

# Control Systems

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**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
```

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### 6.1. The number of directions and encirclements around the point $-1+j0$ in the complex plane

by the Nyquist plot of  $G(s) = \frac{1-s}{4+2s}$

**Solution:** Substitute  $s = j\omega$  evaluate magnitude and phase at  $\omega = 0$  and  $\omega = \infty$

$$G(j\omega) = \frac{1-j\omega}{4+2j\omega} \quad (6.1.1)$$

$$\angle G(j\omega) = \tan^{-1}\left(\frac{-\omega}{1}\right) - \tan^{-1}\left(\frac{\omega}{2}\right) \quad (6.1.2)$$

so from this at  $\omega = 0$   $\angle G(j\omega) = 0$   
and at  $\omega = \infty$   $\angle G(j\omega) = -180$

$$|G(j\omega)| = \frac{\sqrt{1+\omega^2}}{\sqrt{16+4\omega^2}} \quad (6.1.3)$$

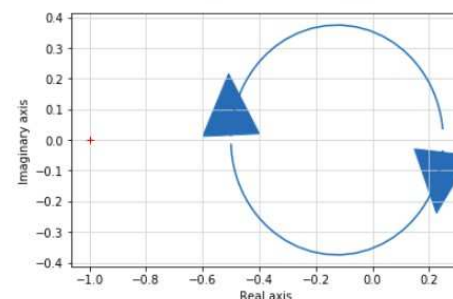
when  $\omega = 0$   $|G(j\omega)| = \frac{1}{4}$   
and at  $\omega = \infty$   $|G(j\omega)| = \frac{1}{2}$

Plot first 0.25 on positive x-axis then turn -180 degrees from that point i.e 180 degrees clockwise(in this case).

Substitute  $s = Re^{j\theta}$

$$\lim_{R \rightarrow \infty} G(Re^{j\theta}) = \frac{1 - Re^{j\theta}}{4 + 2Re^{j\theta}} = \frac{-1}{2} \quad (6.1.4)$$

As there are no  $e^{j\theta}$  terms. There will be no enclosed Nyquist path here. So, for this Transfer function  $G(s)$ , the Nyquist plot is the the Polar plot and its mirror image with respect to real axis.



As from the observed plot the co-ordinate  $-1 + j0$  is outside the contour.

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Hence, the number of encirclements around the  
the given co-ordinate is zero.

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