

Automatic Light Controller - LDR Threshold using NPN Transistor

Case Study

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1. Overview

Short description: This **case study** introduces the fundamental concept of **light-dependent switching using an LDR (Light Dependent Resistor) and an NPN transistor**. Participants will design and build a simple automatic light control circuit that activates an output (LED) when ambient light falls below a defined threshold.

The experiment demonstrates how analog sensor signals can be converted into digital switching behavior using a transistor-based threshold circuit.

The Case Study utilizes the **Analog Discovery device (AD3 / AD Studio / AD Studio MAX)** together with **WaveForms and NI LabVIEW** to observe voltage changes and switching behavior in real time.

Objectives

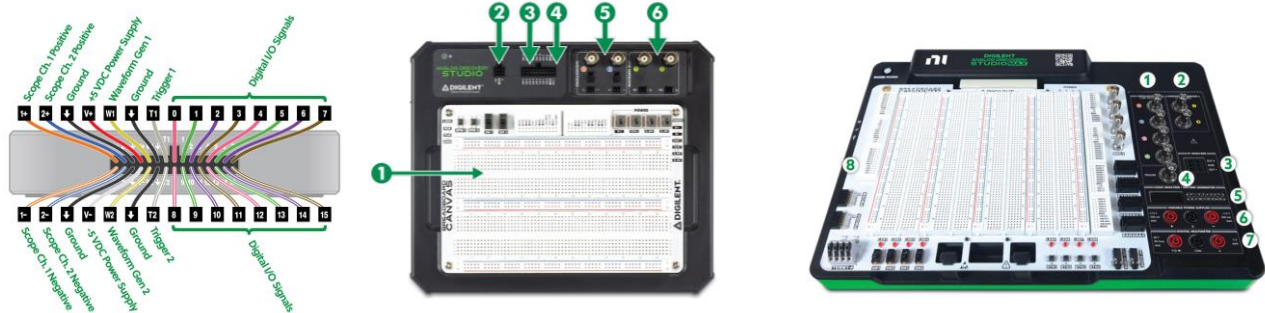
- Understand the operating principle of an LDR sensor
- Analyze voltage divider behavior under varying illumination
- Implement threshold switching using an NPN transistor
- Observe ON/OFF behavior based on light intensity
- Visualize input/output signals using **Digilent** tools
- Correlate analog voltage with digital switching behavior

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
LDR (photoresistor)		1
Resistor 10kΩ – voltage divider		1
Resistor 1kΩ – base resistor		1
NPN transistor (e.g., BC547 / 2N2222)		1
LED		1
Jumper wires		-

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.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 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

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](#)

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

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 Channel</i>
AD 3	Discovery3	mso/1	mso/2	ps/+
AD Studio ³	DiscoveryStudio			
AD Studio MAX ³	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

An LDR (Light Dependent Resistor) is a passive sensor whose resistance varies according to the intensity of incident light. As illumination increases, the resistance of the LDR decreases, and as illumination decreases, the resistance increases. This property allows the LDR to be used for sensing light levels in various control applications.

To convert the resistance variation into a measurable electrical signal, the LDR is commonly used in a voltage divider configuration. In this arrangement, the LDR is connected in series with a fixed resistor, forming a circuit where the output voltage depends on the relative resistance values:

$$V_{ctrl} = V_{cc} \cdot \frac{R_{LDR}}{R_{fixed} + R_{LDR}}$$

When the light intensity changes:

- In **bright** conditions → **LDR** resistance decreases → output voltage decreases
- In **dark** conditions → **LDR** resistance increases → output voltage increases

This voltage (V_{ctrl}) is used as a control signal for further processing.

To implement automatic switching based on light intensity, an NPN transistor is used as a threshold-controlled switch. The transistor operates in two main regions:

- **Cut-off region:** When the base-emitter voltage is below approximately 0.7 V, the transistor is OFF and no current flows through the collector-emitter path.
- **Active/Saturation region:** When the base-emitter voltage exceeds approximately 0.7 V, the transistor turns ON, allowing current to flow and activate the load (e.g., LED).

Threshold Switching Principle

An NPN transistor acts as a switch:

- If **base voltage** > **~0.7V** → transistor ON
- If **base voltage** < **0.7V** → transistor OFF

In this case study, the voltage from the LDR voltage divider is applied to the transistor base through a base resistor. As the ambient light decreases, the control voltage increases. When it reaches the threshold level (**~0.7 V**), the transistor switches ON and the LED lights up.

Thus, the circuit performs an automatic light control function:

- Dark → high voltage → transistor ON → LED ON
- Light → low voltage → transistor OFF → LED OFF

4. Circuit Design – Step by Step Instructions

4.1 Description

The circuit consists of:

- LDR + resistor forming a **voltage divider**
- NPN transistor acting as a **switch**
- LED as output indicator

The voltage from the divider controls the transistor base.

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.

4.2 Step by step instructions³

1. Place the **LDR** on the breadboard.
 - Connect one terminal of the LDR to the **GND rail**.
 - Connect the other terminal of the LDR to the node that will serve as the **Vctrl** measurement point.
2. Place the **10 kΩ** resistor (R2) from **+5 V** to the **Vctrl** node.
 - This forms a voltage divider with the LDR:
 - a. Light → LDR low → Vctrl low
 - b. Dark → LDR high → Vctrl high
3. Place an **NPN transistor** (Q1 — 2N2222) on the breadboard.
4. Connect the **emitter** to **GND**.
5. Connect the **collector** to one terminal of the **LED**.
6. Connect the other terminal of the LED to **+5 V** through a **1 kΩ resistor (R1)**.
 - (+5 V → R1 → LED → Q1 collector → Q1 emitter → GND)
7. Connect the **base** of the transistor to **Vctrl** via a **1 kΩ** resistor (**R1** in schematic = **1 kΩ base** resistor).
 - This sets the base current and defines the switching threshold.
8. Oscilloscope wiring:
 - **Scope Ch.1 Positive** → **Vctrl node**
 - **Scope Ch.1 Negative** → **GND**
 - **Scope Ch.2 Positive** → **Transistor collector**
 - **Scope Ch.2 Negative** → **GND**

³ Given on Figure 2.

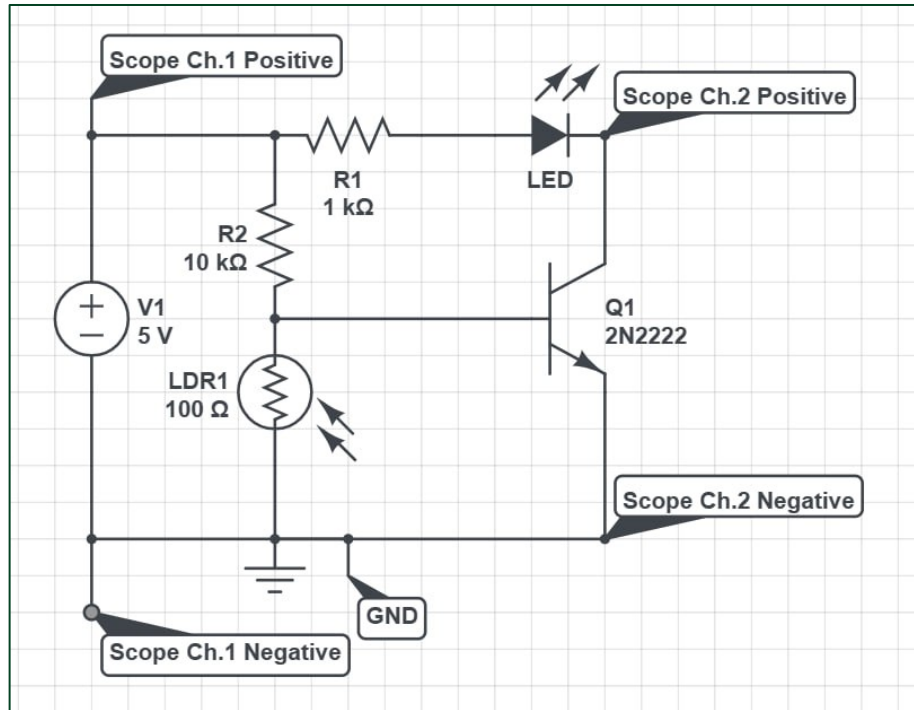


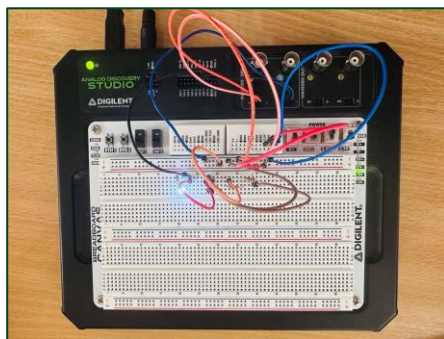
Figure 2. LDR Threshold using NPN Transistor Circuit Diagram

4.3 Assembled Circuit

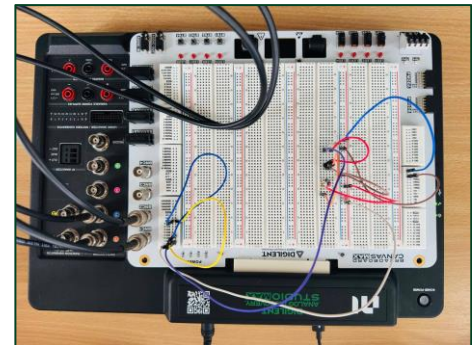
Figure 3 presents complete experimental circuits on different Digilent devices.



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 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 input signal

- 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 (OFF), as only a single supply is required for this circuit.

Figure 4 shows the configuration of the **Device** power supply using the **Digilent WaveForms** environment.

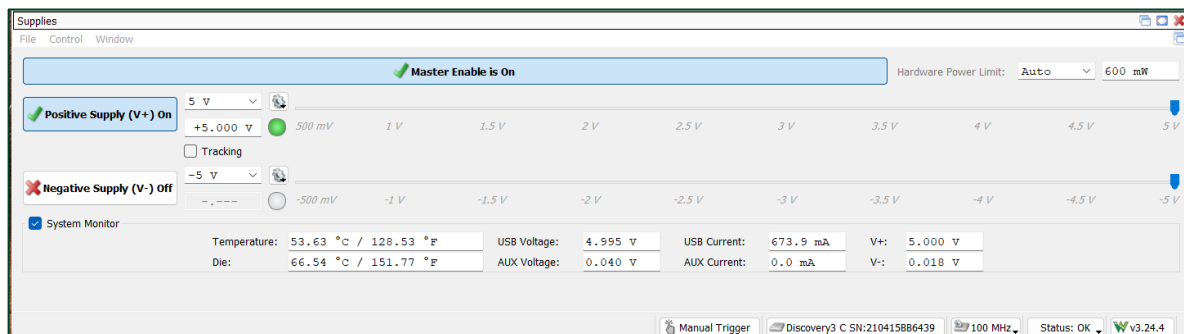


Figure 4. Power Supply Configuration in WaveForms (+5 V enabled, V- disabled)

Step 3. Acquire the signal using the Oscilloscope⁴

a. Observe frequency response

- 3.1. Open the **Scope** instrument on WaveForms.
- 3.2. Enable **Channel 1** to measure the control voltage (**Vctrl**) at the **LDR–R2** divider node.
- 3.3. Enable **Channel 2** to measure the **LED** anode voltage (collector output of the transistor).
- 3.4. Set the vertical scale of both channels to **1–2 V/div**.
- 3.5. Set the time base to **100 ms/div** to clearly observe slow variations caused by light level changes.
- 3.6. Press **Run** to start acquisition.

b. Observation

Manually vary the illumination on the LDR:

- **Cover the LDR → Vctrl increases → Transistor ON → LED ON**
- **Expose the LDR to light → Vctrl decreases → Transistor OFF → LED OFF**

⁴ In the case of AD Studio turn the 5.0V switch on. In the case of AD Studio MAX turn Board Power on.

You should see:

- **Channel 1:** gradual increase/decrease in Vctrl (**Figure 5**)
- **Channel 2:** sudden switching (0V → LED ON voltage)

Note: During the experiment, the light intensity is manually varied to observe the transition between OFF and ON states. This demonstrates how the analog voltage from the LDR controls the transistor switching behavior.

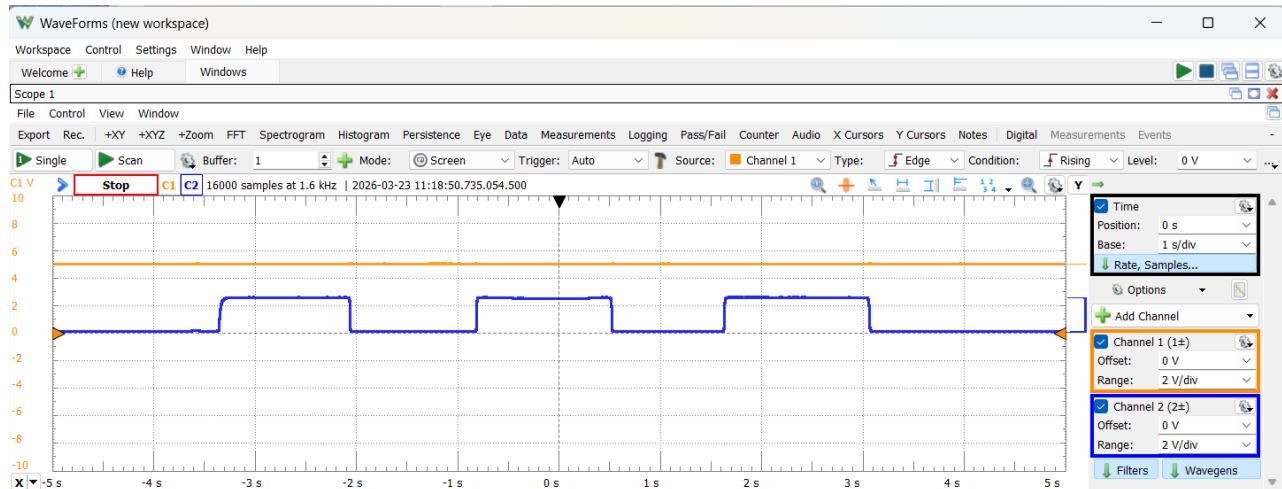


Figure 5. Oscilloscope Measurement of Vctrl (Ch.1) and LED Output (Ch.2) in WaveForms

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 **Digilent WaveForms** and verify that **Device** is detected and shown as *Currently Selected* in the **Device Manager** (Settings -> Device Manager), then close **Digilent WaveForms** software⁵.
- 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 similarly to **Figure 6**.

Figure 6.1 shows the LabVIEW block diagram code applicable only to Analog Discovery 3. **Figure 6.2** 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.



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 and enable both analog input channels (**Scope Ch.1** and **Scope Ch.2**) by entering the appropriate device channel identifiers (e.g., **mso/1:2**), as listed in **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 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 7**. Inside **Device name** String Control write your corresponding **Device** name from **Table 2**.

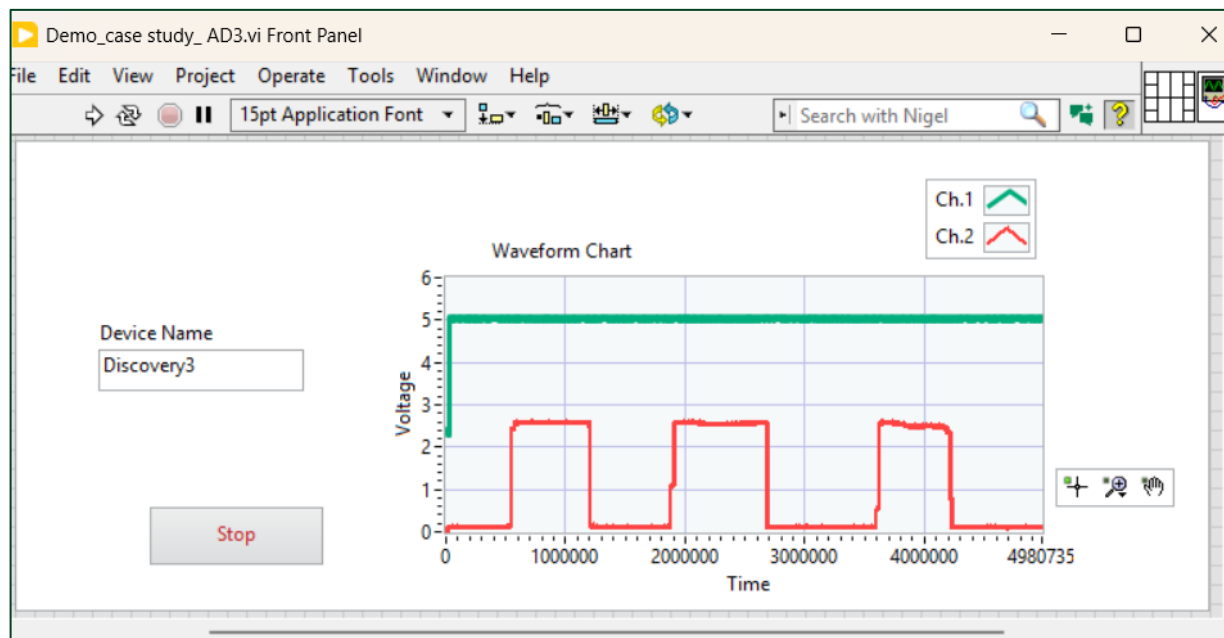


Figure 7. VI Front Panel - Displaying Real-Time Vctrl and LED Output Signals

2.3. Save the VI.

Step 3. Run the code and do measurements in LabVIEW

- 3.1. Click the **Run button** to start the VI.
- 3.2. Observe the waveform chart:
 - **Vctrl** variation with light
 - Output switching behavior
- 3.3. Stop the code execution in LabVIEW and turn off the **Device**.

Experiment procedure

Change light intensity manually and observe:

- Gradual voltage changes at LDR node

- Suddenly ON/OFF switching at output

Analysis

Determine:

- Switching threshold voltage

$$V_{threshold} \approx 0.7V$$

- Relationship between light intensity and output state

Conclusion

This experiment demonstrates:

- Conversion of analog sensor signal into digital switching
- Threshold-based control using a transistor
- Real-time monitoring using LabVIEW

The waveform chart clearly illustrates the conversion of a **slowly varying analog signal (Vctrl)** into a **digital-like switching output**, demonstrating the core principle of this case study: **threshold-based light-activated control using an NPN transistor**.