- ***Two-Pole System***:
  - ***Transfer Function***:

$$A(s) = \frac{A_0}{\left(1 + j\omega/\omega_{p1}\right)\left(1 + j\omega/\omega_{p2}\right)}$$

A_0: ***Low-Frequency Gain***

ω_{p1}, ω_{p2}: ***Two negative real poles***, ***lying on the σ axis***, ***with $\omega_{p2} > \omega_{p1}$***

  - Now, with ***passive feedback*** with ***feedback factor*** f, the ***locations*** of the ***closed-loop poles*** can be found from: $1 + fA(s) = 0$

- Thus:

  $$s^2 + (\omega_{p1} + \omega_{p2})s + (1 + fA_0)\omega_{p1}\omega_{p2} = 0$$

- ***Solution*** gives the ***locations*** of the ***two closed-loop poles***:

$$s_1,\ s_2 = -\frac{\omega_{p1} + \omega_{p2}}{2} \pm \frac{1}{2}\sqrt{\left(\omega_{p1} + \omega_{p2}\right)^2 - 4\left(1 + fA_0\right)\omega_{p1}\omega_{p2}}$$

- With ***increase in feedback***, the ***second term reduces***

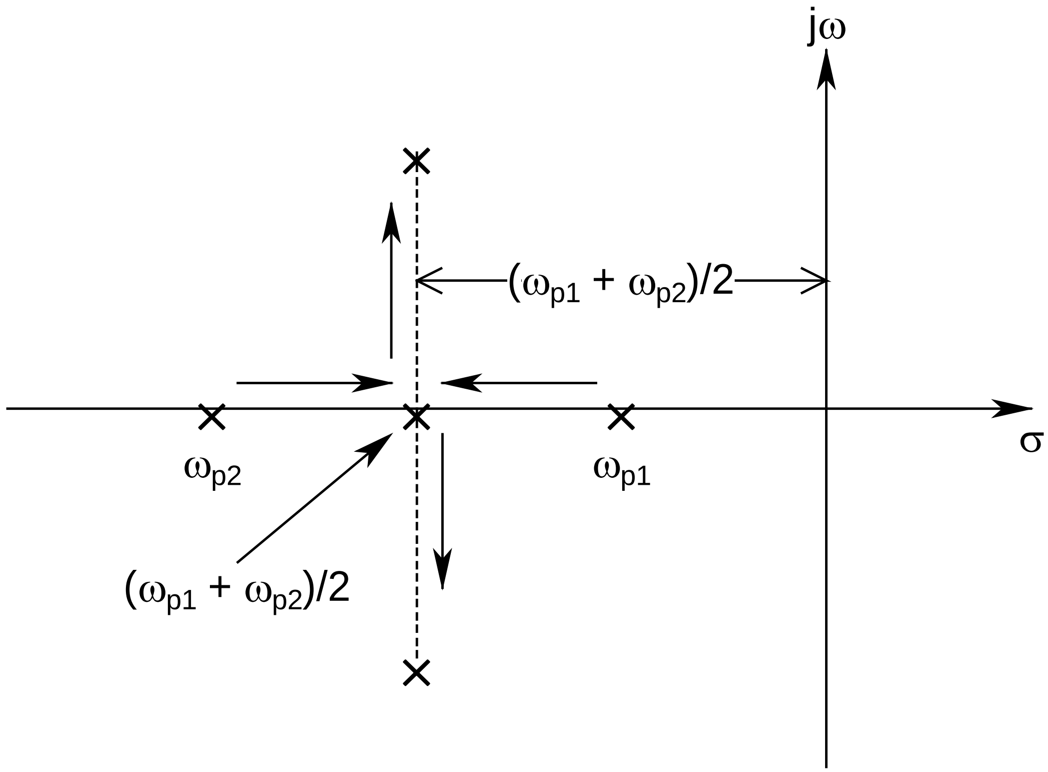
  $\Rightarrow$ ***s_1 and s_2 start to move towards each other along the σ axis***

- Eventually, at a ***particular feedback***, the ***second term would vanish***

- ***At this point***, the ***two poles will merge*** at $(\omega_{p1} + \omega_{p2})/2$
- With ***further increase in feedback***, the ***second term becomes imaginary***, while the ***first term remains constant***

  $\Rightarrow$ ***The poles remain complex conjugates***
- ***Even for f all the way up to unity***, ***when the entire output is fed back to the input***, the ***poles remain in the LHP*** and ***can never enter RHP***

  $\Rightarrow$ ***The system remains unconditionally stable***



Movement of the Poles for a Two-Pole System Under Negative Feedback With Increasing D

- Also, for a ***two-pole system***, the ***phase reaches $-180°$ only when the frequency becomes infinite*** (***mathematically***)
  - $\Rightarrow$ ***There is no physically achievable frequency when this can happen***
  - $\Rightarrow$ ***Unconditional Stability***

- ***System With Three (or More) Poles***:
  - ***Actual mathematical analysis quite tedious***
  - It can be shown that as the ***amount of feedback (D) is increased***:
    - ***The highest frequency pole (ω_{p3}) moves outward along the $-\sigma$-axis***

- ***The other two poles (ω_{p1} and ω_{p2}) move towards each other*** (***similar to a two-pole system***)
- As ***D is increased further***, these ***two poles eventually merge***, and then start having ***imaginary components***
- Their ***real part*** also ***keeps on changing with D***, ***keeping the nature of complex conjugacy intact***, and ***moves right in the s-plane***
- ***The path traced out by these poles is known as the root locus***
- ***For a particular value of D***, this ***root locus intersects the imaginary axis of the s-plane at two symmetric points***

- ***Under this condition***, ***sustained sinusoidal oscillation can be achieved***, ***since it now has a complex conjugate pair of poles without any real part*** (ω_{p3} ***will be so large that it will be inconsequential***)
- ***With further increase in D***, the ***root locus enters the RHP*** with the ***poles now having positive real part***

  $\Rightarrow$ ***Potentially dangerous situation in terms of stability***
- ***In terms of phase***, the ***total can be –270°***

  $\Rightarrow$ ***There exists a particular value of f***, for which the ***phase will become –180°***