Control Systems

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Contents

***Abstract*—This manual is an introduction to control systems based on GATE problems.Links to sample Python codes are available in the text.**

Download python codes using

```
svn co https://github.com/gadepall/school/trunk/
    control/codes
```

1 Feedback Current Amplifier: Shunt-Series

1.1 Introduction

1.1.1. Draw the equivalent control system for the feedback current amplifier shown in 1.1.1.1
Solution: See Fig. 1.1.1.2.

1.1.2. For the feedback current amplifier shown in 1.1.1.1, draw the Small-Signal Model. Neglect the Early effect in Q_1 and Q_2.
Solution: See Fig. 1.1.2.
While drawing a Small-Signal Model, we ground all constant voltage sources and open all constant current sources. All Small-Signal paramters are obtained from DC-Analysis of the circuit. Neglecting Early effect, in Small-Signal Analysis a N-MOSFET is modelled as a Current Source with value of current equal to $g_m v_{gs}$ flowing from Drain to Source. Whereas a P-MOSFET is modelled as a Current Source with value of current equal to $g_m v_{sg}$ flowing from Source to Drain.

1.1.3. Describe how the given circuit is a Negetive Feedback Current Amplifier.
Solution: For the feedback to be negative, I_f must have the same polarity as I_s. To ascertain that this is the case, we assume an increase in I_s and follow the change around the loop: An increase in I_s causes I_i to increase and the drain voltage of Q_1 will increase. Since this

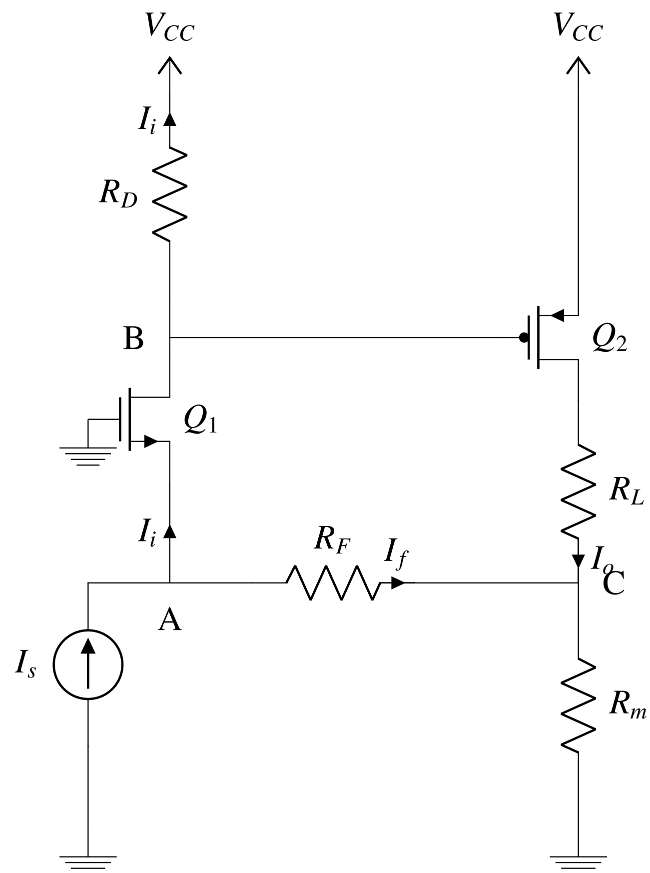

Fig. 1.1.1.1

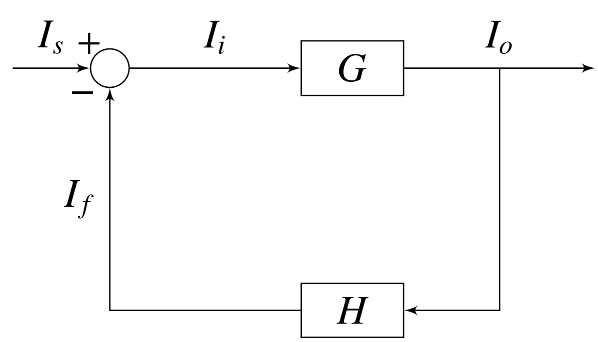

Fig. 1.1.1.2

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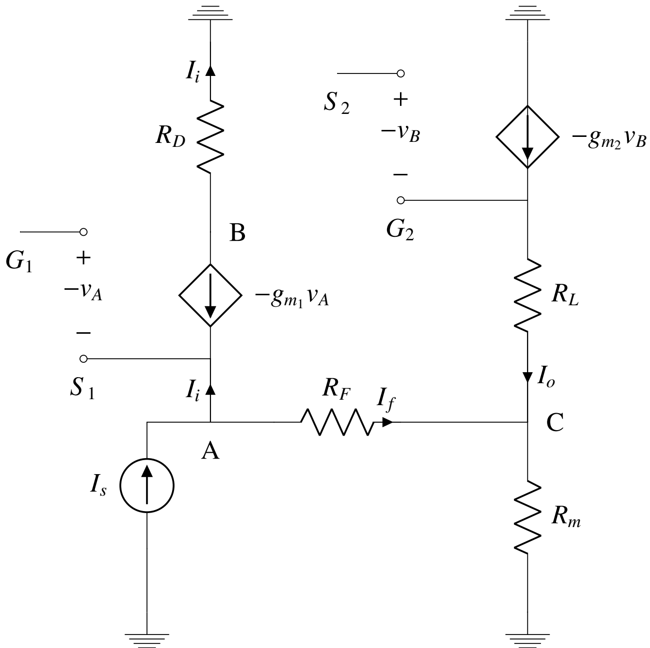

Fig. 1.1.2: Small Signal Model

voltage is applied to the gate of the p-channel device Q_2 , its increase will cause I_o , the drain current of Q_2, to decrease. Thus, the voltage across R_M will decrease, which will cause I_f to increase. This is the same polarity assumed for the initial change in I_s, verifying that the feedback is indeed negative.

1.1.4. Find the Expression for the Open-Loop Gain $G = \frac{I_o}{I_i}$, from the Small-Signal Model. in Fig. 1.1.2.
Solution: In Small-Signal Model,

$$v_B = I_i R_D \tag{1.1.4.1}$$

$$v_{gs_2} = v_B = I_i R_D \tag{1.1.4.2}$$

In Small-Signal Analysis, P-MOSFET is modelled as a current source where current flows from Source to Drain. So, the value of current flowing from Source to Drain in P-MOSFET is,

$$I_o = -g_{m_2} v_{gs_2} = -g_{m_2} I_i R_D \tag{1.1.4.3}$$

So, the Open-Circuit Gain is

$$G = \frac{I_o}{I_i} = -g_{m_2} R_D \tag{1.1.4.4}$$

1.1.5. Find the Expression of the Feedback Factor $H = \frac{I_f}{I_o}$, from Small-Signal Model.
Solution: I_o is fed to a current divider formed by R_M and R_F. R_F is a Large Resistance compared to Input resistance of Amplifier and so most of the current flows through it leaving a small current as input to Amplifier. Hence the voltage at point 'A' is very small and is considered, $v_A \simeq 0$. So R_F and R_M are parallel and Voltage Drop across them is same.

$$(I_o + I_f) R_M \simeq -I_f R_F \tag{1.1.5.1}$$

$$\frac{I_f}{I_o} \simeq -\frac{R_M}{R_F + R_M} \tag{1.1.5.2}$$

So, the Feedback Factor,

$$H \equiv \frac{I_f}{I_o} \simeq -\frac{R_M}{R_F + R_M} \tag{1.1.5.3}$$

1.1.6. Find the Expression for the Closed-Loop Gain $T = \frac{I_o}{I_s}$.
Solution: From (1.1.4.4) and (1.1.5.3),

$$T = \frac{I_o}{I_s} = \frac{G}{1 + GH} \tag{1.1.6.1}$$

$$= -\frac{g_{m_2} R_D}{1 + g_{m_2} R_D / \left(1 + \frac{R_F}{R_M}\right)} \tag{1.1.6.2}$$

$$\implies T = -\frac{g_{m_2} R_D}{1 + g_{m_2} R_D / \left(1 + \frac{R_F}{R_M}\right)} \tag{1.1.6.3}$$