Feedback current amplifier

Sanskar Nanegaonkar*

The feedback current amplifier in Fig. 1.1 utilizes an op amp with an input differential resistance R_{id}, an open-loop gain μ , and an output resistance r_o. The output current I_o that is delivered to the load resistance R_L is sensed by the feedback network composed of the two resistances R_M and R_F and a fraction I_f, is fed back to the amplifier input node. Find expressions for $G = \frac{I_o}{I_i}$, $H = \frac{I_f}{I_o}$ and $T = \frac{I_o}{I_s}$, assuming that the feedback causes the voltage at the input node to be near ground. If the loop gain is large, what does the closed-loop current gain become? State precisely the condition under which this is obtained. For $\mu = 10^4$, $R_{id} = 1$ MΩ, $r_o = 100$ Ω, $R_L = 10$ kΩ , $R_M = 100$ Ω , and $R_F = 10$ kΩ, find G, H, and T.

1. Fig. 1.1 shows a feedback current amplifier. Draw the equivalent control system.
   Solution: See fig 1.2

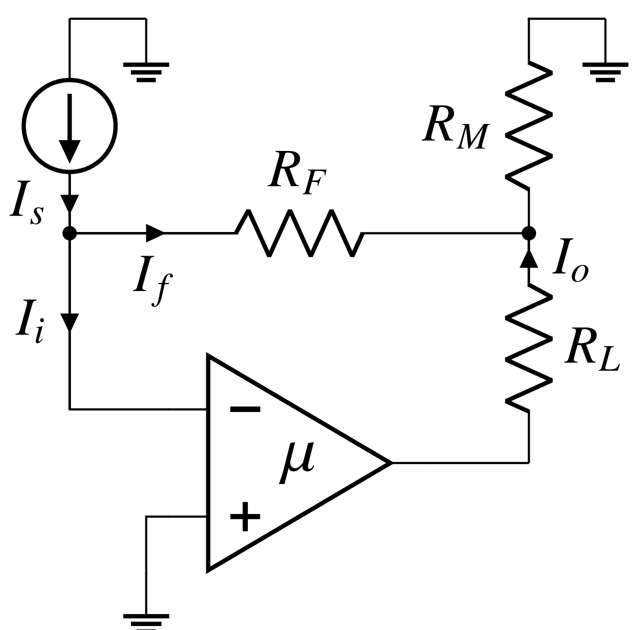

Fig. 1.1

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

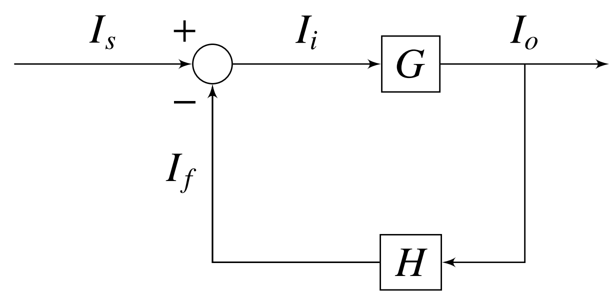

Fig. 1.2

2. Refer table I for the parameters and draw the small signal equivalent model of the fig 1.1
   Solution: See fig 2

Component	Description
R_{id}	Input Resistance of Op Amp
R_{out}	Output Resistance of Op Amp
I_s	Input Current
I_o	Output Current
R_M, R_F	Feedback Resistances
R_L	Load Resistance

TABLE I

3. Given G (open-loop gain) as
$$G = \frac{I_o}{I_i} \tag{3.1}$$
   Find G by considering the general open loop block diagram as shown in fig. 3 and fig. 2
   Solution: Clearly from fig. 2, we can see that,
$$G = \frac{I_o}{I_i} = \mu \tag{3.2}$$
4. Draw the block diagram and equivalent circuit for H (feedback factor).
   Solution: Refer fig. 4.5 and 4.6
5. Considering the feedback circuit as shown in fig. 4.6. Find R11 and R22.
   Solution: The value of R_{11} is obtained by

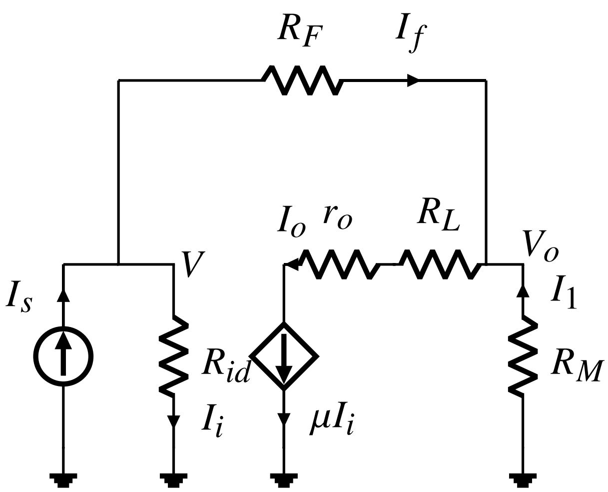

Fig. 2

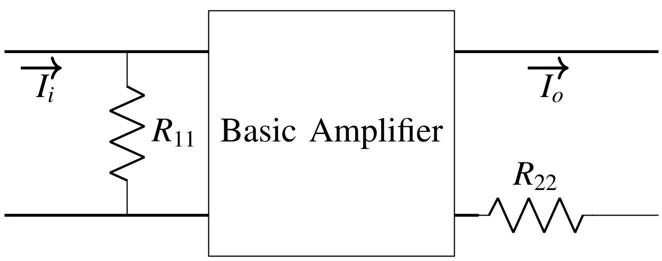

Fig. 3

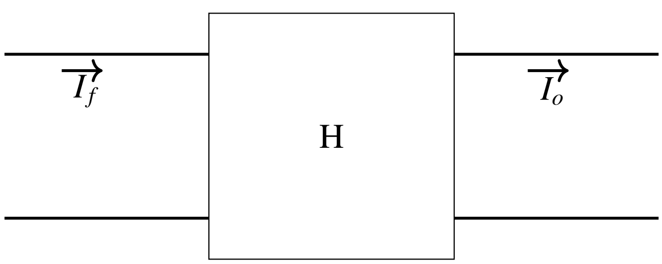

Fig. 4.5

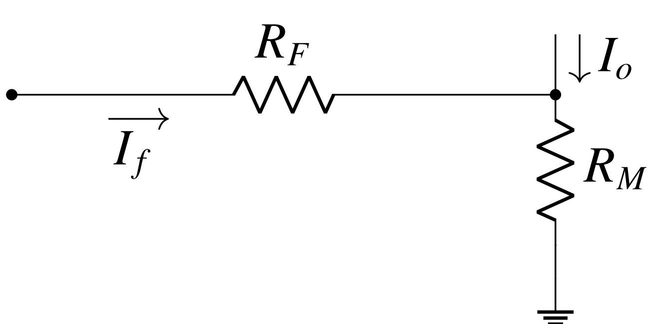

Fig. 4.6

looking from port 1 (left) while it's port 2 is open-circuited and the value of R_{22} is obtained by looking into port 2 (right) while it's port 1 is short-circuited.

$$R_{11} = R_F + R_M \tag{5.1}$$

$$R_{22} = R_F \parallel R_M \tag{5.2}$$

6. Given H as

$$H = \frac{I_f}{I_o} \tag{6.1}$$

Find H from fig. 4.6.
Solution: Using current division,

$$\frac{I_f}{I_o} = -\frac{R_M}{R_F + R_M} \tag{6.2}$$

$$\implies H = \frac{1}{1 + \frac{R_F}{R_M}} \tag{6.3}$$

7. Given T (closed-loop gain) as

$$T = \frac{I_o}{I_s} \tag{7.1}$$

Find T.
Solution: We know,

$$T = \frac{G}{1 + GH} \tag{7.2}$$

Therefore, from eq. 3.2 and 6.3, we get,

$$T = \frac{\mu}{1 + \frac{\mu}{1 + \frac{R_F}{R_M}}} \tag{7.3}$$

8. What will be closed-loop gain(T) if $\mu \to \infty$
Solution: From eq. 7.3 we get,

$$T = \frac{\mu}{1 + \frac{\mu}{1 + \frac{R_F}{R_M}}} \tag{8.1}$$

$$T = \frac{1}{\frac{1}{\mu} + \frac{1}{1 + \frac{R_F}{R_M}}} \tag{8.2}$$

Applying the limit, we get,

$$\implies T = 1 + \frac{R_F}{R_M} \tag{8.3}$$

9. Refer table II and find G, H and T

Component	Value
μ	10^4
R_{id}	$1\ M\Omega$
r_o	$100\ \Omega$
R_L	$10\ \text{k}\Omega$
R_M	$100\ \Omega$
R_F	$10\ \text{k}\Omega$

TABLE II

Solution: Using eqs. 3.2, 6.3 and 7.3
We get,

$$G = \mu = 10^4 \tag{9.1}$$

$$H = \frac{1}{1 + \frac{R_F}{R_M}} = 9.9 \times 10^{-3} \tag{9.2}$$

$$T = \frac{\mu}{1 + \frac{\mu}{1 + \frac{R_F}{R_M}}} = 100 \tag{9.3}$$

10. Tabulate your results.
Solution: Refer table III,

Gain	Value
G	10^4
H	9.9×10^{-3}
T	100

TABLE III

11. Simulate the circuit 1.1 using spice simulators and plot the generated output of the gains using python script
Solution: Refer fig. 11.7 and 11.8 for the plots. Find the netlist of the simulated circuit here:

```
codes/ep18btech11016/spice/
    ep18btech11016.net
```

Python code used for generating the output:

```
codes/ep18betch11016/spice/
    ep18btech11016.py
```

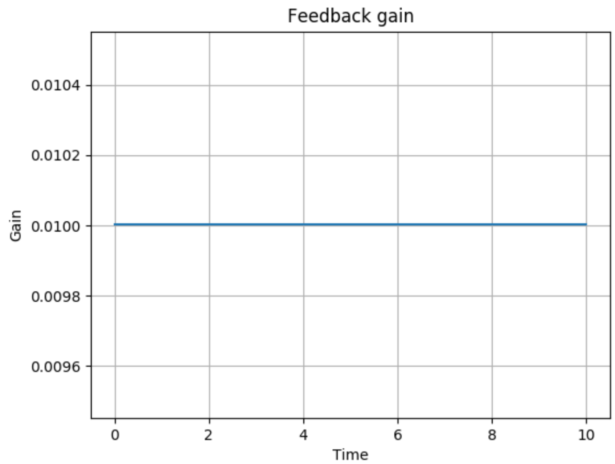

Fig. 11.7

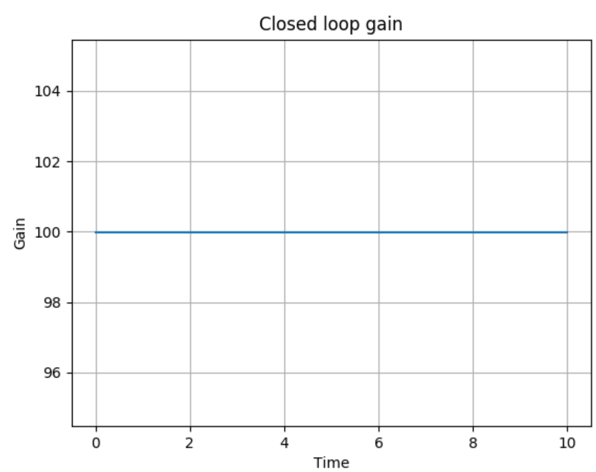

Fig. 11.8