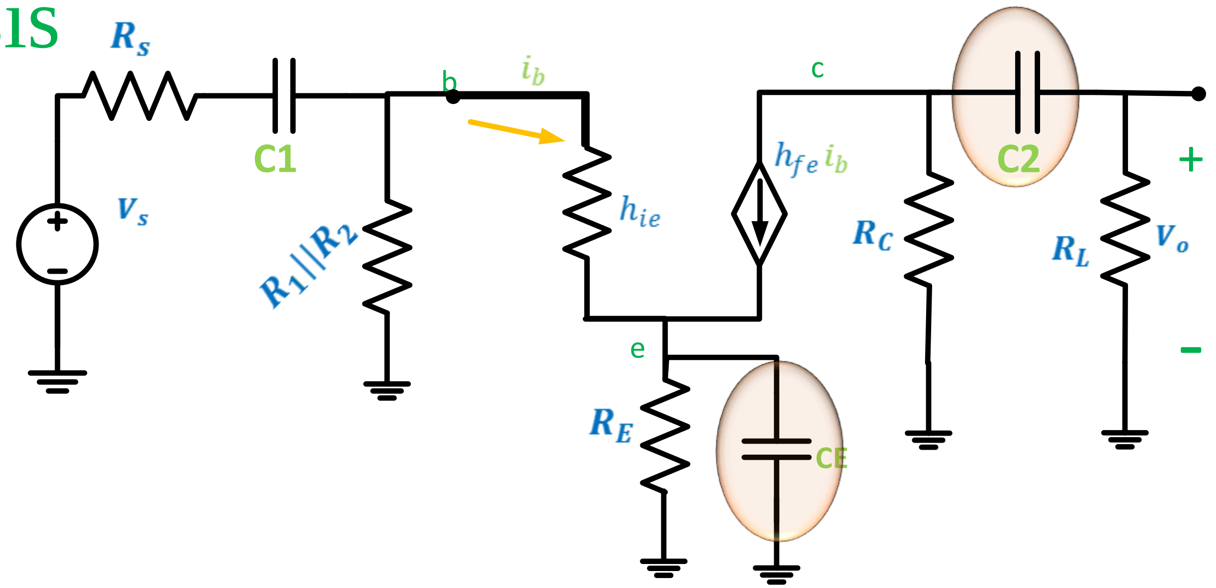
CE Amplifier low-frequency Analysis

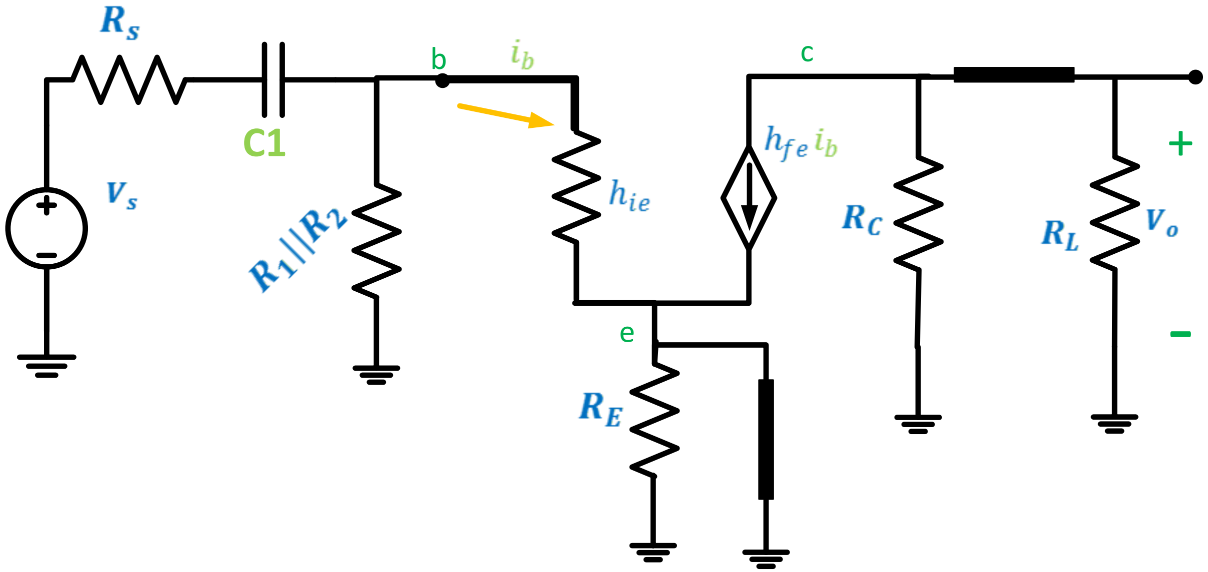
1) To find ω_{c1} , set C_E and C_2 short

$$\omega_{c1} = \frac{1}{R_{TH_1} C_1}$$

$$R_{TH_1} = R_s + R_1 \| R_2 \| h_{ie}$$

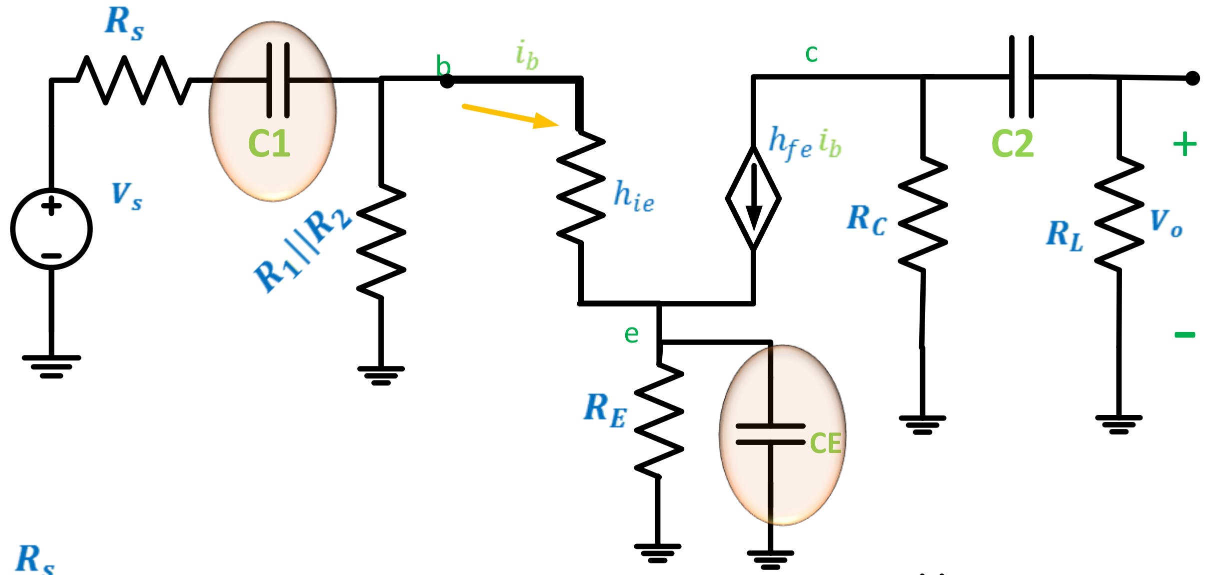
$$\therefore \omega_{c1} = 44.9\, r/s$$





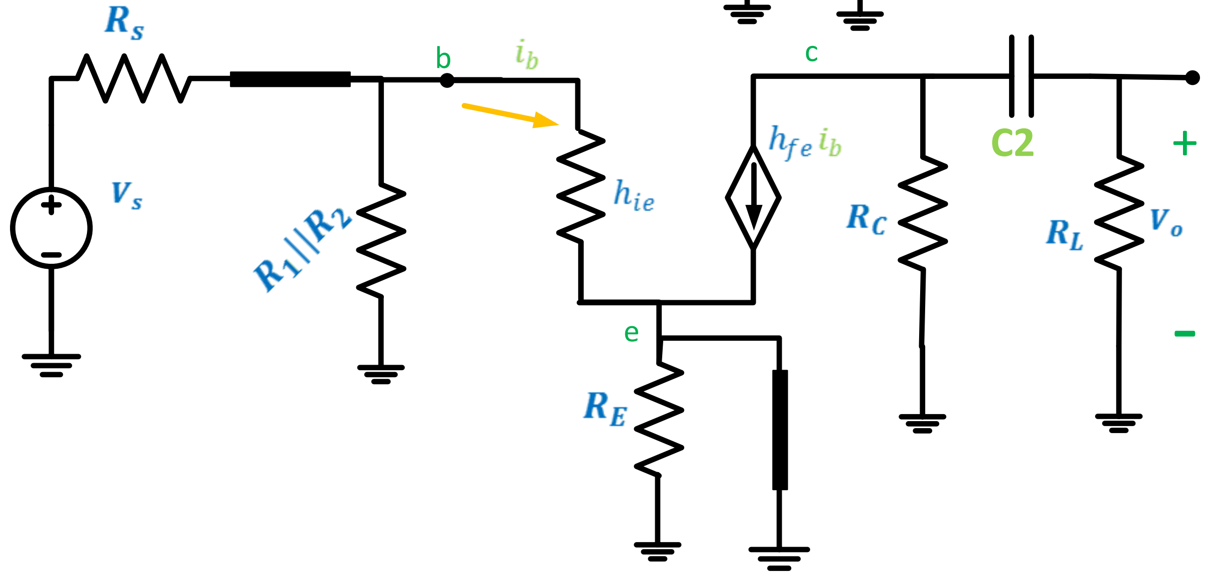
CE Amplifier low-frequency Analysis

- 2) To find ω_{c2}, set C_1 and C_E short



$$\omega_{c2} = \frac{1}{R_{TH_2} C_2}$$

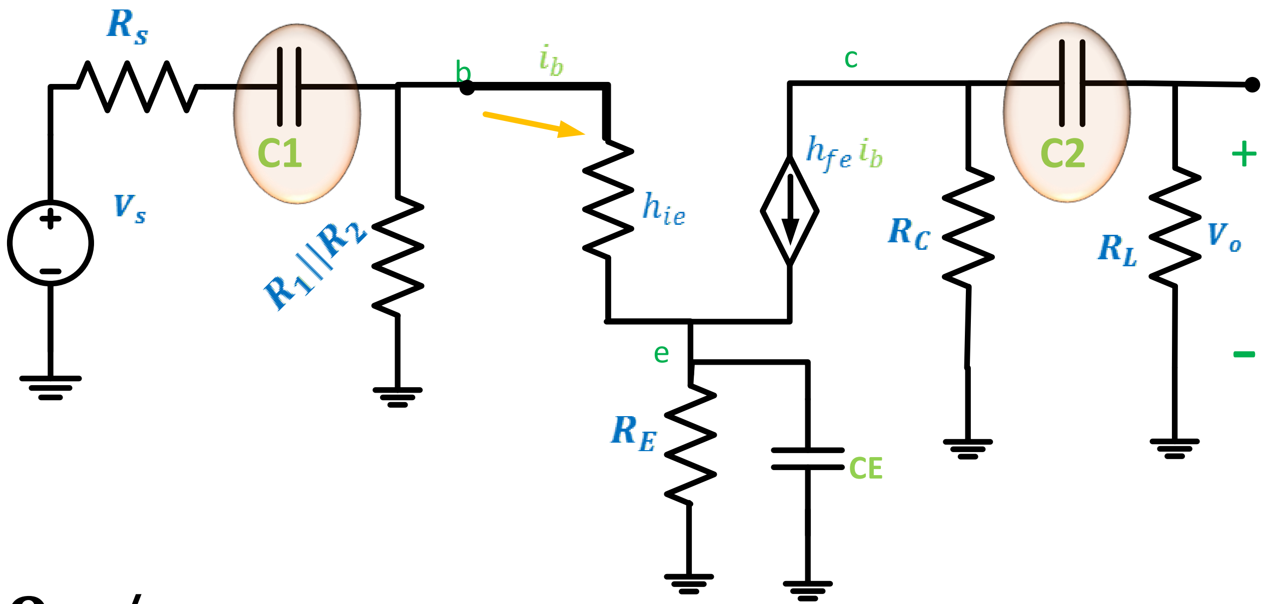
$$R_{TH_2} = R_L + R_c$$



$$\omega_{c2} = 17.86\ r/s$$

CE Amplifier low-frequency Analysis

3) To find ω_{CE}, set C_1 and C_2 short

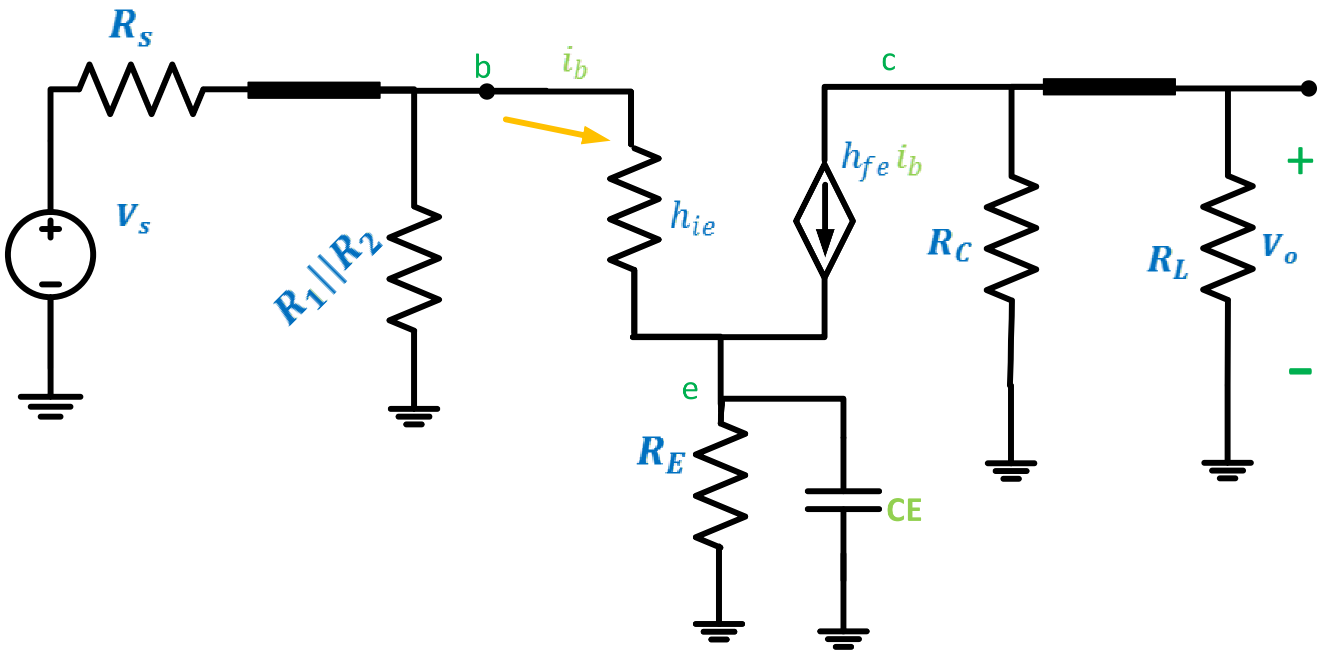


$$\omega_{CE} = \frac{1}{R_{TH_3} C_E}$$

$$R_{TH_3} = R_E \parallel \left(\frac{R_s \parallel R_1 \parallel R_2 + h_{ie}}{h_{fe}+1}\right)$$

$\therefore \omega_{CE} = 616\ r/s$

But $\omega_{c2} = 17.86\ r/s$ and $\omega_{c1} = 44.9\ r/s$



$$\omega_{C1} + \omega_{C2} + \omega_{CE} > \omega_L > \omega_{CE}$$

$$679\ r/s > \omega_L > 616\ r/s$$

$\omega_L \equiv 645\ r/s$ exact

CE Amplifier low-frequency Design

Complete the design so that $W_L = 1000\ r/s$

$$\omega_{C1} + \omega_{C2} + \omega_{CE} = \omega_l = 1000 r/s$$

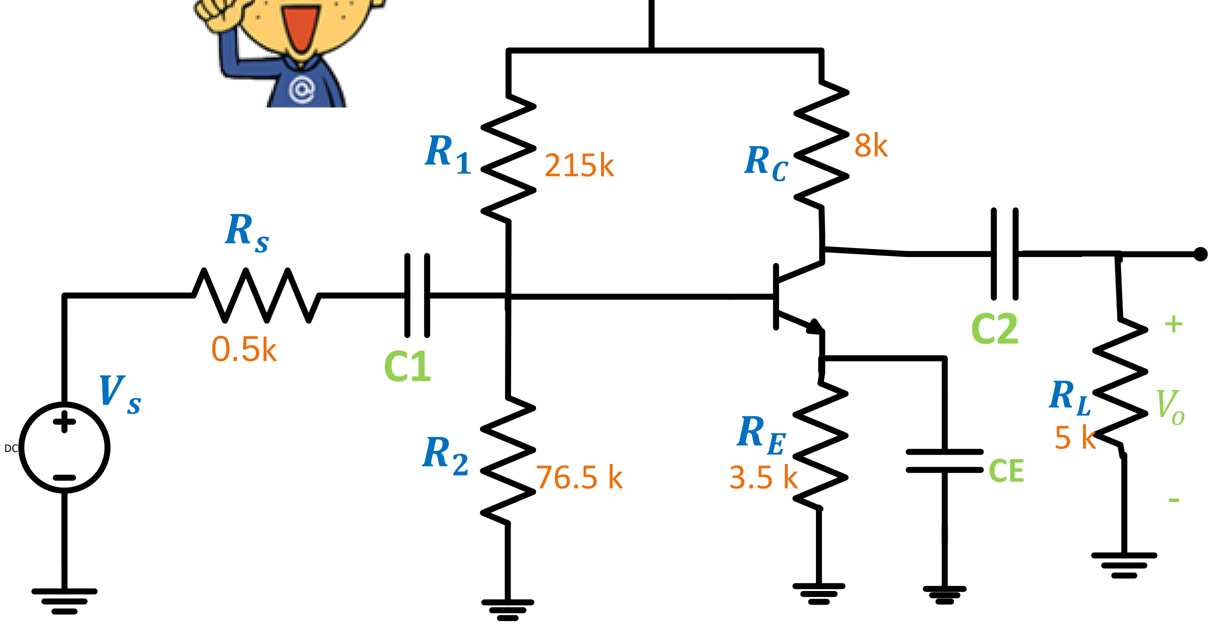
$$\omega_{CE} \geq 70\%\ \omega_L$$

$$\omega_{CE} \geq 0.7\ \omega_L$$

$$\omega_{CE} = 850\ r/s$$

$$\omega_{C2} = 50\ r/s$$

$$\omega_{C1} = 100 r/s$$



$h_{ie} = 5.78k\ ,\ h_{fe} = 350$

CE Amplifier low-frequency Design

$\omega_{CE} = 850\, r/s$

$\omega_{C2} = 50\, r/s$

$\omega_{C1} = 100 r/s$

$$\omega_{CE} = \frac{1}{\left[R_E II \left\{\frac{R_s II R_1 II R_2 + h_{ie}}{1 + h_{fe}}\right\}\right] C_E} = 850\, r/s$$

$\therefore C_E = 65.9 \mu F$

$$\omega_{c1} = \frac{1}{[R_s + R_1 II R_2 II h_{ie}] C_1} = 100\, r/s$$

$\therefore C_1 = 1.74\, \mu F$

Choose $C_E = 80\, \mu F$

$C_1 = C_2 = 2\, \mu F$

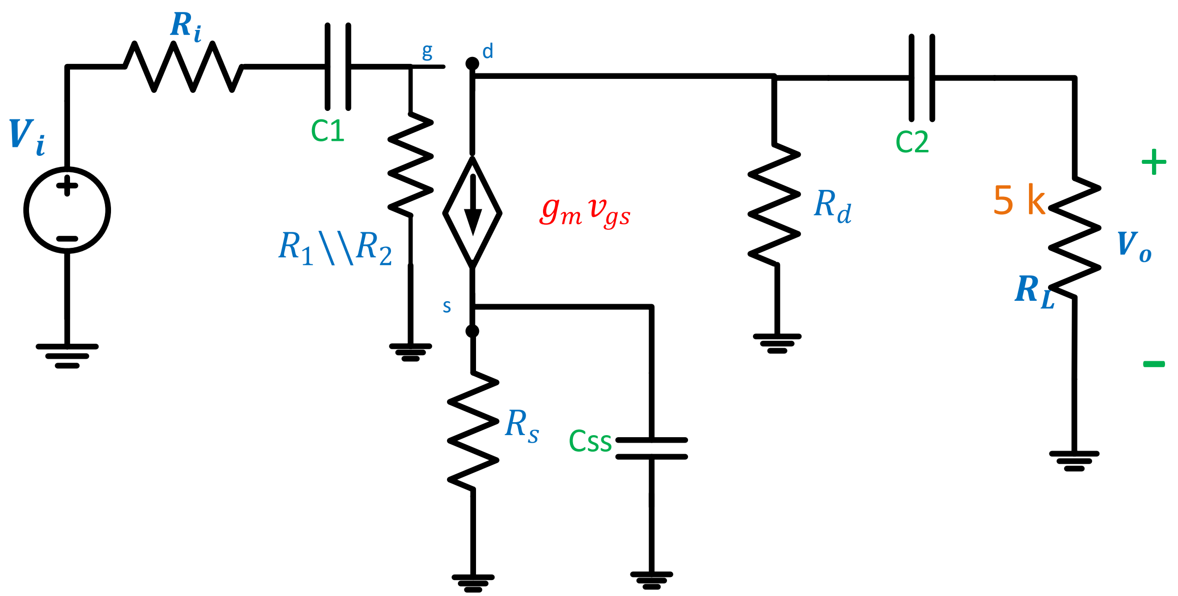
$$\omega_{c2} = \frac{1}{[R_C + R_L] C_2} = 50\, r/s$$

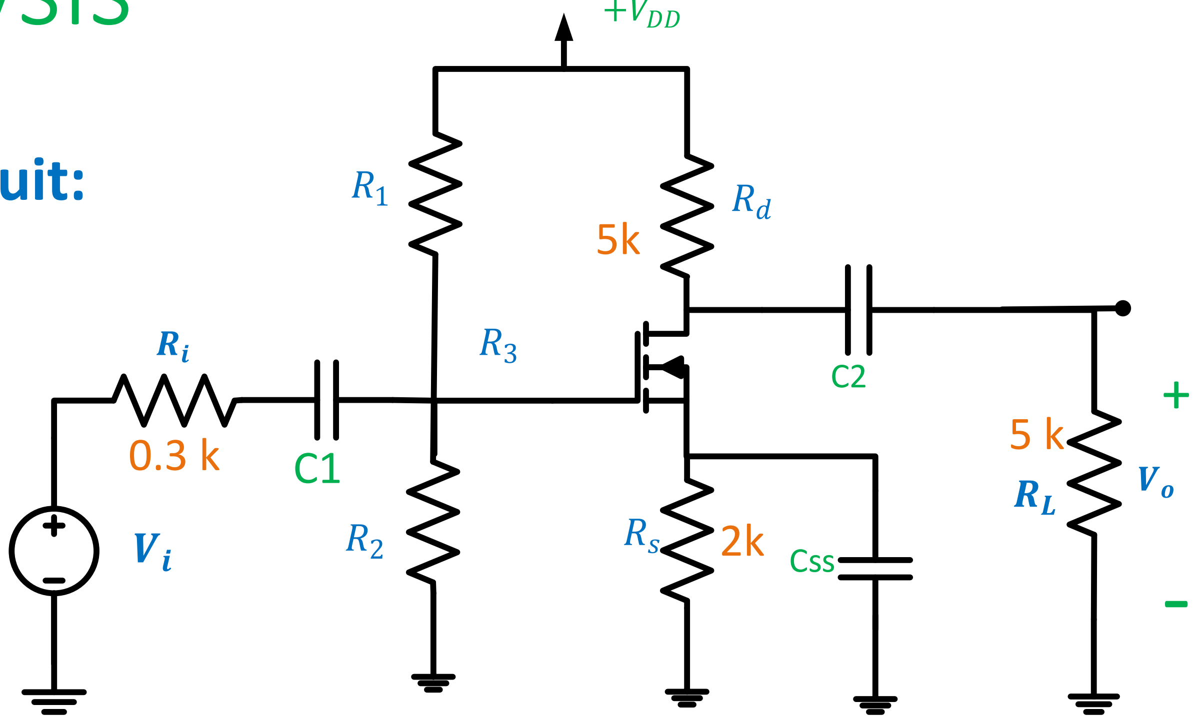
$\therefore C_2 = 1.54\, \mu F$

$\therefore \omega_L = 982\, r/s$

CS Low- Frequency Analysis

Ac small signal low-frequency equivalent circuit:





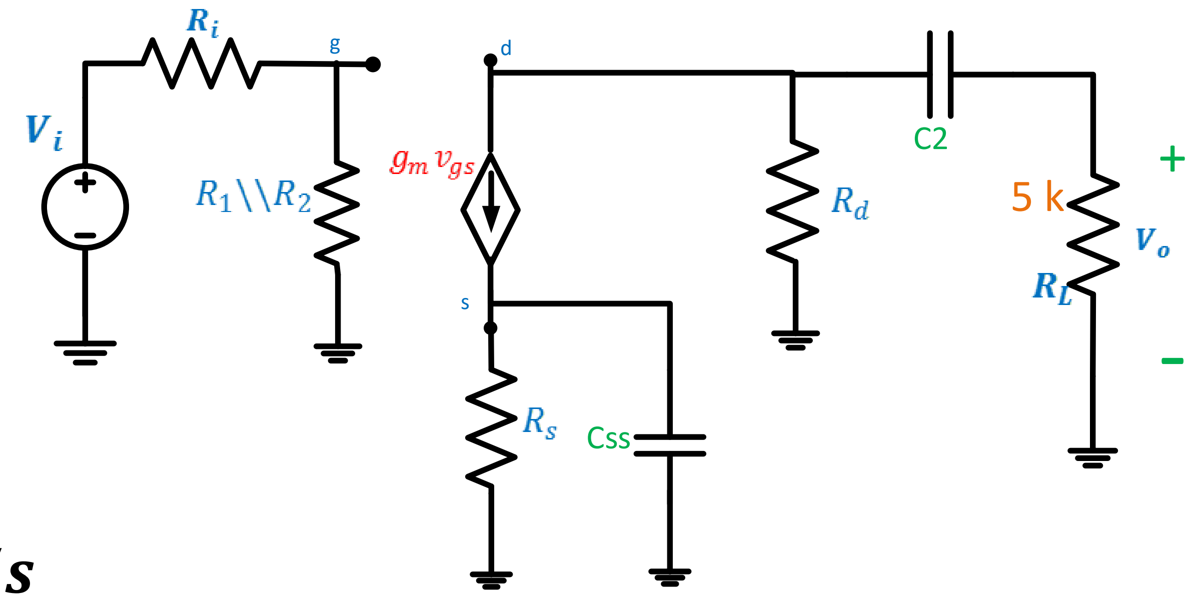
$$R_1 II R_2 = 100k \, , g_m = 10 \, m℧$$

$$C_1 = 0.2 \, \mu F \, , C_2 = 1 \, \mu F \, , C_{ss} = 10 \, \mu F$$

$$\omega_{c1} = \frac{1}{C_1[R_i + R_1 II R_2]} = 49.9 \, r/s$$

$$\omega_{c2} = \frac{1}{C_2[R_L + R_d]} = 100 \, r/s$$

$$\omega_{css} = \frac{1}{C_{ss}\left[R_s II \frac{1}{g_m}\right]} = 1050\ r/s$$



$$\omega_{c1} + \omega_{c2} + \omega_{css} > \omega_L > \omega_{css}$$

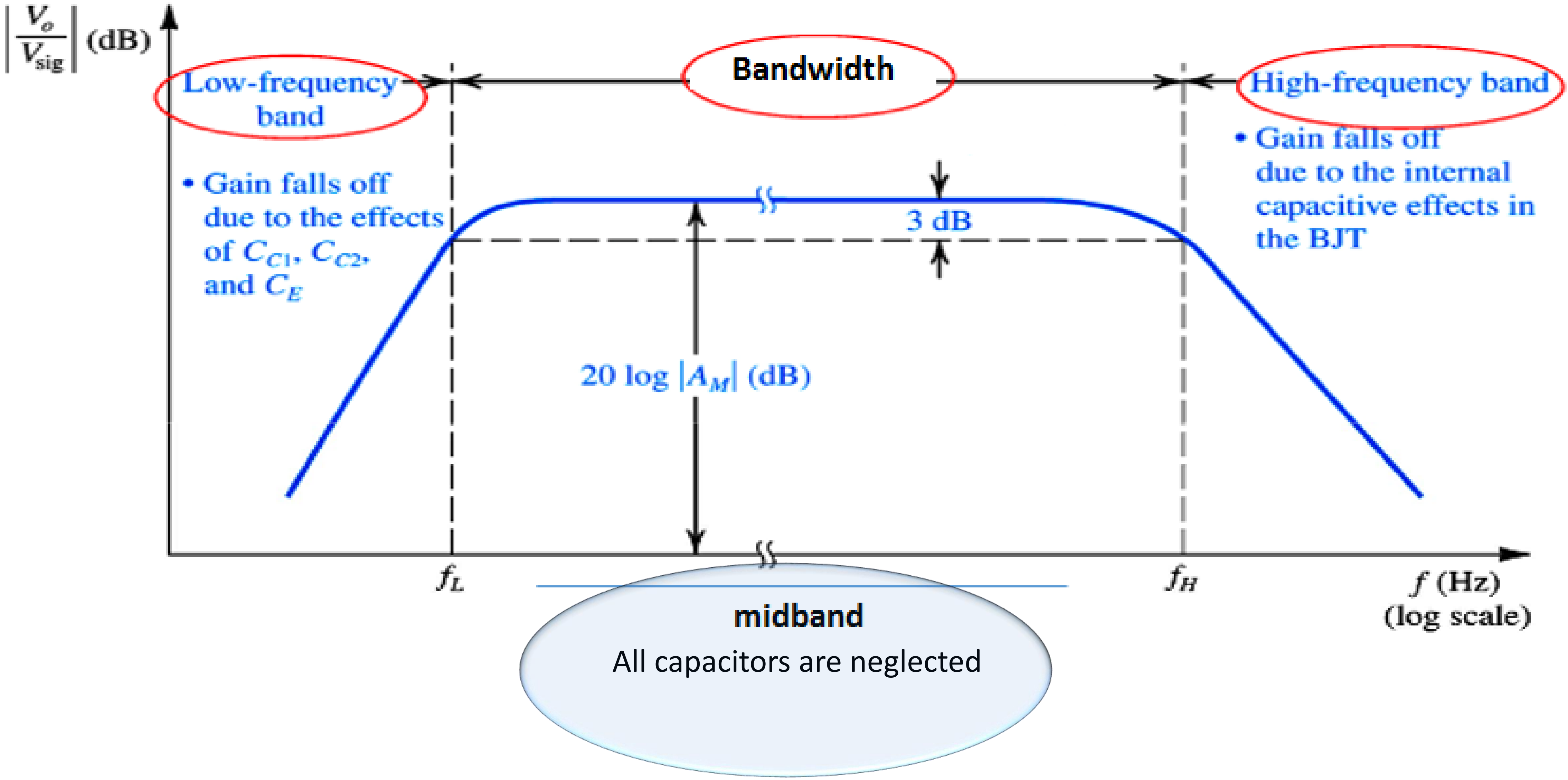
$$1199.9\ r/s > W_L > 1050\ r/s$$

$$\omega_L \equiv 1059.4\ r/s$$

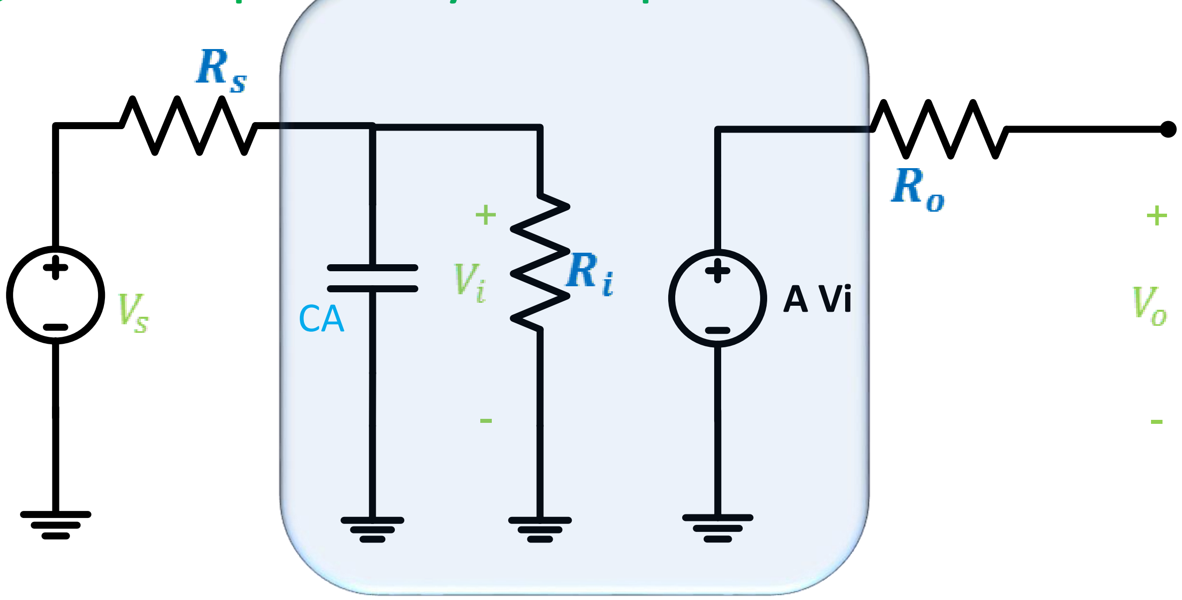
$$\omega_{c1} = \frac{1}{C_1[R_i + R_1 II R_2]} = 49.9\ r/s$$

$$\omega_{c2} = \frac{1}{C_2[R_L + R_d]} = 100\ r/s$$

The Amplifier Frequency Response



Shunt Capacitance and the high-frequency Response

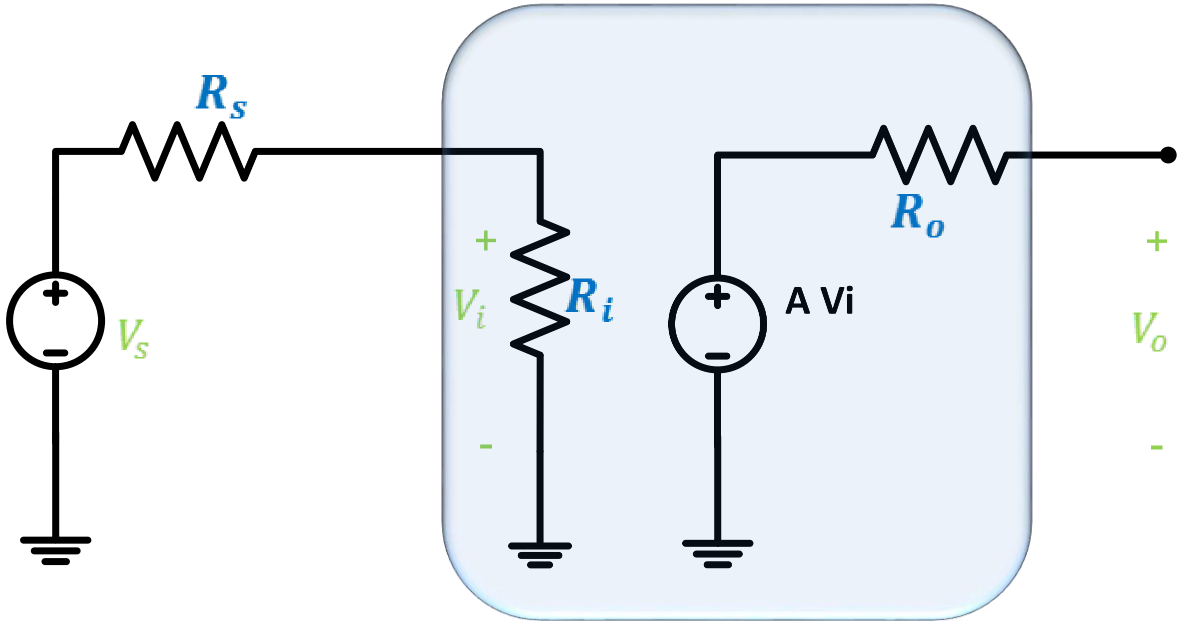


1) At mid band

$$V_o = AV_i$$

$$V_i = \frac{R_i}{R_i + R_s} V_s$$

$$\therefore A_{v(mid)} = \frac{V_o}{V_s} = A \frac{R_i}{R_i + R_s}$$



2) At high- frequency

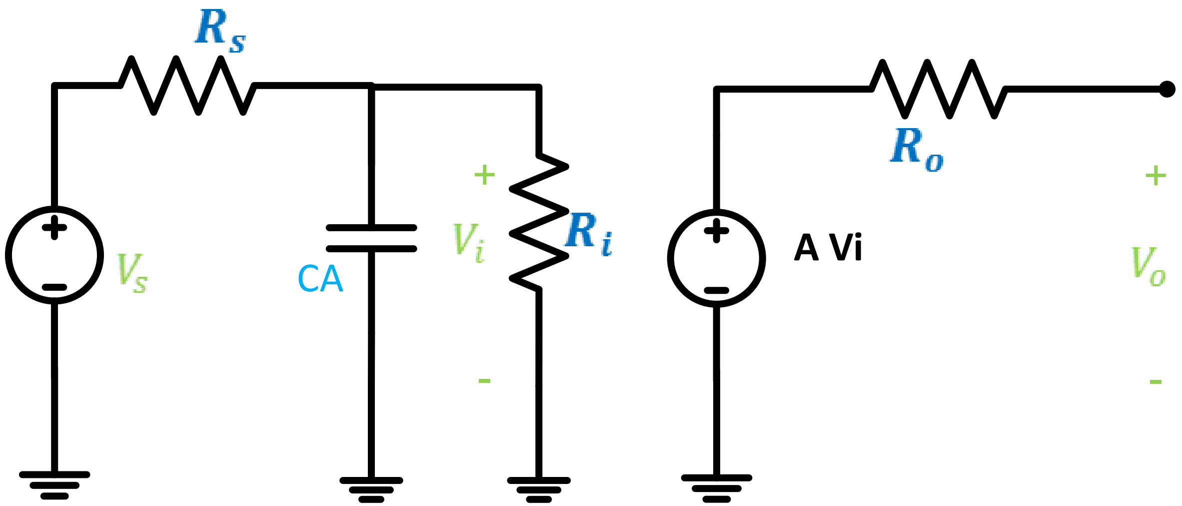
$$V_o = AV_i$$

$$V_i = \frac{R_i || \frac{1}{j\omega c_A}}{R_i || \frac{1}{j\omega c_A} + R_s} V_s$$

$$\therefore A_{v(j\omega)} = \frac{V_o}{V_s}$$

$$\therefore A_{v(j\omega)} = A \frac{R_i}{R_i + R_s} \frac{1}{1 + j\omega c_A (R_s || R_i)}$$

$$\therefore A_{v(j\omega)} = A_{v(mid)} \frac{1}{1 + j\omega c_A (R_s || R_i)}$$



$$\left|A_{v(j\omega)}\right| = A_{v(mid)} \frac{1}{\sqrt{1 + [\omega C_A (R_s || R_i)]^2}}$$

A) for small ω ; $\left|A_{v(j\omega)}\right| = A_{v(mid)}$

B) for large ω ; $\left|A_{v(j\omega)}\right| = 0$

C) for $\omega = \frac{1}{c_A (R_s II R_i)}$; $\left|A_{v(j\omega)}\right| = \frac{A_{v(mid)}}{\sqrt{2}}$

$$\therefore \omega_H = \frac{1}{c_A(R_s||R_i)}$$

But $$\omega_{CA} = \frac{1}{C_A R_{TH}}$$

$$\omega_{CA} = \frac{1}{c_A(R_s||R_i)}$$

$$\therefore \omega_H = \omega_{CA}$$

ω_H : The upper cut off frequency of the C_{KT}

ω_{CA}: The corner frequency of C_A

A) for small ω ; $\left|A_{v(j\omega)}\right| = A_{v(mid)}$

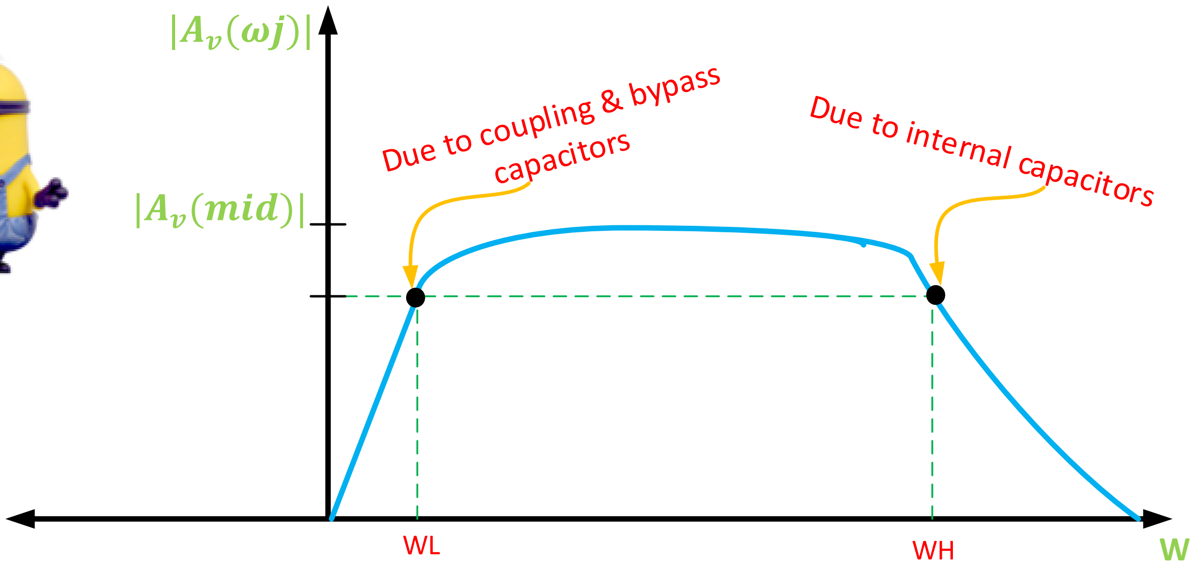
B) for large ω ; $\left|A_{v(j\omega)}\right| = 0$

C) forω $= \frac{1}{c_A(R_s II R_i)}$; $\left|A_{v(j\omega)}\right| = \frac{A_{v(mid)}}{\sqrt{2}}$

$$A_{v(j\omega)} = A_{v(mid)} \frac{1}{1 + j\omega c_A(R_s||R_i)}$$

$$\omega_{CA} = \frac{1}{c_A(R_s||R_i)}$$

$$\therefore A_{v(j\omega)} = A_{v(mid)} \frac{1}{1+\frac{j\omega}{\omega_{CA}}}$$



If we have two internal capacitors :

$$A_{v(j\omega)} = A_{v(mid)} \frac{1}{\left(1 + \frac{j\omega}{\omega_A}\right)\left(1 + \frac{j\omega}{\omega_B}\right)}$$

If $\omega_A = 1\ M\ r/s$, and $\omega_B = 5\ M\ r/s$

$$\omega_H = 0.964\ M\ r/s$$

$\therefore$ if $\omega_A < \omega_B$; $\omega_H < \omega_A$

$$\left|A_{v(j\omega)}\right| = \frac{A_{v(mid)}}{\left|\left(1 + \frac{j\omega}{\omega_A}\right)\left(1 + \frac{j\omega}{\omega_B}\right)\right|}$$

assuming $\omega_A < \omega_B$

$$\left|A_{v(j\omega_H)}\right| = \frac{A_{v(mid)}}{\left|\left(1 + \frac{j\omega_H}{\omega_A}\right)\left(1 + \frac{j\omega_H}{\omega_B}\right)\right|} = \frac{A_{v(mid)}}{\sqrt{2}}$$

$$\therefore \left|\left(1 + \frac{j\omega_H}{\omega_A}\right)\left(1 + \frac{j\omega_H}{\omega_B}\right)\right| = \sqrt{2}$$

Since $\omega_H < \omega_A$, and $\omega_H \ll \omega_B$

$$\therefore \frac{j\omega_H}{\omega_B} \to 0$$

$$\therefore \left|\left(1 + \frac{j\omega_H}{\omega_A}\right)\right| \approx \sqrt{2}$$

$$\omega_H = \omega_A$$

To find the lower limit

$$\left|\left(1+\frac{j\omega_H}{\omega_A}\right)\left(1+\frac{j\omega_H}{\omega_B}\right)\right| = \sqrt{2}$$

$$\left|1 + j\omega_H\left(\frac{1}{\omega_A} + \frac{1}{\omega_B}\right) + \frac{\omega_H}{\omega_A}\ \frac{\omega_H}{\omega_B}\right| = \sqrt{2}$$

Since $\omega_H < \omega_A$, and $\omega_H \ll \omega_B$

$$\frac{\omega_H}{\omega_A} < 1\ and \qquad \frac{\omega_H}{\omega_B} \ll 1$$

$$\frac{\omega_H}{\omega_A}\ \frac{\omega_H}{\omega_B} \rightarrow 0$$

$$\left|\left(1+\frac{j\omega_H}{\omega_A}\right)\left(1+\frac{j\omega_H}{\omega_B}\right)\right| \approx \left|\left(1 + j\omega_H\left(\frac{1}{\omega_A} + \frac{1}{\omega_B}\right)\right)\right| = \sqrt{2}$$

$$\therefore \quad \omega_H = \frac{1}{\left(\frac{1}{\omega_A} + \frac{1}{\omega_B}\right)}$$

$\therefore$ if $\omega_A < \omega_B$

$$\frac{1}{\frac{1}{\omega_A} + \frac{1}{\omega_B}} < \omega_H < \omega_A$$

If $\omega_A = 1\ M\ r/s\ ,\ \omega_B = 5\ M\ r/s$

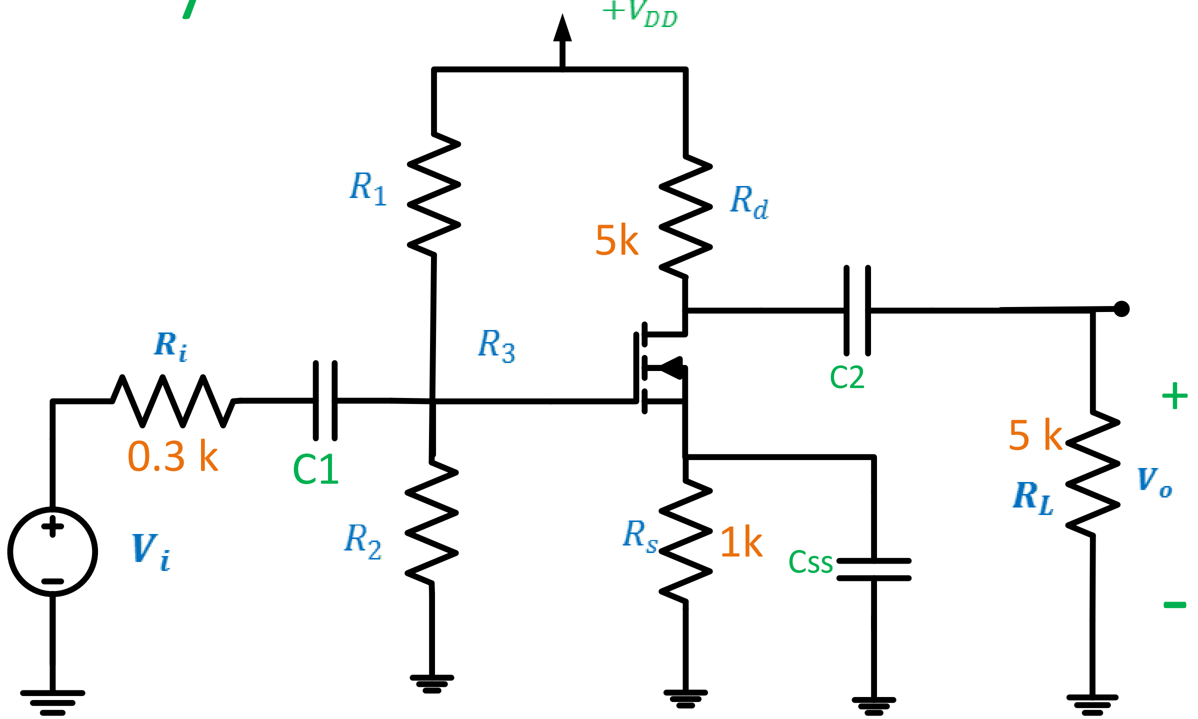
$$\omega_H \equiv 0.964\ M\ r/s$$

$$\frac{1}{\frac{1}{\omega_A} + \frac{1}{\omega_B}} < \omega_H < \omega_A$$

$$0.83\ M\ r/s < \omega_H < 1\ M\ r/s$$

$$0.83\ M\ r/s < 0.964\ M\ r/s < 1\ M\ r/s$$

FET High-Frequency Analysis



1) Common Source Amplifier

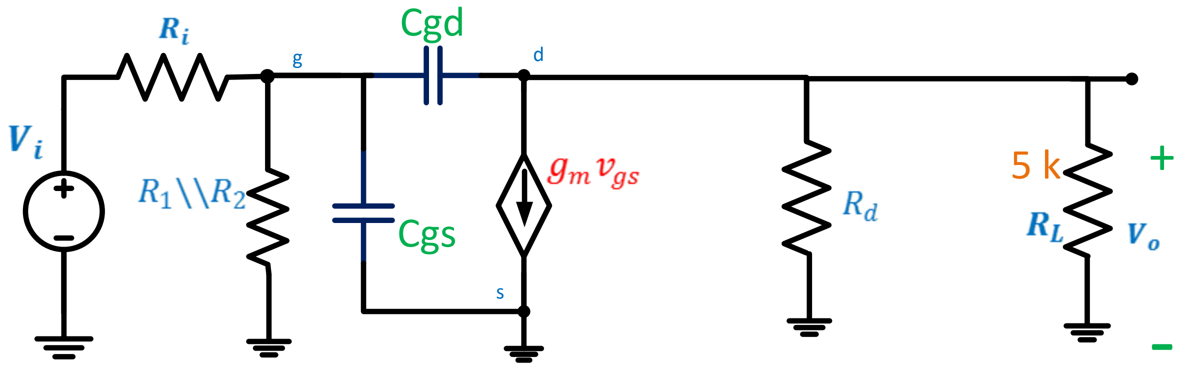
$R_i = 0.3k$, $R_1 || R_2 = 100k$, $R_d = R_L = 5k$

$R_s = 1k$, $g_m = 10\ m℧$

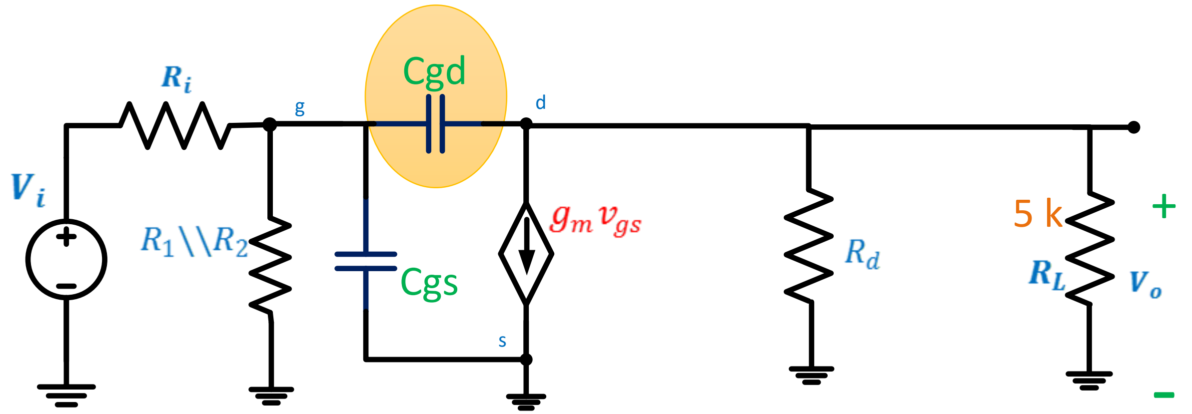
$C_{gd} = 2\ pF$ and $C_{gs} = 5\ pF$

Estimate ω_H

Ac small signal **high-frequency** equivalent C_{KT}



1) To find τ_{gs} ; set C_{gd} open circuit

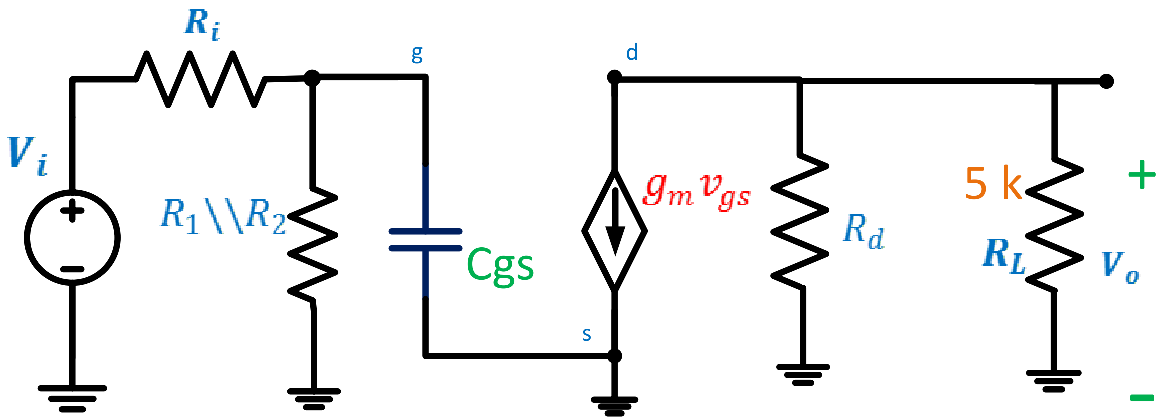


$$\tau_{gs} = C_{gs}R_{gs}$$

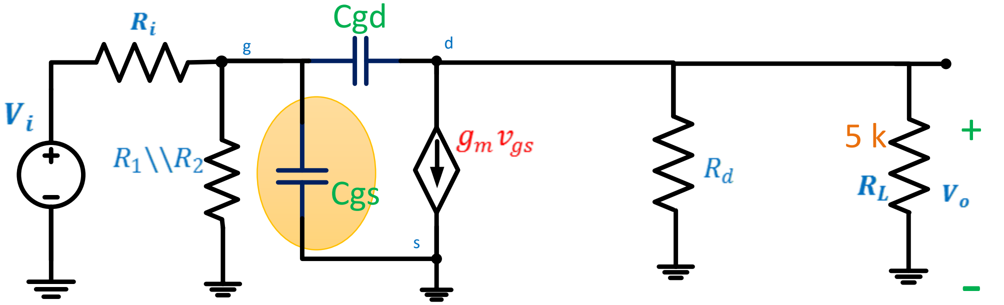
$$R_{gs} = R_i || R_1 || R_2$$

$$\therefore \tau_{gs} = 1.496\, ns$$

$$\therefore \omega_{gs} = \frac{1}{\tau_{gs}} = 668.45\, M\, r/s$$

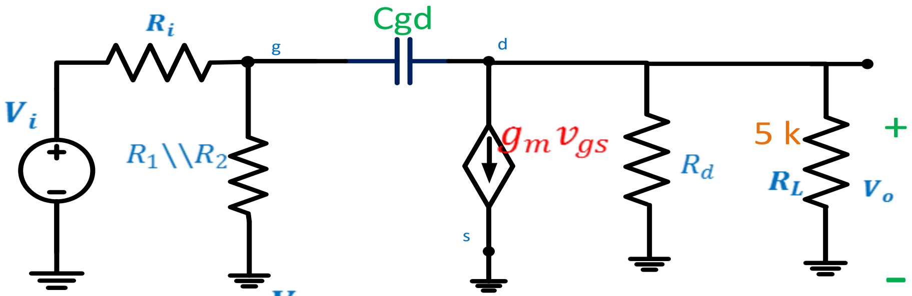


2) To find τ_{gd} ; set C_{gs} open circuit



$$\tau_{gd} = C_{gd}R_{gd}$$

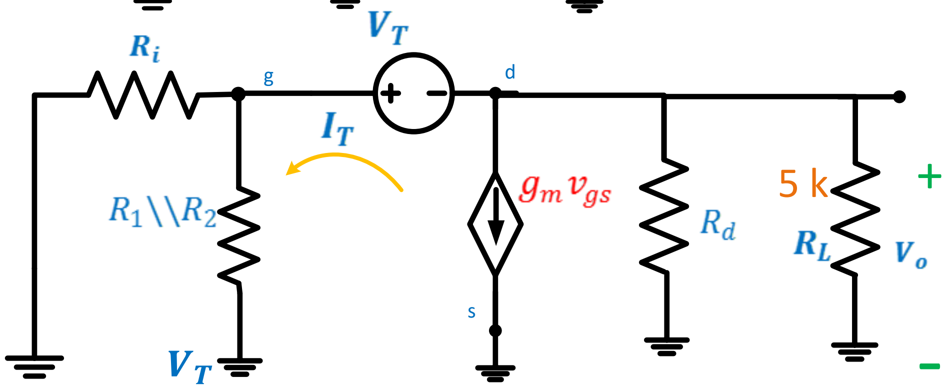
To find R_{gd}



$$\overline{R_L}\left(I_T + g_m V_{gs}\right) + \overline{R_S} I_T = V_T$$

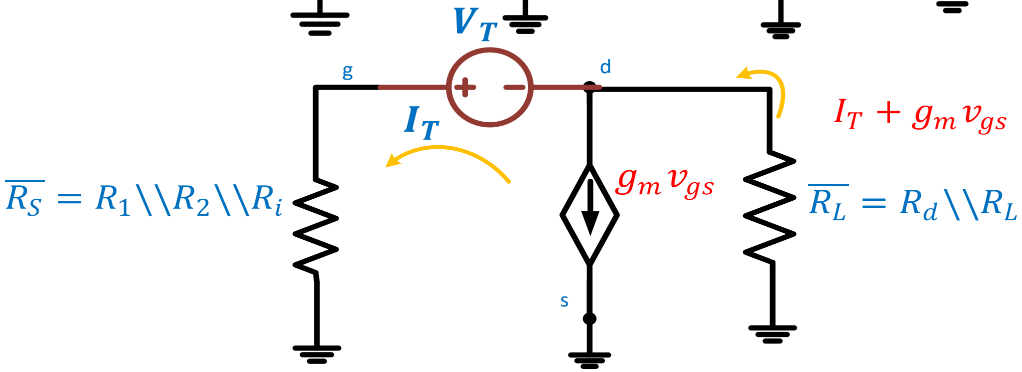
$$V_{gs} = V_g - V_s = V_g = \overline{R_S} I_T$$

$$\therefore \frac{V_T}{I_T} = \overline{R_S} + \overline{R_L} + g_m \overline{R_L}\,\overline{R_S} = R_{gd}$$



$$\tau_{gd} = C_{gd}R_{gd}$$

$$\tau_{gd} = 20.6\ ns$$



$$\therefore\ \omega_{gd} = 48.54\ M\,r/s$$

$$\frac{1}{\tau_{gd} + \tau_{gs}} < \omega_H < 48.54\ Mr/s$$

$$45.3\ Mr/s < \omega_H < 48.54\ Mr/s$$

$$\omega_H \equiv 48.4\ Mr/s$$

$$\tau_{gd} = 20.6\ ns\ ; \tau_{gs} = 1.496\ ns$$

$\therefore$ To increase the bandwidth, we must decrease τ_{gd}

$$\tau_{gd} = C_{gd}R_L^- + C_{gd}R_s^- + C_{gd}g_m R_L^- R_s^-$$

$$\tau_{gd} = 5\ ns + 0.6\ ns + 15\ ns = 20.6\ ns$$

And to decrease τ_{gd} ; we need to decrease $g_m R_L^- \cong A_{v(mid)}$

$$\therefore\ \omega_{gd} = 48.54\ M\ r/s$$

$$\therefore \omega_{gs} = \frac{1}{\tau_{gs}} = 668.45\ M\ r/s$$

Thus increasing bandwidth is usually achieved by reducing the midband gain

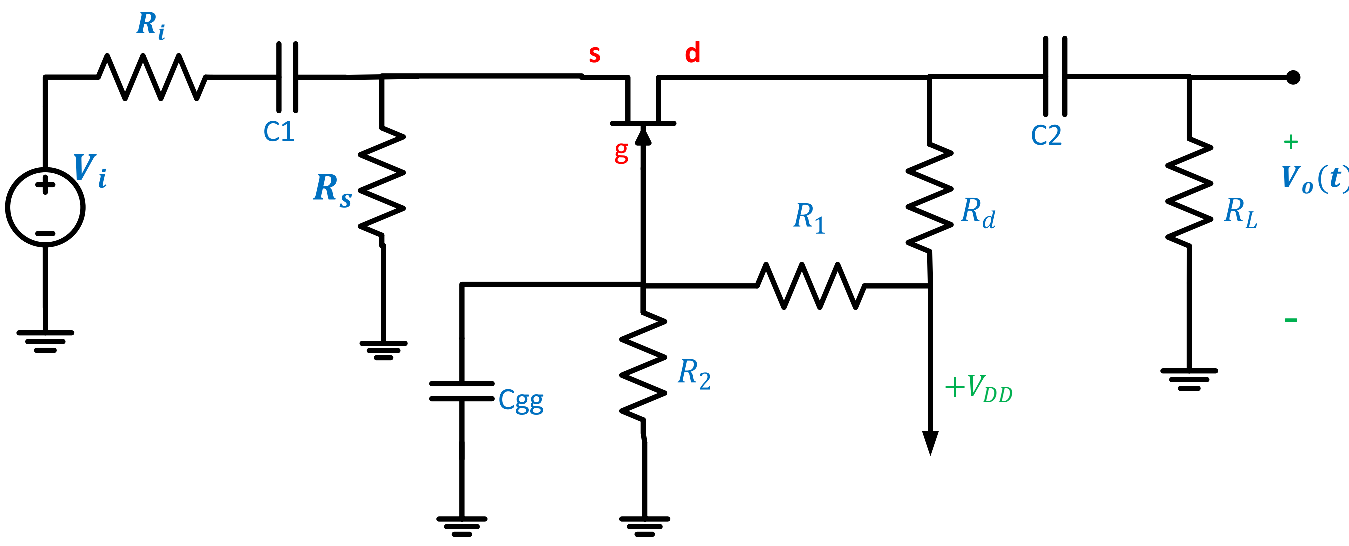
$\therefore$ The product of gain and bandwidth tends to be constant.

2) Common gate amplifier

$R_i = 0.3k\ , R_1 || R_2 = 100k\ \ , R_d = R_L = 5k$

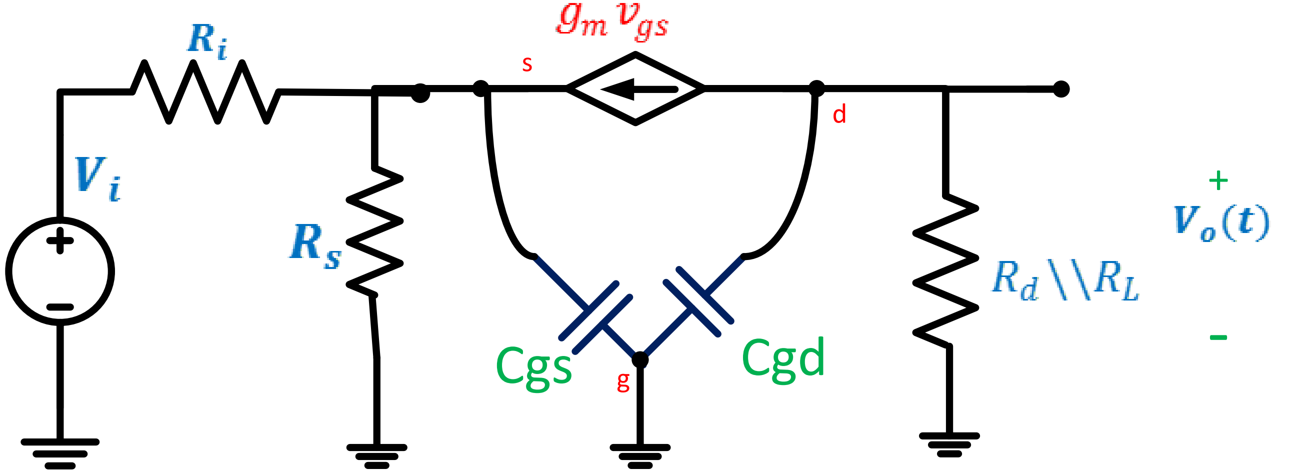
$R_s = 1k\ \ \ , g_m = 10\ m℧$

$C_{gd} = 2\ pF$ and $C_{gs} = 5\ pF$

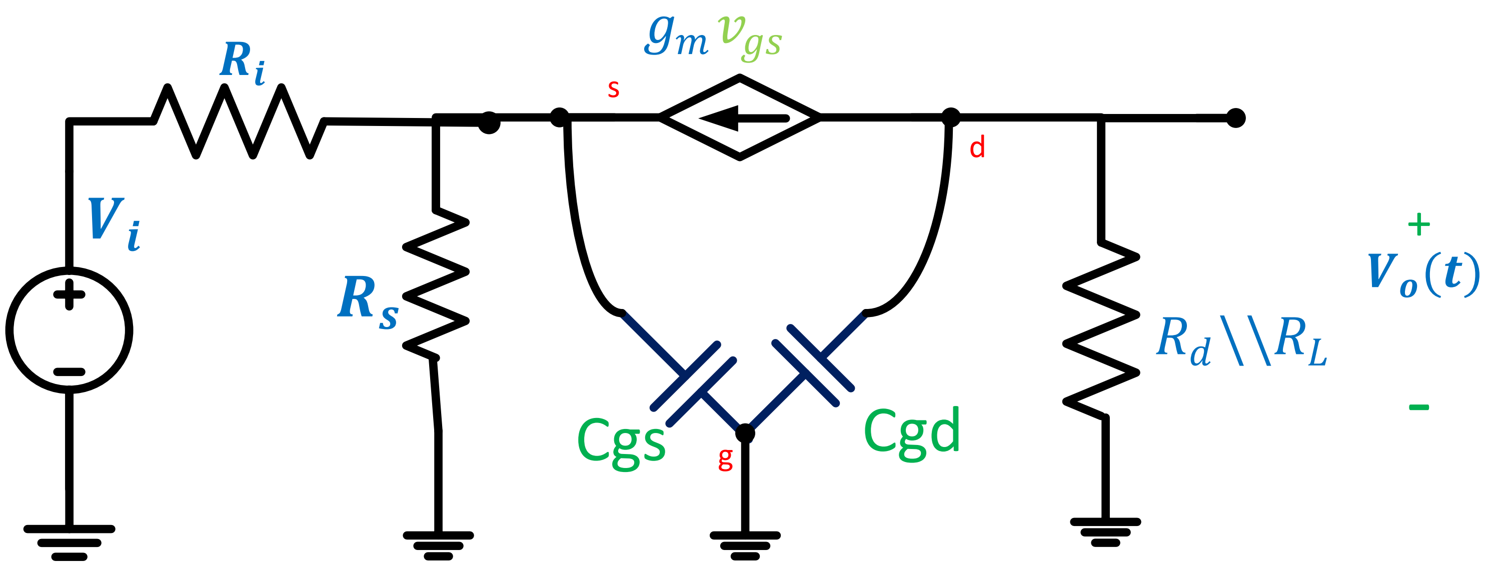


Estimate ω_H

Ac small signal **high-frequency** equivalent C_{KT}



1) To find τ_{gs} ; set C_{gd} open circuit



$$\tau_{gs} = C_{gs}R_{gs}$$

$$R_{gs} = R_s || R_i || \frac{1}{g_m}$$

$$\therefore \tau_{gs} = 0.349\ ns$$

$$\therefore \omega_{gs} = 2865\ Mr/s$$

2) To find τ_{gd} ; set C_{gs} open circuit

$$\tau_{gd} = C_{gd}R_{gd}$$

$$R_{gd} = R_L || R_d$$

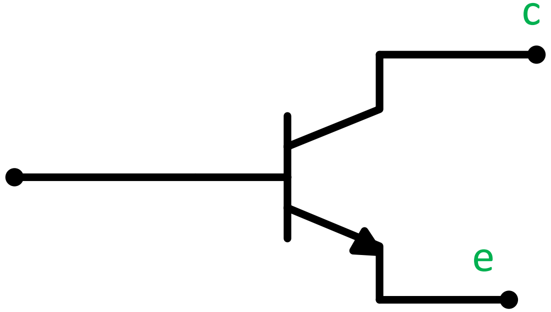
$$\therefore \tau_{gd} = 5\ ns$$

$$\therefore \omega_{gs} = 200\ Mr/s$$

$$\frac{1}{\tau_{gd} + \tau_{gs}} < \omega_H < 200\ Mr/s$$

$$187\ Mr/s < \omega_H < 200\ Mr/s$$

BJT small signal high-frequency equivalent C_{KT}

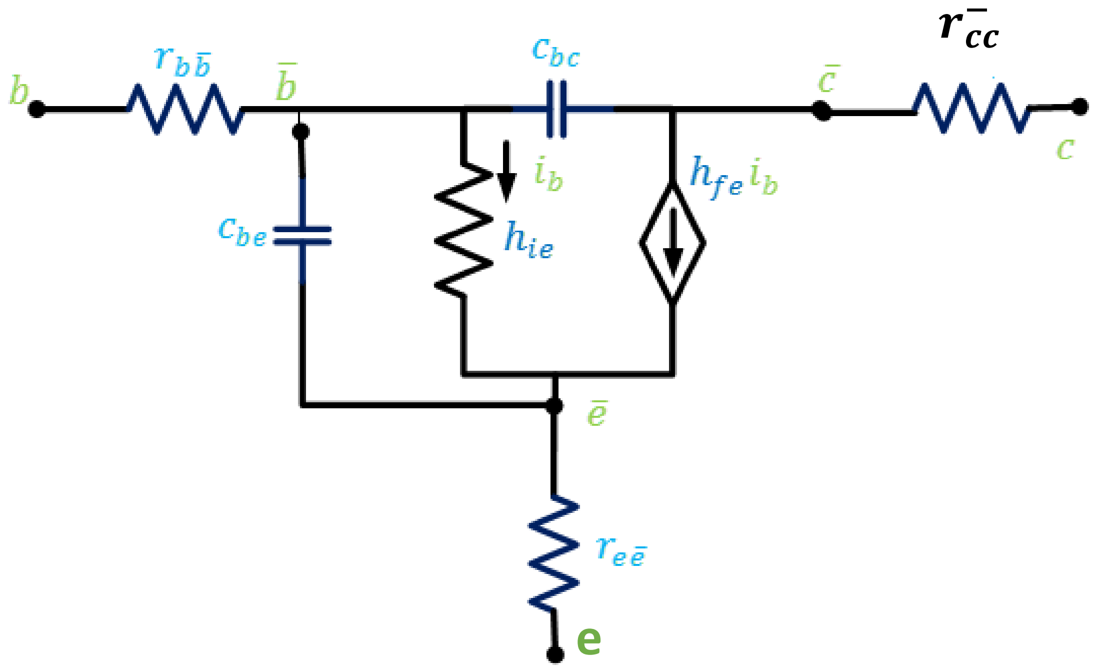


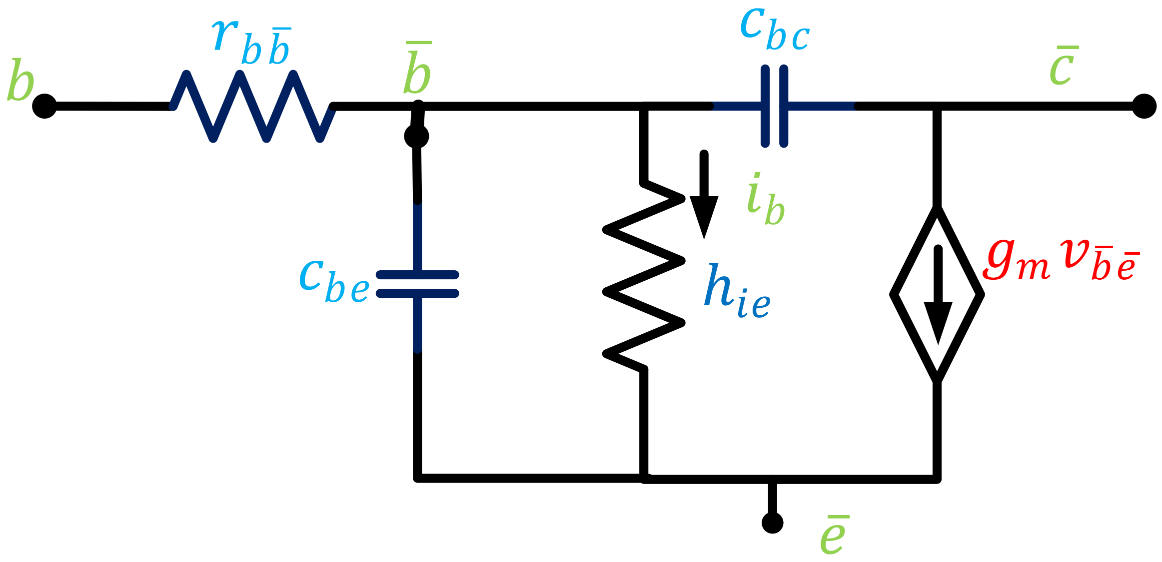
1) Common Emitter and Common Collector

$$r_{b\bar{b}} = (20\Omega - 200\Omega)$$

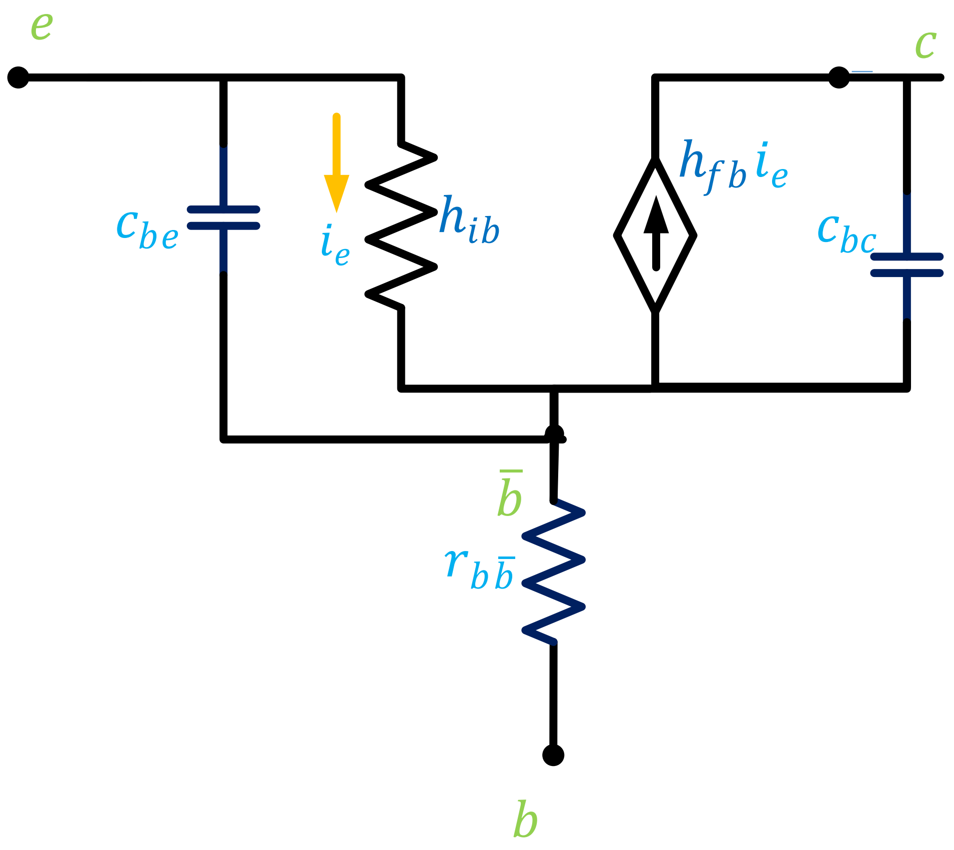
$$r_{c\bar{c}} = r_{e\bar{e}} = (1\Omega - 2\Omega) \rightarrow 0\Omega$$

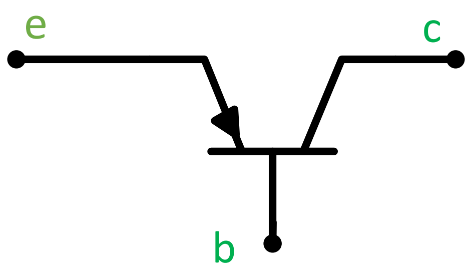
$$h_{fe\,ib} = h_{fe}\frac{v_{\grave{b}\grave{e}}}{h_{ie}} = \frac{h_{fe}}{h_{ie}} v_{\grave{b}\grave{e}} = g_m v_{\grave{b}\grave{e}}$$





2) Common Base





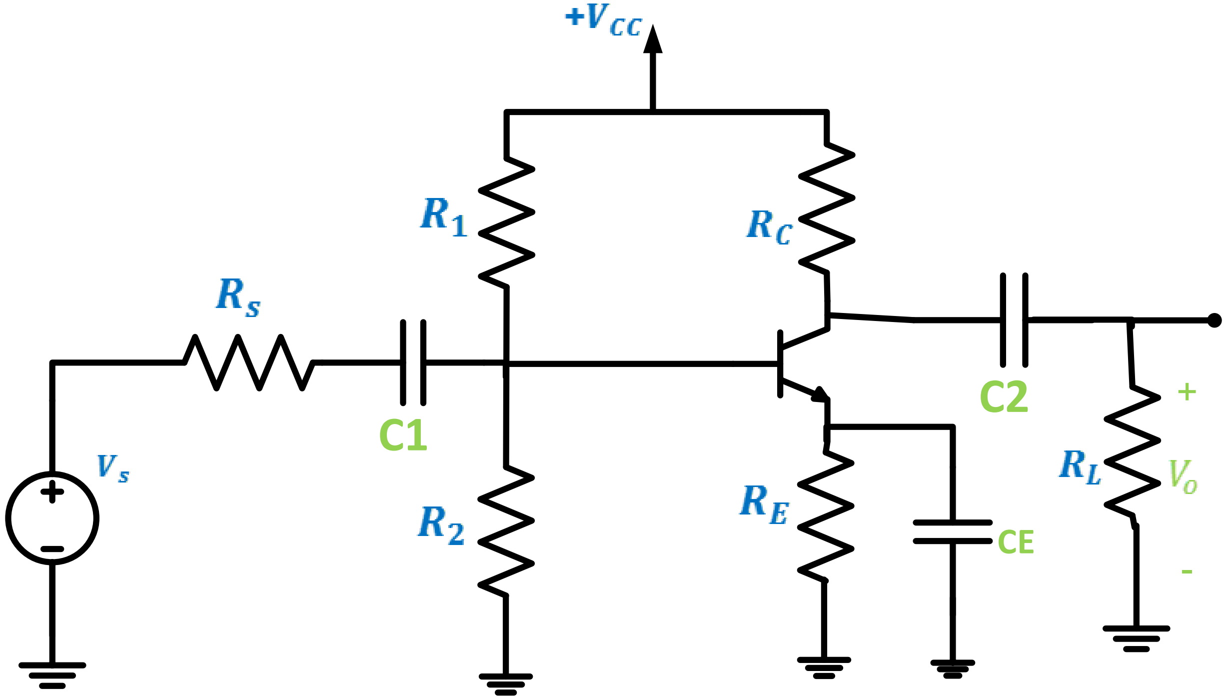
Common Emitter Amplifier High-Frequency Analysis

$g_m = 33.5\ m℧\ , h_{ie} = 8.78k$

$R_1 || R_2 = 16.67k\ , R_s = 1k\ , R_c = 5k$

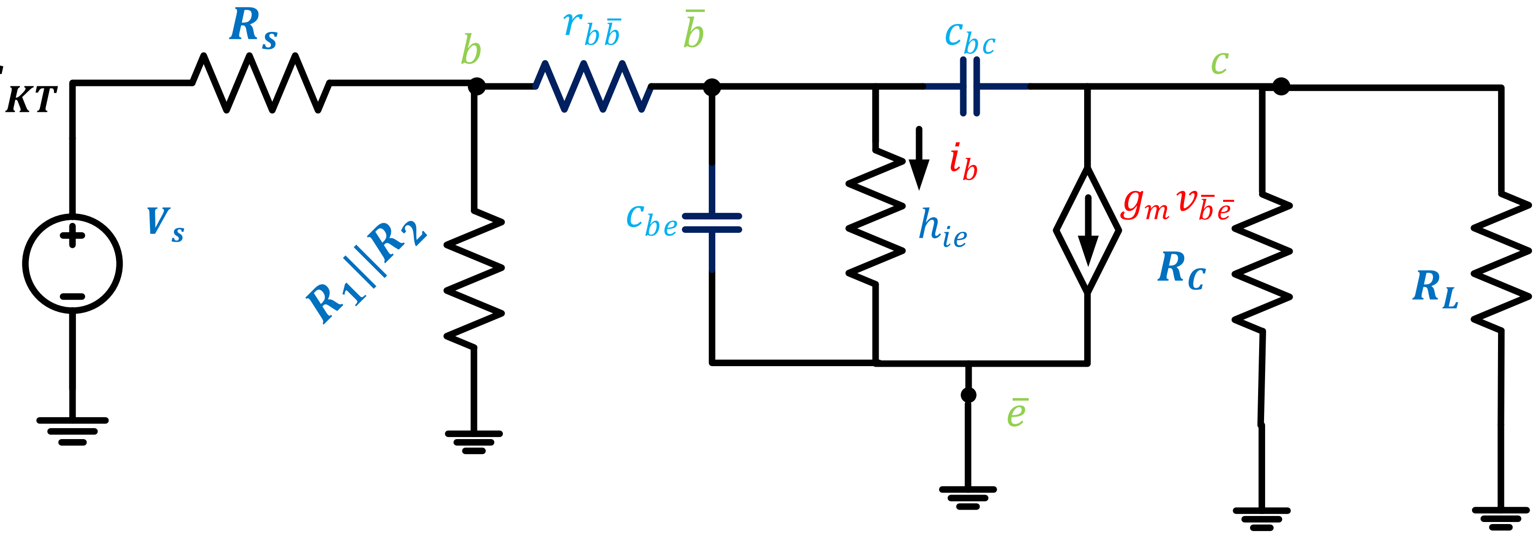
$R_L = 2k\ , R_e = 1k\ , r_{b\bar{b}} = 50\Omega$

$Cbe = 17.25\ pF\ , and\ Cbc = 1.8\ pF$



Estimate ω_H

Ac small signal **high- frequency** equivalent C_{KT}



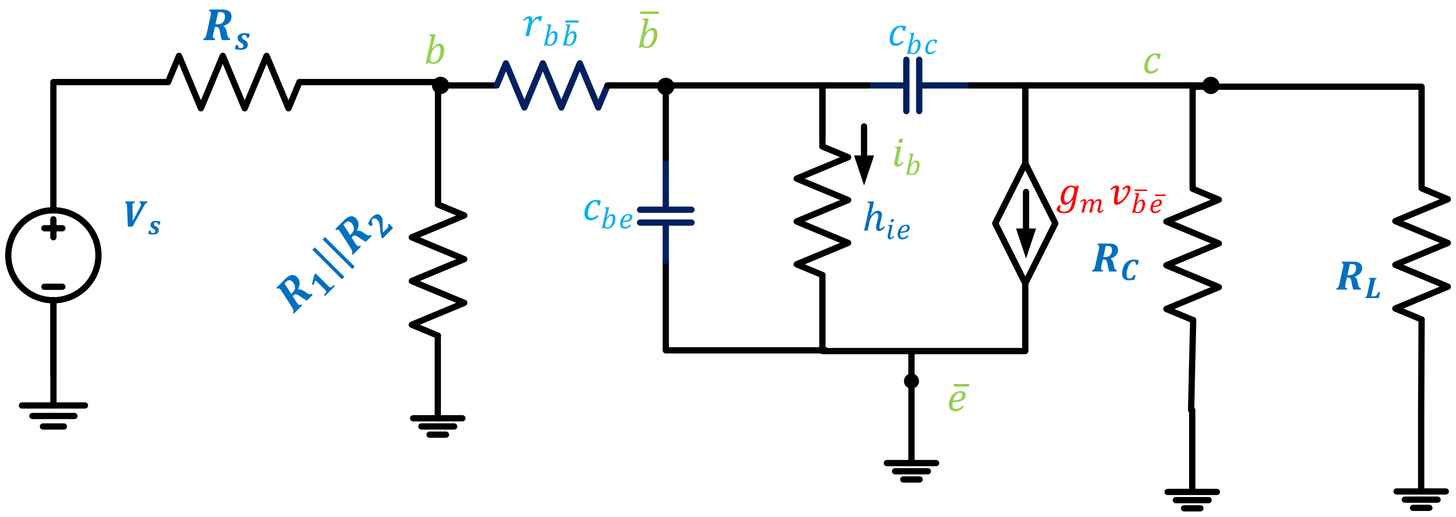
1) To find τ_{be} , set C_{bc} open circuit

$$\tau_{be} = C_{be}\, R_{be}$$

$$R_{be} = (R_s||R_1||R_2 + r_{b\bar{b}}) \,||\, h_{ie}$$

$$\tau_{be} = 14.98\ ns$$

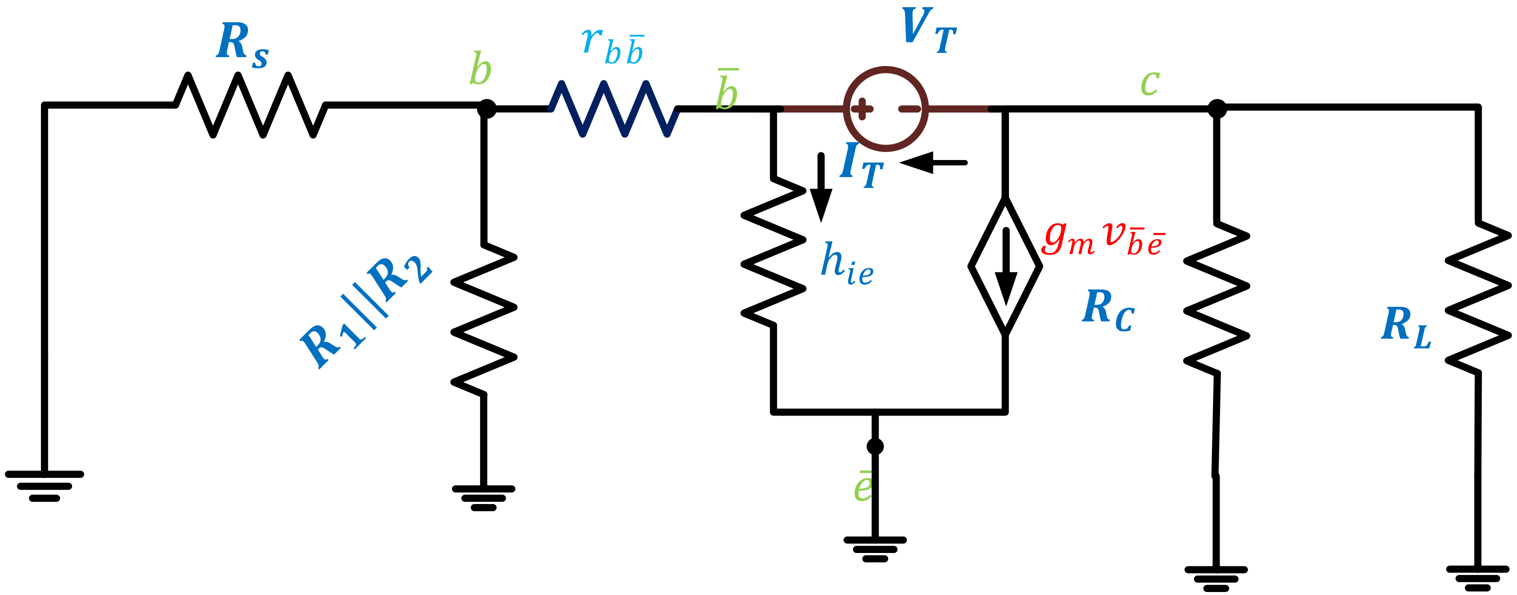
$$\therefore\ \omega_{be} = 66.76\ Mr/s$$



2) To find τ_{bc} , set C_{be} open circuit

$$\tau_{bc} = C_{bc}\, R_{bc}$$

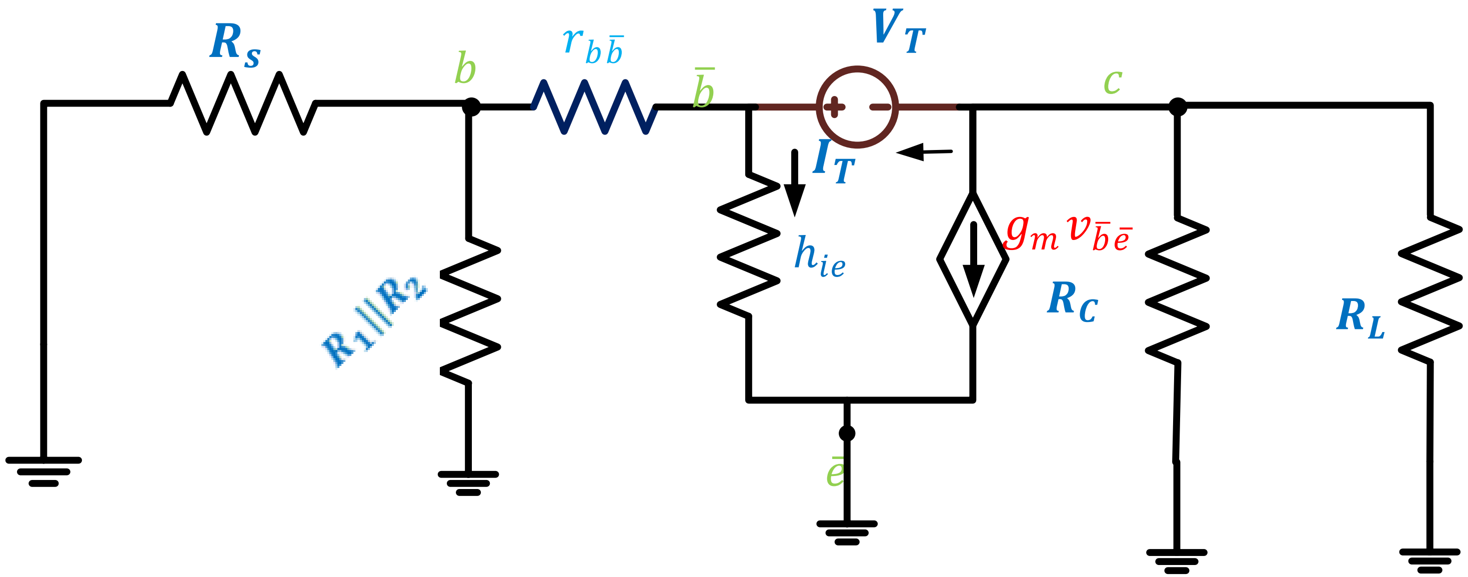
To find R_{bc}



To find R_{bc}

$$R^{-}_{s} = \{(R_s||R_1||R_2 + r_{b\acute{b}})\}||\, h_{ie}$$

$$R^{-}_{L}.(I_T + g_m v_{\acute{b}\acute{e}}) + R^{-}_{s} I_T = V_T$$



$$v_{\acute{b}\acute{e}} = R^{-}_{s} I_T$$

$$\therefore \frac{V_T}{I_T} = R_{bc} = R^{-}_{s} + R^{-}_{L} + g_m R^{-}_{L} R^{-}_{s}$$

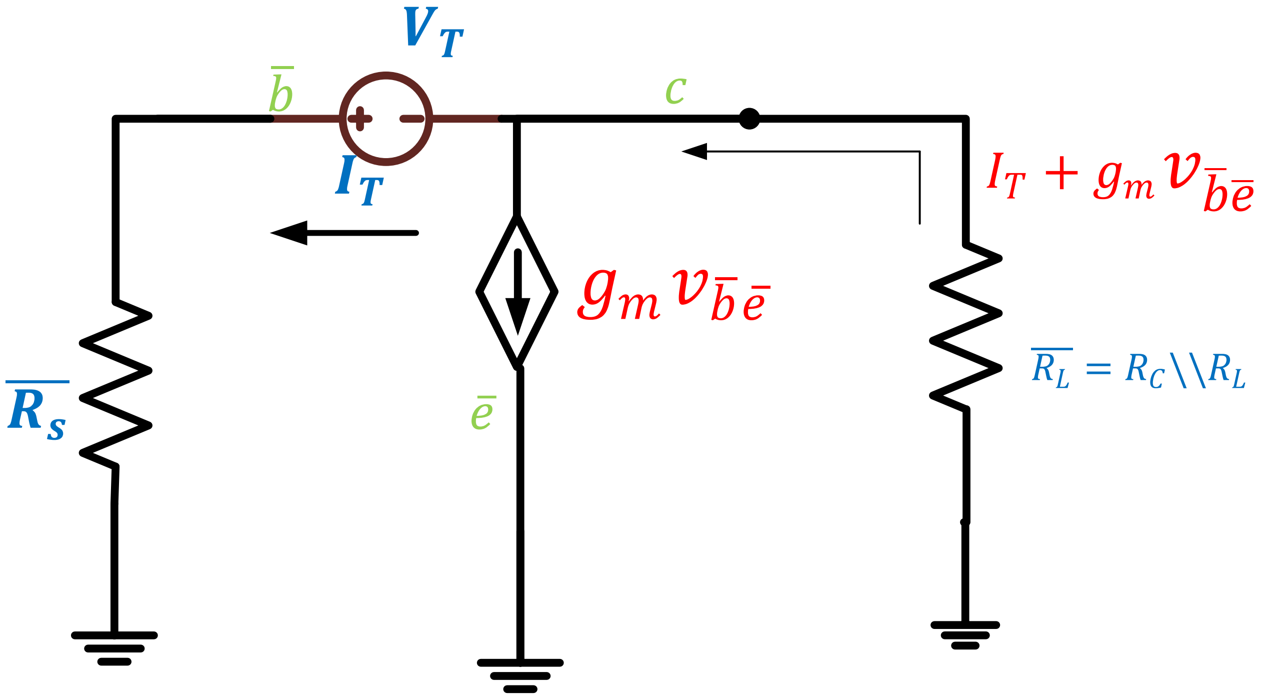
$$\therefore \tau_{bc} = 78.9\ ns$$

$$\therefore\ \omega_{bc} = 12.67\ Mr/s$$

$$\frac{1}{\tau_{be} + \tau_{bc}} < \omega_H < 12.67\ Mr/s$$

$$10.65\ Mr/s < \omega_H < 12.67\ Mr/s$$

$$\omega_H \equiv 10.7 Mr/s$$



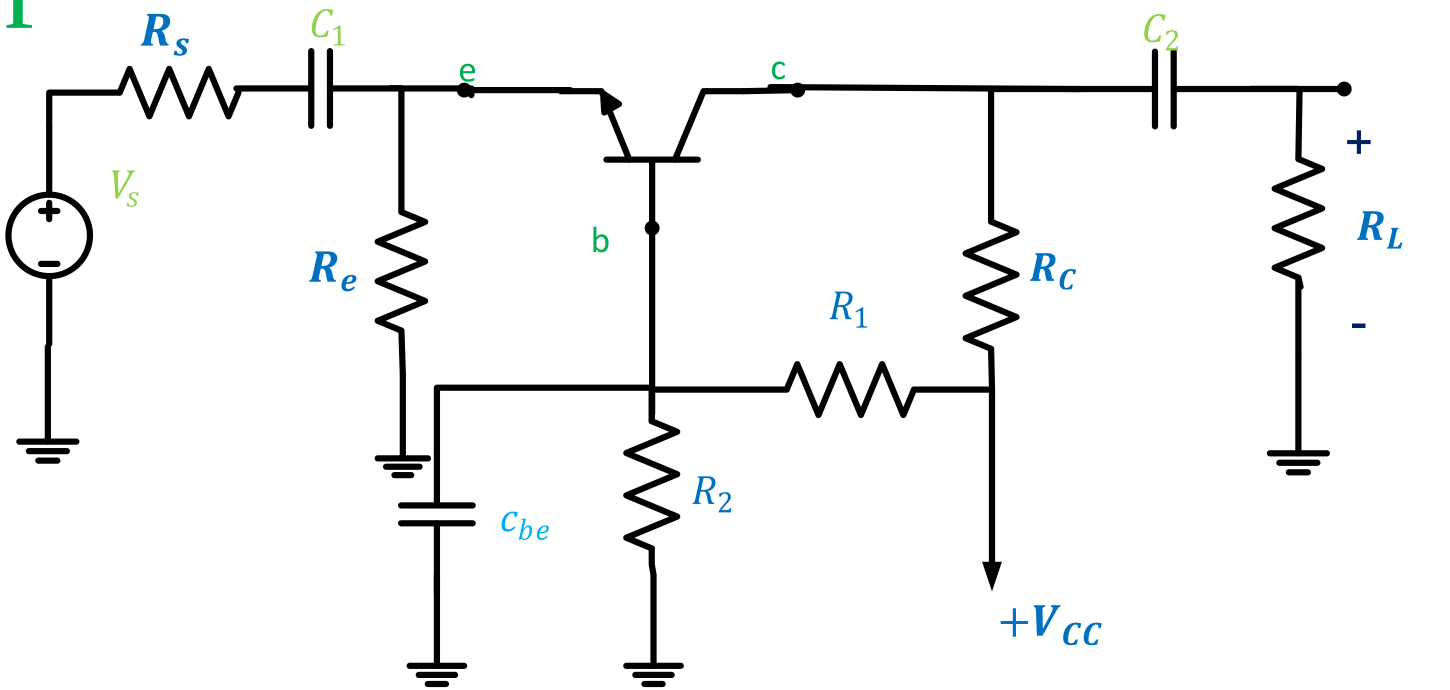
$$\omega_{be} = 66.76\ Mr/s$$

Common base amplifier

$R_s = 0.1k$, $R_e = 1k$, $R_c = 10k$, $R_L = 10k$

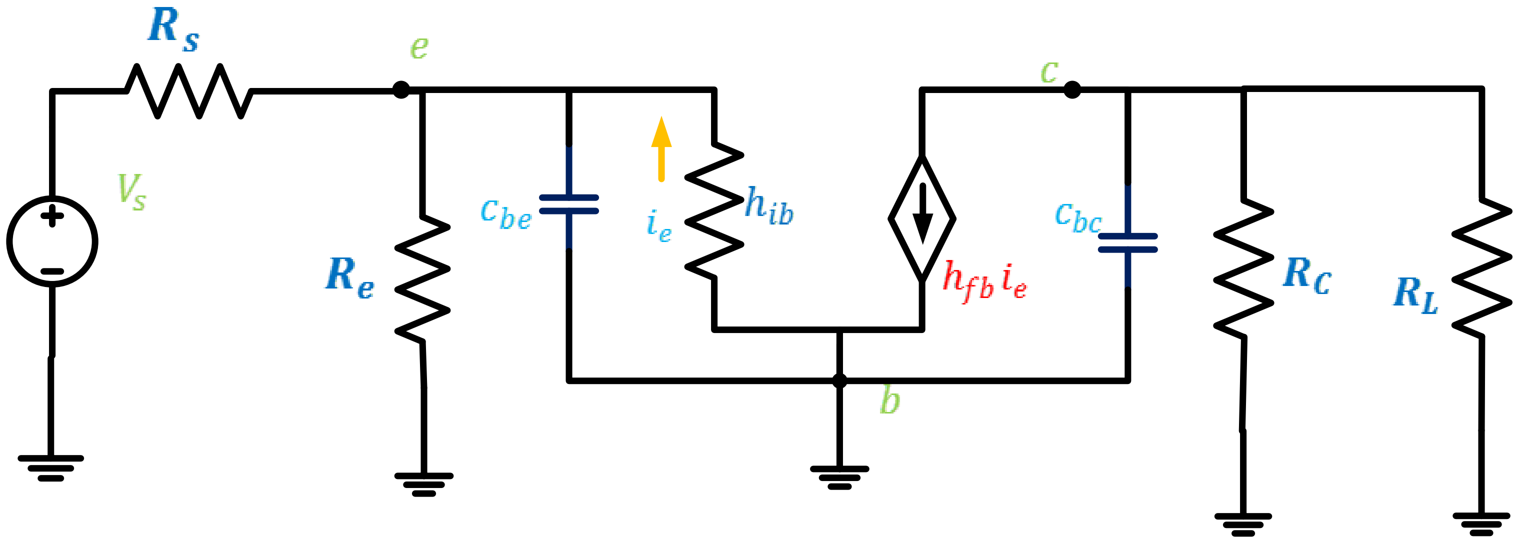
$R_1 \| R_2 = 16.67k$, $h_{ib} = 0.026k$, $r_{\bar{bb}} = 0$

$Cb_e = 20\ pF$, and $Cb_c = 2pF$



Estimate ω_H

Ac small signal high-frequency equivalent C_{KT}



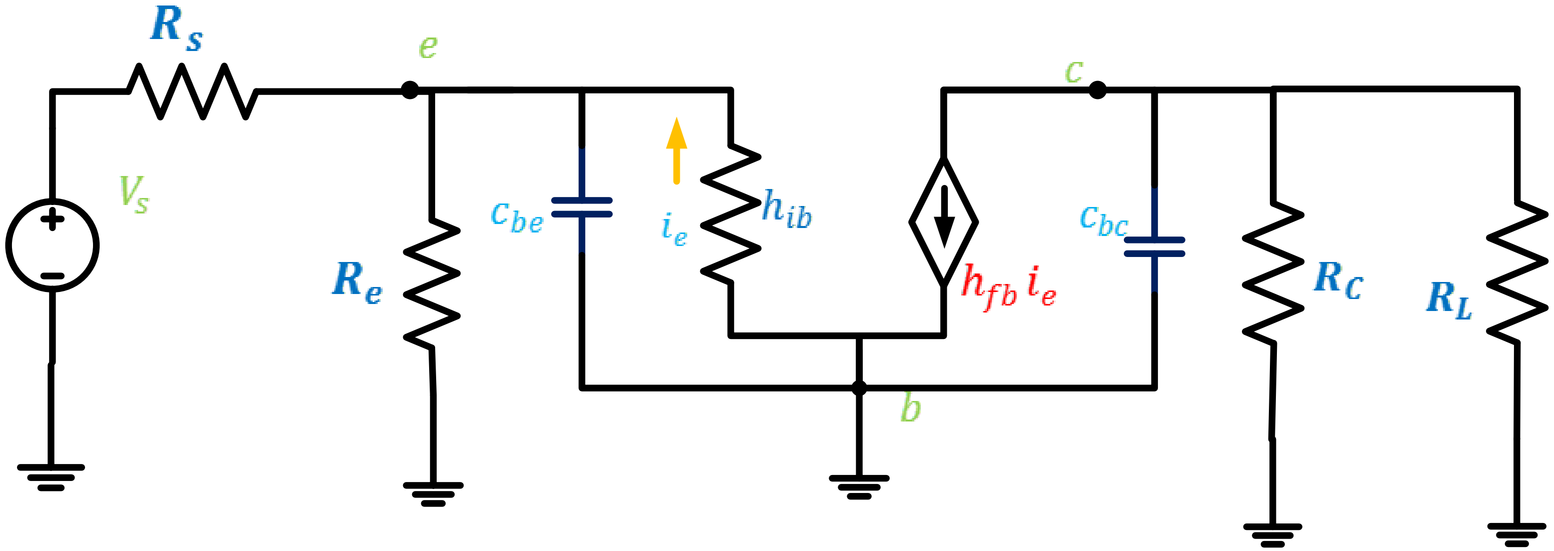
1) To find τ_{be} , set C_{bc} open circuit

$$\tau_{be} = C_{be}\, R_{be}$$

$$R_{be} = R_s || R_e || h_{ib}$$

$$\therefore \tau_{be} = 0.40797\ ns$$

$$\therefore \omega_{be} = 2451\ Mr/s$$



2) To find τ_{bc} , set C_{be} open circuit

$$\tau_{bc} = C_{bc}\, R_{bc}$$

$$R_{bc} = R_c || R_L$$

$$\therefore \tau_{bc} = 10\ ns$$

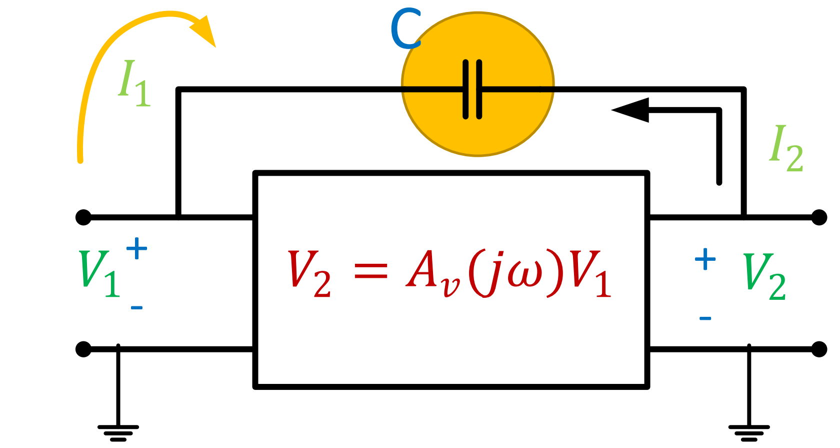
$$\therefore \omega_{be} = 100\ Mr/s$$

$$96.1\ Mr/s < W_H < 100\ Mr/s$$

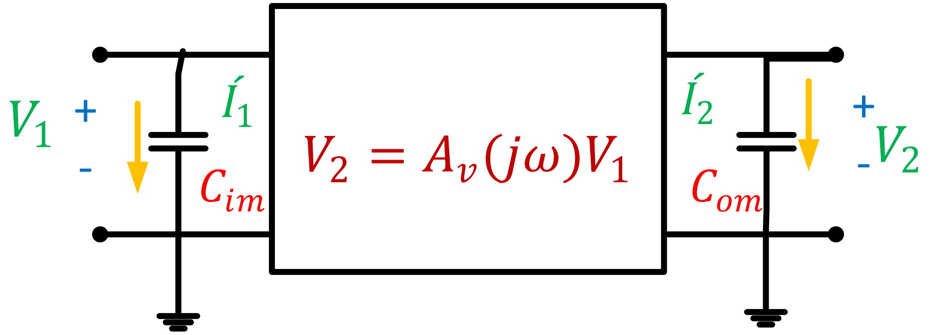
$$\omega_H \equiv 99.8\ Mr/s$$

Miller Effect Capacitor

$$\boldsymbol{C_{im} = C(1 - A_{v(mid)})}$$

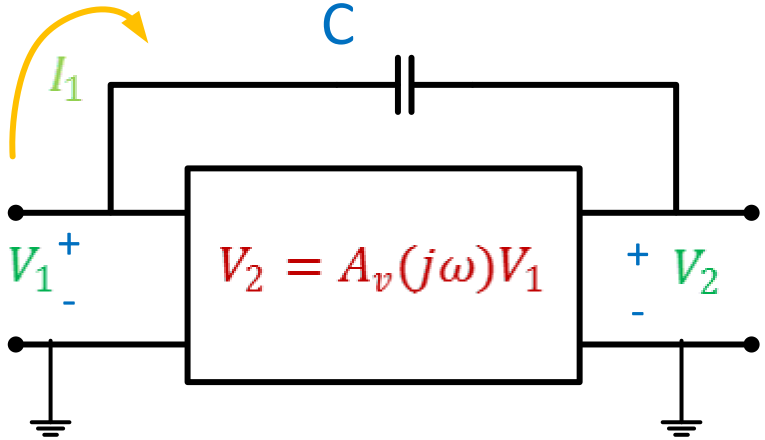


$$\boldsymbol{C_{om} = C\ \left(\frac{A_{v(mid)} - 1}{A_{v(mid)}}\right)}$$



Miller Effect Capacitor

$$I_1 = \frac{V_1 - V_2}{\frac{1}{j\omega c}} = j\omega c(V_1 - V_2)$$



$$I_1 = j\omega c(V_1 - A_{v(jw)}V_1)$$

$$I_1 = j\omega c V_1(1 - A_{v(jw)})$$

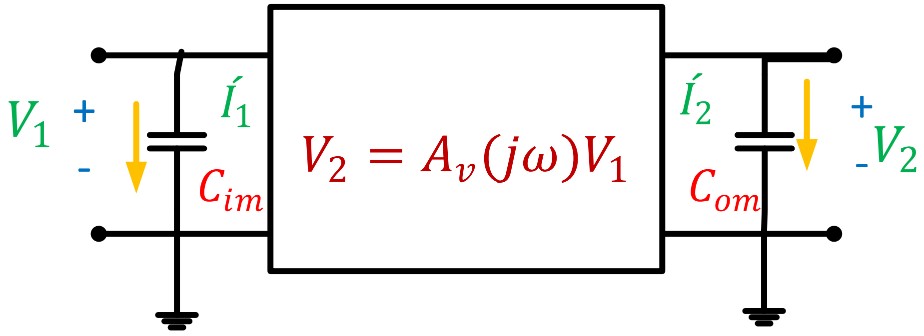
$$I_1 \approx j\omega c V_1(1 - A_{v(mid)})$$

But $I_1^{-} = j\omega C_{im} V_1$

For the two circuit to be equivalent

$$I_1 = I_1^{-}$$

$$\therefore C_{im} = C(1 - A_{v(mid)})$$



Miller Effect Capacitor

$$I_2 = j\omega c(V_2 - V_1)$$

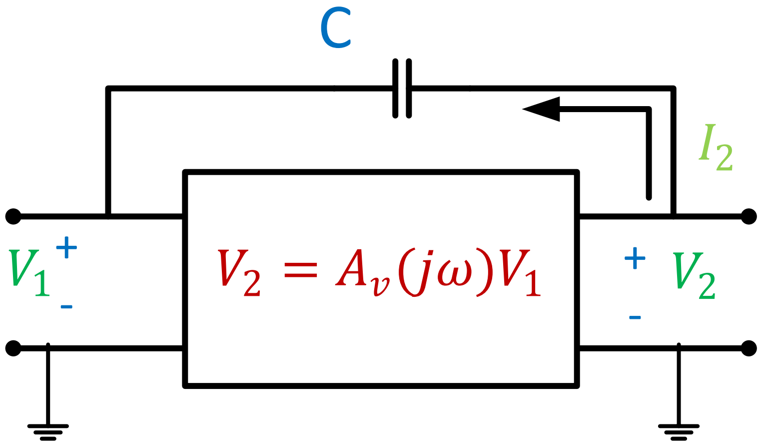
$$I_2 = j\omega c\left(V_2 - \frac{V_2}{A_{v(jw)}}\right)$$

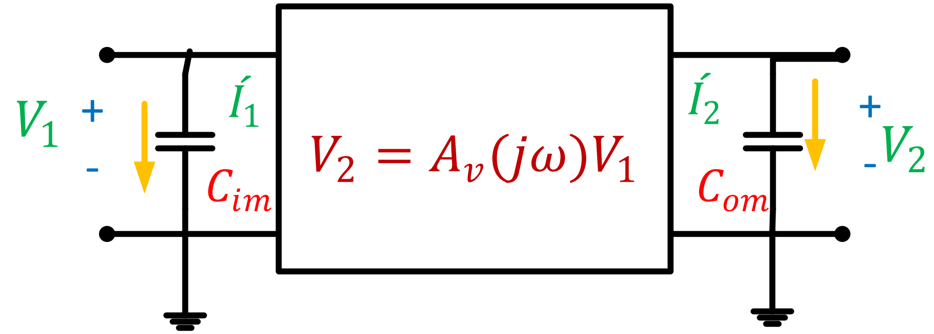
$$I_2 = j\omega c V_2\left(1 - \frac{1}{A_{v(jw)}}\right)$$

$$I_2 \cong j\omega c V_2\left(\frac{A_{v(mid)} - 1}{A_{v(mid)}}\right)$$

But $I_2^{-} = j\omega C_{om} V_2$

$$\therefore C_{om} = C\left(\frac{A_{v(mid)} - 1}{A_{v(mid)}}\right)$$

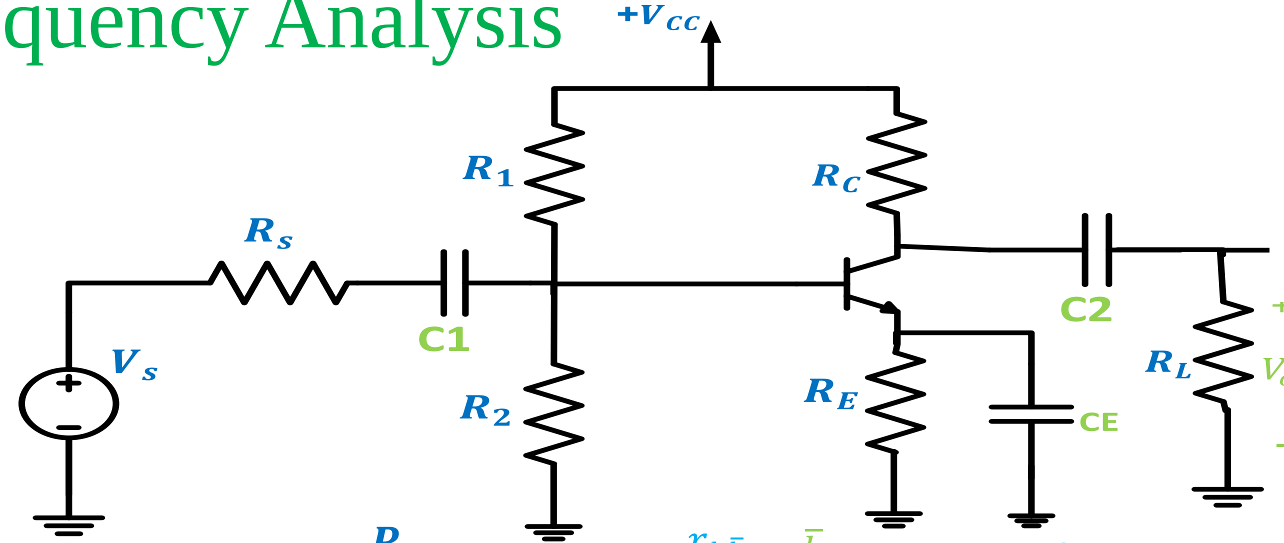


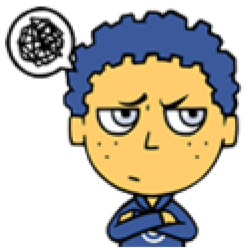


If $\left|A_{v(mid)}\right| \gg 1$

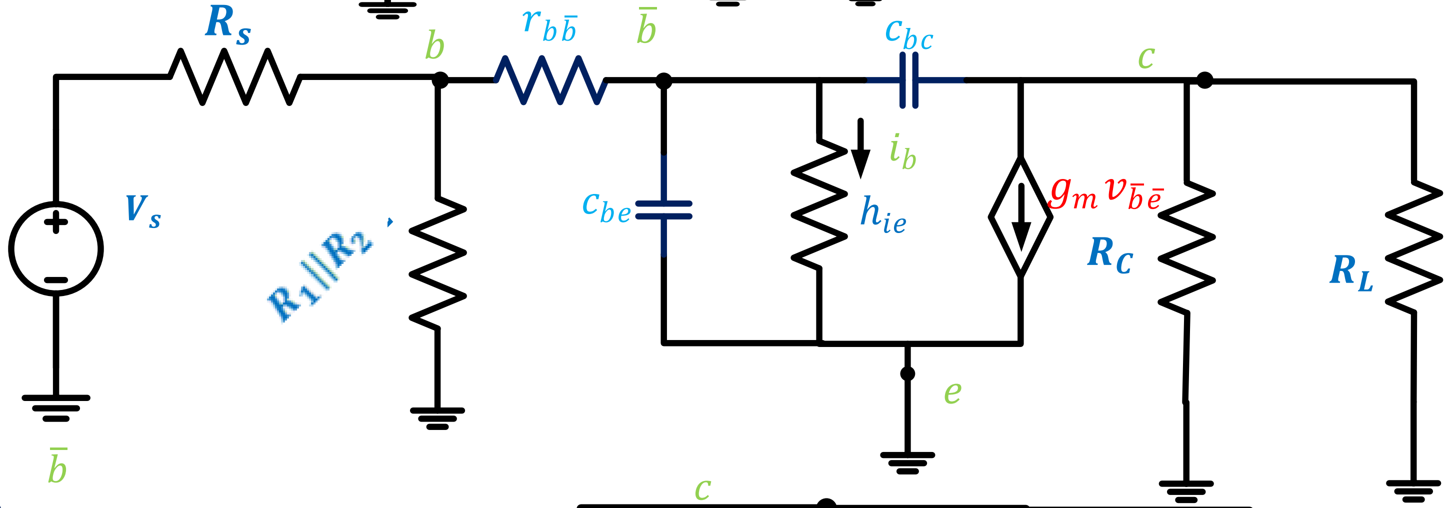
$$C_{om} \cong C$$

Common Emitter High-Frequency Analysis



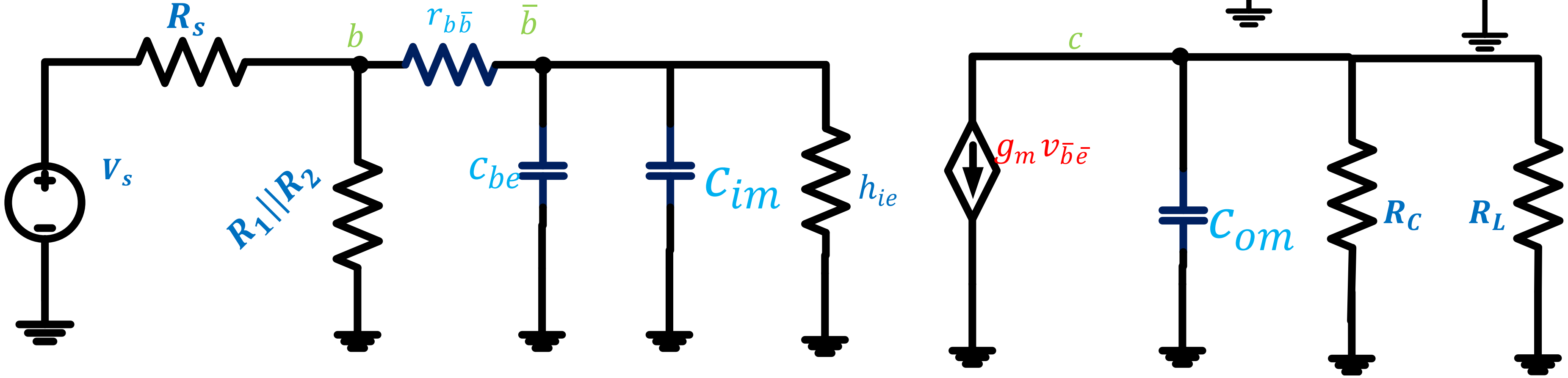


Using Miller-effect Capacitor



$$C_{im} = C_{bc}(1 - A_{v(mid)})$$

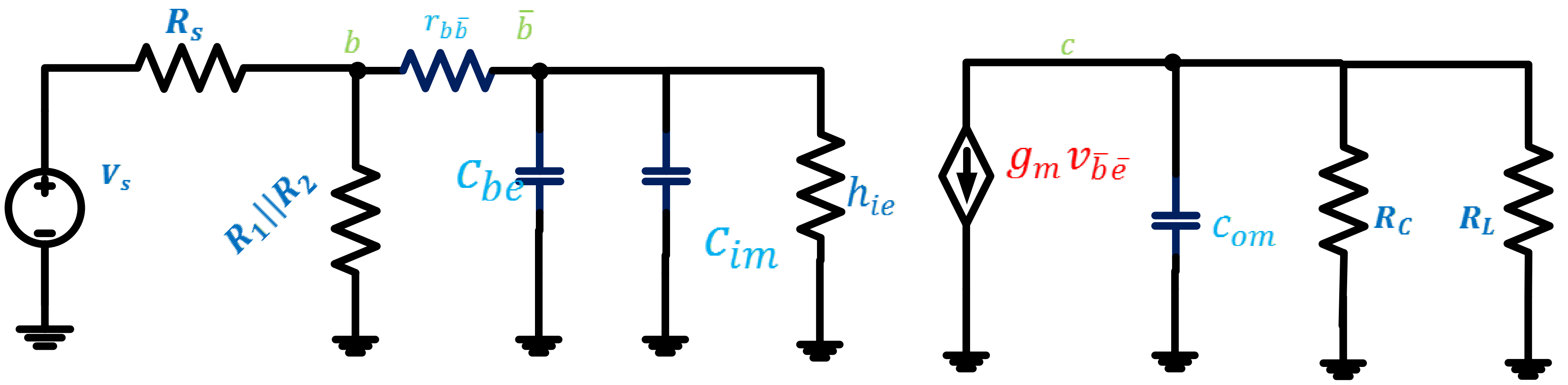
$$C_{iT} = C_{be} + C_{im}$$
$$C_{om} = C_{bc}$$



Common Emitter High-Frequency Analysis

To find τ_{CiT} , set C_{om} open

$$\tau_{CiT} = C_{iT} \, . R_{TH_1}$$



$$R_{TH_1} = h_{ie} \, ||(r_{bb} + R_s||R_1||R_2)$$

$$C_{iT} = C_{be} + C_{im}$$

$$C_{im} = C_{bc}(1 - A_{v(mid)})$$

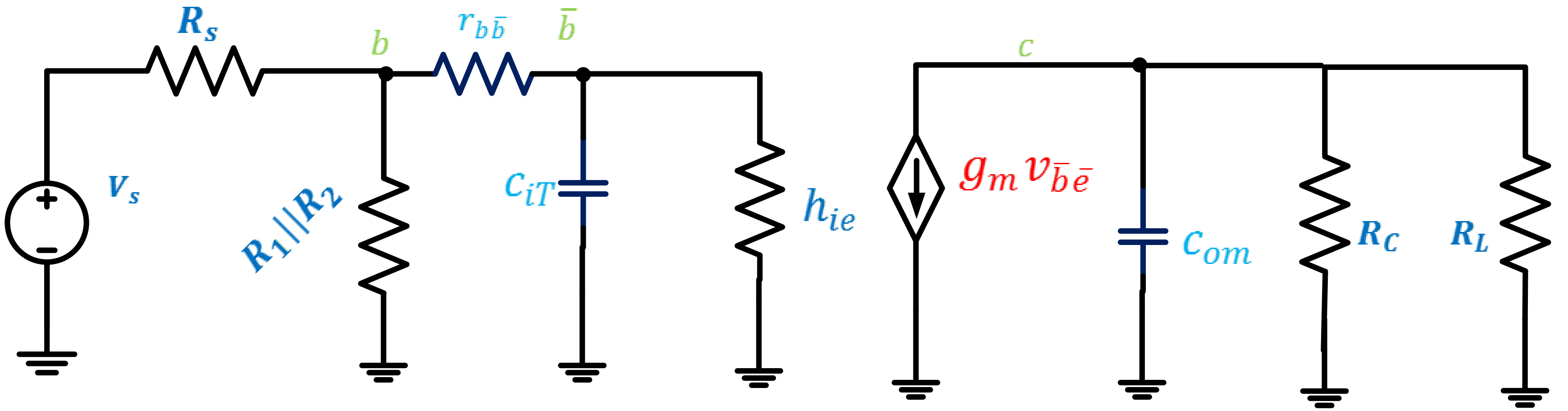
$$A_{v(mid)} = -g_m(R_c||R_L)$$

$\therefore C_{im} = 87.97 \; PF$

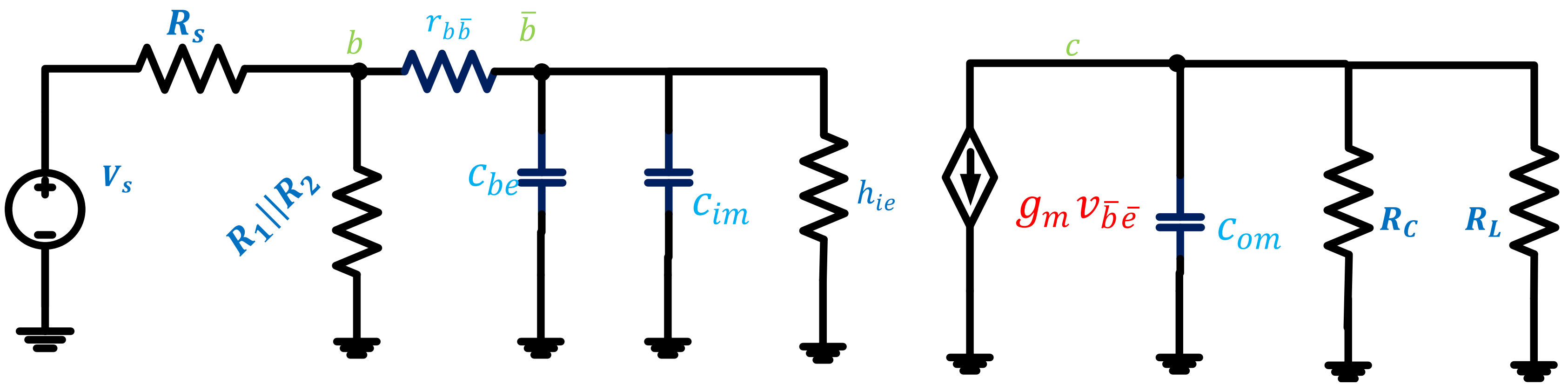
$\therefore C_{iT} = 105.2 \; PF$

$\therefore \tau_{CiT} = 91.3 \; ns$

$\therefore \omega_{CiT} = 10.95 \; Mr/s$



Common Emitter High-Frequency Analysis



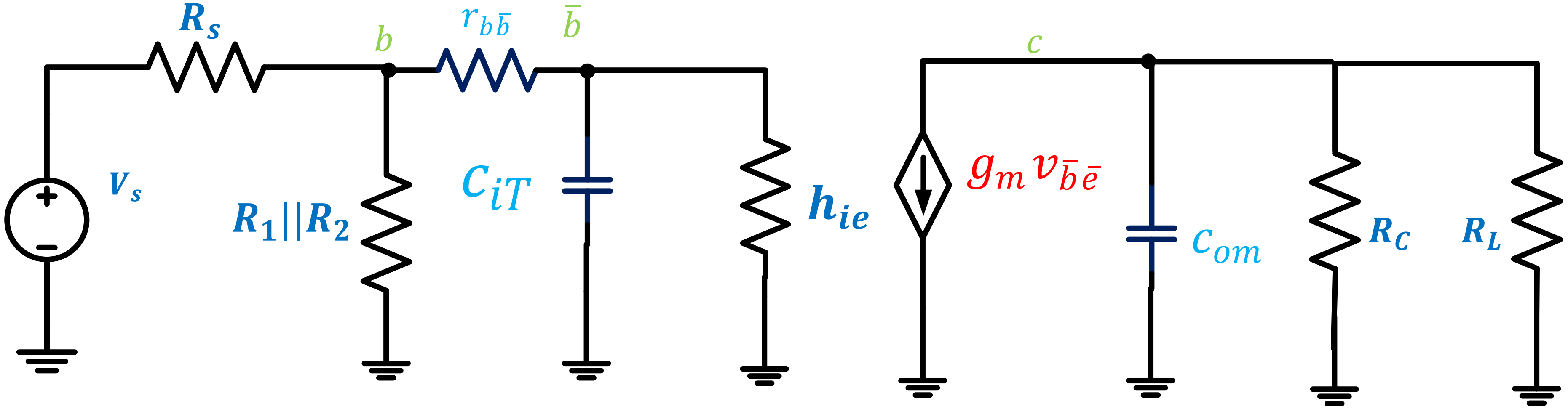
2) To find τ_{com} , set C_{IT} open

$$\tau_{com} = C_{om}\, R_{TH_2}$$

$$R_{TH_2} = R_c||R_L$$

$\therefore \tau_{com} = 2.57\ ns$

$\omega_{com} = 388.9\ Mr/s$



$\therefore \omega_{CiT} = 10.95\ Mr/s$

$$10.65M\ r/s < W_H < 10.95\ Mr/s$$

$$\omega_H \equiv 10.7\ Mr/s$$

The End