Let's do another example

$$GH = 50 \frac{s+3}{s^3 - s^2 + 11s - 51}$$

nyquistex2.m

1 OL pole in RHP $\quad P = 1$

1 CW circle about -1 $\quad N = -1$

$Z = P - N = 1 + 1 = 2$

this system is unstable! (RL @ $K=50$ confirms)

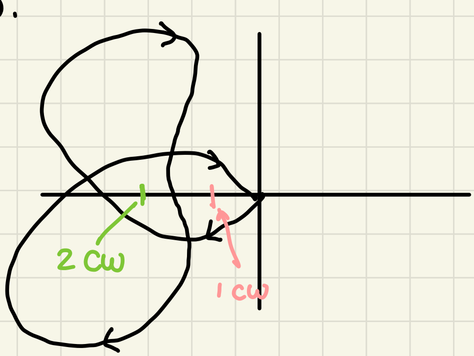
Is there any gain for which we can make it stable?

How could we tell?

since $P=1$, we need one CCW loop about -1 to get stability.

Is there any shift along the real axis that would let this happen?

No!



We can confirm that by looking at our axis crossing gains in RL

→ Real axis CLP will cross to RHP before Im poles get to LHP

Let's try plugging in those axis crossing gains to see how Nyquist reflects this stability

at $K = 9.3$ (Im axis crossing) we have no circles about -1 $\Rightarrow$ $N=0$

$Z = P - N = 1 - 0 = 1$ this is consistent w/ the 1 pole in RHP

at $K = 17.1$ $\rightarrow$ origin crossing for real segment

2 CW circles about -1 $N = -2$

$Z = P - N = 1 - (-2) = 3$ $\Rightarrow$ 3 RHP poles seen in RL

The moral $\rightarrow$ Nyquist gives us a quick, visual way to get CL stability from OL info

We can also get phase and gain margins from our Nyquist plots, and we'll do some quick examples to show how this works.

Phase & Gain Margins from Nyquist Plots

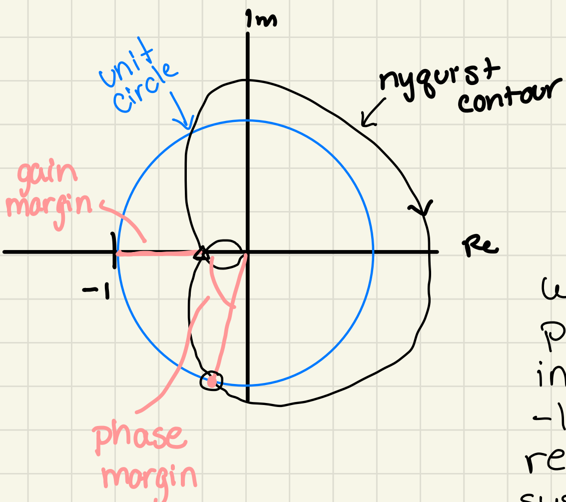
To understand how gain & phase margins are identified on our Nyquist Plots, we need to understand how Nyquist contours shift with changes to gain & phase.

We've already seen that gain changes cause the plot to grow/shrink and shift along the real axis.

Changing the phase moves the phasor either clockwise (phase decrease) or counterclockwise (phase increase).

The angle between the horizontal axis and where the nyquist plot intersects the unit circle tells us the phase margin.

Visually:



(3rd order OLTF w/ no real poles)

↳ need 0 circles a/b -1 for stability

when either the point △ or ○ intersect the -1 point on the real axis, the system will become unstable (a circle will enclose -1)

Let's look at an example: nyquistex3.m

$$G = \frac{K}{s^3 + 6s^2 + 11s + 6}$$

0 poles of OLTF in RHP
need 0 circles for stability

note: turn on grids & margins

① $K = 40$
stable! Gain and phase margins shown

② $K = 60$
marginally stable ⇒ 0 margin

③ $K = 80$
unstable → margins show how far you must move for stability

Change the 11 (coeff of s) to affect phase

= 6 → ustable

= 15 → ↑ phase margin for stability

The bottom line → Nyquist plots give a quick, visual way to assess stability & stability margins

Like Bode, there are ways to map these to our other characterisics of Interest, but that is outside the scope of what we will cover