Sallen-Key low pass filter LTspice simulation

Presented to DR.Fatma Mazen
Prepared by Mai Omar

Contents

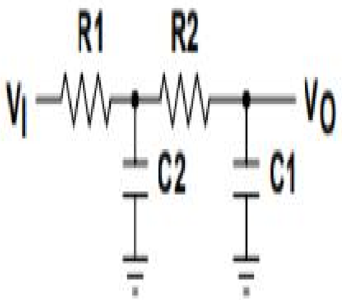
Motivations

The report gives a general overview Sallen-Key General Circuit analysis, followed by detailed discussions of low-pass , including design information, and Simulations.

---

1 Introduction

Figure 1 shows a two-stage RC network that forms a second order low-pass filter. This filter is limited because its Q is always less than 1/2. With R1=R2 and C1=C2, Q=1/3. Q approaches the maximum value of 1/2 when the impedance of the second RC stage is much larger than the first. Most filters require Qs larger than 1/2.

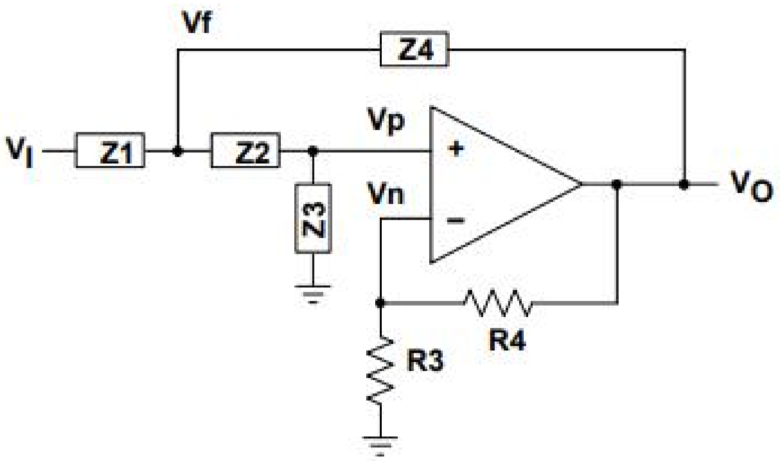


$$\frac{Vo}{Vi} = \frac{1}{s^2(R1C2R2C1) + s(R1C2 + R2C1 + R1C1) + 1}$$

Figure 1. Basic Second Order Low-Pass Filter

Generalized Circuit Analysis

The circuit shown in Figure 2 is a generalized form of the Sallen-Key circuit, where generalized impedance terms, Z, are used for the passive filter components, and R3 and R4 set the pass–band gain



To find the circuit solution for this generalized circuit, find the mathematical relationships between Vi, Vo, Vp, and Vn, and construct a block diagram. KCL at Vf: Vf Z1

KCL at Vf:

$$Vf\left(\frac{1}{Z1} + \frac{1}{Z2} + \frac{1}{Z4}\right) = Vi\left(\frac{1}{Z1}\right) + Vp\left(\frac{1}{Z2}\right) + Vo\left(\frac{1}{Z4}\right)$$

KCL at Vp:

$$Vp\left(\frac{1}{Z2} + \frac{1}{Z3}\right) = Vf\left(\frac{1}{Z2}\right) \Rightarrow Vf = Vp\left(1 + \frac{Z2}{Z3}\right)$$

Substitute Equation (2) into Equation (1) and solve for Vp:

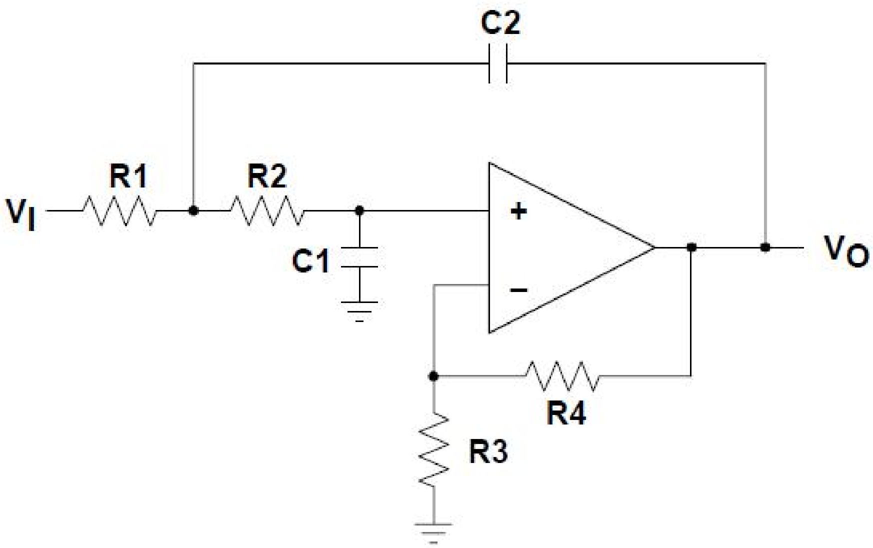
$$Vp = Vi\left(\frac{Z2Z3Z4}{Z2Z3Z4 + Z1Z2Z4 + Z1Z2Z3 + Z2Z2Z4 + Z2Z2Z1}\right) +$$

$$Vo\left(\frac{Z1Z2Z3}{Z2Z3Z4 + Z1Z2Z4 + Z1Z2Z3 + Z2Z2Z4 + Z2Z2Z1}\right)$$

KCL at Vn:

$$Vn\left(\frac{1}{R3} + \frac{1}{R4}\right) = Vo\left(\frac{1}{R4}\right) \Rightarrow Vn = Vo\left(\frac{R3}{R3 + R4}\right)$$

Low-Pass Sallen-Key Circuit



Hand Analysis with Filter Components Equal

Letting R1=R2=R, and C1=C2=C, results in:

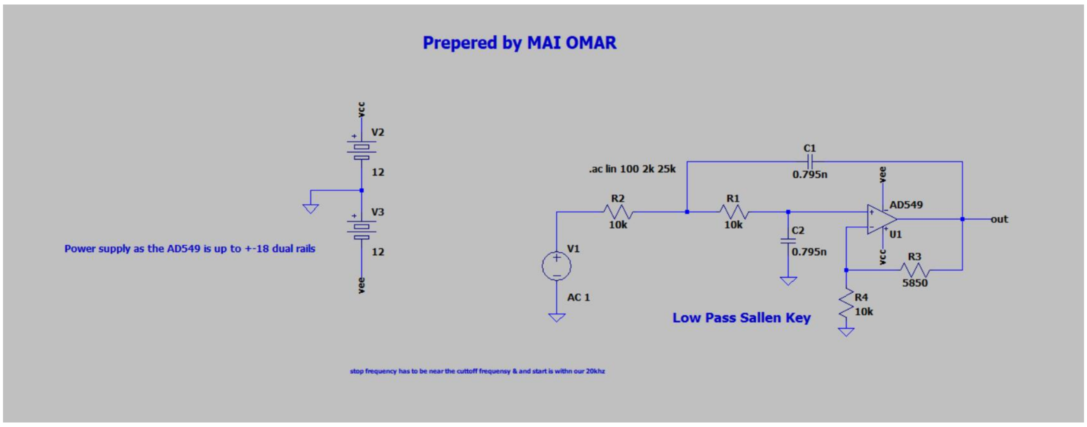
1- Fc =1/2pi RC
2- Wo/Q = 3-k/RC
3- Wo= 1/RC

If we substitute with any Realizable Values for R,C we will get K.

K=1.58 → 20log(K)= 4db

Simulation Results

1- Circuit



2- Putting Vin =1 so gain = Vout (Magnitude &Phase with cursor at 1db)