

Control Systems

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CONTENTS

1 Feedback Voltage Amplifier: Shunt-Shunt

1

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: SHUNT-SHUNT

1.1. The circuit in Fig. 1.1.1 utilizes a voltage amplifier with gain μ in a shunt-shunt feedback topology with the feedback network composed of resistor R_F , to use the feedback equations convert the signal source to its Norton Representation. Also draw the H-Circuit and G-Circuit.

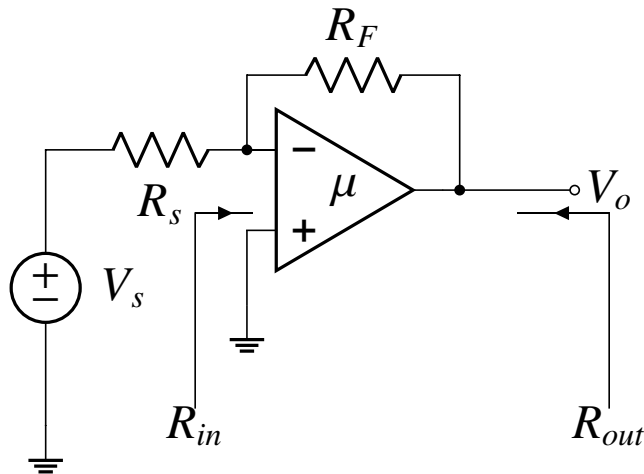


Fig. 1.1.1

Solution: See Fig. 1.1.3 for the Norton Representation, Fig. 1.1.4 for the H-Circuit, Fig. 1.1.5 and Fig. 1.1.6 for the G-Circuit.

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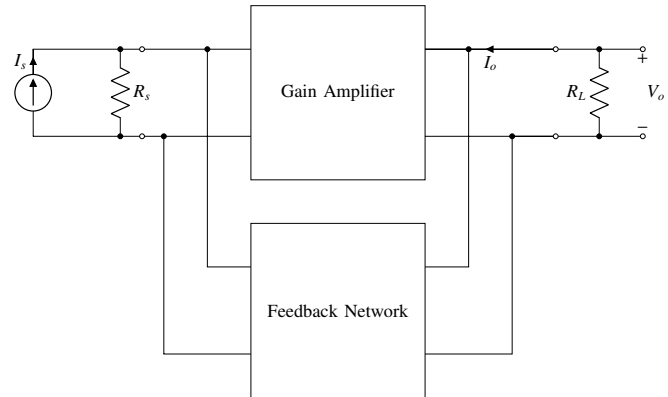


Fig. 1.1.2: Shunt Shunt Amplifier Block Diagram

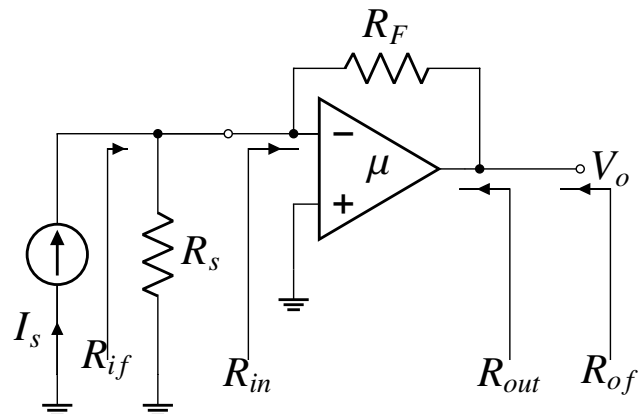


Fig. 1.1.3

1.2. Write all the feedback equations based on all the Figs. using KCL/KVL.

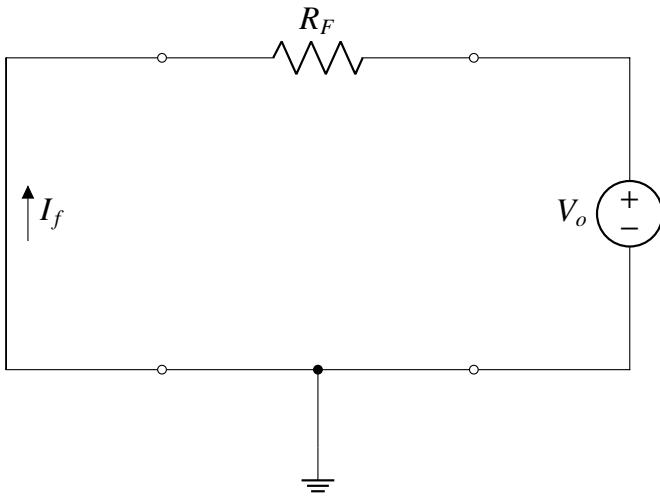


Fig. 1.1.4

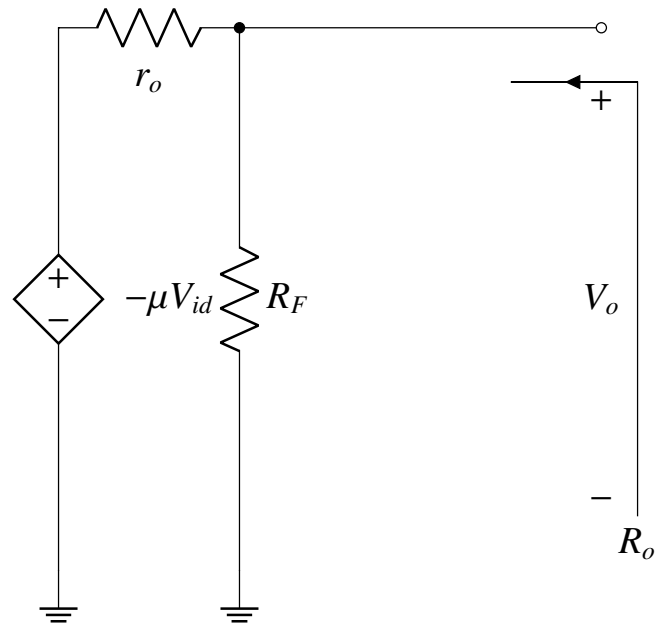


Fig. 1.1.6

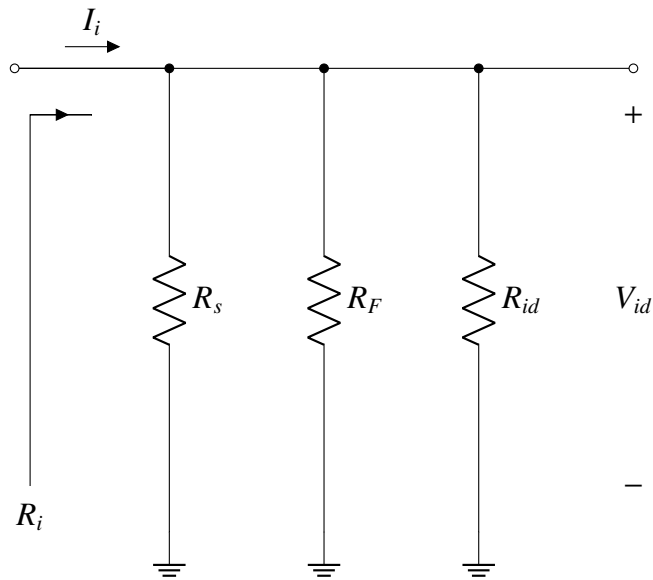


Fig. 1.1.5

Solution: The equations are as follows:

$$T = \frac{V_o}{I_s} = \frac{G}{1 + GH} \quad (1.2.1)$$

$$H = \frac{I_f}{V_o} = -\frac{1}{R_F} \quad (1.2.2)$$

$$I_i = I_s - I_f = \frac{I_s}{1 + GH} \quad (1.2.3)$$

$$R_{if} = \frac{V_i}{I_s} = \frac{V_i}{(1 + GH)I_i} = \frac{R_i}{1 + GH} \quad (1.2.4)$$

$$R_{of} = \frac{R_o}{1 + GH} \quad (1.2.5)$$

$$R_{in} = \frac{1}{\frac{1}{R_{if}} - \frac{1}{R_s}}, R_{out} = \frac{1}{\frac{1}{R_{of}} - \frac{1}{R_L}} \quad (1.2.6)$$

| Parameters | Description |
|------------|--------------------------------|
| G | Open Loop Gain |
| H | Feedback Factor |
| T | Closed Loop Gain |
| V_0 | Output Voltage |
| V_s | Signal Source Voltage |
| V_{id} | Input Voltage of Opamp |
| I_s | Signal Source Current |
| I_f | Feedback Current |
| R_i | Total Input Resistance |
| R_{out} | Total Output Resistance |
| R_{id} | Input resistance of Opamp |
| r_o | Output resistance of Opamp |
| R_i | Input resistance of Open Loop |
| R_o | Output resistance of Open Loop |
| R_{if} | Input resistance of Feedback |
| R_{of} | Output resistance of Feedback |
| R_s | Resistance of Current Source |

TABLE 1.2

1.3. If the loop gain is very large, what approximate closed-loop voltage gain V_o/V_s is realized? Also if $R_s = 1 \text{ k}\Omega$, give the value of R_F that will result in $V_o/V_s \approx -10\text{V/V}$.

Solution: If the loop gain GH is very large then the

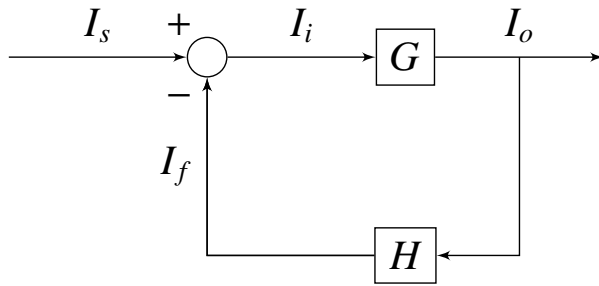


Fig. 1.2.7: Block Diagram

closed loop gain is,

$$T = \frac{V_o}{I_s} = \frac{G}{1 + GH} \quad (1.3.1)$$

$$\because GH \gg 1 \Rightarrow T \approx \frac{1}{H} \quad (1.3.2)$$

From equation 1.2.2 and 1.3.2 we get,

$$T \approx -R_F \quad (1.3.3)$$

$$\Rightarrow \frac{V_o R_s}{V_s} \approx -R_F \quad (1.3.4)$$

$$\Rightarrow \frac{V_o}{V_s} \approx \frac{-R_F}{R_s} \quad (1.3.5)$$

$$\Rightarrow R_F = 10k\Omega \quad (1.3.6)$$

- 1.4. If the amplifier μ has a dc gain of 10^3 V/V, an input resistance $R_{id} = 100$ k Ω , and an output resistance $r_o = 1$ k Ω , find the actual V_o/V_s realized. Also find R_{in} and R_{out} .

Solution: To find V_o/V_s , R_{in} and R_{out} first find the other necessary parameters.

From Fig. 1.1.5 we get,

$$R_i = R_{id} || R_F || R_s \quad (1.4.1)$$

$$R_i = 100k || 10k || 1k = \frac{1000}{1011}k = 0.90k\Omega \quad (1.4.2)$$

$$V_{id} = I_i R_i \quad (1.4.3)$$

From Fig. 1.1.6 we get,

$$R_o = r_o || R_F \quad (1.4.4)$$

$$\Rightarrow R_o = 1k || 10k = 0.91k\Omega \quad (1.4.5)$$

$$V_o = -\mu V_{id} \frac{R_F}{r_o + R_F} \quad (1.4.6)$$

From equation 1.4.3 and 1.4.6 we get the open-loop

gain as,

$$G = \frac{V_o}{I_i} = -\mu R_i \frac{R_F}{r_o + R_F} \quad (1.4.7)$$

$$\Rightarrow G = -(1000)(0.90) \frac{10}{11} = -819.00k\Omega \quad (1.4.8)$$

From equation 1.2.2 and 1.4.8 we get closed loop gain T as,

$$T = \frac{G}{1 + GH} = \frac{-819}{82.9} = -9.88k\Omega \quad (1.4.9)$$

From equation 1.2.1 we know,

$$T = \frac{V_o}{I_s} \quad (1.4.10)$$

$$\Rightarrow T = \frac{V_o R_s}{V_s} \quad (1.4.11)$$

$$\Rightarrow \frac{V_o}{V_s} = \frac{T}{R_s} \quad (1.4.12)$$

$$\Rightarrow \frac{V_o}{V_s} = \frac{-9.88}{1} = -9.88V/V \quad (1.4.13)$$

From equation 1.2.4 and 1.2.6 we know,

$$R_{if} = \frac{R_i}{1 + GH} = \frac{0.90}{82.9} \quad (1.4.14)$$

$$\Rightarrow R_{if} = 10.87\Omega \quad (1.4.15)$$

$$R_{in} = \frac{1}{\frac{1}{R_{if}} - \frac{1}{R_s}} \quad (1.4.16)$$

$$\Rightarrow R_{in} = \frac{1}{\frac{1}{10.87} - \frac{1}{1000}} = 10.99\Omega \quad (1.4.17)$$

Because R_L is not there in the circuit so we take it's value as ∞ , so from equation 1.2.5 and 1.2.6 we know,

$$R_{of} = \frac{R_o}{1 + GH} = \frac{0.91}{82.9} \quad (1.4.18)$$

$$\Rightarrow R_{of} = 10.97\Omega \quad (1.4.19)$$

$$R_{out} = \frac{1}{\frac{1}{R_{of}} - \frac{1}{R_L}} \quad (1.4.20)$$

$$\Rightarrow R_{out} = \frac{1}{\frac{1}{10.97} - \frac{1}{\infty}} = 10.97\Omega \quad (1.4.21)$$

Verify the above calculations using the following Python code.

```
codes/ee18btech11011/ee18btech11011_cal.
ipynb
```