

Aim ⇨ To design and verify the differentiator circuit using Operational Amplifier.

Equipment Required ⇨

Resistors, Capacitor, IC 741 OP-AMP, Function Generator, DSO, Breadboard & Wires.

Theory ⇨

A **differentiator** circuit is an analog circuit that performs mathematical differentiation, generating an output voltage proportional to the input voltage's rate of change (derivative). It is widely used in signal processing, waveform shaping, and control systems. The circuit consists of a capacitor C connected to the input and a resistor R in the feedback loop.

When an input voltage is applied, the capacitor allows current to flow in response to changes in the input signal. The resistor in the feedback loop converts this current into a proportional output voltage. Mathematically, the output voltage is expressed as:

$$V_{out} = -RC \frac{dV_{in}}{dt}$$

The resistor-capacitor combination ensures the differentiation operation, while the negative sign indicates a phase inversion. The circuit is effective for high-frequency signals, differentiating accurately without distortion. However, low-frequency noise or DC offsets can cause output distortion, which design adjustments can mitigate.

The differentiator circuit primarily converts a triangular wave input into a square wave, demonstrating its ability to detect rapid signal changes. The amplitude of the output waveform depends on the rate of change of the input signal and the values of R and C, emphasizing its role in waveform shaping applications. It is also used in analog computers, high-pass filters, and control systems for detecting signal edges or abrupt changes. The circuit's accuracy depends on the components' quality and the power supply's stability.

In practical applications, the circuit is sensitive to high-frequency noise, which can amplify and distort the output. To overcome this, a small capacitor is often placed parallel to the feedback resistor, creating a low-pass filter to stabilize the output. Additionally, proper selection of R and C ensures that the circuit operates effectively within the desired frequency range, with the critical frequency $f_c = \frac{1}{2\pi RC}$ marking the transition between differentiation and attenuation behavior. These

design considerations make the differentiator versatile and robust for real-world applications.

Circuit Diagram ↗

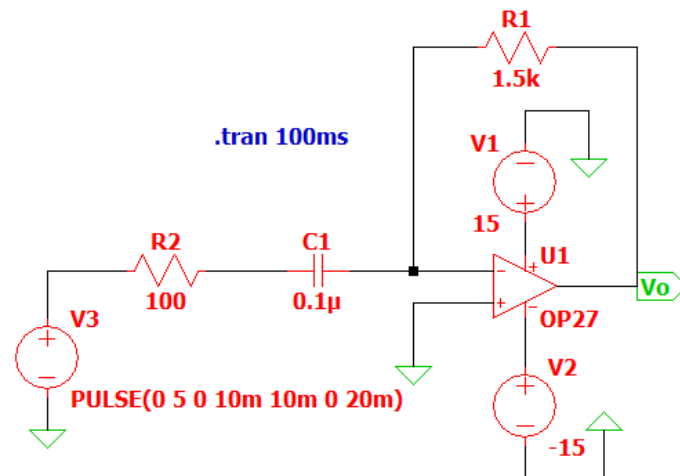


Fig. i) Differentiator Circuit using OpAmp

Graphs ↗

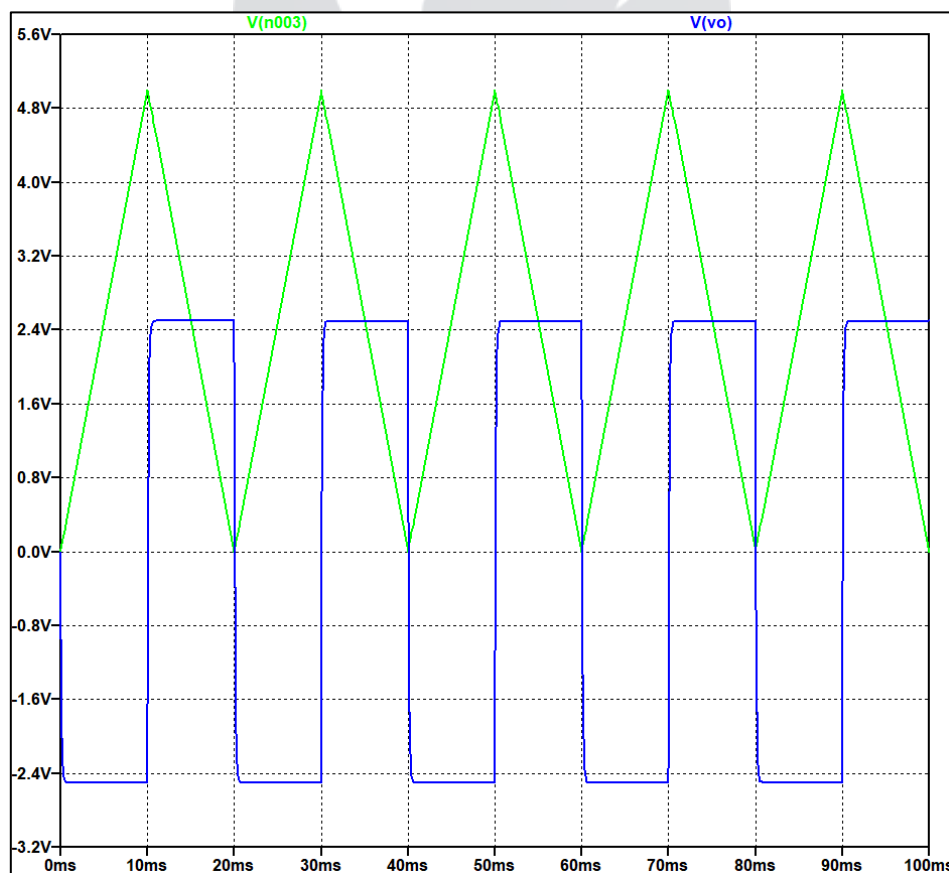


Fig. ii) Differentiating Triangular Wave into Square Wave

Output ⇌

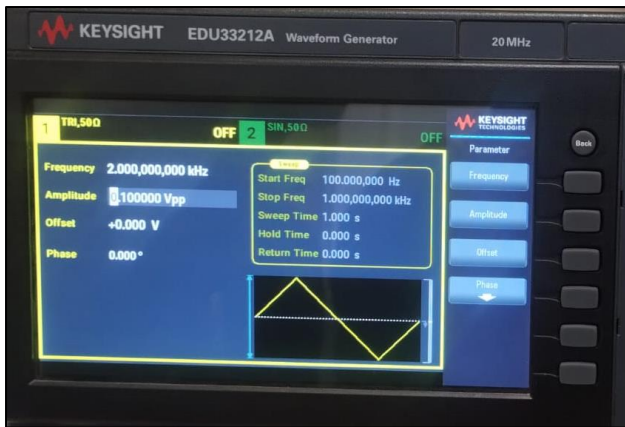


Fig. iii) Input Triangular Wave

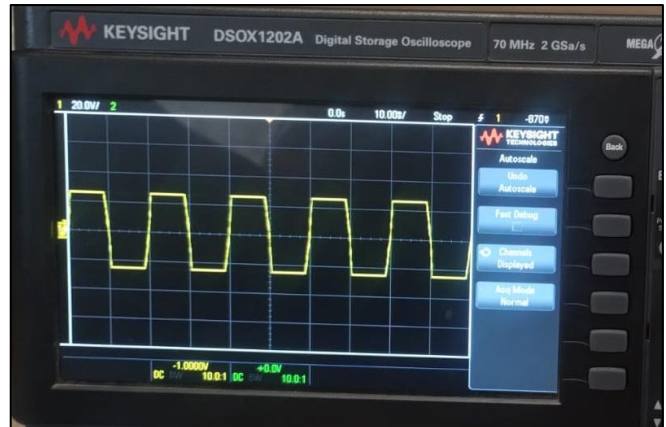


Fig. iv) Output Square Wave

Result ⇌

The differentiator circuit was successfully designed and tested, producing an output waveform proportional to the rate of change of the input signal, as expected.

Conclusion ⇌

The circuit operated as predicted, demonstrating the functionality of the differentiator and validating the theoretical calculations for signal differentiation.

Precautions ⇌

- Ensure proper placement of the resistor and capacitor and correct wiring of the circuit components on the breadboard.
- Verify the power supply connections to the OpAmp to prevent damage.
- Make sure input voltage levels are within the allowable range for the IC 741 OpAmp to avoid distortion or malfunction.
- Double-check the values of the resistor and capacitor to ensure accurate differentiation and proper circuit operation.
- Avoid high-frequency noise at the input, as it can amplify and distort the output waveform.