THE UNIVERSITY OF BRITISH COLUMBIA

Department of Electrical and Computer Engineering

ELEC301 – Electronic Circuits

Midterm - October 20, 2025

Answer all problems.
Time: 50 min.

This examination consists of 9 pages. Please check that you have a complete copy. You may use both sides of each sheet if needed.

#	MAX	GRADE
1	25	
2	25	
3	25	
4	25	
TOTAL	100	

Surname First

Student Number

READ THIS

IMPORTANT NOTE: The announcement “stop writing” will be made at the end of the examination. Anyone writing after this announcement will receive a score of 0. No exceptions, no excuses.

All writings must be on this booklet. The blank sides on the reverse of each page may also be used.

Each candidate should be prepared to produce, upon request, his/her Library/AMS card.

Read and observe the following rules:

No candidate shall be permitted to enter the examination room after the expiration of 15min, or to leave during the first 10min of the examination.

Candidates are not permitted to ask questions of the invigilator(s), except in cases of supposed errors or ambiguities in examination-questions.

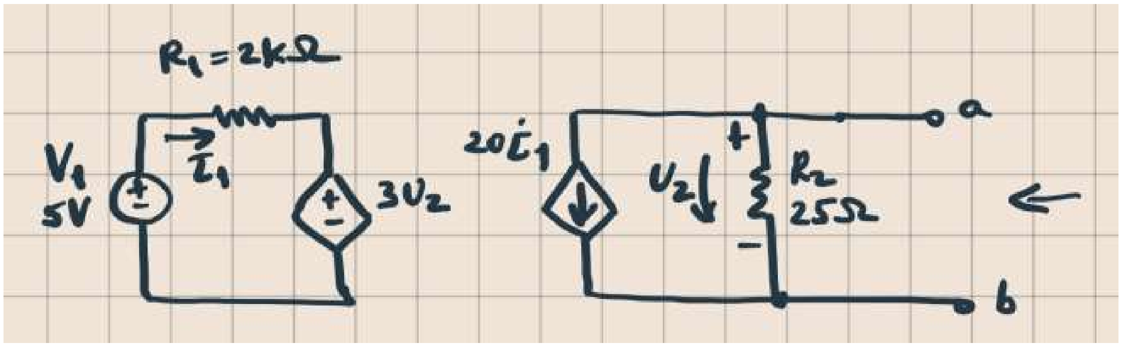
***Caution** - Candidates guilty of any of the following, or similar, dishonest practices shall be immediately dismissed from the examination and shall be liable to disciplinary action:*

- *Making use of any books, papers or memoranda, calculators, audio or visual cassette players or other memory aid devices, other than as authorized by the examiners.*
- *Speaking or communicating with other candidates.*
- *Purposely exposing written papers to the view of other candidates.*

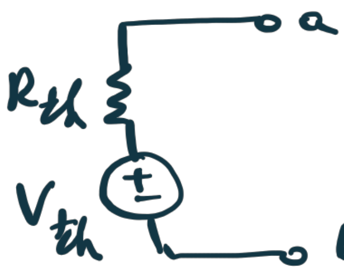
The plea of accident or forgetfulness shall not be received.

1) [25p]

Find the equivalent Thevenin representation with respect to the port a-b of the following circuit (pay attention to the dependent sources).



<u>Sol:</u> We want to reduce the circuit to



We firstly determine $V_{th} = V_{ab}^{oc}$

$$\begin{cases} I_1 = \dfrac{V_1 - 3V_2}{R_1} \\ V_2 = -R_2(20 I_1) \end{cases} \Rightarrow V_2 = -20 R_2 \frac{V_1 - 3V_2}{R_1}$$

$$\Updownarrow$$

$$V_2 = -20 \frac{R_2}{R_1} V_1 + 60 \frac{R_2}{R_1} V_2$$

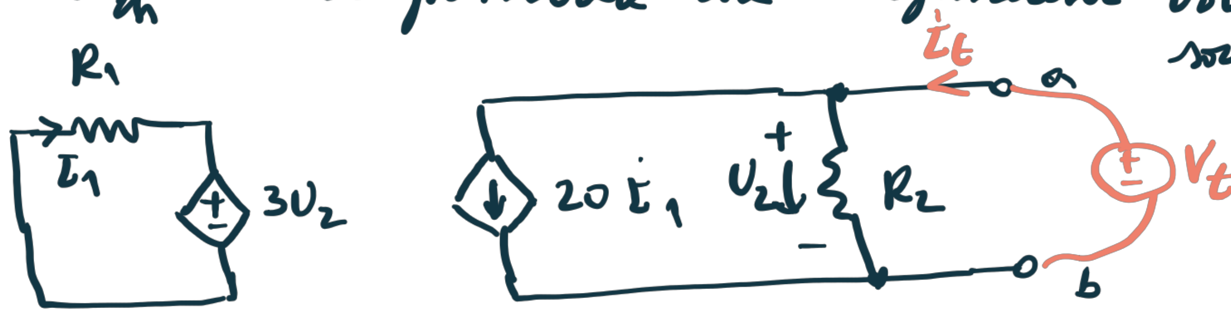
$$20 \frac{R_2}{R_1} V_1 = \left(\frac{60 R_2}{R_1} - 1\right) V_2$$

$$V_2 = V_{th} = \frac{20 R_2/R_1}{\frac{60 R_2}{R_1} - 1} V_1 = \frac{20 R_2}{60 R_2 - R_1} V_1$$

$$V_{th} = \frac{20 \cdot 25}{60 \cdot 25 - 2000} 5V = \frac{20}{-20} = -5V$$

(80)

For R_{th} → we passivate the independent voltage source



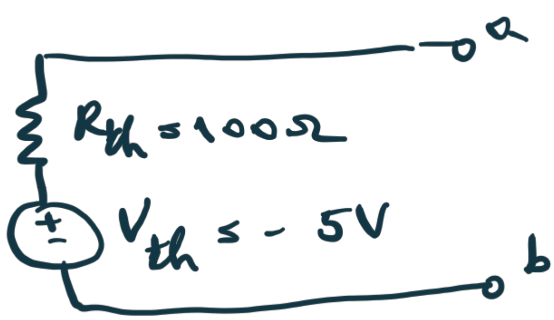
$$U_2 = V_t \Rightarrow i_1 = -\frac{3V_t}{R_1}$$

$$i_t = \frac{V_t}{R_2} + 20\cdot\left(-\frac{3V_t}{R_1}\right) = V_t\left(\frac{1}{R_2} - \frac{60}{R_1}\right) \Rightarrow$$

$$\Rightarrow R_{th} = \frac{V_t}{i_t} = \frac{1}{\frac{1}{R_2} - \frac{60}{R_1}} = \frac{1}{\frac{1}{25} - \frac{6\not{0}}{200\not{0}}}$$

$$R_{th} = \frac{200}{8-6}\,\Omega = \frac{200}{2}\,\Omega = 100\,\Omega$$

Concl



Grading: 25p total - 10p for Vth + 15p for Rth

2) [25p] Given the following transfer function

$$H(s) = \frac{(s+10)(s+100)}{(s^2+1001s+1000)(s+10000)(s+50000)}$$

a. Sketch the Bode plots for both the magnitude and phase
b. What is the input-output phase shift for very high frequencies?
c. Identify the range of frequencies corresponding to the midband operation.
d. Identify the frequency points with the largest approximation errors for magnitude and the phase. respectively.

Sol.: $s^2 + 1001s + 1000 = 0 \Rightarrow \begin{cases} p_1 + p_2 = -1001 \\ p_1 \cdot p_2 = 1000 \end{cases} \Rightarrow$

$\Rightarrow p_1 = -1$
$p_2 = -1000$

$z_1 = -10, \quad z_2 = -100$

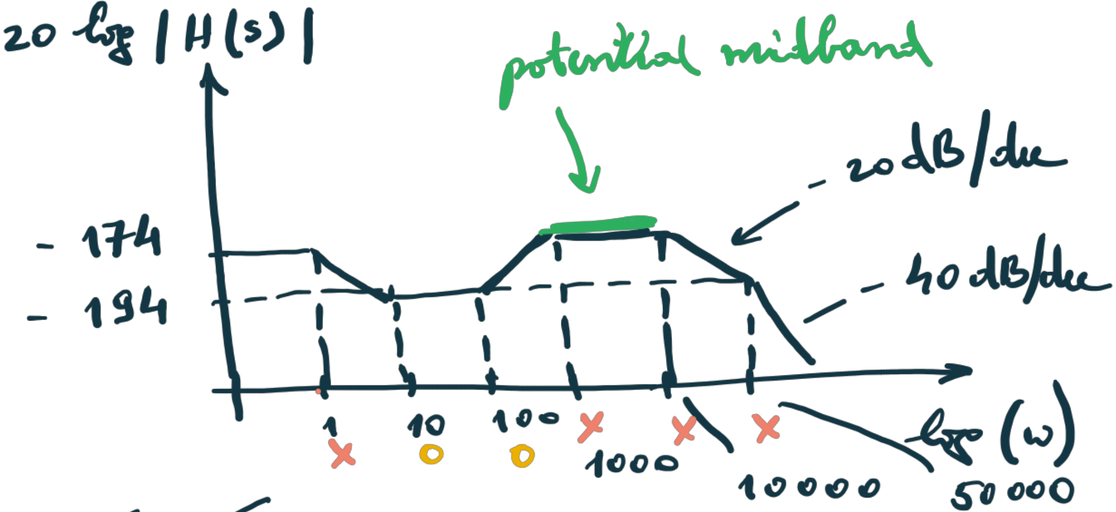
$$H(s) = \frac{(s+10)(s+100)}{(s+1)(s+1000)(s+10000)(s+50000)}$$

$p_1 = -1, \quad p_2 = -1000,$
$p_3 = -10000, \quad p_4 = -50000$

$\omega_{z1} = 10\ rad/s, \quad \omega_{z2} = 100\ rad/s$

$\omega_{p1} = 1\ rad/s, \quad \omega_{p2} = 1000, \quad \omega_{p3} = 10000\ rad/s,$
$\omega_{p4} = 50,000\ rad/s$

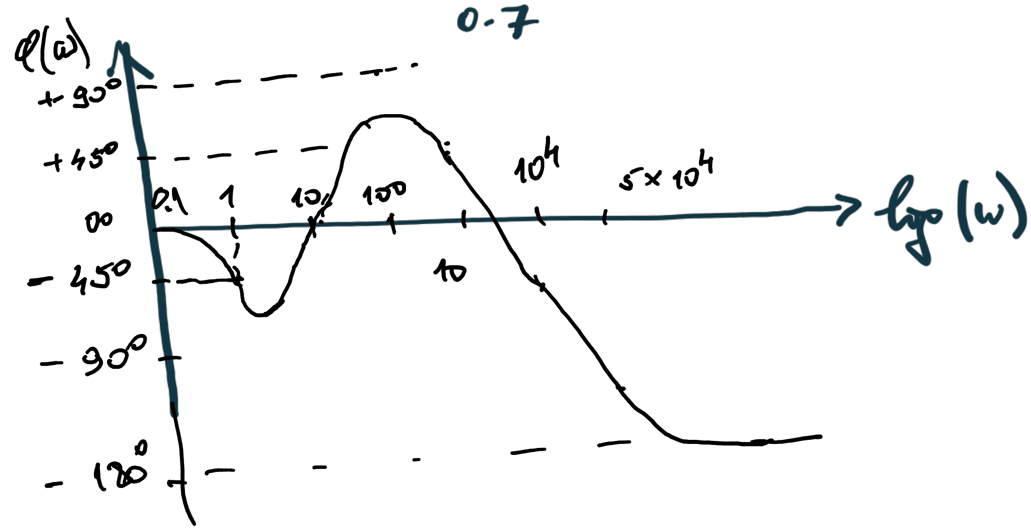
Bode plots:



$$H_{DC} = H(0) = \frac{\cancel{10 \cdot 100}}{1 \cdot \cancel{10^3} \cdot 10^4 \cdot 5 \cdot 10^4} = \frac{1}{5} \cdot 10^{-8}$$

$$20 \log |H(0)| = 20\,(-8 - \underbrace{\log_{10} 5}_{0.7}) \cong -174\,dB$$

Phase plot



(b) for $\omega \geq 10 \times 5 \cdot 10^4$, the phase shift

$$\varphi(\omega) = -180°$$

(c) Midband operation correspond to a flat region in the magnitude response.

Such a region is for $1000\, rad/s \leq \omega \leq 10000\, rad/s$

d) Max error points:

- for $|H(j\omega)| \longrightarrow$ at the critical frequencies

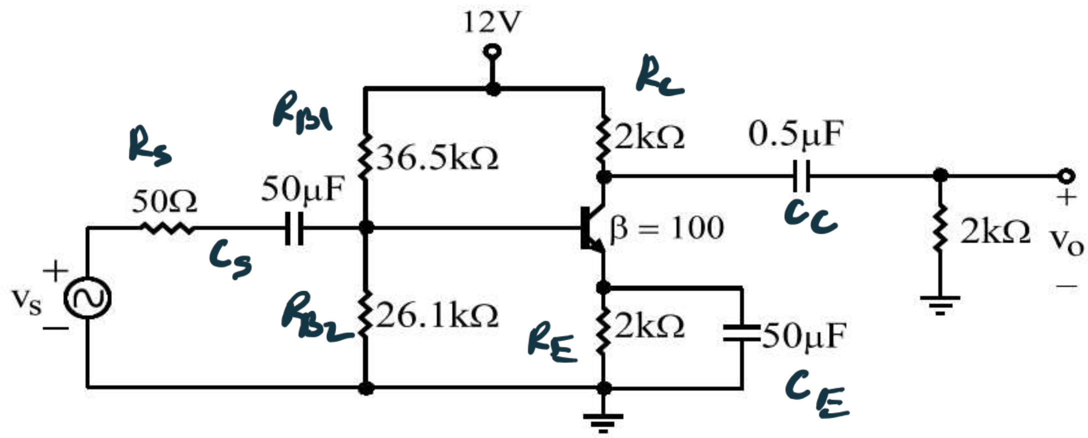
$\omega = 1, 10, 100, 1000, 10\,000, 50000\ rad/s$

– for phase $\varphi(\omega)$ – one decade below and one decade above the poles/zeros frequencies

ω = 0.1, 1, 10, 100, 1000, 5000, 10000, 100 000, 500 000 rad/s

Grading: 25p total
a) 10p - 5p Bode magnitude + 5p Bode phase
b) 5p - phase shift at very high freq = -180deg
c) 5p - identifying a flat region for midband operation
d) 5p - 2.5p for frequency values with max error on magnitude plot + 2.5p for frequency values with max error for phase plot

3) [25p] For the circuit below:



The npn transistor has the parameters β=100, C_π=10pF, C_μ=2pF, $r_o=\infty$

5p a. Determine (with approximation) the quiescent operating point of the transistor

5p b. Compute the small signal parameters and draw the small signal equivalent model

6p c. Draw the low frequency circuit, the midband circuit and the high frequency circuit

5p d. Compute the midband voltage gain v_o/v_s of the amplifier stage

4p e. Compares the advantages and disadvantages of BJT and MOS transistors. When would you prefer BJTs instead of MOS transistors?

Sol:

a) The quiescent point:

$$V_B \approx \frac{R_{B2}}{R_{B1}+R_{B2}} V_{cc} \quad \text{(assume } I_{B2} \gg I_B\text{)}$$

$$V_B = \frac{26.1}{26.1+36.5} 12V = \frac{26.1}{62.6} 12V = 0.417 \cdot 12V = 5V$$

$$I_E = \frac{V_B - 0.7V}{R_E} = \frac{4.3V}{2k\Omega} = 2.15\,mA \Rightarrow I_B = \frac{2.15\,mA}{101} = 21.3\,\mu A$$

$$I_{B2} = \frac{V_B}{R_{B2}} = \frac{5V}{26.1k\Omega} = 192\,\mu A \gg I_B = 21.3\,\mu A$$

(or otherwise you can iterate the computation, for enhanced accuracy)

$$I_C = I_E - I_B \cong 2.13\,mA$$

$$V_C = V_{cc} - R_C I_C = 12V - 2k\Omega \cdot 2.13\,mA = 12V - 4.26V = 7.74V$$

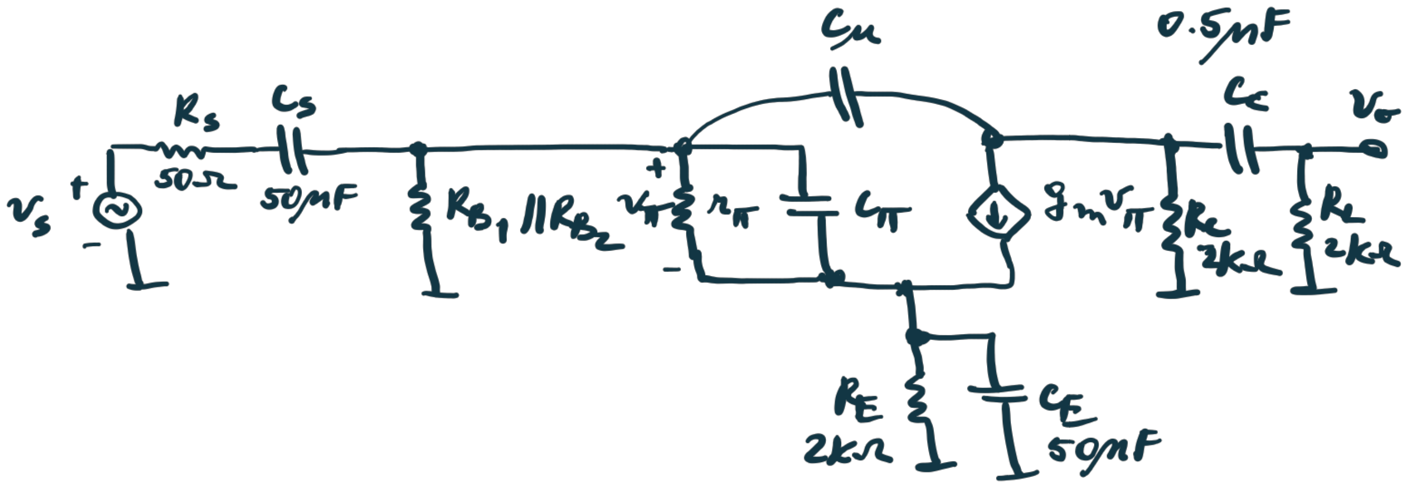
$V_C > V_B \Rightarrow$ CB junction is reversely biased $\Rightarrow$ BJT is biased in the normal active mode

$$\begin{cases} V_B = 5V,\ V_C = 7.74V,\ V_E = 4.3V,\ V_{CE} = 3.44V \\ I_C = 2.13\,mA,\ I_B = 21.3\,\mu A \end{cases}$$

b) Small signal parameters: $g_m = \frac{I_C}{V_T} \approx \frac{2.13\,mA}{25\,mV} = 85.2\,mA/V$

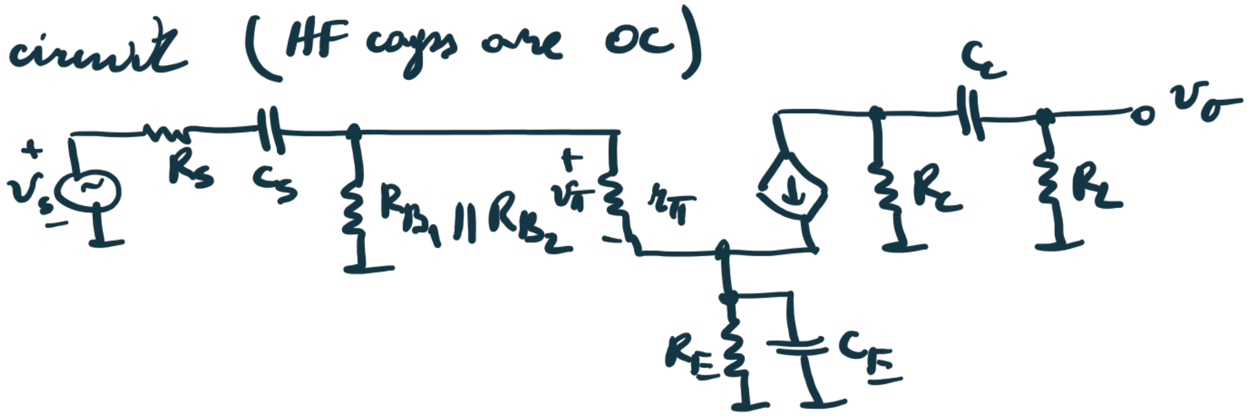
$$r_\pi = \frac{\beta}{g_m} = \frac{100}{85.2}\,k\Omega = 1.17\,k\Omega$$

The small signal equiv:

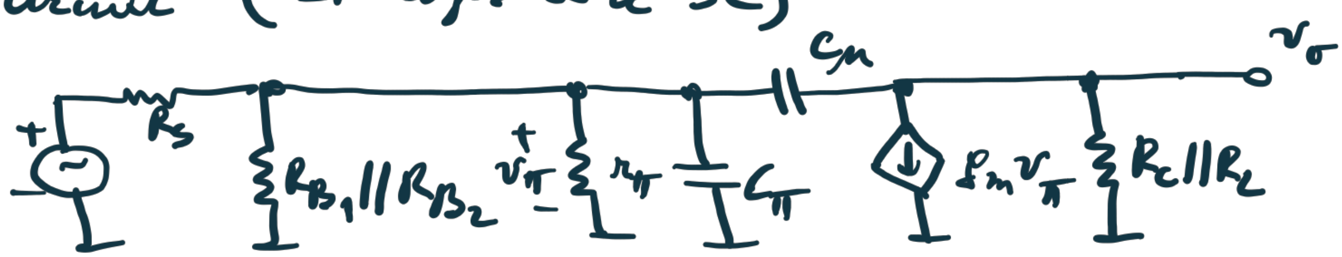


c) C_S, C_C, C_E = LF capacitors
C_π, C_μ – HF capacitors

LF circuit (HF caps are OC)



HF circuit (LF caps are SC)



Midband small signal circuit

Midband voltage gain:

$$v_o = -g_m v_\pi R_C // R_L = -g_m (R_C // R_L) \cdot \frac{r_\pi // \overbrace{R_{B1} // R_{B2}}^{R_{BB}}}{R_S + r_\pi // R_{B1} // R_{B2}} v_s$$

$$A_v = \frac{v_o}{v_s} = -g_m (R_C // R_L) \frac{r_\pi // R_{BB}}{R_S + r_\pi // R_{BB}}$$

$$R_C // R_L = 2k\Omega // 2k\Omega = 1k\Omega$$

$$r_\pi = 1.17 k\Omega$$

$$g_m = 85.2 \, mA/V$$

$$R_{BB} = R_{B1} // R_{B2} = 36.5k\Omega // 26.1k\Omega = \frac{36.5 \times 26.1}{62.6} k\Omega$$

$$= 15.22 k\Omega$$

$$r_\pi // R_{BB} = 1.17k\Omega // 15.22k\Omega \approx r_\pi$$

$$\frac{1.17 \cdot 15.22}{16.39} = 1.09 k\Omega$$

$$A_v = \frac{v_o}{v_s} = -85.2 \cdot 10^{-3} \Omega^{-1} \cdot 10^{3} \Omega \cdot \frac{1.09}{0.05 + 1.09}$$

$$A_v = -85.2 \cdot \frac{1.09}{1.14} = -85.2 \cdot 0.96 = -81.5$$

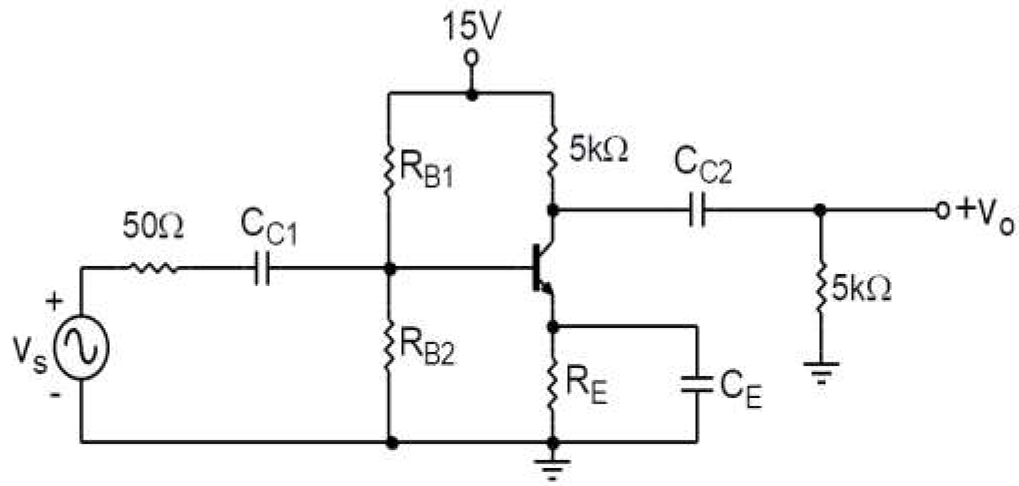
(e) BJT vs MOS transistors

- BJT can provide higher (current) gains
  + lower noise levels for low frequency
- MOS provide much higher input impedance

BJT are for instance preferred for high-power output stages (e.g. class B output audio stages)
(they can also have lower output impedance

Grading: 25p in total
a)5p - quiescent operating point: IC, VCE, IB
b) 5p - small signal model and parameters
c) 6p - 2p (LF circuit), 2p (midband circuit), 2p (HF circuit)
d) 5p Av in midband
e) 4p - BJT vs MOS

4) [25p] For the circuit shown in the figure, the transistor has the parameters β=100, $r_o=\infty$:



7.5p a. Use one of the 1/3rd rules to bias the circuit and determine the values for R_{B1}, R_{B2}, R_E
10p b. Determine the midband voltage gain, with and without the capacitor C_E being present
7.5p c. Determine the input and output impedances of the amplifier stage in the midband range, with and without C_E.

Sol:

first $\frac{1}{3}$ rule:

$V_B = \frac{1}{3} V_{cc}$

$V_C = \frac{2}{3} V_{cc}$

$I_1 = \frac{I_E}{\sqrt{\beta}}$ or $I_1 = 0.1 I_E$

2nd $\frac{1}{3}$ rule:

$V_E = \frac{1}{3} V_{cc}$

$V_C = \frac{2}{3} V_{cc}$

$I_1 = \frac{I_E}{\sqrt{\beta}}$ or $I_1 = 0.1 I_E$

Choose for instance the 2nd form of 1/3 rule:

$V_E = \frac{1}{3} V_{cc} = 5V \implies V_B = 5.7V \quad (V_{BE} \approx 0.7V)$

$V_C = \frac{2}{3} V_{cc} = 10V$, $V_{CE} = 5V$

Select I_C to achieve a desired g_m $\left(g_m = \frac{I_C}{V_T} = \frac{I_C}{25mV}\right)$

In our case $R_C = 5k\Omega \implies I_C = \frac{5V}{5k\Omega} = 1mA$

$g_m = \frac{I_C}{V_T} = \frac{1000}{25}$ mA/V

$\boxed{g_m = 40\ mA/V}$

$I_E \approx I_C = 1mA$

$I_B = \frac{1mA}{100} = 10\mu A$

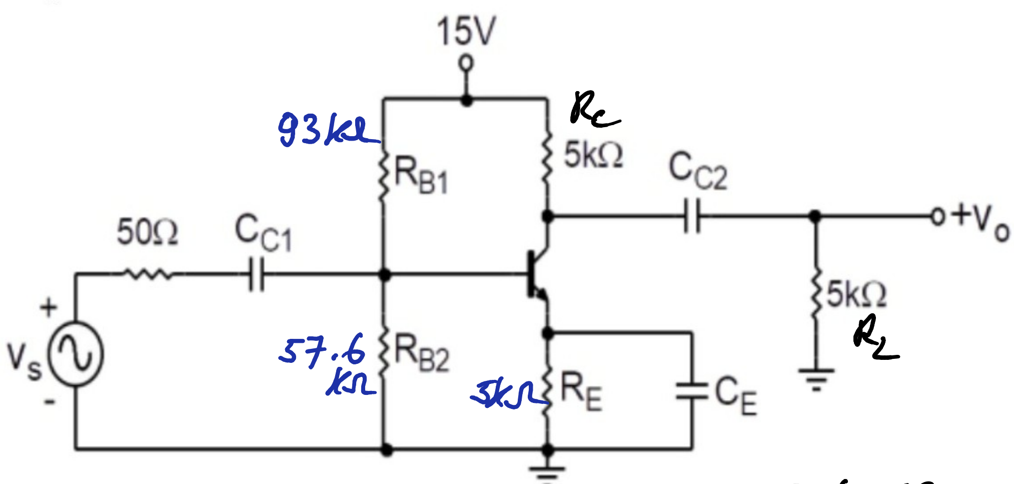
$$V_E = \frac{1}{3} V_{cc} = 5V \Rightarrow R_E \approx R_C = 5k\Omega$$

set $I_1 = 0.1\, I_E = 0.1\,mA$

$$R_{B1} = \frac{V_{cc} - V_B}{I_1} = \frac{15V - 5.7V}{0.1\,mA} = \frac{9.3\,V}{0.1\,mA} = 93\,k\Omega$$

$$R_{B2} = \frac{V_B}{I_1 - I_B} = \frac{5.7V}{0.1\,mA - 0.01\,mA} = \frac{5.7V}{0.099\,A} = 57.6\,k\Omega$$

$r_o = \infty$:

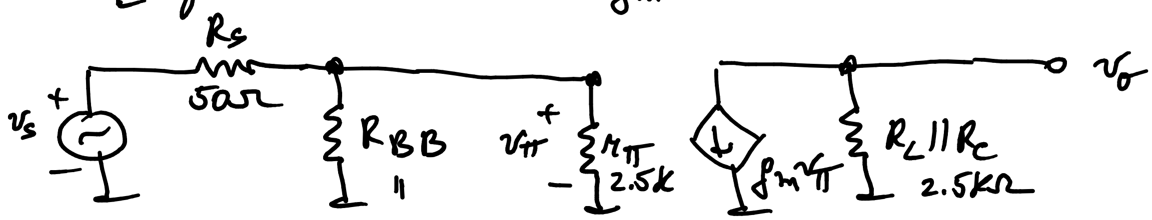


$$R_{BB} = R_{B1} \,//\, R_{B2} = \frac{57.6 \times 93}{150.6} = 35.6k\Omega$$

(b) Midband gain

with C_E present:

$$r_\pi = \frac{\beta}{g_m} = \frac{100}{40} \cdot 10^3\,\Omega = 2.5k\Omega$$



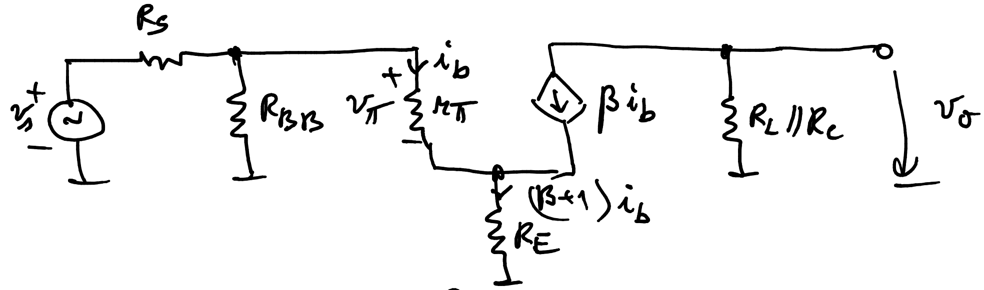
$$R_{B1} \,//\, R_{B2} = 35.6k\Omega$$

$$v_o = -g_m (R_L // R_c)\, v_\pi = -g_m (R_L // R_c) \cdot \frac{r_\pi // R_{BB}}{R_s + r_\pi // R_{BB}}\, v_s$$

$$A_v \Big|_{C_E \to \infty} = -g_m (R_L // R_c) \frac{r_\pi // R_{BB}}{R_s + (r_\pi // R_{BB})}$$

$$A_v = -40 \cdot 10^{-3} \cdot 2.5 \cdot 10^{3} \cdot \frac{2.5k // 35.6k}{50 + 2.5k // 35.6k} \approx -100\ V/V$$

Without C_E



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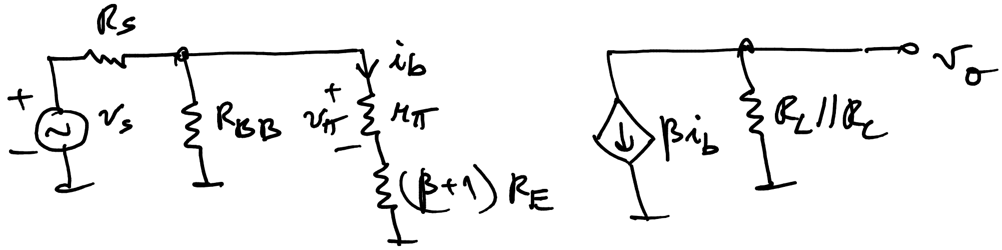
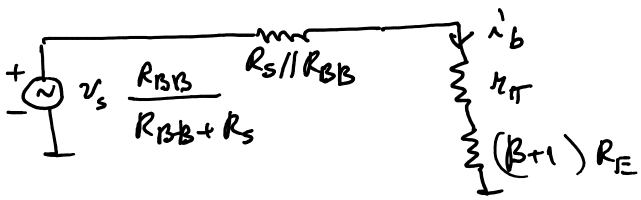


$$v_o = -\beta (R_L // R_C)\, i_b$$



$$i_b = v_s \frac{R_{BB}}{R_{BB}+R_S} \cdot \frac{1}{R_S \| R_{BB} + r_\pi + (\beta+1) R_E}$$

$$v_o\Big|_{R_E} = -\beta (R_L // R_C) \frac{R_{BB}}{R_{BB}+R_S} \cdot \frac{1}{R_S \| R_{BB} + r_\pi + (\beta+1) R_E} v_s$$

$$A_v\Big|_{C_E \to 0} = -\underbrace{\beta}_{100} \underbrace{(R_L \| R_C)}_{2.5k\Omega} \underbrace{\frac{R_{BB}}{R_{BB}+R_S}}_{\frac{35.6k\Omega}{35.6k\Omega+50\Omega} \approx 1} \frac{1}{R_S \| R_{BB} + r_\pi + (\beta+1) R_E}$$

$$\frac{1}{35.6k\Omega + 2.5k\Omega + 101 \cdot 5k\Omega}$$

$$A_v\Big|_{C_E \to 0} = -100 \cdot \frac{2.5}{505 + 35.6 + 2.5} = -100 \frac{2.5}{543.1} = -0.5$$

(c) R_{in}, R_{out} :

(c1) $C_E \to \infty \Rightarrow R_{in} = R_{BB} // r_\pi = 35.6k\Omega // 2.5k\Omega \approx r_\pi = 2.5k\Omega$

$R_{out} = R_C$ (not including R_L) $= 5k\Omega$

(c2) $C_E \to 0 \Rightarrow R_{in} = R_{BB} // (r_\pi + (\beta+1) R_E) = 35.6k\Omega // 507.5k\Omega \approx R_{BB}$

$= 35.6\,k\Omega$

Grading: 25p in total

a) 7.5p - bias computation - 2.5p for each RE, RB1, RB2
b) 10p - 5p Av with CE + 5p Av without CE
c) 7.5p - 3p Rin,Rout with CE, 4.5p Rin, Rout without CE