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Amplifier frequency response
Tutorial 6

1) At sufficiently high frequencies, the capacitive reactances of the coupling capacitors are very small according to the formula $X_C = \frac{1}{2\pi f C}$. That is why, the coupling capacitors do not have a significant effect on gain and they appear effectively as short circuits.

2) At lower frequencies, the reactance is greater, and it decreases as the frequency increases. At low frequencies, capacitively coupled amplifiers have less voltage gain than they have at higher frequencies. The reason is that at lower frequencies more signal voltage is dropped across C_1 and C_3 (coupling capacitors) because their reactances are higher. This higher signal voltage drop at lower frequencies reduces the voltage gain. Also, a phase shift is introduced by the coupling capacitors because C_1 forms a lead circuit with the R_{in} of the amplifier and C_3 forms a lead circuit with R_L in series with R_C or R_D. At lower frequencies, the reactance of bypass capacitor, C_2, becomes significant and emitter is no longer at AC ground. The capacitive reactance X_{C_2} in parallel with R_E creates an impedance that reduces the gain.

3) a) $f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi \cdot (100\,\Omega) \cdot (5\,\mu F)} = 318.3$ Hz.

b) $f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi \cdot (1\,k\Omega) \cdot (0.1\,\mu F)} = 1591.5$ Hz.

4) $A_{p(dB)} = 10 \log \left(\frac{P_{out}}{P_{in}} \right) = 10 \log 10 = 10$ dB

5) $V_{in} = \frac{V_{out}}{A_v} = \frac{1.2\,V_{rms}}{50} = 24\ m\,V_{rms}$

$A_{v(dB)} = 20 \log (A_v) = 20 \log 50 = 33.98$ dB

6) a) $10 \log \left(\frac{2\,mW}{1\,mW} \right) = 3.01$ dBm

b) $10 \log \left(\frac{1\,mW}{1\,mW} \right) = 0$ dBm

c) $10 \log \left(\frac{4\,mW}{1\,mW} \right) = 6.02$ dBm

d) $10 \log \left(\frac{0.25\,mW}{1\,mW} \right) = -6.02$ dBm

7) $\theta = \tan^{-1} \left(\frac{X_{C1}}{R_{in}} \right) = \tan^{-1} \left(\frac{0.5\,R_{in}}{R_{in}} \right) = \tan^{-1} (0.5) = 26.57$ degree

8) $$V_E = \left(\frac{R_2}{R_1+R_2}\right)V_{CC} - 0.7V = \left(\frac{4.7k\Omega}{37.7k\Omega}\right)\cdot 20V - 0.7V = 1.79\ V$$

$$I_E = \frac{V_E}{R_E} = \frac{1.79V}{560\ \Omega} = 3.2\ mA$$

$$r_e' = \frac{25\ mV}{3.2\ mA} = 7.8\ \Omega$$

$$R_c = R_C \| R_L = \frac{2.2 \cdot 5.6}{7.8} = 1.58\ k\Omega$$

$$A_v = \frac{R_c}{r_e'} = \frac{1.58k\Omega}{7.8} = 202.56$$

$$C_{in(miller)} = C_{bc}\cdot(A_v+1) = 814.24\ pF$$

$$C_{out(miller)} = C_{bc}\cdot\left(\frac{A_v+1}{A_v}\right) = 4.02\ pF$$

9)

$$R_{in} = R_1 \| R_2 \| \beta \cdot r_e' = 910.9\ \Omega$$

$$f_{cl(input)} = \frac{1}{2\pi\cdot(R_s+R_{in})\cdot C_1} = \frac{1}{2\pi\cdot(50+910.9)\Omega\cdot 0.1\mu F} = 1656.3\ Hz$$

$$f_{cl(output)} = \frac{1}{2\pi(R_c+R_L)\cdot C_3} = \frac{1}{2\pi\cdot(2.2+5.6)k\Omega\cdot 0.1\mu F} = 204.04\ Hz$$

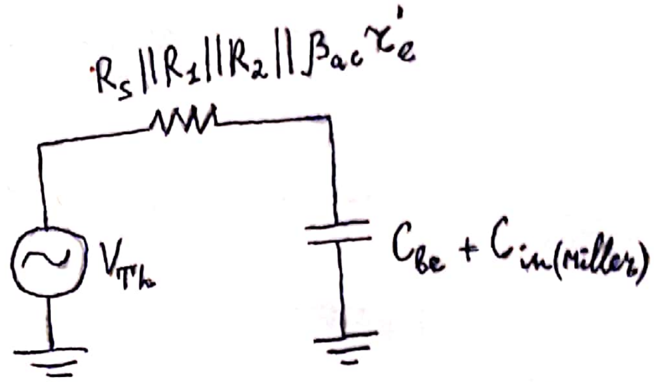
10) $R_{in(gate)} = \left| \frac{V_{GS}}{I_{GSS}} \right| = \left| \frac{-10V}{50\,nA} \right| = 200\,M\Omega$

$R_{in} = R_G \| R_{in\,(gate)} = 10M\Omega \| 200M\Omega = 9.52\,M\Omega$

$f_{cl\,(input)} = \frac{1}{2\pi R_{in} \cdot C_1} = \frac{1}{2\pi \cdot (9.52M\Omega) \cdot 0.005\,\mu F} = 3.35\,Hz$

$f_{cl\,(output)} = \frac{1}{2\pi \cdot (R_D + R_L) \cdot C_2} = \frac{1}{2\pi \cdot (560\Omega + 10k\Omega) \cdot 0.005\,\mu F} = 3.016\,kHz$

11) $V_B = \left(\frac{R_2}{R_1+R_2}\right) \cdot V_{CC} = \left(\frac{4.7k\Omega}{26.7k\Omega}\right) \cdot 10V = 1.76V$



Equivalent high-frequency input RC circuit

$V_E = V_B - 0.7V = 1.06V$

$I_E = \frac{V_E}{R_E} = \frac{1.06V}{470\Omega} = 2.26\,mA$

$r'_e = \frac{25mV}{I_E} = 11.1\,\Omega$

$R_{in\,(tot)} = R_S \| R_1 \| R_2 \| \beta_{ac} \cdot r'_e = 378\,\Omega$

$C_{in\,(Miller)} = C_{bc} \cdot \left(\frac{R_C \| R_L}{r'_e} + 1 \right) = 240\,pF$

$C_{in\,(tot)} = C_{in\,(Miller)} + C_{be} = 240pF + 20pF = 260\,pF$

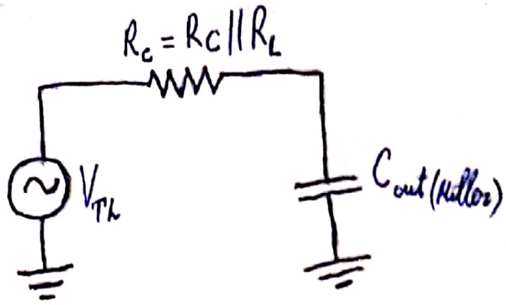
$f_{cu\,(input)} = \frac{1}{2\pi \cdot R_{in(tot)} \cdot C_{in(tot)}} = \frac{1}{2\pi \cdot 378\Omega \cdot 260pF} = 1.62\,MHz$

$A_{v(mid)} = \frac{R_c}{r'_e} = \frac{R_C \| R_L}{r'_e} = 99$

$C_{out\,(Miller)} = C_{bc} \cdot \left(\frac{A_v + 1}{A_v} \right) = 2.42\,pF$

$R_c = R_C \| R_L = 1.1\,k\Omega$

$f_{cu\,(output)} = \frac{1}{2\pi \cdot R_c \cdot C_{out(Miller)}} = 60\,MHz.$



Equivalent high-frequency output RC circuit.