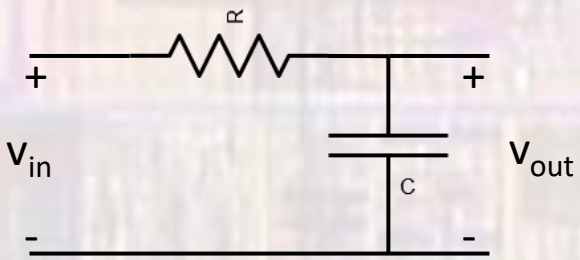
RC Passive Filters

Last updated 1/11/24

RC Passive Filters

- Low Pass
  - Voltage divider



$$v_{out} = v_{in} \left| \frac{Z_C}{Z_R + Z_C} \right|$$

$$v_{out} = v_{in} \frac{\frac{1}{2\pi f C}}{\sqrt{R^2 + \left(\frac{1}{2\pi f C}\right)^2}}$$

$$v_{out} = v_{in}(0.707) \rightarrow F_{corner}$$

C(F)	Frequency (Hz)	Impedance (Ohms)	Voltage Gain (dB)
1.00E-06	1.00E+00	1.00E+00	0
R(Ohms)	1.00E+01	1.00E+00	0
10	1.00E+02	1.00E+00	0
	1.00E+03	9.98E-01	0
	1.00E+04	8.47E-01	-1
	1.00E+05	1.57E-01	-16
	1.00E+06	1.59E-02	-36
	1.00E+07	1.59E-03	-56
	1.00E+08	1.59E-04	-76
	1.00E+09	1.59E-05	-96

Fc = 15.92KHz, Voltage gain = -3dB

$$F_{corner} = F_c = \frac{1}{2\pi RC}$$ Voltage gain @ Fc = -3dB

RC Passive Filters

- Low Pass – second order
  - Voltage divider

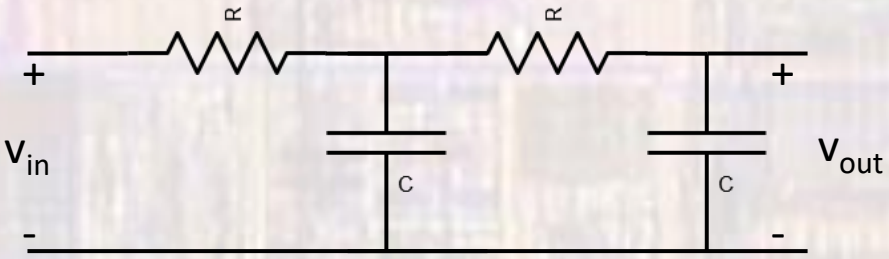
$$v_{out} = v_{in}\left|\frac{Z_{C1}}{Z_{R1}+Z_{C1}}\right|\left|\frac{Z_{C2}}{Z_{R2}+Z_{C2}}\right|$$

$$v_{out} = v_{in}\left(\frac{\frac{1}{2\pi f C1}}{\sqrt{R1^2+\left(\frac{1}{2\pi f C1}\right)^2}}\right)\left(\frac{\frac{1}{2\pi f C2}}{\sqrt{R2^2+\left(\frac{1}{2\pi f C2}\right)^2}}\right)$$

$$v_{out} = v_{in}(0.707)^2 = 0.5v_{in} \rightarrow F_{corner}$$

$$F_{corner} = F_c = \frac{1}{2\pi\sqrt{R_1C_1R_2C_2}}$$

Cascaded Filter



C(F)	Frequency (Hz)	Impedance (Ohms)	Voltage Gain (dB)
1.00E-06	1.00E+00	1.00E+00	0
R(Ohms)	1.00E+01	1.00E+00	0
10	1.00E+02	1.00E+00	0
	1.00E+03	9.96E-01	0
	1.00E+04	7.17E-01	-3
	1.00E+05	2.47E-02	-32
	1.00E+06	2.53E-04	-72
	1.00E+07	2.53E-06	-112
	1.00E+08	2.53E-08	-152
	1.00E+09	2.53E-10	-192

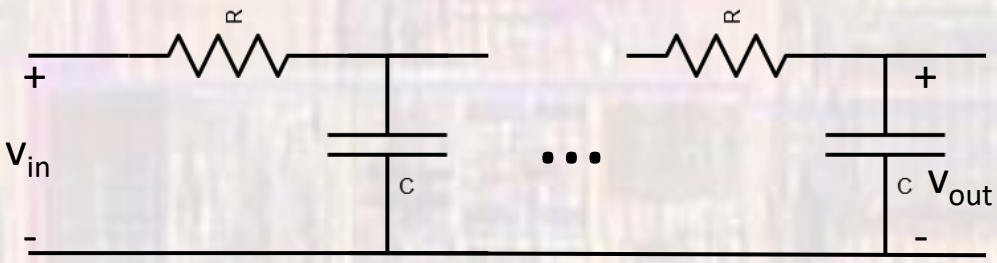
Fc = 15.92KHz, Voltage gain = -6dB

Voltage gain @ Fc = -6dB

RC Passive Filters

- Low Pass – nth order
  - Voltage divider

Cascaded Filter



$$v_{out} = v_{in}\left|\frac{Z_{C1}}{Z_{R1}+Z_{C1}}\right| \ldots \left|\frac{Z_{Cn}}{Z_{Rn}+Z_{Cn}}\right|$$

$$v_{out} = v_{in}\left(\frac{\frac{1}{2\pi f C1}}{\sqrt{R1^2+\left(\frac{1}{2\pi f C1}\right)^2}}\right) \ldots \left(\frac{\frac{1}{2\pi f Cn}}{\sqrt{Rn^2+\left(\frac{1}{2\pi f Cn}\right)^2}}\right)$$

$$f_{(-3dB)} = f_C\sqrt{2^{\left(\frac{1}{n}\right)}-1}$$

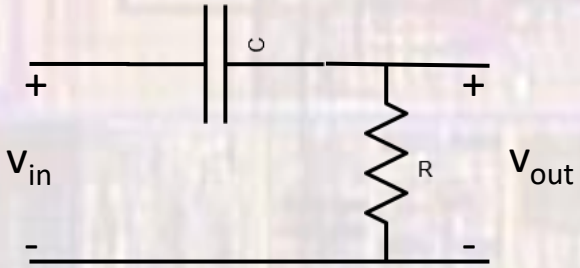
$$v_{out} = v_{in}(0.707)^n \rightarrow F_{corner}$$

$$F_{corner} = F_c = \frac{1}{2\pi\ \sqrt[n]{R_1C_1 \ldots R_n C_n}}$$

Voltage gain @ Fc = $\left(\frac{1}{\sqrt{2}}\right)^n$ = n x (-3dB)

RC Passive Filters

- High Pass
  - Voltage divider



$$v_{out} = v_{in}\left|\frac{Z_R}{Z_R + Z_C}\right|$$

$$v_{out} = v_{in}\frac{R}{\sqrt{R^2 + \left(\frac{1}{2\pi f C}\right)^2}}$$

$$v_{out} = v_{in}(0.707) \rightarrow F_{corner}$$

C(F)	Frequency (Hz)	Impedance (Ohms)	Voltage Gain (dB)
1.00E-06	1.00E+00	6.28E-05	-84
R(Ohms)	1.00E+01	6.28E-04	-64
10	1.00E+02	6.28E-03	-44
	1.00E+03	6.27E-02	-24
	1.00E+04	5.32E-01	-5
	1.00E+05	9.88E-01	0
	1.00E+06	1.00E+00	0
	1.00E+07	1.00E+00	0
	1.00E+08	1.00E+00	0
	1.00E+09	1.00E+00	0

Fc = 15.92KHz, Voltage gain = -3dB

$$F_{corner} = F_c = \frac{1}{2\pi RC}$$ Voltage gain @ Fc = -3dB

RC Passive Filters

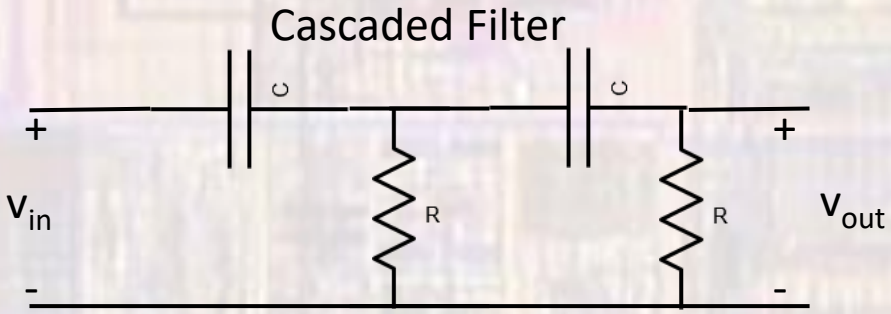
- High Pass – second order
  - Voltage divider

$$v_{out} = v_{in}\left|\frac{Z_{R1}}{Z_{R1}+Z_{C1}}\right|\left|\frac{Z_{R2}}{Z_{R2}+Z_{C2}}\right|$$

$$v_{out} = v_{in}\left(\frac{R1}{\sqrt{R1^2+\left(\frac{1}{2\pi fC1}\right)^2}}\right)\left(\frac{R2}{\sqrt{R2^2+\left(\frac{1}{2\pi fC2}\right)^2}}\right)$$

$$v_{out} = v_{in}(0.707)^2 = 0.5v_{in} \rightarrow F_{corner}$$

$$F_{corner} = F_c = \frac{1}{2\pi\sqrt{R_1C_1R_2C_2}}$$



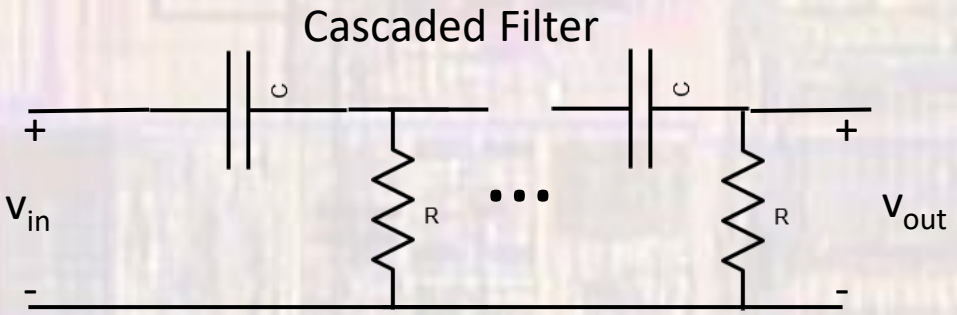
C(F)	Frequency (Hz)	Impedance (Ohms)	Voltage Gain (dB)
1.00E-06	1.00E+00	3.95E-09	-168
R(Ohms)	1.00E+01	3.95E-07	-128
10	1.00E+02	3.95E-05	-88
	1.00E+03	3.93E-03	-48
	1.00E+04	2.83E-01	-11
	1.00E+05	9.75E-01	0
	1.00E+06	1.00E+00	0
	1.00E+07	1.00E+00	0
	1.00E+08	1.00E+00	0
	1.00E+09	1.00E+00	0

Fc = 15.92KHz, Voltage gain = -6dB

Voltage gain @ Fc = -6dB

RC Passive Filters

- Low Pass – nth order
  - Voltage divider



$$v_{out} = v_{in} \left| \frac{Z_{R1}}{Z_{R1} + Z_{C1}} \right| \dots \left| \frac{Z_{Rn}}{Z_{Rn} + Z_{Cn}} \right|$$

$$v_{out} = v_{in} \left(\frac{R1}{\sqrt{R1^2 + \left(\frac{1}{2\pi f C1}\right)^2}} \right) \dots \left(\frac{Rn}{\sqrt{Rn^2 + \left(\frac{1}{2\pi f Cn}\right)^2}} \right)$$

$$f_{(-3dB)} = f_C \sqrt{2^{\left(\frac{1}{n}\right)} - 1}$$

$$v_{out} = v_{in}(0.707)^n \rightarrow F_{corner}$$

$$F_{corner} = F_c = \frac{1}{2\pi \sqrt[n]{R_1 C_1 \dots R_n C_n}}$$

Voltage gain @ Fc = $\left(\frac{1}{\sqrt{2}}\right)^n$ = n x (-3dB)

RC Passive Filters

- Band Pass

$$v_{out} = v_{in}\left|\frac{Z_{C1}}{Z_{R1}+Z_{C1}}\right|\left|\frac{Z_{R2}}{Z_{R2}+Z_{C2}}\right|$$

$$v_{out} = v_{in}\left(\frac{\frac{1}{2\pi f C1}}{\sqrt{R1^2+\left(\frac{1}{2\pi f C1}\right)^2}}\right)\left(\frac{R2}{\sqrt{R2^2+\left(\frac{1}{2\pi f C2}\right)^2}}\right)$$

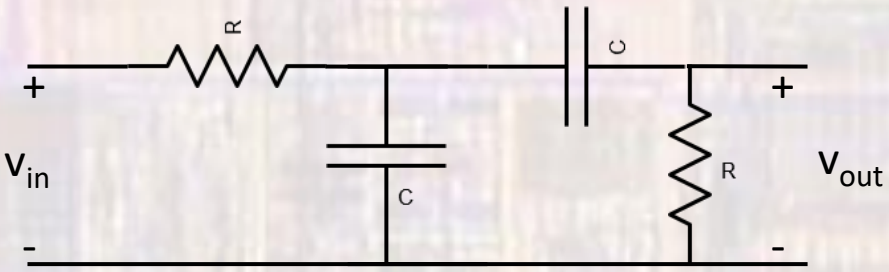
$$v_{out} = v_{in}(0.707)^2 = 0.5v_{in} \rightarrow F_{corner}$$

$$F_{cornerL} = F_{cL} = \frac{1}{2\pi\sqrt{R_1 C_1}}$$

$$F_{cornerU} = F_{cU} = \frac{1}{2\pi\sqrt{R_2 C_2}}$$

Voltage gain @ Fc = -3dB

Cascaded Filter



C1(F)	Frequency (Hz)	Impedance (Ohms)	Voltage Gain (dB)
1.00E-08	1.00E+00	6.28E-03	-44
R1(Ohms)	1.00E+01	6.27E-02	-24
10	1.00E+02	5.32E-01	-5
C2(F)	1.00E+03	9.88E-01	0
1.00E-05	1.00E+04	1.00E+00	0
R2(Ohms)	1.00E+05	9.98E-01	0
100	1.00E+06	8.47E-01	-1
	1.00E+07	1.57E-01	-16
	1.00E+08	1.59E-02	-36
	1.00E+09	1.59E-03	-56

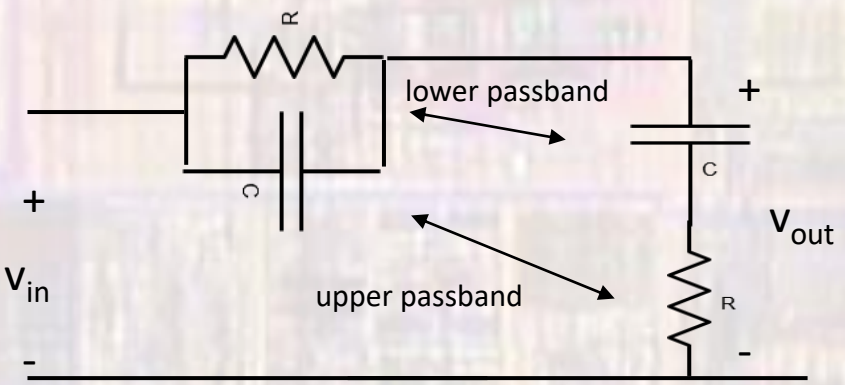
FcU = 1.592MHz, Voltage gain = -3dB

FcL = 159.2Hz, Voltage gain = -3dB

$$f_{center} = \sqrt{f_U x f_L}$$

RC Passive Filters

- Band Stop



$$v_{out} = v_{in}\left|\frac{Z_{C2} + Z_{R2}}{Z_{R1}||Z_{C1} + Z_{C2} + Z_{R2}}\right|$$

$$v_{out} = v_{in}\left[\frac{\frac{1}{2\pi fC2}}{\sqrt{(R1+R2)^2 + \left(\frac{1}{2\pi fC2}\right)^2}} + \frac{R}{\sqrt{(R1||R2)^2 + \left(\frac{1}{2\pi fC1}\right)^2}}\right]$$

C1(F)	Frequency (Hz)	Impedance (Ohms)	Voltage Gain (dB)
1.00E-05	1.00E+00	1.00E+00	0
R1(Ohms)	1.00E+01	9.98E-01	0
100	1.00E+02	8.47E-01	-1
C2(F)	1.00E+03	1.63E-01	-16
1.00E-07	1.00E+04	7.86E-02	-22
R2(Ohms)	1.00E+05	5.34E-01	-5
10	1.00E+06	9.88E-01	0
	1.00E+07	1.00E+00	0
	1.00E+08	1.00E+00	0
	1.00E+09	1.00E+00	0

$$v_{out} = v_{in}(0.707) \rightarrow F_{corner}$$

$$F_{cornerL} = F_{cL} = \frac{1}{2\pi C2(R1+R2)}$$

$$F_{cornerU} = F_{cU} = \frac{1}{2\pi C1(R1||R2)}$$

Voltage gain @ Fc = -3dB

FcU = 176KHz, Voltage gain = -3dB

FcL = 145Hz, Voltage gain = -3dB

$$f_{center} = \sqrt{f_U x f_L}$$