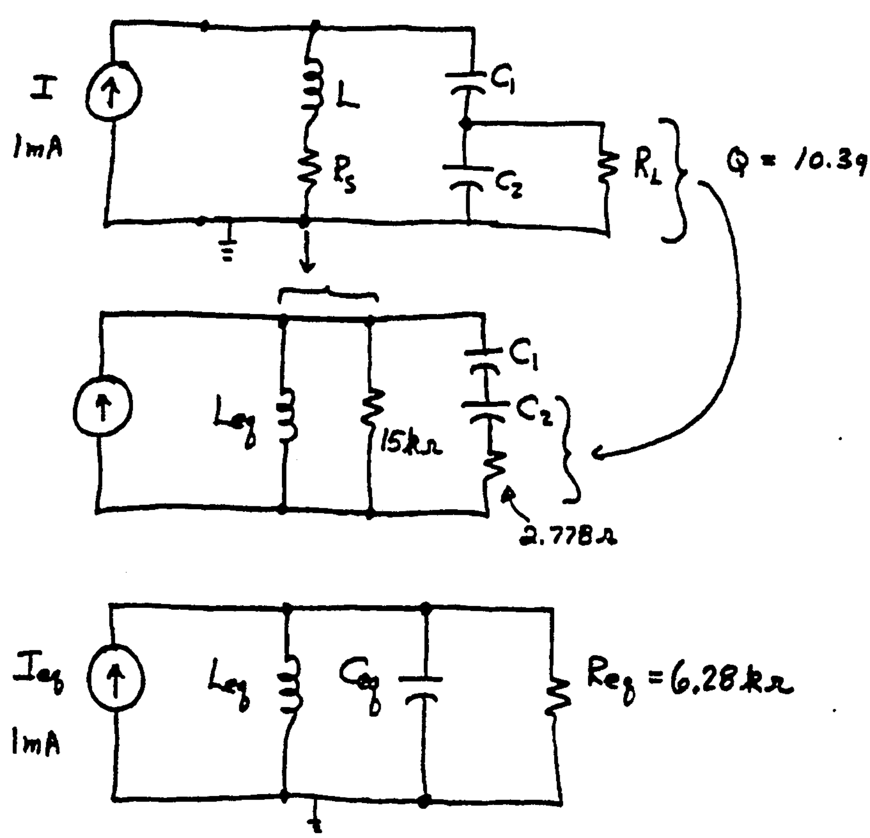
Problem 11.33

Let us assume that high-Q approximations are valid. Then $L_{eq} = L = 0.5\ \mu H$ and $C_{eq} = 1/(1/C_1 + 1/C_2) = 16.67$ pF. Also we have $f_0 = \left[2\pi\sqrt{L_{eq}C_{eq}}\right]^{-1} = 55.133$ MHz.

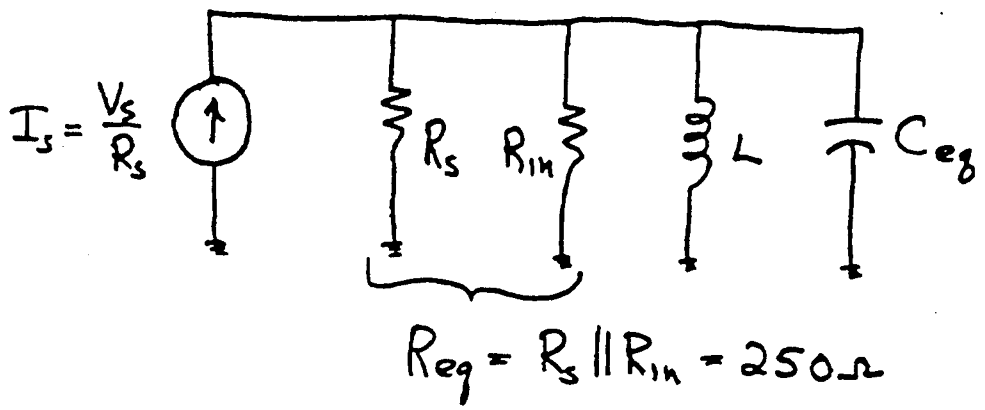


A simulation comparing the voltage across the current s in the original circuit with that of the equivalent circuit stored in the file named P11_33.

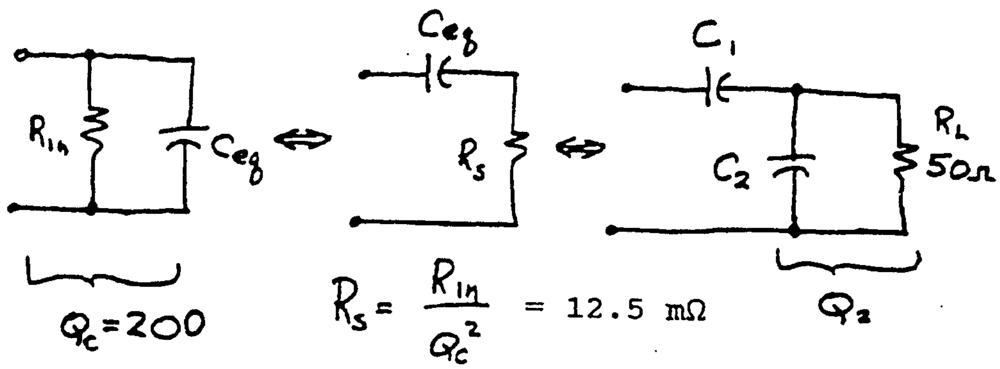
Problem 11.37

$$Q = f_0/B = (10\ \text{MHz})/(100\ \text{kHz}) = 100$$

The parallel equivalent circuit is:



$L = R_{eq}/(Q\omega_0) = 39.8$ nH $\qquad C_{eq} = \frac{1}{\omega_0^2 L} = 6364$ pF



$$R_s = \frac{R_{in}}{Q_c^2} = 12.5\ \text{m}\Omega$$

$$Q_2^2 = R_L/R_s = 63.24 = \omega_0 C_2 R_L \quad \Rightarrow \quad C_2 = 20.13\ \text{nF}$$

$$C_{eq} = \frac{1}{1/C_1 + 1/C_2} \quad \Rightarrow \quad C_1 = 9.305\ \text{nF}$$

The simulation file is P11_37.

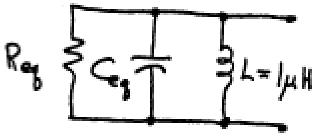
(a) $K = I_{DSS}/V_{to}^2 = (4 \times 10^{-3})/(-2)^2 = 1\ \text{mA/V}^2$

$I_{DQ} = K(V_{GSQ} - V_{to})^2 \Rightarrow V_{GSQ} = -0.585\ \text{V}$

$R_{s1} = R_{s2} = (15 + 0.585)/I_{DQ} = 7.79\ \text{k}\Omega$

Thus we choose the standard value $R_{s1} = R_{s2} = 8.2\ \text{k}\Omega$.

(b)

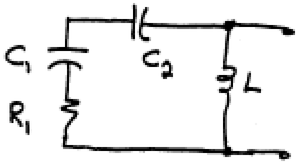


$Q = f_0/B = (10\ \text{MHz})/(500\ \text{kHz}) = 20$

$C_{eq} = 1/\omega_0^2 L = 253.3\ \text{pF}$

$R_{eq} = Q\omega_0 L = 1257\ \Omega$

$\Downarrow$



$R_1 = R_{eq}/Q^2 = 3.142\ \Omega$

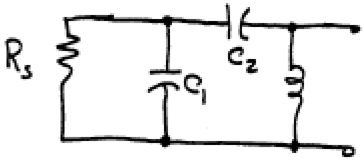
$Q_1 = 1/\omega_0 C_1 R_1 = \sqrt{R_s/R_1} = 3.99$

$C_1 = 1269\ \text{pF}$

$C_{eq} = \dfrac{1}{1/C_1 + 1/C_2}$

$C_2 = 316.43\ \text{pF}$

$\Downarrow$



(c) This part is very similar to part (b). The results are C_3 = 256.51 pF and C_4 = 20.21 nF.

(d) First we compute g_m for the transistors.

$$g_m = \frac{2\sqrt{I_{DSS} I_{DQ}}}{|V_{to}|} = 2.83\ \text{mS}$$

The voltage gain at resonance is the product of three terms:

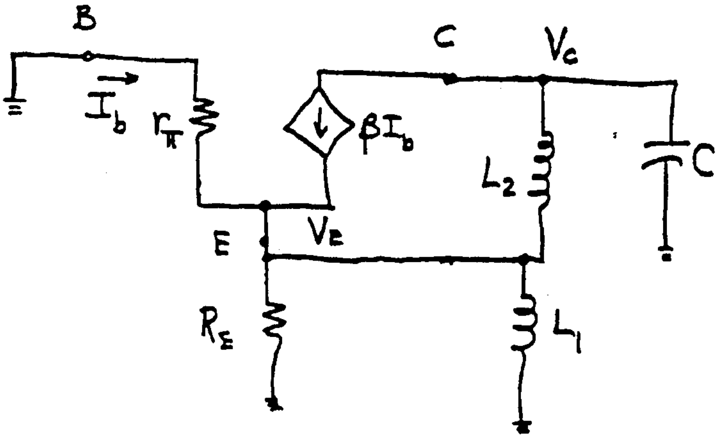
(1) voltage step up in the input circuit
(2) voltage gain of the differential pair
(3) voltage step down in the output circuit

Factors 1 and 3 offset one another and the voltage gain is

$$A_v = g_m R_{eq}/2 = 1.78$$

Problem #49

(a)



(b) Write node voltage equations:

$$\frac{V_E}{r_\pi} + \beta\frac{V_E}{r_\pi} + \frac{V_E}{R_E} + \frac{V_E}{j\omega L_1} + \frac{V_E - V_c}{j\omega L_2} = 0$$

$$-\beta\frac{V_E}{r_\pi} + \frac{V_c - V_E}{j\omega L_2} + j\omega C V_c = 0$$

$$\begin{vmatrix} \frac{1}{R_E} + \frac{\beta+1}{r_\pi} + \frac{1}{j\omega L_1} + \frac{1}{j\omega L_2} & -\frac{1}{j\omega L_2} \\ -\frac{\beta}{r_\pi} - \frac{1}{j\omega L_2} & j\omega C + \frac{1}{j\omega L_2} \end{vmatrix} = 0$$

Eventually we have:

$$\omega = \frac{1}{\sqrt{C(L_1+L_2)}} \qquad \beta_{min} = \frac{L_1}{L_2}\left(1 + \frac{r_\pi}{R_E}\right)$$

(c) Design for $\beta_{min} = 50$

$$R_E \approx \frac{V_{EE} - V_{BEQ}}{I_{CQ}} = 15\,k\Omega$$

$$r_\pi = \beta\frac{V_T}{I_{cq}} = \frac{50\,(26\,mV)}{1\,mA} = 1300\,\Omega$$

Choose $C = 270\,pF$

$$L_1 + L_2 = \frac{1}{\omega^2 C} = 93.8\,\mu H$$

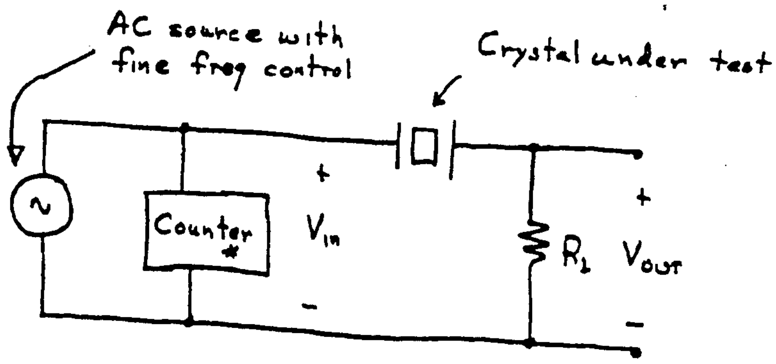
$$\frac{L_1}{L_2} = \frac{\beta_{min}}{1 + r_\pi/R_E} = 46$$

$\Rightarrow$ $L_1 = 91.8\,\mu H$, $L_2 = 2\,\mu H$

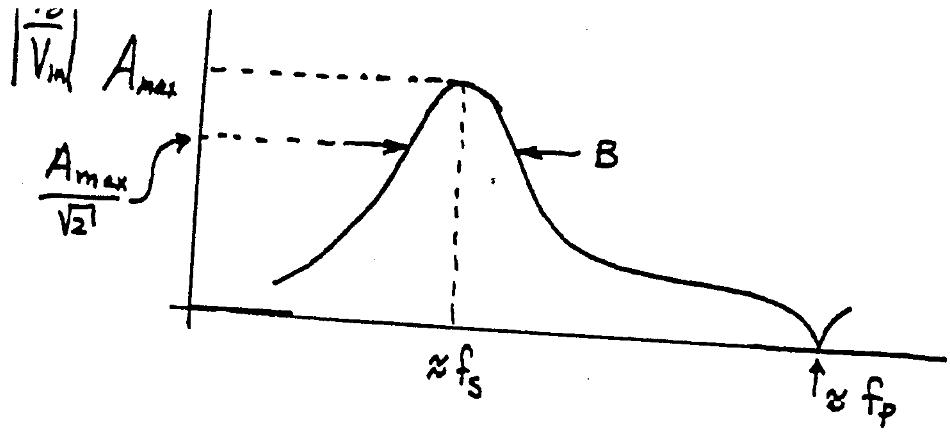
We selected $C_c = 0.01\ \mu F$ so it appears as nearly a short c
at the frequency of oscillation.

Problem 11.59

(a) Set up the system shown below.



Use the counter to accurately measure the frequency of the source. Choose $R_L \cong R_s$ of the crystal. Start with about 50 Ω and adjust as needed. Observe the voltage transfer function magnitude $|V_o/V_{in}|$ which will appear much like the sketch shown on the next page. From the plot, determine the peak A_{max}, f_s at which the transfer function peak occurs, the half-power bandwidth B of the peak, and f_p which is the frequency of the null.



Then the crystal parameters can be calculated:

$$A_{max} = \frac{R_L}{R_s + R_L} \quad \Rightarrow \quad R_s = \frac{1 - A_{max}}{A_{max}} \times R_L$$

$$Q_{circuit} = \frac{f_s}{B} = \frac{\omega_s L_s}{R_s + R_L} = \frac{1}{\omega C_s (R_s + R_L)}$$

$$L_s = \frac{(R_s + R_L) Q_{circuit}}{\omega_s}$$

$$C_s = \frac{1}{\omega_s Q_{circuit} (R_s + R_L)}$$

$$Q = \frac{\omega_s L_s}{R_s}$$

(b) Given $f_s = 1.000000$ MHz, $f_p = 1.000500$ MHz, $R_s = 300\ \Omega$ $= 10{,}000$ we have:

$$L_s = R_s Q / \omega_s = 477.465 \text{ mH}$$

$$C_s = 1/(Q \omega_s R_s) = 53.0516 \times 10^{-15} \text{ F}$$

Let $C_{eq} = \frac{1}{1/C_s + 1/C_p}$ denote the parallel equivalent capacitance. Then we have:

$$C_{eq} = \frac{1}{\omega_p^2 L_s}$$

$$= 52.9986 \times 10^{-15} \text{ F}$$

$$C_p = \frac{1}{1/C_{eq} - 1/C_s} = 53 \text{ pF}$$