

Wave of Light – Running LED Project

Case Study

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1. Overview

Short description: This **Case Study** demonstrates an eight-LED running-light system using the **Digilent Analog Discovery Product Line**, WaveForms software, and the **NI LabVIEW WaveForms Toolkit**. The LEDs are controlled through digital I/O channels using one-hot output patterns. WaveForms is used to generate and verify the LED sequence, while NI LabVIEW provides an interactive implementation with adjustable step delay and Forward/Reverse direction control.

Objectives

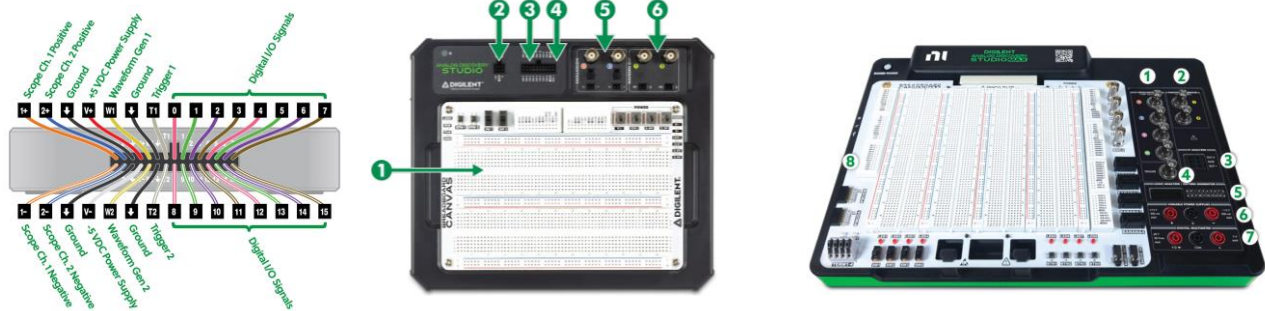
- Configure digital I/O lines to control an eight-LED array.
- Generate and observe sequential one-hot LED patterns in WaveForms.
- Verify the digital output sequence using the Logic Analyzer.
- Implement Forward/Reverse running-LED control with adjustable timing in NI LabVIEW.

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
LED		8
Resistor 220 Ω		8
Jumper wires		-

2. Hardware Setup

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



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 Instrumentation

Table 1 provides a common reference for the physical digital channels across the **Digilent Analog Discovery Product Line**. The **Case Study** is designed to work with all supported devices; therefore, the generic digital channel names are used consistently in the circuit diagrams and wiring instructions.

¹ 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](#)

Table 2 provides the device names and digital line identifiers used in **NI LabVIEW** with the WaveForms Toolkit. The appropriate device name should be selected according to the connected **Digilent** hardware.

Table 1. Physical Digital Channel Mapping for Digilent Analog Discovery Devices

Device	DIO0-DIO7	Ground
AD3	Digital Channels 0–7	GND pin
AD Studio ²		
AD Studio MAX		

Table 2. Device Names and Digital Identifiers in NI LabVIEW

Identifier Device	Device name	Digital Lines
AD3	Discovery3	dig/0:7
AD Studio	DiscoveryStudio	
AD Studio MAX	ADS_Max	

² 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

Running LED Principle

A running LED system is a sequential digital-output application in which the active state moves from one output channel to the next. In this **Case Study**, eight LEDs are connected to eight digital I/O channels of the **Device**.

In the basic implementation, only one digital output is HIGH at a time. This is known as one-hot encoding. By sequentially changing the active output, the LEDs create the visual effect of a moving light.

Forward sequence for eight LEDs

Step	Binary output DIO7...DIO0	Hex value	Active LED
0	00000001	0x01	LED1
1	00000010	0x02	LED2
2	00000100	0x04	LED3
3	00001000	0x08	LED4
4	00010000	0x10	LED5
5	00100000	0x20	LED6
6	01000000	0x40	LED7
7	10000000	0x80	LED8

Timing Relationships

Let T_{step} be the time for which one LED remains active. The step frequency and full-cycle time are:

$$f_{step} = \frac{1}{T_{step}},$$

$$T_{cycle} = N \times T_{step}$$

For $N = 8$ LEDs, a step time of 0.20 s corresponds to a step frequency of 5 steps/s and a full-cycle time of 1.60 s.

LED Polarity and Current Limiting

An LED conducts current primarily in the forward direction. The anode is connected to the digital output through a series resistor, while the cathode is connected to GND.

In this Case Study, a 220 Ω resistor is connected in series with each LED to limit the current and protect both the LED and the digital output channel. All eight LED branches use the same resistor value.

4. Circuit Design - step by step instructions

4.1 Description

The running-LED circuit consists of eight identical LED branches connected to digital output channels DIO0–DIO7. Each branch contains one LED and one 220 Ω series resistor. The LED cathodes are connected to a common GND.

4.2 Step by step instructions³

Running LED Circuit

1. Place eight LEDs, LED1–LED8, on the breadboard, keeping the same orientation for all LEDs.
2. Identify the anode and cathode of each LED and verify the LED polarity before wiring.
3. Place one 220 Ω resistor in series with each LED.
4. Connect DIO0 to the resistor of LED1, DIO1 to the resistor of LED2, and continue in the same way up to DIO7 → LED8.
5. Connect the other side of each resistor to the anode of the corresponding LED.
6. Connect all LED cathodes to the common breadboard GND rail.
7. Connect the Device GND to the breadboard GND rail.
8. Check that each DIO channel is connected to only one resistor–LED branch and verify that there are no short circuits between adjacent breadboard rows.

Important! Refer to **Table 1** to identify the DIO0–DIO7 and GND connections for the selected Diligent Analog Discovery device.

³ Given on Figure 2.

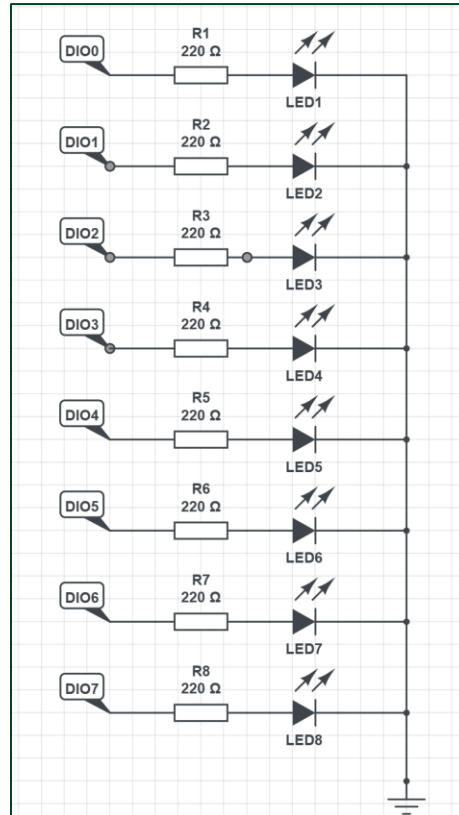
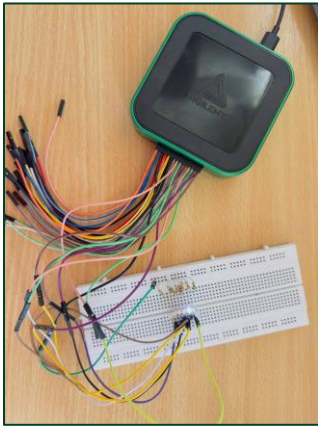


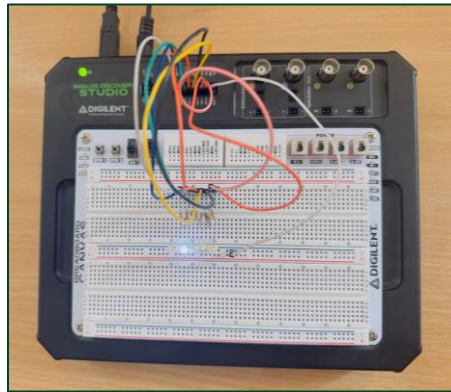
Figure 2. Eight-channel running LED circuit using DIO0-DIO7

4.3 Assembled Circuit

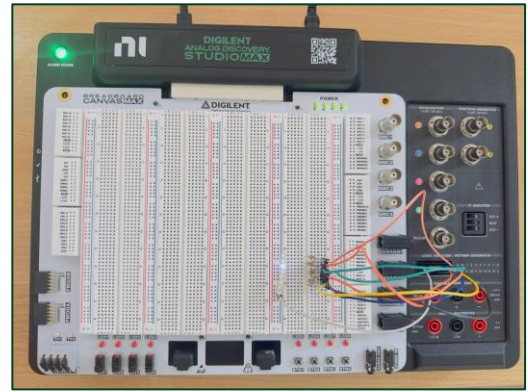
Figure 3 presents complete experimental circuits on different Digilent devices.



a. Analog Discovery 3



b. Analog Discovery Studio



c. Analog Discovery Studio MAX

Figure 3. Assembled circuits for different Devices

5. Software Setup - step by step instructions

5.1 Running LED Control and Analysis in WaveForms

Step 1. Launch WaveForms and connect the device

- 1.1. Connect the **Digilent** 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 Pattern Generator⁴

- 2.1. Open the **Patterns** instrument in **WaveForms**.
- 2.2. Add a **Bus** and select digital channels **DIO0–DIO7**.
- 2.3. Configure the bus with **DIO7** as **MSB** and **DIO0** as **LSB**.
- 2.4. Set **Type** = **Custom**.
- 2.5. Set **Output** = **PP (Push-Pull)**.
- 2.6. Set **Idle** = **0** so that all LEDs are **OFF** when the Pattern Generator is stopped.
- 2.7. Set the pattern frequency to **5 Hz**.
- 2.8. Set **Samples** = **16**.

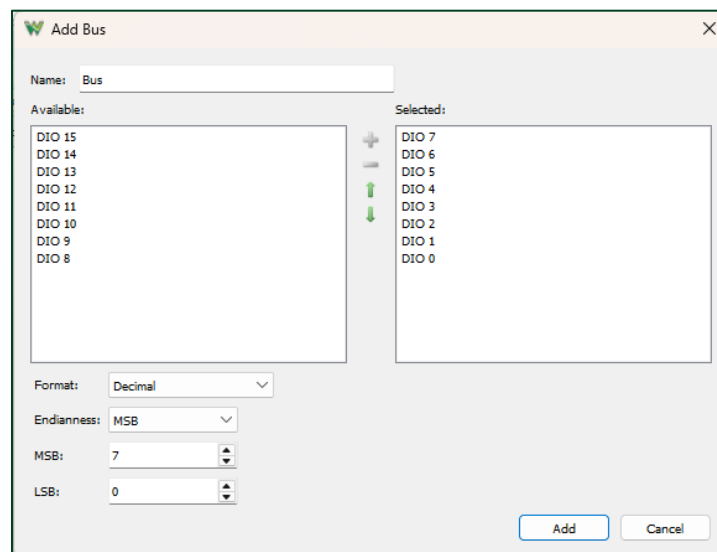


Figure 4. Configuration of DIO0–DIO7 as an 8-bit bus in WaveForms

Step 3. Enter the running-light sequence

- 3.1. Enter the following 16 values in the Bus column:
1, 2, 4, 8, 16, 32, 64, 128, 1, 2, 4, 8, 16, 32, 64, 128
- 3.2. Verify that only one DIO channel is **HIGH** at each sample.
- 3.3. Confirm that the sequence returns directly from **DIO7 to DIO0** without an all-LEDs-OFF interval.

⁴ Given on Figures 4 and 5.

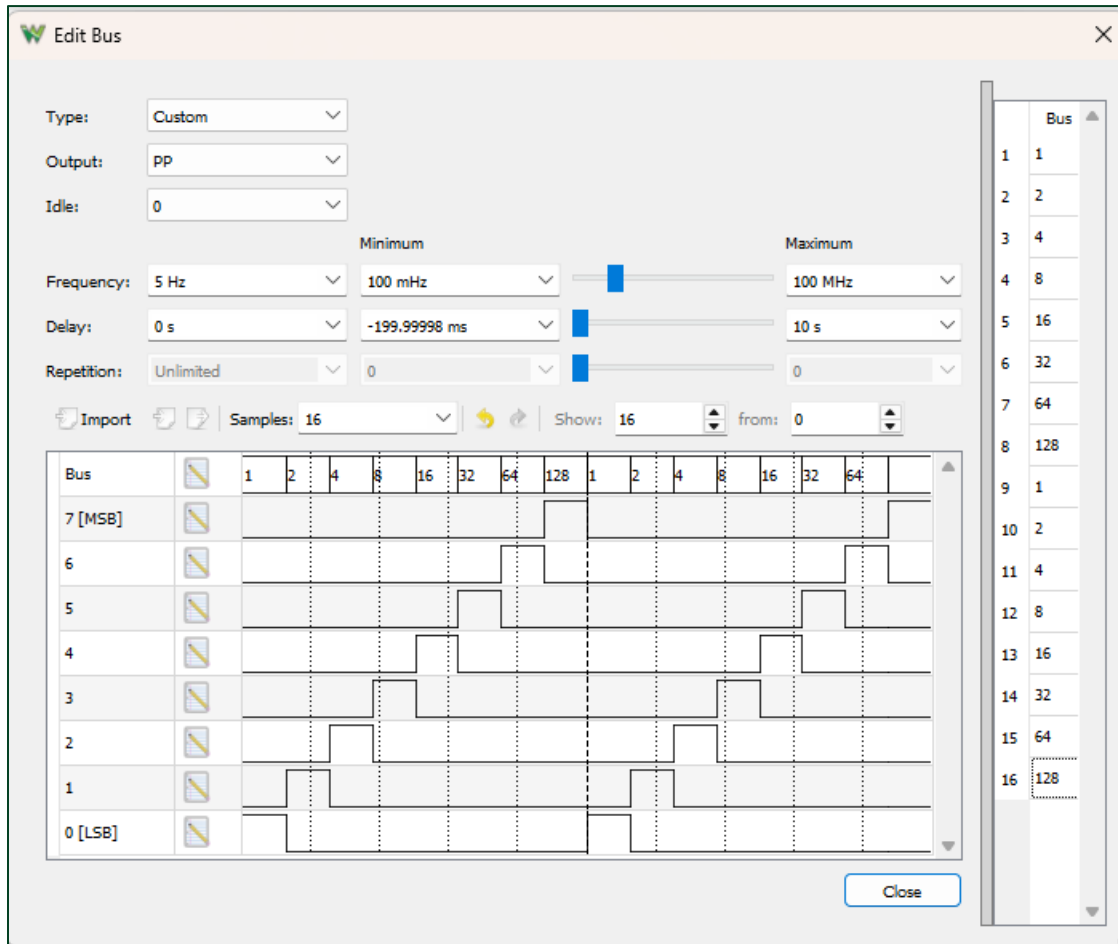


Figure 5. Custom 16-sample Forward running-LED pattern in WaveForms

Optional Pattern Sequences

Pattern	Base decimal sequence
Forward	1, 2, 4, 8, 16, 32, 64, 128
Reverse	128, 64, 32, 16, 8, 4, 2, 1
Bounce	1, 2, 4, 8, 16, 32, 64, 128, 64, 32, 16, 8, 4, 2

For continuous operation, the selected base sequence is repeated according to the configured number of samples.

The Forward sequence is used for the main experiment. Reverse and Bounce patterns can be tested as optional extensions.

Step 4. Run and observe the LED sequence

- 4.1. Click **Run** in the **Patterns** instrument.
- 4.2. Verify that the LEDs turn ON sequentially from **LED1 to LED8**.
- 4.3. Confirm that only one LED is ON at a time.

- 4.4. Change the pattern frequency to **1 Hz, 2 Hz, 5 Hz, and 10 Hz** and observe the change in running speed.
- 4.5. Stop the Pattern Generator and confirm that all LEDs turn **OFF** because **Idle = 0**.
- 4.6. Optionally repeat the experiment using the **Reverse** sequence.

For the one-hot sequence, a pattern frequency of 5 Hz corresponds to 5 LED steps/s.

Theoretical Timing Values for the Continuous 8-LED Sequence

Pattern frequency, f_{step}	Step time, T_{step}	Full cycle time, T_{cycle}
1 Hz	1.00 s	8.00 s
2 Hz	0.50 s	4.00 s
5 Hz	0.20 s	1.60 s
10 Hz	0.10 s	0.80 s

Expected Observation

At low pattern frequencies, the movement is clearly segmented. As the frequency increases, the sequence appears smoother. At very high visible rates, the individual LED states may be difficult to distinguish because of visual persistence.

Step 5. Verify the sequence with the Logic Analyzer

- 5.1. Keep the **Patterns** instrument configured and open the **Logic Analyzer**.
- 5.2. Add **DIO0–DIO7** as digital signals and optionally group them as an **8-bit bus**.
- 5.3. For the **5 Hz** experiment, set the time base to approximately **200 ms/div**.
- 5.4. Select a sampling rate sufficiently higher than the pattern frequency; **500 samples/s** is adequate for this experiment.
- 5.5. Run the **Pattern Generator** and acquire the digital waveform with the **Logic Analyzer**.
- 5.6. Verify that only one **DIO** channel is **HIGH** at each step and that the active channel changes in the order **DIO0 → DIO1 → ... → DIO7 → DIO0**.
- 5.7. If timing measurements are required, use the time cursors to measure the HIGH pulse duration and the full-cycle time.

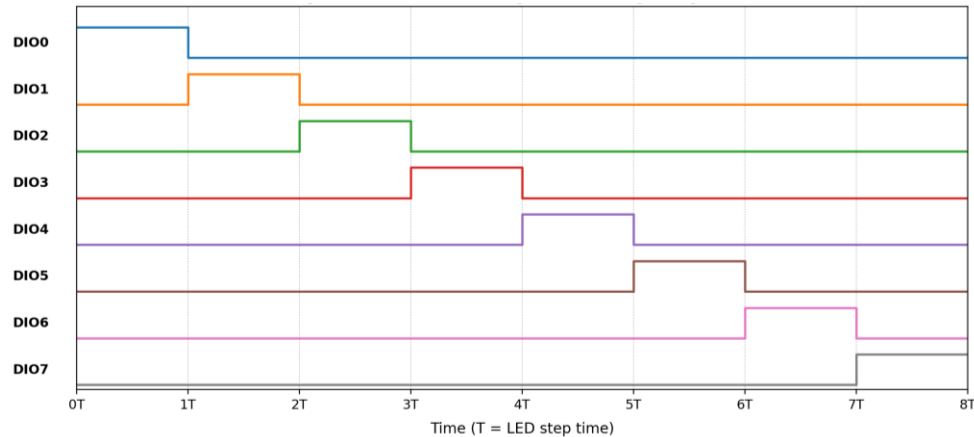


Figure 6. Expected one-hot timing diagram for the forward sequence

Expected Results

Each **DIO** channel should contain one **HIGH** pulse per complete eight-LED cycle. The pulses should not overlap in the **Forward** one-hot sequence. Increasing the pattern frequency shortens the visible **ON** time of each **LED** and decreases the full-cycle time.

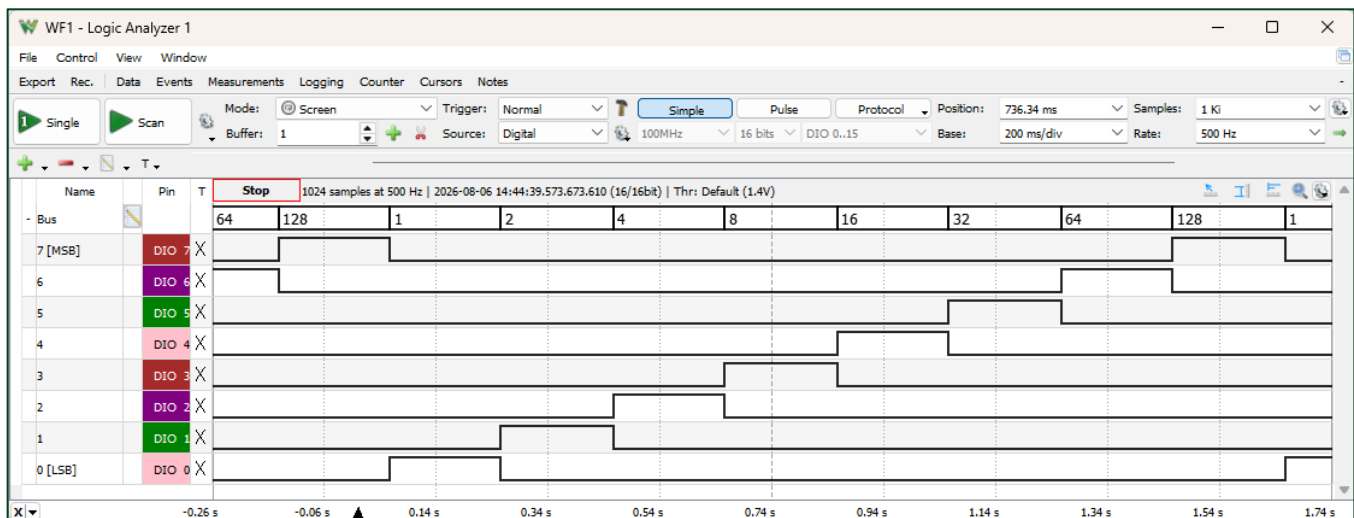


Figure 7. Logic Analyzer verification of the forward one-hot sequence at 5 Hz

Verified Digital Behavior

The **Logic Analyzer** capture confirms that the bus values repeat continuously in the order $1 \rightarrow 2 \rightarrow 4 \rightarrow 8 \rightarrow 16 \rightarrow 32 \rightarrow 64 \rightarrow 128 \rightarrow 1$, with only one **DIO** channel **HIGH** at each step. At the programmed rate of 5 Hz, the corresponding step time is 0.20 s, and one complete eight-LED cycle has a theoretical duration of 1.60 s.

Important: If a DIO line is configured as an output in Static I/O, that configuration may take priority over the **Pattern Generator**. Close Static I/O or remove conflicting output controls before running this experiment.

5.2 Running LED Control Using NI LabVIEW WaveForms Toolkit

Step 1. Launch NI LabVIEW and connect the device

- 1.1. Connect the **Digilent** device to the computer via USB.
- 1.2. Open **WaveForms** and verify that the device is detected in **Device Manager**.
- 1.3. Close the **WaveForms** software before running the **NI LabVIEW VI**.
- 1.4. Open the **NI LabVIEW** software.
- 1.5. Create a new NI LabVIEW VI (**File->New VI**)

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

- 2.1. Modify the block diagram as shown in **Figure 8**.

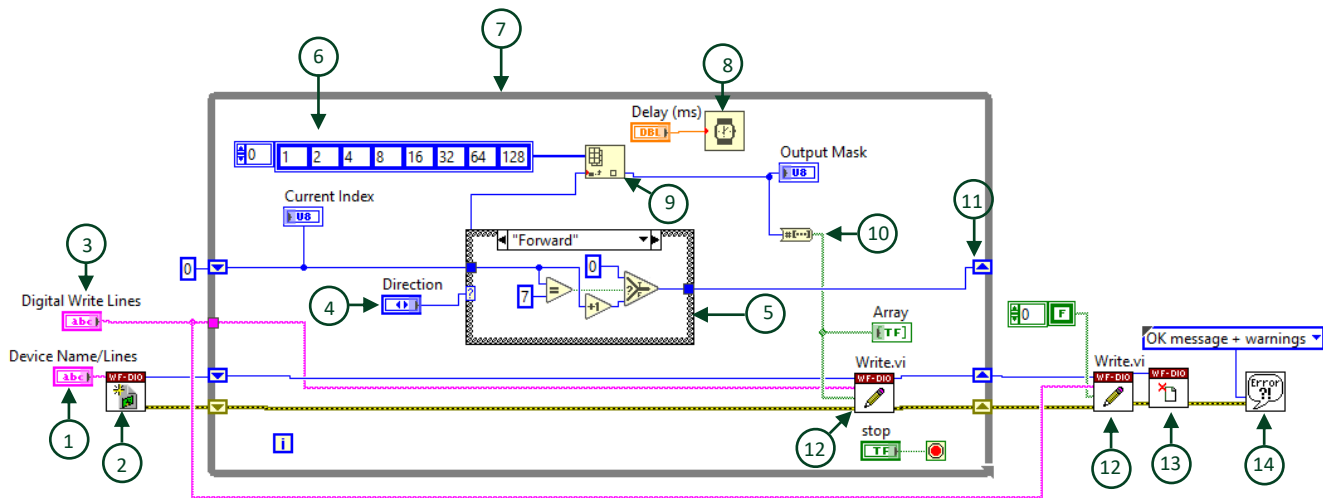


Figure 8. VI Block Diagram

1. **Device Name/Lines** - specifies the connected Digilent Device. Use the appropriate Device name from Table 2.
2. **WF-DIO Initialize** - initializes the digital I/O session for the selected Device.
3. **Digital Write Lines** - defines the digital output channels used for the running-LED circuit. In this VI, **dig/0:7** is used to control DIO0–DIO7.
4. **Direction Control** - an **Enum** control used to select **Forward** or **Reverse** operation.
5. **Case** - executes the index-update logic according to the selected **Direction**. In the **Forward** case, the index increments from 0 to 7 and then returns to 0; in the **Reverse** case, the index decrements from 7 to 0 and then returns to 7.
6. **U8 Lookup Array** - contains the one-hot output values **1, 2, 4, 8, 16, 32, 64, and 128** corresponding to the eight LEDs.
7. **While Loop** - keeps the VI running continuously until the user presses Stop.
8. **Wait (ms)** - defines the time delay between consecutive LED states. The delay value is controlled from the Front Panel. In this VI, the value is set to 200 ms.
9. **Index Array / Output Mask** - uses the current LED index to select the corresponding one-hot value from the U8 lookup array. The Output Mask indicator displays the selected value.

10. **Number to Boolean Array / LED Array** - converts the selected U8 output mask into Boolean states and displays the active LED on the Front Panel.
11. **Shift Register** - provides continuous program execution and stores the current LED index between loop iterations.
12. **WF-DIO Write** - the **Write VI** inside the While Loop updates DIO0–DIO7 during running-LED operation. The second **Write VI**, executed after the loop stops, writes all FALSE values to DIO0–DIO7 so that all LEDs are turned OFF before the device is closed.
13. **WF-DIO Close** - closes the digital I/O session and releases the Device resources.
14. **Simple Error Handler** - displays possible errors or warnings after the VI execution.

2.2. Modify the front panel shown in **Figure 9**. In the **Device Name/Lines** String Control, write your corresponding **Device** name from **Table 2**.

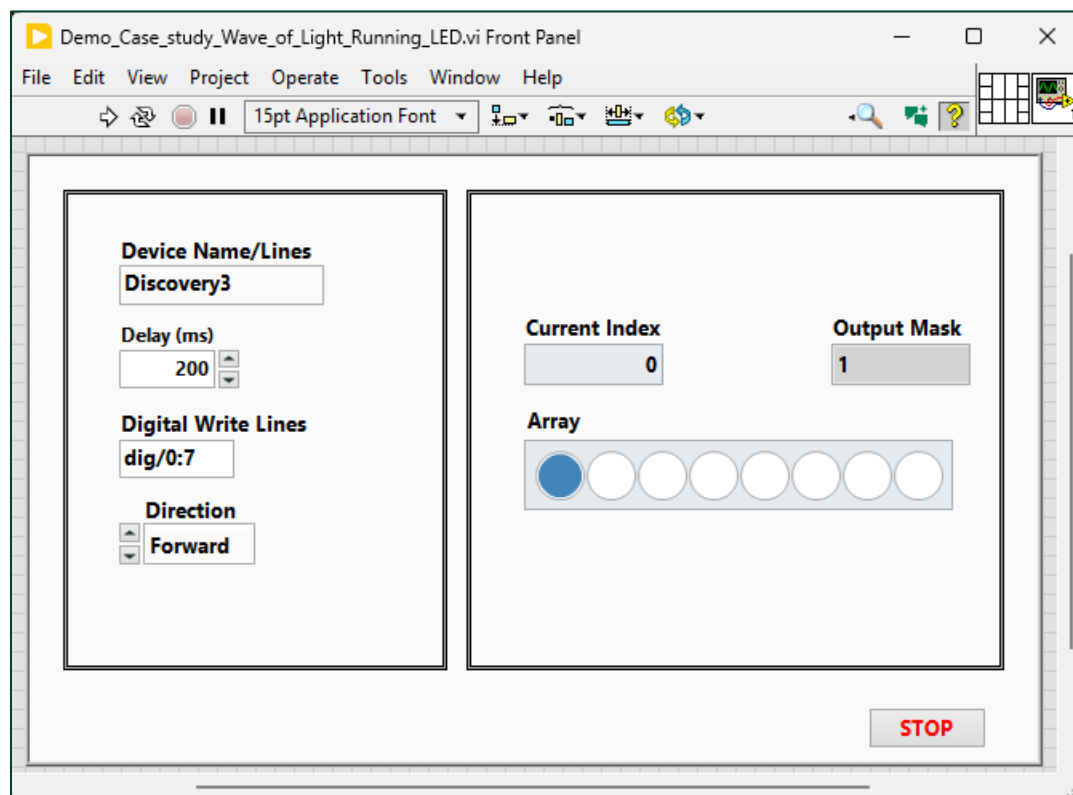


Figure 9. VI Front Panel

2.3. Save the VI.

Step 3. Run the VI and verify the results

- 3.1 Enter the correct **Device Name** from **Table 2** and set **Digital Write** Lines to dig/0:7.
- 3.2 Set **Delay** = 200 ms and select **Forward** direction.
- 3.3 Run the VI and verify that the LEDs activate sequentially from **LED1 to LED8**.
- 3.4 Verify that the **Current Index**, **Output Mask**, and Boolean **LED Array** change consistently with the active physical LED.

- 3.5 Change the Direction control to **Reverse** and confirm that the sequence runs in the opposite direction.
- 3.6 Change the Delay to **500 ms** and **100 ms** and observe the corresponding change in running speed.
- 3.7 Press **Stop** and confirm that all DIO outputs return to logic 0 and all **LEDs** turn **OFF**.

Conclusion

The Wave of Light project demonstrates the implementation and verification of an eight-channel sequential digital-output application using the Digilent Analog Discovery Product Line. A one-hot digital pattern is generated in WaveForms to activate the LEDs sequentially, while the Logic Analyzer is used to verify the output order and timing. The same control principle is implemented in NI LabVIEW using a U8 lookup array, adjustable step delay, and selectable Forward/Reverse direction. The project combines digital pattern generation, timing verification, and software-based control in a practical running-LED application.