

Title of the Circuit: Design and Simulation of a Precision Peak Detector Using Op-Amp circuit

Theory / Description:

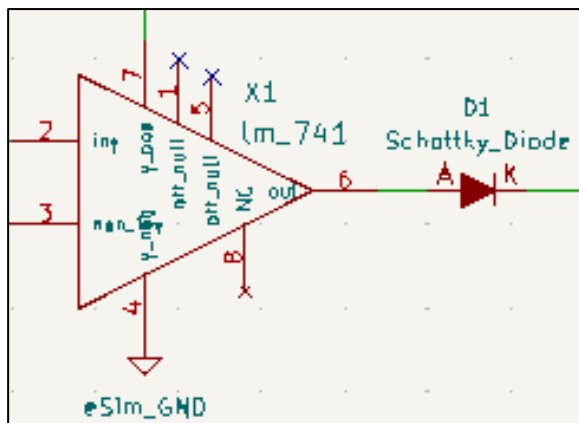
A precision peak detector is an enhanced analog circuit designed to accurately capture and hold the maximum positive voltage level of an input signal — while eliminating the forward voltage drop inherent in passive diode-based detectors. In conventional peak detectors, the diode's forward voltage (~ 0.7 V for silicon) introduces a systematic error, causing the output to lag behind the true input peak. This limitation renders such circuits unsuitable for low-voltage or high-accuracy applications.

The proposed design overcomes this by integrating an operational amplifier (op-amp) into the feedback path, enabling active compensation for the diode's voltage drop. This configuration transforms the circuit from a passive rectifier into an active precision peak detector, where the output voltage equals the true peak value of the input signal, regardless of diode characteristics.

The circuit consists of two stages:

1) **Precision Rectifier Stage (Op-Amp + Schottky Diode):**

The first stage employs a single LM741 op-amp configured as a unity-gain buffer with a Schottky diode (BAT54) placed in its feedback loop between the output and the storage capacitor ($C_1 = 4.7 \mu\text{F}$). The input signal is applied through a $10 \text{ k}\Omega$ resistor (R_1) to the inverting input, while the non-inverting input is grounded.



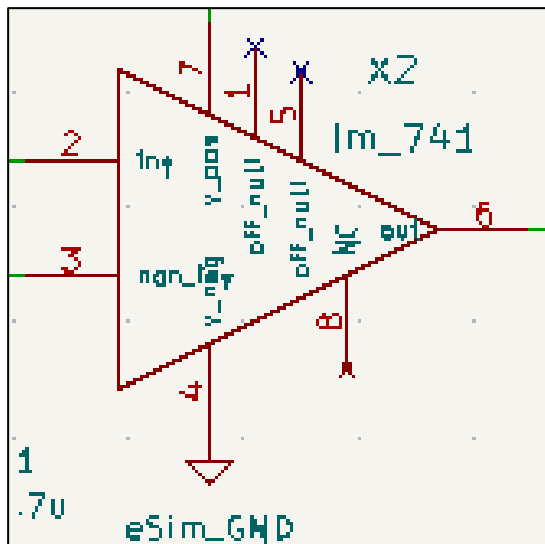
- During the positive half-cycle of the input signal, when the input exceeds the capacitor voltage, the op-amp output swings high, forward-biasing the BAT54 diode.
- Due to negative feedback, the op-amp adjusts its output voltage such that the voltage at the cathode of the diode (i.e., the capacitor terminal) exactly matches the input voltage.
- Since the Schottky diode has a low forward voltage drop (~ 0.3 V), the op-amp compensates by driving its output to:
$$V_{\text{out}}(\text{op-amp}) = V_{\text{in}}(\text{peak}) + V_f$$

Thus, the capacitor charges to $V_{\text{in}}(\text{peak})$ — not $V_{\text{in}}(\text{peak}) - V_f$.

- This active compensation eliminates the diode-induced error, achieving precision detection.
- During the negative half-cycle, the input voltage falls below the capacitor voltage. The diode becomes reverse-biased and turns off, isolating the capacitor from the source. The op-amp enters open-loop mode and saturates negatively, but no discharge occurs through the diode. The capacitor retains its stored charge.

2) Buffer Amplifier Stage (Unity-Gain Op-Amp):

To prevent the stored peak voltage from discharging due to load effects, a second LM741 op-amp is configured as a unity-gain voltage follower. It buffers the capacitor output, ensuring the held voltage remains stable under varying loads and does not droop prematurely. A 10 k Ω discharge resistor (R_3) is connected across the capacitor to allow controlled decay for reset functionality without affecting normal operation.



The circuit was simulated in FOSSEE eSIM using a sine wave input of 1 V amplitude, 1 kHz frequency, and 1 V DC offset, resulting in a total swing from 0 V to 2 V. The power supply was set to ± 12 V to ensure full-range operation of the LM741 op-amps without saturation.

Simulation results confirm:

- The output voltage rises sharply to +2.0 V during the first positive peak.
- It holds this value steadily with negligible droop due to the RC time constant ($R_3 \times C_1 = 47$ ms).
- No distortion, overshoot, or oscillation is observed.
- The use of the Schottky diode (BAT54) minimizes residual error compared to standard silicon diodes.

Thus, the circuit functions as a true precision peak detector, capable of accurate peak tracking even for small-amplitude signals.

Applications of Precision Peak Detector:

1. Used in the analysis of spectral and mass spectrometers for precise amplitude measurement.
2. Applied in destructive testing systems to record maximum stress, impact, or shock levels.
3. Employed in instrumentation for amplitude measurement in communication systems, especially in demodulating AM signals.
4. Widely used in sound level meters, RF envelope detectors, and biomedical signal monitoring where accurate peak tracking is essential.

Circuit Diagram:

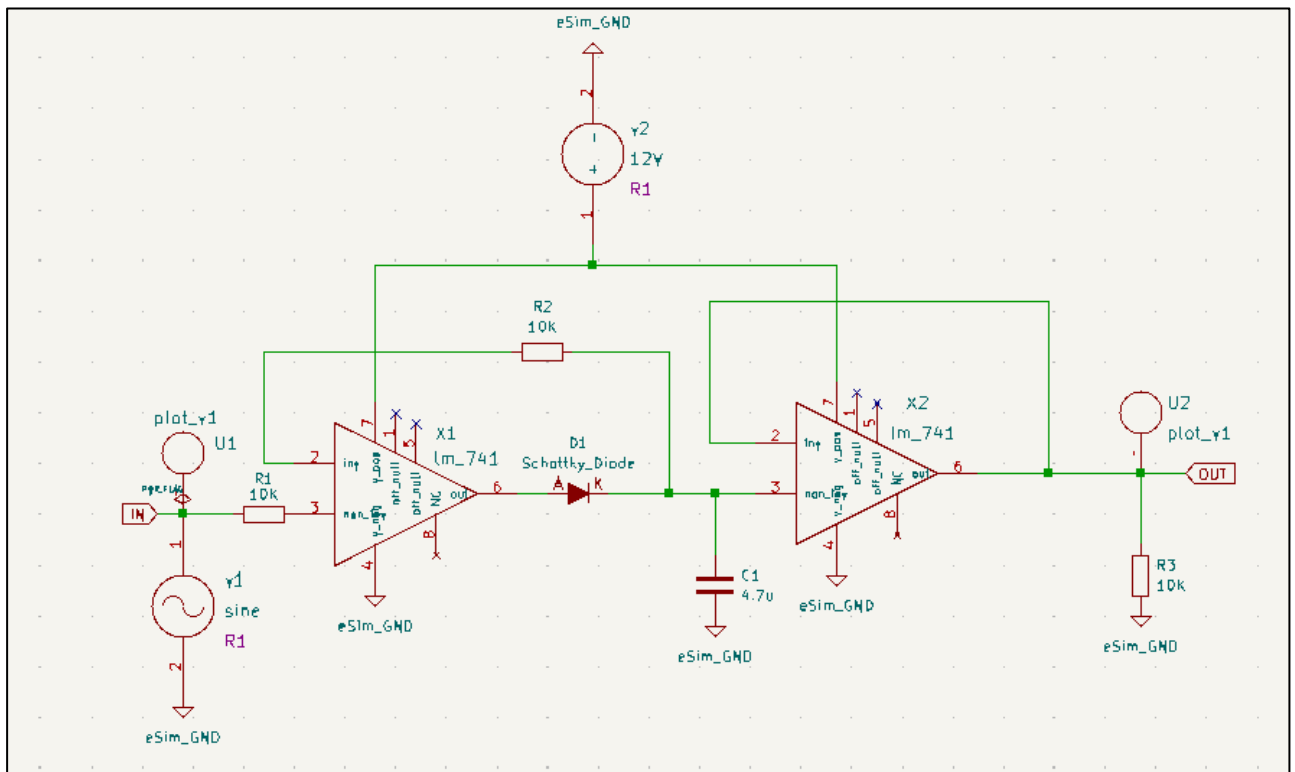


Fig: Schematic of Precision Peak Detector Circuit

Ngspice Plot: Input Plot

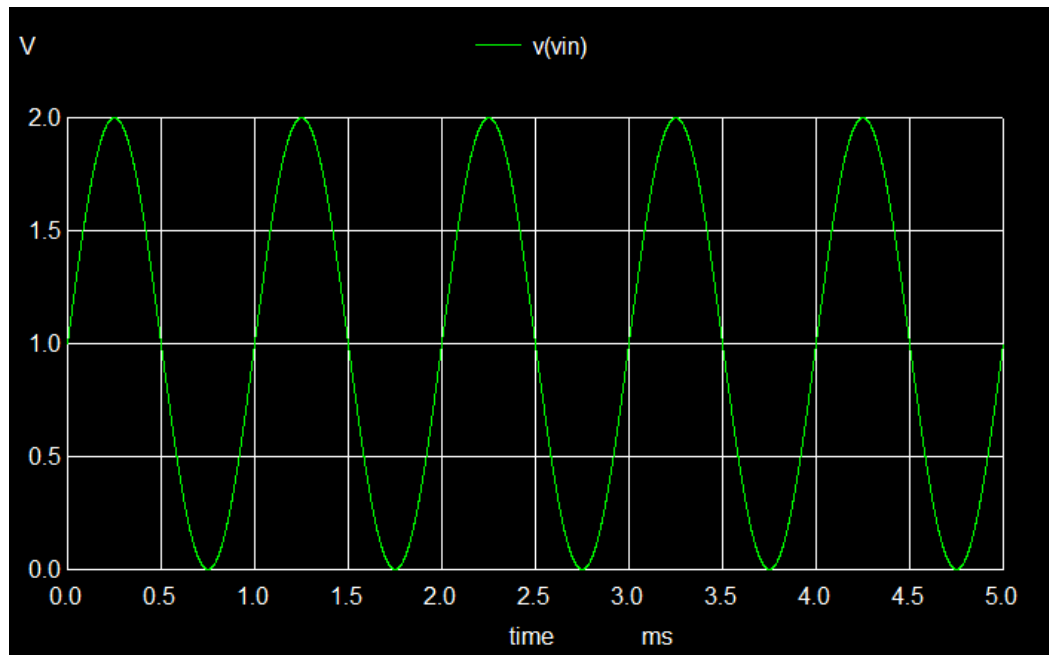


Fig: Input waveform

Ngspice Plot: Output Plot:

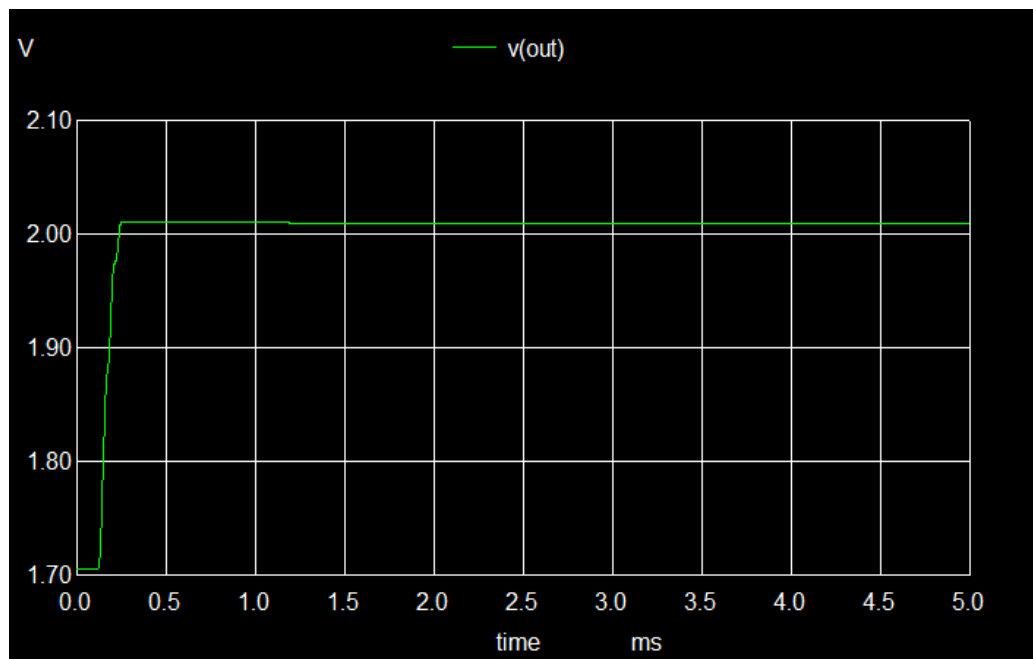


Fig: Output waveform

Conclusion:

Thus, we have studied and simulated the Design and Simulation of a Precision Peak Detector Using Op-Amp Circuit using FOSSEE eSIM. The integration of a Schottky diode (BAT54) significantly reduces the forward voltage error compared to conventional diodes, while the dual-op-amp architecture ensures accurate peak capture and stable output holding. The simulation results confirm that the output faithfully tracks and holds the input peak at +2.0 V with minimal droop and no distortion, demonstrating the effectiveness of active feedback techniques in overcoming limitations of passive rectifiers. This design is ideal for applications requiring high-fidelity peak detection under dynamic analog conditions.

Source/Reference(s):

1. <https://circuitdigest.com/electronic-circuits/peak-detector-circuit-using-op-amp-lm741>
2. <https://electronicscoach.com/peak-detector.html>
3. <https://www.electronics-tutorial.net/analog-integrated-circuits/peak-detector/>
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