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 Transconductance Amplifier: Series-Series

1.0.1. draw the block diagram of a Feedback Transconductance Amplifier(series-series)
Solution: fig.1.0.1 gives us the required block diagram

$$T = \frac{I_o}{V_s} = \frac{G}{1+GH} \tag{1.0.1.1}$$

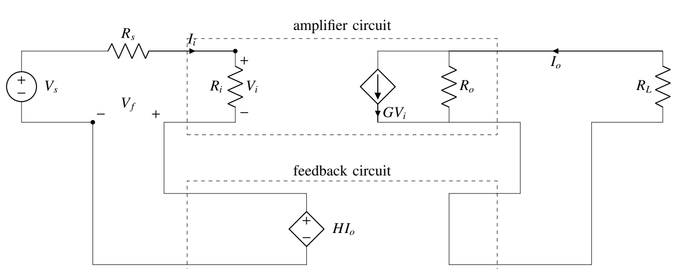

Fig. 1.0.1: Feedback Transconductance Amplifier

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1.0.2. draw the equivalent amplifier circuit block diagram of fig.1.0.1
Solution: fig.1.0.2 gives the required block diagram

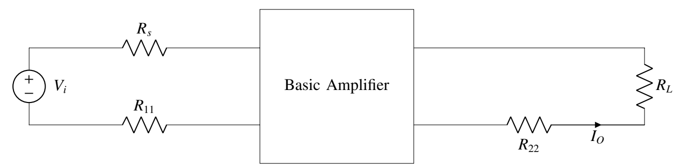

Fig. 1.0.2: Amplifier circuit block diagram

$$G = \frac{I_o}{V_i} \tag{1.0.2.1}$$

R_{11} and R_{22} are obtained from fig.1.0.2

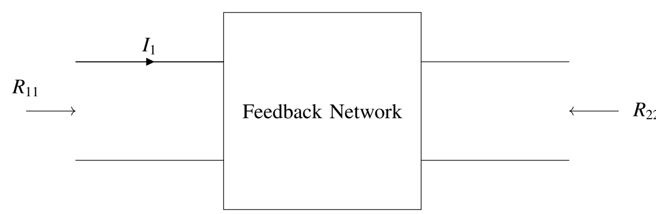

Fig. 1.0.2: feedback network

1.0.3. draw the equivalent feedback circuit block diagram of fig.1.0.1
Solution: fig.1.0.3 gives the required block diagram

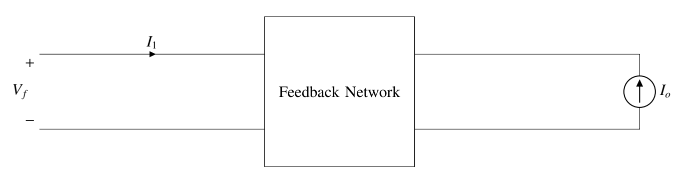

Fig. 1.0.3: Feedback circuit block diagram

$$H = \frac{V_f}{I_o}\Big|_{I_1=0} \tag{1.0.3.1}$$

1.0.4. Part of the circuit of the MC1553 Amplifier is shown in circuit1 in fig.1.0.4 ,Answer below questions using equivalent block diagrams in fig.1.0.1 and values from Table 1.0.4

1.0.5. feedback analysis to find open loop gain G
Solution: employing equivalent amplifier block diagram fig.1.0.2 into circuit in fig.1.0.4, R_{11} and R_{22} are

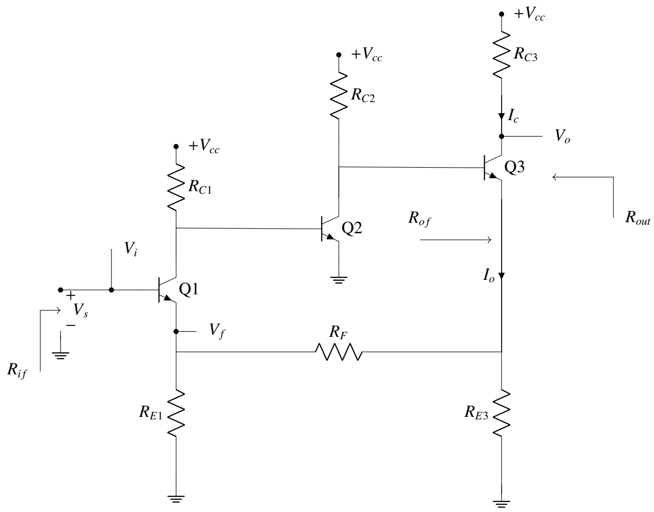

Fig. 1.0.4: circuit1

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 1.0.4: parameters

found from feedback circuit in fig.1.0.4 using rule from fig.1.0.2 we finally obtain

$$R_s, R_L = 0 \tag{1.0.5.1}$$

$$R_{11} = R_{E1} \| (R_F + R_{E2}) \tag{1.0.5.2}$$

$$R_{22} = R_{E2} \| (R_F + R_{E1}) \tag{1.0.5.3}$$

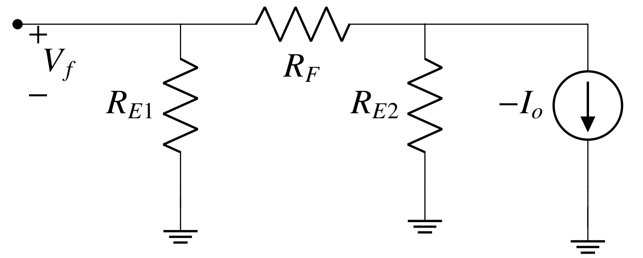

Fig. 1.0.4: H circuit

finally Amplifier circuit is obtained shown in fig.1.0.5

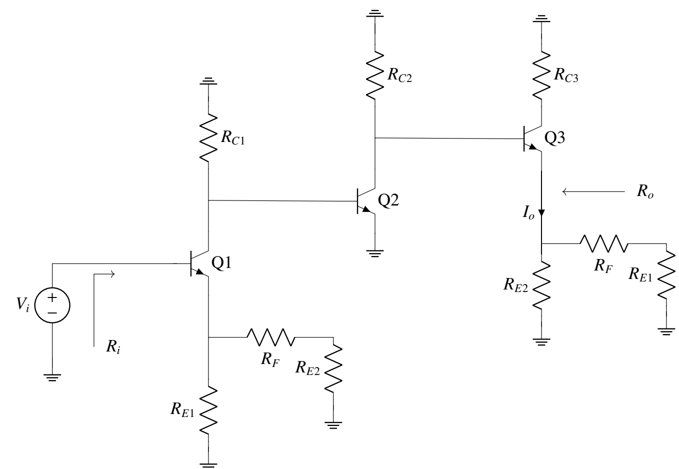

Fig. 1.0.5: G circuit

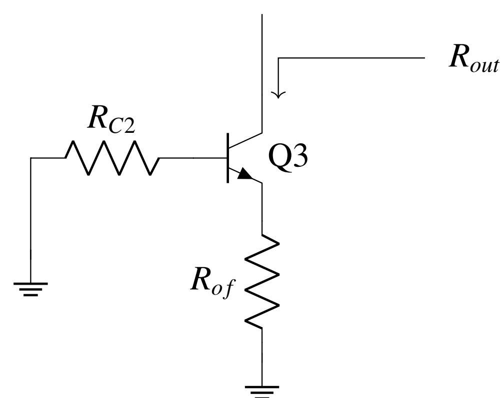

Fig. 1.0.5: circuit4

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

$$\frac{V_{c1}}{V_i} = \frac{-\alpha(R_{c1} \| r_{\pi 2})}{r_{e1} + (R_{E1} \| (R_F + R_{E2}))} \tag{1.0.5.4}$$

using values from 1.0.4

$$\frac{V_{c1}}{V_i} = -14.92V/V \tag{1.0.5.5}$$

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

$$\frac{V_{c2}}{V_{c1}} = -g_{m2}R_{c2}||(h_{fe} + 1)[r_{e3} + (R_{E2}||(R_F + R_{E1}))] \tag{1.0.5.6}$$

substituting ,results in

$$\frac{V_{c2}}{V_{c1}} = -131.2V/V \tag{1.0.5.7}$$

Finally,for the third stage we can write by inspection

$$\frac{I_0}{V_{c2}} = \frac{I_{e3}}{V_{b3}} = \frac{1}{r_{e3} + (R_{E2}||(R_F + R_{E1}))} \tag{1.0.5.8}$$

substituing values from 1.0.4 gives

$$\frac{I_0}{V_{c2}} = 10.6mA/V \tag{1.0.5.9}$$

combining the gains of the three stags results in

$$G = \frac{I_0}{V_i} = -14.92 \times -131.2 \times 10.6 \times 10^{-3} = 20.7A/V \tag{1.0.5.10}$$

1.0.6. Find Feedback Factor H
Solution: employing the equivalent feedback circuit block diagram we get circuit2 in fig.1.0.4

$$H = \frac{V_f}{I_0} = \frac{R_{E2}}{R_{E2} + R_F + R_{E1}} \times R_{E1} \tag{1.0.6.1}$$

$$H = \frac{100}{100 + 640 + 100} \times 100 = 11.9\Omega \tag{1.0.6.2}$$

1.0.7. Find closed loop gain T and Voltage Gain V_0/V_s
Solution:

$$T = \frac{I_0}{V_s} = \frac{G}{1 + GH} = \frac{20.7}{1 + 20.7 \times 11.9} = 83.7mA/V \tag{1.0.7.1}$$

the voltage gain is found from

$$\frac{V_0}{V_s} = \frac{-I_c R_{c3}}{V_s} \approx \frac{-I_0 R_{C3}}{V_s} = -TR_{C3} \tag{1.0.7.2}$$

$$= -83.7 \times 10^{-3} \times 600 = -50.2V/V \tag{1.0.7.3}$$

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

$$T = \frac{I_0}{V_s} \approx \frac{1}{H} \tag{1.0.8.1}$$

as

$$H = \frac{V_f}{I_0} = \frac{R_{E2}}{R_{E2} + R_F + R_{E1}} \times R_{E1} \tag{1.0.8.2}$$

$$= \frac{100}{100 + 640 + 100} \times 100 = 11.9\Omega \tag{1.0.8.3}$$

thus,

$$T = \frac{1}{11.9} = 84mA/V \tag{1.0.8.4}$$

$$\frac{I_c}{V_s} \approx \frac{I_0}{V_s} = 84mA/V \tag{1.0.8.5}$$

which we note is very close to the approximate value found in (1.0.7.1)

1.0.9. Find R_{in} and R_{out} for circuit in fig.1.0.4
Solution:

$$R_{in} = R_{if} = R_i(1 + GH) \tag{1.0.9.1}$$

where R_i is the input resistance of the G circuit.The value of R_i can be found from the circuit in fig.1.0.5 as follows:

$$R_i = (h_{fe} + 1)(r_{e1} + (R_{E1}||(R_F + R_{E2}))) = 13.65K\Omega \tag{1.0.9.2}$$

$$R_{if} = 13.65(1 + 20.7 \times 11.9) = 3.38M\Omega \tag{1.0.9.3}$$

$$R_{of} = R_o(1 + GH) \tag{1.0.9.4}$$

where R_o can be determined to be

$$R_o = (R_{E2}||(R_F + R_{E1})) + r_{e3} + \frac{R_{C2}}{h_{fe} + 1} \tag{1.0.9.5}$$

from values in Table 1.0.4, yields $R_o = 143.9\Omega$. The output resistance R_{of} of the feedback amplifier can now be found as

$$R_{of} = R_o(1 + GH) = 143.9(1 + 20.7 \times 11.9) = 35.6K\Omega \tag{1.0.9.6}$$

R_{out} is found by using circuit4 in fig.1.0.5

$$R_{out} = r_{o3} + [R_{of}||(r_{\pi3} + R_{C2})](1 + g_{m3}r_{o3}\frac{r_{\pi3}}{r_{\pi3} + R_{C2}}) \tag{1.0.9.7}$$

$$= 25 + [35.6||(5.625)][1 + 160 \times 25\frac{0.625}{5.625}] = 2.19M\Omega \tag{1.0.9.8}$$

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

1.0.10. put the obtained parameters in a table
Solution:

1.0.11. Represent this amplifier in a control system Block Diagram
Solution: figure in fig.1.0.11 represents our control system

1.0.12. write a code for doing calculations and verify the values obtained in 1.0.10
Solution: following code does all the calculations of above equations to give parameters in 1.0.10

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

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 1.0.10: parameters

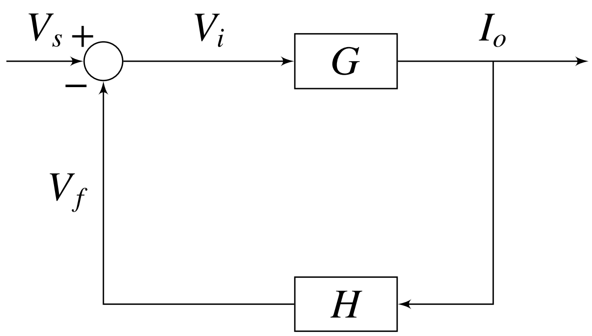

Fig. 1.0.11: block diagram

2 Feedback Voltage Amplifier: Series-Shunt

3 Feedback Current Amplifier: Shunt-Series

3.1 Ideal Case

3.2 Practical Case