**MECE 441 Control System Design Laboratory**

1. A simplified form of the open-loop transfer function of an airplane with an autopilot in the longitudinal mode is

$$G\left(s\right)H\left(s\right)=\frac{K(s+a)}{s(s-b)(s^{2}+2ζω\_{n}s+ω\_{n}^{2})}, a>0, b>0$$

Such a system involving an open-loop pole in the right-half s plane may be conditionally stable. Sketch the root loci when a = b = 1,$ ζ=0.5$ and$ ω\_{n}=4$. Find the range of gain K for stability.

1. How do we design a feedback controller for the system using the root-locus method?

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| --- | --- |
|  | $$H\left(s\right)=\frac{s+7}{s(s+5)(s+15)(s+20)}$$ |

Let's assume our design criteria are;

* 5% overshoot and
* 1 second rise time.

Obtain the root locus of H(s)



You can calculate $ζ$by using the formula given $ζ=\frac{-ln⁡(\%Overshoot/100)}{\sqrt{π^{2}+ln^{2}(}\%Overshoot/100)}$

The Matlab commands to calculate the zeta is given below.

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| --- |
| OS = 5; %Overshoot percentage |
|   |
| zeta = -log(OS/100)/(sqrt(pi^2+(log(OS/100))^2)); |
|  |
| zeta = 0.6901 |

To find natural frequency you can use $T\_{r}≈\frac{1.8}{ω\_{n}}$ for responses with moderate overshoot.

wn = 1.8

Enter the following command to your \*.m file

|  |
| --- |
| sgrid(zeta,wn) |



* To make the overshoot less than 5%, the poles have to be in between the two angled dotted lines,
* To make the rise time shorter than 1 second, the poles have to be outside of the dotted semicircle. (*The semicircle indicates pole locations with a natural frequency* $ω\_{n}$*= 1.8; inside of the circle,* $ω\_{n}$*< 1.8 and outside of the circle* $ω\_{n}$*> 1.8*).

So now we know what part of the root locus satisfy the given requirements. All the poles in this location are in the left-half plane, so the closed-loop system will be stable.

It can be seen from the plot above that there is part of the root locus inside the desired region. 🡺 We need only a proportional controller to move the poles to the desired region.

You can use the *rlocfind* command to choose the desired poles on the locus:

|  |
| --- |
| [k,poles] = rlocfind(sys) |

* At this step you should have K value. (Obtained from above command)
* Use commands given below and verify the step response of system.

|  |
| --- |
| sys\_closedloop = feedback(k\*sys,1) |

* Show that your design satisfy requirements by plotting the step response of the closed-loop system.
1. Write the command below to MATLAB command window

s = tf('s');

sys = (s + 7)/(s\*(s + 5)\*(s + 15)\*(s + 20));

controlSystemDesigner(sys)