Using a Comparator in Oscillator Circuits

AND90426/D

INTRODUCTION

Comparators are commonly used in oscillator circuits due to their fast switching behavior and well defined output states. When combined with positive feedback and an RC timing network, a comparator (such as NCS2250) can function as a square-wave generator or relaxation oscillator (nonlinear electronic oscillator circuit that produces a non-sinusoidal repetitive output signal). This application note describes the operating principles, design considerations, and typical circuit configurations for comparator based oscillators.

OPERATING PRINCIPLE

A comparator compares an input voltage against a reference threshold and drives its output high or low depending on the polarity of the difference.

In an oscillator configuration:

- The comparator output feeds back to the input through a resistor network, creating hysteresis (Schmitt trigger behavior).
- An RC network introduces a time delay, causing the input voltage to ramp up and down.
- The comparator output switches state when the RC voltage crosses the upper or lower threshold, generating oscillation.

The combination of hysteresis and the RC charging/discharging profile produces a stable square-wave output.

BASIC RELAXATION OSCILLATOR USING A COMPARATOR

Circuit Diagram

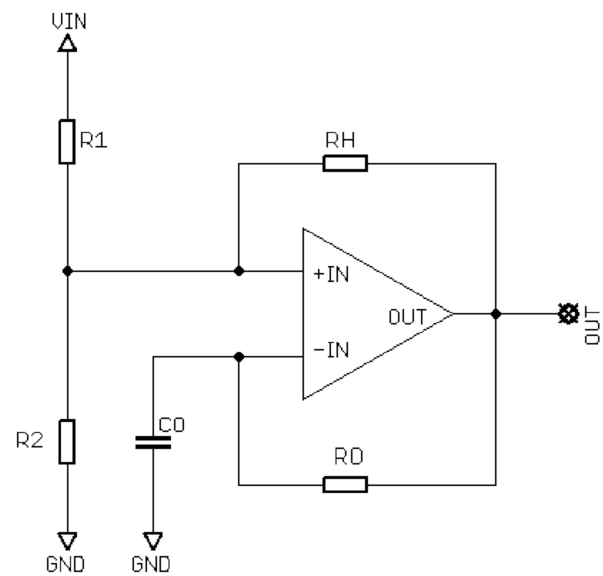

Figure 1. Circuit Diagram

NOTES:
1. R_1 and R_2 create voltage divider from input to create positive/ negative threshold
2. R_H creates feedback from output (hysteresis)
3. R_0 and C_0 create oscillator time constant
4. The output toggles when the capacitor voltage reaches one of the two switching thresholds
5. V_{IN} voltage is input voltage for resistive divider and supply voltage of the comparator

Comparator Thresholds

The upper and lower switching thresholds are (in case of rail-to-rail output):

$$V_{TH+} = \frac{R_2}{R_1 \parallel R_H + R_2} \cdot V_{IN} \qquad \text{(eq. 1)}$$

$$V_{TH-} = \frac{R_1 \parallel R_H}{R_1 + R_2} \cdot V_{IN} \qquad \text{(eq. 2)}$$

These thresholds determine the amplitude of the capacitor voltage swing.

Oscillation Frequency

The frequency is defined by the RC time constant and the hysteresis window (the hysteresis window is input V_{IN} voltage independent when comparator is supplied from V_{IN} voltage an d rail to rail comparator is used):

$$f = \frac{1}{2 \cdot R_0 \cdot C_0 \cdot \left| \ln\left(\frac{V_{TH-}}{V_{TH+}}\right) \right|} \qquad \text{(eq. 3)}$$

For symmetric thresholds defined by $R_1 = R_2 = R_H$ and rail-to-rail output, this simplifies to approximately:

$$f \approx \frac{1}{2 \cdot R_0 \cdot C_0 \cdot |\ln(0.5)|} \qquad \text{(eq. 4)}$$

Then

$$R_0 = \frac{1}{2 \cdot f \cdot C_0 \cdot |\ln(0.5)|}, \quad C_0 = \frac{1}{2 \cdot f \cdot R_0 \cdot |\ln(0.5)|} \qquad \text{(eq. 5)}$$

DESIGN CONSIDERATIONS

Comparator Type

Select a comparator with:

- *Rail-to-rail output* for predictable thresholds
- *Fast propagation delay* if high frequency is desired
- *Push-pull output* (open-collector also possible but requires pull up resistor)
- *Input common-mode range* compatible with capacitor voltage swing

Hysteresis Level

Greater hysteresis increases:

- Stability
- Noise immunity
- Oscillation amplitude

But decreases maximum oscillation frequency due to larger voltage swing.

Power Supply

A stable and sufficiently large supply voltage improves:

- Switching speed
- Output waveform shape
- Threshold accuracy

Capacitor Selection

Use:

- Film or C0G/NP0 ceramic capacitors for frequency stability
- Larger capacitor values for lower frequency oscillators

Component Selection

Based on above equations one of component (R_O or C_O) has to be selected and second component can be calculated. The chart and table below are results of calculated frequency and should help to select appropriate components values.

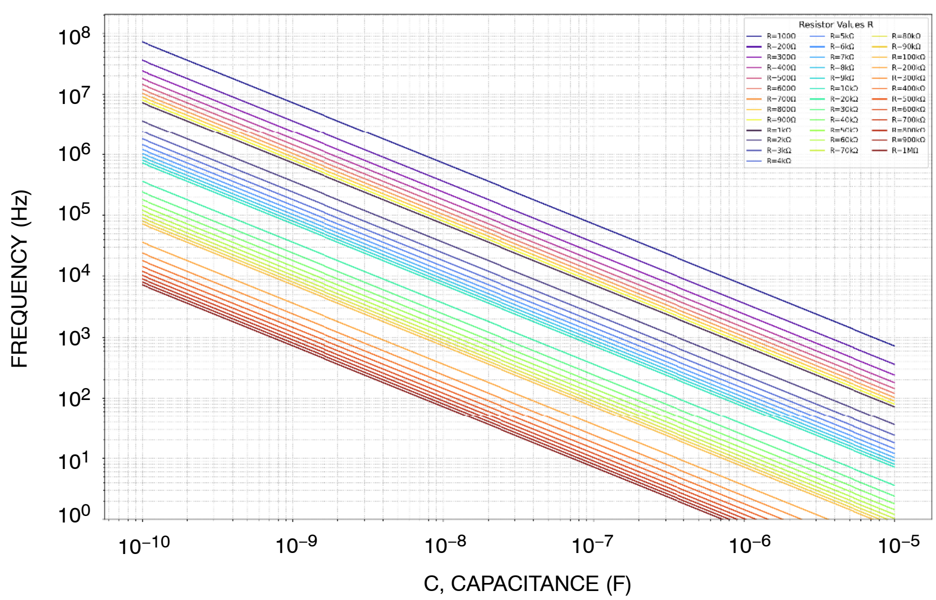

Figure 2. Frequency vs Capacitance C for Various Resistor Values R

Targeted Frequency (Hz)	R_O (Ω, E24)	C_O (F, E24)	Calculated Frequency (Hz)
1	200 kΩ	3.6 μF	1.0019
10	24 kΩ	3.0 μF	10.0187
100	2 kΩ	3.6 nF	100.187
1 000	20 kΩ	36 nF	1001.87
10 000	2 kΩ	36 nF	10018.7
100 000	2 kΩ	3.6 nF	100187
1 000 000	2 kΩ	360 pF	1 001 872
10 000 000	24 kΩ	3.0 pF	10 018 720

DESIGN EXAMPLE

Target frequency: 1 kHz
Supply voltages: 3.3 V
Comparator: NCS2250 like
Selected values:

- R_1 = 8.2 kΩ
- R_2 = 8.2 kΩ
- R_H = 8.2 kΩ
- R_O = 20 kΩ
- C_O = 36 nF

Comparator Type

With these values:

- Thresholds ≈ 1.1 V and 2.2 V
- Calculated frequency ≈ 1.002 kHz

The output will be a square wave with nearly 50% duty cycle as is shown on simulation result (simulated frequency is 1/1.01359 = 0.908 kHz):

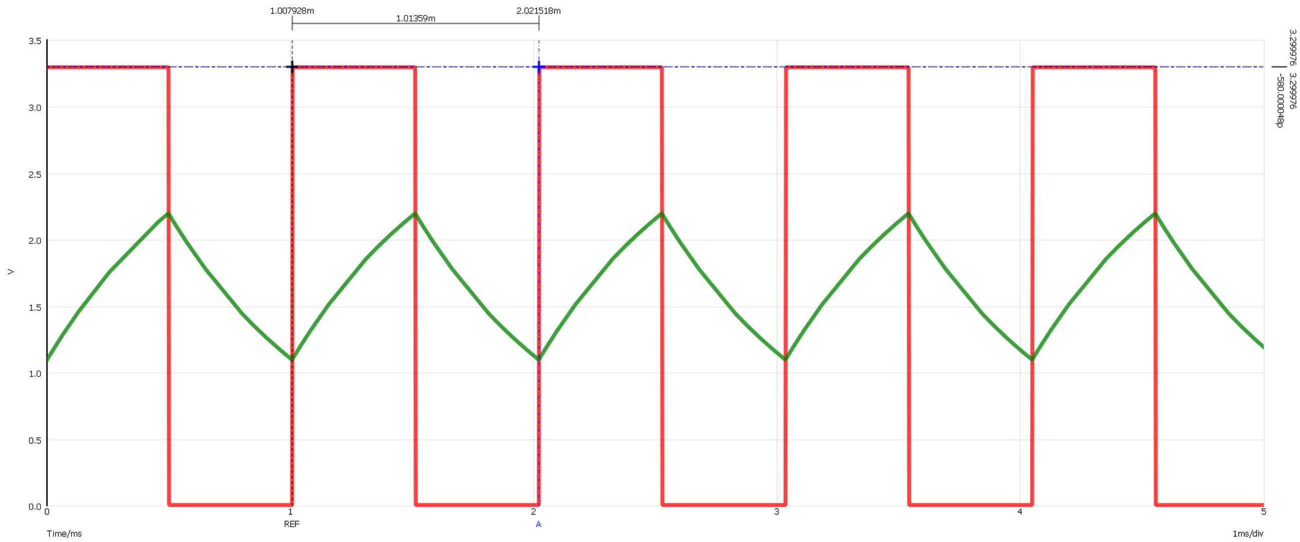

Figure 3. Design Example Simulated Waveforms Red – Output, Green – Co

ADVANTAGES OF COMPARATOR-BASED OSCILLATORS

- Simple architecture
- Wide frequency range (Hz to MHz)
- Excellent for digital or mixed signal systems
- Wide supply voltage compatibility
- Easy frequency adjustment (change R or C)

APPLICATIONS

- Clock generation
- PWM and timing control circuits
- LED flashers
- Voltage-to-frequency converters (when V_{IN} and comparator supply voltage are independent)
- Reset generators
- Sensor excitation signals

CONCLUSION

Comparators offer an effective and flexible way to generate oscillation using a minimal number of external components. By implementing positive feedback and an RC timing network, designers can create stable and customizable oscillator circuits suitable for a wide range of applications.

REVISION HISTORY

Revision	Description of Changes	Date
0	Initial document release.	6/5/2026