

# Control Systems

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CONTENTS		
<b>1</b>	<b>Signal Flow Graph</b>	<b>1</b>
1.1	Mason's Gain Formula . . .	1
1.2	Matrix Formula . . . . .	1
1.3	Example . . . . .	1
<b>2</b>	<b>Gain of Feedback Circuits</b>	<b>1</b>
<b>3</b>	<b>Bode Plot</b>	<b>3</b>
3.1	Introduction . . . . .	3
3.2	Example . . . . .	3
3.3	Phase . . . . .	3
3.4	Example . . . . .	3
<b>4</b>	<b>Second order System</b>	<b>3</b>
4.1	Damping . . . . .	3
4.2	Peak Overshoot . . . . .	3
4.3	Settling Time . . . . .	3
4.4	Example . . . . .	3
<b>5</b>	<b>Routh Hurwitz Criterion</b>	<b>3</b>
5.1	Routh Array . . . . .	3
5.2	Marginal Stability . . . . .	3
5.3	Stability . . . . .	3
5.4	Example . . . . .	3
<b>6</b>	<b>State-Space Model</b>	<b>3</b>
6.1	Controllability and Observability . . . . .	3
6.2	Second Order System . . .	3
6.3	Example . . . . .	3
<b>7</b>	<b>Nyquist Plot</b>	<b>3</b>
7.1	Introduction . . . . .	3
7.2	Example . . . . .	3
<b>8</b>	<b>Compensators</b>	<b>3</b>
8.1	Phase Lead . . . . .	3
8.2	Lead Circuit . . . . .	3
8.3	Lag Lead . . . . .	3
8.4	Example . . . . .	3
<b>9</b>	<b>Gain Margin</b>	<b>3</b>
9.1	Introduction . . . . .	3
9.2	Example . . . . .	3
<b>10</b>	<b>Phase Margin</b>	<b>3</b>
10.1	Intoduction . . . . .	3
10.2	Example . . . . .	3
<b>11</b>	<b>Oscillator</b>	<b>3</b>
11.1	Introduction . . . . .	3
11.2	Example . . . . .	3
<b>12</b>	<b>Root Locus</b>	<b>3</b>
12.1	Introduction . . . . .	3
12.2	Example . . . . .	3
<b>13</b>	<b>Polar Plot</b>	<b>3</b>
13.1	Introduction . . . . .	3
<b>14</b>	<b>PID Controller</b>	<b>3</b>
14.1	Introduction . . . . .	3

**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 SIGNAL FLOW GRAPH

1.1 Mason's Gain Formula

1.2 Matrix Formula

1.3 Example

## 2 GAIN OF FEEDBACK CIRCUITS

2.0.1. For the feedback current amplifier shown in 2.0.1, Draw the small signal model

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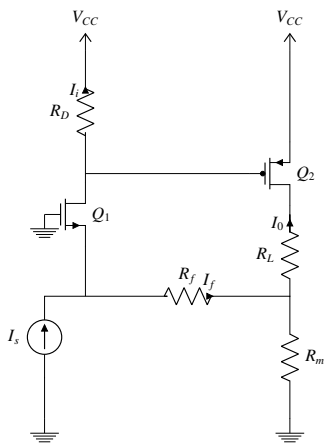


Fig. 2.0.1

**Solution:** While drawing a Small-Signal Model, we ground all constant voltage sources and open all constant current sources. All Small-Signal parameters are obtained from DC-Analysis of the circuit.

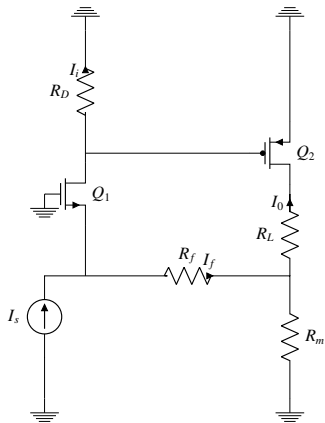


Fig. 2.0.1

- 2.0.2. Find the Expression for the Open-Loop Gain  $A = \frac{I_o}{I_i}$ , from the Small-Signal Model. For simplicity, neglect the Early effect in  $Q_1$  and  $Q_2$ .
- 2.0.3. Find the Expression of the Feedback Factor  $\beta = \frac{I_f}{I_o}$ , from Small-Signal Model. For simplicity, neglect the Early effect in  $Q_1$  and  $Q_2$ .
- 2.0.4. Find the Expression for the Closed-Loop Gain  $A_f = \frac{I_o}{I_s}$ . For simplicity, neglect the Early effect in  $Q_1$  and  $Q_2$ .

### 3 BODE PLOT

#### 3.1 *Introduction*

#### 3.2 *Example*

#### 3.3 *Phase*

#### 3.4 *Example*

### 4 SECOND ORDER SYSTEM

#### 4.1 *Damping*

#### 4.2 *Peak Overshoot*

#### 4.3 *Settling Time*

#### 4.4 *Example*

### 5 ROUTH HURWITZ CRITERION

#### 5.1 *Routh Array*

#### 5.2 *Marginal Stability*

#### 5.3 *Stability*

#### 5.4 *Example*

### 6 STATE-SPACE MODEL

#### 6.1 *Controllability and Observability*

#### 6.2 *Second Order System*

#### 6.3 *Example*

### 7 NYQUIST PLOT

#### 7.1 *Introduction*

#### 7.2 *Example*

### 8 COMPENSATORS

#### 8.1 *Phase Lead*

#### 8.2 *Lead Circuit*

#### 8.3 *Lag Lead*

#### 8.4 *Example*

### 9 GAIN MARGIN

#### 9.1 *Introduction*

#### 9.2 *Example*

### 10 PHASE MARGIN

#### 10.1 *Intoduction*

#### 10.2 *Example*

### 11 OSCILLATOR

#### 11.1 *Introduction*

#### 11.2 *Example*

### 12 ROOT LOCUS

#### 12.1 *Introduction*

#### 12.2 *Example*

### 13 POLAR PLOT

#### 13.1 *Introduction*

### 14 PID CONTROLLER

#### 14.1 *Introduction*