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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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,

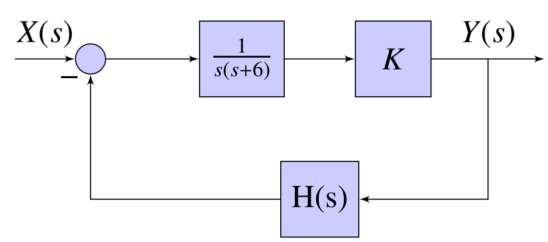

Fig. 4.1

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

For Nyquist plot,

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

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

From 4.1.4 and 4.1.5

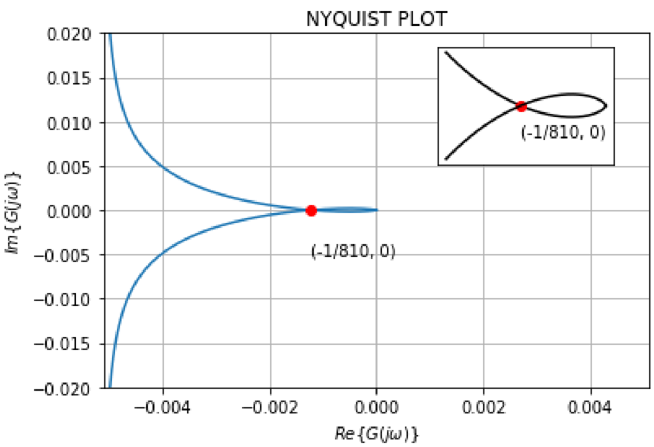

Fig. 4.1: Nyquist plot for $G_1(s)H(s)$

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,

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

$$\implies K < 810 \tag{4.1.11}$$

And also,

$$K > 0 \tag{4.1.12}$$

$$\implies 0 < K < 810 \tag{4.1.13}$$

The following python code generates Fig. 4.1

codes/ee18btech11028_1.py