SOLUTIONS MANUAL

MICROWAVE TRANSISTOR AMPLIFIERS

Analysis and Design

SECOND EDITION

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CONTENTS

3.1) (a) $G_T = \dfrac{P_L}{P_{AVS}}$, $G_p = \dfrac{P_L}{P_{IN}}$, $G_A = \dfrac{P_{AVN}}{P_{AVS}}$, $P_{IN} = P_{AVS} M_s$ $(M_s \le 1)$,

AND $P_L = P_{AVN} M_L$ $(M_L \le 1)$.

HENCE, [SEE (2.7.29)]: $G_T = G_p M_s$ OR $G_T \le G_p$, AND

$G_T = G_A M_L$ OR $G_T \le G_A$.

$G_T = G_p$ WHEN $\Gamma_s = \Gamma_{IN}^*$ (OR WHEN $M_s = 1$)

$G_T = G_A$ WHEN $\Gamma_L = \Gamma_{OUT}^*$ (OR WHEN $M_L = 1$)

(b) G_T IN (3.2.1) AND G_p IN (3.2.3) SHOULD BE IDENTICAL WHEN $\Gamma_s = \Gamma_{IN}^*$ (i.e., $P_{IN} = P_{AVS}$ WHEN $\Gamma_s = \Gamma_{IN}^*$). FROM (3.2.1) WITH $\Gamma_s = \Gamma_{IN}^*$:

$$G_T = \frac{1-|\Gamma_{IN}|^2}{|1-\Gamma_{IN}\Gamma_{IN}^*|^2}|S_{21}|^2\frac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2} = \frac{\cancel{1-|\Gamma_{IN}|^2}}{(1-|\Gamma_{IN}|^2)^{\cancel{2}}}|S_{21}|^2\frac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2}$$

HENCE:

$$G_T = G_p = \frac{1}{1-|\Gamma_{IN}|^2}|S_{21}|^2\frac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2}$$

G_T IN (3.2.2) AND G_A IN (3.2.4) SHOULD BE IDENTICAL WHEN $\Gamma_L = \Gamma_{OUT}^*$ (i.e, $P_L = P_{AVN}$ WHEN $\Gamma_L = \Gamma_{OUT}^*$). FROM (3.2.2) WITH $\Gamma_L = \Gamma_{OUT}^*$:

$$G_T = \frac{1-|\Gamma_s|^2}{|1-S_{11}\Gamma_s|^2}|S_{21}|^2\frac{1-|\Gamma_{OUT}|^2}{|1-\Gamma_{OUT}\Gamma_{OUT}^*|^2} = \frac{1-|\Gamma_s|^2}{|1-S_{11}\Gamma_s|^2}|S_{21}|^2\frac{\cancel{1-|\Gamma_{OUT}|^2}}{(1-|\Gamma_{OUT}|^2)^{\cancel{2}}}$$

HENCE:

$$G_T = G_A = \frac{1-|\Gamma_s|^2}{|1-S_{11}\Gamma_s|^2}|S_{21}|^2\frac{1}{1-|\Gamma_{OUT}|^2}$$

3.2) (a) WITH $Z_s = Z_L = Z_o$ THEN $\Gamma_s = \Gamma_L = 0$, AND FROM (3.2.1):

$$G_T = |S_{21}|^2$$

(b) FROM (3.2.5): $\Gamma_{IN} = S_{11}$ WHEN $\Gamma_L = 0$. THEREFORE, FROM (3.2.3):

$$G_p = \frac{|S_{21}|^2}{1-|\Gamma_{IN}|^2} = \frac{|S_{21}|^2}{1-|S_{11}|^2}$$

(c) FROM (3.2.6): $\Gamma_{OUT} = S_{22}$ WHEN $\Gamma_s = 0$. THEREFORE, FROM (3.2.4):

$$G_A = \frac{|S_{21}|^2}{1-|\Gamma_{OUT}|^2} = \frac{|S_{21}|^2}{1-|S_{22}|^2}$$

3.3)(a) WITH THE VALUES GIVEN IN THE PROBLEM IT FOLLOWS THAT:

FROM (3.2.5): $\Gamma_{IN} = 0.671 \angle 160.72^\circ$

FROM (3.2.6): $\Gamma_{OUT} = 0.615 \angle -82.8^\circ$

FROM (3.2.1): $G_T = 8.575$ OR $9.33\,dB$

FROM (3.2.3): $G_p = 9.487$ OR $9.77\,dB$

FROM (3.2.4): $G_A = 8.745$ OR $9.42\,dB$

(b) $P_{AVS} = \dfrac{|E_1|^2}{8\,Re[Z_1]} = \dfrac{10^2}{8(50)} = 0.25\,W$, $M_s = \dfrac{G_T}{G_p} = \dfrac{8.575}{9.487} = 0.904$

$P_{IN} = P_{AVS} M_s = 0.25(0.904) = 0.226\,W$

$P_L = G_p P_{IN} = 9.487(0.226) = 2.144\,W$

$P_{AVN} = G_A P_{AVS} = 8.745(0.25) = 2.186\,W$

3.4) $\Gamma_s = 0$ AND $\Gamma_L = 0.5 \angle 90^\circ$. HENCE:

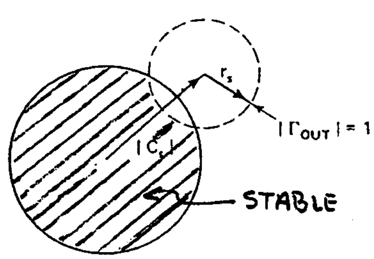
$G_T = G_{TU} = 11.294$ OR $10.53\,dB$

$G_p = 22.145$ OR $13.45\,dB$

$G_A = 21.33$ OR $13.29\,dB$

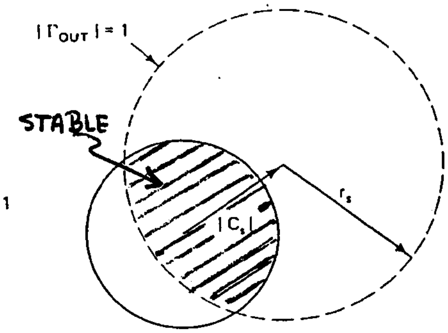
3.5) OBSERVE THAT $\Gamma_{OUT} = S_{22}$ WHEN $\Gamma_s = 0$. THEREFORE, THE ORIGIN (i.e., $\Gamma_s = 0$) IS A STABLE POINT WHEN $|S_{22}| < 1$.

THE "SHADED" PART IS THE "STABLE REGION".



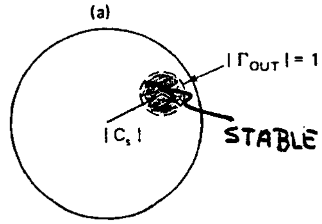
$K < 1, |S_{11}| > 1, |S_{22}| < 1$

(a)



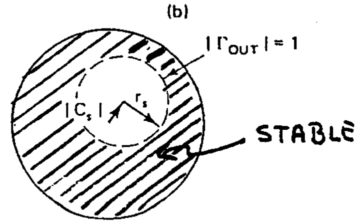
$K < 1, |S_{11}| > 1, |S_{22}| < 1$

(b)



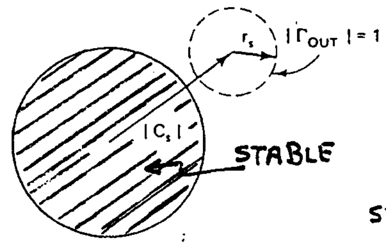
$K > 1, |\Delta| > 1, |S_{11}| < 1, |S_{22}| > 1$

(c)



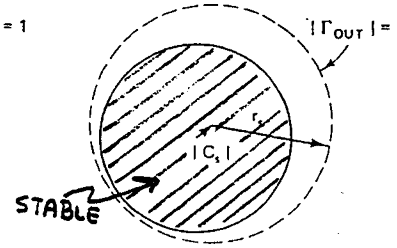
$K > 1, |\Delta| > 1, |S_{11}| > 1, |S_{22}| > 1$

(d)



$K > 1, |\Delta| < 1, |S_{11}| < 1, |S_{22}| < 1$

(e)

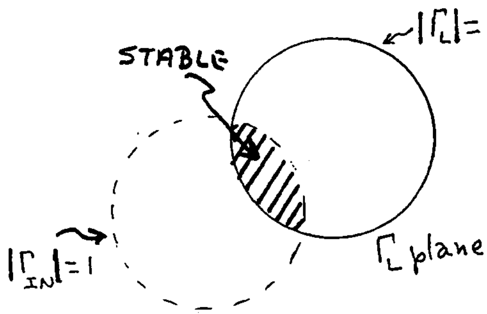


$K > 1, |\Delta| < 1, |S_{11}| < 1, |S_{22}| < 1$

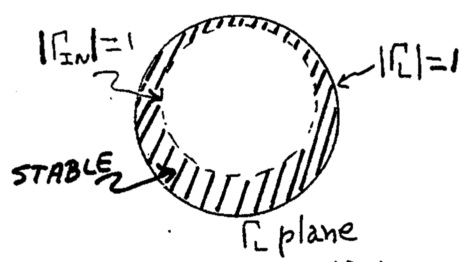
(f)

3.6) OBSERVE THAT $\Gamma_{IN} = S_{11}$ WHEN $\Gamma_L = 0$. THEREFORE, THE ORIGIN (i.e., $\Gamma_L = 0$) IS A STABLE POINT WHEN $|S_{11}| < 1$.

THE "SHADED" PART IS THE "STABLE REGION".



$|S_{11}| > 1, |S_{22}| < 1$



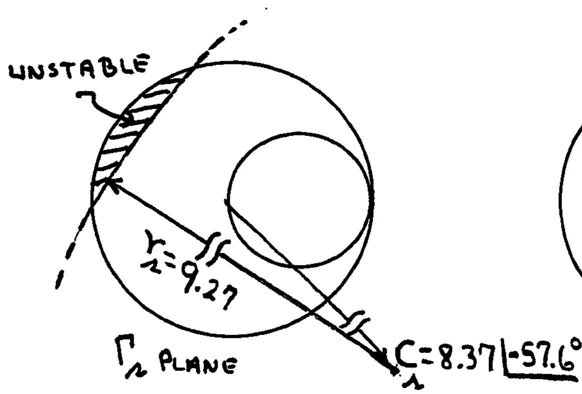
$|S_{11}| > 1, |S_{22}| > 1$

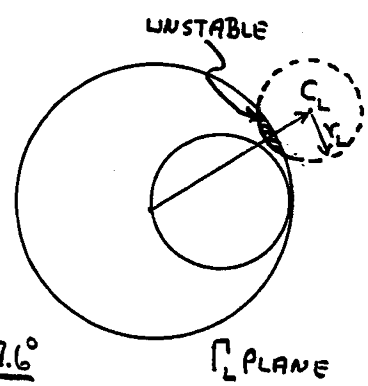
3.7) (a) $K = 1.284$, $\Delta = 0.386 \angle 134.2°$ ∴ UNCONDITIONALLY STABLE.

(b) $K = 0.909$, $\Delta = 0.402 \angle -65.04°$ ∴ POTENTIALLY UNSTABLE.

INPUT STABILITY CIRCLE $\begin{cases} r_s = 9.27 \\ C_s = 8.37 \angle -57.6° \end{cases}$

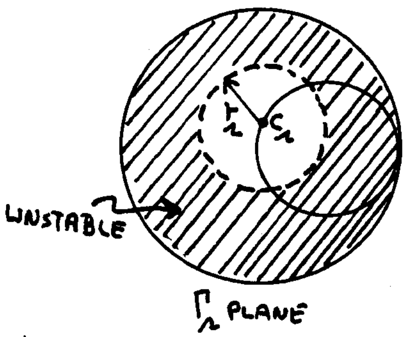
OUTPUT STABILITY CIRCLE $\begin{cases} r_L = 0.19 \\ C_L = 1.18 \angle 29.8° \end{cases}$

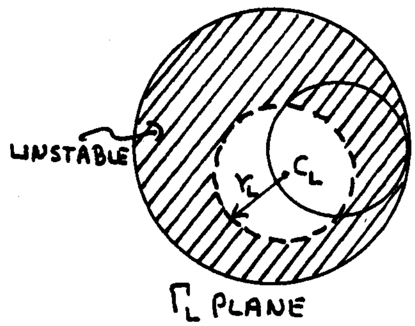




(c) $K = 1.202$, $\Delta = 1.76\angle 18.5°$ $\therefore$ POTENTIALLY UNSTABLE

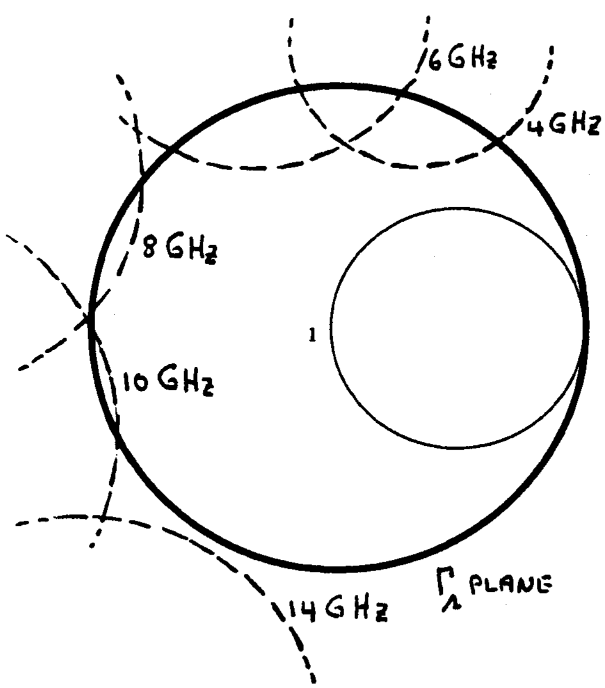
INPUT STABILITY CIRCLE $\begin{cases} r_s = 0.518 \\ C_s = 0.152\angle 82.1° \end{cases}$ OUTPUT STABILITY CIRCLE $\begin{cases} r_L = 0.494 \\ C_L = 0.239\angle -58° \end{cases}$

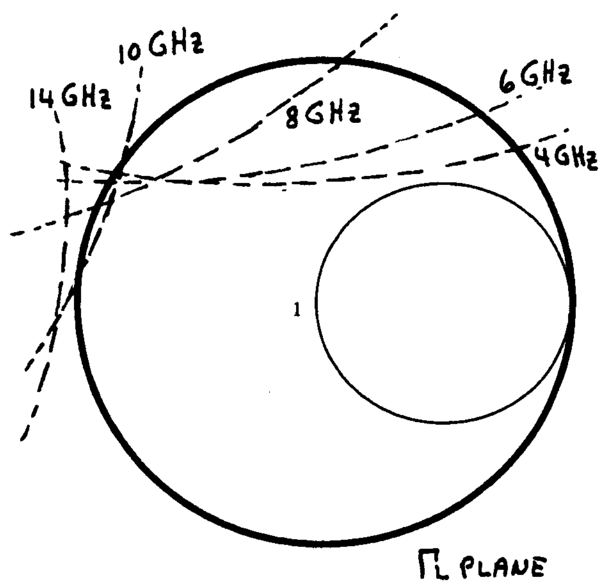




3.8)

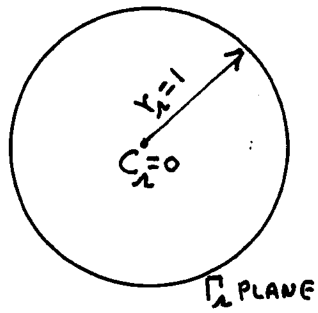
f(GHz)	K	Δ	STABILITY CIRCLE	STABILITY CIRCLE
4	0.412	$0.65\angle -90.3°$	$r_s = 0.444$, $C_s = 1.25\angle 80.9°$	$r_L = 3.79$, $C_L = 4.3\angle 91.4°$
6	0.56	$0.57\angle -131.1°$	$r_s = 0.604$, $C_s = 1.43\angle 111.6°$	$r_L = 6.316$, $C_L = 6.93\angle 107.8°$
8	0.78	$0.43\angle 174.9°$	$r_s = 0.789$, $C_s = 1.69\angle 152.6°$	$r_L = 7.39$, $C_L = 8.2\angle 126.1°$
10	0.89	$0.32\angle 114°$	$r_s = 0.759$, $C_s = 1.72\angle -171.8°$	$r_L = 3.49$, $C_L = 4.41\angle 150.1°$
14	1.33	$0.17\angle -2.4°$	$r_s = 0.513$, $C_s = 1.62\angle -110.2°$	$r_L = 1.87$, $C_L = 3.08\angle -171.7°$



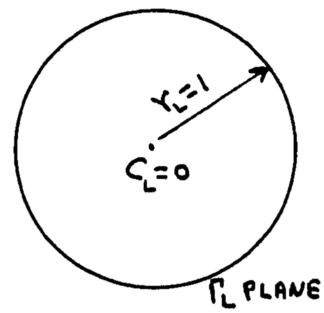


3.9) (a) $K=1\ ,\ \Delta=1$

INPUT STABILITY CIRCLE:
$$\begin{cases} r_s = 1 \\ C_s = 0 \end{cases}$$

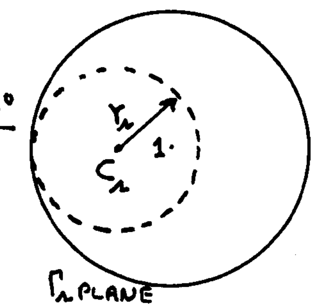


OUTPUT STABILITY CIRCLE:
$$\begin{cases} r_L = 1 \\ C_L = 0 \end{cases}$$

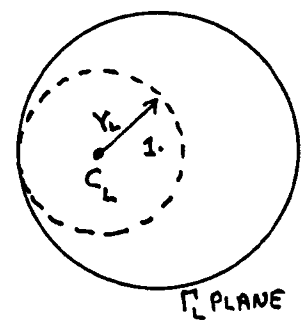


(b) $K=1\ ,\ \Delta=-2.414$

$$\begin{cases} r_s = 0.55 \\ C_s = 0.45\underline{|180^\circ} \end{cases}$$

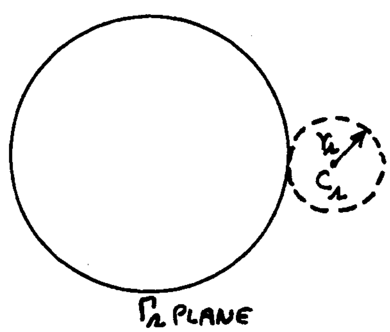


$$\begin{cases} r_L = 0.55 \\ C_L = 0.45\underline{|180^\circ} \end{cases}$$

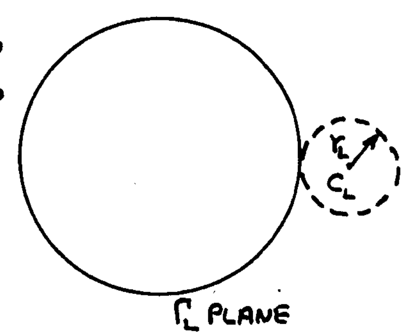


(c) $K=1\ ,\ \Delta=0.415$

$$\begin{cases} r_s = 0.26 \\ C_s = 1.26 \end{cases}$$

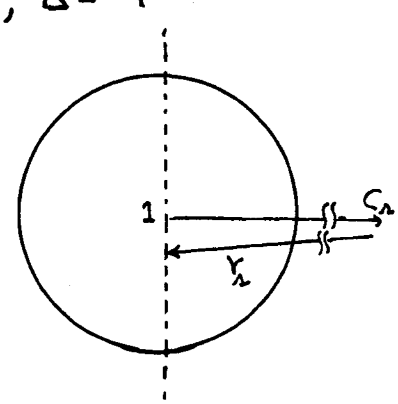


$$\begin{cases} r_L = 0.26 \\ C_L = 1.26 \end{cases}$$

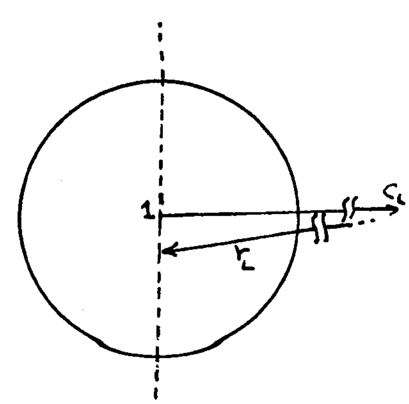


(d) $K=0\ ,\ \Delta=-1$

$$\begin{cases} r_s = \infty \\ C_s = \infty \end{cases}$$



$$\begin{cases} r_L = \infty \\ C_L = \infty \end{cases}$$



3.10) (a) FROM (3.3.7) AND (3.3.8) : $\lim_{S_{12}\to 0} \Delta = S_{11}S_{22}$. THEN,

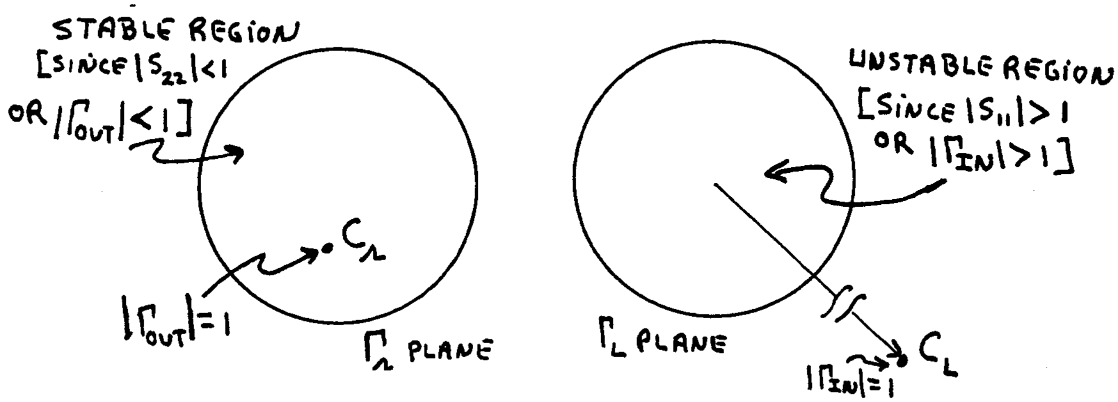
$$\lim_{S_{12}\to 0} r_L = 0$$

AND

$$\lim_{S_{12}\to 0} C_L = \frac{(S_{22} - S_{11}S_{22}S_{11})^*}{|S_{22}|^2 - |S_{11}S_{22}|^2} = \frac{S_{22}^*(1-|S_{11}|^2)}{|S_{22}|^2(1-|S_{11}|^2)} = \frac{S_{22}^*}{|S_{22}|^2} = \frac{1}{S_{22}}$$

SIMILARLY: $\lim_{S_{12}\to 0} r_s = 0$ AND $\lim_{S_{12}\to 0} C_s = \frac{1}{S_{11}}$

(b) $\begin{cases} r_s = 0 \\ C_s = \frac{1}{S_{11}} = 0.5\angle -90^\circ \end{cases}$ $\qquad$ $\begin{cases} r_L = 0 \\ C_L = \frac{1}{S_{22}} = 10\angle -45^\circ \end{cases}$



3.11) THE SOURCE STABILITY CIRCLE DOES NOT ENCLOSE THE CENTER OF THE SMITH CHART WHEN: $|C_s| > r_s$. FROM (3.3.9) AND (3.3.10) WE OBTAIN: $|S_{11} - \Delta S_{22}^*| > |S_{12}S_{21}|$

FROM PROBLEM 3.20 : $|S_{11} - \Delta S_{22}^*|^2 = |S_{12}S_{21}|^2 + (1-|S_{22}|^2)(|S_{11}|^2 - |\Delta|^2)$

HENCE: $|S_{12}S_{21}|^2 + (1-|S_{22}|^2)(|S_{11}|^2 - |\Delta|^2) > |S_{12}S_{21}|^2$

OR $\quad (1-|S_{22}|^2)(|S_{11}|^2 - |\Delta|^2) > 0 \quad (1)$

FROM (1) : $\begin{cases} \text{If } |S_{22}|<1 \text{ then } |\Delta| < |S_{11}| \\ \text{If } |S_{22}|>1 \text{ then } |\Delta| > |S_{11}| \end{cases}$

SIMILARLY : $|C_L| > r_L \Rightarrow |S_{22} - \Delta S_{11}^*| > |S_{12}S_{21}|$ OR

$(1-|S_{11}|^2)(|S_{22}|^2 - |\Delta|^2) > 0 \quad (2)$

FROM (2): $\begin{cases} \text{If } |S_{11}|<1 \text{ then } |\Delta| < |S_{22}| \\ \text{If } |S_{11}|>1 \text{ then } |\Delta| > |S_{22}| \end{cases}$

3.12) THE ANSWER TO THIS PROBLEM FOLLOWS FROM THE RESULTS IN APPENDIX J. THAT IS, WITH $C_{ii}=0$ AND $r_{ii}=1$ WE OBTAIN:

$$C_{OUT}=\frac{S_{22}-\Delta S_{11}^*}{1-|S_{11}|^2} \quad \text{AND} \quad r_{OUT}=\frac{|S_{12}S_{21}|}{1-|S_{11}|^2}$$

ALSO, WITH $C_{oo}=0$ AND $r_{oo}=1$ WE OBTAIN:

$$C_{IN}=\frac{S_{11}-\Delta S_{22}^*}{1-|S_{22}|^2} \quad \text{AND} \quad r_{IN}=\frac{|S_{12}S_{21}|}{1-|S_{22}|^2}$$

3.13) (a) $\Delta = S_{11}S_{22}-S_{12}S_{21}$ AND $S_{11}S_{22}=\Delta+S_{12}S_{21}$

$\therefore$ $|\Delta|=|S_{11}S_{22}-S_{12}S_{21}|$ AND $|S_{11}S_{22}|=|\Delta+S_{12}S_{21}|$

HENCE: $|\Delta|\le|S_{11}S_{22}|+|S_{12}S_{21}|$ (1) $\qquad |S_{11}S_{22}|\le|\Delta|+|S_{12}S_{21}|$ (2)

FROM (3.3.13): $K>1$ OR $1-|S_{11}|^2-|S_{22}|^2+|\Delta|^2>2|S_{12}S_{21}|$ (3)

(1) INTO (3): $1-|S_{11}|^2-|S_{22}|^2+|\Delta|^2>2|\Delta|-2|S_{11}S_{22}|$ (4)

(2) INTO (3): $1-|S_{11}|^2-|S_{22}|^2+|\Delta|^2>2|S_{11}S_{22}|-2|\Delta|$ (5)

FROM (4): $(1-|\Delta|)^2>(|S_{11}|-|S_{22}|)^2$ (6)

FROM (5): $(1+|\Delta|)^2>(|S_{11}|+|S_{22}|)^2$ (7)

FROM (6) AND (7): $(1-|\Delta|)^2(1+|\Delta|)^2>(|S_{11}|-|S_{22}|)^2(|S_{11}|+|S_{22}|)^2$

$$(1-|\Delta|^2)^2>(|S_{11}|^2-|S_{22}|^2)^2 \quad (8)$$

SINCE: $B_1=1+|S_{11}|^2-|S_{22}|^2-|\Delta|^2$ AND $B_2=1+|S_{22}|^2-|S_{11}|^2-|\Delta|^2$

THEN: $B_1B_2=(1-|\Delta|^2)^2-(|S_{11}|^2-|S_{22}|^2)^2$ (9), $B_1+B_2=2(1-|\Delta|^2)$ (10)

FROM (8) AND (9) WE HAVE: $B_1B_2>0$ (11)

(b) THE RELATION $B_1B_2>0$ SHOWS THAT IF $B_1>0$ THEN $B_2>0$. THEREFORE, THE CONDITIONS $K>1$ AND $B_1>0$ ARE SIMILAR TO $K>1$ AND $B_2>0$.

(c) IF $B_1>0$ THEN $B_2>0$. HENCE, FROM (10):

$$2(1-|\Delta|^2)>0$$

OR $\quad |\Delta|<1$

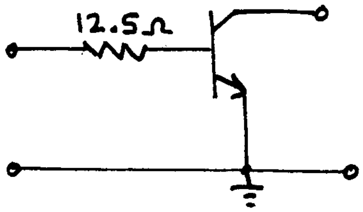
3.14) FOR THIS TRANSISTOR: $K = 0.532$, $\Delta = 0.617\angle{-85.4^\circ}$

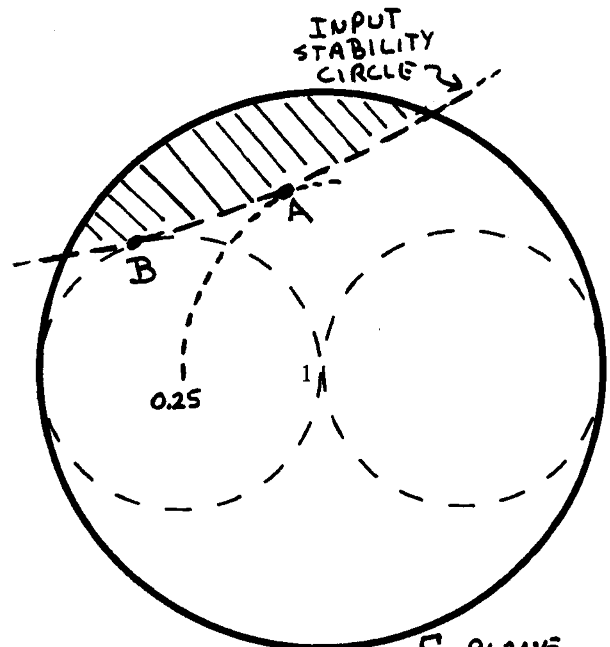
$r_s = 1.96$ $\qquad$ $r_L = 0.576$

$C_s = 2.64\angle{116.7^\circ}$ $\qquad$ $C_L = 1.4\angle{41.5^\circ}$

AT POINT A: $r = 0.25$

$\therefore\ R = 0.25(50) = 12.5\,\Omega$

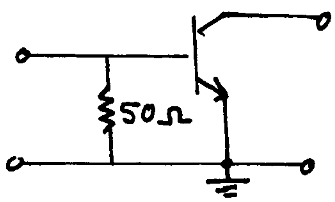




Γ_s PLANE

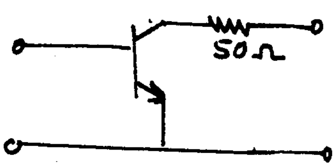
AT POINT B: $g = 1$

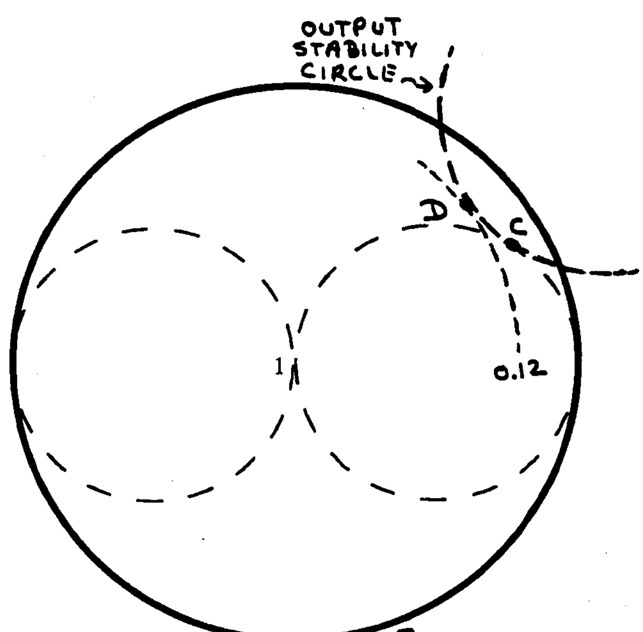
$\therefore\ G = \frac{1}{50} = 20\,mS$ (OR $50\,\Omega$)



AT POINT C: $r = 1$

$\therefore\ R = 1(50) = 50\,\Omega$

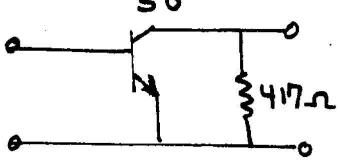




Γ_L PLANE

AT POINT D: $g = 0.12$

$G = \frac{0.12}{50} = 2.4\,mS$ (OR $417\,\Omega$)



FOR THIS CIRCUIT IT FOLLOWS THAT: $S_{11} = 0.695\angle{-77.3^\circ}$, $S_{12} = 0.03\angle{42.5^\circ}$, $S_{21} = 5.13\angle{124.1^\circ}$, AND $S_{22} = 0.665\angle{-25.8^\circ}$.

HENCE, $K = 1.02$ AND $\Delta = 0.488\angle{-84.7^\circ}$

AND THE CIRCUIT IS UNCONDITIONALLY STABLE.

3.15) THE MAXIMUM VALUE OF $G_i = \dfrac{1-|\Gamma_i|^2}{|1-S_{ii}\Gamma_i|^2}$ IS OBTAINED AS FOLLOWS:

LET $\Gamma_i = x + jy$ AND $S_{ii} = a + jb$. THEN

$$G_i = \frac{1-x^2-y^2}{(1-xa+yb)^2+(xb+ya)^2} = \frac{1-x^2-y^2}{D} \; ; \; D = (1-xa+yb)^2+(xb+ya)^2$$

$$\begin{cases} \dfrac{\partial G_i}{\partial x} = \dfrac{-2x}{D} - \dfrac{(1-x^2-y^2)[-2a(1-xa+yb)+2b(xb+ya)]}{D^2} = 0 \\[2ex] \dfrac{\partial G_i}{\partial y} = \dfrac{-2y}{D} - \dfrac{(1-x^2-y^2)[2b(1-xa+yb)+2a(xb+ya)]}{D^2} = 0 \end{cases}$$

OR

$$\begin{cases} 2xD = -(1-x^2-y^2)[-2a(1-xa+yb)+2b(xb+ya)] & (1) \\ 2yD = -(1-x^2-y^2)[2b(1-xa+yb)+2a(xb+ya)] & (2) \end{cases}$$

DIVIDING (1) BY (2) GIVES:

$$\frac{x}{y} = \frac{-a(1-xa+\cancel{yb})+b(xb+\cancel{ya})}{b(1-\cancel{xa}+yb)+a(\cancel{xb}+ya)} = \frac{-a+xa^2+xb^2}{b+yb^2+ya^2}$$

OR

$$xb+\cancel{yb^2x}+\cancel{ya^2x} = -ay+\cancel{xa^2y}+\cancel{xb^2y} \Rightarrow x = -\frac{ay}{b} \quad (3)$$

(3) INTO (1): $-2\dfrac{ay}{b}\left(1+\dfrac{a^2y}{b}+yb\right)^2 = -\left(1-\dfrac{a^2y^2}{b^2}-y^2\right)\left(-2a\left(1+\dfrac{a^2y}{b}+yb\right)\right)$

OR

$$-\frac{y}{b}\left(1+\cancel{\frac{a^2y}{b}}+\cancel{yb}\right) = 1-\cancel{\frac{a^2y^2}{b^2}}-\cancel{y^2} \Rightarrow y = -b \quad (4)$$

(4) INTO (3): $x = -\dfrac{a}{b}(-b)$ OR $x = a$ (5)

FROM (4) AND 5: $\Gamma_i = x + jy = a - jb$ OR $\Gamma_i = S_{ii}^*$.

3.16) (a) FOR $G_{TU,max}$: $\Gamma_s = S_{11}^* = 0.706\angle 160^\circ$ AND

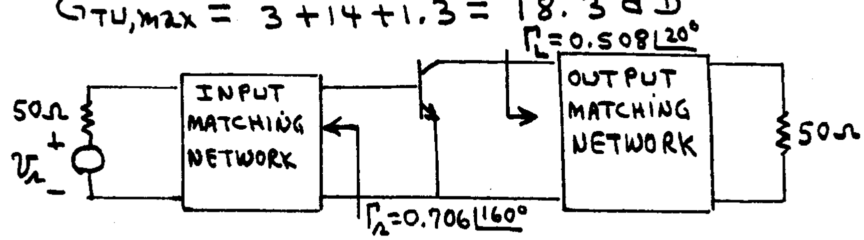
$\Gamma_L = S_{22}^* = 0.508\angle 20^\circ$.

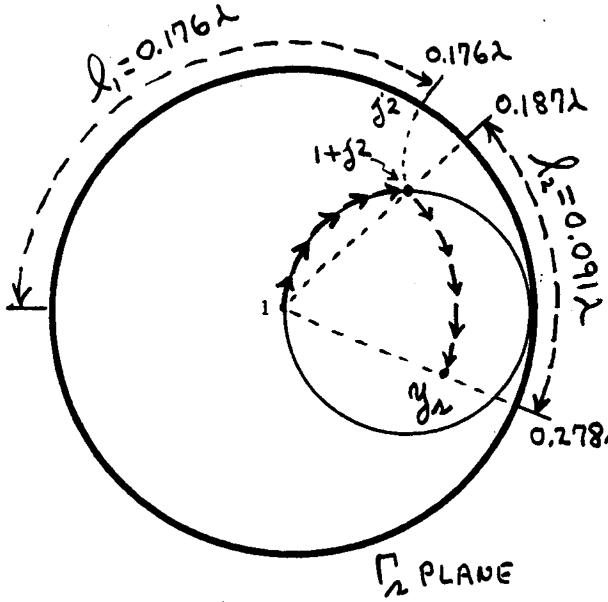
$$G_{s,max} = \frac{1}{1-|S_{11}|^2} = \frac{1}{1-(0.706)^2} = 1.99 \text{ OR } 3\text{ dB}$$

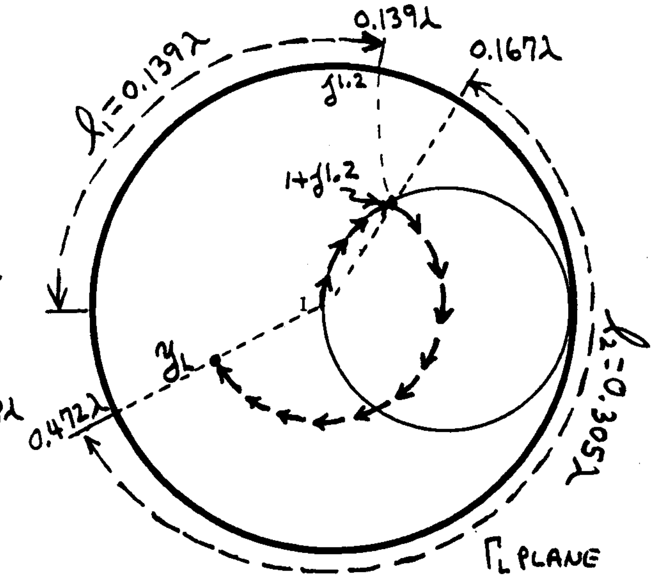
$$G_o = |S_{21}|^2 = (5.01)^2 = 25.1 \text{ OR } 14\text{ dB}$$

$$G_{L,max} = \frac{1}{1-|S_{22}|^2} = \frac{1}{1-(0.508)^2} = 1.35 \text{ OR } 1.3\text{ dB}$$

$$G_{TU,max} = 3+14+1.3 = 18.3\text{ dB}$$

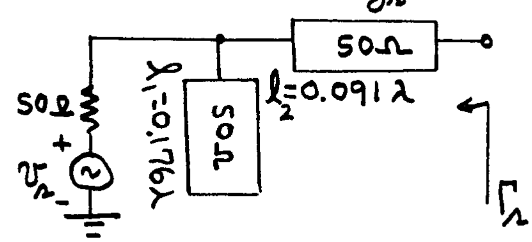


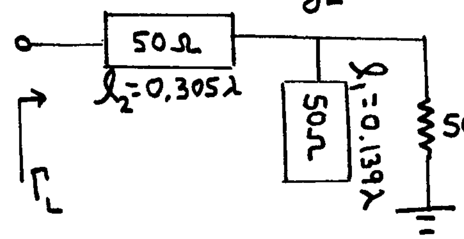




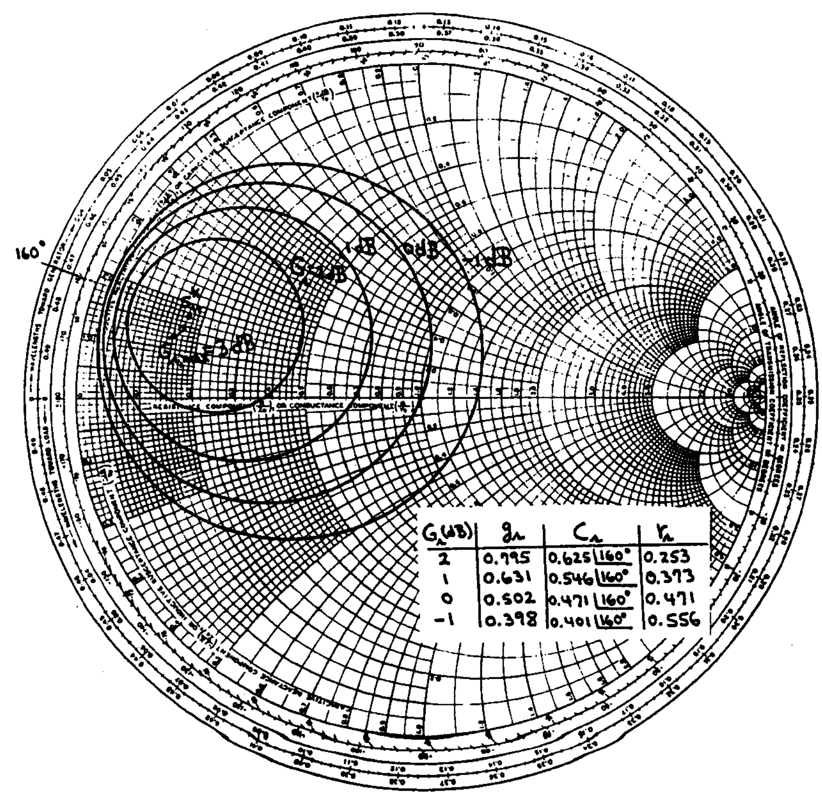
$\Gamma_s = 0.706\angle 160°$, $y_s = \frac{1}{z_s} = 2.9 - j2.8$

$\Gamma_L = 0.508\angle 20°$, $y_L = \frac{1}{z_L} = 0.335 - j0.157$





(b)



G_s(dB)	g_s	C_s	r_s
2	0.795	$0.625\angle 160°$	0.253
1	0.631	$0.546\angle 160°$	0.373
0	0.502	$0.471\angle 160°$	0.471
−1	0.398	$0.401\angle 160°$	0.556

3.17) (a) THE INPUT RESISTANCE IS CALCULATED AS FOLLOWS:

$$\Gamma_{IN} = S_{11} = 2.3\underline{|-135^\circ} \quad , \quad Z_{IN} = 50(-0.45 - j0.341) = -22.48 - j17.04\ \Omega.$$

Z_{IN} CAN ALSO BE CALCULATED USING THE SMITH CHART.

PLOT $\frac{1}{S_{11}^*} = 0.435\underline{|-135}$ AND READ $Z_{IN} = 50(-0.45 - j0.34) = -22.5 - j17\ \Omega$

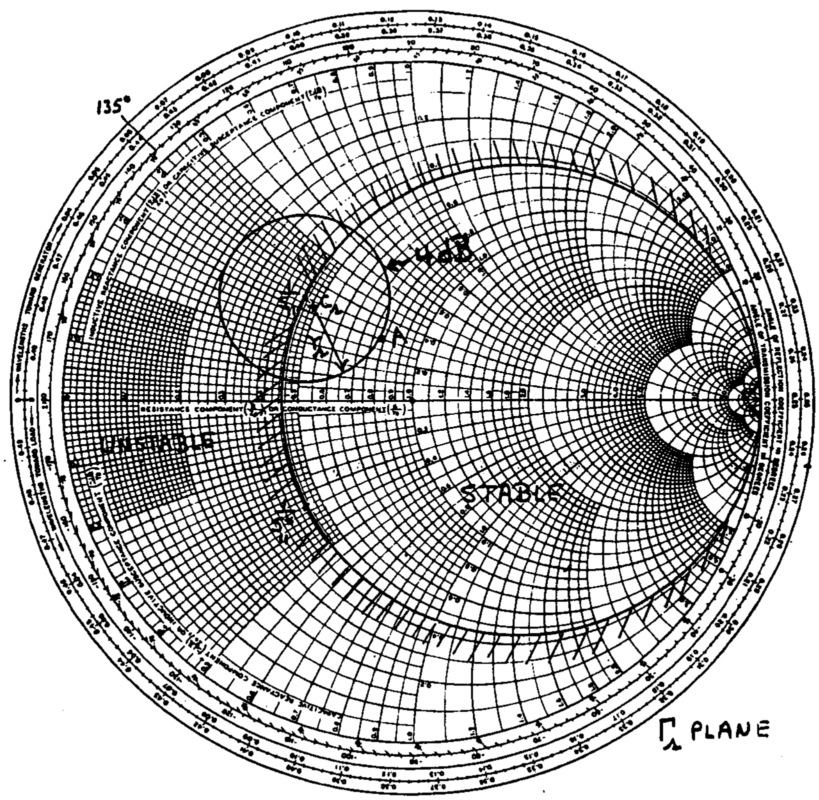
FOR $G_s = 4$ dB , $g_s = 2.512[1-(2.3)^2] = -10.78$

FROM (3.4.11) AND (3.4.12): $C_s = 0.404\underline{|135^\circ}$ AND $r_s = 0.24$

(b) AT POINT A, Γ_s HAS THE LARGEST REAL PART ON THE $G_s = 4$ dB CIRCLE. THAT IS,

$\Gamma_s = 0.2\underline{|115^\circ}$

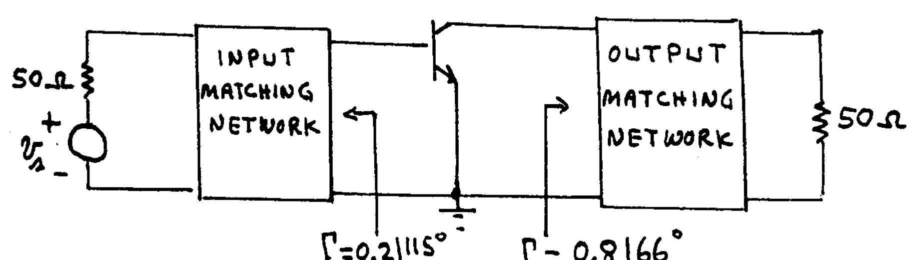
THE INPUT MATCHING CIRCUIT MUST TRANSFORM 50 Ω TO $\Gamma_s = 0.2\underline{|115^\circ}$.



(c) DESIGN FOR $\Gamma_s = 0.2\underline{|115^\circ}$ AND $\Gamma_L = S_{22}^* = 0.8\underline{|66^\circ}$. THEN,

$G_s = 4$ dB, $G_o = |S_{21}|^2 = 16$ (OR 12.04 dB), $G_{L,max} = \frac{1}{1-(0.8)^2} = 2.78$ (OR 4.4 dB)

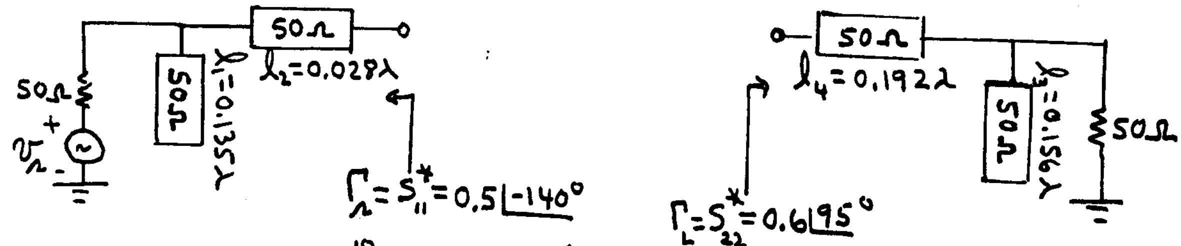
$$\therefore\ G_{TU}(\text{dB}) = G_s + G_o + G_{L,max} = 4 + 12.04 + 4.4 = 20.4\ \text{dB}$$



3.18) (a) $G_{s,max} = \frac{1}{1-(0.5)^2} = 1.33$ OR $1.25\,dB$, $G_{L,max} = \frac{1}{1-(0.6)^2} = 1.563$ OR $1.94\,dB$

$G_o = |S_{21}|^2 = 25$ OR $13.98\,dB$, $\therefore G_{TU,max} = 1.25 + 13.98 + 1.94 = 17.2\,dB$

(b) A MATCHING NETWORK DESIGN AT 900 MHz IS:



AT 900 MHz: $\lambda = \frac{3\,10^{10}}{9\,10^8} = 33.3\,cm$, $l_1 = 0.135\lambda = 4.496\,cm$,

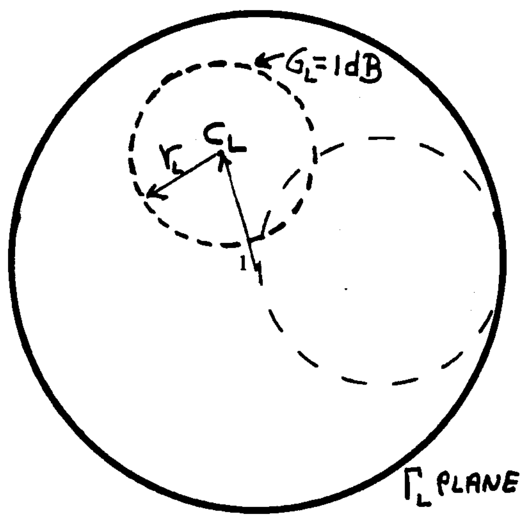
$l_2 = 0.028\lambda = 0.932\,cm$, $l_3 = 0.156\lambda = 5.195\,cm$, $l_4 = 0.192\lambda = 6.394\,cm$

(c) $g_L = \frac{G_L}{G_{L,max}} = \frac{1.259}{1.563} = 0.805$

FROM (3.4.11) AND (3.4.12):

$C_L = 0.519\angle 95°$

$r_L = 0.304$



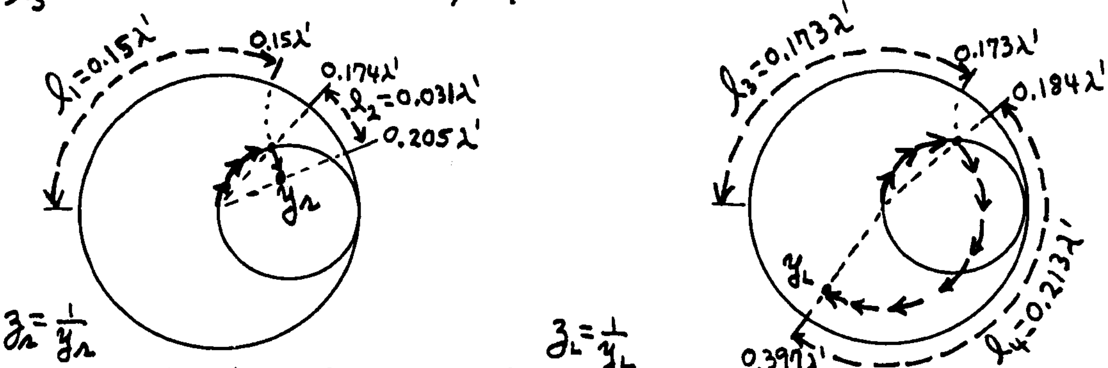
(d) LET $\lambda' = \frac{c}{f'}$ WHERE $f' = 1\,GHz$,

AND $\lambda = \frac{c}{f}$ WHERE $f = 900\,MHz$.

$\therefore \frac{\lambda}{\lambda'} = \frac{f'}{f}$ OR $\lambda = \frac{f'}{f}\lambda' = \frac{10^9}{9\,10^8}\lambda' = 1.11\lambda'$

$l_1 = 0.135\lambda = 0.135(1.11\lambda') = 0.15\lambda'$, $l_2 = 0.028(1.11\lambda') = 0.031\lambda'$,

$l_3 = 0.156(1.11\lambda') = 0.173\lambda'$, $l_4 = 0.192(1.11\lambda') = 0.213\lambda'$



$y_s = 1.79 + j1.58$, $\Gamma_s = 0.55\angle{-146°}$

$y_L = 0.28 - j0.72$, $\Gamma_L = 0.693\angle 74.4°$

$\therefore G_{TU} = \frac{1-(0.55)^2}{|1-0.48\angle 137°(0.55\angle{-146°})|^2}(4.6)^2\frac{1-(0.693)^2}{|1-0.57\angle{-99°}(0.693\angle 74.4°)|^2} = 31.97$ OR $15.05\,dB$

3.19) (a) $\Gamma_{MS}^* = S_{11} + \frac{S_{12}S_{21}\Gamma_{ML}}{1-S_{22}\Gamma_{ML}} = \frac{S_{11}-\Delta\Gamma_{ML}}{1-S_{22}\Gamma_{ML}}$ (1)

$$\Gamma_{ML}^* = S_{22} + \frac{S_{12}S_{21}\Gamma_{MS}}{1-S_{11}\Gamma_{MS}} = \frac{S_{22}-\Delta\Gamma_{MS}}{1-S_{11}\Gamma_{MS}} \quad (2)$$

SOLVING (2) FOR Γ_{MS} GIVES: $\Gamma_{MS} = \frac{\Gamma_{ML}^* - S_{22}}{S_{11}\Gamma_{ML}^* - \Delta}$ (3)

EQUATING (1) AND (3): $\frac{S_{11}-\Delta\Gamma_{ML}}{1-S_{22}\Gamma_{ML}} = \frac{\Gamma_{ML} - S_{22}^*}{S_{11}^*\Gamma_{ML} - \Delta^*}$

$$|S_{11}|^2\Gamma_{ML} - S_{11}\Delta^* - \Delta S_{11}^*\Gamma_{ML}^2 + |\Delta|^2\Gamma_{ML} = \Gamma_{ML} - S_{22}^* - S_{22}\Gamma_{ML}^2 + |S_{22}|^2\Gamma_{ML}$$

$$\Gamma_{ML}^2(S_{22}-\Delta S_{11}^*) - \Gamma_{ML}\left(1+|S_{22}|^2-|S_{11}|^2-|\Delta|^2\right) + S_{22}^* - S_{11}\Delta^* = 0$$

OR

$$\Gamma_{ML}^2 - \Gamma_{ML}\frac{B_2}{C_2} + \frac{C_2^*}{C_2} = 0 \quad \text{WHERE} \begin{cases} B_2 = 1+|S_{22}|^2-|S_{11}|^2-|\Delta|^2 \\ C_2 = S_{22} - \Delta S_{11}^* \end{cases}$$

THE SOLUTIONS ARE:

$$\Gamma_{ML} = \frac{\frac{B_2}{C_2} \pm \sqrt{\left(\frac{B_2}{C_2}\right)^2 - 4\frac{C_2^*}{C_2}}}{2} = \frac{B_2 \pm \sqrt{B_2 - 4|C_2|^2}}{2C_2}$$

SIMILARLY, SOLVING (1) FOR Γ_{ML} AND EQUATING THE RESULT TO (2) GIVES: $\Gamma_{MS} = \frac{B_1 \pm \sqrt{B_1 - 4|C_1|^2}}{2C_1}$ WHERE $\begin{cases} B_1 = 1+|S_{11}|^2-|S_{22}|^2-|\Delta|^2 \\ C_1 = S_{11} - \Delta S_{22}^* \end{cases}$

(b) FOR $S_{12}\to 0$ IT FOLLOWS FROM (3.6.3) AND (3.6.4) THAT

$$\Gamma_{MS} = \left(S_{11} + \frac{S_{12}S_{21}\Gamma_{ML}}{1-S_{22}\Gamma_{ML}}\right)^* \approx S_{11}^*$$

AND

$$\Gamma_{ML} = \left(S_{22} + \frac{S_{12}S_{21}\Gamma_{MS}}{1-S_{11}\Gamma_{MS}}\right)^* \approx S_{22}^*$$

3.20) (a) $|C_1|^2 = |S_{11} - \Delta S_{22}^*|^2 = (S_{11}-\Delta S_{22}^*)(S_{11}^* - \Delta^* S_{22})$

$$= |S_{11}|^2 - S_{11}S_{22}\Delta^* - S_{11}^*S_{22}^*\Delta + |\Delta S_{22}|^2$$

$$= |S_{11}|^2 - |S_{11}S_{22}|^2 + S_{11}S_{22}S_{12}^*S_{21}^* - |S_{11}S_{22}|^2 + S_{11}^*S_{22}^*S_{12}S_{21} + |\Delta S_{22}|^2 \quad (1)$$

SINCE $|\Delta|^2 = (S_{11}S_{22} - S_{12}S_{21})(S_{11}^*S_{22}^* - S_{12}^*S_{21}^*)$

$$= |S_{11}S_{22}|^2 - S_{11}S_{22}S_{12}^*S_{21}^* - S_{11}^*S_{22}^*S_{12}S_{21} + |S_{12}S_{21}|^2$$

THEN: $|S_{11}S_{22}|^2 - S_{11}S_{22}S_{12}^*S_{21}^* - S_{11}^*S_{22}^*S_{12}S_{21} = |\Delta|^2 - |S_{12}S_{21}|^2$ (2)

(2) INTO (1): $|C_1|^2 = |S_{11}|^2 - |\Delta|^2 + |S_{12}S_{21}|^2 - |S_{11}S_{22}|^2 + |\Delta|^2|S_{22}|^2$

$$= |S_{12}S_{21}|^2 + |S_{11}|^2(1-|S_{22}|^2) - |\Delta|^2(1-|S_{22}|^2)$$

$$= |S_{12}S_{21}|^2 + (1-|S_{22}|^2)(|S_{11}|^2 - |\Delta|^2)$$

SIMILARLY: $|C_2|^2 = |S_{12}S_{21}|^2 + (1-|S_{11}|^2)(|S_{22}|^2-|\Delta|^2)$

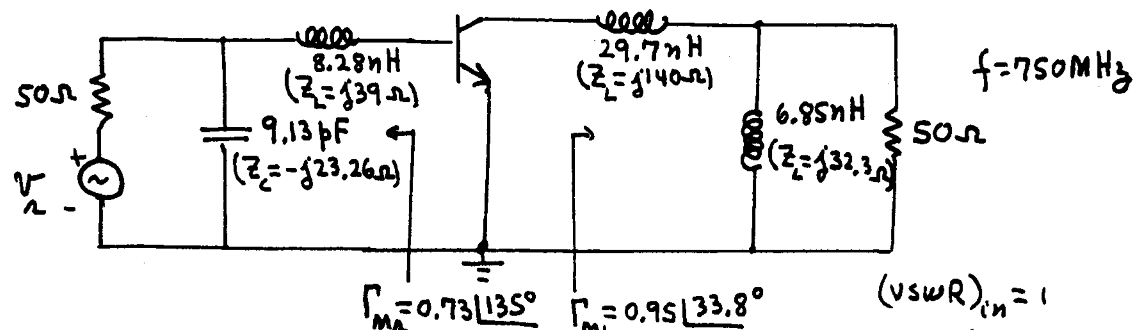
3.21) $K = 1.03$ AND $\Delta = 0.324\angle{-64.8°}$ $\therefore$ UNCONDITIONALLY STABLE

FROM (3.6.5) : $\Gamma_{Ms} = 0.73\angle{135°}$

FROM (3.6.6) : $\Gamma_{ML} = 0.95\angle{33.8°}$

FROM (3.6.10) : $G_{T,max} = 19.08$ OR 12.8 dB

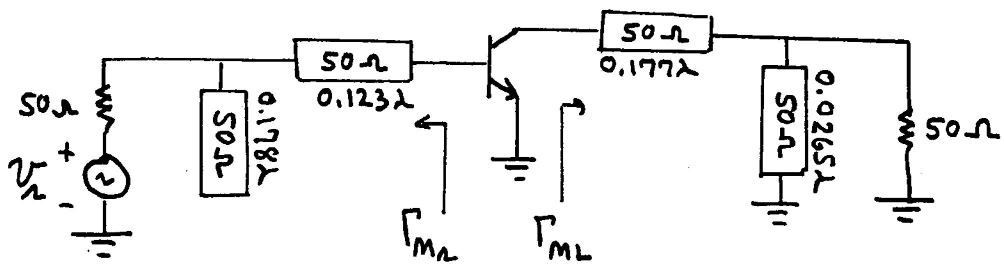
A DESIGN USING LUMPED ELEMENTS IS :



$(VSWR)_{in} = 1$

$(VSWR)_{out} = 1$

A DESIGN USING MICROSTRIP LINES IS :



3.22) (a) THE ADMITTANCE OF THE 70 Ω STUB IS : $y_{oc} = j$ OR $Y_{oc} = \frac{j}{70}$

THE ADMITTANCE OF THE TWO PARALLEL STUBS IS :

$$Y_{oc,TOTAL} = \frac{j}{70} + \frac{j}{70} = \frac{2j}{70} = \frac{j}{35} = j29 \text{ mS}$$

THE ADMITTANCE OF THE 50-Ω LOAD PLUS $Y_{oc,TOTAL}$ IS (CALLED Y_x):

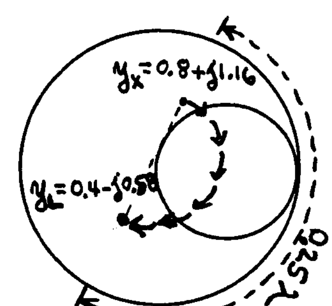
$$Y_x = \frac{1}{50} + \frac{j}{35} = 20 + j29 \text{ mS}$$

NORMALIZING Y_x WITH $Y_{o1} = \frac{1}{Z_{01}} = \frac{1}{40}$ ($y_x = 0.8 + j1.16$)

AND ROTATING IN THE SMITH CHART

A DISTANCE $l = 0.25\lambda$ GIVES

$z_L = \frac{1}{y_L} = 0.8 + j1.16$ $\therefore \Gamma_L = \Gamma_{ML} = 0.55\angle{67°}$



(b) FROM FIG. 2.5.4 (WITH $\epsilon_r = 10$ AND $h = 30$ mils):

$W = 28.5$ mils AND $\epsilon_{ff} = 6.68$, $\lambda_o = \frac{3\,10^{10}}{2\,10^9} = 15$ cm.

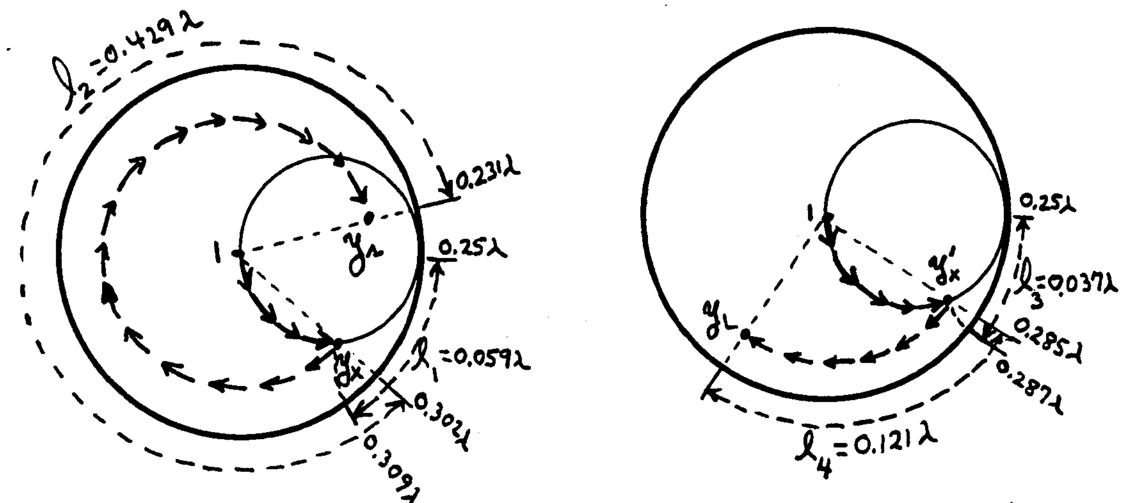
$\therefore l_1 = 0.25\lambda = \frac{0.25\lambda_o}{\sqrt{\epsilon_{ff}}} = \frac{0.25(15)}{\sqrt{6.68}} = 1.45$ cm.

3.23) THE OUTPUT IS MATCHED WITH $\Gamma_{ML} = \Gamma_{OUT}^* = 0.718\angle 103.9^\circ$.
THEREFORE, $\Gamma_X = 0$ (OR $Z_X = 50\Omega$) AND $(VSWR)_{out} = 1$.

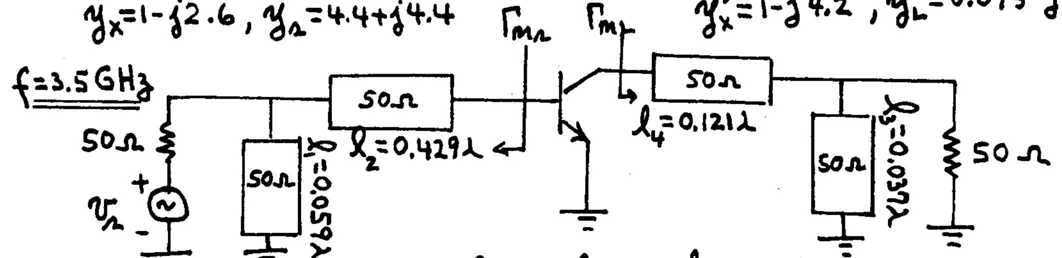
NOTE: THIS IS THE OUTPUT MATCHING NETWORK IN FIG. 3.6.4 (SEE FIG. 3.6.3b). IT IS SIMPLE TO VERIFY THAT $\Gamma_X = 0$ USING FIG. 3.6.3b. THAT IS, PLOT $y_{out} = y_{ML}^* = 0.414 + j1.19$ IN THE SMITH CHART AND FIND y_X, WHICH WILL BE $y_X = 1$ ($Z_X = 50\Omega$ OR $\Gamma_X = 0$).

3.24) (a) SINCE $K = 1.19$ AND $\Delta = 0.399\angle 126.5^\circ$ (i.e., $|\Delta| < 1$) THE BJT IS UNCONDITIONALLY STABLE AT 3.5 GHz. THEREFORE, IT CAN BE DESIGNED FOR A SIMULTANEOUS CONJUGATE MATCH.

(b) FROM (3.6.5) AND (3.6.6): $\Gamma_{Ms} = 0.798\angle -166.9^\circ$, $\Gamma_{ML} = 0.904\angle 68^\circ$
FROM (3.6.10): $G_{T,max} = 23.06$ OR 13.63 dB.
A DESIGN FOR THE AMPLIFIER AT 3.5 GHz IS:



$y_x = 1 - j2.6$, $y_s = 4.4 + j4.4$ $\qquad$ $y_x' = 1 - j4.2$, $y_L = 0.073 - j0.67$



(c)

f(GHz)	λ		l_1	l_2	l_3	l_4
$f_1 = 3$	$\lambda_1 = \frac{c}{f_1}$	$\lambda_2 = \frac{f_1}{f_2}\lambda_1 = 0.857\lambda_1$	$0.051\lambda_1$	$0.368\lambda_1$	$0.032\lambda_1$	$0.104\lambda_1$
$f_2 = 3.5$	$\lambda_2 = \frac{c}{f_2}$	λ_2	$0.059\lambda_2$	$0.429\lambda_2$	$0.037\lambda_2$	$0.121\lambda_2$
$f_3 = 4$	$\lambda_3 = \frac{c}{f_3}$	$\lambda_2 = \frac{f_3}{f_2}\lambda_3 = 1.143\lambda_3$	$0.067\lambda_3$	$0.49\lambda_3$	$0.042\lambda_3$	$0.138\lambda_3$

USING THE SMITH CHART IT IS SIMPLE TO FIND THE VALUES OF Γ_s AND Γ_L AT f_1 AND f_3. THE VALUES OF G_T ARE CALCULATED USING (3.2.1). THE RESULTS ARE:

f(GHz)	Γ_s	Γ_L	G_T
3	$0.833\angle{-118.5^\circ}$	$0.934\angle{82.2^\circ}$	0.944 OR −0.25 dB
3.5	$0.798\angle{-166.9^\circ}$	$0.904\angle{68^\circ}$	23.06 OR 13.63 dB
4	$0.749\angle{145.6^\circ}$	$0.878\angle{51.5^\circ}$	2.257 OR 3.54 dB

3.25) (a) THE TRANSISTOR IS UNCONDITIONALLY STABLE ($K=1.033$, $\Delta=0.324\angle{-64.8^\circ}$)

WITH $g_p=\dfrac{G_p}{|S_{21}|^2}=\dfrac{10^1}{(1.92)^2}=2.713$, WE OBTAIN FROM (3.7.4) AND (3.7.5):

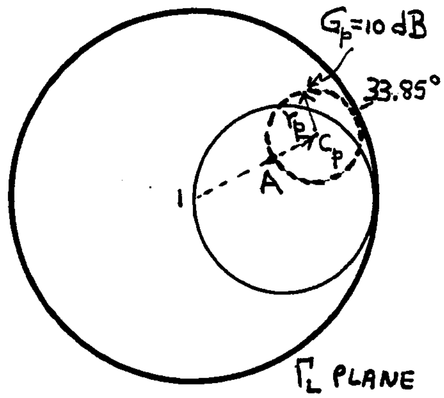
$$C_p=0.781\angle{33.85^\circ} \quad \text{AND} \quad r_p=0.214$$

THE $G_p=10\,\text{dB}$ GAIN CIRCLE IS DRAWN IN THE SMITH CHART. SELECTING Γ_L AT POINT "A": $\Gamma_L=0.567\angle{33.85^\circ}$, GIVES

$$\Gamma_s=\Gamma_{IN}^*=0.276\angle{93.33^\circ}.$$

AND

$$\Gamma_{OUT}=0.86\angle{-33.85^\circ}$$



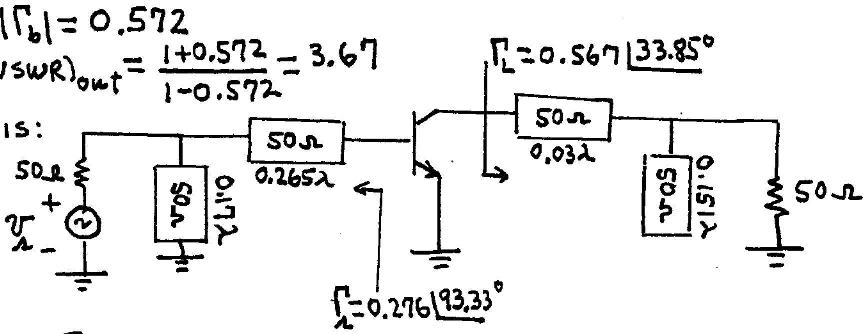
FROM (2.8.3): $|\Gamma_a|=0$ (SINCE $\Gamma_s=\Gamma_{IN}^*$)

HENCE: $(VSWR)_{in}=1$

FROM (2.8.6): $|\Gamma_b|=0.572$

HENCE: $(VSWR)_{out}=\dfrac{1+0.572}{1-0.572}=3.67$

A DESIGN IS:



(b) $G_{p,max}=G_{T,max}=19.08$ OR $12.8\,\text{dB}$

THE $G_{p,max}$ GAIN CIRCLE (i.e., a point) OCCURS AT:

$$g_{p,max}=\frac{G_{p,max}}{|S_{21}|^2}=\frac{19.08}{(1.92)^2}=5.176,\ C_{p,max}=0.95\angle{33.8^\circ},\ r_{p,max}=0.$$

OBSERVE (SEE PROBLEM 3.21) THAT: $\Gamma_{ML}=C_{p,max}=0.95\angle{33.8^\circ}$ AND $\Gamma_s=\Gamma_{IN}^*=0.73\angle{135^\circ}$ IS IDENTICAL TO Γ_{Ms}.

3.26) FOR THIS TRANSISTOR: $K = 1.053$ AND $\Delta = 0.576\angle{-85.4^\circ}$.
THEREFORE, IT IS UNCONDICIONALLY STABLE.

$$G_{p,max} = G_{T,max} = 77.12 \text{ OR } 18.87 \text{ dB}$$

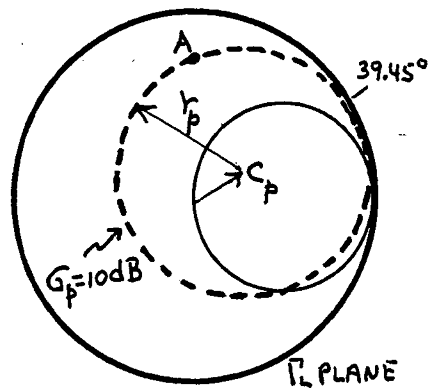
$G_p = 10$ dB CIRCLE: $g_p = 0.977$, $C_p = 0.306\angle{39.45^\circ}$, $r_p = 0.693$

THE $G_p = 10$ dB CONSTANT-GAIN CIRCLE IS SHOWN IN THE SMITH CHART. THE Γ_L SELECTED IS SHOWN AS "A": $\Gamma_L = 0.85\angle{89^\circ}$.

THEN: $\Gamma_s = \Gamma_{IN}^* = 0.793\angle{64.2^\circ}$, $\Gamma_{OUT} = 0.798\angle{-42.3^\circ}$

$|\Gamma_a| = 0$, $(VSWR)_{in} = 1$

$|\Gamma_b| = 0.9$, $(VSWR)_{out} = 18.9$



3.27) (a) $K = 0.53$, $\Delta = 0.524\angle{-142.9^\circ}$; IT IS POTENTIALLY UNSTABLE.

OUTPUT STABILITY CIRCLE [(3.3.7) AND (3.3.8)]:

$$C_L = 1.47\angle{76.6^\circ} \text{ AND } r_L = 0.668$$

$G_p = 10$ dB CONSTANT-GAIN CIRCLE [(3.7.4) AND (3.7.5)]: $g_p = \frac{10^1}{(2.43)^2} = 1.694$,

$$C_p = 0.41\angle{76.6^\circ} \text{ AND } r_p = 0.641$$

(b) THE $G_p = 10$ dB GAIN CIRCLE IS DRAWN ON THE SMITH CHART. THREE VALUES OF Γ_L ARE DENOTED BY "a", "b", AND "c". THEN,

	Γ_L	$\Gamma_s = \Gamma_{IN}^*$	Γ_{OUT}	$\lvert\Gamma_b\rvert$	$(VSWR)_{in}$	$(VSWR)_{out}$
"a"	$0.59\angle{0^\circ}$	$0.687\angle{106.11^\circ}$	$0.84\angle{-70.73^\circ}$	0.889	1	17
"b"	$0.24\angle{-90^\circ}$	$0.757\angle{100.35^\circ}$	$0.83\angle{-76.22^\circ}$	0.891	1	17.3
"c"	$0.67\angle{145^\circ}$	$0.851\angle{97.7^\circ}$	$0.84\angle{-83.74^\circ}$	0.889	1	17

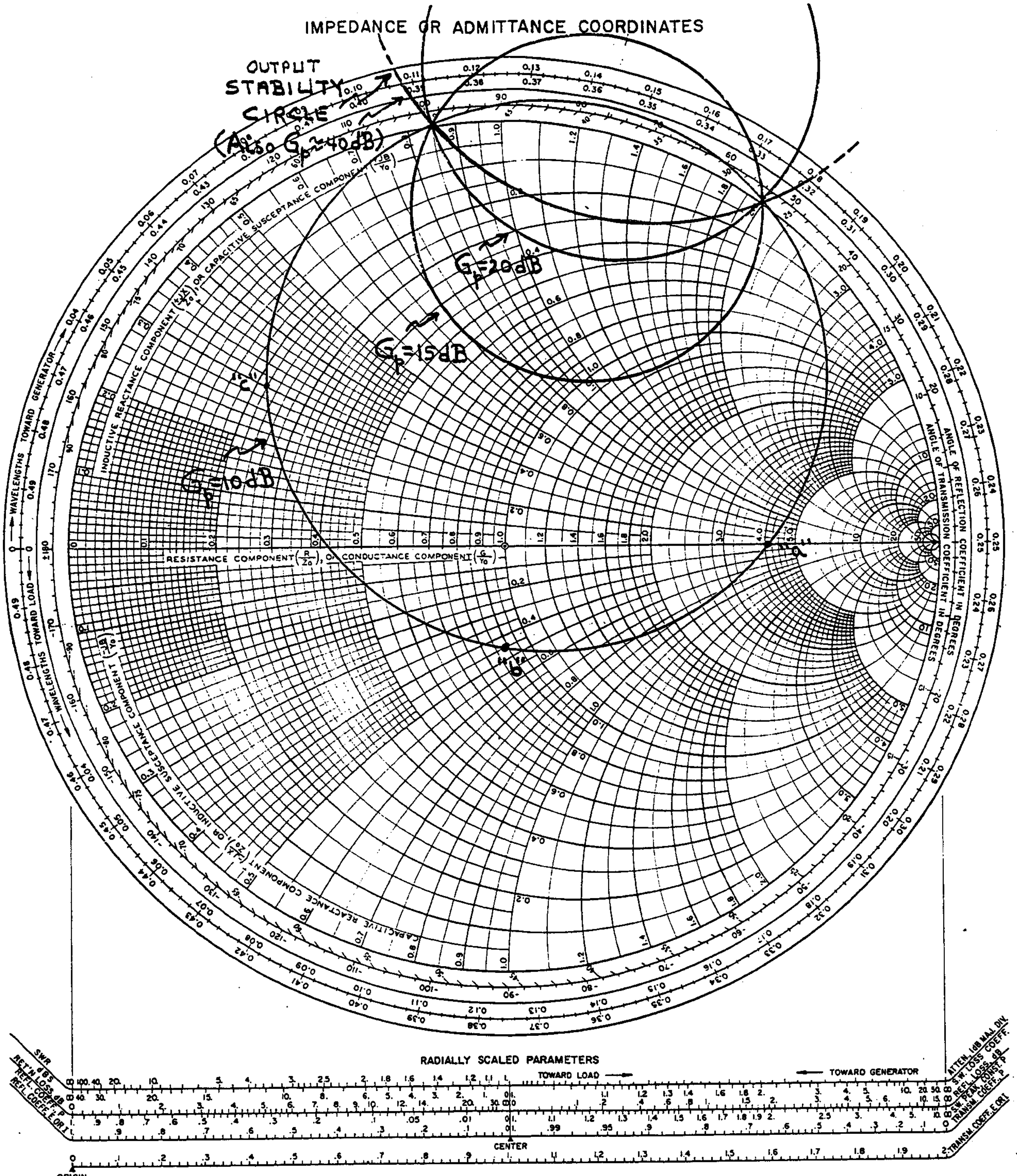
THE 3 VALUES OF Γ_s ARE IN THE STABLE REGION, SINCE $C_s = 1.3\angle{115.7^\circ}$ AND $r_s = 0.46$.

(c) FOR $G_p = 15$ dB: $g_p = \frac{10^{1.5}}{(2.43)^2} = 5.355$, $C_p = 0.81\angle{76.6^\circ}$, $r_p = 0.402$

FOR $G_p = 20$ dB: $g_p = \frac{10^2}{(2.43)^2} = 16.94$, $C_p = 1.17\angle{76.6^\circ}$, $r_p = 0.457$

FOR $G_p = 40$ dB: $g_p = \frac{10^4}{(2.43)^2} = 1,694$, $C_p = 1.46\angle{76.6^\circ}$, $r_p = 0.665$

THE $G_p = 15$ dB, 20 dB, AND 40 dB GAIN CIRCLES ARE ALSO DRAWN ON THE SMITH CHART. THE $G_p = 40$ dB CIRCLE ALMOST COINCIDES WITH THE OUTPUT STABILITY CIRCLE.


IMPEDANCE OR ADMITTANCE COORDINATES
OUTPUT STABILITY CIRCLE (Also G_p=40dB)
G_p=20dB
G_p=15dB
G_p=10dB
"a"
"b"
"c"
RESISTANCE COMPONENT ($\frac{R}{Z_0}$), OR CONDUCTANCE COMPONENT ($\frac{G}{Y_0}$)
INDUCTIVE REACTANCE COMPONENT ($\frac{+jX}{Z_0}$) OR CAPACITIVE SUSCEPTANCE COMPONENT ($\frac{+jB}{Y_0}$)
CAPACITIVE REACTANCE COMPONENT ($\frac{-jX}{Z_0}$) OR INDUCTIVE SUSCEPTANCE COMPONENT ($\frac{-jB}{Y_0}$)
WAVELENGTHS TOWARD GENERATOR
WAVELENGTHS TOWARD LOAD
ANGLE OF REFLECTION COEFFICIENT IN DEGREES
ANGLE OF TRANSMISSION COEFFICIENT IN DEGREES
RADIALLY SCALED PARAMETERS
TOWARD LOAD
TOWARD GENERATOR
SWR
dBS
RET'N LOSS dB
REFL. COEFF. P
REFL. COEFF. E OR I
ATTEN. 1dB MAJ. DIV.
S.W. LOSS COEFF.
REFL. LOSS dB
S.W. PEAK (CONST. P)
TRANSM. COEFF. P
TRANSM. COEFF. E OR I
CENTER
ORIGIN

3.28) OUTPUT STABILITY CIRCLE: $|\Gamma_L - C_L|^2 = r_L^2$

OR $$|\Gamma_L|^2 - \Gamma_L C_L^* - \Gamma_L^* C_L + |C_L|^2 = r_L^2 \qquad (1)$$

(1) INTERSECTS THE SMITH CHART WHEN $|\Gamma_L| = 1$; THEN

$$1 - \Gamma_L C_L^* - \Gamma_L^* C_L + |C_L|^2 = r_L^2$$

LET $\Gamma_L = U_L + jV_L$ AND $C_L = \mathrm{Re}[C_L] + j\,\mathrm{Im}[C_L]$:

$$-(U_L + jV_L)(\mathrm{Re}[C_L] - j\,\mathrm{Im}[C_L]) - (U_L - jV_L)(\mathrm{Re}[C_L] + j\,\mathrm{Im}[C_L]) = r_L^2 - |C_L|^2 - 1$$

$$2U_L \mathrm{Re}[C_L] + 2V_L \mathrm{Im}[C_L] = 1 + |C_L|^2 - r_L^2$$

OR

$$V_L = -\frac{\mathrm{Re}[C_L]}{\mathrm{Im}[C_L]} U_L + \frac{1 + |C_L|^2 - r_L^2}{2\,\mathrm{Im}[C_L]} \qquad (2)$$

(2) IS THE EQUATION OF A STRAIGHT LINE WITH SLOPE $m_L = -\frac{\mathrm{Re}[C_L]}{\mathrm{Im}[C_L]}$ AND INTERCEPT $b_L = \frac{1 + |C_L|^2 - r_L^2}{2\,\mathrm{Im}[C_L]}$. THIS LINE INTERSECTS THE SMITH CHART (i.e., $|\Gamma_L| = 1$) AT TWO POINTS.

SIMILARLY, THE POWER GAIN CIRCLE INTERSECTS $|\Gamma_L| = 1$ AT TWO POINTS DETERMINED BY: (LET $C_p = \mathrm{Re}[C_p] + j\,\mathrm{Im}[C_p]$)

$$V_L = -\frac{\mathrm{Re}[C_p]}{\mathrm{Im}[C_p]} U_L + \frac{1 + |C_p|^2 - r_p^2}{2\,\mathrm{Im}[C_p]} = -m_p U_L + b_p$$

THE POINTS OF INTERSECTION DETERMINED BY (2) AND (3) ARE EQUAL IF $m_L = m_p$ AND $b_L = b_p$.

$$m_L = -\frac{\mathrm{Re}[C_L]}{\mathrm{Im}[C_L]} = -\frac{\mathrm{Re}[S_{22}^* - \Delta^* S_{11}]}{\mathrm{Im}[S_{22}^* - \Delta^* S_{11}]}$$

$$m_p = -\frac{\mathrm{Re}[C_p]}{\mathrm{Im}[C_p]} = -\frac{\mathrm{Re}[C_2^*]}{\mathrm{Im}[C_2^*]} = -\frac{\mathrm{Re}[S_{22}^* - \Delta^* S_{11}]}{\mathrm{Im}[S_{22}^* - \Delta^* S_{11}]}$$

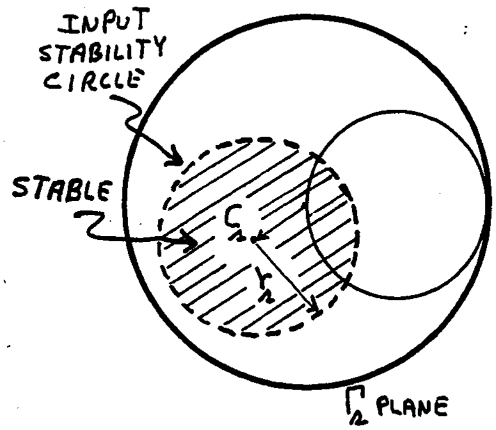
$$\therefore m_L = m_p$$

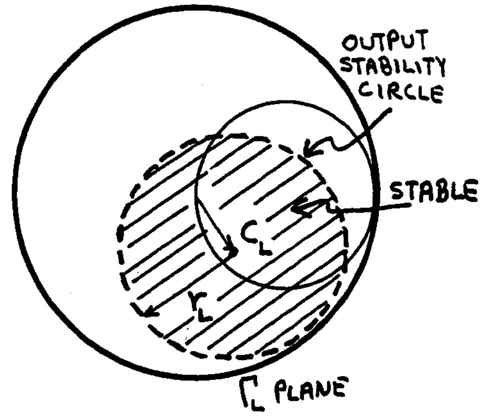
IT ALSO FOLLOWS THAT $b_L = b_p$.

3.29) (a) $K = 1.032$, $\Delta = 1.65\angle 78.1^\circ$ ∴ POTENTIALLY UNSTABLE

FROM (3.3.7) TO (3.3.10):

INPUT STAB. CIRCLE $\begin{cases} C_s = 0.285\angle -161.1^\circ \\ r_s = 0.65 \end{cases}$ OUTPUT STAB. CIRCLE $\begin{cases} C_L = 0.315\angle -61.5^\circ \\ r_L = 0.627 \end{cases}$





(b) FROM (3.2.3) WITH $\Gamma_L = 0$: (AND $\Gamma_{IN} = S_{11}$ WHEN $\Gamma_L = 0$)

$$G_p = \frac{|S_{21}|^2}{1-|S_{11}|^2} = \frac{4^2}{1-(0.5)^2} = 21.33 \text{ OR } 13.3\,dB$$

(c) G_p CAN BE INFINITE, BECAUSE IT IS POTENTIALLY UNSTABLE. AS Γ_L APPROACHES THE STABILITY CIRCLE, $G_p \to \infty$.

3.30) FROM EXAMPLE 3.8.1: $G_{A,max} = 9.66\,dB$, $G_A = 9.66 - 2 = 7.66\,dB$.

FROM (3.7.15) AND (3.7.16), FOR THE $G_A = 7.66\,dB$ GAIN CIRCLE:

$$g_a = \frac{10^{0.766}}{(2.3)^2} = 1.103, \quad C_a = 0.503\angle -40.45^\circ, \quad r_a = 0.436$$

THE VALUES OF Γ_s ON THE 7.6 dB CIRCLE ARE GIVEN BY:

$$\Gamma_s = C_a + r_a e^{j\theta_1} = 0.503\angle -40.45^\circ + 0.436 e^{j\theta_1}$$

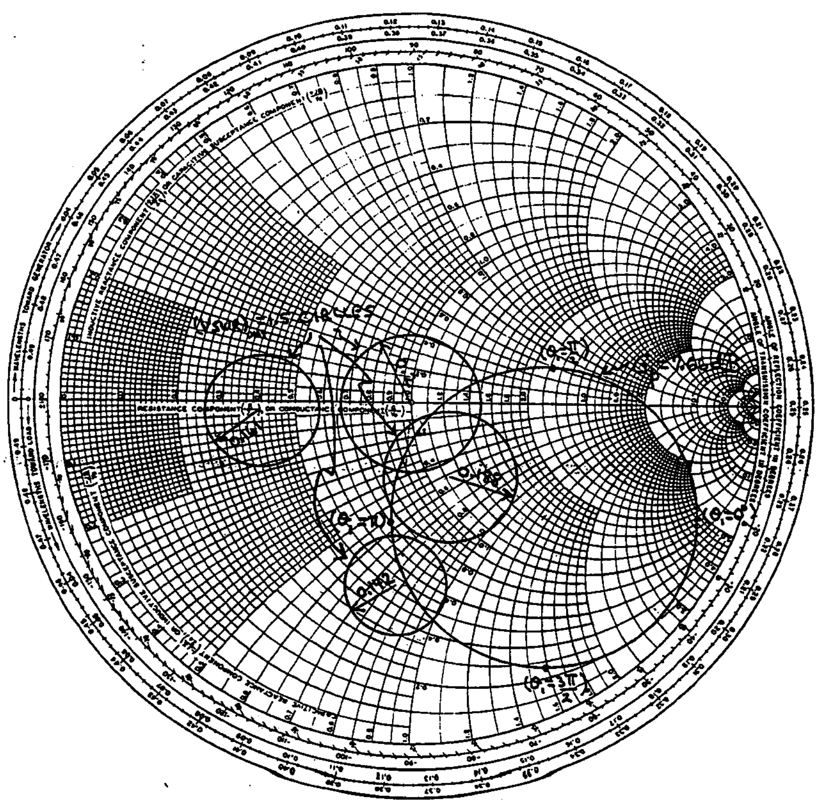
LETTING $\theta_1 = 0, \frac{\pi}{2}, \pi$, AND $\frac{3\pi}{2}$ WE OBTAIN THE VALUES OF Γ_s SHOWN IN THE TABLE. THE ASSOCIATED VALUES OF Γ_{OUT} ARE ALSO SHOWN.

FOR $(VSWR)_{out} = 1.5$ (OR $|\Gamma_b| = 0.2$), USING (3.8.7) AND (3.8.8), THE CENTER AND RADIUS OF THE $(VSWR)_{out} = 1.5$ CIRCLE ARE CALCULATED.

THE VALUES OF Γ_L ON THE $(VSWR)_{out} = 1.5$ CIRCLE ARE GIVEN BY: $\Gamma_L = C_{V_o} + r_{V_o} e^{j\theta_2}$. LETTING $\theta_2 = 0, \frac{\pi}{2}, \pi$, AND $\frac{3\pi}{2}$, FOUR VALUES OF Γ_L ON THE $(VSWR)_{out} = 1.5$ CIRCLE ARE CALCULATED, AS SHOWN IN THE TABLE. THE ASSOCIATED VALUES OF Γ_{IN}, $|\Gamma_a|$, AND $(VSWR)_{in}$ ARE ALSO SHOWN.

Γ_s	Γ_{OUT}	$(VSWR)_{out}=1.5$ CIRCLE	Γ_L	Γ_{IN}	$\lvert\Gamma_a\rvert$	$(VSWR)_{in}$
$(\theta_1=0^\circ)$ $0.881\angle{-21.73^\circ}$	$0.451\angle 176.74^\circ$	$C_{V_o}=0.437\angle{-176.74^\circ}$ $r_{V_o}=0.161$	$0.276\angle{-174.8^\circ}$ $(\theta_2=0)$	$0.683\angle 33.8$	0.596	3.95
			$0.457\angle 162.7^\circ$ $(\theta_2=\frac{\pi}{2})$	$0.712\angle 28.8^\circ$	0.507	3.05
			$0.598\angle{-177.6^\circ}$ $(\theta_2=\pi)$	$0.771\angle 30.9^\circ$	0.495	2.96
			$0.474\angle{-156.9^\circ}$ $(\theta_2=\frac{3\pi}{2})$	$0.748\angle 35.7^\circ$	0.604	4.05
$(\theta_1=\pi/2)$ $0.398\angle 15.99^\circ$	$0.005\angle 95.36^\circ$	$C_{V_o}=0.005\angle{-95.36^\circ}$ $r_{V_o}=0.2$	$0.2\angle{-1.4^\circ}$ $(\theta_2=0)$	$0.539\angle 38.5^\circ$	0.501	3.00
			$0.195\angle 90.1^\circ$ $(\theta_2=\frac{\pi}{2})$	$0.582\angle 30.3^\circ$	0.491	2.93
			$0.2\angle{-178.6^\circ}$ $(\theta_2=\pi)$	$0.659\angle 34^\circ$	0.591	3.89
			$0.2\angle{-90.1^\circ}$ $(\theta_2=\frac{3\pi}{2})$	$0.628\angle 41.5^\circ$	0.598	3.98
$(\theta_1=\pi)$ $0.331\angle{-99.26^\circ}$	$0.249\angle 62.12^\circ$	$C_{V_o}=0.24\angle{-62.12^\circ}$ $r_{V_o}=0.188$	$0.368\angle{-35.2^\circ}$ $(\theta_2=0)$	$0.539\angle 47^\circ$	0.473	2.79
			$0.115\angle{-12.1^\circ}$ $(\theta_2=\frac{\pi}{2})$	$0.569\angle 38^\circ$	0.543	3.38
			$0.225\angle{-109.6^\circ}$ $(\theta_2=\pi)$	$0.652\angle 40.8^\circ$	0.613	4.17
			$0.416\angle{-74.3^\circ}$ $(\theta_2=\frac{3\pi}{2})$	$0.633\angle 48.8^\circ$	0.56	3.54
$(\theta_1=3\pi/2)$ $0.853\angle{-63.34^\circ}$	$0.547\angle 94.15^\circ$	$C_{V_o}=0.531\angle{-94.15^\circ}$ $r_{V_o}=0.142$	$0.54\angle{-78.9^\circ}$ $(\theta_2=0)$	$0.666\angle 51.8^\circ$	0.526	3.22
			$0.39\angle{-95.6^\circ}$ $(\theta_2=\frac{\pi}{2})$	$0.673\angle 45.7^\circ$	0.606	4.07
			$0.559\angle{-108.8^\circ}$ $(\theta_2=\pi)$	$0.742\angle 46.3^\circ$	0.597	3.97
			$0.673\angle{-93.3^\circ}$ $(\theta_2=\frac{3\pi}{2})$	$0.74\angle 51.9^\circ$	0.485	2.88

FROM THESE CALCULATIONS IT IS SEEN THAT A DESIGN WITH $\Gamma_s=0.331\angle{-99.26^\circ}$ AND $\Gamma_L=0.368\angle{-35.2^\circ}$ RESULTS IN $(VSWR)_{in}=2.79$ AND $(VSWR)_{out}=1.5$.



3.31) (a) $K=1.344$, $\Delta=2.156\angle{-16.6^\circ}$ $\therefore$ POTENTIALLY UNSTABLE

(b) OUTPUT STABILITY CIRCLE: $C_L=0.261\angle{-36.3^\circ}$, $r_L=0.409$

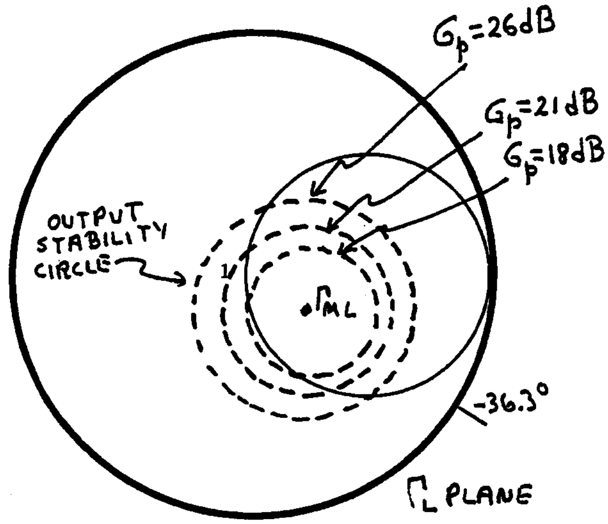
(c) FROM (3.6.6) (USING THE + SIGN): $\Gamma_{ML}=0.319\angle{-36.3^\circ}$

(d) $G_{p,min}=G_{T,min}=44.82$ OR 16.51 dB

(e)

G_p	CENTER AND RADIUS
18 dB	$C_p=0.31\angle{-36.3^\circ}$, $r_p=0.234$
21 dB	$C_p=0.28\angle{-36.3^\circ}$, $r_p=0.34$
26 dB	$C_p=0.266\angle{-36.3^\circ}$, $r_p=0.39$
36 dB	$C_p=0.261\angle{-36.3^\circ}$, $r_p=0.407$

THE 26 dB GAIN CIRCLE, THE 36 dB GAIN CIRCLE, AND THE OUTPUT STABILITY CIRCLE ALMOST COINCIDE.



(f) INPUT STABILITY CIRCLE : $C_s=0.102\angle{107.4^\circ}$, $r_s=0.44$

FROM (3.6.5) (USING THE + SIGN) : $\Gamma_{Ms}=0.127\angle{107.44^\circ}$

(g) $(VSWR)_{in}=(VSWR)_{out}=1$.

3.32) (a) $K=1.17$, $\Delta=0.368\angle{27.91^\circ}$ UNCONDITIONALLY STABLE

$G_{p,max}=9.24$ OR 9.66 dB, $G_p=9.66-1=8.66$ dB

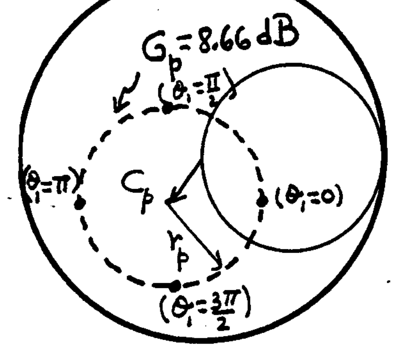
FOR THE $G_p=8.66$ dB CIRCLE : $g_p=1.388$, $C_p=0.292\angle{-129.4^\circ}$, $r_p=0.466$

(b) THE VALUES OF Γ_L ON THE 8.66 dB CIRCLE ARE:

$\Gamma_L=C_p+r_p e^{j\theta_1}=0.292\angle{-129.4^\circ}+0.466e^{j\theta_1}$

LETTING $\theta_1=0, \frac{\pi}{2}, \pi$, AND $\frac{3\pi}{2}$ WE OBTAIN THE VALUES OF Γ_L SHOWN IN THE TABLE. THE ASSOCIATED VALUES OF Γ_{IN} ARE ALSO SHOWN.

FOR $(VSWR)_{in}=1.5$ (OR $|\Gamma_a|=0.2$), USING (3.8.3) AND (3.8.4), THE CENTER AND RADIUS OF THE $(VSWR)_{in}=1.5$ CIRCLE ARE CALCULATED.



(c) THE VALUES OF Γ_s ON THE $(VSWR)_{in}=1.5$ CIRCLE ARE GIVEN BY $\Gamma_s = C_{V_i} + r_i e^{j\theta_2}$. LETTING $\theta_2 = 0$ AND π, TWO VALUES OF Γ_s ON THE $(VSWR)_{in}=1.5$ CIRCLE ARE CALCULATED (SEE THE TABLE). THE ASSOCIATED VALUES OF Γ_{OUT}, $|\Gamma_b|$, AND $(VSWR)_{OUT}$ ARE ALSO SHOWN

Γ_L	Γ_{IN}	$(VSWR)_{in}=1.5$ CIRCLE	Γ_s	Γ_{OUT}	$\lvert\Gamma_b\rvert$	$(VSWR)_{out}$
$(\theta_1=0)$		$C_{V_i}=0.532\angle -47.1^\circ$	$0.637\angle -37.7^\circ$ $(\theta_2=0)$	$0.311\angle 129.5^\circ$	0.475	2.8
$0.36\angle -38.8^\circ$	$0.548\angle 47.1^\circ$	$r_{V_i}=0.142$	$0.448\angle -60.5^\circ$ $(\theta_2=\pi)$	$0.259\angle 91.2^\circ$	0.304	1.875
$(\theta_1=\pi/2)$						
$0.304\angle 127.6^\circ$	$0.634\angle 27.9^\circ$	$C_{V_i}=0.619\angle -27.9^\circ$	$0.729\angle -23.4^\circ$ $(\theta_2=0)$	$0.314\angle 161.7^\circ$	0.368	2.16
		$r_{V_i}=0.122$	$0.514\angle -34.3^\circ$ $(\theta_2=\pi)$	$0.219\angle 123.5^\circ$	0.419	2.44
$(\theta_1=\pi)$						
$0.689\angle -160.9^\circ$	$0.81\angle 34.2^\circ$	$C_{V_i}=0.799\angle -34.2^\circ$	$0.859\angle -31.5^\circ$ $(\theta_2=0)$	$0.501\angle 153.7^\circ$	0.306	1.88
		$r_{V_i}=0.071$	$0.741\angle -37.3^\circ$ $(\theta_2=\pi)$	$0.399\angle 136.2^\circ$	0.483	2.87
$(\theta_1=3\pi/2)$						
$0.716\angle -105^\circ$	$0.782\angle 49.4^\circ$	$C_{V_i}=0.77\angle -49.4^\circ$	$0.824\angle -45.2^\circ$ $(\theta_2=0)$	$0.518\angle 124.3^\circ$	0.430	2.51
		$r_{V_i}=0.08$	$0.721\angle -54.2^\circ$ $(\theta_2=\pi)$	$0.429\angle 107.5^\circ$	0.415	2.42

FROM THESE CALCULATIONS IT IS SEEN THAT A DESIGN WITH $\Gamma_L = 0.689\angle -160.9^\circ$ AND $\Gamma_s = 0.859\angle -31.5^\circ$ GIVES: $G_p = 8.66\,dB$, $(VSWR)_{in} = 1.88$, $(VSWR)_{out} = 1.5$.

3.33) (a) FROM EXAMPLE 3.7.2, FOR THE $G_p = 10\,dB$ CIRCLE: $C_p = 0.572\angle 97.2^\circ$, $r_p = 0.473$

FROM (3.8.9) AND (3.8.10), WITH $C_{oo} = C_p$ AND $r_{oo} = r_p$, WE OBTAIN:

$$C_i = 1.131\angle 170.6^\circ \text{ AND } r_i = 0.622$$

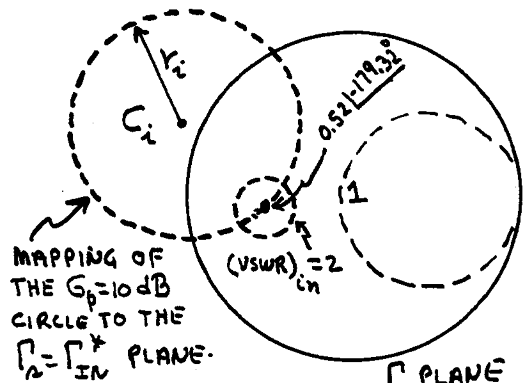
(b) FOR $\Gamma_L = 0.1\angle 97^\circ$, $\Gamma_{IN} = 0.52\angle 179.32^\circ$,

$\Gamma_s = \Gamma_{IN}^* = 0.52\angle -179.32^\circ$

THEN $(VSWR)_{in} = 1$

FOR $(VSWR)_{in} = 2$ (OR $|\Gamma_a| = 0.333$), WE OBTAIN FROM (3.8.3) AND (3.8.4):

$C_{V_i} = 0.477\angle 179.32^\circ$, $r_{V_i} = 0.251$



3.34) $K = 0.924$, $\Delta = 0.137\angle{-139^\circ}$ $\therefore$ POTENTIALLY UNSTABLE

$$G_{MSG} = \frac{|S_{21}|}{|S_{12}|} = \frac{8}{0.03} = 266.6 \text{ OR } 24.3\,dB$$

DESIGN FOR $G_p = 20$ dB (i.e., 4.3 dB LESS THAN G_{MSG}).

OUTPUT STABILITY CIRCLE:

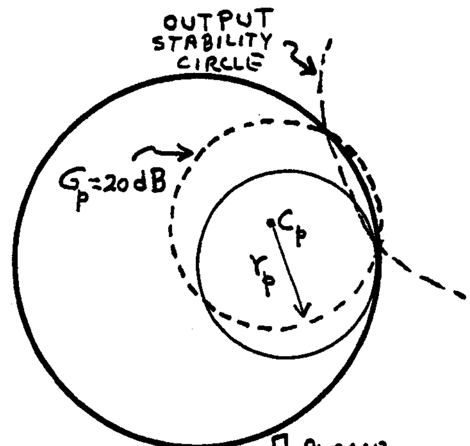
$C_L = 2.26\angle 40.1^\circ$, $r_L = 1.307$

$G_p = 20$dB CONSTANT-GAIN CIRCLE: ($g_p = 1.563$)

$C_p = 0.505\angle 40.1^\circ$, $r_p = 0.519$

VALUES OF Γ_L ON $G_p = 20$dB CIRCLE:

$$\Gamma_L = C_p + r_p e^{j\theta_1} = 0.505\angle 40.1 + 0.519 e^{j\theta_1}$$



THE TABLE SHOWS TWO VALUES OF Γ_L (i.e, for $\theta_1 = \pi$ AND $\theta_1 = \frac{3\pi}{2}$), THE ASSOCIATED VALUES OF $\Gamma_s = \Gamma_{IN}^*$, Γ_{OUT}, $|\Gamma_b|$, AND $(VSWR)_{OUT}$.

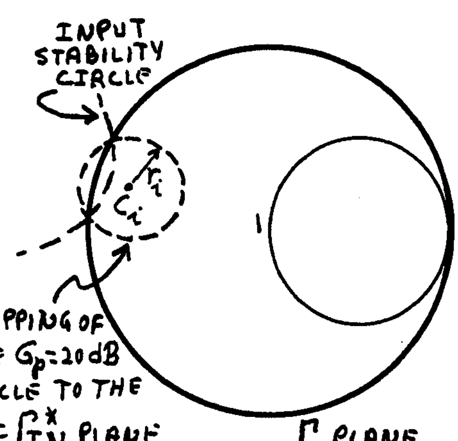
Γ_L	$\Gamma_s = \Gamma_{IN}^*$	$(VSWR)_{in}$	Γ_{OUT}	$\lvert\Gamma_b\rvert$	$(VSWR)_{OUT}$
($\theta_1 = \pi$) $0.352\angle 112.2^\circ$	$0.655\angle 163.4^\circ$	1	$0.668\angle{-44.8^\circ}$	0.667	30.25
($\theta_1 = 3\pi/2$) $0.432\angle{-26.6^\circ}$	$0.607\angle{-179.2^\circ}$	1	$0.674\angle{-34.3^\circ}$	0.668	30.25

MAPPING OF THE $G_p = 20$ dB CIRCLE TO THE $\Gamma_s = \Gamma_{IN}^*$ PLANE:

$C_i = 0.823\angle 175.3^\circ$, $r_i = 0.227$

INPUT STABILITY CIRCLE: $C_s = 1.65\angle 175.3^\circ$, $r_s = 0.679$

THE VALUES OF $(VSWR)_{OUT} = 30.25$ SHOW THAT THE OUTPUT HAS TO BE MISMATCHED IN ORDER TO REDUCE THE GAIN TO 20 dB. THE DESIGNER CAN TRY TO REDUCE $(VSWR)_{OUT}$ BY RELAXING THE INPUT VSWR VALUE (SAY, LET $(VSWR)_{in} \le 1.5$), AS DISCUSSED IN EXAMPLE 3.8.2.



3.35) $K = 0.875$, $\Delta = 0.445 \angle 160.4^\circ$ $\therefore$ POTENTIALLY UNSTABLE

$$G_{MSG} = \frac{|S_{21}|}{|S_{12}|} = \frac{3.1}{0.125} = 24.8 \quad \text{OR} \quad 13.9\,\text{dB}$$

DESIGN FOR $G_A = 10\,\text{dB}$ (i.e, 3.9 dB LESS THAN G_{MSG})

INPUT STABILITY CIRCLE:

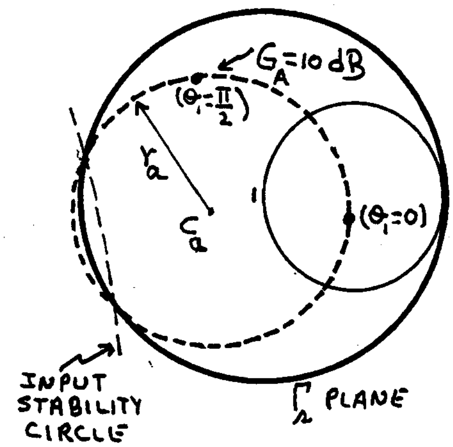
$C_s = 3.303 \angle -173.2^\circ$, $r_s = 2.392$

$G_A = 10\,\text{dB}$ CONSTANT-GAIN CIRCLE: ($g_a = 1.041$)

$C_a = 0.296 \angle -173.2^\circ$, $r_a = 0.73$

VALUES OF Γ_s ON THE $G_A = 10\,\text{dB}$ CIRCLE:

$$\Gamma_s = C_a + r_a e^{j\theta_1} = 0.296 \angle -173.2^\circ + 0.73 e^{j\theta_1}$$



THE TABLE SHOWS TWO VALUES OF Γ_s (i.e, for $\theta_1 = 0$ AND $\theta_1 = \frac{\pi}{2}$), THE ASSOCIATED VALUES OF $\Gamma_L = \Gamma_{OUT}^*$, Γ_{IN}, $|\Gamma_a|$, AND $(VSWR)_{in}$.

Γ_s	$\Gamma_L = \Gamma_{OUT}^*$	$(VSWR)_{out}$	Γ_{IN}	$\lvert\Gamma_a\rvert$	$(VSWR)_{in}$
$(\theta_1 = 0)$ $0.437 \angle -4.6^\circ$	$0.405 \angle 70.8^\circ$	1	$0.565 \angle 172^\circ$	0.802	9.1
$(\theta_1 = \pi/2)$ $0.755 \angle 112.9^\circ$	$0.08 \angle 133.5^\circ$	1	$0.624 \angle -171.9^\circ$	0.802	9.1

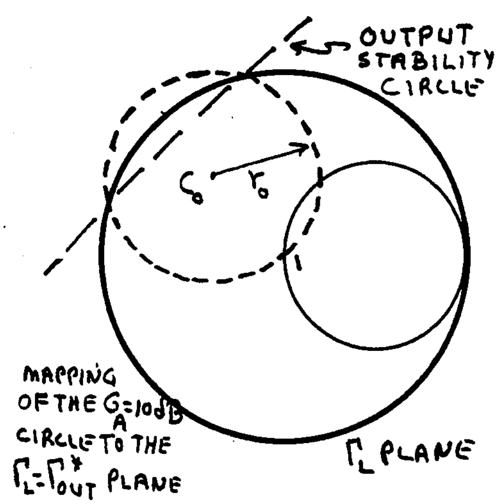
MAPPING OF THE $G_A = 10\,\text{dB}$ CIRCLE TO THE $\Gamma_L = \Gamma_{OUT}^*$ PLANE:

$C_o = 0.646 \angle 130.9^\circ$ AND $r_o = 0.566$

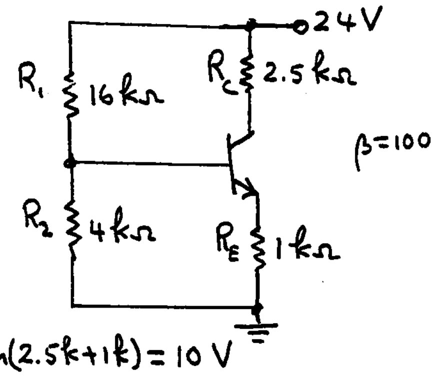
OUTPUT STABILITY CIRCLE:

$C_L = 9.33 \angle -49.1^\circ$, $r_L = 10.19$

THE VALUES OF $(VSWR)_{in} = 9.1$ SHOW THAT THE INPUT HAS TO BE MISMATCHED IN ORDER TO REDUCE THE GAIN TO 10 dB. (i.e, $G_A = 10\,\text{dB}$). THE DESIGNER CAN TRY TO REDUCE $(VSWR)_{in}$ BY RELAXING THE OUTPUT VSWR.



3.36) (a) dc MODEL



(b) $V_{TH} = \frac{24(4k)}{4k+16k} = 4.8\text{ V}$

$R_{TH} = 4k \| 16k = 3.2\text{ k}\Omega$

$V_{TH} = I_B R_{TH} + 0.7 + I_C R_E \quad (I_C \approx I_E)$

$\therefore\ I_B = \frac{V_{TH} - 0.7}{R_{TH} + \beta R_E} = 40\,\mu A$

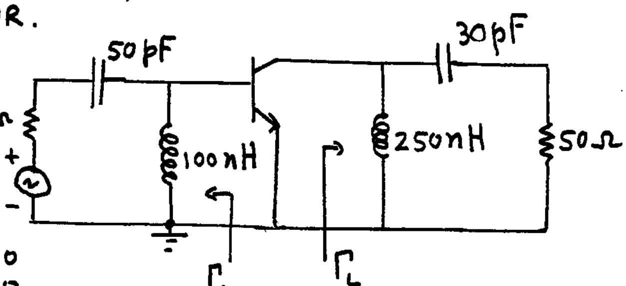
$I_C = \beta I_B = 4\text{ mA}$

$V_{CE} = V_{CC} - I_C(R_C + R_E) = 24 - 4m(2.5k + 1k) = 10\text{ V}$

(c) AT 500 MHz THE 0.1 μF ($Z_C = -j0.003\,\Omega$) ACT AS SHORT CIRCUITS TO THE AC SIGNAL. THUS, RFCs ARE NOT NEEDED IN SERIES WITH THE 16kΩ AND 2.5kΩ RESISTORS.

THE 100 nH INDUCTOR ($Z_L = j314\,\Omega$) IMPEDANCE IS ABOUT 10% OF THE RESISTANCE OF $R_2 = 4k\Omega$. THUS, A RFC SHOULD BE USED IN SERIES WITH THE 4kΩ RESISTOR.

(d) ac MODEL



(e) $Z_{50pF} = \frac{1}{j2\pi 500 10^6 50 10^{-12}} = -j6.37\,\Omega$

$Z_{100nH} = j2\pi 500 10^6 100 10^{-9} = j314.2\,\Omega$

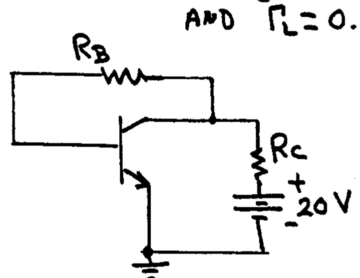
USING THE ZY CHART IT IS SIMPLE TO CALCULATE: $z_s = 1.015 + j0.035$

AND $\Gamma_s = 0.02\angle 65.8°$

SIMILARLY: $z_L = 1.05 - j0.11$

AND $\Gamma_L = 0.06\angle -61°$

3.37) (a) dc MODEL



(b) $20 = I_C R_C + V_{CE}$

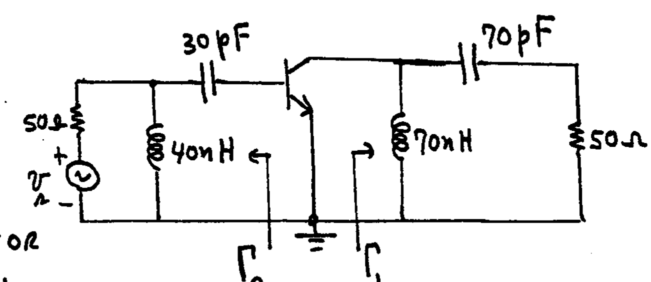
OR $R_C = \frac{20-10}{5m} = 2\text{ k}\Omega$

$V_{CE} = I_B R_B + 0.7$

$R_B = \frac{10 - 0.7}{\left(\frac{5m}{100}\right)} = 186\text{ k}\Omega$

THIS TYPE OF DC BIAS RESULTS IN A LARGE VALUE FOR R_B.

(c) ac MODEL



AT f=300 MHz: $Z_{30pF} = -j17.68\,\Omega$,

$Z_{70pF} = -j7.58\,\Omega$, $Z_{40nH} = j75.4\,\Omega$

$Z_{70nH} = j131.9\,\Omega$

USING THE ZY SMITH CHART OR SIMPLE CALCULATIONS, WE OBTAIN:

$Z_s = 35\,\Omega + j5.2\,\Omega$ OR $\Gamma_s = 0.185\angle 157.3°$; $Z_L = 49.9 + j1.25\,\Omega$ OR $\Gamma_L = 0.96\angle 0°$.

3.38) LET $V_{cc} = 20V$, $R_E = \frac{10\% V_{cc}}{I_c} = \frac{0.1(20)}{10m} = 200\Omega$

$$V_{cc} = V_{CE} + I_c(R_c + R_E) \Rightarrow R_c + 200 = \frac{20-10}{4m} = 2.5k, \text{ OR } R_c = 2.3\ k\Omega$$

FOR GOOD β STABILITY LET $R_{TH} = \frac{\beta R_E}{10} = \frac{100(200)}{10} = 2\ k\Omega$

$$V_{TH} = I_B R_{TH} + 0.75 + I_c R_E = \frac{4m}{100}(2k) + 0.75 + 4m(200) = 1.63\ V$$

$$R_1 = R_{TH}\frac{V_{cc}}{V_{TH}} = 2.3k\,\frac{20}{1.63} = 28.22\ k\Omega$$

$$R_2 = \frac{R_{TH}}{1 - V_{TH}/V_{cc}} = \frac{2.3k}{1 - \left(\frac{1.63}{20}\right)} = 2.5\ k\Omega$$

3.39) $I_{c2} = 10\ mA$. LET $I_3 = 20\ mA$, THEN $I_{c1} = I_3 - I_{c2} = 20m - 10m = 10\ mA$

$$\therefore\ R_4 = \frac{0.75}{I_{c1}} = \frac{0.75}{10m} = 75\ \Omega \quad . \text{ LET } V_{cc} = 20\ V$$

$$R_3 = \frac{V_{cc} - V_{CE,2}}{I_3} = \frac{20-10}{20m} = 500\ \Omega$$

FOR GOOD β STABILITY LET $I_{R_1} \simeq I_{R_2} = 20\, I_{B1} = 20\ \frac{10m}{100} = 2\ mA$,

$$V_{B,1} = V_{CE,2} - 0.75 = 9.25\ V$$

$$R_1 = \frac{V_{cc} - V_{B,1}}{I_{R_1}} = \frac{20 - 9.25}{2m} = 5.37\ k\Omega$$

$$R_2 = \frac{V_{B,1}}{I_{R_2}} = \frac{9.25}{2m} = 4.63\ k\Omega$$

3.40) (a) IN FIG. 3.9.2a: $V_{cc} = (I_B + I_c)R_c + I_B R_B + V_{BE}$ (1)

AND $I_c = h_{FE} I_B + (h_{FE}+1) I_{cBo}$ (2)

SUBSTITUTING (2) INTO (1) GIVES:

$$V_{cc} - V_{BE} = \left(\frac{I_c}{h_{FE}} - I_{cBo}\frac{(h_{FE}+1)}{h_{FE}}\right)(R_c + R_B) + I_c R_c$$

OR
$$I_c = \frac{h_{FE}(V_{cc} - V_{BE})}{R_B + R_c(h_{FE}+1)} + \frac{I_{cBo}(h_{FE}+1)(R_c + R_B)}{R_B + R_c(h_{FE}+1)}$$

$$S_i = \frac{\partial I_c}{\partial I_{cBo}} = \frac{(h_{FE}+1)(R_c + R_B)}{R_B + R_c(h_{FE}+1)}$$

$$S_{V_{BE}} = \frac{\partial I_c}{\partial V_{BE}} = \frac{-h_{FE}}{R_B + R_c(h_{FE}+1)}$$

IN THE DERIVATION OF $S_{h_{FE}}$ WE NEGLECT THE CONTRIBUTION FROM I_{cBo}. HENCE,

$$I_{C2} = \frac{h_{FE,2}(V_{CC}-V_{BE})}{R_B + R_C(h_{FE,2}-1)} \quad \text{AND} \quad I_{C1} = \frac{h_{FE}(V_{CC}-V_{BE})}{R_B + R_C(h_{FE}-1)}$$

$$\frac{I_{C2}}{I_{C1}} - 1 = \frac{h_{FE,2}[R_B+R_C(h_{FE}-1)]}{h_{FE}[R_B+R_C(h_{FE,2}-1)]} - 1 = \frac{(h_{FE,2}-h_{FE})}{h_{FE}} \frac{S_{i2}}{h_{FE,2}}$$

OR $$S_{h_{FE}} = \frac{\Delta I_C}{\Delta h_{FE}} = \frac{I_{C2}-I_{C1}}{h_{FE,2}-h_{FE}} = \frac{I_{C1}\, S_{i2}}{h_{FE}\, h_{FE,2}}$$

(b) $$I_B = \frac{I_C}{h_{FE}} = \frac{10\,10^{-3}}{50} = 0.2\,mA \;,\; R_B = \frac{V_{CE}-0.7}{I_B} = \frac{10-0.7}{0.2\,10^{-3}} = 46.5\,k\Omega$$

$$R_C = \frac{V_{CC}-V_{CE}}{I_C+I_B} = \frac{20-10}{10.2\;\;3} = 980\,\Omega$$

(c) IF $h_{FE}=100$, I_C INCREASES FROM 10 mA TO:

$$I_{C2} = \frac{h_{FE,2}(V_{CC}-0.7)}{R_B + R_C(h_{FE,2}+1)} \quad \text{WHERE } h_{FE,2}=100$$

$$= \frac{100\,(20-0.7)}{46.5\,10^3 + 0.98\,10^3\,(100+1)} = 13.3\,mA$$

AND $$V_{CE} = V_{CC} - I_{C2}R_C = 20 - 13.3\,10^{-3}(0.98\,10^3) = 7\,V$$

3.41) (a) LET $V_{CC}=12\,V$, $R_E = \frac{10\%\,V_{CC}}{I_C} = \frac{0.1(12)}{1m} = 1.2\,k\Omega$

$$V_{CC} = V_{CE} + I_C(R_C+R_E) \Rightarrow R_C + 1.2k = \frac{12-6}{1m} = 6\,k\Omega \text{ OR } R_C = 4.8\,k\Omega.$$

FROM $$S_i = \frac{(\beta+1)(R_{TH}+R_E)}{R_{TH}+(\beta+1)R_E} \Rightarrow 5 = \frac{101\,(R_{TH}+1.2k)}{R_{TH}+(101)\,1.2k} \therefore R_{TH} = 5.05\,k\Omega$$

$$V_{TH} = I_B R_{TH} + 0.7 + I_C R_E = \frac{1m}{100}(4.8k) + 0.7 + 1m(1.2k) = 1.95\,V$$

$$R_1 = R_{TH}\frac{V_{CC}}{V_{TH}} = 5.05k\,\frac{12}{1.95} = 31.1\,k\Omega$$

$$R_2 = \frac{R_{TH}}{1 - V_{TH}/V_{CC}} = \frac{5.05k}{1 - 1.95/12} = 6.03\,k$$

(b) $$I_{CBO,2} = 1\,10^{-6}\,2^{\frac{75-25}{10}} = 32\,\mu A \;,\; h_{FE,2} = 100 + \frac{0.5}{100}(75-25)100 = 125$$

$$S_i = 5 \;,\; S_{V_{BE}} = \frac{-100}{5.05\,10^3+(101)1.2\,10^3} = 0.8\,10^{-3} \;,\; S_{h_{FE}} = \frac{10^{-3}(5.4)}{100\,(125)} = 4.3\,10^{-7}$$

AT 75°C: $$I_C = \frac{125(1.95-0.7)}{5.05\,10^3+(126)1.2\,10^3} + \frac{126\,(32\,10^{-6})(5.05\,10^3+1.2\,10^3)}{5.05\,10^3+(126)1.2\,10^3}$$
$$= 1.16\,mA$$

3.42) $I_D = I_{DSS}\left[1 - \frac{V_{GS}}{V_P}\right]^2 \Rightarrow 10m = 30m\left[1+\frac{V_{GS}}{3}\right]^2 \therefore V_{GS} = -1.268V$

$$R_s = \frac{-V_{GS}}{I_D} = \frac{1.268}{10m} = 126.8\,\Omega$$

LET $V_{CC} = V_{EE} = 10V$ AND $I_{R_1} = 20mA$, WHERE $I_{R_1} = I_C + I_D$

$\therefore\ I_C = 20m - 10m = 10\,mA$

THE VOLTAGE AT THE GATE IS ZERO (i.e, ACROSS R_G). HENCE,

$$R_S = \frac{0-(-V_{EE})}{I_C} = \frac{10}{10m} = 1\,k\Omega$$

$$V_E = V_{DS} + V_{R_S} = 3 + 1.268 = 4.27\ V$$

THEN, $R_1 = \frac{V_{CC}-V_E}{I_{R_1}} = \frac{10-4.27}{20m} = 287\,\Omega$

LET $I_{R_2} \approx I_{R_3} = 20\ I_B = 20\ \frac{10m}{100} = 2\ mA$

$$V_B = V_E - 0.7 = 4.27 - 0.7 = 3.57\,V$$

$$R_2 = \frac{V_{CC}-V_B}{I_{R_2}} = \frac{10-3.57}{2m} = 3.21\,k\Omega$$

$$R_3 = \frac{V_B}{I_{R_3}} = \frac{3.57}{2m} = 1.78\,k\Omega$$