Control Systems

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Contents

***Abstract*—This manual is an introduction to control systems in feedback circuits. Links to sample Python codes are available in the text.**

Download python codes using

```
svn co https://github.com/gadepall/school/trunk/
    control/feedback/codes
```

1 Feedback Voltage Amplifier: Series-Shunt

2 Feedback Current Amplifier: Shunt-Series

2.1 Ideal Case

2.2 Practical Case

3 Feedback Current Amplifier: Example

4 Feedback Transconductance Amplifier: Series-Series

4.1. Part of the circuit of the MC1553 Amplifier is shown in circuit1 in Fig. 4.1.1 with values of various parameters given in Table 4.1. Draw the equivalent block diagrams.
Solution: The block diagrams are available in Figs. 4.1.2 and 4.1.3.

4.2. Draw the block diagram and equivalent circuit for H for Fig. 4.1.3.

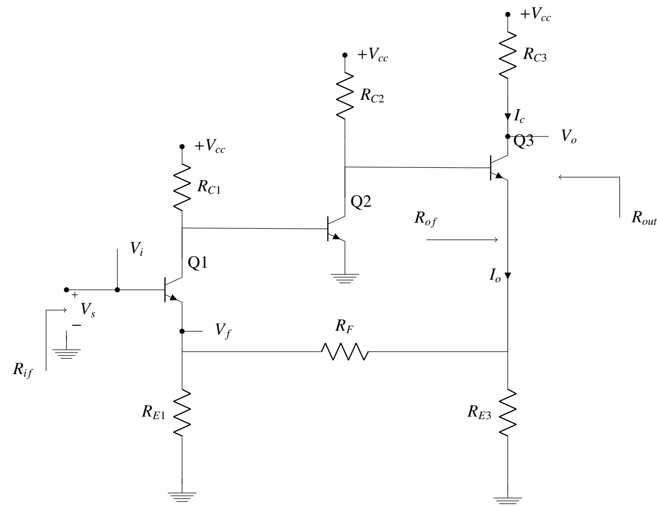

Fig. 4.1.1

Parameter	Value
R_{C1}	$9k\Omega$
R_{E1}	100Ω
R_{C2}	$5k\Omega$
R_F	640Ω
R_{E2}	100Ω
R_{C3}	600Ω
h_{fe}	**100**
r_o	$\infty\Omega$
I_{C1}	**0.6mA**
I_{C2}	**1mA**
I_{C3}	**4mA**
r_{e1}	41.7Ω
$r_{\pi 2}$	$2.5k\Omega$
$\alpha 1$	**0.99**
g_{m2}	**40mA/V**
r_{e3}	6.25Ω
r_{o3}	$25k\Omega$
$r_{\pi 3}$	625Ω

TABLE 4.1: parameters

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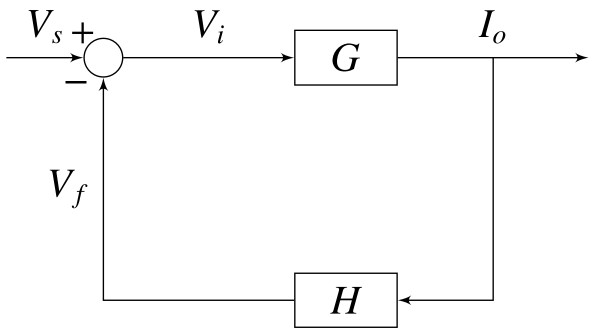

Fig. 4.1.2: block diagram

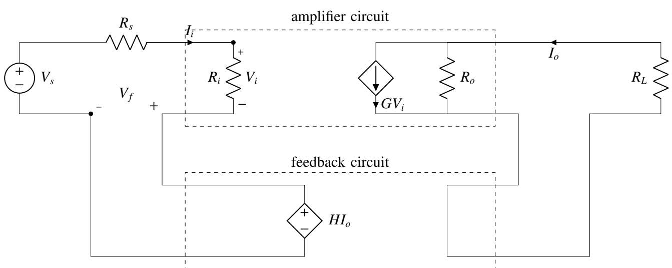

Fig. 4.1.3: Feedback Transconductance Amplifier

Solution: Fig. 4.2.4 gives the required block diagram

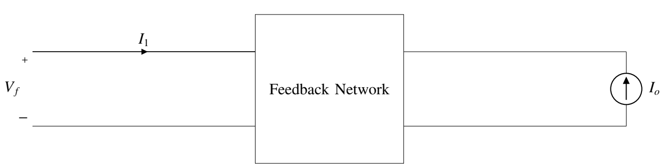

Fig. 4.2.4: Feedback circuit block diagram

$$H = \frac{V_f}{I_o}|_{I_1=0} \tag{4.2.1}$$

and the equivalent H circuit is available in Fig. 4.2.5.

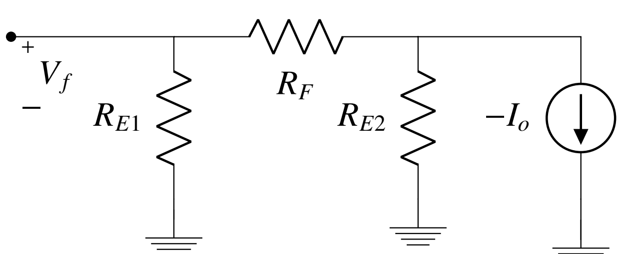

Fig. 4.2.5: H circuit

4.3. Find the feedback Factor H

Solution: From Fig. 4.2.5,

$$H = \frac{V_f}{I_0} = \frac{R_{E1}R_{E2}}{R_{E2} + R_F + R_{E1}} \tag{4.3.1}$$

4.4. Find R_{11} and R_{22} from Figs. 4.4 and 4.2.5

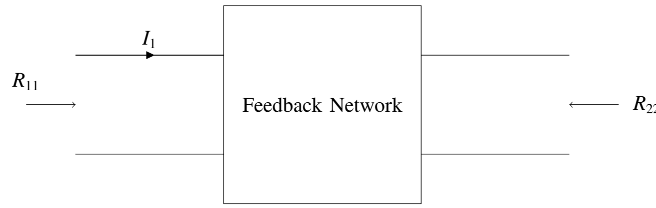

Fig. 4.4: feedback network

Solution:

$$R_{11} = R_{E1}||(R_F + R_{E2}) \tag{4.4.1}$$

$$R_{22} = R_{E2}||(R_F + R_{E1}) \tag{4.4.2}$$

4.5. Draw the block diagram and equivalent circuit for G.

Solution: The required block diagram is available in Fig. 4.5 and the equivalent circuit in

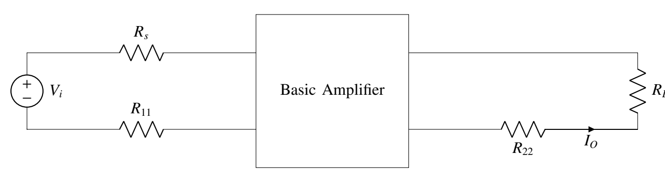

Fig. 4.5: Amplifier circuit block diagram

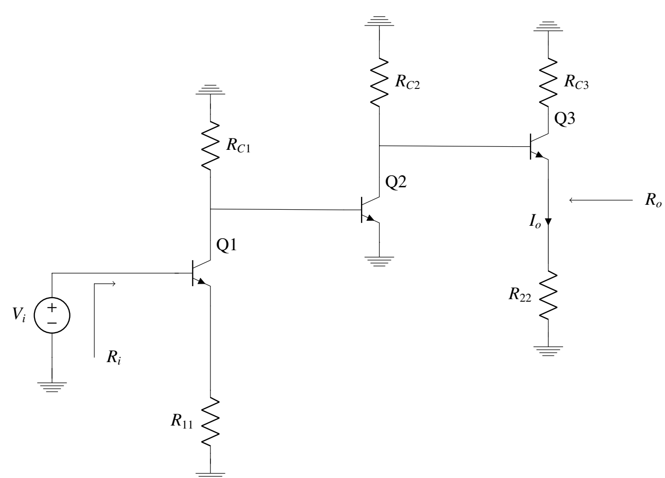

Fig. 4.5: G circuit

4.6. Find G

Solution: This is the equivalent circuit of AC analysis Refer Fig.4.6.9

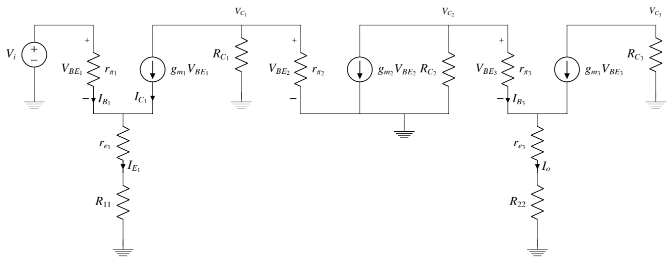

Fig. 4.6.9: ac analysis circuit

To find $G = \frac{I_0}{V_i}$ we determine the gain of first stage(where $\beta = h_{fe}$) Refer Fig. 4.6.10

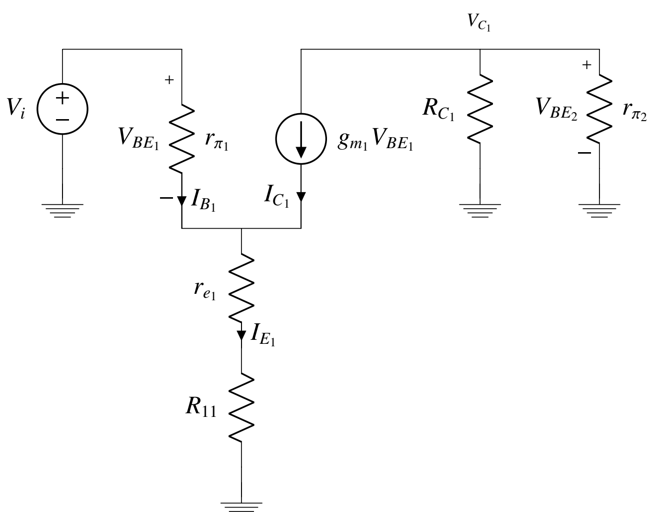

Fig. 4.6.10: circuit6

As

$$V_{C_1} = -I_{C_1}(R_{C_1} \parallel r_{\pi_2}) \tag{4.6.1}$$

By writing KVL we get

$$V_i - \frac{r_{\pi_1}}{1+\beta} I_{E_1} - I_{E_1}(r_{e_1} + R_{11}) = 0 \tag{4.6.2}$$

$$V_i = I_{E_1}\left(\frac{r_{\pi_1}}{1+\beta} + r_{e_1} + R_{11}\right) \tag{4.6.3}$$

$$\frac{V_{C_1}}{V_i} = \frac{-I_{C_1}(R_{C_1} \parallel r_{\pi_2})}{I_{E_1}(\frac{r_{\pi_1}}{1+\beta} + r_{e_1} + R_{11})} \tag{4.6.4}$$

As

$$I_{C_1} = \alpha I_{E_1} \tag{4.6.5}$$

$$\frac{V_{C_1}}{V_i} = \frac{-\alpha(R_{C_1} \parallel r_{\pi_2})}{(\frac{r_{\pi_1}}{1+\beta} + r_{e_1} + R_{11})} \tag{4.6.6}$$

$$\therefore \frac{V_{C_1}}{V_i} \simeq \frac{-\alpha(R_{C_1} \parallel r_{\pi_2})}{(r_{e_1} + R_{11})} \tag{4.6.7}$$

$$\tag{4.6.8}$$

Next, we determine the gain of the second stage,(noting that $V_{b2} = V_{c1}$)

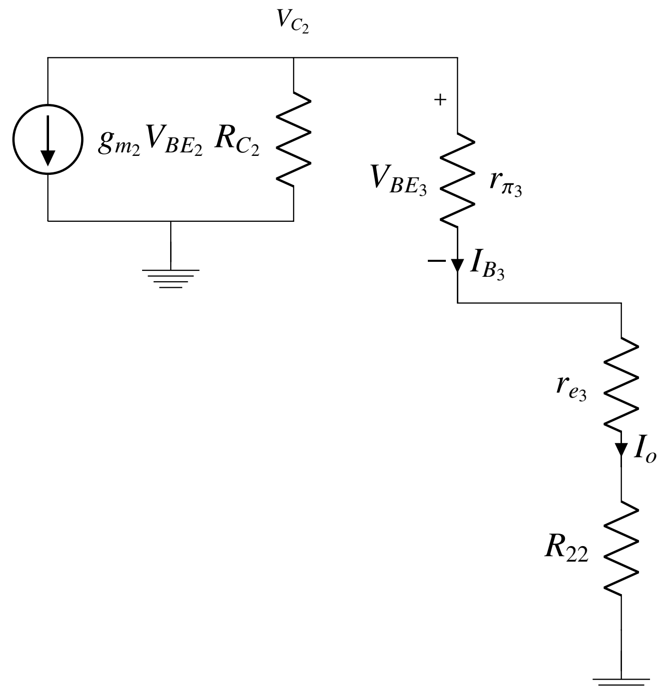

Fig. 4.6.11: circuit7

As here

$$V_{BE_2} = V_{C_1} \tag{4.6.9}$$

By writing KCL we get

$$V_{C_2} - r_{\pi_3} I_{B_3} - R_{22}(1+\beta) I_{B_3} = 0 \tag{4.6.10}$$

$$V_{C_2} = (r_{\pi_3} + R_{22}(1+\beta)) I_{B_3} \tag{4.6.11}$$

$$V_{C_2} \simeq (R_{22}(1+\beta)) I_{B_3} \tag{4.6.12}$$

$$I_{B_3} = \frac{V_{C_2}}{R_{22}(1+\beta)} \tag{4.6.13}$$

By writing KVL at node V_{C_2}

$$-g_{m_2} V_{C_1} = \frac{V_{C_2}}{R_{C_2}} + I_{B_3} \tag{4.6.14}$$

Sub I_{B_3}

$$-g_{m_2}V_{C_1} = \frac{V_{C_2}}{R_{C_2}} + \frac{V_{C_2}}{(1+\beta)R_{22}} \quad (4.6.15)$$

$$-g_{m_2}V_{C_1} = (\frac{1}{R_{C_2}} + \frac{1}{(1+\beta)R_{22}})V_{C_2} \quad (4.6.16)$$

$$\frac{V_{C_2}}{V_{C_1}} = -g_{m_2} \times \frac{1}{(\frac{1}{R_{C_2}} + \frac{1}{(1+\beta)R_{22}})} \quad (4.6.17)$$

$$\therefore \frac{V_{C_2}}{V_{C_1}} = -g_{m_2}(R_{C_2} \parallel (1+\beta)R_{22}) \quad (4.6.18)$$

Finally,for the third stage

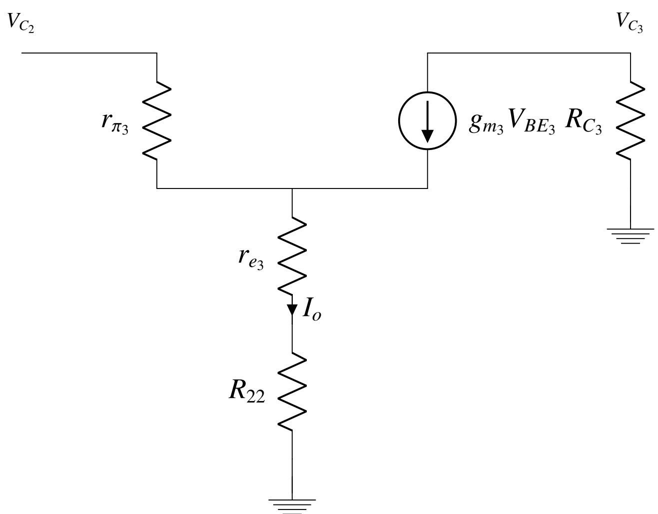

Fig. 4.6.12: circuit8

By writing KVL we get

$$V_{C_2} - \frac{r_{\pi_3}}{(1+\beta)}I_o - (r_{e_3} + R_{22})I_o = 0 \quad (4.6.19)$$

$$V_{C_2} = (\frac{r_{\pi_3}}{(1+\beta)} + r_{e_3} + R_{22})I_o \quad (4.6.20)$$

$$V_{C_2} \simeq (r_{e_3} + R_{22})I_o \quad (4.6.21)$$

$$\therefore \frac{I_o}{V_{C_2}} = \frac{1}{R_{22} + r_{e_3}} \quad (4.6.22)$$

4.7. Find closed loop gain T and Voltage Gain V_0/V_snumerically.
Solution:

$$T = \frac{I_0}{V_s} = \frac{G}{1+GH} = \frac{20.7}{1+20.7\times 11.9} = 83.7mA/V \quad (4.7.1)$$

4.8. Now assume Loop gain is large and find approximate expression for closed loop gain $T = \frac{I_o}{V_s}$
Solution: When GH $\gg$1,

$$T \approx \frac{I_0}{V_s} \approx \frac{1}{H} \quad (4.8.1)$$

$$= \frac{1}{11.9} = 84mA/V \quad (4.8.2)$$

$$\frac{I_c}{V_s} \approx \frac{I_0}{V_s} = 84mA/V \quad (4.8.3)$$

which we note is very close to the approximate value found in (4.7.1)

4.9. Tabulate all your results.
Solution: See Table 4.9.

Parameter	**Value**
G	**20.7A/V**
H	11.9Ω
T	**83.7mA/V**
V_o/V_s	**-50.2V/V**
R_{in}	$3.38M\Omega$
R_{out}	$2.19M\Omega$
R_{of}	$35.6k\Omega$

TABLE 4.9: calculated parameters

4.10. Write a code for doing calculations and verify the values obtained in 4.9
Solution: The following code does all the calculations of above equations to give parameters in 4.9

```
codes/ee18btech11007/circuit_calc.py
```