\[ V_i(t) \]

\[ Q_1 < Q_2 < Q_3 < Q_4 < Q_5 \]

\[ Q_2 = \frac{1}{2}, \quad Q_5 = \infty \]

sinusoid that does not die out

\[
1 + \frac{s}{\omega_0 Q} + \frac{s^2}{\omega_0^2} \quad \leftrightarrow \quad 1 + \frac{2Q}{A_{of} \omega_p} + \frac{s^2}{\omega_p^2 \omega_{of}}
\]

2-pole freq. amp.

\[ \omega_0 = \omega_p \sqrt{A_{of}} \]

\[ Q = \frac{\sqrt{A_{of}}}{2} \]

trying to realize large \( A_{of} \) \( \Rightarrow Q \) is very large

Not good enough
3rd order system

\[
A(s) = \frac{A_0}{(1 + \frac{s}{w_p})^3}
\]

\[
= \frac{A_0}{1 + \frac{3s}{w_p} + \frac{3s^2}{w_p^2} + \frac{s^3}{w_p^3}}
\]

\[
CLC A(s) = \frac{1}{f} \cdot \frac{A_0 f}{1 + A_0 f} \cdot \frac{1}{1 + \left[\frac{3s}{w_p} + \frac{3s^2}{w_p^2} + \frac{s^3}{w_p^3}\right]} \cdot \frac{1}{1 + A_0 f}
\]

\[
D(s)
\]

\[
D(s) = 1 + \frac{3s}{w_p (1 + A_0 f)} + \frac{3s^2}{w_p^2 (1 + A_0 f)}
\]

\[
+ \frac{s^3}{w_p^3 (1 + A_0 f)}
\]

\[
D \left( \frac{s}{w_p} \right) = 1 + \frac{3s}{1 + A_0 f} + \frac{3s^2}{1 + A_0 f} + \frac{s^3}{1 + A_0 f}
\]

\[
\Omega_{wh} f \left( 1 + A_0 f \right) + 3s + 3s^2 + s^3
\]

\[
(1 + s)^3 = -A_0 f
\]
\[ S = -1 + \left( -A \cdot f \right)^{1/3} \]

**Example**  
\[ A \cdot f = 8 \]

\[ S_1 = -1 - 2 = -3 \]
\[ S_2 = -1 - 2 e^{-j \frac{2\pi}{3}} \]
\[ S_3 = -1 - 2 e^{j \frac{2\pi}{3}} \]

\[ S = -3, \pm j \sqrt{3} \]

Poles are \(-3w_p, \pm j \sqrt{3} \cdot w_p\)

\[ A \cdot f = 0 \Rightarrow \text{all 3 roots lie at } (-1) \]

Sum of roots = \(-3(w_p)\)

**Issue**:  
\[ A \cdot f > 8 \Rightarrow \text{complex conjugate roots move into RHP} \]
4th order will be worse

Solution 1:

\[
\left( \frac{A_0}{1 + \frac{s}{w_p}} \right)^2 \frac{\left( 1 + \frac{s}{w_p} \right)^2}{\left( 1 + \frac{s}{w_{p2}} \right)^2}
\]

\[\frac{V_{DD}}{Z} \to v_0 \quad \text{1-pole system}\]

Solution 2:

1st order \to \text{low gain} \to \text{unconditionally stable}

2nd order \to \text{larger gain} \to \text{terminally stable}

3rd order \to \text{very large gain} \to \text{unstable}
make a higher order system look like a 1st order system

\[
\frac{A_0}{(1+\frac{s}{w_p})^3} \quad \rightarrow \quad \frac{A_0}{(1+\frac{s}{w_d})(1+\frac{s}{w_p})^3}
\]

\[w_d \ll w_p\]

1) \[\frac{A_0}{1+\frac{s}{w_d}}\]

2) \[\frac{A_0}{(1+\frac{s}{w_p})^3}\]

3) \[\frac{A_0}{(1+\frac{s}{w_d})(1+\frac{s}{w_p})^3}\]

\[A_{of} < 1\] will not cause instability