

NE555 Timer - Generating Pulse Signals and Observing Frequency Changes

Case Study

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1. Overview

Short description: This **Case study** explores the NE555 timer operating in an astable mode to generate continuous pulse (square wave) signals. Two LEDs alternate blinking to visualize the output, while participants adjust potentiometers and capacitor values to see how frequency and duty cycle change. Analog Discovery Product Line ([AD3](#) or [AD Studio](#) / [Studio MAX](#), hereby **Device**) provides both power and measurement, allowing real-time observation of waveform behavior and illustrating how RC components determine pulse timing.

Objectives

- Understand the operating principle of the NE555 timer in an astable mode.
- Configure a LED blinking circuit and observe pulse generation on the oscilloscope.
- Adjust potentiometer and capacitor values to see changes in frequency and duty cycle.
- Measure output waveform characteristics using the **Device**.

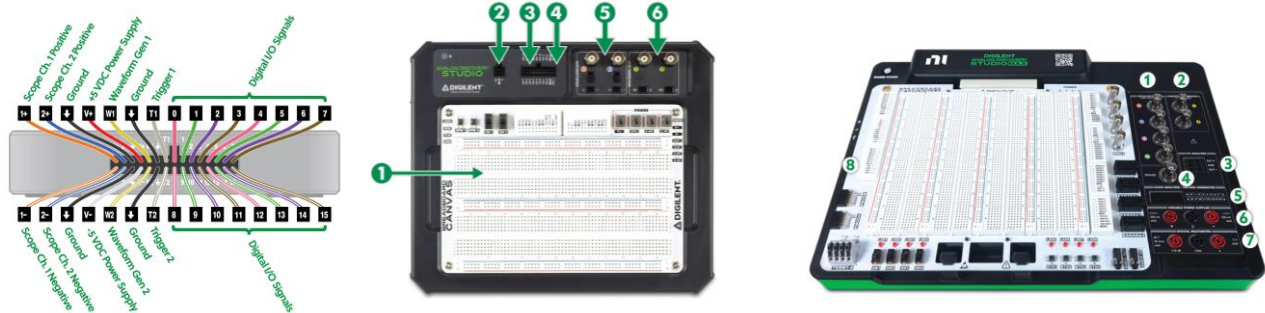
Software & Hardware Requirements

Software		Version
Digilent WaveForms (Runtime + SDK)		Latest (64-bit)
NI LabVIEW		2025 64-bit
WaveForms Toolkit for LabVIEW		Latest
Hardware		Quantity*
Digilent Analog Discovery Product Line		
Option 1	Digilent Analog Discovery 3	1
Option 2	Digilent Analog Discovery Studio	1
Option 3	Digilent Analog Discovery Studio MAX	1
List of Components		Quantity*
Canvas Breadboard		1
NE555 Timer IC		1
Potentiometer 10kΩ		2
Resistor 220 Ω		2
Capacitor (electrolytic) 100 μF		1
Capacitor (electrolytic) 20 μF		1
Capacitor 100 nF		1
LED (5 mm, 2–2.5 V)		2
DMM (optional)		1
Jumper wires		-
BNC to BNC cable ¹		1

¹ BNC cable required only for the Analog Discovery Studio MAX.

2. Hardware Setup

This section describes the **Digilent Analog Discovery Product Line** hardware setup for **Case studies**. Before assembling the measurement circuit, it is essential to understand the pinout and available connections of the **Devices**. **Figure 1** highlights the pinouts and instrumentations of the Digilent Analog Discovery product line.²



a. Analog Discovery 3

- Power Supplies
- Logic Analyzer and Pattern Generator
- Triggers
- Oscilloscope Waveform Generator

b. Analog Discovery Studio

1. Breadboard Canvas
2. Power Supplies
3. Logic Analyzer and Pattern Generator
4. Triggers
5. Oscilloscope
6. Waveform Generator

c. Analog Discovery Studio MAX

1. Oscilloscope
2. Waveform Generator
3. IV Analyzer
4. Trigger
5. Logic Analyzer and Pattern Generator
6. Variable Power Supplies
7. Digital Multimeter
8. Breadboard Canvas

Figure 1. Digilent Analog Discovery Products Pinout and Instrumentations

Table 1 provides a common reference for physical channels' names across the **Digilent Analog Discovery product line**. The **Case studies** are designed to work with all supported devices, so the generic channels' names shown in the first row are used consistently in all circuit diagrams and wiring instructions.

Table 2 provides a common reference for device names and instrument identifiers used in NI LabVIEW with the WaveForms Toolkit across the **Digilent Analog Discovery product line**. The Case studies are designed to work with all supported devices; therefore, the generic instruments and

² For detailed electrical specifications, pin descriptions, and operating limits, always refer to the official datasheets of each device (Analog Discovery 3, Analog Discovery Studio, and Analog Discovery Studio MAX). The latest datasheets are available on the Digilent website:

- [Analog Discovery 3](#)
- [Analog Discovery Studio](#)
- [Analog Discovery Studio MAX](#)

channels identifiers shown in Table 2 are used consistently throughout the LabVIEW block diagrams and configuration steps.

Table 1 Physical Channels Mapping for Digilent Analog Discovery Devices

<i>Channel Device</i>	<i>Scope Ch.1 Positive</i>	<i>Scope Ch.1 Negative</i>	<i>Scope Ch.2 Positive</i>	<i>Scope Ch.2 Negative</i>	<i>+V</i>
AD 3	Scope Ch.1 Positive (Pin 1+)	Scope Ch.1 Negative (Pin 1-)	Scope Ch.2 Positive (Pin 2+)	Scope Ch.1 Negative (Pin 2-)	+VDC Power Supply (Pin V+)
AD Studio ³	OSCILLOSCOPE 1 (Pin + or BNC Positive Cable)	OSCILLOSCOPE 1 (Pin - or BNC Negative Cable)	OSCILLOSCOPE 1 (Pin + or BNC Positive Cable)	OSCILLOSCOPE 2 (Pin - or BNC Negative Cable)	+5.0V (on canvas board)
AD Studio MAX ³	OSCILLOSCOPE 1 (BNC Positive Cable)	OSCILLOSCOPE 1 (BNC Negative Cable)	OSCILLOSCOPE 2 (BNC Positive Cable)	OSCILLOSCOPE 2 (BNC Negative Cable)	+5.0V (on canvas board)

Table 2 Device Names and Instruments Identifiers in NI LabVIEW (WaveForms Toolkit)

<i>Identifier Device</i>	<i>Device name</i>	<i>Scope Ch.1</i>	<i>Scope Ch.2</i>	<i>PS</i>
AD 3	Discovery3	mso/1	mso/2	Ps/+
AD Studio ³	DiscoveryStudio			
AD Studio MAX ³	ADS_Max			

³ For the Analog Discovery Studio and Analog Discovery Studio MAX, ensure the devices are powered by turning ON the main power switch before use.

3. Background Information

The NE555 timer is a versatile integrated circuit used for generating precise time delays and periodic waveforms. In this **Case study**, the NE555 is configured in an astable mode, where it operates as a free-running oscillator and continuously generates a square-wave output without requiring an external trigger. A standard NE555 timer circuit used for generating pulse signals is shown in Figure 2.

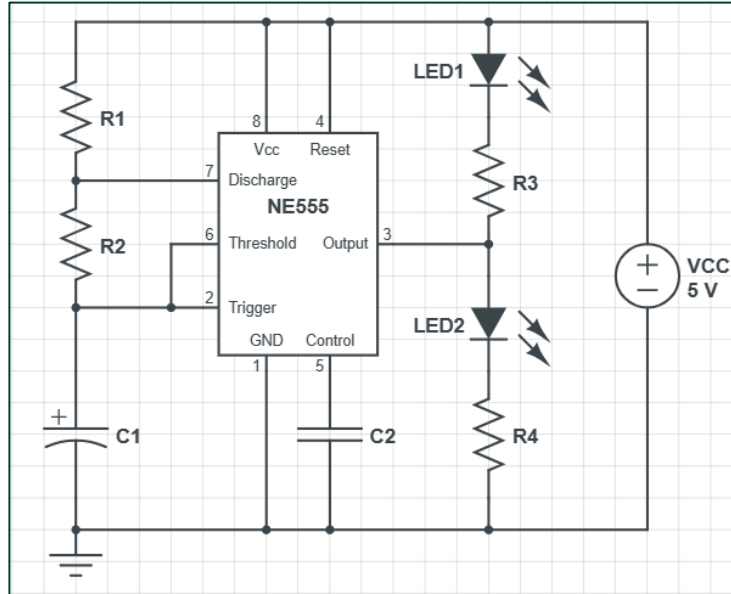


Figure 2. NE555 Astable Pulse-Generation Circuit

In an astable mode:

- External capacitor **C** charges through **R₁ + R₂**
- The capacitor discharges through **R₂** only
- Two internal comparators monitor the capacitor voltage:
 - Upper threshold: $\frac{2}{3}V_{cc}$
 - Lower threshold: $\frac{1}{3}V_{cc}$
- When these thresholds are reached, the output toggles between **HIGH** and **LOW** states.

This repetitive charge-discharge process produces a continuous pulse signal at the output (Pin 3). The timing characteristics of the NE555 in an astable mode are determined by the resistor and capacitor values. The time during which the output remains in the HIGH state depends on both resistors and the capacitor value and is given by:

$$T_H = 0.693 \cdot (R_1 + R_2) \cdot C \quad (1)$$

The time during which the output remains in the LOW state is determined only by **R₂** and the capacitor, since the discharge path bypasses **R₁**. The LOW time is expressed as

$$T_L = 0.693 \cdot R_2 \cdot C \quad (2)$$

The total period of the output waveform is the sum of the **HIGH** and **LOW** times. Substituting the above expressions yields:

$$T = T_H + T_L \quad (3)$$

The oscillation frequency is the inverse of the period. Therefore, the output frequency can be calculated as:

$$f = \frac{1}{T} = \frac{1}{0.693 \cdot (R_1 + 2R_2) \cdot C} \quad (4)$$

This relationship clearly illustrates that the frequency is inversely proportional to the RC time constant. As a result, increasing resistance or capacitance reduces the output frequency, while decreasing these values increases it. Finally, the duty cycle describes the percentage of time the output signal remains HIGH within one complete cycle. It is defined as the ratio of HIGH time to the total period and is expressed as:

$$D = \frac{T_H}{T} \times 100\% = \frac{R_1 + R_2}{R_1 + 2R_2} \times 100\% \quad (5)$$

From this equation, it can be observed that in the standard astable configuration, the duty cycle is always greater than 50 %. Adjusting **R₁** primarily influences the duty cycle, while **R₂** affects both frequency and duty cycle simultaneously.

4. Circuit Design – step by step instructions

4.1 Description

The measurement circuit is based on an NE555 timer configured in an astable mode to generate a continuous square-wave output. Two 10 kΩ potentiometers set the charge and discharge paths of the timing capacitor (100 μF), allowing the oscillation frequency and duty cycle to be adjusted. The output signal at Pin 3 drives two LEDs through 220 Ω resistors, causing them to blink alternately as the timer toggles between HIGH and LOW states. The output waveform is monitored by connecting **Scope Ch.1 Positive** to the NE555 output node and **Scope Ch.1 Negative** to **GND**, enabling real-time observation of how potentiometer adjustments affect the pulse frequency and LED behavior.

Important! Refer to **Table 1** to determine the exact physical pin, connector, or cable that corresponds to each generic connection on the specific Digilent Analog Discovery device being used. The remaining rows in the table show how each generic channel maps the actual hardware connections for each device.

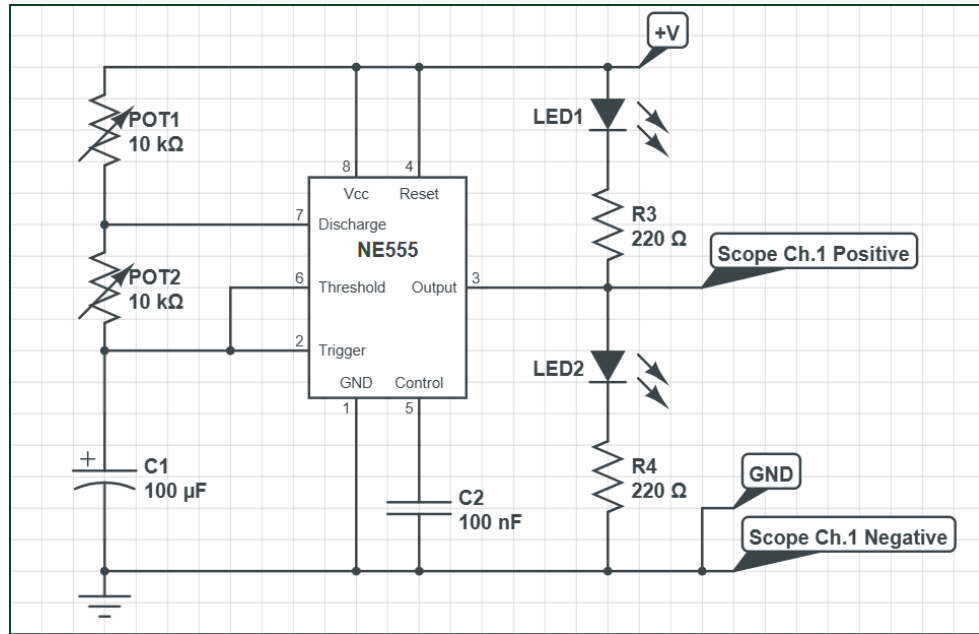


Figure 3. NE555 Astable Pulse-Generation Circuit for Device

4.2 Step by step instructions⁴

1. Place the **NE555 timer** on the Canvas breadboard⁵, ensuring that its pins are correctly aligned and inserted into different rows.
2. Connect the **VCC pin (Pin 8)** of the NE555 to the **Device +V** supply (see **Table 1**).
3. Connect the **GND pin (Pin 1)** of the NE555 to the **Device GND**.
4. Connect **Pin 4 (Reset)** to **Pin 8 (Vcc)** to ensure the NE555 operates continuously.
5. Insert the **first potentiometer (POT1)** into the breadboard. Connect its first outer terminal to **+V** supply, connect the middle wiper terminal to **Pin 7 (Discharge)** of the NE555, and leave the third outer terminal unconnected (floating). This wiring ensures that POT1 functions as an adjustable resistor.
6. Insert the **second potentiometer (POT2)** into the breadboard. Connect its first outer terminal to **Pin 7 (Discharge)** of the NE555, connect the middle wiper terminal to **Pin 6 (Threshold)** of the NE555, and leave the third outer terminal unconnected (floating). This wiring ensures that POT2 functions as an adjustable resistor.
7. Connect **Pin 6 (Threshold)** to **Pin 2 (Trigger)**.
8. Place the **100 μF capacitor (C1)** and connect its positive terminal to **Pin 6/2 (Threshold/Trigger node)** and its negative terminal to **GND**.
9. Connect **Pin 5 (Control Voltage)** to **GND** through a **100 nF capacitor (C2)** (for noise reduction).
10. Connect **LED1** through a **220 Ω resistor (R3)** from the **output pin (Pin 3)** to **VCC**, ensuring the LED is oriented correctly (anode to VCC, cathode toward resistor and output).
11. Connect **LED2** through a **220 Ω resistor (R4)** from the **output pin (Pin 3)** to **GND**, ensuring proper polarity.

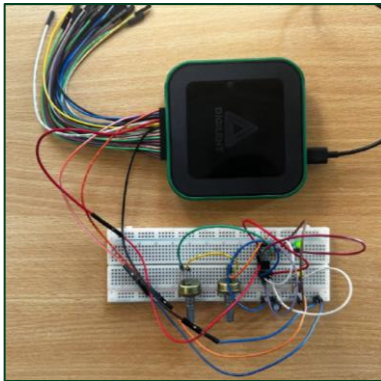
⁴ Given on Figure 3.

⁵ Use external breadboard in the case of Analog Discovery 3.

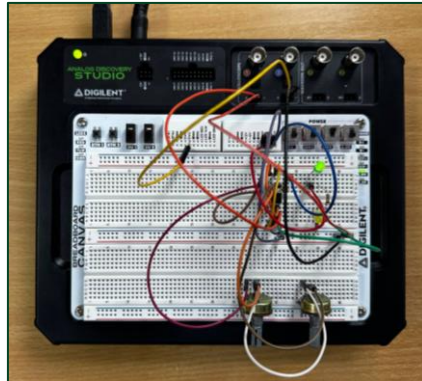
12. Connect **Scope Ch.1 Positive to Pin 3 (Output)** to monitor the generated square wave using a jumper wire or a BNC cable (if available).
13. Connect **Scope Ch.1 Negative to Device GND** to complete the measurement reference.

4.3 Assembled Circuit

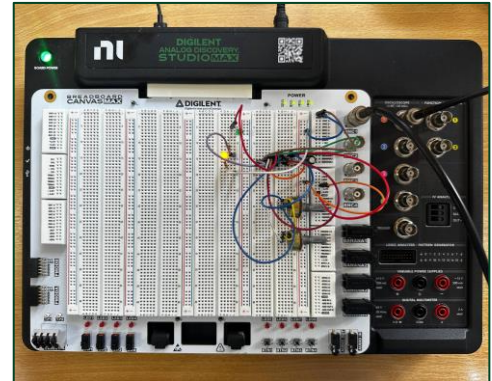
Figure 4 presents complete experimental circuits on different Digilent devices.



a. Analog Discovery 3



b. Analog Discovery Studio



c. Analog Discovery Studio MAX

Figure 4. Assembled circuits for different Devices

5. Software Setup - step by step instructions

5.1 Data Visualization and Analysis in Waveforms

Step 1. Launch WaveForms and connect the device

- 1.1. Connect the **Device** to the computer via USB.
- 1.2. Open the **Digilent WaveForms** software.
- 1.3. Verify that the device is detected and shown as *Currently Selected* in the **Device Manager** (Settings -> Device Manager).

Step 2. Configure the Power Supply in WaveForms⁶

- 2.1. Open the **Supplies** instrument in **WaveForms**.
- 2.2. Enable the **Positive Supply (V+)**.
- 2.3. Set the output voltage to **+5.000 V DC**.
- 2.4. Enable the **Master Enable** switch to activate the power output.
- 2.5. Keep the **Negative Supply (V-)** disabled (a single positive voltage is only required for the LDR voltage divider circuit).

Figure 5 shows the configuration of the **Device** power supply using the Digilent WaveForms environment.

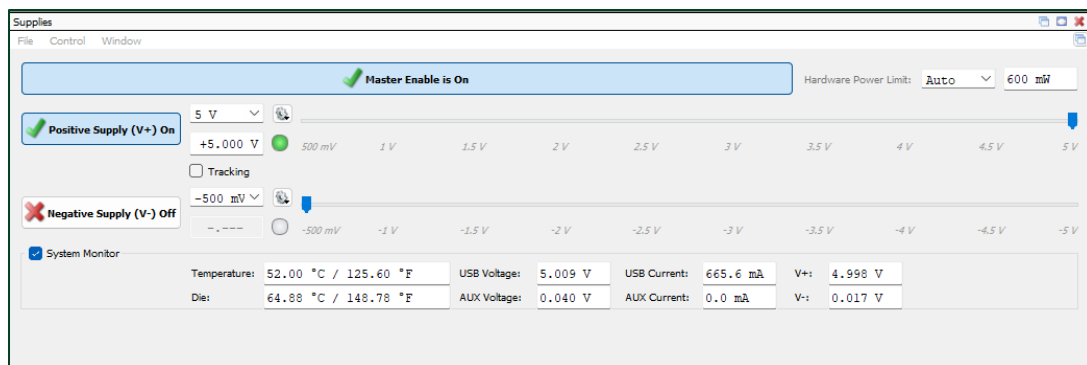


Figure 5. Power Supply Configuration in WaveForms Software

Step 3. Acquire the signal using the Oscilloscope⁷

- 3.1. Open the **Scope** instrument on WaveForms.
- 3.2. Enable **Channel 1**.
- 3.3. Adjust the **Range to 1 V/div** so the signal fits clearly on the screen.
- 3.4. Adjust the **Time Base to 1s/div** to observe stable voltage changes.

Figure 6 shows the real-time pulse signal generated by the NE555 timer and acquired using the Scope tool in Digilent WaveForms. The displayed waveform illustrates the periodic HIGH and LOW transitions produced by the astable configuration, demonstrating how the circuit continuously oscillates based on the selected resistor and capacitor values.

⁶ This step is mandatory for the Digilent Analog Discovery 3. Skip if you are using another device.

⁷ In the case of AD Studio turn the 5.0V switch on. In the case of AD Studio MAX turn Board Power on.

Note: If, after running the circuit, the LEDs are not blinking, slightly adjust the **POT1** and **POT2** values until the NE555 begins oscillating. The recommended starting values are:

- **POT1 $\approx 1\text{ k}\Omega$**
- **POT2 $\approx 10\text{ k}\Omega$**

Use a DMM to confirm the actual resistance values.

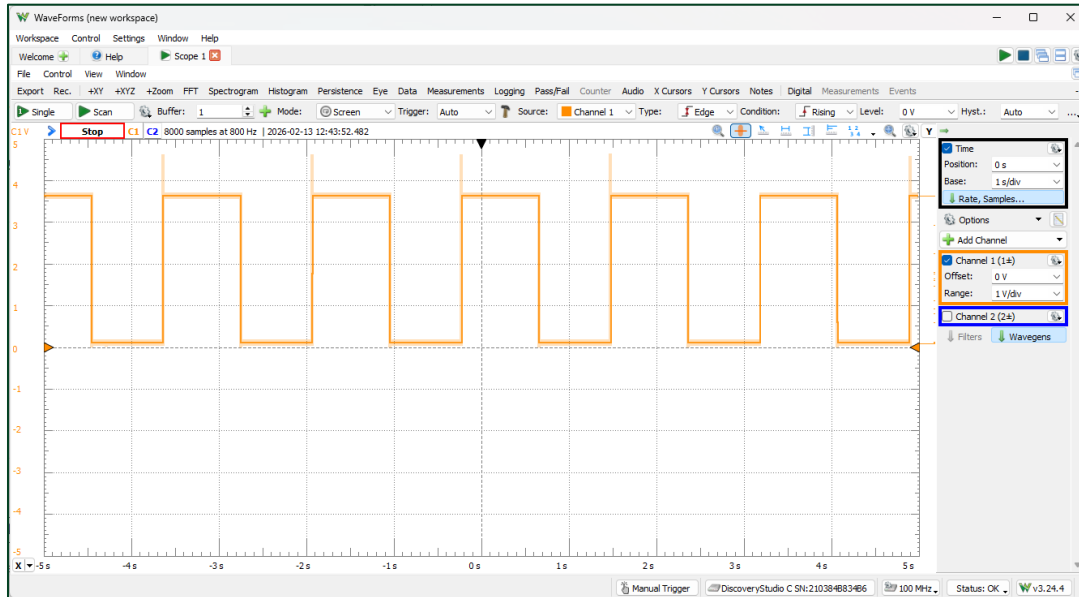


Figure 6. NE555 Astable Output Signal Displayed in WaveForms

Step 4. Measuring Pulse Parameters Using WaveForms

- 4.1. Click on the **Quick measure: Horizontal** tool in the **Scope** window. Use the cursor measurement tools in the WaveForms Oscilloscope to determine the **pulse total period** and calculate frequency.
- 4.2. Use the same cursor tools to measure the **HIGH-state duration** of the pulse signal (see Figure 7).
- 4.3. Calculate the **duty cycle** by dividing the HIGH-state time by the total period.
- 4.4. Using **Equation (4)** and **Equation (5)** with the RC values from the circuit, compute the theoretical frequency and duty cycle, and compare them with the measured values to ensure they are approximately the same.
- 4.5. Stop all instruments in WaveForms and turn off the **Device** power supply.
- 4.6. Replace the **C1** capacitor with a **20 μF capacitor** or change **POT1** and **POT2** resistance.
- 4.7. Turn the **Device** power supply on again, restart **WaveForms**, and repeat all measurements to observe how the decreased capacitance changes the timing parameters.

Figure 7 illustrates the NE555 output signal measurement using cursor tools in the WaveForms Oscilloscope. The cursors are used to observe how the output waveform changes after replacing the timing capacitor, enabling analysis of how capacitance affects the oscillation behavior.

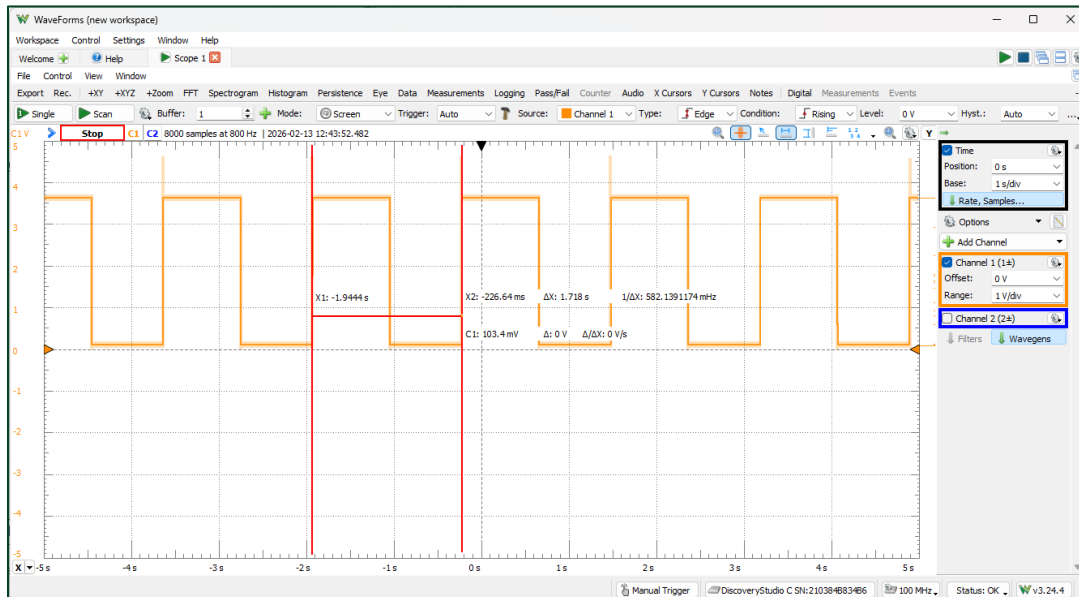


Figure 7. Signal Period Measurement using WaveForms Cursor tools

5.2 Data Visualization and Analysis Using NI LabVIEW WaveForms Toolkit

Step 1. Launch NI LabVIEW and connect the Device

- 1.1. Connect the **Device** to the computer via USB.
- 1.2. Open **Diligent Waveforms** and verify that **Device** is detected and shown as *Currently Selected* in the **Device Manager** (Settings -> Device Manager), then close **Diligent Waveforms** software⁸.
- 1.3. Open the **NI LabVIEW** software.
- 1.4. Create a new NI LabVIEW VI (**File->New VI**)

Step 2. Create Block Diagram and Front Panel in NI LabVIEW

- 2.1. Modify the block diagram as shown in **Figure 7.1** and **Figure 7.2**.

⁸ Before running NI LabVIEW, please ensure that the Diligent WaveForms software is closed.

8. **WF-MSO Close** - Remove the session and reset all values for scope.
9. **WF-PS Initialize** (only for AD3) - this VI initializes the power supply.
10. **PS Channel** (only for AD3) - specify your **Device PS** channel. Use **Table 2** for your **Device**.
11. **WF-PS Enable All Outputs** (only for AD3) - this VI enables all outputs for power supply.
12. **WF-PS Enable All Outputs** (only for AD3) - this VI configures voltage outputs for power supply.
13. **WF-PS Close** (only for AD3) - Remove the session and reset all values for power supply.
14. **Wait (ms)** - connect it to an integer constant and set the value to 30 ms.
15. **While Loop** - used to enable continuous data acquisition.
16. **OR** - Allow the code to stop using the **Stop** button or automatically when an error occurs.

2.2. Modify the front panel shown in **Figure 8**. Inside **Device name** String Control write your corresponding **Device** name from **Table 2**.

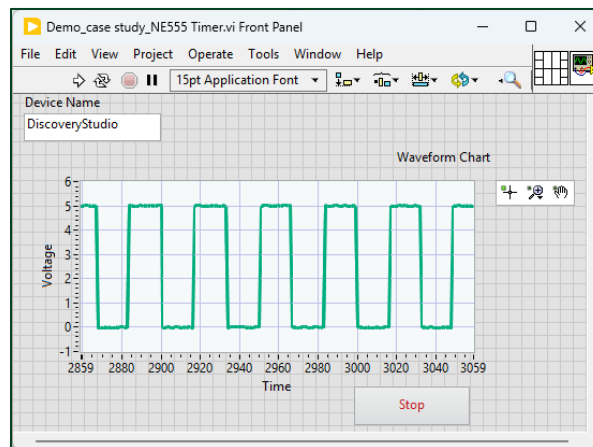


Figure 8. VI Front Panel

2.3. Save the VI.

Step 3. Run the code and do measurements in LabVIEW

- 3.1. Run the code by clicking on the **Run** button.
- 3.2. Right-click on the **Waveform Chart**, select **Visible Items**, and enable the **Graph Palette**.
- 3.3. From the **Graph Palette**, click the **Zoom** tool () and choose **Zooms in an area of the graph or chart on the x-axis tool** (). Use this tool on the Waveform Chart to determine the total period of the pulse and calculate its frequency. Use the same tool to measure the HIGH-state duration of the signal⁹.
- 3.4. Using **Equation (4)** and **Equation (5)** with the RC values from the circuit, compute the theoretical frequency and duty cycle, and compare them with the measured values to ensure they are approximately the same.
- 3.5. **Stop** the code execution in LabVIEW and turn off the **Device** power supply.
- 3.6. Replace the **C1** capacitor with a **20 μ F capacitor** or change **POT1** and **POT2** resistance.
- 3.7. Turn the **Device** power supply on again, run **LabVIEW**, and repeat all measurements to observe how the decreased capacitance changes the timing parameters.

⁹ The chart X-axis does not represent time; it shows the measurement index (sample number). To obtain the real time, multiply the X-axis value by the loop iteration time, which is 30 ms.