Control Systems

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Contents

***Abstract*—The objective of this manual is to introduce control system design at an elementary level.**

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1 Feedback Circuits

1.0.1. For a feedback transconductance amplifier in Fig 1.0.1.1, derive an approximate expression for the closed loop transconductance T for the case of GH ≫1. Hence select a value of R_2 to obtain T=100 mA/V. If Q is biased to obtain g_m = 1mA/V, specify the value of the gian μ of the differential amplifier to obtain an amount of feedback of 60 dB. If Q has r_o = 50 kΩ find the R_{out}.

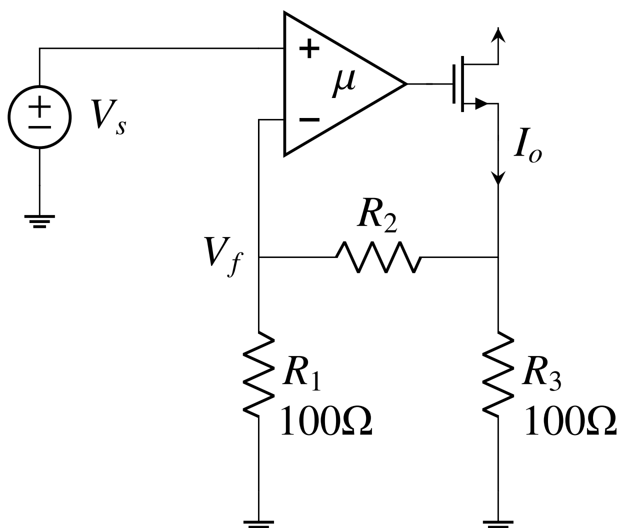

Fig. 1.0.1.1: Complete Circuit

Solution:

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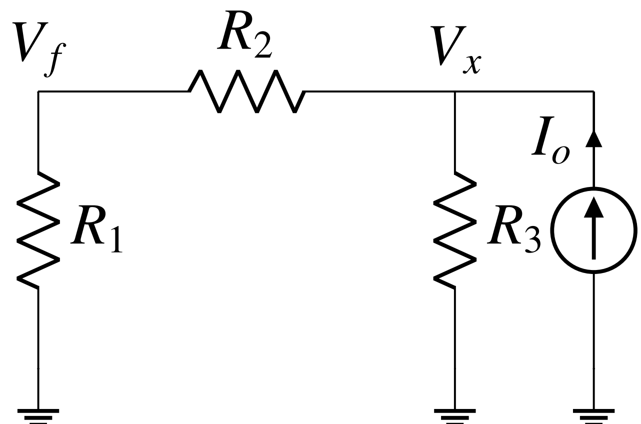

Fig. 1.0.1.2: Feedback Circuit

$$H = \frac{I_f}{I_o} \tag{1.0.1.1}$$

$$V_x = ((R_2 + R_3)||R_1)I_o \tag{1.0.1.2}$$

$$V_f = I_f R_3 \tag{1.0.1.3}$$

$$V_x - V_f = R_2 I_f \tag{1.0.1.4}$$

From equations 1.0.1.1 to 1.0.1.4 we get

$$H = \frac{V_f}{I_o} = \frac{R_1 R_3}{R_1 + R_2 + R_3} \tag{1.0.1.5}$$

As GH ≫ 1 ,

$$T = \frac{1}{H} \tag{1.0.1.6}$$

For T = 100 mA/V,

$$R_2 = 800\Omega \tag{1.0.1.7}$$

$\implies H = 10$

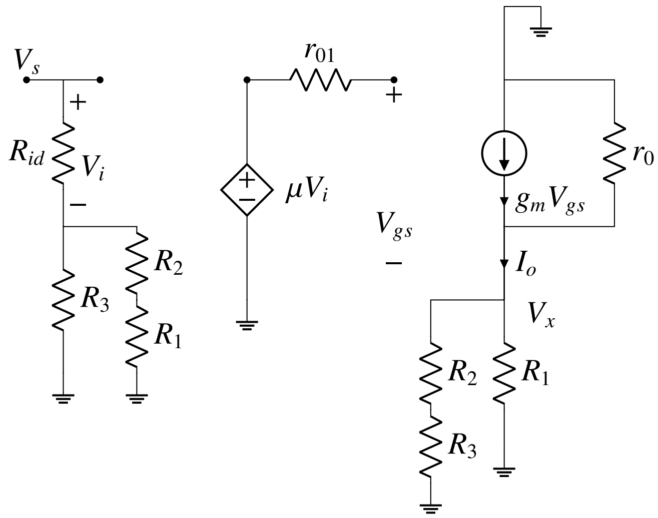

Fig. 1.0.1.3: Small signal model

$$G = \frac{I_o}{V_i} \tag{1.0.1.8}$$

$$V_{gs} = \mu V_i - V_x \tag{1.0.1.9}$$

$$g_m V_{gs} - \frac{V_x}{r_o} = I_o \tag{1.0.1.10}$$

From equations 1.0.1.9 to 1.0.1.10

$$G = \frac{I_o}{V_i} = \frac{g_m \mu r_o}{r_o + (1 + g_m r_o)((R_2 + R_3)||R_1)} \tag{1.0.1.11}$$

Given GH = 60dB,

$$20 \log_{10} GH = 60dB \tag{1.0.1.12}$$

$$\implies G = 100 \tag{1.0.1.13}$$

Substituting the values in the Eq. 1.0.1.11

$$\mu = 109180 \tag{1.0.1.14}$$

For output reistance,

$$R_o = r_o + g_m r_o((R_2 + R_3)||R_1) + ((R_2 + R_3)||R_1) \tag{1.0.1.15}$$

Substituting the values in Eq.1.0.1.15

$$R_o = 54.59k\Omega \tag{1.0.1.16}$$

$$R_{out} = R_o(1 + GH) \tag{1.0.1.17}$$

$$\implies R_{out} = 54.64 \text{ M}\Omega$$

Parameter	**Value**
$1/g_m$	$1k\Omega$
G	$100A/V$
H	$10V/A$
GH	1000
T	$0.1A/V$
R_o	$54.59k\Omega$
R_{out}	$54.64M\Omega$

TABLE 1.0.1

The following code generates the values

```
codes/ee18btech11041.py
```