**EE 254**

# Electronic Instrumentation

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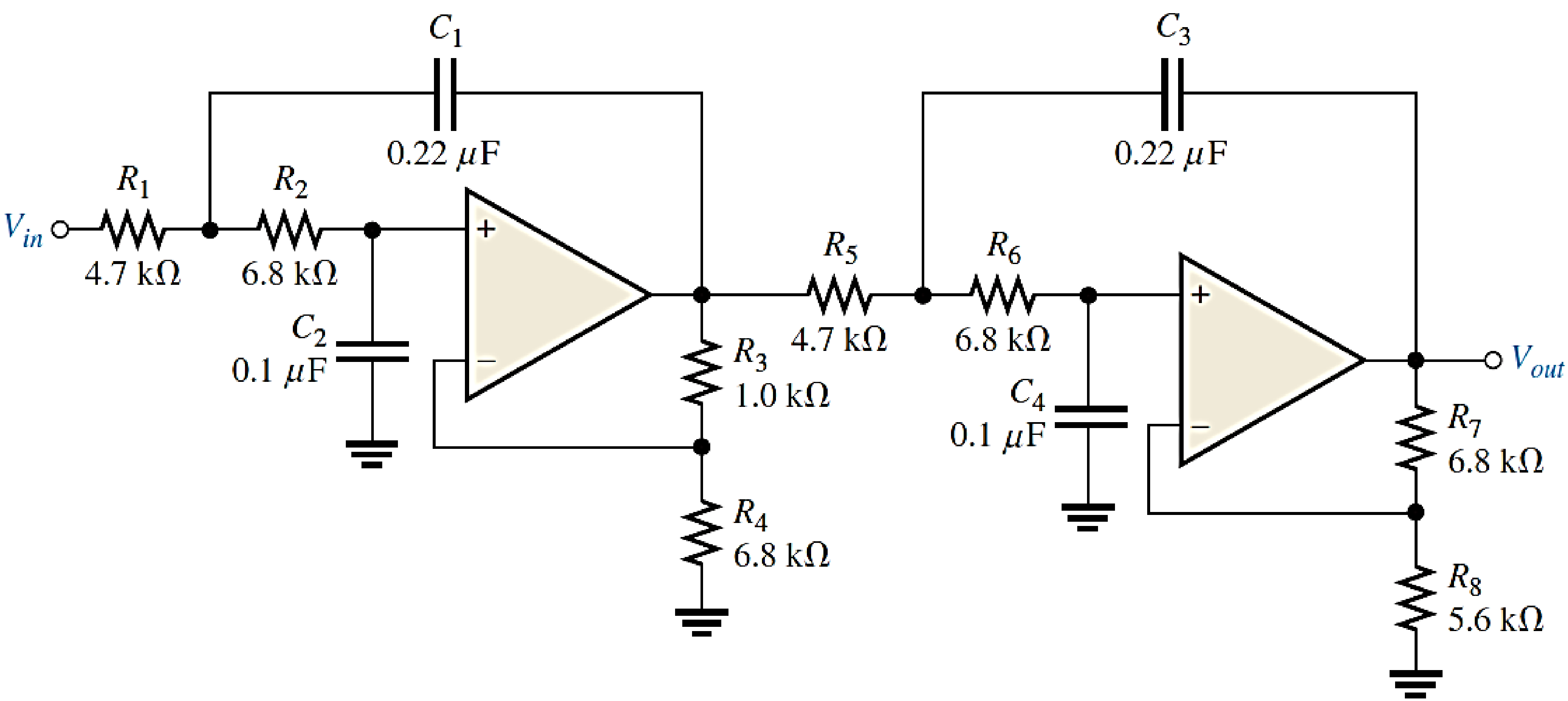
*Week #03 – Lecture Note #07*

# Low-Pass and High-Pass Filters

# - More Examples -

# Ex. 05

a) Is the four-pole filter in Figure below approximately optimized for a Butterworth response? What is the roll-off rate?



# Ex. 05 (cont'd)

## High Pass

First Stage:

$$DF = 2 - \frac{R_3}{R_4} = 2 - \frac{1.0}{6.8} = 1.85$$

Second Stage:

$$DF = 2 - \frac{R_7}{R_8} = 2 - \frac{6.8}{5.6} = 0.786$$

| | | 1ST STAGE | | | 2ND STAGE | | | 3RD STAGE | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ORDER | ROLL-OFF DB/DECADE | POLES | *DF* | $R_1/R_2$ | POLES | *DF* | $R_3/R_4$ | POLES | *DF* | $R_5/R_6$ |
| 1 | −20 | 1 | Optional | | | | | | | |
| 2 | −40 | 2 | 1.414 | 0.586 | | | | | | |
| 3 | −60 | 2 | 1.00 | 1 | 1 | 1.00 | 1 | | | |
| 4 | −80 | 2 | 1.848 | 0.152 | 2 | 0.765 | 1.235 | | | |
| 5 | −100 | 2 | 1.00 | 1 | 2 | 1.618 | 0.382 | 1 | 0.618 | 1.382 |
| 6 | −120 | 2 | 1.932 | 0.068 | 2 | 1.414 | 0.586 | 2 | 0.518 | 1.482 |

# Ex. 05 (cont'd)

| ORDER | ROLL-OFF DB/DECADE | 1ST STAGE | | | 2ND STAGE | | | 3RD STAGE | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | POLES | *DF* | $R_1/R_2$ | POLES | *DF* | $R_3/R_4$ | POLES | *DF* | $R_5/R_6$ |
| 1 | −20 | 1 | Optional | | | | | | | |
| 2 | −40 | 2 | 1.414 | 0.586 | | | | | | |
| 3 | −60 | 2 | 1.00 | 1 | 1 | 1.00 | 1 | | | |
| 4 | −80 | 2 | 1.848 | 0.152 | 2 | 0.765 | 1.235 | | | |
| 5 | −100 | 2 | 1.00 | 1 | 2 | 1.618 | 0.382 | 1 | 0.618 | 1.382 |
| 6 | −120 | 2 | 1.932 | 0.068 | 2 | 1.414 | 0.586 | 2 | 0.518 | 1.482 |

***From the table***

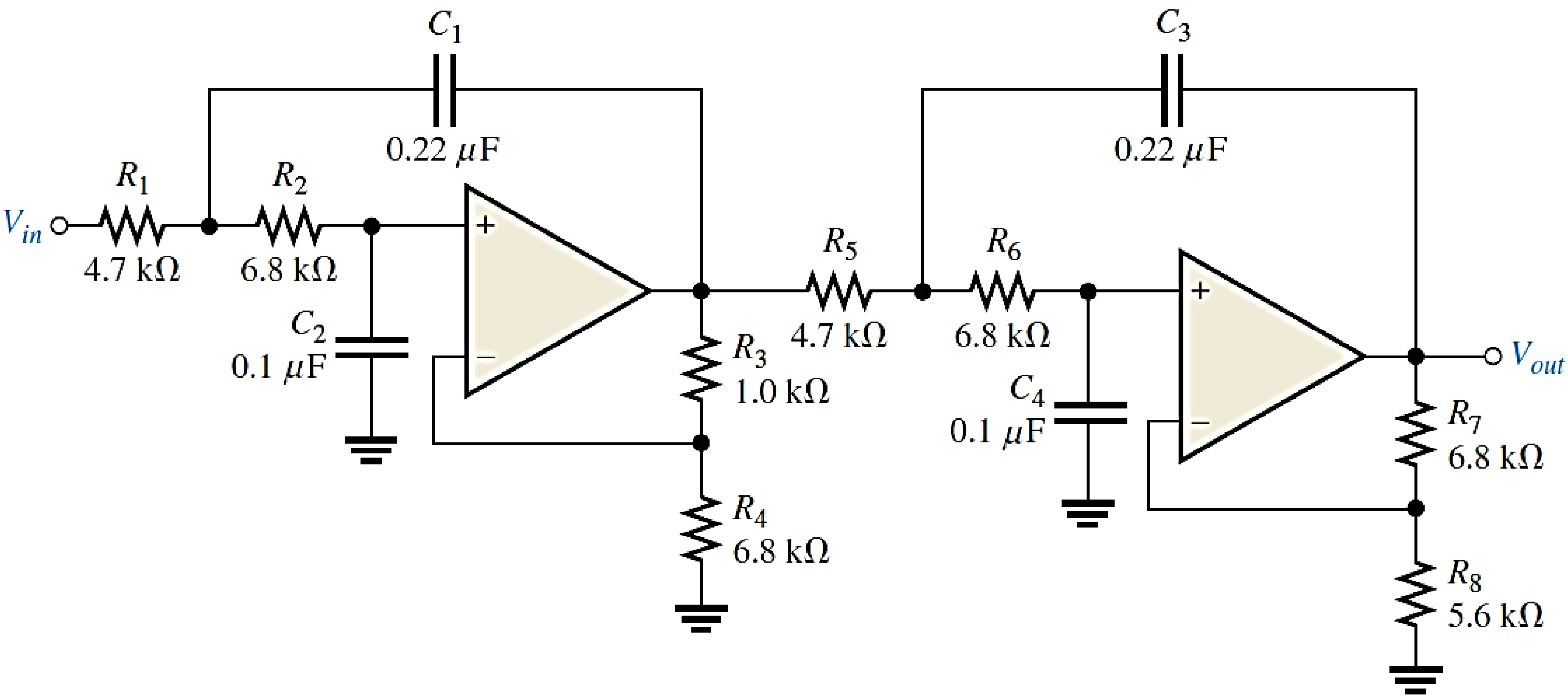
1st stage *DF* =1.848 and 2nd stage *DF*=0.765

Therefore, this filter is **approximately Butterworth.**

Roll-off rate = **80 dB/decade**

# Ex. 05 (cont'd)

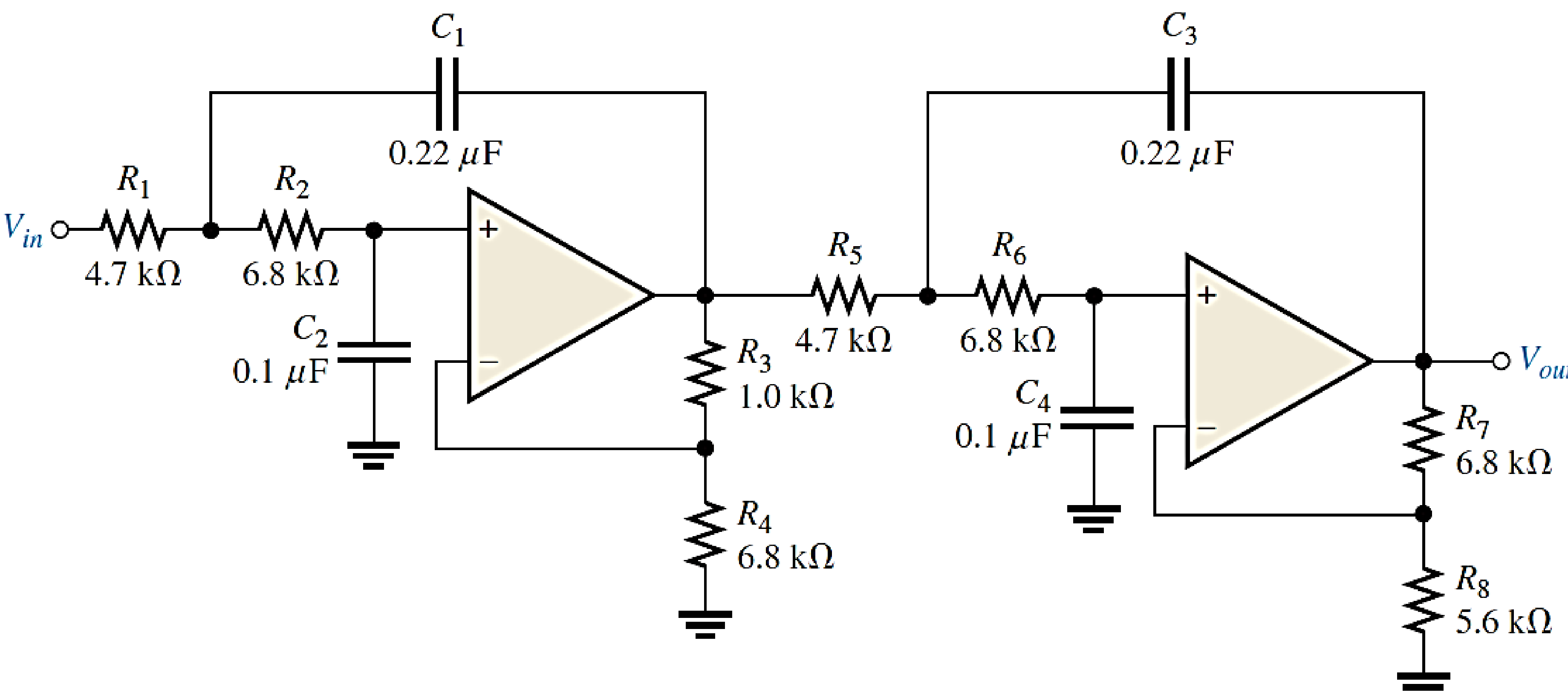
b) Determine the critical frequency of the filter circuit below.




$$f_c = \frac{1}{2\pi\sqrt{R_1R_2C_1C_2}} = \frac{1}{2\pi\sqrt{R_5R_6C_3C_4}} = \frac{1}{2\pi\sqrt{(4.7\text{ k}\Omega)(6.8\text{ k}\Omega)(0.22\ \mu\text{F})(0.1\ \mu\text{F})}} = \mathbf{190\ Hz}$$

# Ex. 05 (cont'd)

c) Without changing the response curve, adjust the component values in the filter circuit to make it an equal-value filter. Select for both stages.



# Ex. 05 *(cont'd)*

$R = R_1 = R_2 = R_5 = R_6$ and $C = C_1 = C_2 = C_3 = C_4$

Let $\boldsymbol{C = 0.22\mu F}$ **(**for both stages)

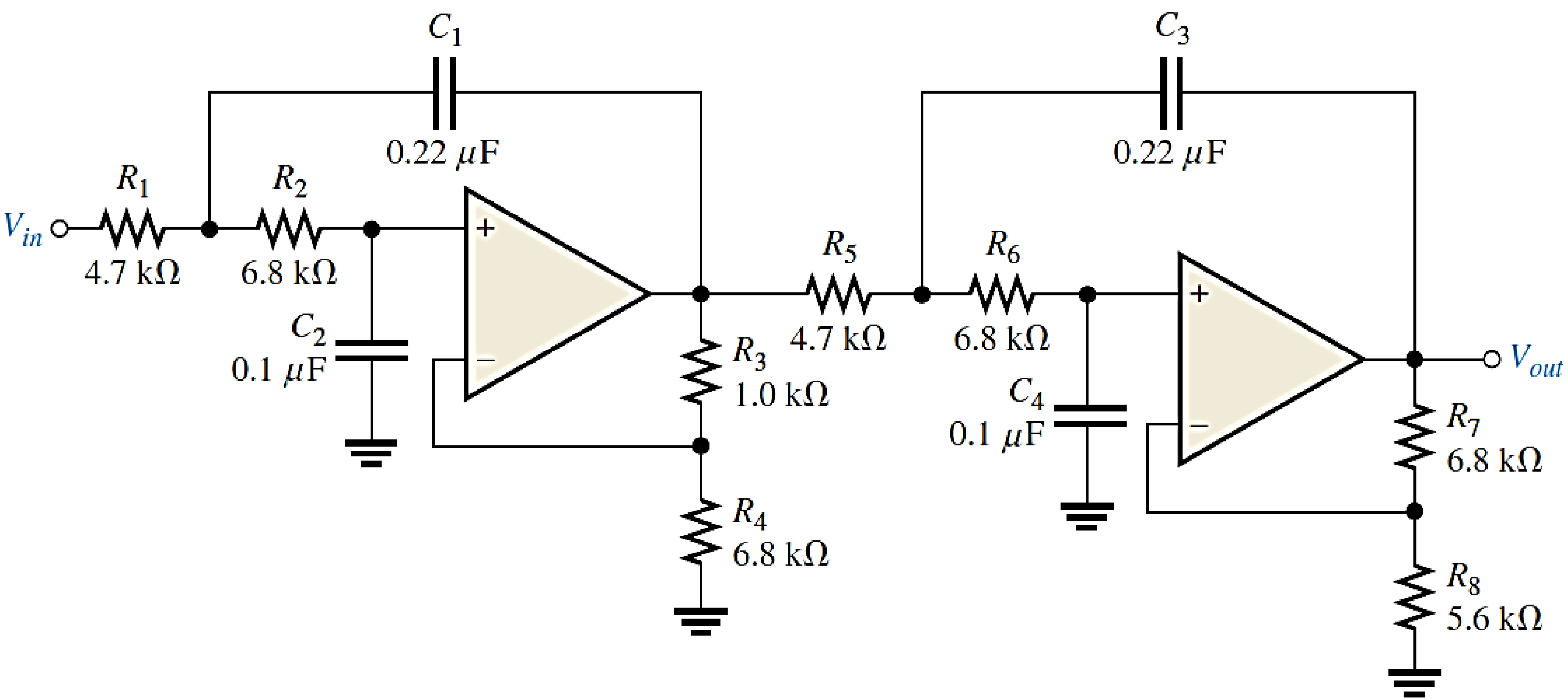
$$f_c = \frac{1}{2\pi\sqrt{R^2C^2}} = \frac{1}{2\pi RC}$$

$$R = \frac{1}{2\pi f_c C} = \frac{1}{2\pi(190\ \text{Hz})(0.22\ \mu\text{F})} = 3.81\ \text{k}\Omega$$

Choose $\boldsymbol{R = 3.9\ k\Omega}$ **(**for both stages)

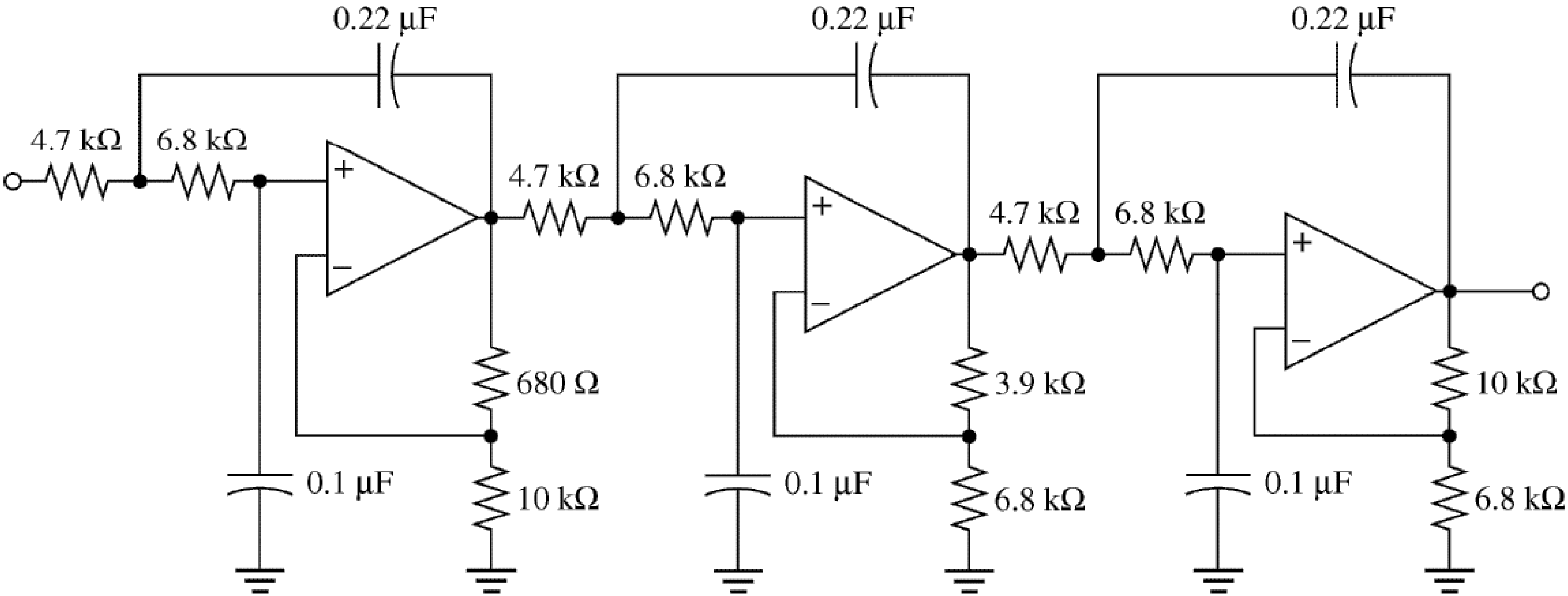
# Ex. 05 (cont'd)

d) Modify the filter circuit in the Figure to increase the roll-off rate to -120 dB/decade while maintaining an approximate Butterworth response.



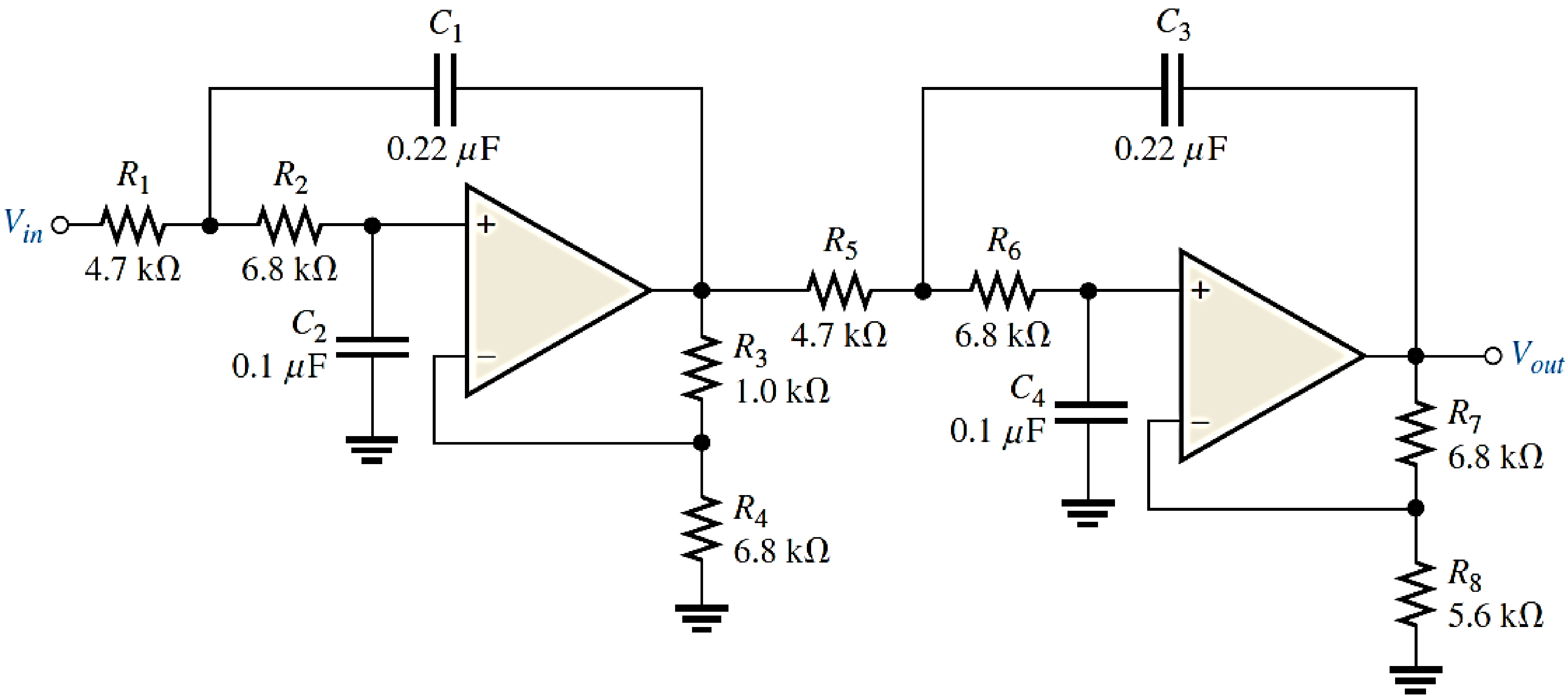
# Ex. 05 (cont'd)

Add another identical stage and change the ratio of the feedback resistors to 0.068 for first stage, 0.586 for second stage, and 1.482 for third stage.

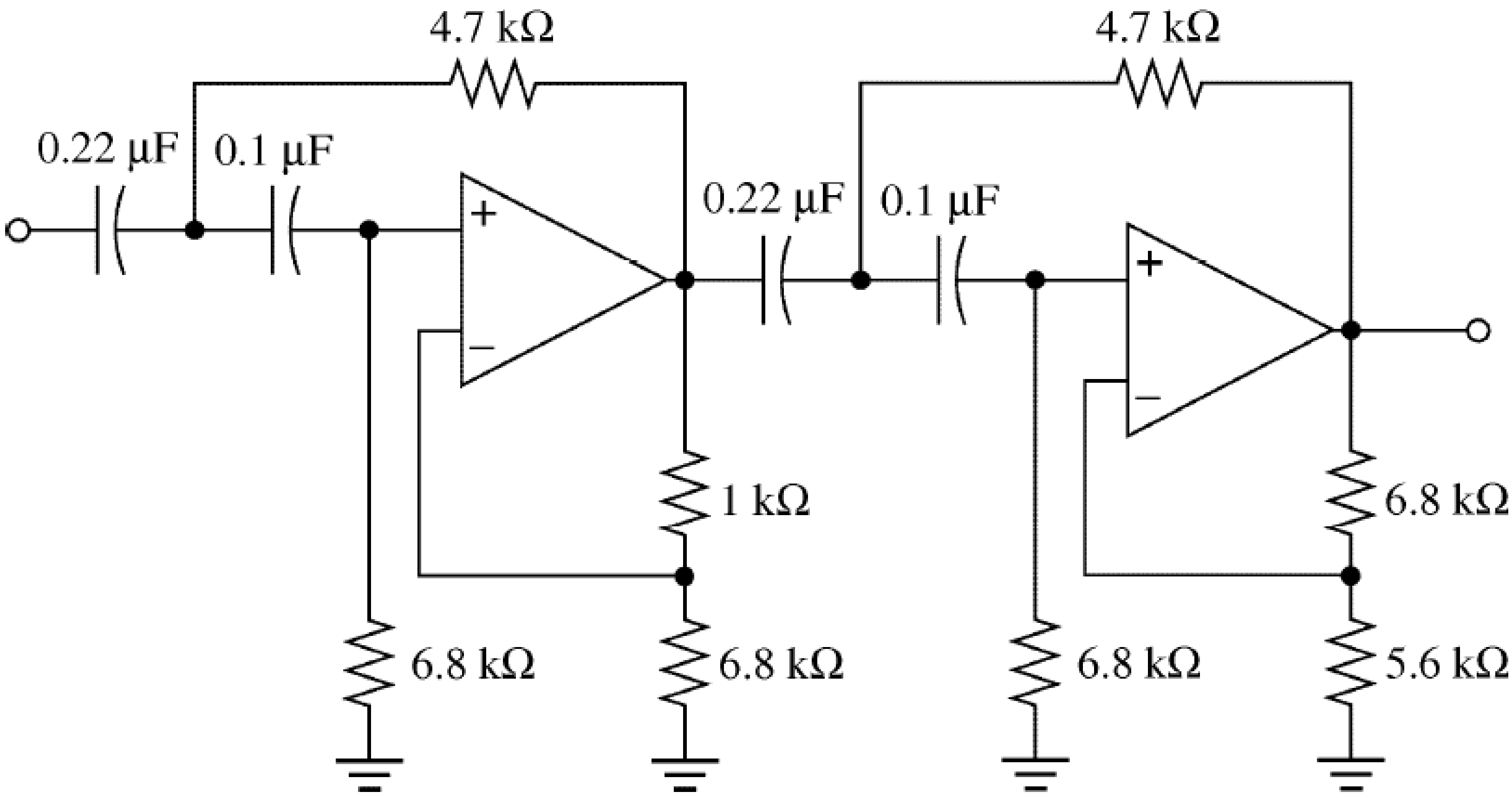


# Ex. 06

a) Convert the filter below to a high-pass with the same critical frequency and response characteristic.



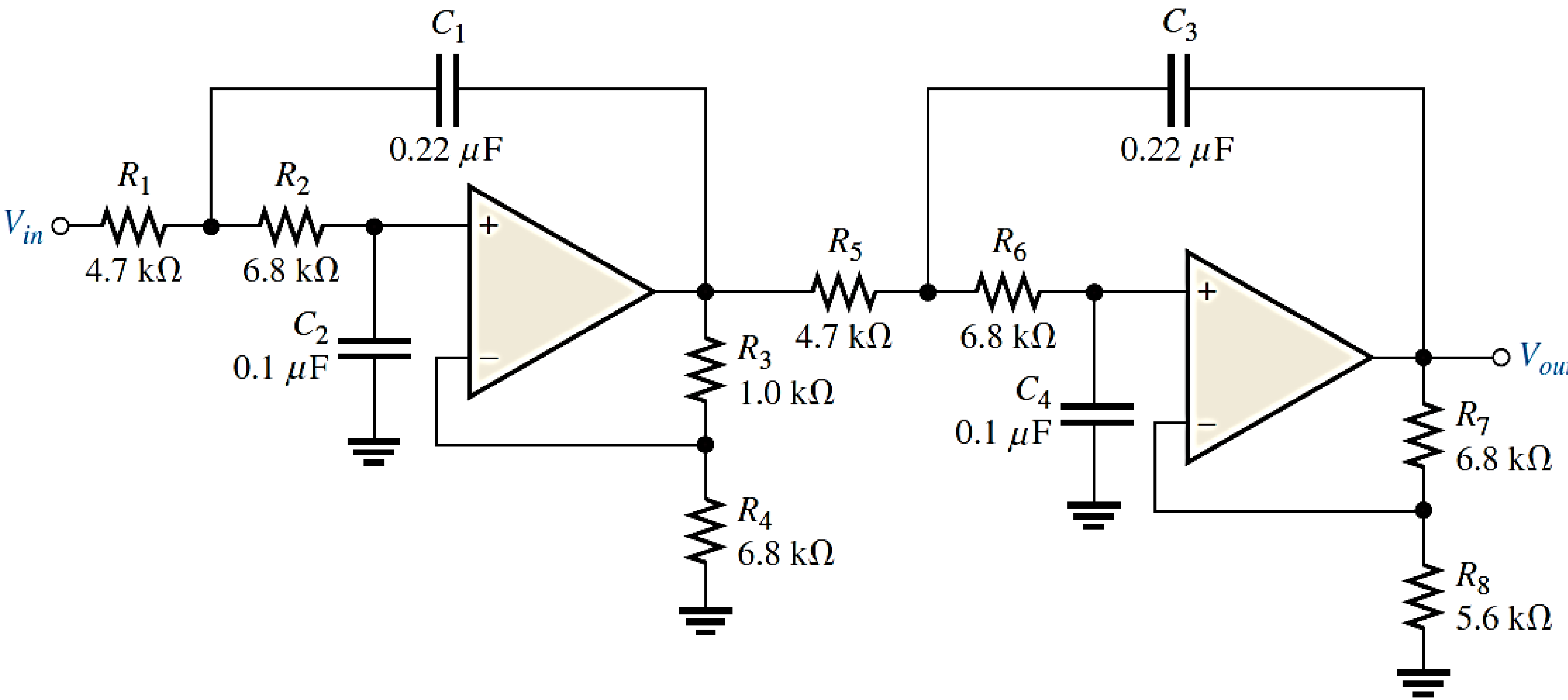
# Ex. 06 (cont'd)



4.7 kΩ
4.7 kΩ
0.22 μF
0.1 μF
0.22 μF
0.1 μF
+
−
+
−
1 kΩ
6.8 kΩ
6.8 kΩ
6.8 kΩ
6.8 kΩ
6.8 kΩ
5.6 kΩ

# Ex. 06 (cont'd)

b) Make the necessary circuit modification to reduce by half the critical frequency in Ex. 05(b).



# Ex. 06 *(cont'd)*

$$f_c = \frac{1}{2\pi RC}$$

$$f_0 = \frac{190\ \text{Hz}}{2} = 95\ \text{Hz}$$

$$R = \frac{1}{2\pi f_c C} = \frac{1}{2\pi(95\ \text{Hz})(0.22\ \mu\text{F})} = 7615\ \Omega$$

Let $\boldsymbol{R = 7.5\ k\Omega}$.

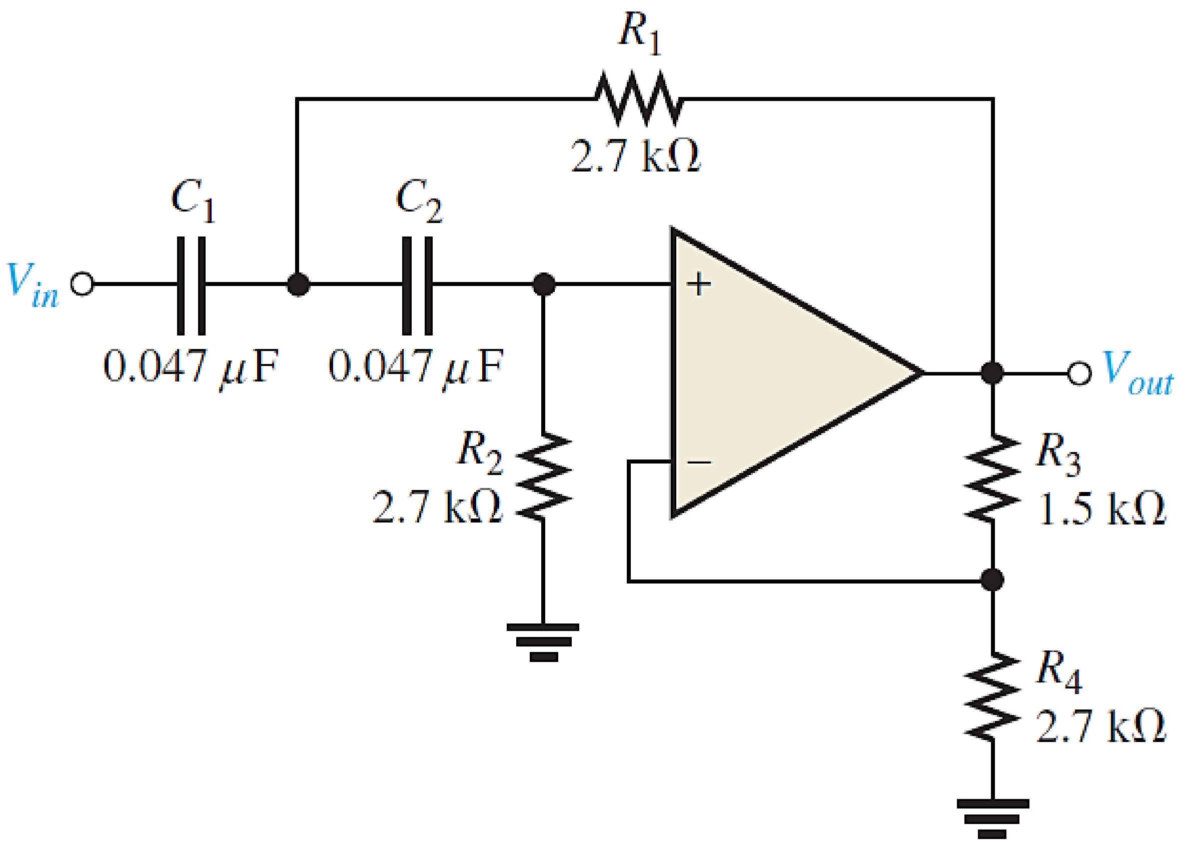
And choose $R_1, R_2, R_3$ and $R_6$ to $\boldsymbol{7.5\ k\Omega}$

# Ex. 06 (cont'd)

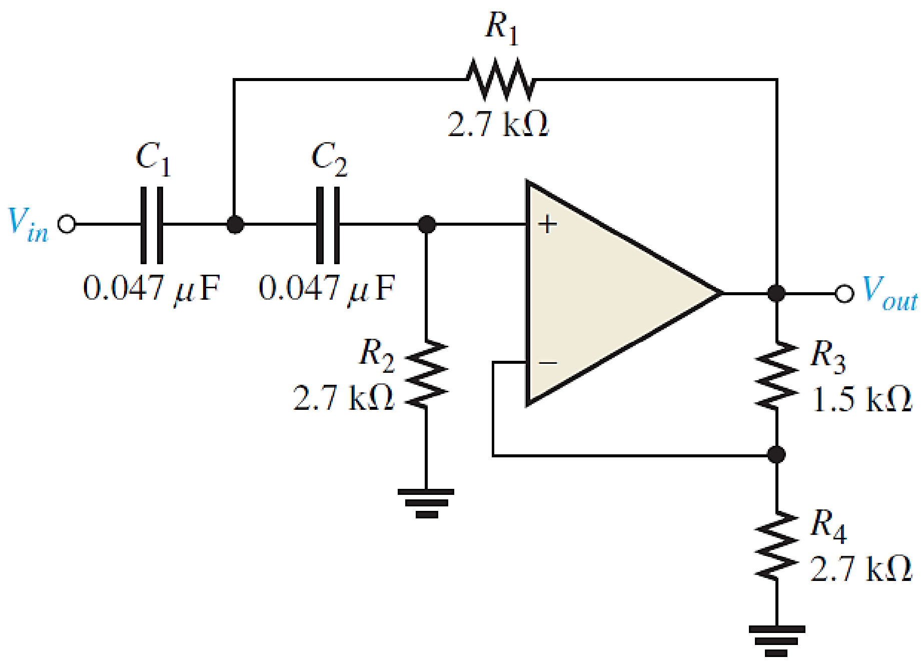
c) For the filter in Figure below,

   i. how would you increase the critical frequency?

   ii. How would you increase the gain?



# Ex. 06 (cont'd)




$$f_c = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}}$$

$$A_{cl(NI)} = \frac{R_3}{R_4} + 1$$

i. Decrease $R_1$ and $R_2$ or $C_1$ and $C_2$.

ii. Increase $R_3$ or decrease $R_4$.