Contents

***Abstract*—This manual is an introduction to control systems based on GATE problems.Links to sample Python codes are available in the text.**

Download python codes using

1 Stability

2 Routh Hurwitz Criterion

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4 Nyquist Plot

5 Feedback systems

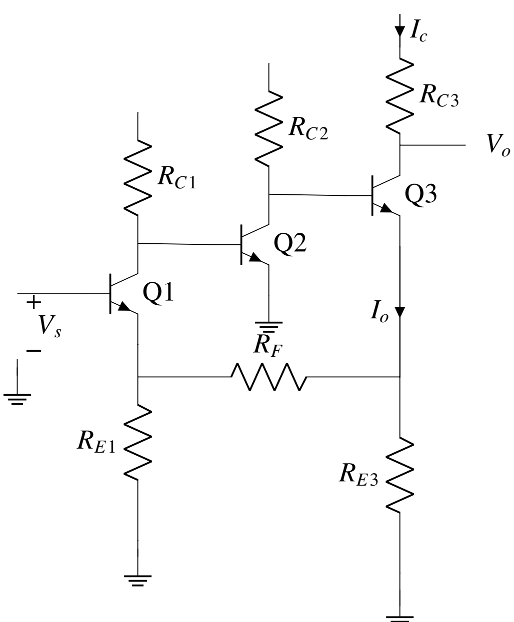

Fig. 5.0.0: circuit1

5.0.1. Part of the circuit of the MC1553 Amplifier is shown in circuit1 in fig.5.0.0 Assume the loop gain is large, find an approximate expression and value for the closed loop gain $A_f = \frac{I_0}{V_s}$ and hence for $\frac{I_c}{V_s}$,take $R_{E1} = 100\Omega$,$R_{C1} = 9K\Omega$,$R_{C2} = 5K\Omega$,$R_F =$

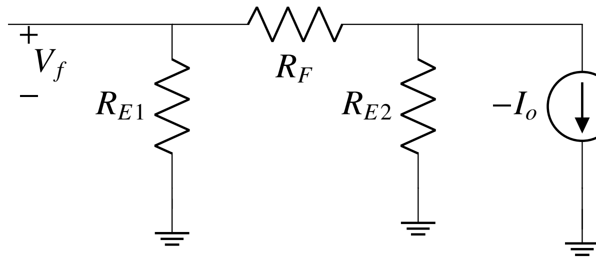

Fig. 5.0.1: circuit2

640Ω,$R_{E2} = 100\Omega$,$R_{C3} = 600\Omega$,$h_{fe} = 100$,$r_0 = \infty$,$I_{C1} = 0.6mA$,$I_{C2} = 1mA$,$I_{C3} = 4mA$

Solution: When GH >>1,

$$A_f = \frac{I_0}{V_s} \approx \frac{1}{H} \tag{5.0.1.1}$$

feedback factor H can be found from feedback network.The feedback network consists of resistors R_{E1}, R_F, R_{E2} using circuit2 in fig.5.0.1 we get

$$H = \frac{V_f}{I_0} = \frac{R_{E2}}{R_{E2} + R_F + R_{E1}} \times R_{E1} \tag{5.0.1.2}$$

$$= \frac{100}{100 + 640 + 100} \times 100 = 11.9\Omega \tag{5.0.1.3}$$

thus,

$$A_f \approx \frac{1}{H} \tag{5.0.1.4}$$

$$= \frac{1}{R_{E2}}(1 + \frac{R_{E2} + R_F}{R_{E1}}) \tag{5.0.1.5}$$

$$= \frac{1}{11.9} = 84mA/V \tag{5.0.1.6}$$

$$\frac{I_c}{V_s} \approx \frac{I_0}{V_s} = 84mA/V \tag{5.0.1.7}$$

5.0.2. Find $\frac{V_0}{V_s}$

Solution:

$$\frac{V_0}{V_s} = \frac{-I_c R_{C3}}{V_s} = -84 \times 0.6 = -50.4V/V \tag{5.0.2.1}$$

5.0.3. use feedback analysis to find G , H , A_f , $\frac{V_0}{V_s}$, R_{in} and R_{out}.for calculating R_{out} assume r_0 of Q_3 is 25kΩ

Solution: employing loading rules in fig.5.0.0,we obtain circuit3 given in fig.5.0.3

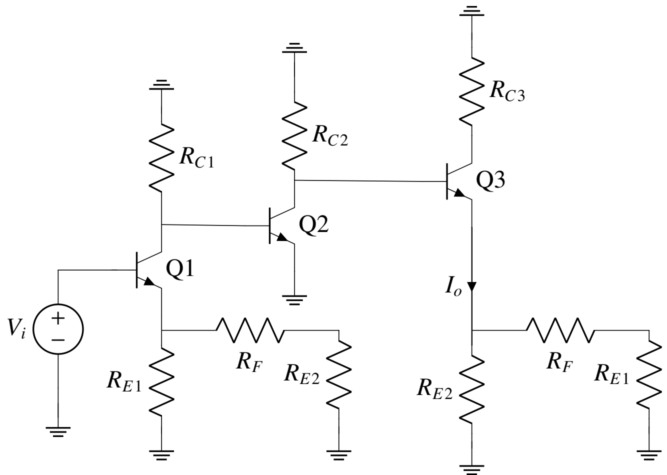

Fig. 5.0.3: circuit3

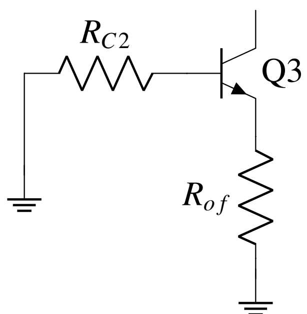

Fig. 5.0.3: circuit4

to find $G = \frac{I_0}{V_i}$ we determine the gain of first stage,this is written by inspection as-

$$\frac{V_{c1}}{V_i} = \frac{-\alpha(R_{c1}||r_{\pi 2})}{r_{e1} + (R_{E1}||(R_F + R_{E2}))} \tag{5.0.3.1}$$

Since Q_1 is biased at 0.6mA,r_{e1} = 41.7Ω.Transistor Q_2 is biased at 1mA:thus $r_{\pi 2} = \frac{h_{fe}}{g_{m2}} = \frac{100}{40} = 2.5K\Omega$. Substituting these values together with α_1=0.99,$R_{C1} = 9K\Omega$,$R_{E1} = 100\Omega$,$R_F = 640\Omega$,and $R_{E2} = 100\Omega$, results in

$$\frac{V_{c1}}{V_i} = -14.92V/V \tag{5.0.3.2}$$

Next, we determine the gain of the second stage,which can be written by inspection(noting that $V_{b2} = V_{c1}$)as

$$\frac{V_c2}{V_{c1}} = -g_{m2}R_{c2}||(h_{fe} + 1)[r_{e3} + (R_{E2}||(R_F + R_{E1}))] \tag{5.0.3.3}$$

substituting the values ,results in

$$\frac{V_{c2}}{V_{c1}} = -131.2V/V \tag{5.0.3.4}$$

Finally,for the third stage we can write by inspection

$$\frac{I_0}{V_{c2}} = \frac{I_{e3}}{V_{b3}} = \frac{1}{r_{e3} + (R_{E2}||(R_F + R_{E1}))} \tag{5.0.3.5}$$

$$\frac{1}{6.25 + (100||740)} = 10.6mA/V \tag{5.0.3.6}$$

combining the gains of the three stags results in

$$G = \frac{I_0}{V_i} = -14.92 \times -131.2 \times 10.6 \times 10^-3 = 20.7A/V \tag{5.0.3.7}$$

the closed loop gain A_f is found from

$$A_f = \frac{I_0}{V_s} = \frac{G}{1 + GH} = \frac{20.7}{1 + 20.7 \times 11.9} = 83.7mA/V \tag{5.0.3.8}$$

which we note is very close to the approximate value found in (5.0.1.7),above the voltage gain is found from

$$\frac{V_0}{V_s} = \frac{-I_cR_{c3}}{V_s} \approx \frac{-I_0R_{C3}}{V_s} = -A_fR_{C3} \tag{5.0.3.9}$$

$$= -83.7 \times 10^{-3} \times 600 = -50.2V/V \tag{5.0.3.10}$$

which is also very close to the approximate value found in (5.0.1.7) above given by

$$R_in = R_if = R_i(1 + GH) \tag{5.0.3.11}$$

where R_i is the input resistance of the G circuit.The value of R_i can be found from the circuit in fig.5.0.3 as follows:

$$R_i = (h_{fe} + 1)(r_{e1} + (R_{E1}||(R_F + R_{E2}))) = 13.65K\Omega \tag{5.0.3.12}$$

$$R_{if} = 13.65(1 + 20.7 \times 11.9) = 3.38M\Omega \tag{5.0.3.13}$$

$$R_{of} = R_o(1 + GH) \tag{5.0.3.14}$$

where R_o can be determined to be

$$R_o = (R_{E2}||(R_F + R_{E1})) + r_{e3} + \frac{R_{C2}}{h_{fe} + 1} \tag{5.0.3.15}$$

which, for the values given, yields R_o = 143.9Ω. The output resistance R_{of} of the feedback amplifier can now be found as

$$R_{of} = R_o(1 + GH) = 143.9(1 + 20.7 \times 11.9) = 35.6K\Omega \quad (5.0.3.16)$$

R_{out} is found by using circuit4 in fig.5.0.3

$$R_{out} = r_o3 + [R_{of} \| (r_{\pi 3} + R_{C2})](1 + g_{m3} r_{o3} \frac{r_{\pi 3}}{r_{\pi 3} + R_{C2}}) \quad (5.0.3.17)$$

$$= 25 + [35.6 \| (5.625)][1 + 160 \times 25 \frac{0.625}{5.625}] = 2.19M\Omega \quad (5.0.3.18)$$

thus R_{out} is increased (from r_{o3}) but not by (1+GH)

5.0.4. Represent this amplifier in a control system Block Diagram
Solution: figure in fig.5.0.4 represents our control system

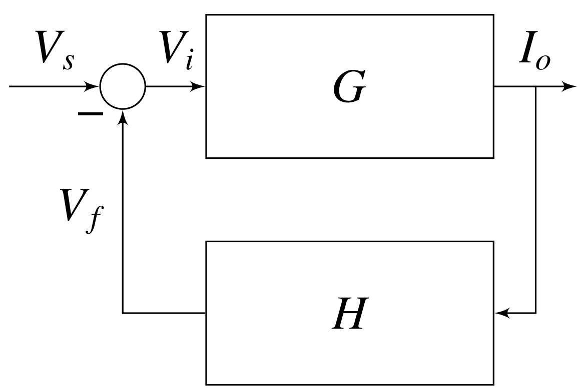

Fig. 5.0.4: block diagram