# Control Systems

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


Download python codes using

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


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## 1 Polar Plot

### 1.1 Introduction

### 1.2 Example

### 1.3 Example

### 1.4 Example

### 1.5 Example

### 1.6 Example

### 1.7 Example

## 2 Bode Plot

### 2.1 Gain and Phase Margin

### 2.2 Example

### 2.3 Example

## 3 PID Controller

### 3.1 Introduction

## 4 Nyquist Plot

4.1. Using Nyquist criterion find the range of $K$ for which closed loop system is stable.

$$G(s) = \frac{K}{s(s+6)}. \tag{4.1.1}$$

And,

$$H(s) = \frac{1}{s+9} \tag{4.1.2}$$

**Solution:** The system flow can be described as,

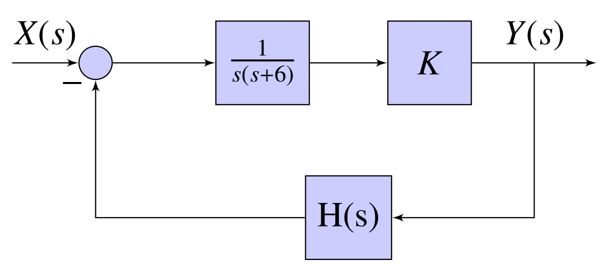


Fig. 4.1

$$G_1(s) = \frac{1}{s(s+6)}. \tag{4.1.3}$$

For Nyquist plot,

$$\operatorname{Im}\{G_1(\jmath\omega)H(\jmath\omega)\} = \frac{-(54-\omega^2)}{(\omega)(\omega^2+56)(\omega^2+81)} \tag{4.1.4}$$

$$\operatorname{Re}\{G_1(\jmath\omega)H(\jmath\omega)\} = \frac{-15\omega}{(\omega)(\omega^2+56)(\omega^2+81)} \tag{4.1.5}$$

From (4.1.4) and (4.1.5)

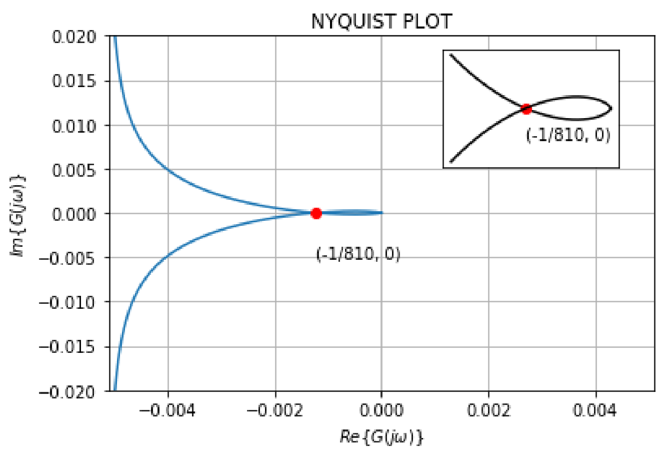


Fig. 4.1: Nyquist plot for $G_1(s)H(s)$

**Nyquist Stability Criterion:**

$$N = Z - P \tag{4.1.6}$$

where Z is # unstable poles of closed loop transfer function, P is # unstable poles of open loop transfer function and N is # clockwise encirclement of $(-1/K, 0)$.
For stable system,

$$Z = 0 \tag{4.1.7}$$

From (4.1.2) and (4.1.3),

$$P = 0 \tag{4.1.8}$$

$$\implies N = 0 \tag{4.1.9}$$

Since, there is a zero at origin, an infinite radius half circle will enclose the right hand side of end points of the Nyquist plot. So for (4.1.9),

$$\implies \frac{-1}{K} < \frac{-1}{810} \implies K < 810 \tag{4.1.10}$$

And also,

$$K > 0 \tag{4.1.11}$$

$$\implies 0 < K < 810 \tag{4.1.12}$$

The following python code generates Fig. 4.1

| |
|---|
| codes/ee18btech11028_1.py |