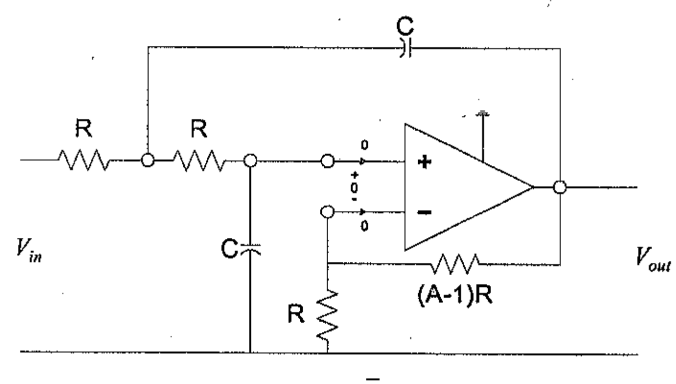
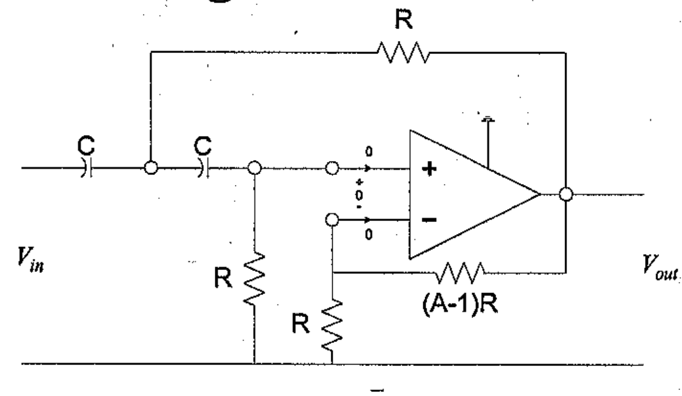
# *Second-Order Sallen-Key Filters*

## S.K. Low-Pass Filter



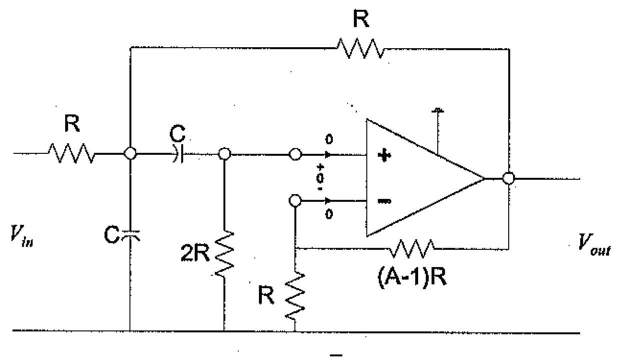

$$\omega_c = \frac{1}{RC},\quad A_v = A,\quad Q = \frac{1}{3-A}$$

## S.K. High-Pass Filter



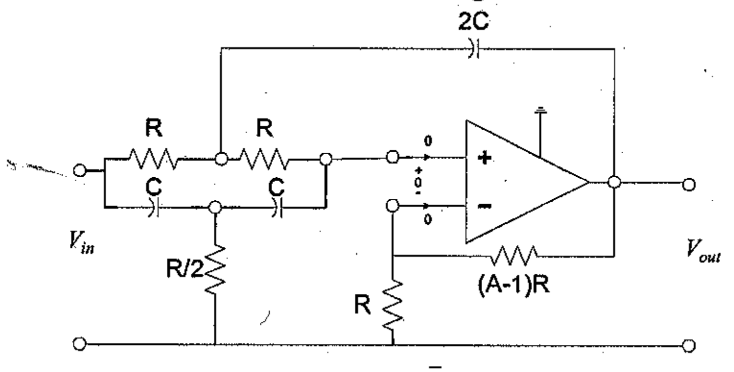

$$\omega_c = \frac{1}{RC},\quad A_v = A,\quad Q = \frac{1}{3-A}$$

## S.K. Band-Pass Filter




$$\omega_o = \frac{1}{RC}\quad Q = \frac{1}{3-A}\quad A_v = AQ$$

## S.K. Band-Reject Filter




$$\omega_o = \frac{1}{RC}\quad Q = \frac{1}{4-2A}\quad A_v = A$$

**Properties of Sallen-Key Filters:**

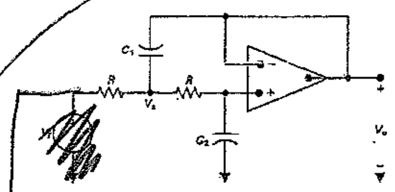
1. **Simplicity of the design**
2. **Non-Inverting Amplifier (positive Gain)**
3. **Replication of elements**

**Limitations of Sallen-Key Filters:**

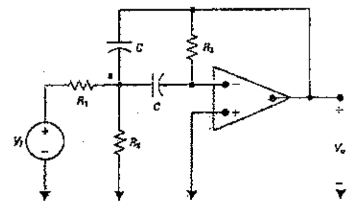
1. **The Gain and Q are related**
2. ***O* must be > ½, since *A* must be > 1**

6. Given these filter circuits with associated transfer functions:

HPF

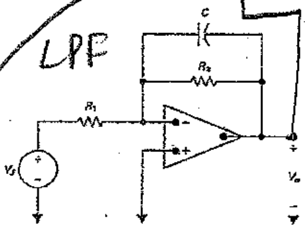


$$\frac{s^2}{s^2+2s/(RC_1)+1/(R^2C_1C_2)}$$

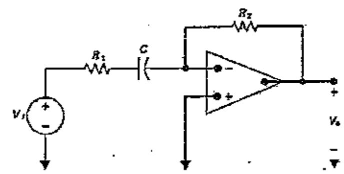


$$\frac{-s/(R_1C)}{s^2+2s/(R_3C)+(R_1+R_2)/(R_1R_2R_3C^2)}$$

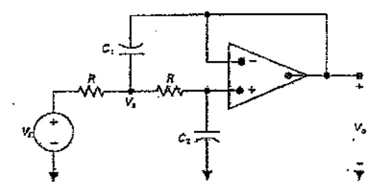
LPF



$$\frac{-1/(R_1C)}{s+1/(R_2C)}$$



$$\frac{-sR_2/R_1}{s+1/(R_1C)}$$



$$\frac{1/(R^2C_1C_2)}{s^2+2s/(RC_1)+1/(R^2C_1C_2)}$$

Using the above active filter blocks, design a broadband bandpass filter with corner frequencies of $\omega_{c1} = 2000$ rad/s and $\omega_{c2} = 10^5$ rad/s and a pass-band gain of 200 (46dB). At high frequencies, a drop-off of -20dB/decade is sufficient. However, for low frequencies, the gain must be below 0dB for frequencies below 100 rad/s. Also, the gain at the lower corner frequency ($\omega_{c1}$) should be 160. Choose all component values. (30)

$$\frac{\omega_{c1}}{\omega_s} = \frac{2000}{100} = 20 = 10^{1.3} \qquad \frac{46\,dB}{1.3\ \text{decades}} = 37\ \frac{dB}{\text{decade}} \qquad n \geq 2 \text{ for HPF}$$

Thus can use 2nd order HPF w/ $W_{c1} = 2000\ \frac{rad}{s}$ & $Q = \frac{160}{200} = 0.8$

and 1st order LPF w/ $W_{c2} = 10^5$ and gain of 200

For HPF, $W_{c1}^2 = (2000)^2 = \frac{1}{R^2C_1C_2}$ and $\frac{W_{c1}}{Q} = \frac{2000}{0.8} = \frac{2}{RC_1}$

Take $R = 10k\Omega = 10^4$, then $C_1 = \frac{2(0.8)}{2000(10^4)} = 8\times10^{-8}F = 80nF$

$$C_2 = \frac{1}{(2000)^2(10^4)^2\, 8\times10^{-8}} = \frac{1}{32\times10^6} = 3.1\times10^{-8} = 31nF$$

For LPF, $W_{c2} = 10^5 = 1/R_2C$, $|A_{pb}| = 200 = \frac{R_2}{R_1}$

Use $R_2 = 200k\Omega$

$R_1 = 1k\Omega$

$$C = \frac{1}{(2\times10^5)(10^5)} = 5\times10^{-11}F = 50pF$$

End Of Exam