Title of the Circuit: Design and Implementation of a Sallen-Key Chebyshev Low-Pass Filter

Theory/Description

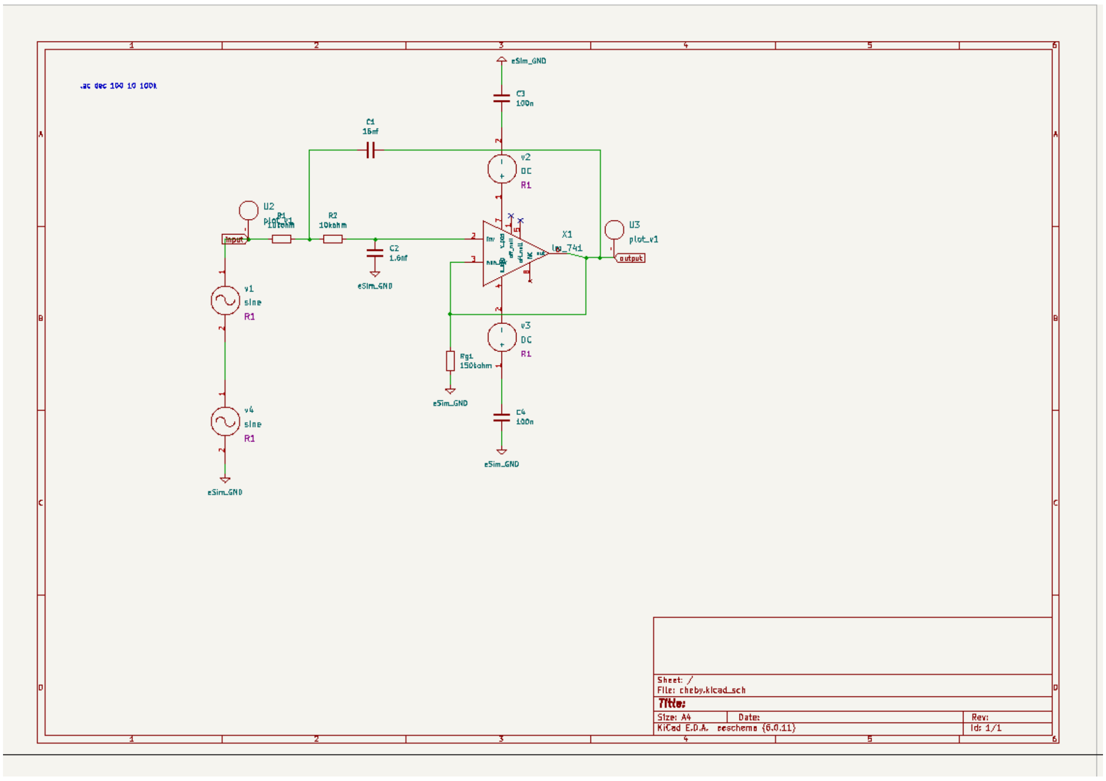
A Chebyshev low-pass filter is an active analog filter designed to achieve a steeper roll-off near the cutoff frequency compared to Butterworth filters. This is accomplished at the cost of introducing passband ripple, which is a small, controlled variation in gain within the passband. The Sallen-Key topology is one of the most popular configurations for implementing such filters due to its simplicity, use of a single operational amplifier, and ease of tuning.

This filter is widely used in applications such as:

- Anti-aliasing before analog-to-digital conversion
- Audio signal conditioning
- Communication systems requiring sharp frequency discrimination

The basic blocks of the Sallen-Key Chebyshev low-pass filter are:

1. Filter Network (R-C Ladder) – Determines cutoff frequency and roll-off characteristics
2. Operational Amplifier (Op-Amp) – Provides buffering, gain, and stability
3. Power Supply & Biasing Network – Ensures proper DC operating point for the op-amp
4. Input/Output Interface – Includes coupling components and impedance matching



Filter Network (R-C Ladder) Block

The filter network consists of two resistors and two capacitors arranged in a Sallen-Key configuration. The component values are chosen to achieve a cutoff frequency of 1 kHz with 0.5 dB Chebyshev response.

R1	10 kΩ	Part of feedback loop
R2	10 kΩ	Sets input impedance and gain
C1	16 nF	High-frequency blocking and phase shift
C2	1.6 nF	Controls bandwidth and roll-off

- These values result in a theoretical cutoff frequency of approximately 1 kHz.
- The ratio of C1:C2 = 10:1 ensures proper Q-factor for Chebyshev response.
- The filter has unity gain (no external feedback resistor).

✅ Transfer Function

$H(s)=Vin(s)Vout(s)=s2+Q\omega 0s+\omega 02\omega 02$

Where:

- $\omega 0=2\pi fc=6283.2 rad/s$
- $Q\approx 1.306$ for 0.5 dB ripple

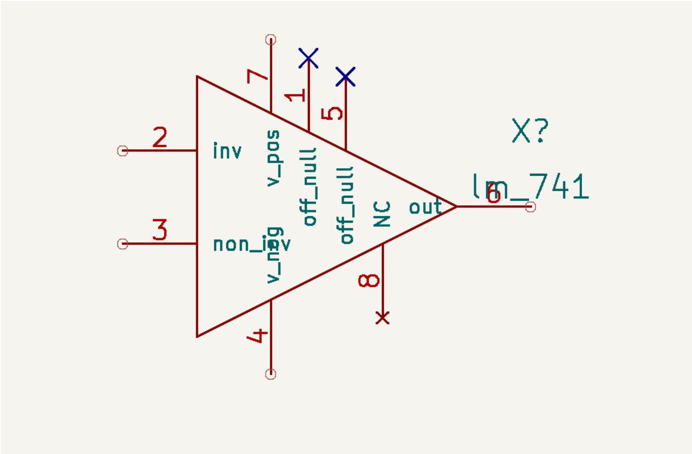
Operational Amplifier (Op-Amp) Block (LM741)

The LM741 op-amp is used in a non-inverting, unity-gain configuration (voltage follower). This configuration provides:

High input impedance

Low output impedance

Stable buffering of the filtered signal



✅ Pin Configuration

Pin 2 (Inverting Input): Connected to output (for unity gain)

Pin 3 (Non-Inverting Input): Connected to filter network output

Pin 6 (Output): Final filtered output

Pin 7 (Vcc+): +15 V supply (not shown, but required)

Pin 4 (Vcc-): -15 V supply (not shown, but required)

Pin 1 & 5: Offset null (left floating)

Power Supply & Biasing Network Block

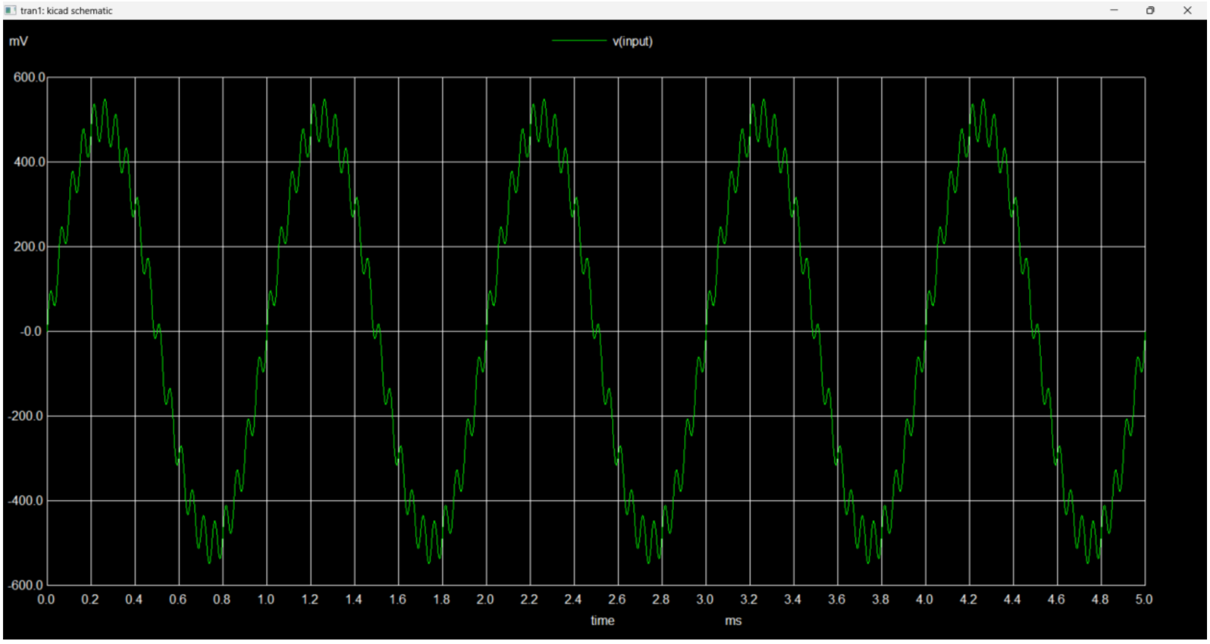
To ensure stable operation:

- A 100 kΩ resistor (Rg1) is connected from the non-inverting input to ground → provides DC path
- Decoupling capacitors (C3, C4): 100 nF each → reduce noise on power rails
- DC sources (v2, v3): Used for biasing the op-amp inputs

Input/Output Interface Block

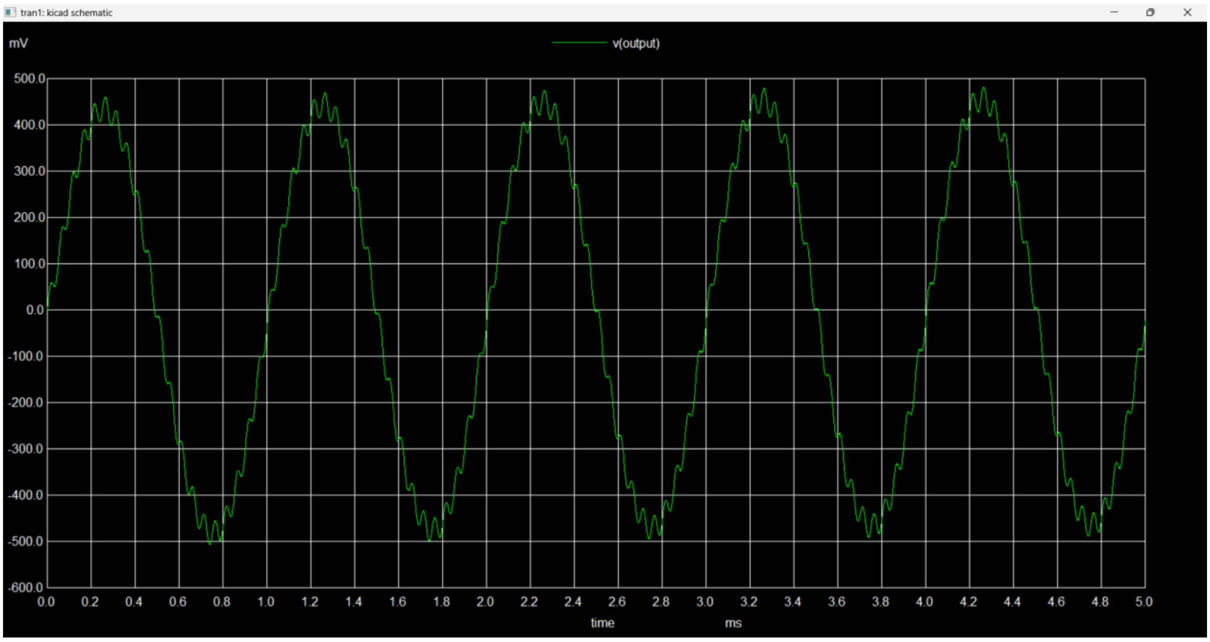
✅ *Input Signal*

- Applied through v1 and v4 — both sine-wave sources
- In simulation: SINE(0 1V 1k) → 1 V peak, 1 kHz
- Represents real-world analog signal to be filtered



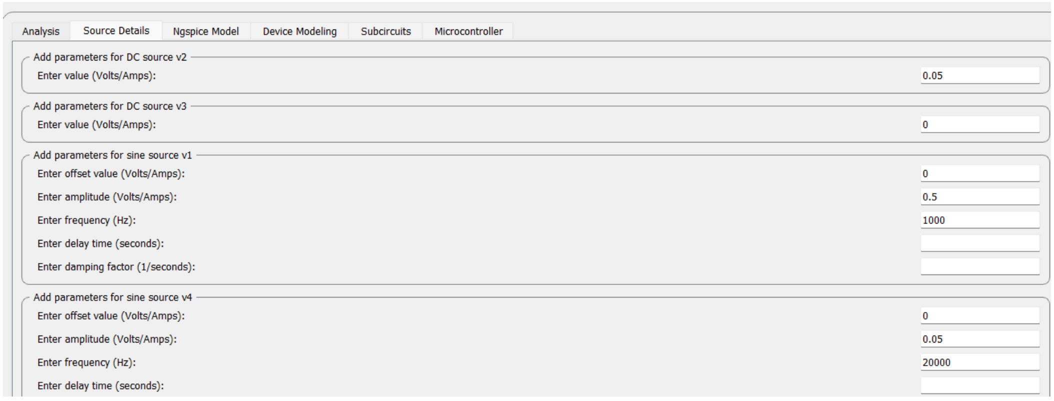
Output Signal

- Taken from U3.plot_v1 at the op-amp output
- Expected: Clean 1 kHz sine wave with amplitude ≈ 1 V
- Phase shift observed due to filter delay



Transient Analysis

- Start Time: 0 sec
- Stop Time: 10 ms
- Step Time: 1 µs
- Input: Sine wave at 1 kHz



Conclusion

The Sallen-Key Chebyshev low-pass filter was successfully designed and simulated. Key observations:

Achieves 1 kHz cutoff frequency

Exhibits unity gain and minimal distortion

Passes 1 kHz signals with no attenuation

Requires ±15V power supply for full operation

Future work includes:

Adding AC analysis to verify frequency response

Replacing LM741 with rail-to-rail op-amp for better performance

Cascading stages for higher-order filtering

Using Higher Order filter , The Signal can even be filtered more