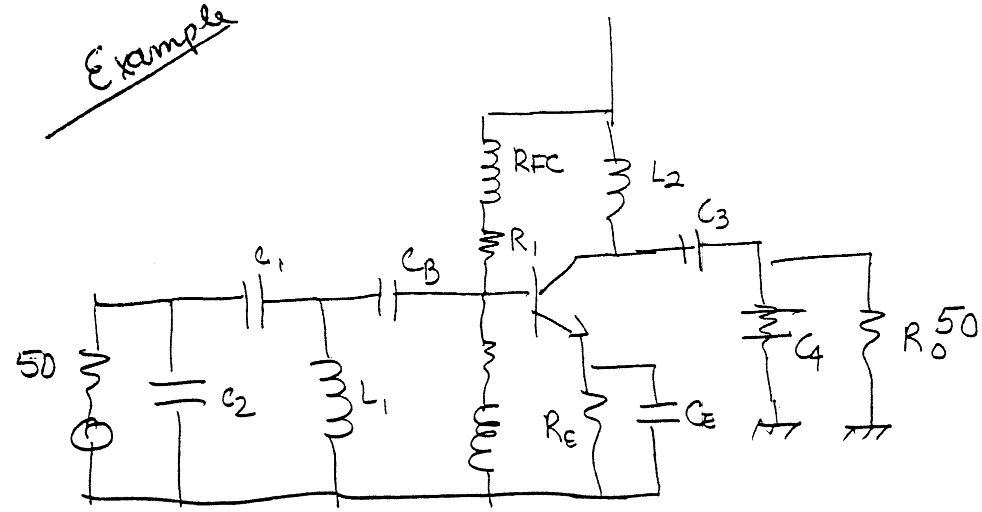
Example



$f_0 = 5\text{MHz}$

$B = \frac{1}{4}$ MHz.

$y_{11} = 3.6 + j18 \qquad y_{12} = -.04 - j0.6$

$y_{21} = 29 - j10 \qquad y_{22} = .0029 + j0.6$

$C > 1$

use loading to get $K = 4$

for noise considerations $G_S = 2.5\,m℧$ (400 Ω)

use Stern equation to get $G_L = 3.6975$. for stability

computer algorithm starts at $G_S = 2.5$
increases G_L to get stern

to calculate b_S and b_L we need an interative method because of feedback between input and output.

recall $\quad y_{IN} = y_{11} - \dfrac{y_{12}y_{21}}{y_{22} + y_L}$

$y_{OUT} = y_{22} - \dfrac{y_{12}y_{21}}{y_{11} + Y_G}$

Example #1

Consider the common base transistor amplifier whose y-parameters are given:

$$Y_{CB} = \begin{bmatrix} 100\,m℧ & 0 \\ -91\,m℧ & 0 \end{bmatrix}$$

(a) Add a capacitor (feed back) between the input and output terminals. What are the composite parameters if $y_c = j1.0\,m℧$.

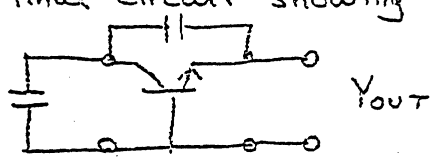
$$[Y_c] = \begin{bmatrix} 100 + y_f & -y_f \\ -91 - y_f & +y_f \end{bmatrix} = \begin{bmatrix} 100 + j1 & -j1 \\ -91 - j1 & j1 \end{bmatrix}$$

(b) If this composite amplifier is connected to a source admittance $Y_S = j10m℧$, what is Y_{OUT}?

$$Y_{OUT} = y_{22} - \frac{y_{12}\,y_{21}}{y_{11} + y_s} = j1 - \frac{(-j1)(-91-j1)}{(100+j1)+j10} = j1 + \frac{(j1)(-91-j1)}{100+j11}$$

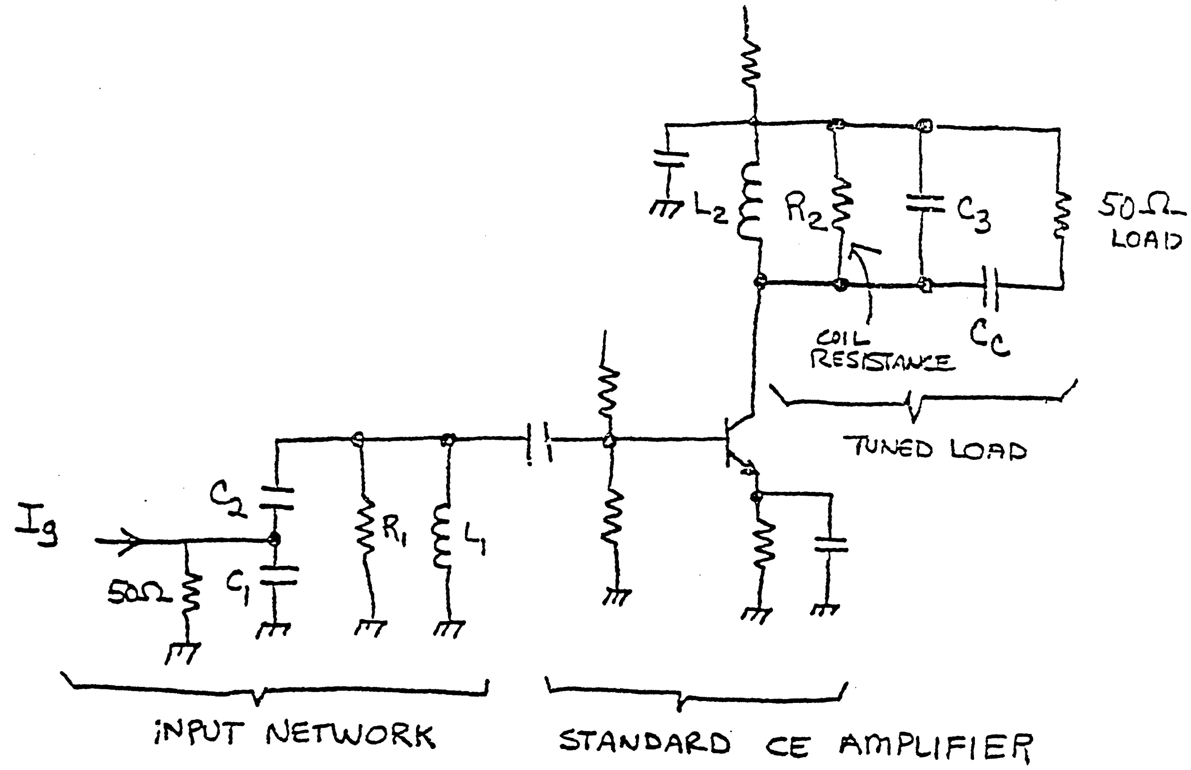
$$= j1 + \frac{1 - j91}{100 + j11} = j1 + (-.089 - j.9) = -.089 + j0.1$$

(c) Draw the final circuit showing Y_c and Y_s. Don't show bias components.



(d) Suggest a use for this circuit? <u>OSCILLATOR</u>

R.F. Amplifier design (unconditionally stable) 1



DESIGN FOR $f_0 = 60\text{MHz}$

$BW = 2\text{MHz}$

$S \le 0.3$

50Ω input and output

TRANSISTOR : $y_{11} = (6.8 + j6.1) \times 10^{-3}$ ℧ $\quad y_{12} = -j0.81 \times 10^{-3}$

$y_{21} = (33.6 - j44.2) \times 10^{-3} \quad y_{22} = (1.24 + j1.92) \times 10^{-}$

STEP 1 Compute Linvill stability factor

$$C = \frac{|y_{12} y_{21}|}{2g_{11} g_{22} - Re(y_{12} y_{21})}$$

$$y_{12} y_{21} = (-j0.81 \times 10^{-3})(33.6 - j44.2) \times 10^{-3}$$

$$= -j3.58 \times 10^{-5} - j2.72 \times 10^{-5} = -35.8 \times 10^{-6} - j27.2 \times 10^{-6}$$

$$|y_{12} y_{21}| = \sqrt{(35.8)^2 + (27.2)^2} = 44.9 \times 10^{-6}$$

$$Re(y_{12} y_{21}) = -35.8 \times 10^{-6}$$

drop all exponents for convenience

$$C = \frac{44.9}{2(6.8)(1.24) - (-35.8)} = \frac{44.9}{16.86 + 35.8} = 0.854$$

since $C < 1$ amplifier is unconditionally stable so design for maximum gain

STEP 2 Compute Linvill figure of merit

$$G_{00} = \frac{|y_{21}|^2}{4 g_{11} g_{22} - 2\,\mathrm{Re}(y_{12} y_{21})} = \frac{|(33.6 - j44.2) \times 10^{-3}|^2}{4(6.8\times10^{-3})(1.24\times10^{-3}) - 2(-35.8\times10^{-6})}$$

$$= \frac{\left(\sqrt{(33.6)^2 + (44.2)^2}\right)^2}{4(6.8)(1.24) + 2(35.8)} = \frac{(55.52)^2}{16.86 + 71.6} = 34.8$$

[dropping exponents]

STEP 3 Compute maximum gain

$$A_{MAG} = A_{P,\,MAX} = 2\,\frac{1 - \sqrt{1 - C^2}}{C^2}\,G_{00} \quad \text{where} \quad C = 0.854, \quad C^2 = 0.729$$

$$\frac{1 - \sqrt{1 - C^2}}{C^2} = \frac{1 - \sqrt{1 - 0.729}}{0.729} = \frac{1 - \sqrt{0.271}}{0.729} = \frac{0.480}{0.729} = 0.658$$

$$A_{MAG} = 2(0.658)(34.8) = 38.5$$

STEP 4 What are load and source terminations for maximum gain?

$$g_{LO} = \frac{1}{2g_{11}}\left[[2g_{11}g_{22} - \mathrm{Re}(y_{12}y_{21})]^2 - |y_{12}y_{21}|^2\right]^{\frac{1}{2}}$$

$A_{T,\,MAX}$ does not necessarily correspond to a stable amplifier

$$= \frac{1}{2(6.8\times10^{-3})}\left[\{(52.66)^2 - (44.9)^2\}\times10^{-12}\right]^{\frac{1}{2}}$$

$$= \frac{\sqrt{(52.66)^2 - (44.9)^2}\times10^{-6}}{13.6\times10^{-3}} = \frac{27.5}{13.6}\times10^{-3} = 2.023\times10^{-3}\,\mho$$

$(494.3\,\Omega)$

$$g_{GO} = \frac{g_{11}}{g_{22}}\,g_{LO} = \left(\frac{6.8\times10^{-3}}{1.24\times10^{-3}}\right)(2.023\times10^{-3}) = 11.09\times10^{-3}\,\mho$$

$(90.1\,\Omega)$

$$b_{LO} = -b_{22} + \frac{\text{Im}[y_{12}y_{21}]}{2g_{11}}$$

$$= -(1.92)\times 10^{-3} + \frac{-27.2\times 10^{-6}}{2(6.8)\times 10^{-3}} = -1.92\times 10^{-3} - 2.0\times 10^{-3}$$

$$= -3.92\times 10^{-3}\ ℧ \quad [$$

$$b_{GO} = -b_{11} + \frac{\text{Im}[y_{12}y_{21}]}{2g_{22}}$$

$$= -(6.1\times 10^{-3}) + \frac{-27.2\times 10^{-6}}{2(1.24\times 10^{-3})} = -6.1\times 10^{-3} - 10.97\times 10^{-3}$$

$$= -17.07\times 10^{-3}\ ℧$$

STEP 5 How easy is it to tune? Use optimum values for Y_L.

$$S = \frac{|y_{12}y_{21}||Y_L|}{|y_{22}+Y_L||y_{11}(y_{22}+y_L) - y_{12}y_{21}|}$$

$$y_{22}+Y_L = 1.24 + j1.92 + 2.015 - 3.92 = 3.255 - j2$$

$$S = \frac{|-35.8 \quad -j27.2 \quad || 2.015 - j3.92|}{|3.255 - j2||(6.8+j6.1)(3.255-j2) - (-35.8 - j27.2)|}$$

$$= 0.667$$

This is TOO sensitive !!

How do we reduce S? The only dependent parameter is Y_L. There is one Y_L in numerator, two Y_L's in denominator so increase Y_L by decreasing R_L and hope S decreases appropriately. g_L was 2.023×10^{-3}, So increase g_L to 5×10^{-3} [200 Ω]. b_L will remain constant, i.e.

$$Y_L' = 5\times 10^{-3} + j(-3.92\times 10^{-3}).$$

$$S = \frac{(44.2)|5-j3.92|}{|6.24 - j2||(6.8+j6.1)(6.24-j2) + j(35.8+j27.2)|} = 0.418$$

S still does not meet goal so increase g_L to 9×10^{-3}.

$$S=\frac{|144.92||9-j3.92|}{|10.24-j2||(6.8+j61)(10.24-j2)+j(35.8+j27.2)|}$$

$S = 0.302$ Acceptable design !

Step 6 Since the termination is no longer optimum what is gain. We now longer have A_{MAG} so we have to use general expression for gain of two port network with terminations given by $Y_L = \underbrace{9\times10^{-3}}_{\text{non-optimum } g} - \underbrace{j\,3.92\times10^{-3}}_{\text{optimum } b}$

$$A_p = \frac{|y_{21}|^2 g_L}{|y_{22}+Y_L|^2\left[g_{11} - Re\left(\frac{y_{12}y_{21}}{y_{22}+Y_L}\right)\right]}$$

$$= \frac{[(33.6)^2+(44.2)^2]\times 9}{[10.24-j2]^2\left[6.8 - Re\left(\frac{-35.8-j27.2}{10.24-j2}\right)\right]}$$

$$= \frac{27743.4}{[108.86][6.8 - Re(-2.87-j3.22)]}$$

$$= \frac{27743.4}{(108.86)(6.8+2.87)} = 26.355$$

This may seem like a huge loss in power gain [recall $A_{P,MAX} = 38.5$] but

$10 \log 38.5 = 15.85$ db

$10 \log 26.4 = 14.21$ db

The net loss is only 1.64 db.

Step 7 What is the new Y_{IN} as a result of our new loading? We cannot use $g_{GO} + j b_{GO}$ to match.

New Y_{IN} is given by

$$Y_{IN} = y_{11} - \frac{y_{12}y_{21}}{y_{22}+Y_L} = 6.8 + j61 - \frac{-35.8-j27.2}{10.24-j2}$$

$$= (9.67 + j9.32)\times10^{-3}$$

as compared to

NOTE CONJUGATE MATCH AT INPUT

$Y_{opt} = (11.05 - j17.07)\times10^{-3}$

$$Y_{OUT} = y_{22} - \frac{y_{12}y_{21}}{y_{11}+y_G} = (1.24+j1.92) - \frac{-35.8-j27.2}{6.8+j61+9.67-j9.32}$$

$$Y_{OUT} = (3.022 + j3.92) \times 10^{-3}$$

STEP 8 COMPUTE STERN STABILITY FACTOR.

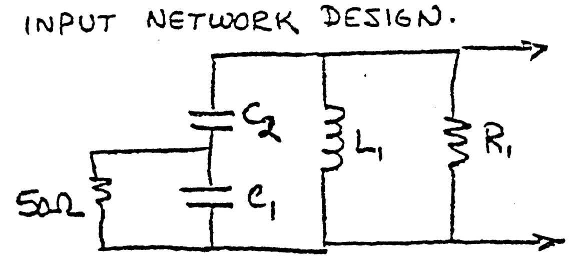
Not really needed since transistor is unconditionally stable.

$$K = \frac{2(g_{11}+g_G)(g_{22}+g_L)}{|y_{12}y_{21}| + Re(y_{12}y_{21})} = \frac{2(6.8+9.67)(1.24+3.022)}{44.9 - 35.8}$$

$$= 36.8$$

So amplifier is VERY stable.

STEP 9 INPUT NETWORK DESIGN.



where R_1 is the parallel resistance of L_1

$Y_{IN} = (9.67 + j9.32) \times 10^{-3}$

for conjugate match use

$Y_G = (9.67 - j9.32) \times 10^{-3}$

Even though we think we know how to do this let's review it. For a conjugate match from a 50Ω generator to the two-port with $Y_{IN} = (9.67 + j9.32) \times 10^{-3}$ ℧. Even though this is a tapped capacitor network we must remember that it is connected to a admittance Y_{IN}. For the conjugate match the network must transform 50Ω into $N^2 50$ which will be in parallel with R_1, i.e. $N^2 50 \| R_1$, which must equal the load conductance 9.67m℧ (103.4Ω).

$$N^2 50 \| R_1 = 103.4\ \Omega$$

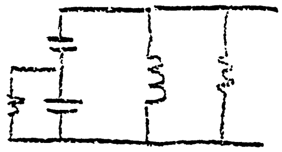
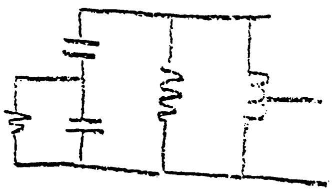
This circuit should have a tank Q of $\frac{60}{2} = 30$. The capacitance C is determined from the circuit bandwidth.

$$C = \frac{1}{2\pi B R_t} = \frac{1}{2\pi(2\times10^6)(103.4)} = 769.5\,pf$$

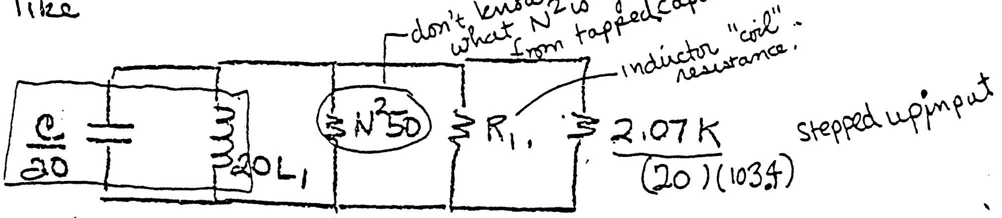
The corresponding L is

$$L = \frac{1}{\omega_o^2 C} = \frac{1}{(2\pi \times 60\times10^6)^2(769.5\times10^{-12})} = 9.14\,nH.$$

This is a very small and unrealistic value of L so we use a transformer to step it up. A transformer impedance ratio of 20 would increase L from 9.14nH to 0.182 μH, a more reasonable value at $f_o = 60MHz$. What we are doing is using a 20:1 transformer to step down our output impedance from the matching network.

 looks like 

If we choose a transformer with a 20:1 impedance ratio we find the input impedance of 103.4 Ω stepped up to 2.07K Ω. The resulting circuit looks like



Note that because the coil inductance increased by 20, the capacitance must decrease by 20 to maintain the same resonant frequency. The Q of this circuit is determined by the resistors. Since,

$$C = \frac{1}{2\pi B R_t} = \frac{Q_t}{2\pi f_o R_t} = \frac{Q_t}{\omega_o R_t}.$$

we have $Q_t = \omega_o R_t C$, or, in general, $Q \propto R$. For a circuit with just a coil resistance we would have

$$Q_{coil} = \omega_o R_{coil,\,parallel}\, C. = \omega_o R_1 C$$

Assuming we can wind a 0.182 μH with a Q of 80 and recalling we need a circuit Q of 30 we can set up the ratio

$$\frac{Q=80}{Q=30} = \frac{\omega_o R_1 C}{\omega_o (R_1 \| N^2 50 \| 2.07K) C} = \frac{R_1}{R_1 \| N^2 50 \| 2.07K}$$

if we didn't have $N^2 50$ and R_1 unknown we could directly determine the R we need from $B = \frac{1}{2\pi R_t C}$

But, for conjugate matching

$$R_1 \| N^2 50 = 2.07K \leftarrow \text{conjugate matching}$$

thus

$$\frac{80}{30} = \frac{R_1}{2.07K \| 2.07K}$$ or solving for R_1, $R_1 = 2.76K$.

This is the parallel resistance of the coil, the series resistance is much lower. We can now solve for $N^2 50$ to get the turns ratio of the tapped capacitor network.

$$2.76K \| N^2 50 = 2.07K.$$

$$\frac{(2{,}760)(N^2 50)}{2{,}760 + N^2 50} = 2{,}070$$

$$(2760) N^2 50 = 5.71 \times 10^6 + (2070) N^2 50$$

$$(690) N^2 50 = 5.71 \times 10^6$$

$$N^2 = 165.5$$

$$N = 12.86$$

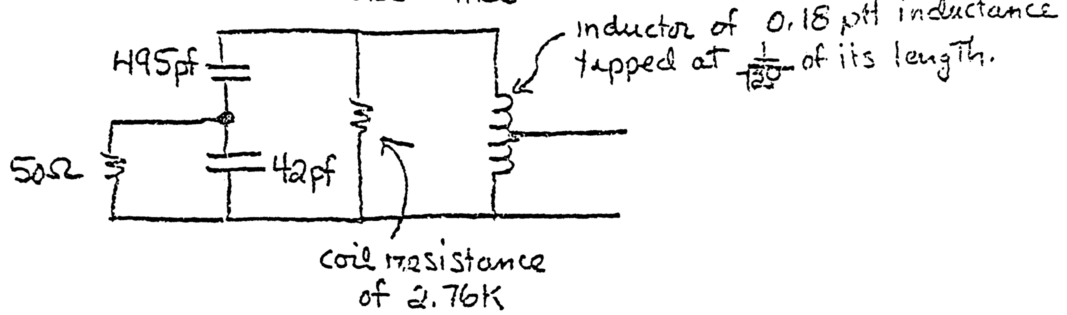
The rest of the network design is now simple. Since C is now $\frac{769.5}{20}$ pf or 38.475pf. we have

$$C_2 = NC = (12.86)(38.475) \cong 495 \text{ pf}.$$

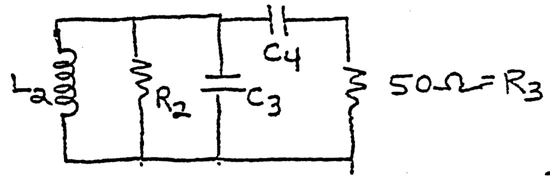
The other capacitor is

$$C_1 = \frac{C_2}{N-1} = \frac{495\ pf}{12.86-1} = 41.72\ pf.$$

Our input network now looks like

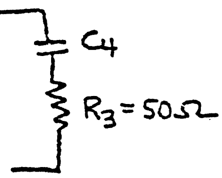


Step 10 design output network



where R_2 is the parallel equivalent resistance of the inductor.

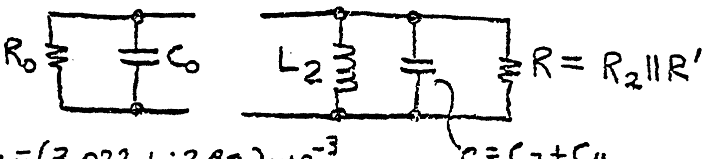
Our first task is to do a series to parallel conversion on the $R_3 - C_4$.



$$Q_S = \frac{X_S}{R_S}$$ in this case $$X_S = \frac{1}{2\pi(60\times10^6)\,C}$$

in general $R_S \ll X_S$ so we will assume $Q_S > 10$

The output circuit now reduces to



where $R' = Q_S X_S = \frac{1}{50\omega_o^2 C_4^2}$

$Y_{out} = (3.022 + j3.92)\times10^{-3}$

for matching we require $Y_L = (3.022 - j3.92)\times10^{-3}$

$$= \frac{1}{R} + j\omega_o(C_3+C_4) - j\frac{1}{\omega_o L_2}$$

Find R from Q as before and solve for L and C.

However, we decided to mismatch to reduce S, the sensitivity.

We changed R_L to 331Ω, i.e. $Y_L = (9 - j3.92)\times10^{-3}$.

We require $R = R_2 \| R' = \frac{1}{9\times10^{-3}} = 111.1\,\Omega$.

we find R_2 from the Q-relationships

$$\frac{Q_{COIL}}{Q_{TANK}} = \frac{R_2}{R_2 \| R' \| R_o} = \frac{80}{30}$$

This assumes a coil Q = 80.

Recalling that $R_2 \| R' = 111.1\Omega$ we have

$$\frac{R_2}{111.1 \| R_o} = \frac{8}{3} \quad \text{or since } R_o = 331\Omega.$$

$$R_2 = \left\{(111.1)\|(331)\right\}\left(\frac{8}{3}\right) = \frac{(111.1)(331)}{111.1+331}\,\frac{8}{3} = (83.18)\frac{8}{3} = 221.81\Omega$$

and solving $R_2 \| R' = 111.1$ we get $R' = 222.59\Omega$.

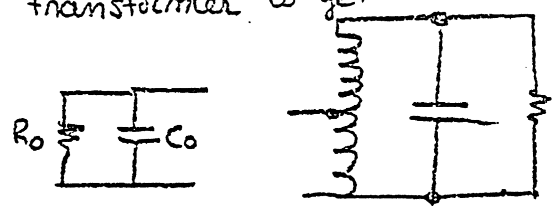
Knowing the coil Q we can determine L

$$Q_{coil} = \frac{R_2}{\omega_o L} \quad \therefore \quad L = \frac{R_2}{\omega_o Q_{COIL}} = \frac{221.81}{(2\pi \times 60 \times 10^6)(80)}$$

$$= 0.00735\ \mu H.$$

This is not a realistic value of inductor to use in a circuit!

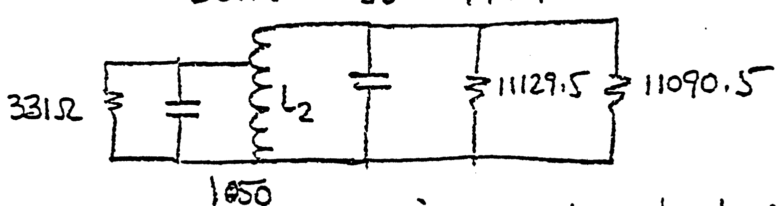
So use a transformer to get a better value.



Choose a factor of 50 for the transformer turns ratio this will give a inductance of $0.368\ \mu H$ which is realistic. A transformer will step up Z from the load to the transistor and vice versa. As drawn the transformer steps Z_L down by a factor of 50. This would increase Y_L by a factor of 50.

Both resistors R' and R_2 are now multiplied by 50 to give the same loading, i.e.

$$222.59 \times 50 = 11129.5$$
$$221.81 \times 50 = 11090.5$$



The current value of L_2 is determined by the tank circuit to the right of the transformer (this is chosen for convenience) since R_2 (the coil resistance) is defined there.

$$Q_{coil} = \frac{R_2}{\omega_o L}$$

$$L_2 = \frac{R_2}{\omega_o Q_{coil}} = \frac{11090.5}{(2\pi \times 60 \times 10^6 \times 80)}$$

$L_2 = 0.3678$ (exactly 50 times the former value as we designed for)

Now we match and resonate.

Transform $j\omega_0 C_0$ to the right of the transformer
impedance steps up by 50
admittance steps down by 50

so $j\omega_0 C_0$ becomes $\dfrac{j\omega_0 C_0}{50}$

and conjugating for matching

$$-j\frac{3.92\times10^{-3}}{50} = j\omega_0(C) - j\frac{1}{\omega_0 L_2}$$

since $\omega_0 L_2 = (2\pi\times60\times10^6)(0.3678\times10^{-6}) = 138.65$

all quantities but $\omega_0 C$ are known and solving for $\omega_0 C$

$$\omega_0 C = -\frac{3.92\times10^{-3}}{50} + \frac{1}{138.66}$$

$$= -78.4\times10^{-6} + 7.212\times10^{-3} = 7.134\times10^{-3}$$

$$C = \frac{7.134\times10^{-3}}{2\pi\times60\times10^6} = 18.92 \text{ pf.}$$

Let's go back and solve for C_4. Recall $R' = \dfrac{1}{50\,\omega_0^2 C_4^2}$

so $C_4^2 = \dfrac{1}{50\,\omega_0^2 R'} = \dfrac{1}{(50)(2\pi\times60\times10^6)^2(11129.5)} = 12.64\times10^{-24}$

$C_4 = 3.556$ pf.

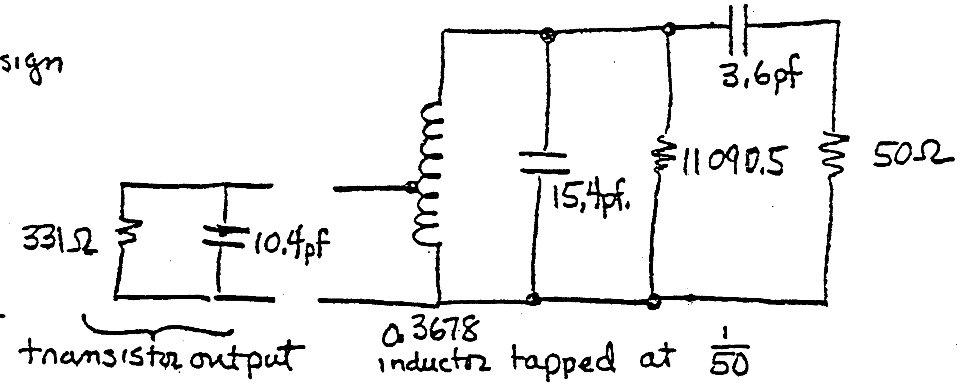
$C = C_4 + C_3$ so $C_3 = C - C_4 = 18.92 - 3.556 = 15.36$ pf.

Check if $Q_S > 10$

$$Q_S = \frac{1}{50\,\omega_0 C_4} = \frac{1}{50(2\pi\times60\times10^6)(3.6\times10^{-12})} \approx 15$$ so assumption is OK.

Final design

$Y = j\omega_0 C_0$
$\dfrac{3.92\times10^{-3}}{2\pi\times60\times10^6}$
$C_0 = 10.4$ pf



You are given the following information about a 2N5109 rf amplifier at 200 M

12

$y_{11} = 22 + j9$ m℧ For your convenience (units are NOT m℧)

$y_{12} = -j2.2$

$y_{21} = 40 - j185$

$y_{22} = 1 + j8$

$y_{12}y_{21} = -407 - j88 \times 10^{-6}$ ℧^{2}

$|y_{12}y_{21}|^2 = 173.39 \times 10^{-9}$ ℧^{4}

$|y_{12}y_{21}| = 416 \times 10^{-6}$ ℧^{2}

$|y_{21}| = 188 \times 10^{-3}$ ℧

$|y_{21}|^2 = 35.8 \times 10^{-3}$ ℧^{2}

(a) Is this amplifier unconditionally stable.

$$C = \frac{|y_{12}y_{21}|}{2g_{11}g_{22} - Re(y_{12}y_{21})} = \frac{416 \times 10^{-6}}{2(22\times10^{-3})(1\times10^{-3}) + 407\times10^{-6}} = 0.922 \quad \underline{\text{Yes!}}$$

(b) What is the maximum transducer gain possible

$$G_{00} = \frac{|y_{21}|^2}{4g_{11}g_{22} - 2Re(y_{12}y_{21})} = \frac{35.8\times10^{-3}}{4(22\times10^{-3})(1\times10^{-3}) + 814\times10^{-6}} = 39.69$$

$$A_{T,max} = 2\,\frac{1-\sqrt{1-C^2}}{C^2}\,G_{00} = 2\,\frac{1-\sqrt{1-(.922)^2}}{(.922)^2}(39.69) = 52.8$$

(c) is this amplifier stable when $Y_S = (20 - j50)$ m℧ $Y_L = (1.5 + j5)$ m℧

is stable from (a) but let's evaluate anyway

$$K = \frac{2(g_{11}+g_S)(g_{22}+g_L)}{|y_{12}y_{21}| + Re(y_{12}y_{21})} = \frac{2(22+20)(1+1.5)}{416 - 407} = 23.3 \quad \text{(Very stable!)}$$

(d) What are Y_{IN} and Y_{OUT} for the above terminations

$$y_{IN} = y_{11} - \frac{y_{12}y_{21}}{y_{22}+Y_L} = (22+j9) - \frac{(-407-j88)}{(2.5+j13)} = (22+j9) - (-12.3+j28.9)$$

$y_{IN} = 34.3 - j19.9$ m℧

$$-y_{OUT} = y_{22} - \frac{y_{12}y_{21}}{y_{11}+Y_S} = (1+j8) - \frac{(-407-j88)}{42-j41} = 1+j8 - (-3.91 - j5.92)$$

$y_{OUT} = 4.91 + j13.92$

(e) What is the transducer gain for the terminations of part (c). <u>Assume input and output are tuned by additional reactive components to resonance at 200 MHz, i.e. $Y_{OUT} + Y_L$ and $Y_{IN} + Y_S$ are real only.</u>

$$A_T = \frac{4g_Lg_S|y_{21}|^2}{|Y_S+Y_{IN}|^2\,|Y_{22}+Y_L|^2} = \frac{4(1.5\times10^{-3})(20\times10^{-3})(35.8\times10^{-3})}{|20+34.3|^2\,|1+1.5|^2 \times 10^{-3}} = \frac{4.296\times10^{-6}}{(2.948\times10^{-3})(6.25\times1}$$

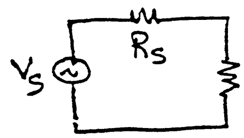
$= 233.1$

(f) If the input is 1 milliwatt rms, what is the output power? $R_S = 50\,\Omega$. from (c).

available $P_{INPUT} = \dfrac{V_S^2}{4R_S} = \dfrac{(1\times10^{-3})^2}{4\,(50)} = 5\times10^{-9}$ watts

$$P_{LOAD} = P_A A_T = (5\times10^{-9})(233.1) = 1.166\times10^{-6} \text{ watts}$$

(g) What is the overall voltage gain of the amplifier?



$R_{IN} = \dfrac{1}{34.3\times10^{-3}} = 29.15\,\Omega$ $\qquad \dfrac{V_{IN}}{V_S} = \dfrac{29.15}{50+29.15} = 0.368$

$$\left|\frac{V_o}{V_i}\right| = \frac{|y_{fe}|}{|y_o + Y_L|} \simeq \frac{189\times10^{-3}}{|1+j8+1.5+j5|} = \frac{189\times10^{-3}}{|2.5+j13|\times10^{-3}} = 75.6$$

$$A_V = \frac{V_o}{V_S} = \frac{V_i}{V_S}\,\frac{V_o}{V_i} = (.368)(75.6) = 27.82.$$

(h) Using the results of (g), what is the output power for a 1mV input signal.

It should be the same as f, but let's check.

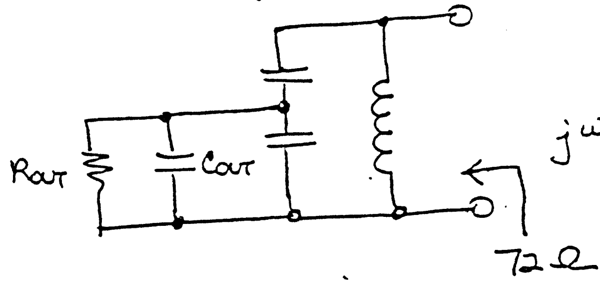
$$V_o = 27.82\,V_s = 27.82\times10^{-3} \text{ volts.}$$

$$P_{LOAD} = \frac{V_o^2}{R_{LOAD}} = \frac{(27.82\times10^{-3})^2}{667\,\Omega} = 1.160\times10^{-6} \text{ watts}$$

(close enough)

A 2N6084 r.f. power transistor has an output admittance $Y_{OUT} = (573 + j2.2)$, at 175 MHz. Design a tapped capacitor network to match Y_{OUT} to a 72-ohm resistive load. Design for a Q of 10 at 175 MHz.

Network must go from low impedance to high impedance; hence, it must look like



$$R_{OUT} = \frac{1}{573 \times 10^{-3}} = 1.75\,\Omega$$

$$j\omega C_{OUT} = j(2\pi)(175 \times 10^{6})\,C_{OUT} = 2.2 \times 10^{-3}$$

$$C_{OUT} = 2\,\text{pf}$$

Plug and grind !

$$Q = 10$$

$$B = \frac{f}{Q} = \frac{175}{10} = 17.5\ \text{MHz}$$

$$C = \frac{1}{2\pi R_t B} = \frac{1}{2\pi(72)(17.5 \times 10^{6})} = 126\ \text{pf}$$

$$L = \frac{1}{\omega_0^2 C} = \frac{1}{(2\pi \times 175 \times 10^{6})^2 (126 \times 10^{-12})} = 6.56\ \underline{\text{nano}}\ \text{henrys}$$

$$N = \sqrt{\frac{R_t}{R_2}} = \sqrt{\frac{72}{1.75}} = 6.414$$

$$Q_p = \frac{Q}{N} = 1.56$$

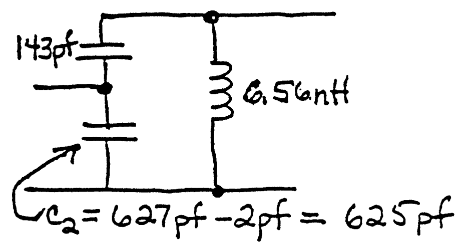
since $Q_p < 10$ use exact formula

$$C_2 = \frac{Q_p}{\omega_0 R_2} = \frac{1.206}{(2\pi \times 175 \times 10^{6})(1.75)} = 627\,\text{pf}$$

$$C_{se} = C_2\left(\frac{Q_p^2 + 1}{Q_p^2}\right) = 1058\ \text{pf}$$

$$C_1 = \frac{C_{se}\,C}{C_{se} - C} = \frac{(1058)(126)}{1058 - 126} = 143\,\text{pf.}$$

final circuit



Consider the common base transistor amplifier whose y-parameters are:

$y_{11} = 77\ m℧ \quad y_{12} = 0 \quad y_{21} = 77\ m℧ \quad y_{22} = 0$

a) If a capacitor is added between the input and output terminals, what are the composite parameters if $y_c = j.0063\ ℧$

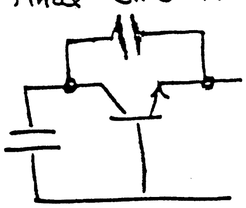
$$Y_c = \begin{bmatrix} 77 + y_c & -y_c \\ 77 - y_c & +y_c \end{bmatrix} = \begin{bmatrix} 77 + j6.3 & -j6.3 \\ 77 - j6.3 & j6.3 \end{bmatrix}$$

(b) If this amplifier is connected to a source admittance $Y_S = j.063\ ℧$ what is Y_{OUT}?

$$Y_{OUT} = y_{22} - \frac{y_{21} y_{12}}{y_{11} + y_S} = j6.3 - \frac{(-j6.3)(77 - j6.3)}{77 + j6.3 + j63} = j6.3 - (-3.42 - j3.22$$ 11

$$= +3.42 + j9.52\ m℧$$

c) Draw the final circuit showing y_c and y_s. Don't show bias components.



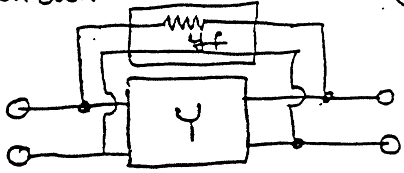
This circuit is a capacitive feedback oscillator. If $Re\,(y_{OUT}) < 0$ it will oscillate

A BJT has the following measured common emitter y-parameters at 500 MHz:

$$y_{11} = 14 + j22 \qquad y_{12} = -j2$$
$$y_{21} = 235 + j153 \qquad y_{22} = -1 + j5$$

(a) Determine the component values necessary to unilateralize this transistor

for unilateralization we want $(y_{12})_{composite} = 0$



composite parameters are given by

$$Y_{composite} = \begin{bmatrix} y_{11}+y_f & y_{12}-y_f \\ y_{21}-y_f & y_{22}+y_f \end{bmatrix}$$

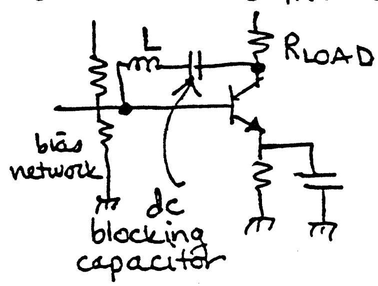
Therefore $-j2 - y_f = 0$ for unilateralization

$$y_f = -j2$$

this is an inductor of value $-j2\times10^{-3} = -\dfrac{j}{(2\pi \times 5\times10^{8})L}$

$$L = \frac{1}{(6.28)(5\times10^{8})(2\times10^{-3})} = 0.159\ \mu H.$$

(b) Draw a simple common emitter amplifier circuit illustrating how this feedback network is connected to the transistor



(c) What are the composite y-parameters for the transistor and unilateralization network?

from (a) $Y_c = \begin{bmatrix} 14+j22-j2 & -j2+j2 \\ 235+j153+j2 & -1+j5-j2 \end{bmatrix} = \begin{bmatrix} 14+j20 & 0 \\ 235+j155 & -1+j3 \end{bmatrix}$

A BJT has the measured common emitter y-parameters. For computational assistanc(

$y_{11} = 3.8 + j4.5$ $\qquad$ $y_{12}y_{21} = (-23.83 - j103.2)\times 10^{-6}$

$y_{12} = -.03 - j0.4$ $\qquad$ $|y_{12}y_{21}| = 105.92 \times 10^{-6}$

$y_{21} = 261 - j40$ $\qquad$ $y_{11}y_{22} = (-3.98 + j2.59)\times 10^{-6}$

$y_{22} = -.1 + j0.8$ $\qquad$ $|y_{11}y_{22}| = 475 \times 10^{-6}$

(a) Is this transistor unconditionally stable? (b) Is it stable when $R_S = R_L = 50\,\Omega$.

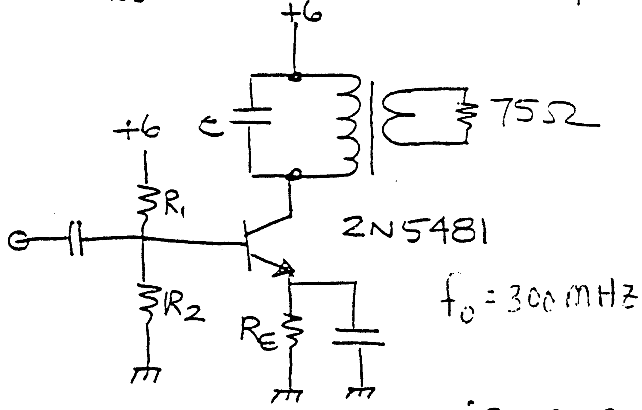
evaluate $2g_{11}g_{22} - Re(y_{12}y_{21}) = 2(3.8)(-.1) - Re(-23.83 - j103.2) = 23.07\times 10^{-6}$

$$C = \frac{|y_{12}y_{21}|}{2g_{11}g_{22} - Re(y_{12}y_{21})} = \frac{105.92}{23.07} = 4.59 \geq 1$$ so transistor is conditionally stable.

$$K = \frac{2(g_i+g_s)(g_o+g_L)}{|y_{12}y_{21}| + Re(y_{12}y_{21})} = \frac{2(3.8+20)(-1+20)\times10^{-6}}{105.92\times10^{-6} - 23.83\times10^{-6}} = \frac{2(23.8)(19.9)}{82.09}$$

$K \approx 11.5$ so transistor is stable.

You are to design a tuned common-emitter amplifier as shown below. The transformer matches the amplifier to a 75-ohm load.



from data tables

$y_{fe} = 24 - j46$ $\qquad \beta = 100$

$y_{re} = -j2$

$y_{oe} = 2.2 + j3.5$ $\qquad$ all at 300 MHz

$y_{ie} = 3.5 + j4.5$

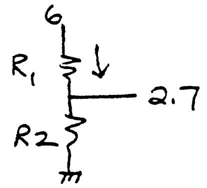
$|y_{fe}| = 51.88$

(a) do a d.c. design to specify R_1, R_2 and R_E. Use $V_{CE} = 4.0V$, $I_C = 10mA$.

$V_E = 6 - 4 = 2$ volts

$R_E = V_E / I_E = \dfrac{2\text{ volts}}{10mA} = 200\,\Omega$

$I_B = I_C / h_{FE} = \dfrac{10mA}{100} = 0.1mA$



use $I_D = 1mA$

$R_2 = \dfrac{2.7\text{ volts}}{1mA} = 2.7K$

$R_1 = \dfrac{6 - 2.7}{1mA} = 3.3K.$

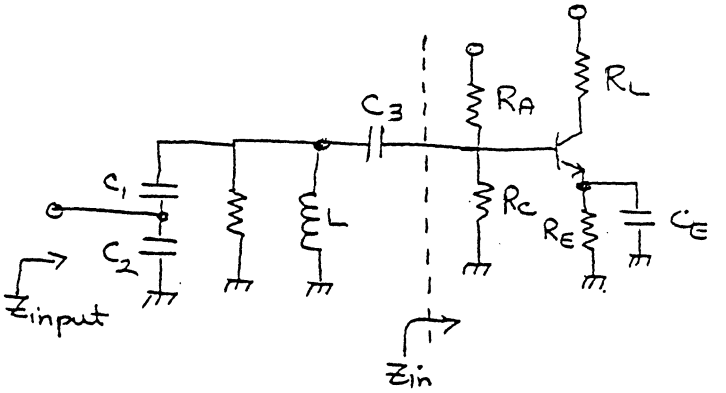
(b) Evaluate the Linville stability parameter. The amplifier is to operate at f = 300 MHz. Is it necessary to evaluate the Stern parameter?

$$C = \frac{|y_{fe} y_{re}|}{2 g_i g_o - Re(y_{fe} y_{re})}$$

$y_{fe} y_{re} = (24 - j46)(0 - j2) = -92 - j48$

$2 g_i g_o = 2(3.5)(2.2) = 15.4$

$$= \frac{\sqrt{(92)^2 + (48)^2}}{15.4 + 92} = \frac{103.76}{107.4} < 1 \Rightarrow \underline{\text{unconditionally stable}}$$



$y_{ie} = 20 + j10$
$y_{re} = -j$
$y_{fe} = 100 - j100$
$y_{oe} = 1 + j5$
$f_o = 100\,\text{mHz}$
$B = 5\,\text{mHz}$
$Q_L = 200$
$R_B = R_A \| R_C$

Assume R_B is very large and can be neglected. Assume C_E properly bypasses R_E at 100 mHz.

(a) Evaluate the complex Z_{in} for $R_L = 1000\Omega$ and $R_L = 50\Omega$. You may instead evaluate y_{IN} if you wish.

@ $R_L = 1K$ $\quad g_L = 1m\mho$ $\quad y_{IN} = y_{ie} - \dfrac{y_{fe}\,y_{re}}{y_{e} + y_L} = (20+j10) - \dfrac{(100-j100)(-j)}{(1+j5+1)}$

$y_{IN} = (20+j10) - (-24.13 + j10.3) = 44.13 - j0.3 \quad m\mho$

@ $R_L = 50\Omega$ $\quad g_L = 20m\mho$ $\quad y_{IN} = (20+j10) - \dfrac{(100-j100)(-j)}{(1+j5+20)} = (20+j10) - (-5.57 - j3.43)$

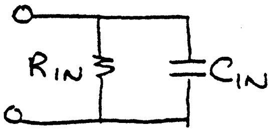
$= 25.57 + j13.43$

(b) Physically interpret the signs appearing in your results for (a). What is the effect of changing R_L?

for $R_L = 1K$ the input looks like a resistor and inductor in parallel

for $R_L = 50\Omega$ the input looks like a resistor and capacitor in parallel

(c) For $R_L = 50\Omega$ only draw the equivalent circuit for the transistor amplifier as seen by the resonant network.

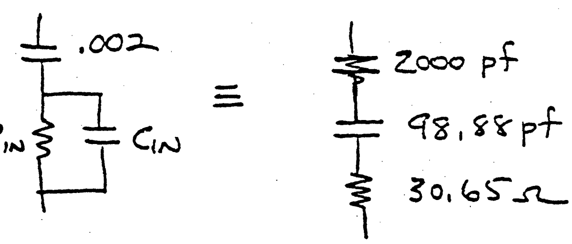


$\omega_o C_{IN} = 13.43 \times 10^{-3}$

$C_{IN} = \dfrac{13.43 \times 10^{-3}}{2\pi \times 100 \times 10^6} = 21.37\,pf$

$R_{IN} = 39.1\Omega$

(d) If $C_3 = 0.002\,\mu f$, reduce the resonant network of (c) to a form found in the tables at the end of Chapter 3 of KBR. Convert all impedances (admittances) to capacitances, inductances and resistances.



$Q_P = \dfrac{R_P}{X_P} = \dfrac{39.1}{74.46} = .525$

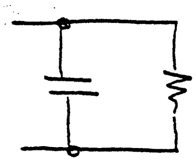
$R_{se} = \dfrac{R_P}{1+Q_P^2} = \dfrac{39.1}{1+.2757} = 30.65\Omega$

$C_{se} = C_P\left(\dfrac{(.525)^2+1}{(.525)^2}\right) = 98.88\,pf.$

$\dfrac{(2000)(98.88)}{2000+98.88} = 94.22\,pf$

30.65Ω

≡



$X_S = \dfrac{1}{\omega C_S} = \dfrac{1}{2\pi 10^8 (94.22 \times 10^{-12})}$

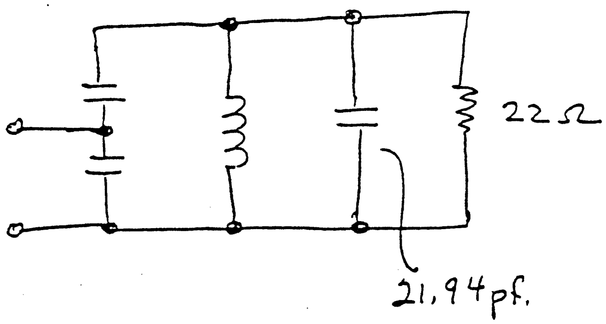
$= 16.89$

$Q_S = \dfrac{X_S}{R_S} = \dfrac{16.89}{30.65} = .551$

$R_P = R_S(1+Q_S^2) = 22$

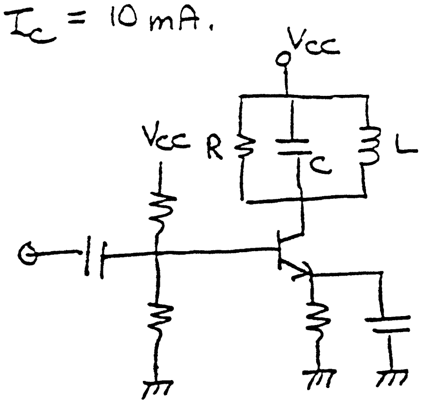
$C_P = C_S\left(\dfrac{Q_S^2}{Q_S^2+1}\right) = 21.94\,pf.$

(e) <u>Without evaluating</u>, describe the design procedure used to determine C_1, C_2 and L. Point out what is known and what can be solved for at each step. Write down any equations you refer to. (8)

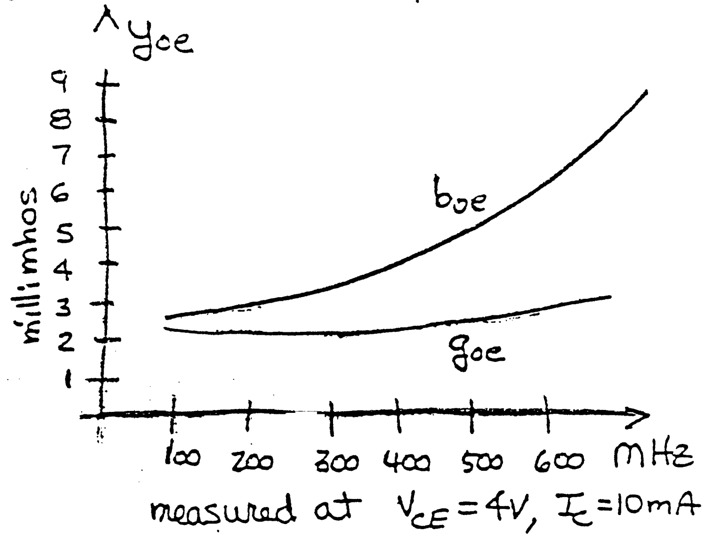


It is impossible to match any resistance greater than 22Ω using this network.

You are to design a 400 MHz tuned amplifier using a 2N5431 transistor. The parameters for the 2N5431 are listed on the next page. You may assume you have properly biased the transistor to operate at $V_{CE} = 4V$, $I_C = 10$ mA.



R=1K



2N5481 NPN silicon high-frequency transistor

③

electrical characteristics	symbol	min	typ	max	unit
dc current gain (I_C=10mA, V_{CE}=4V)	h_{FE}	25	100	200	
collector base capacitance ($V_{CB}=4V$, f=100 MHz)	C_{cb}		0.9	1.5	pf.
emitter base capacitance ($V_{EB}=0.5V$, f=100 MHz)	C_{eb}		0.7	1.1	pf.

let Q_t = the tank circuit Q.

(a) To achieve a Q_t of 40 with this circuit what must C be? What must the Q of the inductor be for its resistance (series) to be negligible?

$$Q_t = \frac{400}{B} = 40 \quad \therefore \quad B = 10 \text{ MHz} \qquad \mathcal{B} = 2\pi B = 62.83\times10^6 \text{ rad/sec.}$$

to specify C:
$$\mathcal{B} = \frac{2(g_{oe}+G)}{2C + C_{oe} + C_{oe}'}$$

from graphs $g_{oe} \cong 2.3\times10^{-3}$ ℧

from problem $G = \frac{1}{1000} = 10^{-3}$ ℧

from graphs: $b_{oe} = 4\times10^{-3}$

$$j\omega C_{oe} = j b_{oe} \quad \therefore \quad C_{oe} = \frac{4\times10^{-3}}{2\pi\times4\times10^{8}} = 1.59\times10^{-12}$$

$$C_{oe}' = \frac{\Delta C_{oe}}{\Delta\omega} = \frac{1}{\omega}\frac{\Delta b_{oe}}{\Delta\omega} = \frac{1}{\omega}\frac{\Delta b_{oe}}{\Delta f}\frac{\Delta f}{\Delta\omega} = \frac{1}{2\pi\omega}\frac{\Delta b_{oe}}{\Delta f}$$

$$= \frac{1}{(2\pi)(400\times10^6)}\cdot\frac{(5.8-1)\times10^{-3}}{(600-0)\times10^6} \approx 3.8\times10^{-21}$$

$\therefore$ C_{oe}' is totally negligible in this case

$$B = \frac{2(g_{oe}+G)}{2C + C_{oe}}$$

$$62.83 \times 10^6 = \frac{2(2.3+1)\times 10^{-3}}{2C + 1.59 \times 10^{-12}}$$

$$2C + 1.59\times 10^{-12} = \frac{2(3.3)\times 10^{-3}}{62.83 \times 10^{6}} = 105 \times 10^{-12}$$

$$2C = 105 - 1.6 \text{ pf.}$$

$$C = 51.7 \text{ pf.}$$

for the resistance r_L of the inductor to be negligible we need

$$g_L \leq \frac{g_{oe}+G}{10} = \frac{(3.3 \times 10^{-3})}{10} = 0.33 \times 10^{-3}$$

$$\therefore r_L \geq 3030 \text{ ohms}$$

$$Q_u \geq \frac{r_L}{\omega_0 L}$$ · need L to complete This calculation

$$L = \frac{1}{\omega_0^2 (C_{oe}+C)} = \frac{1}{(2\pi \times 400 \times 10^6)^2 (53.3 \times 10^{-12})} \cong 2.97 \times 10^{-9} \text{ Henrys.}$$ 4

$$Q_u \geq \frac{3030}{(2\pi \times 400 \times 10^6)(2.97 \times 10^{-9})} = 405.9$$

(b) What is the required L for operation at 400 mHz?
(see above)

(c) What is the circuit voltage gain?

$$A_V = \frac{|y_{fe}|}{g_{oe}+G} = \frac{|18^2+48^2|^{\frac{1}{2}} \times 10^{-3}}{2.3\times 10^{-3} + 1 \times 10^{-3}} = \frac{51.26 \times 10^{-3}}{3.3 \times 10^{-3}} = 15.5$$

Note: read y_{fe} from graphs