HW#3 Solutions 2008
EE 411/511

1) a) The transistor is an ideal NPN \( \Rightarrow C_{bc} = 0, C_{be} = 0 \)

Since \( C_1, C_2 \) and \( C_3 \) are very large they do not affect the upper cutoff frequency and will be short circuited as mentioned in Open-Circuit finite constants method.

\[
\begin{align*}
L = 0 & \Rightarrow X_{C_L} = 1k\Omega / 33k\Omega \\
& = 1k\Omega \\
X_{C_L} & = R_{C_L} \cdot C_L \\
& = 16\mu F
\end{align*}
\]

\[
W_{h,est} = \frac{1}{X_{C_L}} \Rightarrow W_{h,est} = \frac{1}{16 \times 10^{-6}} = 62,500 \text{ sec}^{-1}
\]

\[
\Phi_{n,est} = 9.95 \text{ MHz}
\]

b) In order to extend the upper cutoff frequency, short peaking technique is utilized for this amplifier.

The impedance of the RLC network can be written as:

\[
Z(s) = \frac{(sL + 1k)}{1} || \frac{33k}{sC} = \frac{(sL + 1k)}{1} || \frac{33k}{sC}
\]

assuming that \( 33k \) is large compared to \((sL + 1k)\)

Now, as explained in Section 8.2.1 of the course book, an expression for \( \frac{W_{h,new}}{W_{h,old}} \) can be derived from this impedance \( Z(s) \):

\[
\frac{W_{h,new}}{W_{h,old}} = \sqrt{\left(\frac{-m^2}{2} + M + 1\right) + \sqrt{\left(\frac{-m^2}{2} + M + 1\right)^2 + m^2}} \text{, where } M = \frac{RC}{L/R}, \quad R = 1k\Omega
\]

Then, maximum -3dB frequency \( (\Phi_{n,new}) \) is found as 1.85 times \( \Phi_{n,old} \), when \( M = \sqrt{2} \).

\[
\Rightarrow M = \frac{RC}{L/R} = 1.41 = 10^3 \times 16 \times 10^{-12} \Rightarrow L = 11.3 \mu H
\]
If we use a test voltage source to find the admittance seen by the tank circuit, we end up with an equivalent resistance in parallel with an equivalent capacitance:

\[ C_{eq} = C_{gd} \left[ 1 + \delta \left( \frac{1k\Omega}{10k\Omega/30k\Omega} \right) \right] \]

\[ = 0,1 \cdot 10^{-12} \left[ 1 + 20 \cdot 10^{-3} \cdot 882 \right] \]

\[ = 1,86 \, \text{pF} \]

\[ \Rightarrow \ C_{\text{Total}} = 11,86 \, \text{pF} \]

b) \[ C_{\text{input}} = C_{gs} + C_{gd} \left( 1 + \delta_{mRL} \right) \]

* See lecture notes (Tuned Amplifiers)

\[ = 0,2 \cdot 10^{-12} + 0,1 \cdot 10^{-12} \left( 1 + 20 \cdot 10^{-3} \cdot 882 \right) \]

\[ = 6,3 \, \text{pF} \]

C) \[ R_{cin} = 1k\Omega \parallel 10k\Omega \parallel 30k\Omega = 882 \, \Omega \]

Using Open Circuit time constants estimation:

\[ \omega_{n,\text{est}} = \frac{1}{\tau_{cin}} = \frac{1}{R_{cin} C_{in}} = \frac{1}{882 \cdot 6,3 \times 10^{-12}} = 1,8 \times 10^6 \, \text{rad/sec} \]

\[ \Rightarrow f_{n,\text{est}} = \frac{28,6 \, \text{Hz}}{2} \]