NWAGWUAGWU TOCHUKWU DAISY
17/ENG04/043 ELECTRICAL ELECTRONICS ENGINEERING
EEE 441
SERVO MECHANISM AND CONTROL SYSTEMS

QUESTION 1
Briefly explain the Root Locus technique
The root locus is a graphical representation in S-domain and it is symmetrical about the real axis. Because the open loop poles and zeros exist in the S-domain having the values either as real or as complex conjugate pairs.

DIFFERENT STEPS IN CONSTRUCTING ROOT LOCUS.

STEP 1: Locate the poles and zeros in the s plane from the transfer function given.
Poles are denoted by x
Zeros are denoted by o

STEP 2: Find the Number of Root Locus Branches
Knowing that the root locus branches start at the open loop poles and terminates at open loop zeros. So, No of root locus branches, N is equal to number of finite open loop poles P or zeros Z whichever is greater

So, if $P > Z$ then $N = P$
if $Z > P$ then $N = Z$

STEP 3: Determine the Direction of the Branches on the real axis.
A branch of root locus lies on the real axis, if the total number of poles and zeros to the right side of the point is ODD.

STEP 4: Determine the centroid α and angle of asymptotes θ
The Asymptotes give the direction of these root locus branches. The intersection point of asymptotes on the real axis is known as centroid

$$\text{centroid } \alpha = \frac{\sum \text{poles} - \sum \text{zeros}}{P - Z}$$

Angle of asymptots θ is

$$\theta = \frac{(2q+1)180°}{P - Z}$$

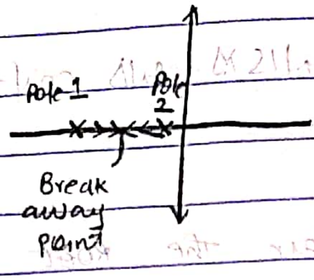
where $q = 0, 1, 2 \ldots, (P-Z)-1$

Scanned with CamScanner

STEP 5; Determine the Break-away point.

When two branches move towards each other on the real axis, coincident point is called Break-Away Point.

It occurs between 2 adjacent open loop poles on the real axis.



To calculate it there are 2 ways;

- First by differentiating the transfer function $G(s)$ with respect to S and equaling to 0 then simplify the equation and determine the value of S.
  Appropriate value of S (i.e value in between the 2 poles) is call Break away point.
- Secondly, write K in terms of S from the xteristic equation. It $G(s)H(s)=0$
  Differentiate K with respect to S and equate it to 0
  Solve K to get value of S which is appropriate.

STEP 6; Determine the Intersection points of root locus branches with an imaginary axis

Using Rouths stability criterion and applying $j\omega$ to the characteristic eqn.

- Applying $j\omega$ to the characteristic equation in place of S, then simplify and seperate the real part (K) and imaginary part.
- Using Rouths Stability Criterion. When entire row is zero.
  from the characteristic equation use the routh stability criterion and using the equation from the routh table you'll get K then using the auxiliary or subsidiary equation just above the coefficient you have put equal to zero row then put the value of K to get the points with an imaginary point.

STEP 7: Determine the angles of departure and arrival in case of complex poles

Departure angle $\phi_D = 180° - (\phi_P - \phi_Z)$ if complex pole is given

$\phi_P \rightarrow$ sum of angles subtended by all poles

$\phi_Z \rightarrow$ sum of angle subtended by all zeros

Arrival angle of complex zero is given

$$\phi_A = -180° + (\phi_P - \phi_Z)$$

QUESTION 2

Describe the use of Routh Hurwitz to find the stability of a closed loop system when:

ⓐ An entire row is zero on the Routh Table

ⓑ To determine the poles on the $j\omega$ axis

ⓐ If an entire row of zeros appears on the Routh table;

- Create an auxiliary polynomial from the row above the row of zeros, skipping every other power of s
- Differentiate the auxiliary polynomial with respect to s
- Replace the zero row with the coefficients of the resulting polynomial
- Complete the Routh table as usual
- Evaluate the sign of the first column entries

E.G considering $T_{CSS} = \dfrac{1}{s^5 + 5s^4 + 11s^3 + 23s^2 + 28s + 12}$

s^5 | 1   11   28

s^4 | 5   23   12

s^3 | $\dfrac{-\begin{vmatrix} 1 & 11 \\ 5 & 23 \end{vmatrix}}{5} = \cancel{6.4}\ 1$ $\dfrac{-\begin{vmatrix} 1 & 28 \\ 5 & 12 \end{vmatrix}}{5} = \cancel{25.6}\ 4$ 0

s^2 | $\dfrac{-\begin{vmatrix} 5 & 23 \\ 1 & 4 \end{vmatrix}}{1} = \cancel{3}\ 1$ $\dfrac{-\begin{vmatrix} 5 & 12 \\ 1 & 0 \end{vmatrix}}{1} = \cancel{12}\ 4$ 0

s^1 | $\dfrac{-\begin{vmatrix} 1 & 4 \\ 1 & 4 \end{vmatrix}}{1} = 0$ $\dfrac{-\begin{vmatrix} 1 & 0 \\ 1 & 0 \end{vmatrix}}{1} = 0$ 0

A row of zero appeared

an auxiliary polynomial from s^2 (above the row of zeros)

$P(s) = s^2 + 4$

differentiate $\dfrac{dP}{ds} = 2s$

replacing s' row with dP/ds coefficient

Scanned with CamScanner

S^5	1	11	28
S^4	5	23	12
S^3	1	4	0
S^2	1	4	0
S^1	$\cancel{0}$ 2	0	0
S^0	1	4	0

$\frac{-2\ \ 0}{2} = 4 \quad \frac{-2\ \ 0}{2} = 0 \quad 0$

No sign changes and Row of zeros indicates marginally stable system

(b) To determine the poles on the $j\omega$ axis

When the entries from the row before the row of zeros to the last row are looking at the even polynomials and there are no sign changes then all the poles there belong to the $j\omega$ axis.