

Push-Button Debounce Analysis

Case Study

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1. Overview

Short description: This **Case Study** introduces the practical analysis of mechanical push-button bouncing and debounce techniques. When a mechanical push-button is pressed or released, the electrical contact does not switch cleanly from **LOW** to **HIGH** or from **HIGH** to **LOW**. Instead, the signal may oscillate rapidly for a short time before reaching a stable state. This unwanted transition behavior is called **contact bounce**.

The Case Study uses the **Digilent Analog Discovery Product Line** together with **WaveForms** and **NI LabVIEW** to observe, measure, and analyze push-button bouncing. The raw button signal is compared with an RC-filtered signal using a hardware debounce method.

The main goal is to understand why debounce is necessary in digital systems and how the RC filter helps obtain a more stable button signal.

Objectives

- Understand the mechanical origin of push-button bounce and its effect on the push-button signal waveform.
- Observe and measure raw push-button transitions using WaveForms during press and release events.
- Analyze hardware debounce using an RC low-pass circuit and compare raw and debounced signals.
- Observe the effect of the RC hardware debounce filter using WaveForms and NI LabVIEW waveform visualization.

Software & Hardware Requirements

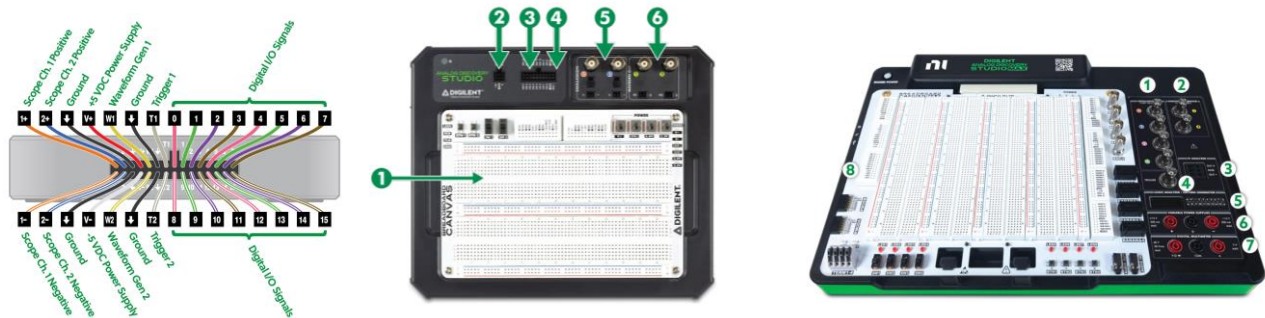
Software		Version
Digilent WaveForms (Runtime + SDK)		Latest (64-bit)
NI LabVIEW		2025 64-bit
WaveForms Toolkit for LabVIEW		Latest
Hardware		Quantity*
Digilent Analog Discovery Product Line		
Option 1	Digilent Analog Discovery 3	1
Option 2	Digilent Analog Discovery Studio	1
Option 3	Digilent Analog Discovery Studio MAX	1
List of Components		Quantity*
Canvas Breadboard		1
Push-button		1
Resistor 10 kΩ		1
Capacitor 100 nF ¹		1
Jumper wires		-

¹ The capacitor is used only for the hardware debounce version. The circuit can first be tested without the capacitor to observe the raw bouncing behavior.

2. Hardware Setup

This section describes the **Digilent Analog Discovery Product Line** hardware setup for **Case studies**. Before assembling the circuit, it is important to identify the available oscilloscope channels, power supply pins, and ground connections. The experiment can be performed using one oscilloscope channel to observe the voltage waveform at the push-button signal node. The oscilloscope channel is used to observe the raw bouncing signal and the RC-filtered debounced signal at the button signal node. Supply voltage provides the logic HIGH level, and **GND** is used as the common circuit reference.

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 1** provides a common reference for the physical connections used in push-

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](#)

button debounce analysis experiments. The experiment uses an oscilloscope channel for observing the push-button signal waveform, a supply voltage for generating the HIGH logic level, and common GND connections.

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 scope channel identifiers shown in **Table 2** are used consistently throughout the **NI LabVIEW** block diagrams and configuration steps for push-button debounce analysis.

Table 1 Physical Channels Mapping for Digilent Analog Discovery Devices

<i>Channel Device</i>	<i>Analog observation point</i>	<i>+Vs</i>	<i>GND</i>
AD 3	Scope Channel 1	+VDC Power Supply (Pin V+)	GND Pin
AD Studio ³	Scope Channel 1	+5.0V (on canvas board)	GND Pin
AD Studio MAX ³	Scope Channel 1	+5.0V (on canvas board)	GND Pin

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

<i>Identifier Device</i>	<i>Device name</i>	<i>Scope channel</i>
AD 3	Discovery3	scope/1
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

Push-Button Principle

A push-button is a mechanical switch that connects or disconnects two electrical nodes. In a digital circuit, it is usually used to generate logic input:

Button State	Electrical State	Digital Interpretation
Not pressed	LOW or HIGH depending on pull configuration	0 or 1
Pressed	Opposite logic state	1 or 0

There are two common connection methods:

Pull-down configuration

The input is normally LOW. When the button is pressed, the input becomes HIGH.

Pull-up configuration

The input is normally HIGH. When the button is pressed, the input becomes LOW.

For this Case Study, the **pull-down configuration** is selected because it is intuitive for beginners:

- Button not pressed → input = LOW
- Button pressed → input = HIGH

Contact Bounce

Mechanical contacts do not close or open instantly. When the button is pressed, the contacts may physically vibrate before settling. As a result, the signal may contain several fast HIGH–LOW transitions.

For example, one real button press may appear in the measured signal as several rapid transitions:

Time	Raw Signal
0 ms	LOW
1 ms	HIGH
2 ms	LOW
3 ms	HIGH
4 ms	LOW
5 ms	HIGH stable

Without debounce, the signal may show several rapid transitions during one physical button press.

Debounce Concept

Debouncing is the process of rejecting short unwanted transitions and accepting the button state only after it remains stable for a defined time.

There are two main debounce methods:

1. Hardware debounce

Uses external components such as:

- Resistor
- Capacitor
- Schmitt trigger input

The most common simple method is an **RC low-pass filter**, where the capacitor smooths the fast-bouncing transitions.

2. Software debounce

Uses an algorithm that waits until the input signal remains unchanged for a selected debounce time.

Although software debounce is also widely used, this Case Study focuses on hardware debounce using an RC low-pass filter.

For this experiment, a debounce time of **20 ms** is recommended.

RC Debounce Principle

For an RC debounce circuit:

$$\tau = R \cdot C$$

where:

- τ – time constant, s
- R – resistance, Ω
- C – capacitance, F

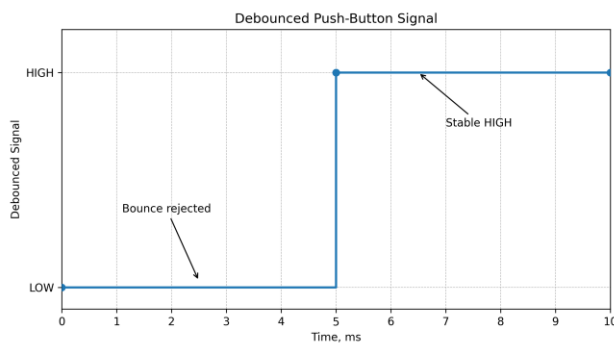


Figure 2a. Debounced Push-Button Signal

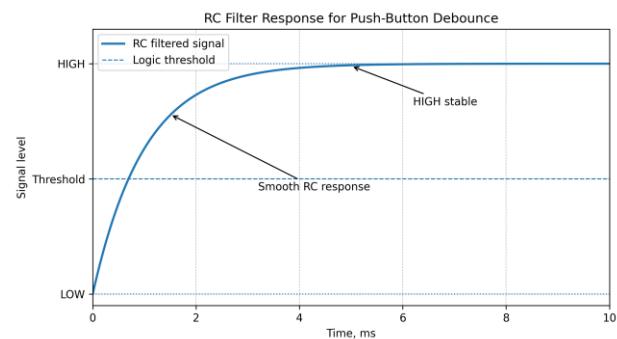


Figure 2b. RC Filter Response for Push-Button Debounce

Example:

$$R = 10 \text{ k}\Omega, C = 100 \text{ nF}, \tau = 10\,000 \times 100 \times 10^{-9} = 0.001 \text{ s} = 1 \text{ ms}$$

The signal becomes almost stable after approximately: $5\tau = 5 \text{ ms}$

This reduces the fast oscillations caused by mechanical contact bounce.

4. Circuit Design – Step by Step Instructions

4.1 Description

The circuit consists of one push-button, one pull-down resistor, and, for hardware debounce, one optional capacitor.

The push-button is connected between the supply voltage and the signal node. A **10 kΩ resistor** pulls the input node to **GND** when the button is not pressed.

The same signal node is connected to **Oscilloscope Channel 1** for voltage waveform observation.

Hardware debounce is implemented by connecting a 100 nF capacitor from the input node to **GND**.

4.2 Step by Step Instructions

A. Raw Push-Button Pull-Down Circuit for Bounce Observation

1. Insert the push-button on the breadboard.
2. Connect one side of the push-button to **V+ / 5 V**.
3. Connect the other side of the push-button to the signal node.
4. Connect a **10 kΩ** resistor from the signal node to **GND**.
5. Connect **Scope Channel 1** positive input to the signal node.
6. Connect **Scope Channel 1** negative input to **GND**.
7. Verify that all grounds are common.

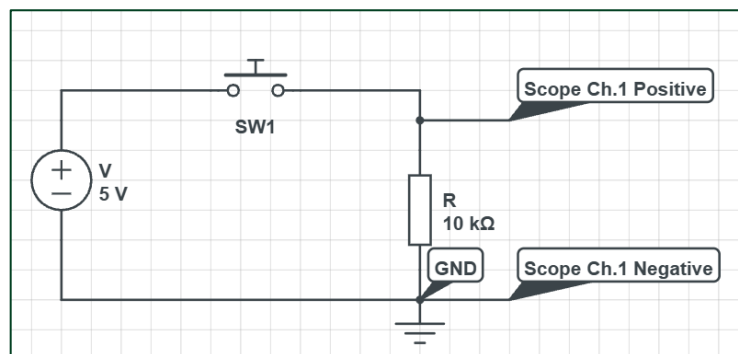


Figure 3a. Push-Button Pull-Down Circuit for Raw Bounce Observation

B. Hardware Debounce Circuit with RC Filter

1. Keep the same push-button and pull-down resistor connections.
2. Connect a **100 nF** capacitor from the signal node to **GND**.
3. Observe the difference between the raw and filtered transition.
4. Press and release the button several times and compare the waveform 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.

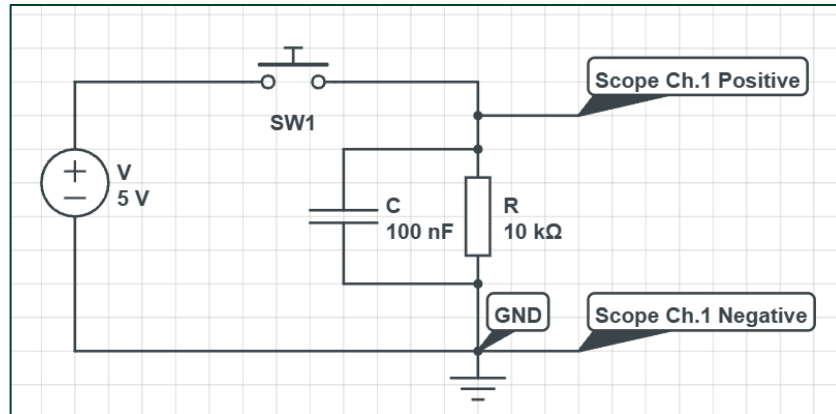
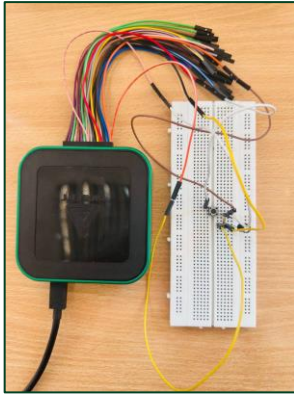


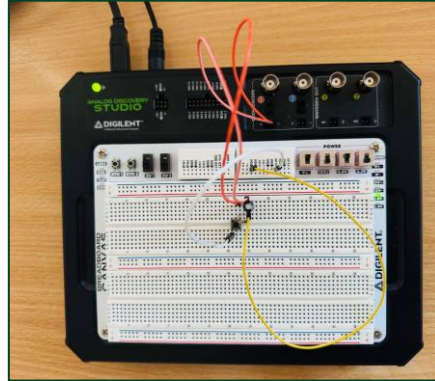
Figure 3b. Push-Button Pull-Down Circuit with RC Low-Pass Debounce Filter

4.3 Assembled Circuit

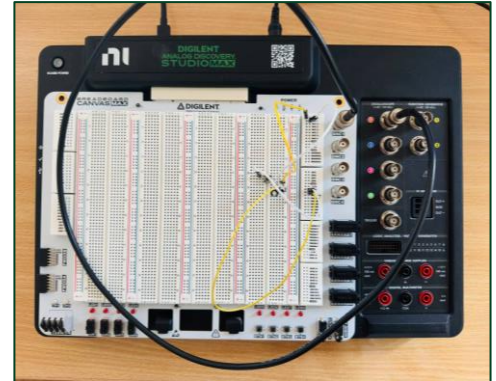
Figure 4 shows complete experimental circuits implemented on different **Digilent** devices.



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).
- 1.4. Select the correct device.

Step 2. Configure the Power Supply in WaveForms⁴

- 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 because only a single positive voltage is required for the push-button circuit.

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

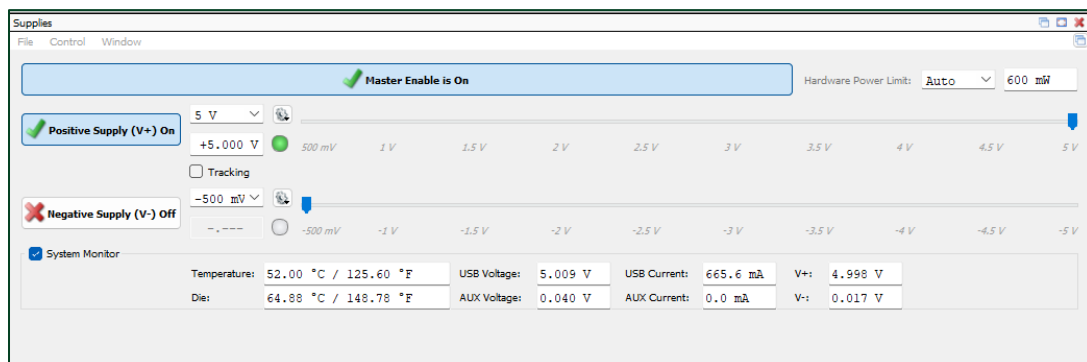


Figure 5. Power Supply Configuration in WaveForms Software

Step 3. Configure the Scope Instrument in WaveForms

- 3.1. Open the **Scope** instrument.
- 3.2. Connect **Channel 1** to the push-button signal node.
- 3.3. Set the vertical scale according to the used logic voltage:

Supply Voltage	Suggested Vertical Scale
5 V	1 V/div or 2 V/div

- 3.4. Set the time base to observe bouncing clearly:

⁴ This step is mandatory for the Digilent Analog Discovery 3. Skip if you are using another device.

Parameter	Recommended Value
Time base	1 ms/div to 10 ms/div
Acquisition mode	Normal / Single
Trigger type	Edge
Trigger edge	Falling edge
Trigger level for 5 V logic	2.5 V

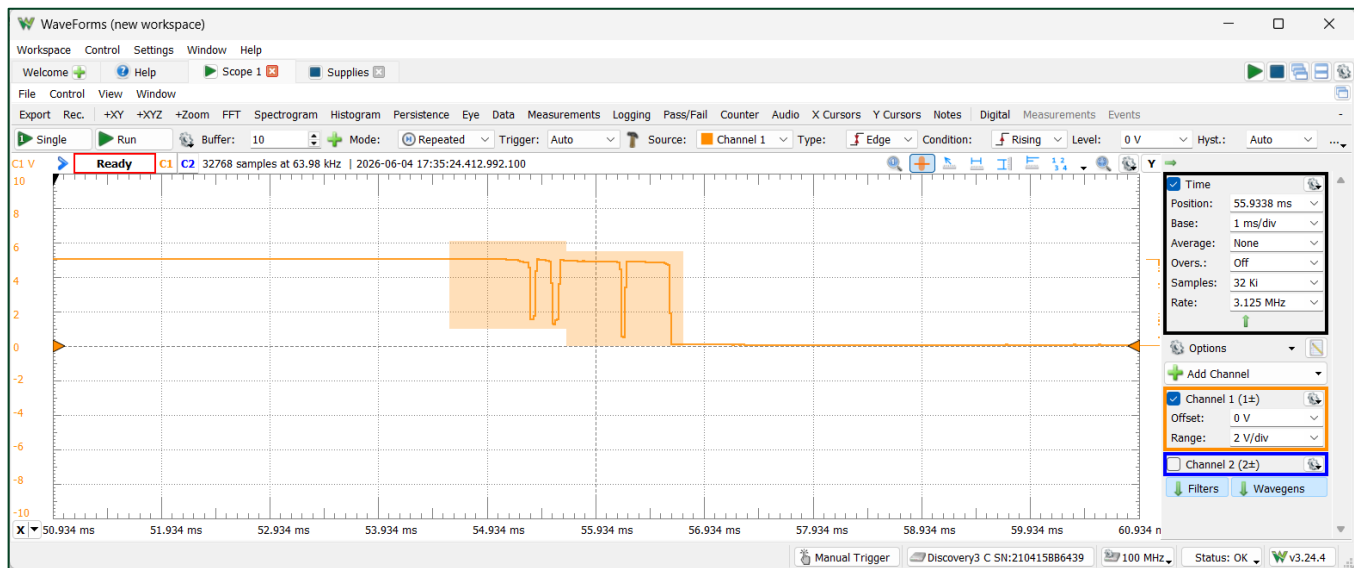


Figure 6. Raw Push-Button Bounce Signal in WaveForms Scope and Zoom

Step 4. Observe the raw bouncing signal

- 4.1. Remove the capacitor if it is already connected.
- 4.2. Press the push-button once.
- 4.3. Observe the transition on the oscilloscope.
- 4.4. Use cursors to measure the bounce duration.
- 4.5. Repeat the test for release events.
- 4.6. Record the maximum observed bounce time.

Expected observation:

- The signal does not change cleanly.
- Several short pulses appear before the final stable HIGH or LOW state.
- The bouncing duration may vary from press to press.

Step 5. Observe the hardware debounced signal

- 5.1. Connect the 100 nF capacitor from the signal node to GND.
- 5.2. Press and release the button again.
- 5.3. Observe the waveform on Scope Channel 1.
- 5.4. Compare the new transition with the raw signal.
- 5.5. Measure the rise time and settling behavior.

Expected observation:

- Fast oscillations are reduced.
- The signal transition becomes smoother.
- The observed waveform becomes smoother and less affected by short mechanical bounces.

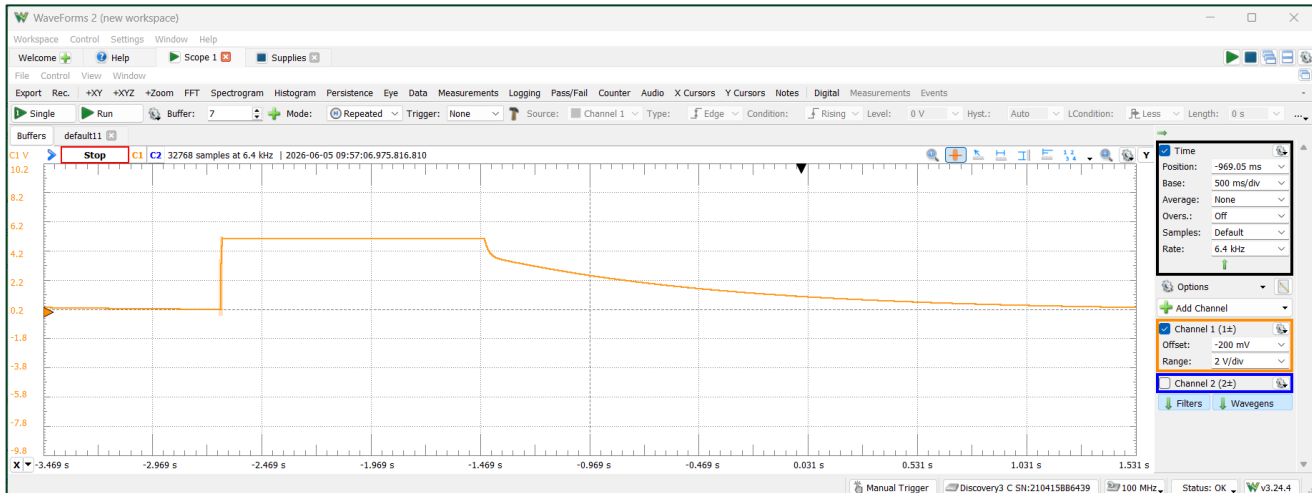


Figure 7. Debounced Push-Button Signal with RC Filter

5.2 Push-Button Signal Visualization 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 **Digilent WaveForms** and verify that **Device** is detected and shown as *Currently Selected* in the **Device Manager** (Settings -> **Device Manager**).
- 1.3. Close **Digilent WaveForms** software⁵.
- 1.4. Open the **NI LabVIEW** software.
- 1.5. 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 8a** and **Figure 8b**.

Figure 8a shows the LabVIEW block diagram code applicable only to Analog Discovery 3. **Figure 8b** shows the LabVIEW block diagram code applicable only to the **Analog Discovery Studio** and **Analog Discovery Studio MAX** devices.

⁵ Before running NI LabVIEW, please ensure that the Digilent WaveForms software is closed.

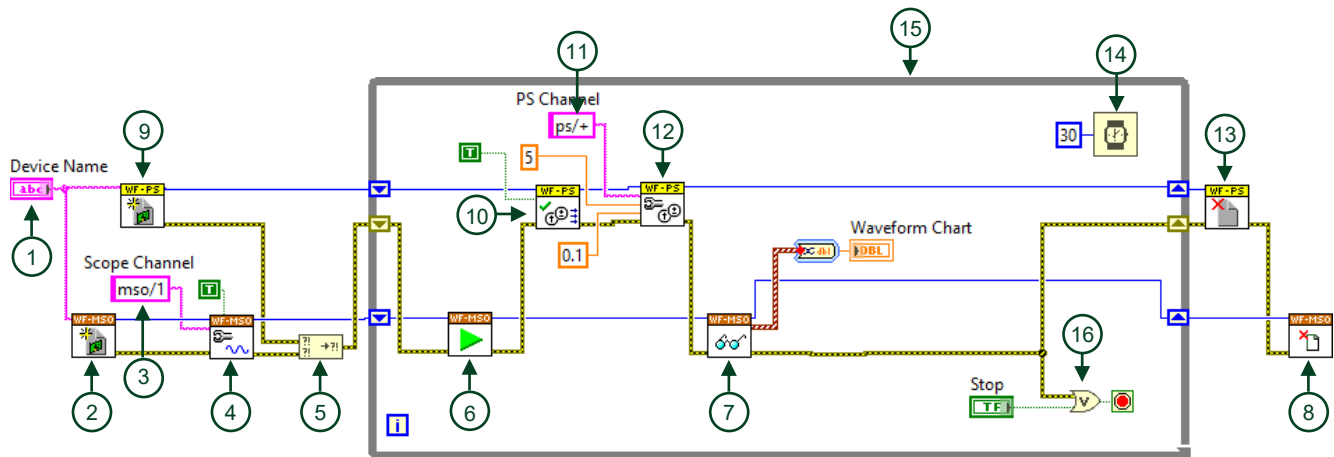


Figure 8a. VI Block Diagram for Push-Button Signal Visualization for AD3

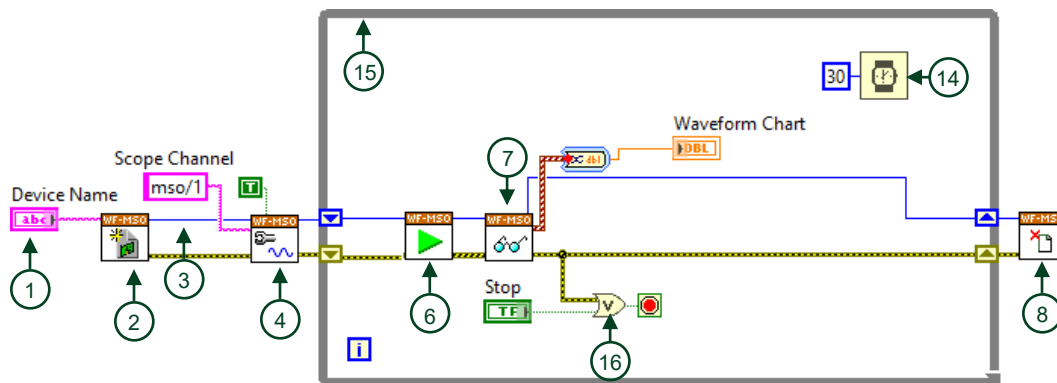


Figure 8b. VI Block Diagram for Push-Button Signal Visualization for ADS and ADS MAX

1. **Device Name** - specify the name of your **Device**. Use **Table 2** for your **Device**.
2. **WF-MSO Initialize** - this VI initializes the scope.
3. **Scope Channel** - specify your **Device Scope Ch.1** channel. Use **Table 2** for your **Device**.
4. **WF-MSO Configure Analog Channel** - this VI configures the settings for the measurement channel. Connect Enable Channel to True constant.
5. **Merge Errors** (only for AD3) - used to combine error lines from the PS and MSO.
6. **WF-MSO Run** - Run the acquisition.
7. **WF-MSO Read** - Transfer data from the **Device** to NI LabVIEW. **Analog Waveforms** output connected to **Convert to Dynamic Data** function then to **Waveform Chart** to visualize the measured data.
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 Configure Voltage Output** (only for AD3) - this VI configures the voltage level for the 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 9**. Inside **Device name** String Control write your corresponding **Device** name from **Table 2**.

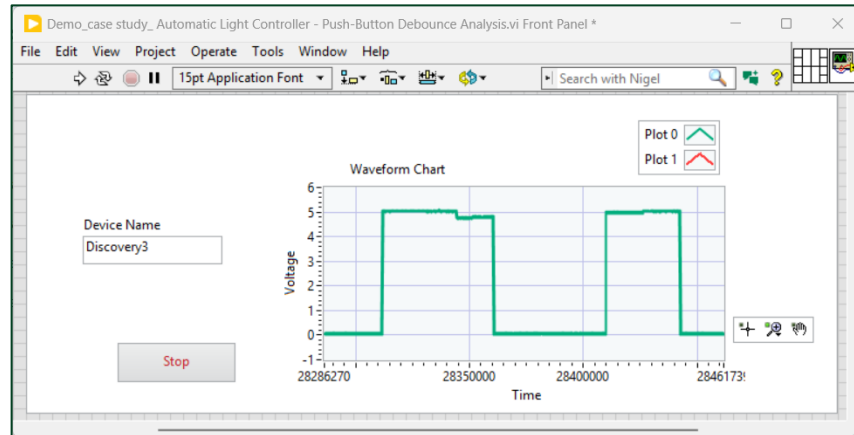


Figure 9a. VI Front Panel for Push-Button Raw Bounce Signal Visualization

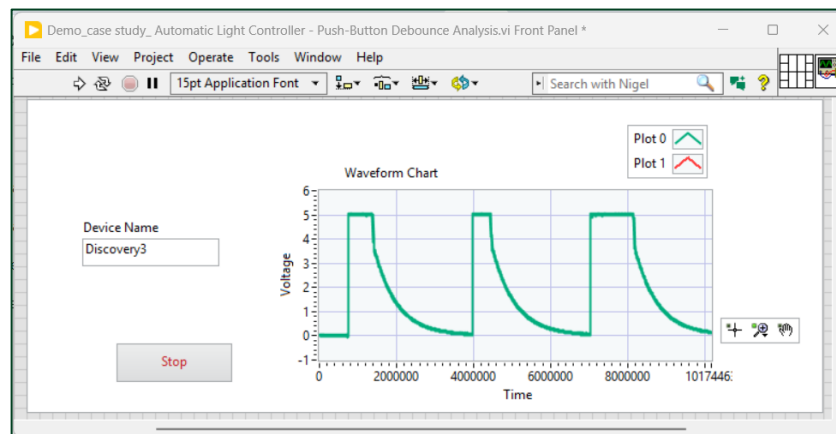


Figure 9b. VI Front Panel for Push-Button Signal Visualization with RC Low-Pass Debounce Filter

2.3. Save the VI.

Step 3. Run the VI and observe debounce behavior.

- 3.1. Click the Run button.
- 3.2. Set **Device** Name according to the connected **Device**.
- 3.3. Remove the capacitor if it is already connected.
- 3.4. Observe the raw push-button waveform on the waveform chart.
- 3.5. Connect the 100 nF capacitor and observe the RC-filtered waveform.
- 3.6. Compare the raw bouncing signal with the filtered signal.
- 3.7. Press **Stop** to end the VI.