# Control Systems

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Contents



***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
```

## 1 Stability

### 1.1 Second order System

## 2 Routh Hurwitz Criterion

## 3 Compensators

## 4 Nyquist Plot

4.1. Using Nyquist criterion, find out the range of K for which the closed loop system will be stable.

$$
\begin{aligned}
G(s) &= \frac{K}{(s+1)(s+3)} \\
H(s) &= \frac{1}{(s+5)(s+7)}
\end{aligned}
\tag{4.1.1}
$$

4.2. The system flow can be described by Fig. 4.2

4.3. Find the open loop transfer function G(s)H(s)
**Solution:** From (4.1.1),

$$
\begin{aligned}
L(s) &= G(s)H(s) \\
&= \frac{K}{(s+1)(s+3)(s+5)(s+7)}
\end{aligned}
\tag{4.3.1}
$$

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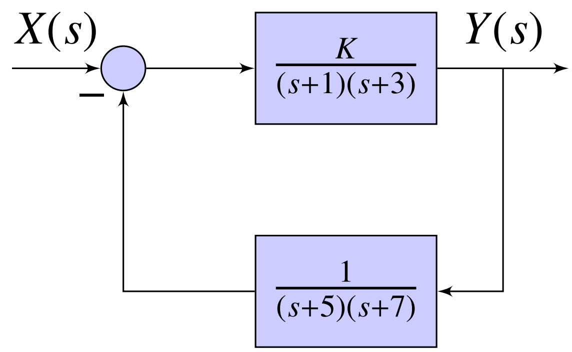


Fig. 4.2

$$
\begin{aligned}
L(j\omega) &= G(j\omega)H(j\omega) \\
&= \frac{K}{(j\omega+1)(j\omega+3)(j\omega+5)(j\omega+7)}
\end{aligned}
\tag{4.3.2}
$$

4.4. Sketch the Nyquist plot.
**Solution:** The Nyquist plot is a graph of $\mathrm{Re}\{L(jw)\}$ vs $\mathrm{Im}\{L(j\omega)\}$. Let's take K=1 and draw the nyquist plot.

The following python code generates the Nyquist plot.

```
/codes/es17btech11015.py
```

The Fig. 4.4 shows the Nyquist plot for K = 1

4.5. Using the Nyquist Stability criterion, determine the value of K for which the system in (4.1.1) is stable.
**Solution:**
**Nyquist criterion**-For the stable system :

$$
Z = P + N = 0, \tag{4.5.1}
$$

where,
Z = Poles of $\frac{G(s)}{1+G(s)H(s)}$ in right half of s plane

P = Poles of $G(s)H(s)$ in right half of s plane

N = No. of encirclements of $G(s)H(s)$ about -1 in the Nyquist plot

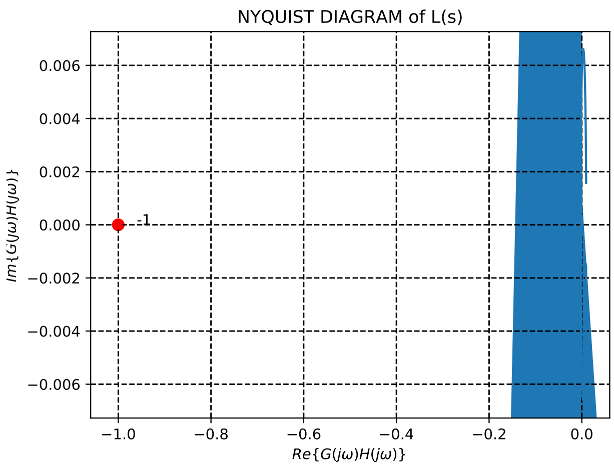


Fig. 4.4

Since from the equation (4.3.1), P = 0

So, for Z to be equal to 0 ,we have to choose the range of K such that N is equal to 0.

4.6. Find the range of K from Nyquist criterion. **Solution:** From the figure 4.4, we can observe that the plot is not cutting the x-axis. If we consider the Nyquist plot with K term even then the plot won't cut the x-axis.
So, N = 0 irrespective of K.
Therefore, the system is stable for

$$-\infty < K < \infty \tag{4.6.1}$$