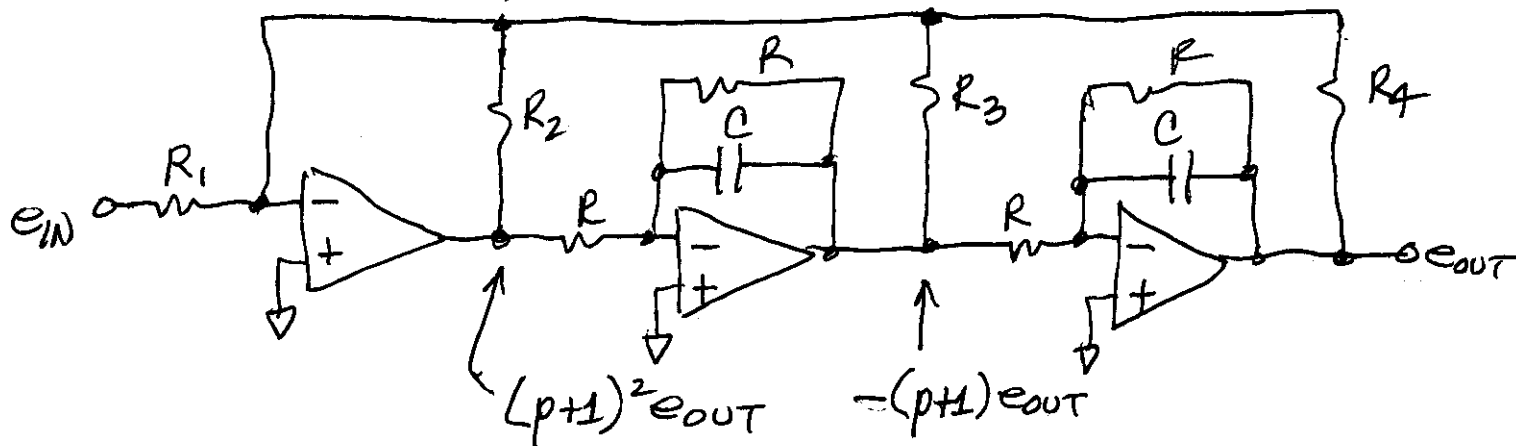


THIS IS A CONFIGURATION, SIMILAR TO STATE VARIABLE, THAT I USED IN THE EARLY 1970'S. IT HAS TWO ADVANTAGES, (1) SAVES ONE OPAMP (WHICH CAN BE USED TO INSERT ZEROS, & (2) THE SHUNT R SWAMPS OUT ANY DISSIPATION FACTOR EFFECTS.

$$p = RCs \text{ (FREQUENCY NORMALIZED)}$$



$$\frac{(p+1)^2 e_{OUT}}{R_2} - \frac{(p+1) e_{OUT}}{R_3} + \frac{e_{OUT}}{R_4} = - \frac{e_{IN}}{R_1}$$

$$\left[(p+1)^2 - \frac{R_2}{R_3} (p+1) + \frac{R_2}{R_4} \right] e_{OUT} = - \frac{R_2}{R_1} e_{IN}$$

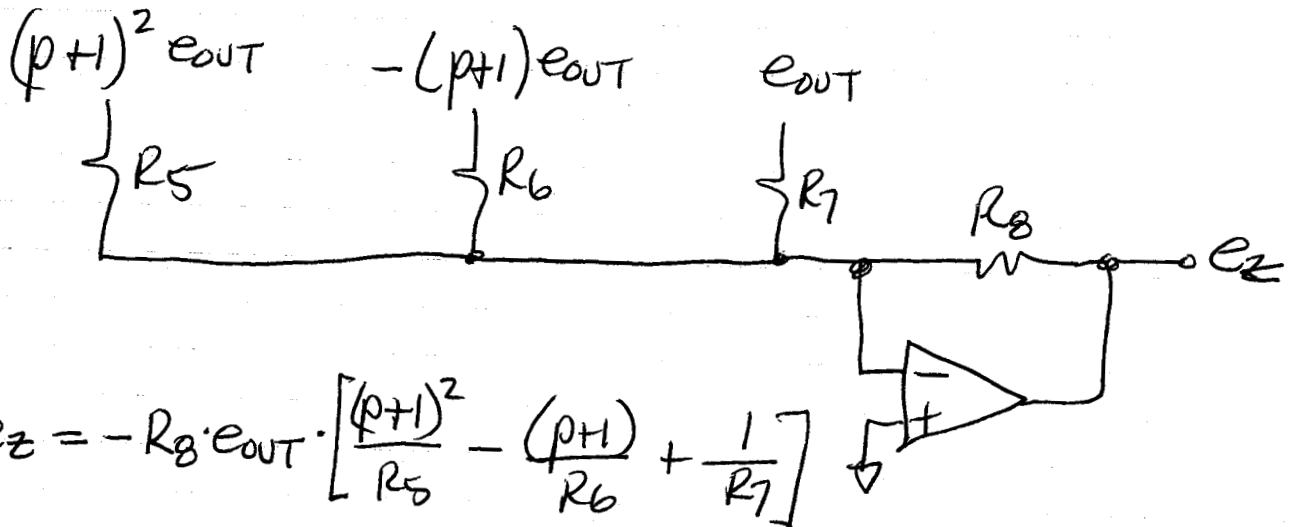
$$\begin{array}{r} p^2 + 2p + 1 \\ - \frac{R_2}{R_3} p - \frac{R_2}{R_3} \\ + \frac{R_2}{R_4} \end{array}$$

$$\left[p^2 + \left(2 - \frac{R_2}{R_3}\right) p + \left(1 - \frac{R_2}{R_3} + \frac{R_2}{R_4}\right) \right] e_{OUT} = - \frac{R_2}{R_1} e_{IN}$$

CHOOSE $\frac{R_2}{R_3} = \frac{R_2}{R_4} = 2 - \sqrt{2}$ FOR BUTTERWORTH LP

JET 12/10/2015

ADDING ZEROS:



$$e_z = -R_8 \cdot e_{out} \cdot \left[\frac{(p+1)^2}{R_5} - \frac{(p+1)}{R_6} + \frac{1}{R_7} \right]$$

$$= -R_8 \cdot e_{out} \cdot \left[\frac{p^2 + 2p + 1}{R_5} - \frac{p+1}{R_6} + \frac{1}{R_7} \right]$$

for a zero ON the axis \rightarrow no p term:

$$\frac{2}{R_5} - \frac{1}{R_6} = 0, \quad \frac{2}{R_5} = \frac{1}{R_6} \rightarrow R_5 = 2 \cdot R_6$$

$$\frac{p^2 + 1}{2 \cdot R_6} - \frac{1}{R_6} + \frac{1}{R_7}$$

$$p^2 + 1 - 2 + \frac{2R_6}{R_7}$$

$$p^2 - 1 + \frac{2R_6}{R_7}$$

$$\text{THUS } \omega_z^2 = \frac{2R_6}{R_7} - 1$$

REMEMBER: NORMALIZED TO RCS