Feedback Voltage Amplifier: Shunt-Shunt

Deep*

Contents

The circuit in Fig. 0 utilizes a voltage amplifier with gain μ in a shunt-shunt feedback topology with the feedback network composed of resistor R_F.In order to be able to use the feedback equations you should first convert the signal source to it's Norton Representation.

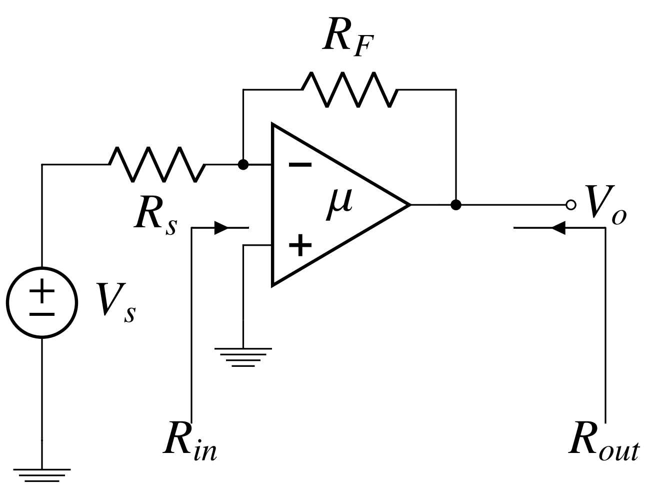

Fig. 0

1) If the loop gain is very large, what approximate closed loop voltage gain V_o/V_s is realized? If R_s = 1kΩ, give the value of R_F that will result in $V_o/V_s \simeq$ -10V/V.
2) If the amplifier μ has a dc gain of 10^3 V/V, an input resistance R_{id} = 100kΩ, and an output resistance r_o = 1kΩ , find the actual V_o/V_s realized. Also find R_{in} and R_{out}.
3) If the amplifier μ has an upper 3-dB frequency of 1 kHz and a uniform -20-dB/decade gain rolloff, what is the 3-dB frequency of the gain $\mid V_o/V_s \mid$.

1. Draw the Norton Representation of Fig. 0 and the equivalent block diagram and the eqivalent control system.
Solution: See Figs. 1.1, 1.2 and 1.3 respectively.

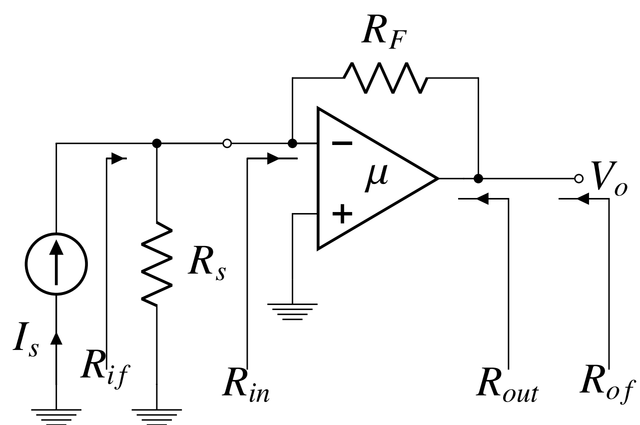

Fig. 1.1

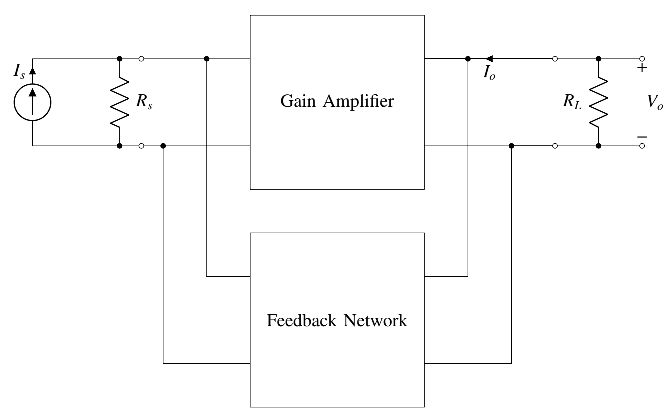

Fig. 1.2: Shunt Shunt Amplifier Block Diagram

2. Daw the circuit for H and find it.
Solution: From Fig. 2.

$$H = \frac{I_f}{V_o} = -\frac{1}{R_F} \tag{2.1}$$

$$\tag{2.2}$$

3. Draw the equivalent circuit for G and find it.
Solution: See Figs. 3.1 and 3.2 denoting the

*The author is with the Department of Electrical Engineering, Indian Institute of Technology, Hyderabad 502285 India.

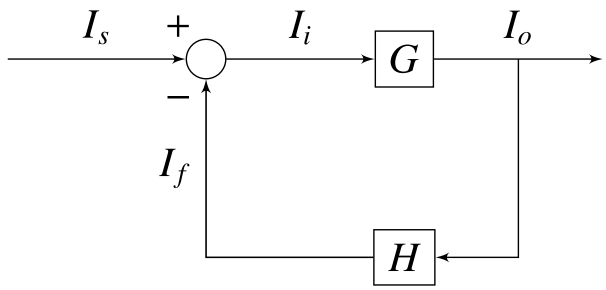

Fig. 1.3: Block Diagram

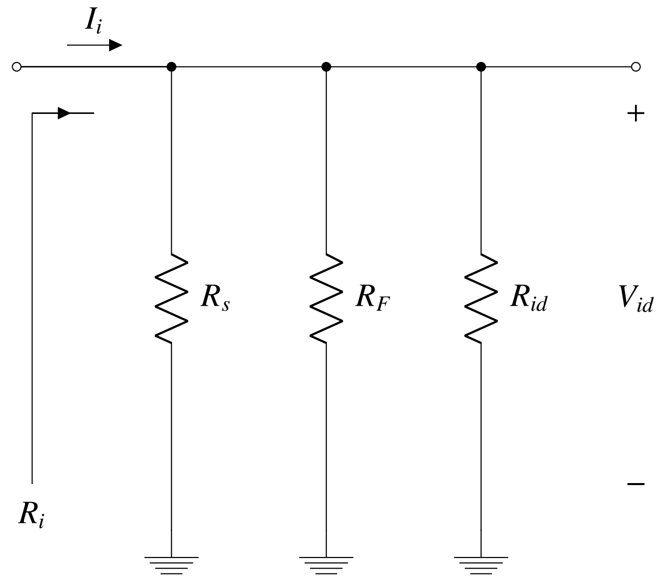

Fig. 3.1

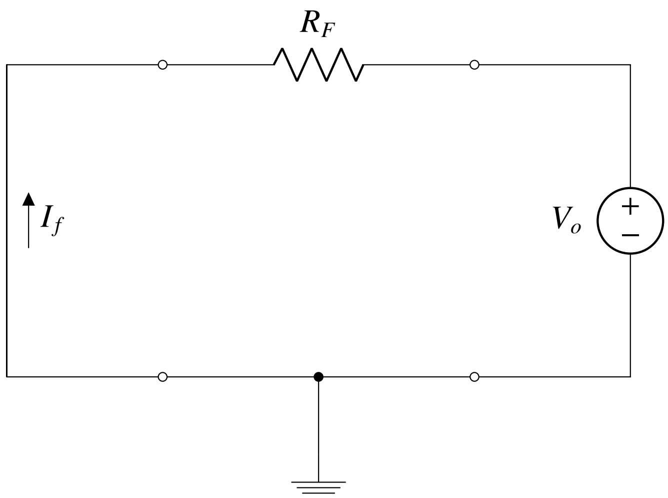

Fig. 2

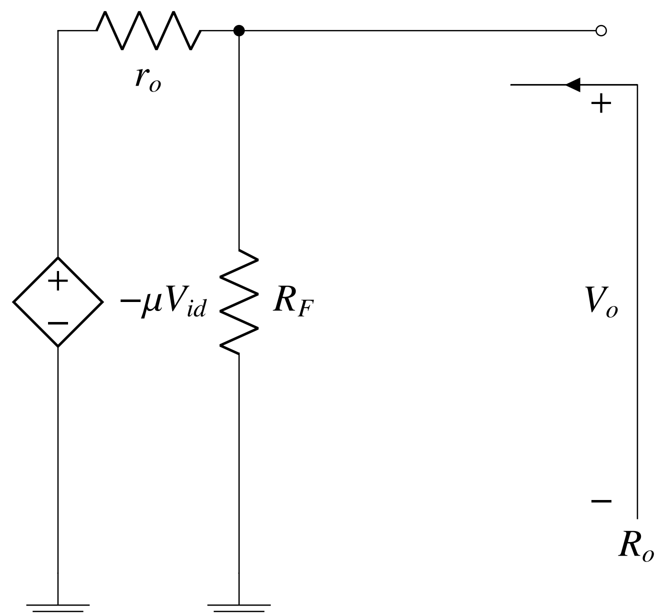

Fig. 3.2

input and output parts of the circuit for G. Refer to Table 3 for the various parameters.

$$R_o = r_o \| R_F \tag{3.1}$$

$$V_o = -\mu V_{id} \frac{R_F}{r_o + R_F} \tag{3.2}$$

$$R_i = R_{id} \| R_F \| R_s \tag{3.3}$$

$$= 100k \| 10k \| 1k = 0.90k\Omega \tag{3.4}$$

$$V_{id} = I_i R_i \tag{3.5}$$

$$G = \frac{V_o}{I_i} = -\mu \frac{R_F}{r_o + R_F} (R_{id} \| R_F \| R_s) \quad = -819.00k\Omega \tag{3.6}$$

4. If the loop gain is very large, what approximate closed-loop voltage gain V_o/V_s is realized?Also if R_s = 1 kΩ , give the value of R_F that will result in $V_o/V_s \simeq$ -10 V/V.
Solution: For

$$GH \gg 1, \tag{4.1}$$

$$T = \frac{V_o}{I_s} \approx \frac{1}{H} \tag{4.2}$$

$$\implies \frac{V_o R_s}{V_s} = -R_F \tag{4.3}$$

$$\text{or, } \frac{V_o}{V_s} = -\frac{R_F}{R_s} \tag{4.4}$$

$$\implies R_F = 10k\Omega \tag{4.5}$$

Parameters	Description
G	Open Loop Gain
H	Feedback Factor
T	Closed Loop Gain
V_o	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 Ouput 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
V_f	Voltage across R_s
V_{in}	Voltage at -ve terminal of opamp
f	Closed loop 3-dB freq.

TABLE 3

5. If the amplifier μ has a dc gain of 10^3 V/V, an input resistance $R_{id} = 100$ kΩ , and an output resistance $r_o = 1$ kΩ , find the actual V_o/V_s realized. Also find R_{in} and R_{out}.
Solution:
From equation 2.1 and 3.6

$$T = \frac{G}{1+GH} \tag{5.1}$$
$$\implies \frac{V_o}{V_s} = -9.88 \tag{5.2}$$

$$R_{if} = \frac{R_i}{1+GH} \tag{5.3}$$
$$\implies R_{if} = 10.87\Omega \tag{5.4}$$
$$R_{in} = \frac{1}{\frac{1}{R_{if}} - \frac{1}{R_s}} \tag{5.5}$$
$$\implies R_{in} = \frac{1}{\frac{1}{10.87} - \frac{1}{1000}} = 10.99\Omega \tag{5.6}$$

Because R_L is not there in the circuit so we take it's value as ∞,

$$R_{of} = \frac{R_o}{1+GH} = \frac{0.91}{82.9} \tag{5.7}$$
$$\implies R_{of} = 10.97\Omega \tag{5.8}$$
$$R_{out} = \frac{1}{\frac{1}{R_{of}} - \frac{1}{R_L}} \tag{5.9}$$
$$\implies R_{out} = \frac{1}{\frac{1}{10.97} - \frac{1}{\infty}} = 10.97\Omega \tag{5.10}$$

Verify the above calculations using the following Python code.

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

6. If the amplifier μ has an upper 3-dB frequency of 1 kHz and a uniform -20-dB/decade gain rolloff, what is the 3-dB frequency of the gain $| V_o/V_s |$.
Solution: To find the 3-dB frequency i.e., ω_{3dB} we need to look at the Fig.6.

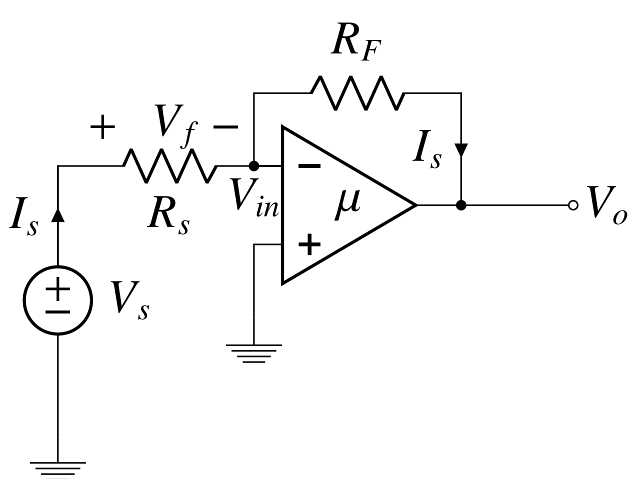

Fig. 6

The open loop gain G is given as follows in terms of frequency:

$$G = \frac{\mu}{1 + \frac{jf}{f_c}} \tag{6.1}$$

From Fig.6 we can say that:

$$V_{in} = V_s - V_f \tag{6.2}$$
$$V_o = -GV_{in} \tag{6.3}$$
$$\frac{V_f}{R_s} = \frac{V_{in} - V_o}{R_F} \tag{6.4}$$

From equation 6.3 and 6.4 we get:

$$\frac{V_f}{R_s} = \frac{-\frac{V_o}{G} - V_o}{R_F} \tag{6.5}$$

$$\implies \frac{V_f}{V_o} = -\frac{(1+G)}{G}\frac{(R_s)}{(R_F)} = -H \tag{6.6}$$

$$\because G >> 1 \implies H = \frac{R_s}{R_F} \tag{6.7}$$

Now from equation 6.2, 6.3 and 6.6 we get:

$$-\frac{V_o}{G} = V_s + HV_o \tag{6.8}$$

$$\implies \frac{V_o}{V_s} = -\frac{G}{1+GH} \tag{6.9}$$

Now, for "f" to be 3-dB frequency given condition should be match i.e.,:

$$|\frac{V_o}{V_s}| = \frac{1}{\sqrt{2}} \tag{6.10}$$

$$\implies |-\frac{G}{1+GH}| = \frac{1}{\sqrt{2}} \tag{6.11}$$

$$\implies \frac{\frac{\mu}{1+\frac{jf}{fc}}}{1+\frac{(R_s)}{(R_F)}\frac{\mu}{1+\frac{jf}{fc}}} = \frac{1}{\sqrt{2}} \tag{6.12}$$

Parameters	Values
R_s	1kΩ
R_F	10kΩ
μ	1000
f_c	1kHz

TABLE 6

Now putting the appropriate values as given in Table 6 we get:

$$\frac{\frac{1000}{1+\frac{jf}{1000}}}{1+\frac{(1)}{(10)}\frac{1000}{1+\frac{jf}{1000}}} = \frac{1}{\sqrt{2}} \tag{6.13}$$

$$\frac{f^2}{10^{12}} + \frac{101^2}{10^6} = 2 \tag{6.14}$$

$$f \approx 1.41MHz \tag{6.15}$$

7. Using ngspice verify the Closed-Loop Transfer function or V_o/V_s.
Solution: From 5.2 we know that:

$$\frac{V_o}{V_s} = -9.88V/V \tag{7.1}$$

So, to verify this use the following spice file.

```
spice/ee18btech11011/ee18btech11011.net
```

and finally to get the result use the following python code.

```
spice/ee18btech11011/ee18btech11011_spice.
    py
```

Result:

```
figs/ee18btech11011/
    ee18btech11011_spice_result.eps
```

```
figs/ee18btech11011/
    ee18btech11011_spice_result.pdf
```

Following are the instructions to run the spice file.

```
spice/ee18btech11011/README.md
```