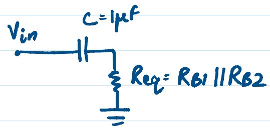
HW2

12 April 2020 02:36 PM

① $V_{CC} = 5V$, $C = 1\mu F$, $\beta = 100$

ⓐ $V_B = 1V$, $f_{3dB} = 10Hz$



$$f_{3dB} = \frac{1}{2\pi R_{eq} C}$$

$$R_{eq} = \frac{1}{2\pi \times 10 \times 1\mu F} = 15.915 K\Omega = \frac{R_{B1} R_{B2}}{R_{B1}+R_{B2}} \quad \text{——} (1)$$

$$V_B = V_{CC}\left(\frac{R_{B2}}{R_{B2}+R_{B1}}\right)$$

$$\Rightarrow \frac{R_{B2}}{R_{B2}+R_{B1}} = \frac{1}{5} \quad \text{——} (2)$$

Choose $R_{B1} = 80K\Omega$, $R_{B2} = 20K\Omega$

$\Rightarrow R_{eq} = 16K\Omega \Rightarrow f_{3dB} < 10Hz$

ⓑ For Simplified model $V_{BE} = 0.6V$, $I_C = 1mA$

$$I_E = I_C + \frac{I_C}{\beta} = I_C\left(1+\frac{1}{\beta}\right)$$

$$I_E = 1m\left(1+\frac{1}{100}\right)$$

$$I_E = \underline{\underline{1.01mA}}$$

$$V_E = V_B - V_{BE} = 1 - 0.6V = \underline{\underline{0.4V}}$$

$$R_E = \frac{V_E}{I_E} = \frac{0.4}{1.01m} = \underline{\underline{396\Omega}}$$

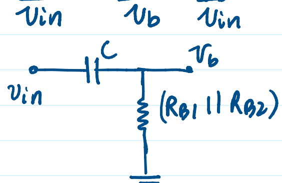
$$a_v = -\frac{R_C}{R_E} = -10V/V \Rightarrow \underline{\underline{R_C = 3.96K\Omega}}$$

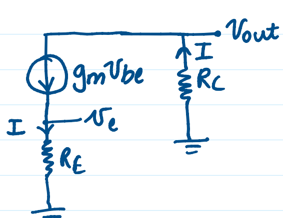
$$V_{CE} = V_{CC} - I_C R_C - I_E R_E$$

$$= 5 - 3.96 - 1.01(396)$$

$$\underline{\underline{V_{CE} = 0.64V}}$$

ⓒ $$\frac{v_{out}}{v_{in}} = \frac{v_{out}}{v_b} \cdot \frac{v_b}{v_{in}}$$





$$\frac{v_b}{v_{in}} = \frac{(R_{B1} \| R_{B2})}{(R_{B1} \| R_{B2}) + \left(\frac{1}{sC}\right)}$$

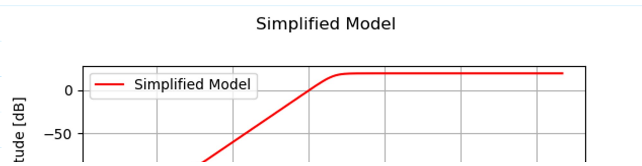
$$I = -\frac{v_{out}}{R_C} = \frac{v_e}{R_E}$$

$$v_e = -v_{out}\frac{R_E}{R_C} \quad \text{——} (2)$$

$$\frac{v_b}{v_{in}} = \frac{j\omega C (R_{B1} \| R_{B2})}{1 + j\omega C (R_{B1} \| R_{B2})} \quad \text{——} (1)$$

$$g_m v_{be} = -\frac{v_{out}}{R_C}$$

$$g_m\left(v_b + v_{out}\frac{R_E}{R_C}\right) = -\frac{v_{out}}{R_C}$$



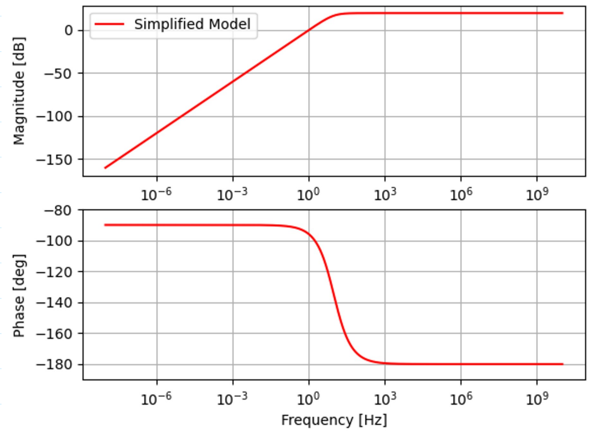
$$g_m v_{be} = -\frac{V_{out}}{R_C}$$

$$g_m\left(v_b + V_{out}\frac{R_E}{R_C}\right) = -\frac{V_{out}}{R_C}$$

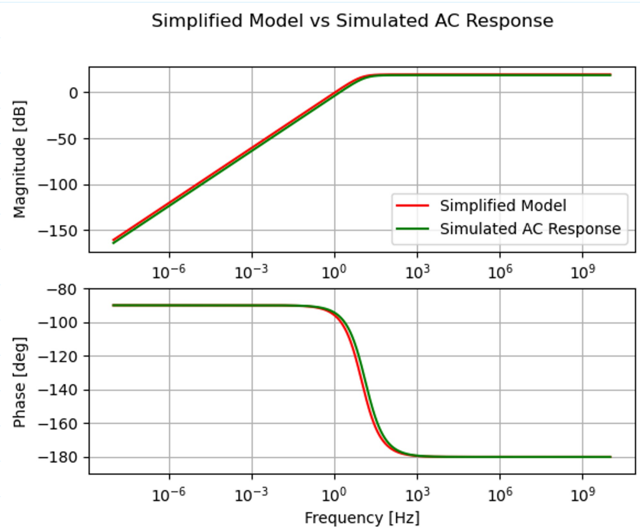
$$g_m v_b = V_{out}\left[g_m\frac{R_E}{R_C} - \frac{1}{R_C}\right]$$

$$\frac{V_{out}}{v_b} = -\frac{1}{\frac{R_E}{R_C} + \frac{1}{R_C g_m}} \Rightarrow \frac{V_{out}}{v_b} = -\frac{R_C}{\frac{1}{g_m} + R_E} \quad \text{—— (3)}$$

$$\frac{V_{out}}{V_{in}} = -\frac{j\omega C(R_{B1} \| R_{B2})}{1 + j\omega C(R_{B1} \| R_{B2})} \cdot \frac{R_C}{\left(\frac{1}{g_m} + R_E\right)} \quad \text{—— (4)}$$



(d)



i) Simplified Model appears to have a higher gain & lower cutoff frequency

One of the reasons is due to the presence of finite input resistance at the base of the BJT.
Also the Base emitter junction is assumed to be a constant (0.6V) which is not the case for a real BJT.
These two factors have introduced error into our estimations.

(2) $V_{CC} = 5V$, $I_S = 10^{-16}$, $\beta = 100$

a) $V_{in} = ?$ $R_E = ?$ $I_C = 1mA$ $V_{out} = 1V$

$$I_E = I_C\left(1 + \frac{1}{\beta}\right)$$

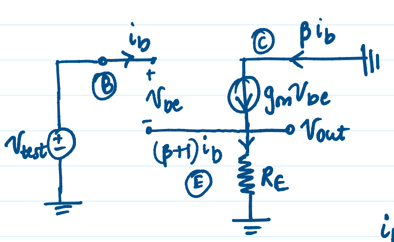
$$I_E = 1m\left(1 + \frac{1}{100}\right) \Rightarrow \underline{I_E = 1.01mA}$$

$$R_E = \frac{V_{out}}{I_E} = \frac{1}{1.01m} = \underline{990.1\Omega}$$

$$V_{BE} = V_T \ln\frac{I_C}{I_S} = 25.85m \cdot \ln\frac{10^{-3}}{10^{-16}} = \underline{0.7738V}$$

$$V_{in} = V_{BE} + V_{out} = 0.7738 + 1 = \underline{1.7738V}$$

(b)



Input Impedance

$$R_{in} = \frac{V_{test}}{i_{test}}$$

$i_b = i_{test}$ & $V_{test} = V_{be} + V_{out}$

$$g_m V_{be} = \beta i_b$$

$i_b = i_{test}$ & $V_{test} = V_{be} + V_{out}$

$g_m V_{be} = \beta i_b$

$g_m (V_{test} - V_{out}) = \beta i_{test}$ & $V_{out} = (\beta+1) i_b R_E$

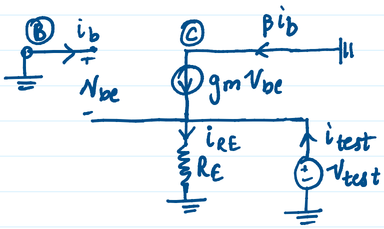
$g_m (V_{test} - (\beta+1) i_b R_E) = \beta i_{test}$

$g_m V_{test} = \beta i_{test} + (\beta+1) i_{test} R_E g_m$

$$R_{in} = \frac{V_{test}}{i_{test}} = \underline{\underline{\frac{\beta}{g_m} + (\beta+1) R_E}} = 100(25.85) + (101)(990.1)$$

$$= \underline{\underline{102.585\,K\Omega}}$$

ⓒ



$V_{be} = -V_{test}$ —①

$g_m V_{be} = \beta i_b$

$-g_m V_{test} = \beta i_b$

$\Rightarrow i_b = -\frac{g_m V_{test}}{\beta}$ —①

$\frac{V_{test}}{R_E} = i_{RE}$

$\frac{V_{test}}{R_E} = (\beta+1) i_b + i_{test}$

$\frac{V_{test}}{R_E} = (\beta+1)\left(\frac{-g_m V_{test}}{\beta}\right) + i_{test}$

$V_{test}\left[\frac{1}{R_E} + \left(\frac{\beta+1}{\beta}\right) g_m\right] = i_{test}$

$\frac{\beta+1}{\beta} = 1 + \frac{1}{\beta} \approx 1$

$R_O = \frac{V_{test}}{i_{test}} = \frac{1}{\frac{1}{R_E} + g_m}$

$$\Rightarrow \underline{\underline{R_O = R_E \parallel \frac{1}{g_m}}} = \frac{990.1 \times 25.85}{990.1 + 25.85} = \underline{\underline{25.192\,\Omega}}$$

ⓓ 1. DC Simulation results

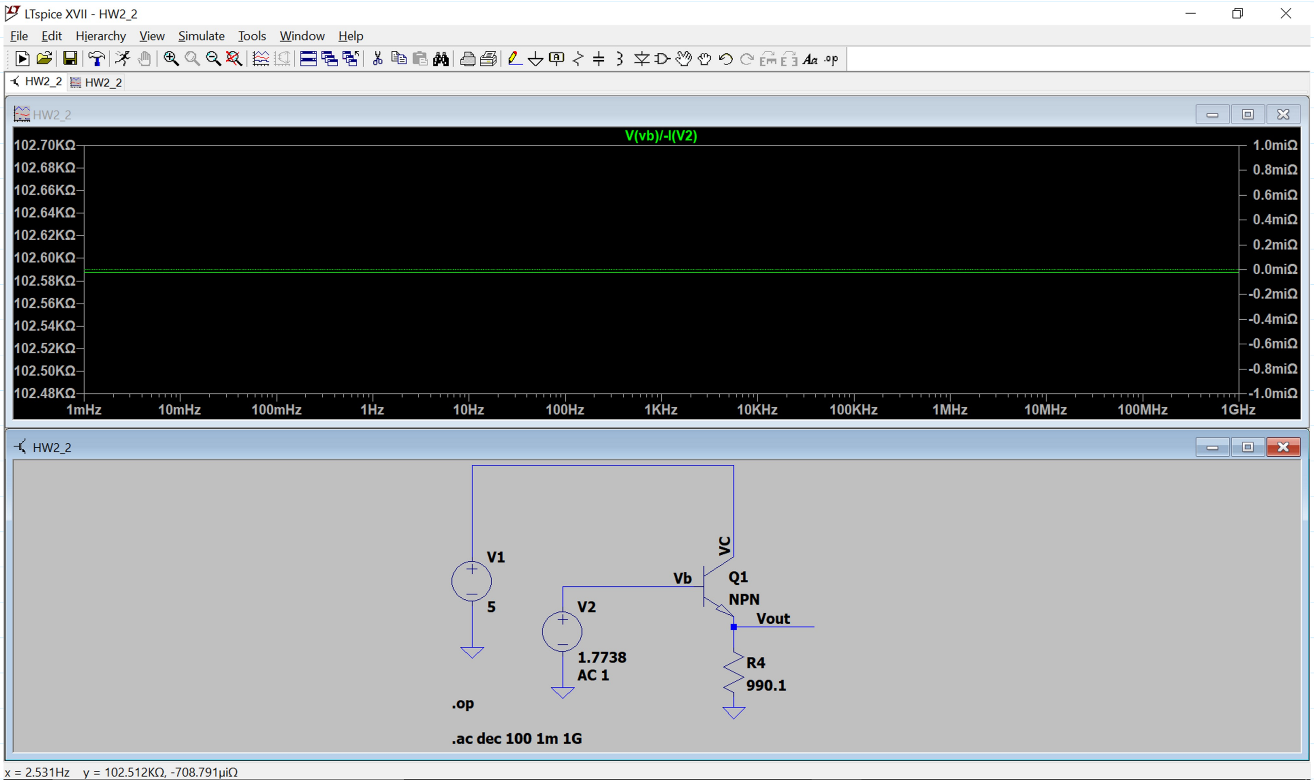
```
* D:\OneDrive - UW\School\UDub\2020 Q3\EE 538\HW\HW2\LTspice\HW2_2.asc
       --- Operating Point ---

V(vout):        0.999579       voltage
V(vc):          5              voltage
V(vb):          1.7738         voltage
Ic(Q1):         0.000999583    device_current
Ib(Q1):         9.99582e-06    device_current
Ie(Q1):         -0.00100958    device_current
I(I1):          0              device_current
I(R4):          0.00100957     device_current
I(V2):          -9.99578e-06   device_current
I(V1):          -0.000999579   device_current
```

Simulation Result

$I_C = 0.999\,mA$ (0.1% error)

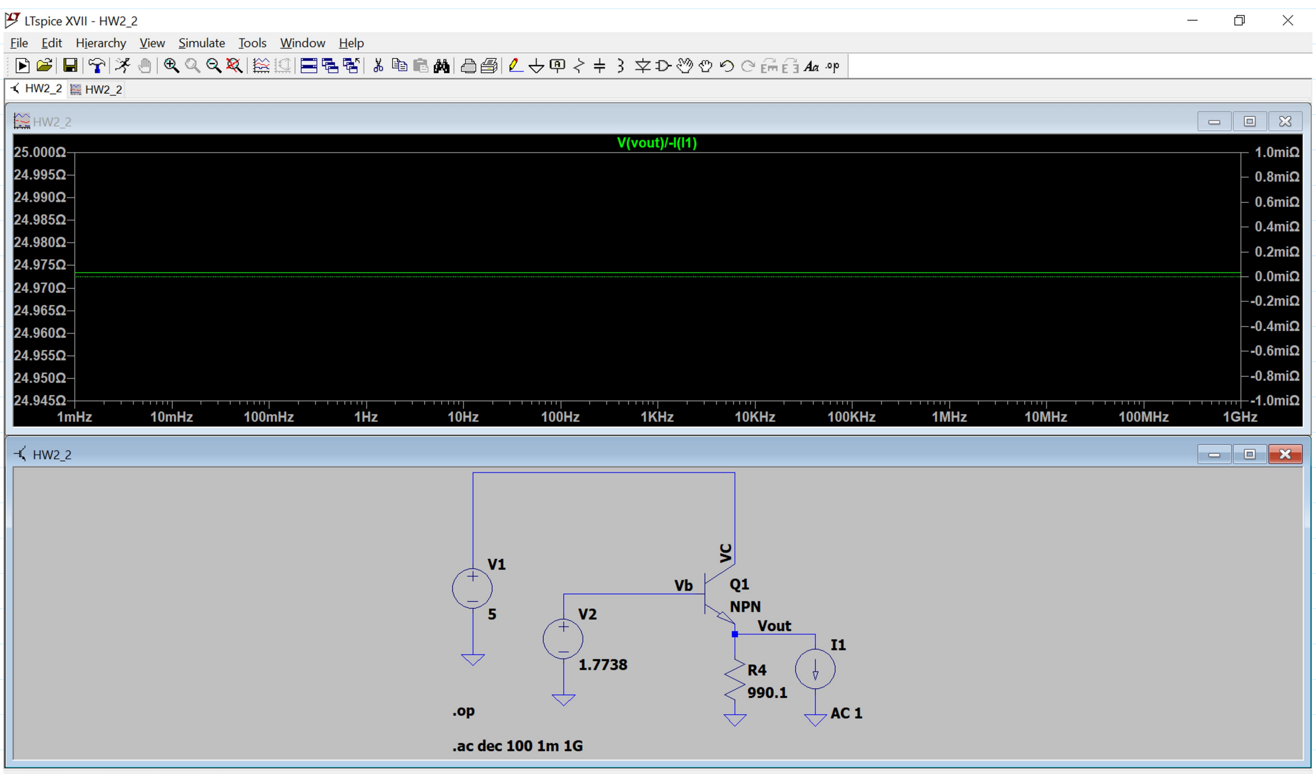
$V_{out} = 0.999\,V$ (0.1% error)

2. Input Resistance



Input resistance = 102·512KΩ $\left(\text{error} = \frac{102585 - 102512}{102585} \cdot 100\% = 0.07\%\right)$

3. Output resistance



output resistance = 24.956Ω $\left(\text{error} = \frac{25.192 - 24.956}{25.192} \times 100\% = 0.93\% \right)$