5.16 **a)** Explain why the rules for series and parallel resistors cannot be used for the circuit shown in Figure P5.16.
b) Use the node-equation method to find the voltages of nodes A and B with respect to the ground node.
c) Find the currents i_o and i_1 and the equivalent resistance connected across the source.

b).

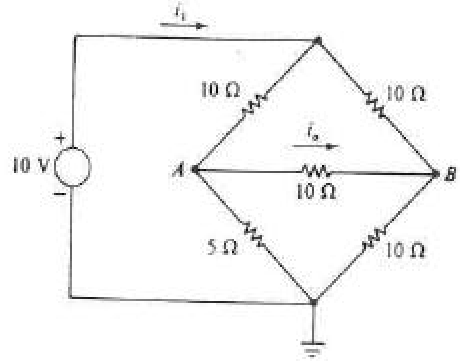


FIGURE P5.16

Current Equation for node A

10

$$\frac{10 - e_A}{10} = \frac{e_A - e_B}{10} + \frac{e_A - 0}{5} \quad (1)$$

Node B

$$\frac{10 - e_B}{10} = \frac{e_B - e_A}{10} + \frac{e_B - 0}{10} \quad (2)$$

Simplify (1)

$$10 - e_A = 3e_A - e_B$$

or $4e_A - e_B = 10$

Simplify (2)

$$10 - e_B = 2e_B - e_A$$

or $3e_B - e_A = 10$

In matrix form $\begin{bmatrix} 4 & -1 \\ -1 & 3 \end{bmatrix} \begin{bmatrix} e_A \\ e_B \end{bmatrix} = \begin{bmatrix} 10 \\ 10 \end{bmatrix}$

Cramer's Rule

$$e_A = \frac{\begin{vmatrix} 10 & -1 \\ 10 & 3 \end{vmatrix}}{\begin{vmatrix} 4 & -1 \\ -1 & 3 \end{vmatrix}} = \frac{40}{11}$$

$$e_B = \frac{\begin{vmatrix} 4 & 10 \\ -1 & 10 \end{vmatrix}}{\begin{vmatrix} 4 & -1 \\ -1 & 3 \end{vmatrix}} = \frac{50}{11}$$

C) Find i_o and i_1 and the equivalent resistance

Note $i_1 = i_2 + i_3$

$$i_2 = \frac{10 - e_A}{10} = 1 - \frac{e_A}{10} = 1 - \frac{40}{110}$$

$$i_3 = \frac{10 - e_B}{10} = 1 - \frac{50}{110}$$

$$i_1 = i_2 + i_3 = 1 - \frac{40}{110} + 1 - \frac{50}{110} = 2 - \frac{90}{110} = 1\frac{2}{11} = \frac{13}{11}$$

$$i_o = \frac{e_B - e_A}{10} = \frac{\frac{50}{11} - \frac{40}{11}}{10} = \frac{10}{10 \cdot 11} = \frac{1}{11}$$

Equivalent Resistance

$$10V = R_e \cdot i_1 \Rightarrow R_e = \frac{10}{\frac{13}{11}} = \frac{110}{13}$$

8.34 Find the transfer function for the circuit shown in Figure 8.12 by characterizing the passive elements by their impedances.

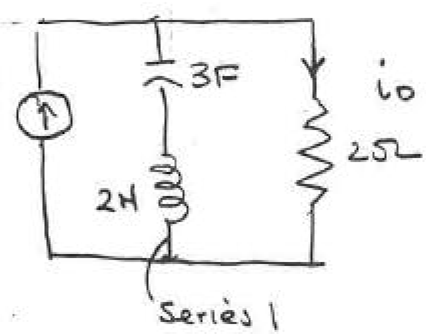


Fig 8.12

$$Z_{e_1} = \frac{1}{3s} + 2s \quad \text{(series 1)}$$

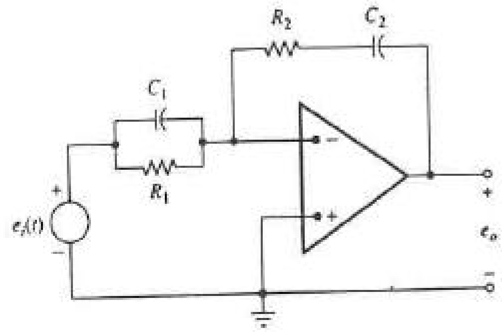
$$= \frac{1 + 6s^2}{3s}$$

Current sharing rule:

$$I_o(s) = I_i(s) \cdot \frac{Z_{e_1}}{Z_{e_1} + 2} = I_i(s) \cdot \frac{1 + 6s^2}{3s} \cdot \frac{1}{\left(\frac{1 + 6s^2}{3s} + 2\right)}$$

$$= I_i(s) \cdot \frac{1 + 6s^2}{6s^2 + 6s + 1} \quad . \quad T(s) = \frac{1 + 6s^2}{6s^2 + 6s + 1}$$

8.39 a) Use impedances and the results of Example 8.16 to find the transfer function for the op-amp circuit shown in Figure P8.39.
b) Plot the pole-zero pattern.



(a) From Example 8.16.

$$\frac{E_o(s)}{E_i(s)} = -\frac{Z_2(s)}{Z_1(s)}$$

Z_1: Elements in parallel.

$$\Rightarrow \quad Z_1 = \frac{\frac{R_1}{C_1 s}}{\frac{1}{C_1 s} + R_1} = \frac{R_1}{1 + R_1 C_1 s}$$

Z_2: Elements in series

$$Z_2 = R_2 + \frac{1}{C_2 s} = \frac{R_2 C_2 s + 1}{C_2 s}$$

Then

$$\frac{E_o(s)}{E_i(s)} = -\frac{R_2 C_2 s + 1}{\frac{C_2 s \cdot R_1}{1 + R_1 C_1 s}}$$

$$= -\frac{(R_2 C_2 s + 1)(R_1 C_1 s + 1)}{C_2 s R_1}$$

$$\frac{E_o(s)}{E_i(s)} = -\frac{(R_1 R_2 C_1 C_2 s^2 + (R_1 C_1 + R_2 C_2) s + 1}{C_2 s R_1} = T(s).$$

— — — — — — — — —

Grader: This step not necessary.

$$= -\left(R_2 C_1 s + \frac{(R_1 C_1 + R_2 C_2)}{C_2 R_1} + \frac{1}{C_2 R_1 s}\right)$$

↓ Takes derivative ↓ Gain ↓ integrates.

ADDITIONAL PROBLEMS

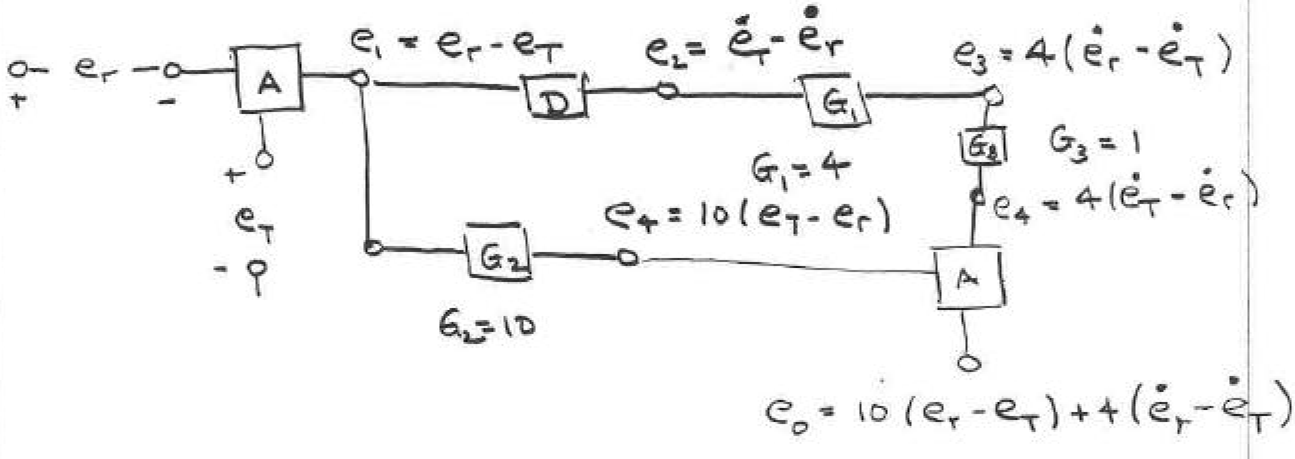
1. See problem sheet.

Note [A] - additive op-amp

[G] - linear gain op-amp

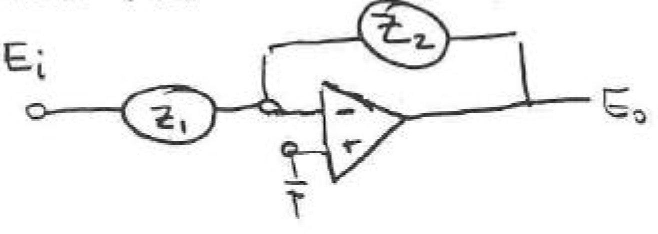
[D] - op-amp takes derivation

See handout for actual configuration



2. Need an op-amp configuration that will integrate.

We know that



$$E_o = -\frac{Z_2}{Z_1} E_i$$

Integration: want $-\frac{Z_2}{Z_1} = -\frac{3}{s} \Rightarrow Z_2 = 3$

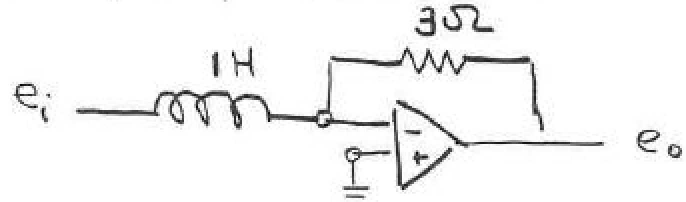
$Z_1 = s$

$\Rightarrow$ $Z_2 = 3\Omega$ (Resistor)

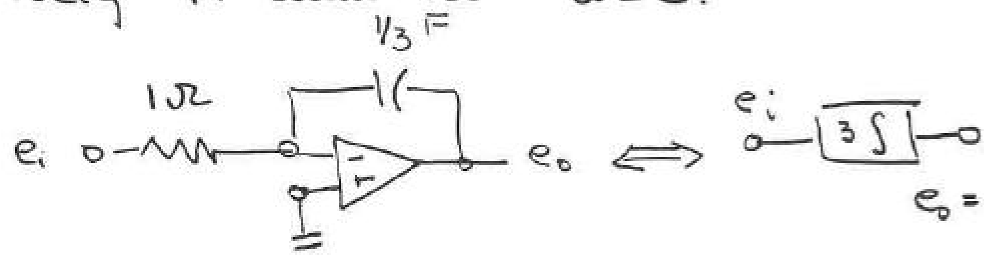
$Z_1 = s$ (inductor)

(Could use capacitor for Z_2 and resistor for Z_1)

i.e. Op-Amp looks like



Alternatively it could look like.



$e_o = -3\int e_i$

Then full circuit