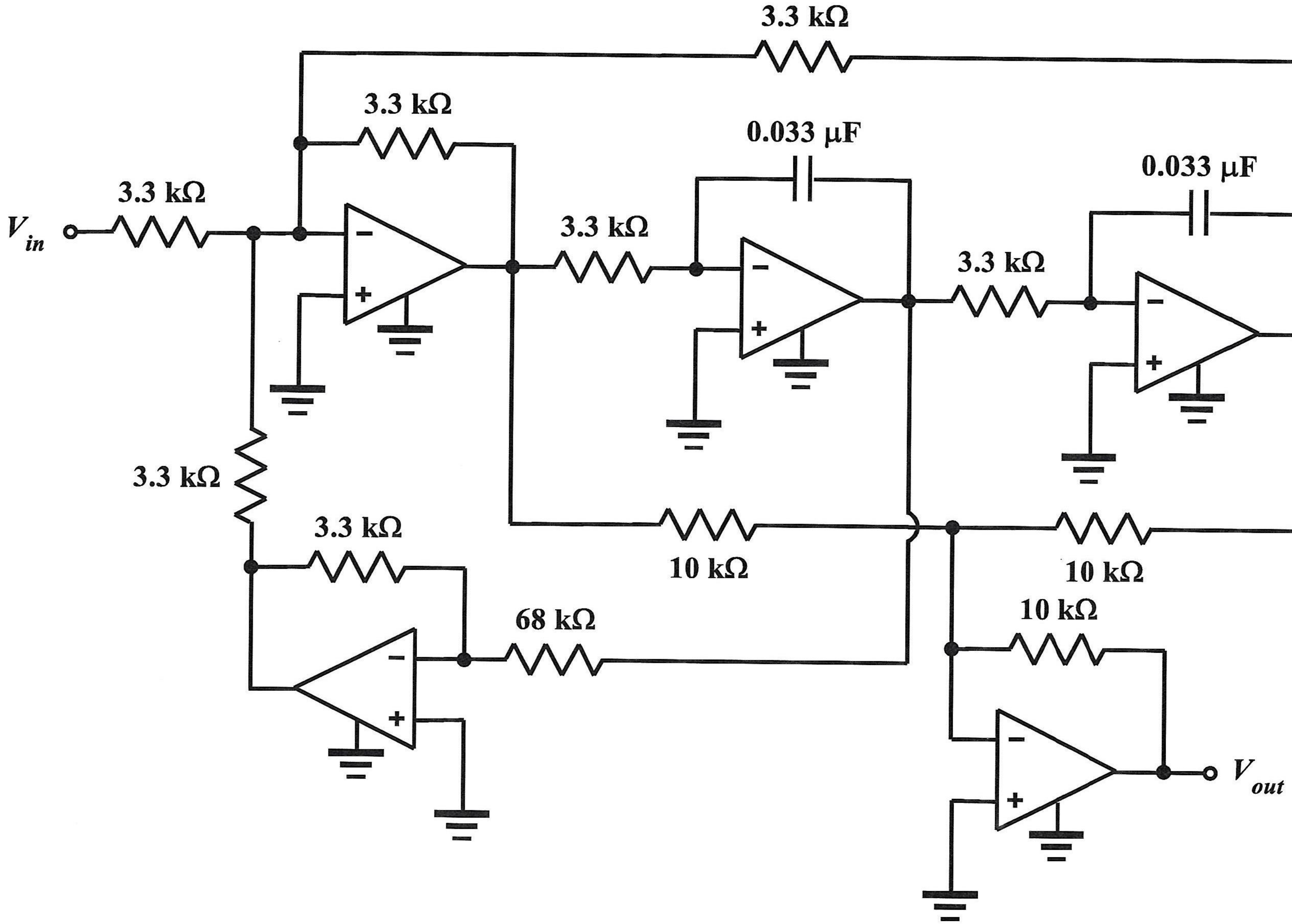
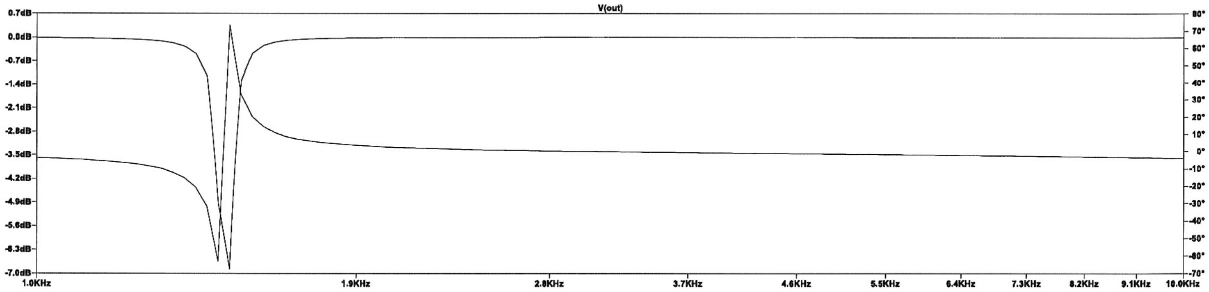
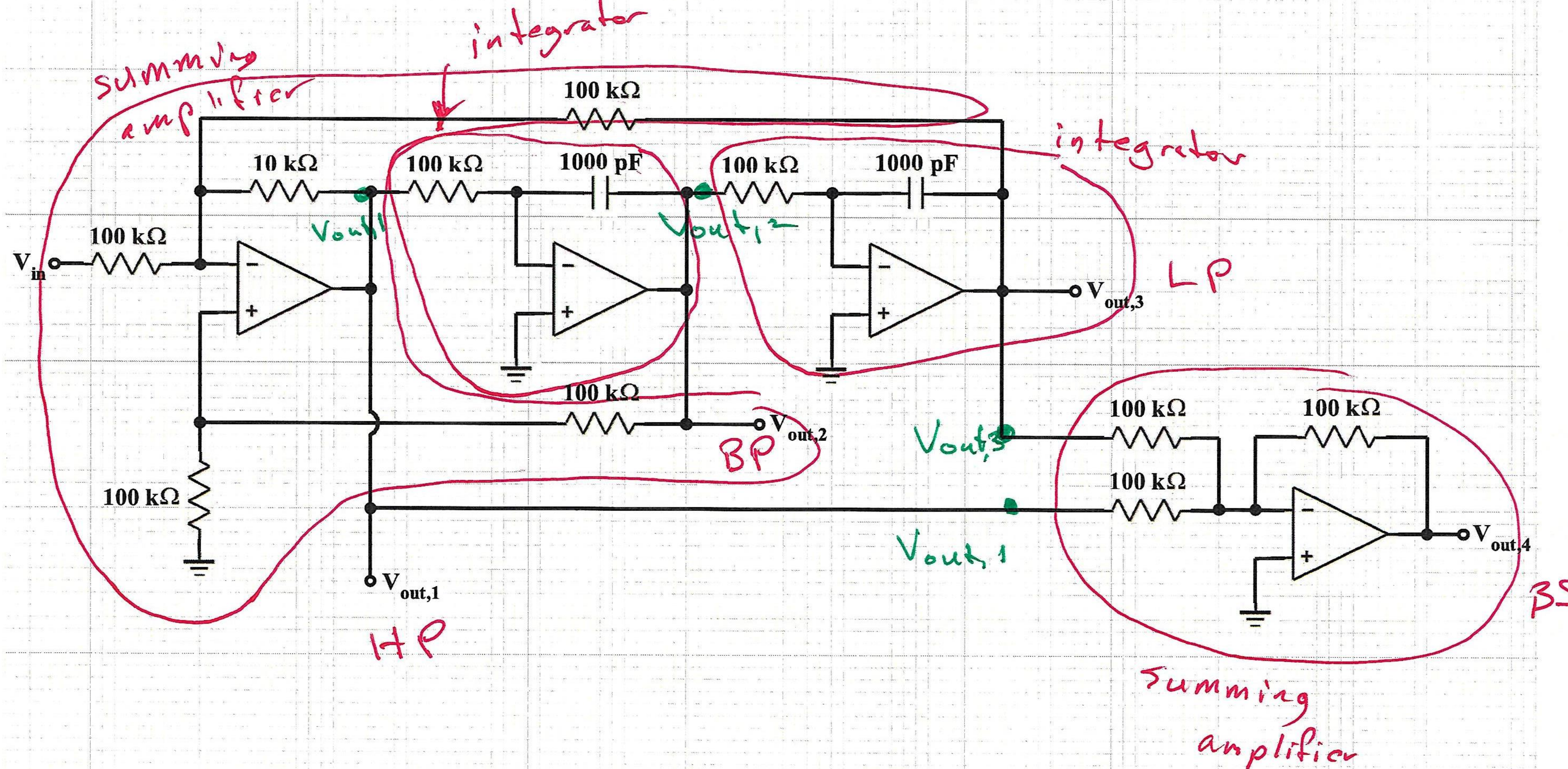
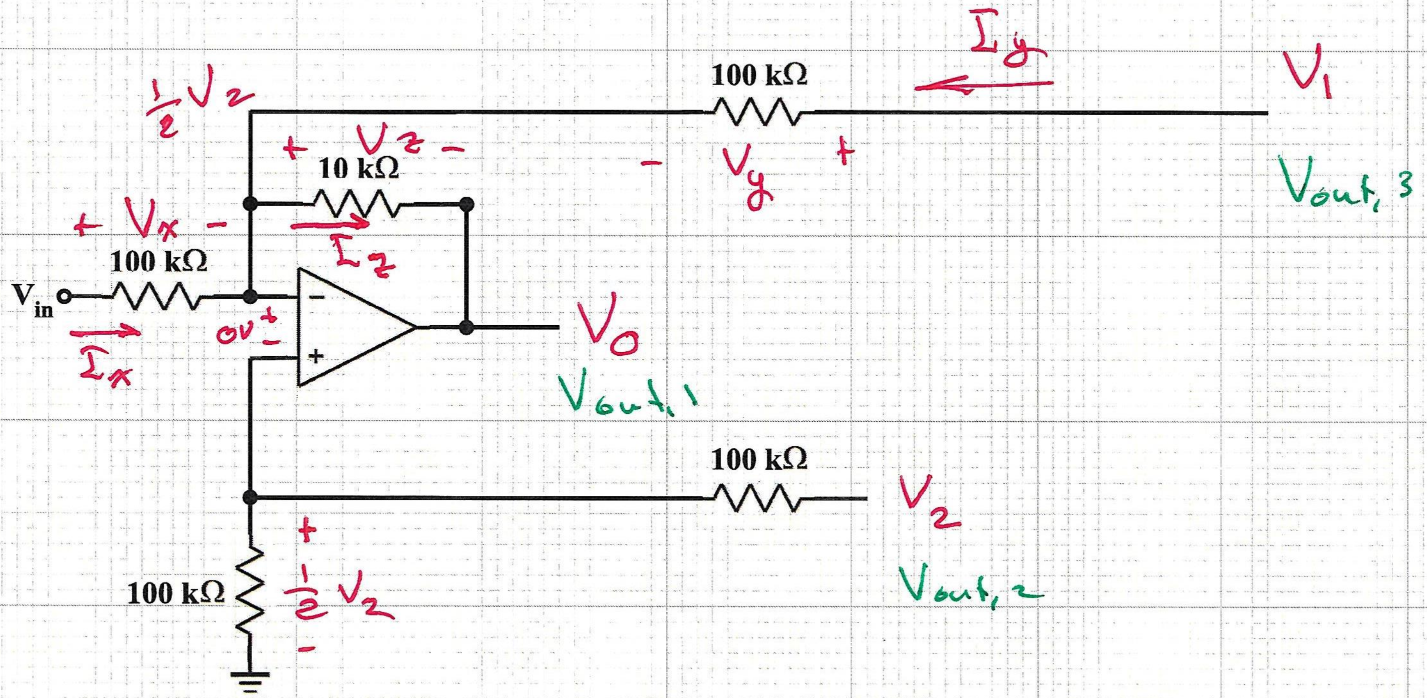

3.3 kΩ
3.3 kΩ
0.033 μF
0.033 μF
V_in
3.3 kΩ
3.3 kΩ
3.3 kΩ
3.3 kΩ
3.3 kΩ
10 kΩ
10 kΩ
10 kΩ
68 kΩ
V_out



V(out)
0.7dB
0.0dB
-0.7dB
-1.4dB
-2.1dB
-2.8dB
-3.5dB
-4.2dB
-4.9dB
-5.6dB
-6.3dB
-7.0dB
80°
70°
60°
50°
40°
30°
20°
10°
0°
-10°
-20°
-30°
-40°
-50°
-60°
-70°
1.0KHz
1.9KHz
2.8KHz
3.7KHz
4.6KHz
5.5KHz
6.4KHz
7.3KHz
8.2KHz
9.1KHz
10.0KHz



summing amplifier
integrator
integrator
100 kΩ
10 kΩ
100 kΩ
1000 pF
100 kΩ
1000 pF
V in
100 kΩ
Vout,1
Vout,2
LP
V out,3
100 kΩ
V out,2
BP
Vout,3
100 kΩ
100 kΩ
100 kΩ
100 kΩ
100 kΩ
Vout,1
V out,4
V out,1
HP
BS
summing amplifier



Summing Amplifier

$$V_o = \frac{1}{10}\left(V_{in} + V_1 - V_2\right)$$

$$V_x = V_{in} - \frac{1}{2} V_2$$

$$V_y = V_1 - \frac{1}{2} V_2$$

$$I_y = \frac{V_y}{100k\Omega}$$

$$I_x = \frac{V_x}{100k\Omega}$$

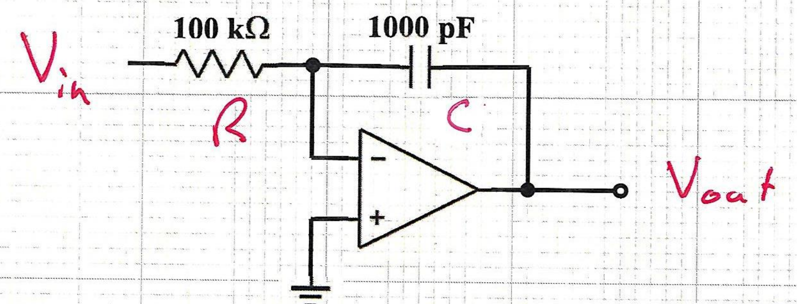
$$I_z = I_x + I_y = \frac{V_x}{100k\Omega} + \frac{V_y}{100k\Omega}$$

$$= \frac{V_{in} - \frac{1}{2} V_2}{100k\Omega} + \frac{V_1 - \frac{1}{2} V_2}{100k\Omega}$$

$$= \frac{V_{in} + V_1 - V_2}{100k\Omega}$$

$$V_z = 10k\Omega (I_z) = \frac{1}{10} (V_{in} + V_1 - V_2)$$

Integrator



$$V_{out} = -\frac{1}{RC}\int V_{in}\,dt$$

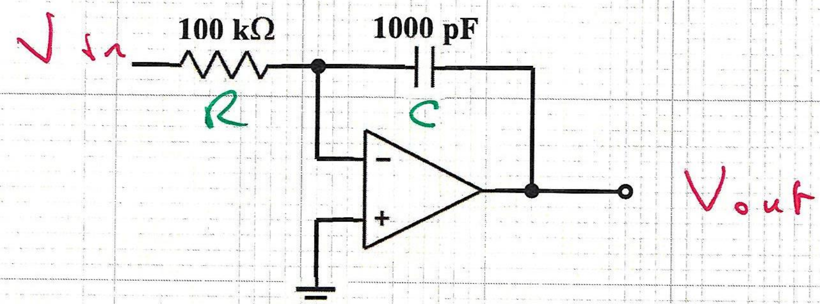
$$V_{out} = -\frac{1}{RC}\cdot\frac{1}{j\omega}V_{in}$$ phasor notation

let $s = j\omega$

$$V_{out} = -\frac{1}{sRC}V_{in}$$

$$V_{in} = -sRC\,V_{out}$$

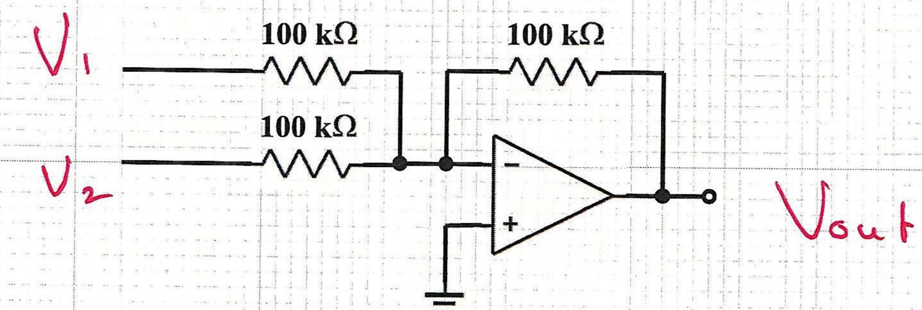
Integrator



$$V_{in} = -sRC\,V_{out}$$

or

$$V_{out} = -\frac{1}{sRC}\,V_{in}$$



$$V_{out} = -V_1 - V_2$$

$$V_{out,4} = -V_{out,3} - V_{out,1}$$

$$V_{out,2} = -sRC \; V_{out,3}$$

$$V_{out,1} = -sRC \; V_{out,2}$$

$$V_{out,1} = \frac{1}{10}\left(V_{in} + V_{out,3} - V_{out,2} \right)$$

$$V_{out,1} = \frac{1}{10}\Big\{ V_{in} - \frac{1}{sRC}\underset{\substack{\uparrow \\ -\frac{1}{sRC}V_{out,1}}}{V_{out,2}} - \frac{1}{sRC} V_{out,1} \Big)$$

$$10\, V_{out,1} = V_{in} + \frac{1}{s^2R^2C^2} V_{out,1} - \frac{1}{sRC} V_{out,1} \Big)$$

Multiply through by $s^2 R^2 C^2$

1c

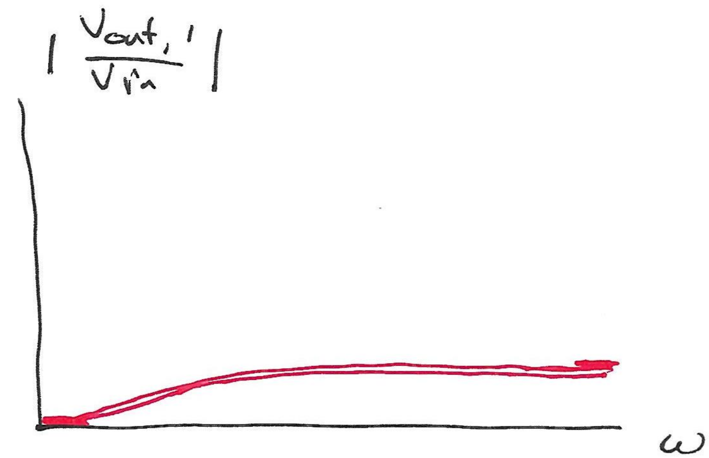
$$10\, s^2R^2C^2\, V_{out,1} = s^2R^2C^2\, V_{in} + V_{out,1} - sRC$$

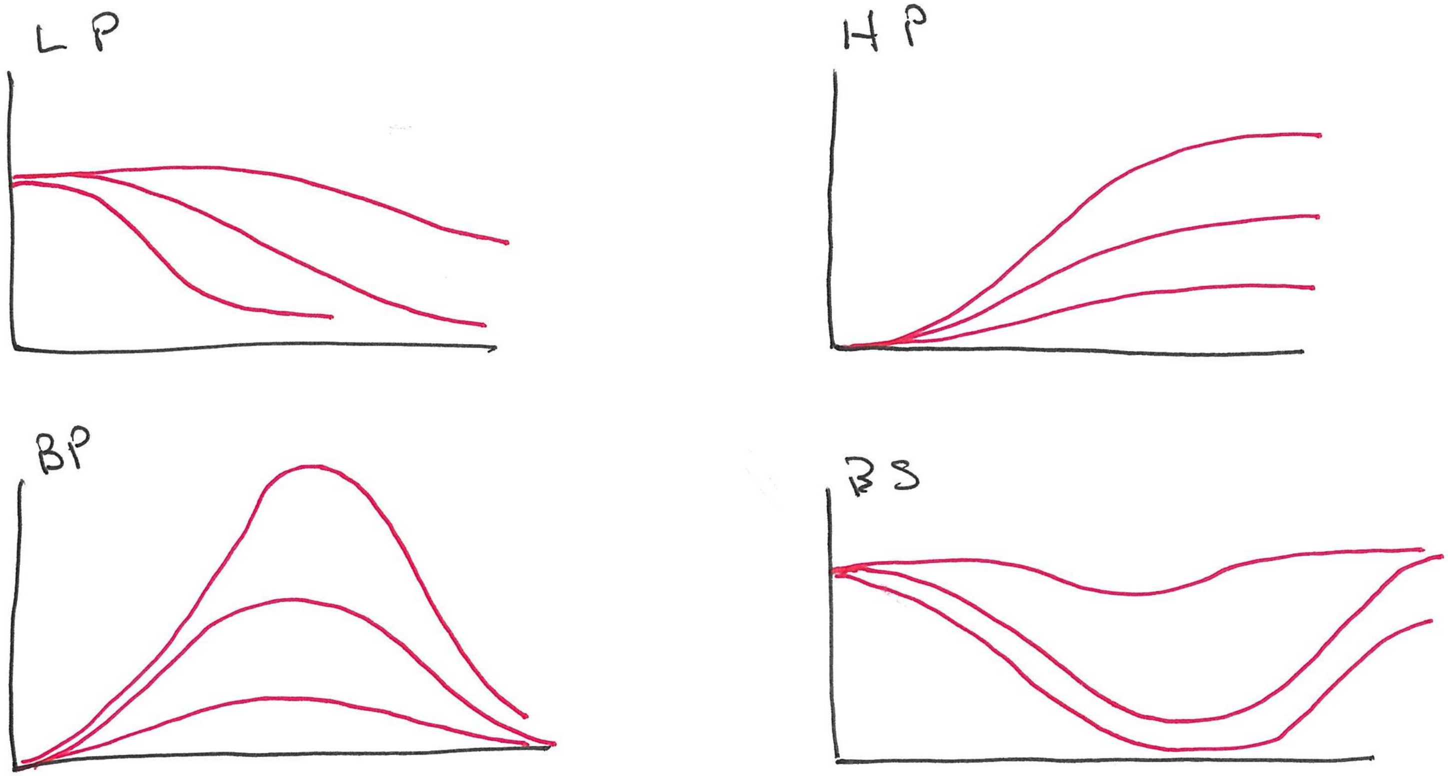
$$s^2R^2C^2 V_{in} = (1 - sRC - 10\, s^2R^2C^2)\, V_{out,1}$$

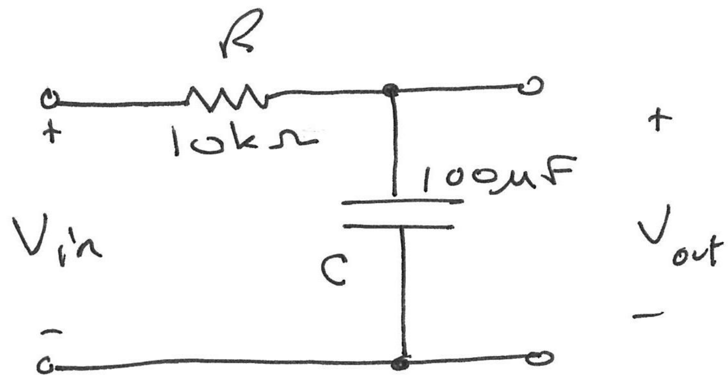
$$\frac{V_{out,1}}{V_{in}} = \frac{s^2R^2C^2}{1 - sRC - 10\, s^2R^2C^2}$$

$$\lim_{\omega \to 0} \frac{V_{out,1}}{V_{in}} = \frac{0}{1} = 0$$

$$\lim_{\omega \to \infty} \left| \frac{V_{out,1}}{V_{in}} \right| = + \frac{1}{10}$$



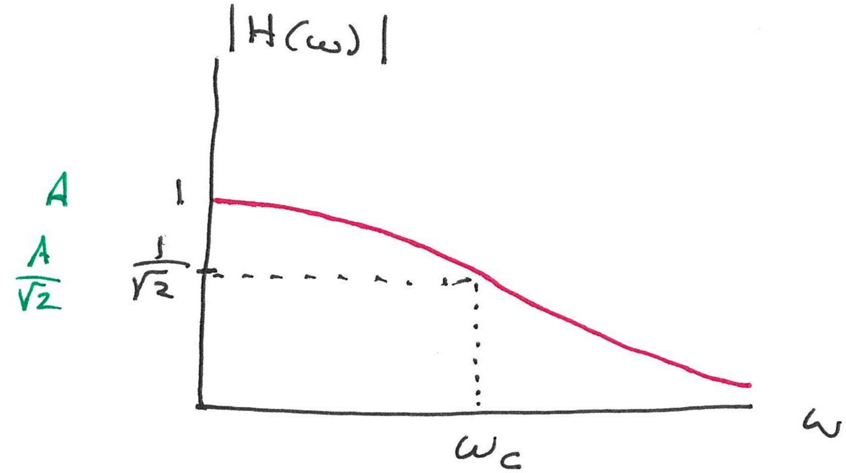

LP
HP
BP
BS



$$H(\omega) = \frac{\frac{1}{j\omega C}}{R + \frac{1}{j\omega C}} = \frac{1}{1 + j\omega RC}$$

$$\lim_{\omega \to 0} H(\omega) = 1$$

$$\lim_{\omega \to \infty} H(\omega) = 0$$



$$|H(\omega)| = \frac{1}{\sqrt{1^2 + (\omega RC)^2}}$$

At the cutoff frequency

$$|H(\omega_c)| = \frac{|H(0)|}{\sqrt{2}} = \frac{1}{\sqrt{2}}$$

$$|H(\omega_c)| = \frac{1}{\sqrt{1^2 + (\omega_c RC)^2}} = \frac{1}{\sqrt{2}}$$

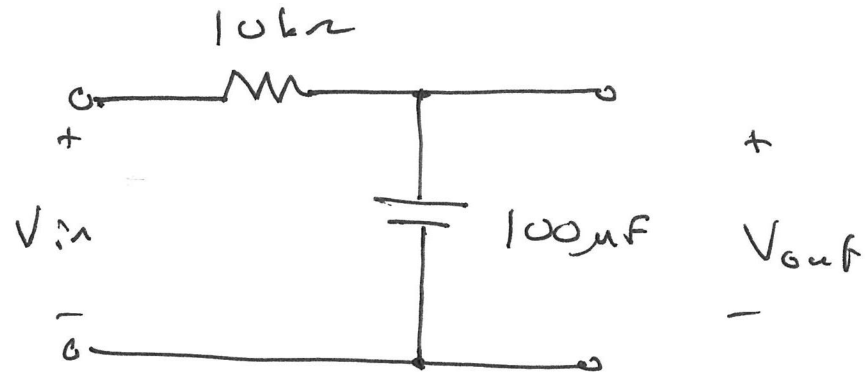
$$\frac{1}{1^2 + (\omega_c RC)^2} = \frac{1}{2}$$

or $$1 + (\omega_c RC)^2 = 2$$

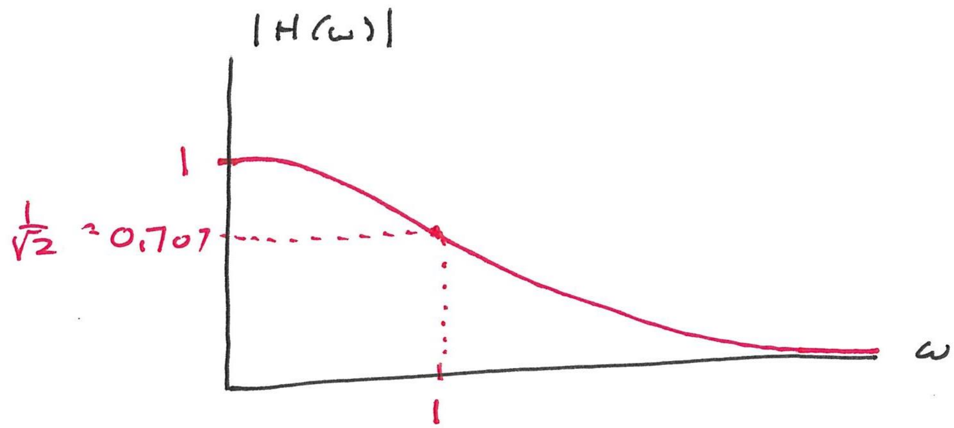
$$(\omega_c RC)^2 = 1$$

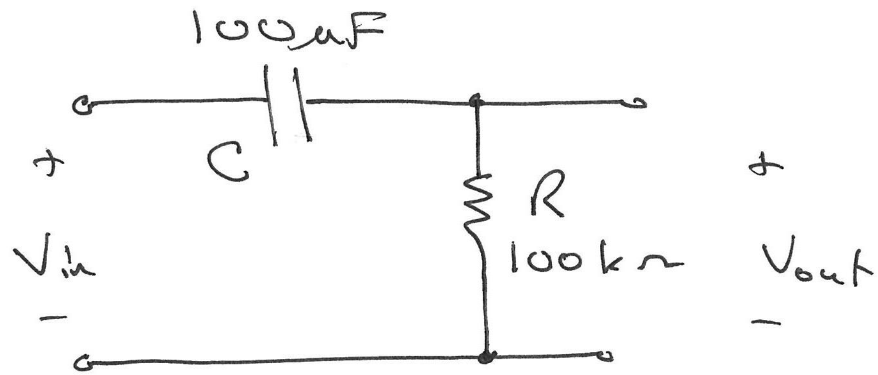
$$\omega_c = \frac{1}{RC}$$

Given



$$\omega_c = \frac{1}{RC} = 1$$

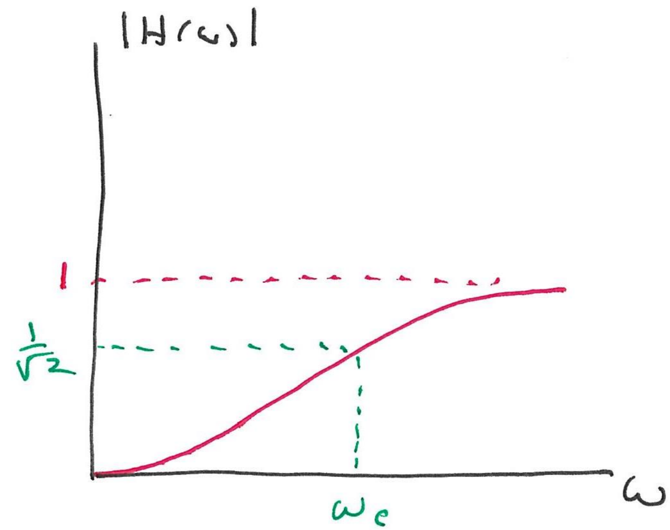




$$H(\omega) = \frac{R}{R + \frac{1}{j\omega C}} = \frac{j\omega RC}{1 + j\omega RC}$$

$$\lim_{\omega \to 0} H(\omega) = \frac{0}{1} = 0$$

$$\lim_{\omega \to \infty} H(\omega) = 1$$



$$|H(\omega)| = \frac{\omega RC}{\sqrt{1^2 + (\omega RC)^2}}$$

At cutoff

$$|H(\omega_c)| = \frac{\omega_c RC}{\sqrt{1^2 + (\omega_c RC)^2}} = \frac{1}{\sqrt{2}}$$

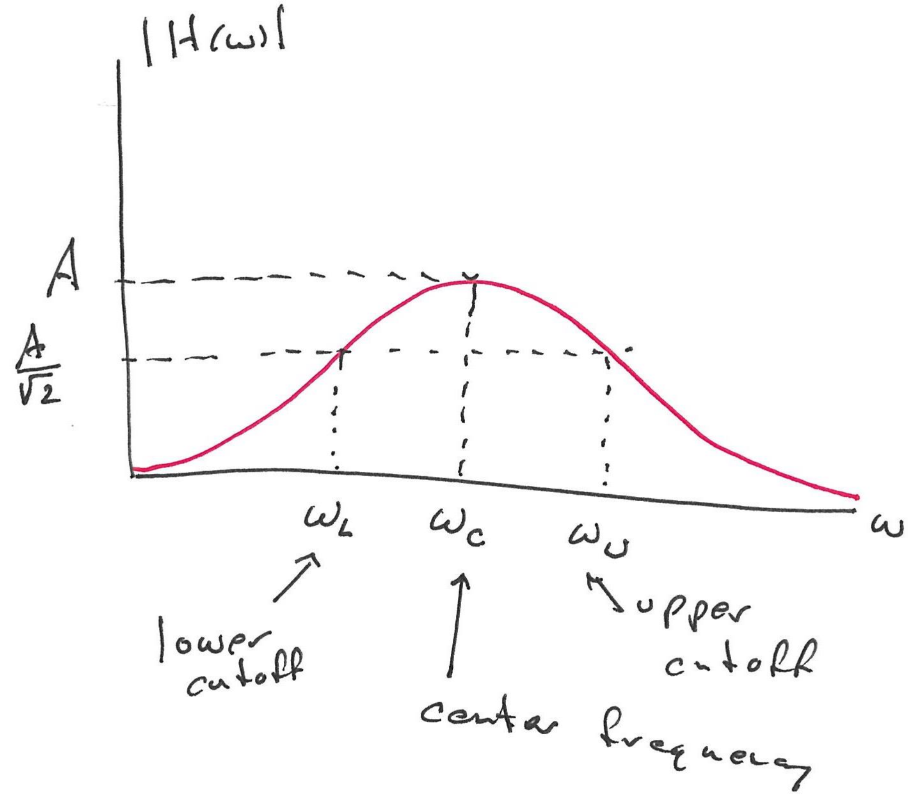
$$\frac{(\omega_c RC)^2}{1^2 + (\omega_c RC)^2} = \frac{1}{2}$$

$$2(\omega_c RC)^2 = 1 + (\omega_c RC)^2$$

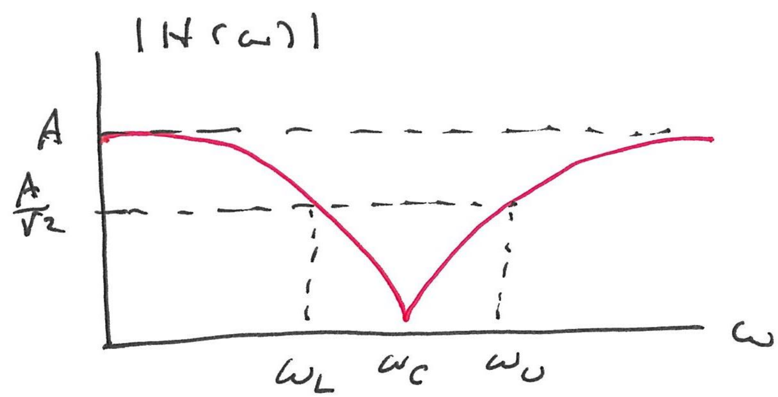
$$1 = (\omega_c RC)^2$$

$$\omega_c = \frac{1}{RC}$$

For BP


$|H(\omega)|$
A
$\frac{A}{\sqrt{2}}$
ω_L
ω_c
ω_U
ω
lower cutoff
center frequency
upper cutoff

For BS


$|H(\omega)|$
A
$\frac{A}{\sqrt{2}}$
ω_L
ω_c
ω_U
ω