

Thermistor Sensor - Measuring Temperature through Voltage Variation

Case Study

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1. Overview

Short description: This **Case study** explores how a thermistor can be used to measure temperature by converting resistance changes into electrical voltage variations. Participants observe how heating or cooling the thermistor affects the measured signal and learn how resistance-to-temperature relationships translate into real-world applications. Analog Discovery Product Line ([AD3](#) or [AD Studio](#) / [Studio MAX](#), hereby **Device**) supplies power to the voltage divider and simultaneously measures the output using the oscilloscope.

Objectives

- Understand the operating principle of a thermistor and how its resistance varies with temperature.
- Configure a voltage divider circuit to convert thermistor resistance changes into measurable voltage levels.
- Observe how heating or cooling the thermistor affects output voltage in real time using the **Device**.

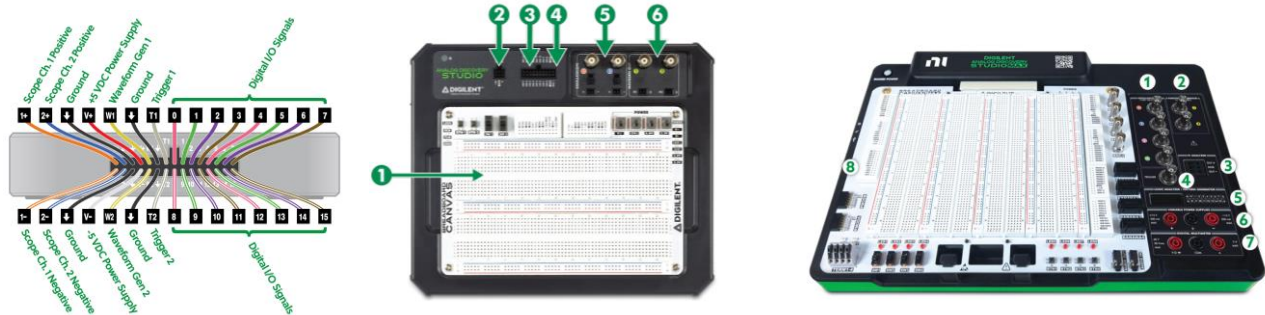
Software & Hardware Requirements

Software		Version
<u>Digilent WaveForms</u> (Runtime + SDK)		Latest (64-bit)
NI LabVIEW		2025 64-bit
WaveForms Toolkit for LabVIEW		Latest
Hardware		Quantity*
Digilent Analog Discovery Product Line		
Option 1	<u>Digilent Analog Discovery 3</u>	
Option 2	<u>Digilent Analog Discovery Studio</u>	
Option 3	<u>Digilent Analog Discovery Studio MAX</u>	
List of Components		Quantity*
Canvas Breadboard		1
NTC Thermistor 10kΩ		1
Resistor 10kΩ		1
Light Bulb 12V		1
9V Battery or Variable Power Supply		1
Jumper wires		-
BNC to BNC cable ¹		1
Banana to Banana cable ¹		2

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>+Vs</i>	<i>+V1</i>
AD 3	Scope Ch.1 Positive (Pin 1+)	Scope Ch.1 Negative (Pin 1-)	+VDC Power Supply (Pin V+)	External 9V Battery + connector
AD Studio ³	OSCILLOSCOPE 1 (Pin + or BNC Positive Cable)	OSCILLOSCOPE 1 (Pin - or BNC Negative Cable)	+5.0V (on canvas board)	+VDC Power Supply (Pin V+)
AD Studio MAX ³	OSCILLOSCOPE 1 (BNC Positive Cable)	OSCILLOSCOPE 1 (BNC Negative Cable)	+5.0V (on canvas board)	Variable Power Supply (V+, use Banana to Banan connector)

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			

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

A thermistor is a temperature-sensitive resistor whose resistance varies predictably with temperature. In this **Case study**, a negative temperature coefficient (NTC) thermistor is used to measure ambient temperature by incorporating it into a voltage divider circuit. The voltage divider converts the thermistor's resistance change into a measurable voltage variation. In this **Case study**, a light bulb (lamp) is used as a controlled heat source. When powered, the lamp generates thermal energy that increases the ambient temperature around the thermistor. This causes a change in the thermistor's resistance, allowing the system to demonstrate temperature-dependent voltage variation in real time. A standard thermistor-based voltage divider circuit with an external heat source is shown in Figure 2.

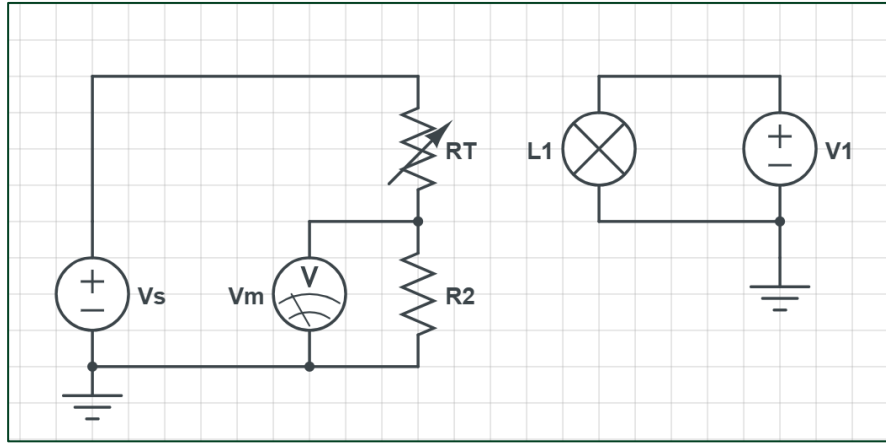


Figure 2. NTC Thermistor Voltage Divider Measurement Circuit

The presented circuit is based on a voltage divider configuration consisting of a thermistor R_T and a fixed resistor R_2 , supplied by a DC voltage source V_s . The output voltage V_m is measured across the fixed resistor R_2 . According to the voltage divider principle, the measured voltage V_m is:

$$V_m = V_s \frac{R_2}{R_T + R_2} \quad (1)$$

Rearranging this expression to determine the thermistor resistance R_T , we obtain:

$$R_T = \frac{R_2(V_s - V_m)}{V_m} \quad (2)$$

This equation allows the thermistor resistance to be calculated from the measured voltage.

Once the thermistor resistance R_T is determined, the temperature can be calculated using the linear approximation of resistance variation:

$$T = T_0 + \frac{R_T - R_0}{\alpha \cdot R_0} \quad (3)$$

where:

- T - temperature in °C
- T_0 - reference temperature⁴

- R_T - measured thermistor resistance
- R_0 - resistance at reference temperature T_0 ⁴
- α - temperature coefficient of resistance (TCR)⁴

This equation describes the relationship between resistance and temperature assuming a linear behavior around the reference point. Final equation showing dependance between measured voltage and environment temperature can be presented as follows:

$$T(V_m) = T_0 + \frac{R_2(V_s - V_m) - R_0 V_m}{\alpha R_0 V_m} \quad (4)$$

4. Circuit Design – step by step instructions

4.1 Description

The measurement circuit is based on a voltage divider configuration used for temperature sensing. A 10 k Ω NTC thermistor (R_T) and a fixed 10 k Ω resistor (R_2) are connected in series between the DC supply (+V1) and ground (GND). The junction between R_T and R_2 provides the output voltage, which varies according to temperature changes. As the thermistor temperature increases, its resistance decreases, causing a corresponding change in the divider output voltage. This voltage is monitored by connecting **Scope Ch.1 Positive** to the midpoint of the voltage divider and **Scope Ch.1 Negative** to GND, allowing real-time observation of voltage variations. A lamp (L1), powered by a separate supply (+V2), acts as a heat source. When energized, it increases the ambient temperature around the thermistor, producing a measurable change in resistance and therefore in the output voltage. This setup enables practical demonstration of temperature-dependent voltage behavior using a simple resistive sensing scheme.

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.

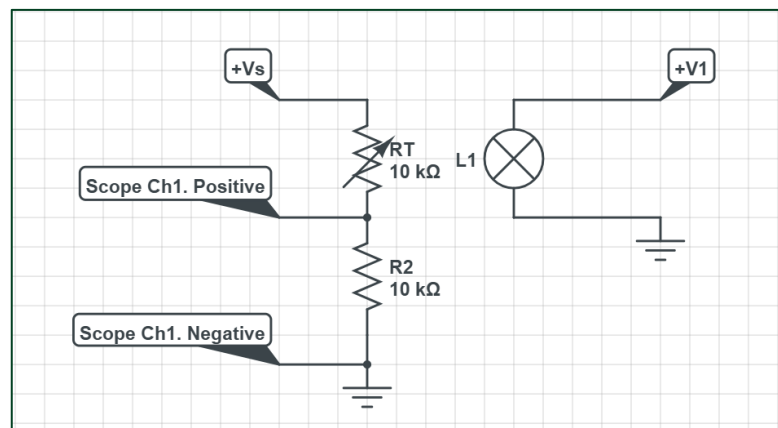


Figure 3. NTC Thermistor Voltage Divider Measurement Circuit for Device

⁴ These parameters can be obtained from your thermistor documentation.

Important! *The Analog Discovery 3 (AD3) has only one power supply output. This supply is used to power the voltage divider circuit for the thermistor measurement. Therefore, the lamp must be powered using an external 9 V battery.*

For Analog Discovery Studio or Discovery Studio Max devices, a fixed 5 V supply is available and should be used to power the voltage divider circuit. In this case, the lamp can be powered using the variable power supply output of the device.

4.2 Step by step instructions⁵

1. Place the thermistor (R_T , 10 k Ω) on the Canvas breadboard⁶, ensuring its two pins are inserted into different rows (not shorted together).
2. Place the 10 k Ω resistor (R_2) on the breadboard so it can form a series pair with the thermistor (for a voltage divider).
3. Connect the top pin of the thermistor (R_T) to the Device +Vs supply.
4. Connect the bottom pin of the resistor (R_2) to GND.
5. Connect the lower pin of the thermistor (R_T) to the upper pin of the resistor (R_2). This junction is the divider output node (measurement point).
6. Connect **Scope Ch.1 Positive** to the junction between R_T and R_2 (the divider output voltage V_m).
7. Connect **Scope Ch.1 Negative** to **GND** (same ground used by the voltage divider).
8. Place the **Lamp** (L_1) in the circuit area, connect it to the separate supply **+V1**. Connect the positive terminal (+) of the supply to one terminal of the lamp and connect the negative terminal (–) of the supply (GND) to the other terminal of the **Lamp**. Ensure the **Lamp** circuit ground is connected to the same common **GND** (or confirm both circuits share the reference ground in your setup), so measurements remain stable.

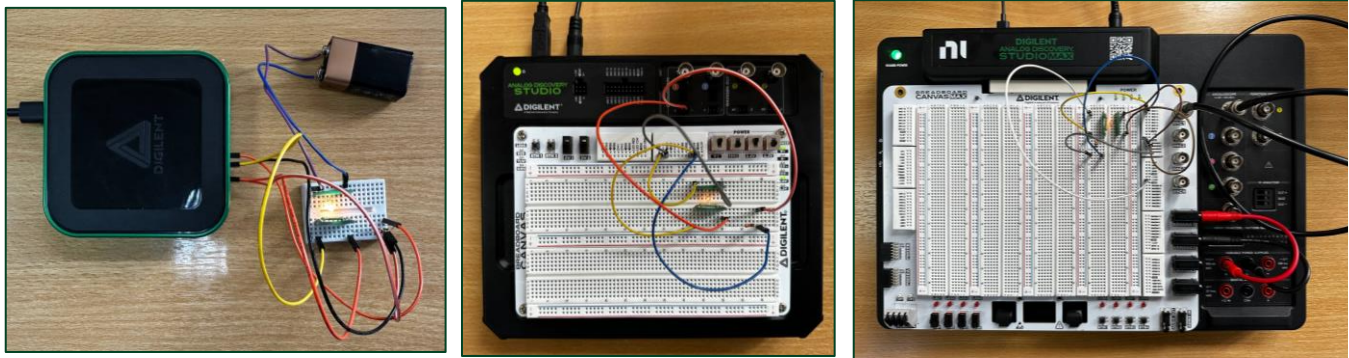
Important! *Position the thermistor close to the lamp (but not touching it) so the lamp heat changes the thermistor temperature gradually and safely.*

⁵ Given on Figure 3.

⁶ Use external breadboard in the case of Analog Discovery 3.

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 WaveForms⁷

- 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.

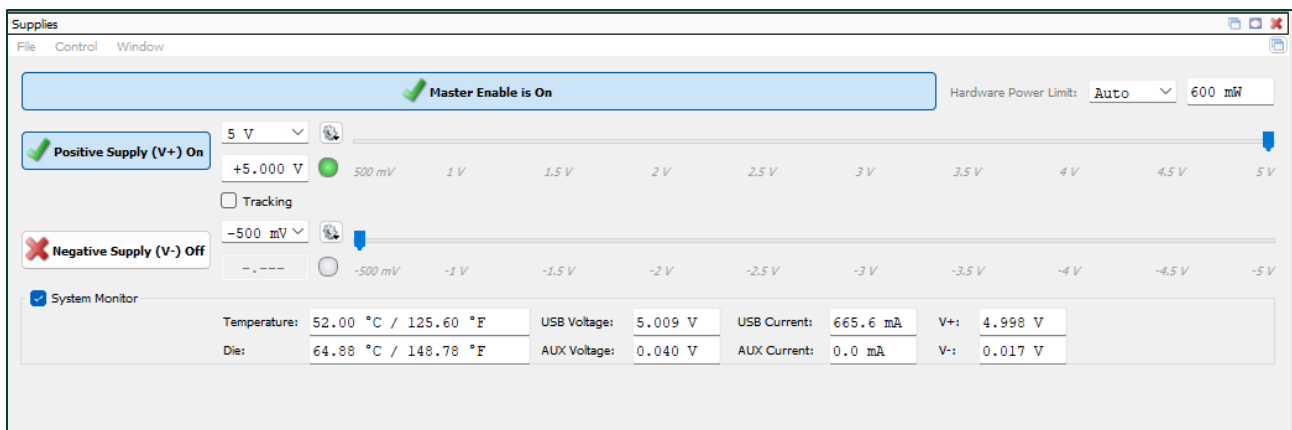


Figure 5. Power Supply Configuration in WaveForms Software

Step 3. Acquire the signal using the Oscilloscope⁸

- 3.1. Open the **Scope** instrument on WaveForms.
- 3.2. Enable **Channel 1**.
- 3.3. Adjust the **Range to 2 V/div** so the signal fits clearly on the screen.
- 3.4. Adjust the **Time Base to 500ms/div**.
- 3.5. To observe voltage changes, click **Measurements** from the top toolbar. Select **Add**, then choose **Defined Measurements**. In the **Add Measurements** window, select **Channel 1** → **Vertical** → **Average**, and click **Add**.

⁷ This step is mandatory for the Digilent Analog Discovery 3. Skip if you are using another device.

⁸ In the case of AD Studio turn the 5.0V & V± switch on. In the case of AD Studio MAX turn Board Power on.

Step 4. Turn on the Lamp voltage source and observe the voltage change displayed on the Scope⁹

- 4.1. Open the **Supplies** instrument in **WaveForms** (only for ADS or ADS MAX).
- 4.2. Enable the **Positive Supply (V+)** (only for ADS or ADS MAX).
- 4.3. Set the output voltage to **+5.000 V DC** (only for ADS or ADS MAX).
- 4.4. Enable the **Master Enable** switch to activate the power output (only for ADS or ADS MAX).
- 4.5. Keep the **Negative Supply (V-)** disabled (a single positive voltage is only required for the LDR voltage divider circuit) (only for ADS or ADS MAX).
- 4.6. Open **Scope** and observe voltage changes in **Measurements** window.
- 4.7. Turn off the **Lamp**.

Figure 6 shows the real-time voltage variation measured at the output of the thermistor-based voltage divider and acquired using the Scope tool in Digilent WaveForms. The displayed signal illustrates how the output voltage changes in response to temperature variations. When the temperature increases due to the lamp acting as a heat source, the resistance of the NTC thermistor decreases, causing a corresponding shift in the measured voltage.

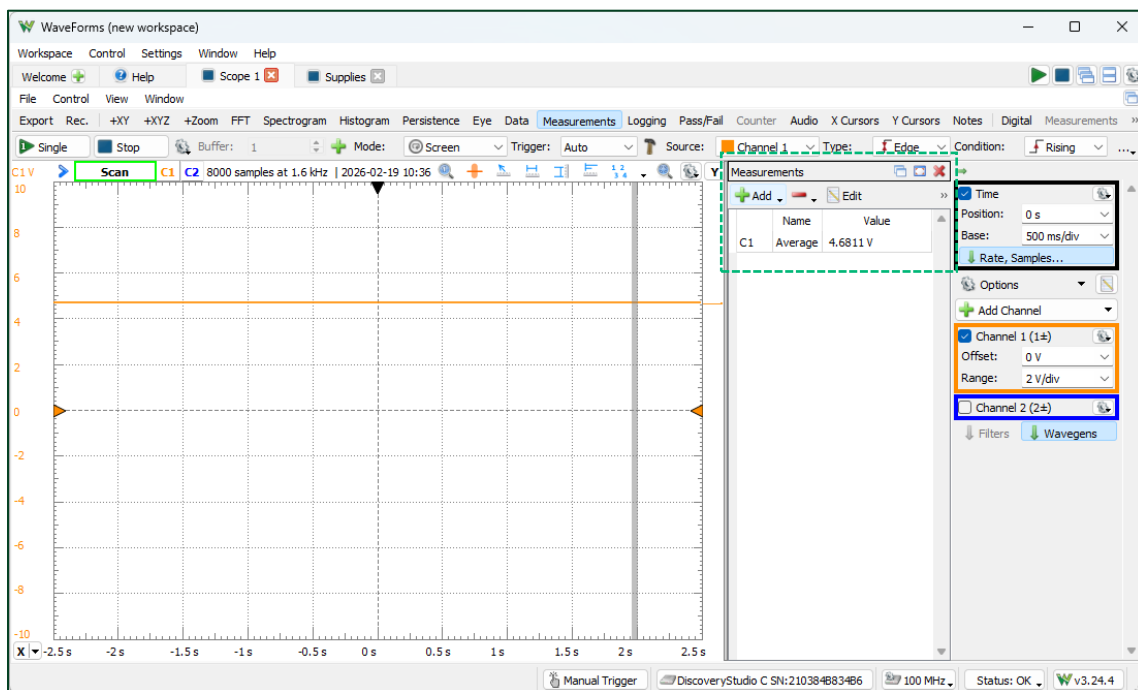


Figure 6. Voltage Divider Output Signal Displayed in WaveForms

Step 5. Calculating Temperature in Waveforms

- 5.1. Click the **Add Channel** button ( Add Channel) in the right-side panel in **WaveForms** and choose the **Custom (Software)** option.

⁹ In the case of AD 3 use an external 9 V battery to power the lamp. Skip steps 4.1–4.5.

- 5.2. Using **Equation (4)**, insert the thermistor parameters from the documentation and derive the temperature–voltage relationship. For the given parameters: $V_S = 5\text{ V}$, $T_0 = 20^\circ\text{C}$, $\alpha = -0.03$, $R_0 = 1000\ \Omega$, $R_2 = 10000\ \Omega$, the resulting dependence is:

$$T(V_m) = \frac{1160}{3} - \frac{5000}{3} \cdot \frac{1}{V_m}$$

Instead of V_m , replace it with your actual measurement channel name. In this setup, the channel name is **C1**, so the equation becomes:

$$T = 1160/3 - 5000/(3 * C1)$$

- 5.3. In the **Math 1** window, enter the equation obtained in the previous step. Change the **Units** to $^\circ$. Select **OK** to apply the configuration. **Figure 7** presents the **Math 1** window configuration.

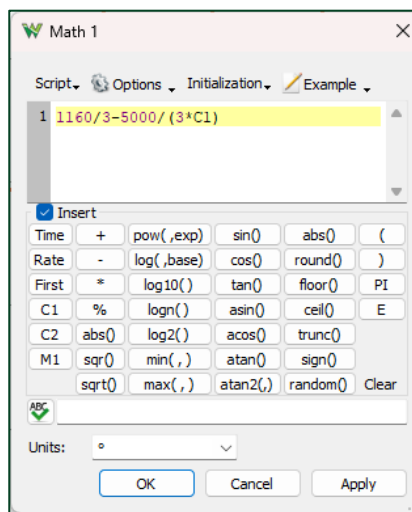


Figure 7. Custom (Software) window in Waveforms

- 5.4. Turn off **Channel 1** and **Channel 2**. Adjust the **Math 1** vertical range to **10 $^\circ\text{C}/\text{div}$** (or appropriate scale for clear temperature visualization).
- 5.5. To display the average temperature value, in the right-side **Measurements** window, click **Add**, select **Defined Measurement**, then in the **Add Measurement** window choose **Math1** $\rightarrow$ **Vertical** $\rightarrow$ **Average**, and click **Add**.
- 5.6. Click **Histogram** from the top toolbar to enable the histogram view.
- 5.7. Turn on the **Lamp** voltage source and observe the temperature change displayed in both the Histogram and the Measurements window.

Figure 8 illustrates the measured temperature changes in the WaveForms. The upper graph displays the calculated temperature signal obtained through the Math1 function, while the lower panel shows the corresponding histogram distribution of the temperature values. The Measurements window presents the average temperature value in real time. This configuration allows clear visualization of how the temperature varies when the thermistor is heated by the lamp.

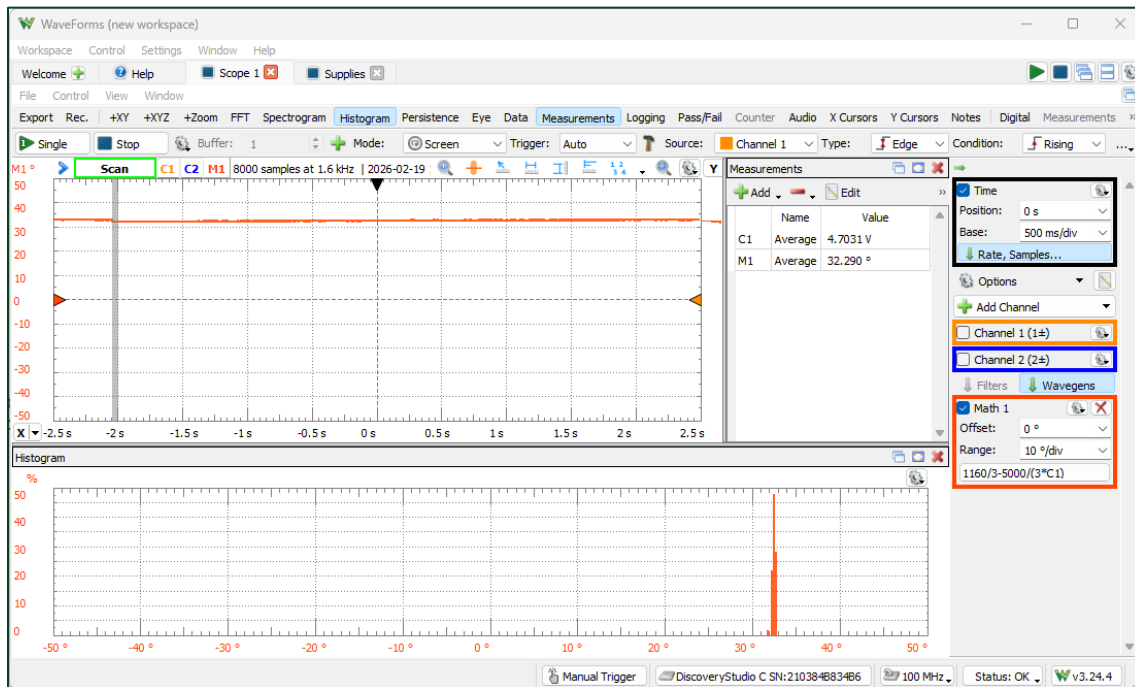


Figure 8. Temperature Measurement in Waveforms

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** software¹⁰.
- 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 9.1** and **Figure 9.2**.

Figure 9.1 shows the LabVIEW block diagram code applicable only to ADS and ADS Max devices.

Figure 9.2 shows the LabVIEW block diagram code applicable only to the AD 3 device.

¹⁰ Before running NI LabVIEW, please ensure that the Digilent WaveForms software is closed.

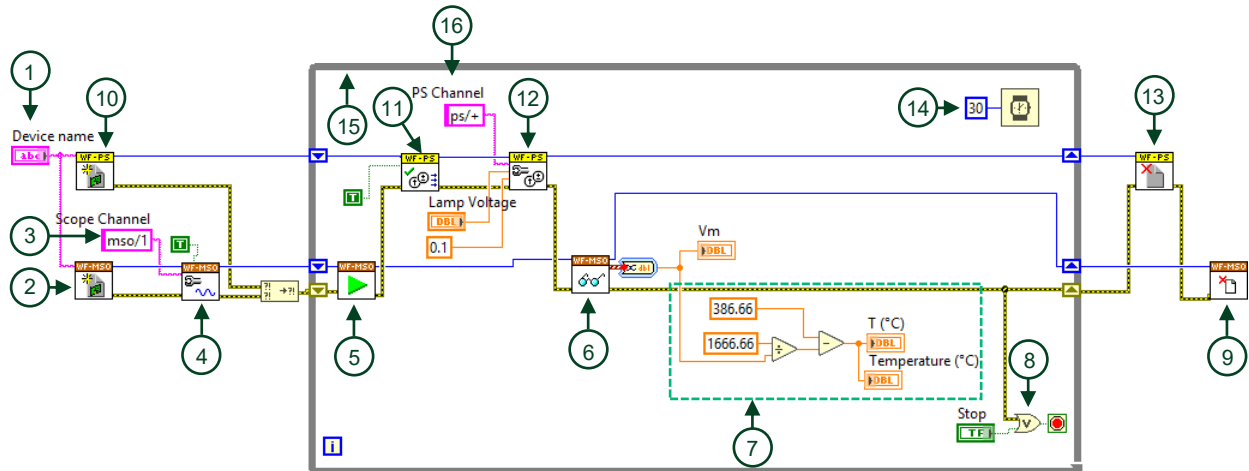


Figure 9.1 VI Block Diagram for ADS and ADS MAX

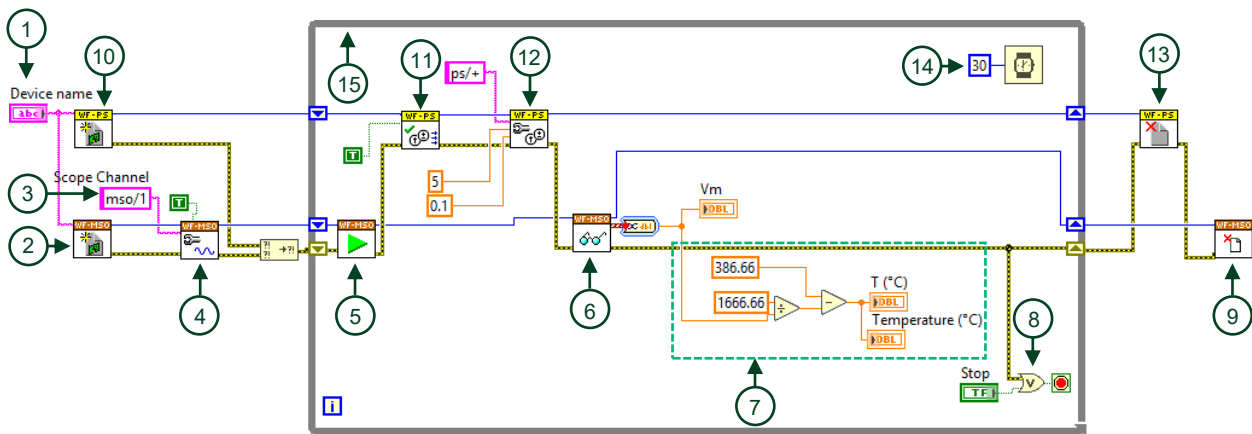


Figure 9.2. VI Front Panel for AD 3

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. **WF-MSO Run** - Run the acquisition.
6. **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.
7. Convert measured voltage to temperature using Equation (4).
8. **OR** - Allow the code to stop using the **Stop** button or automatically when an error occurs.
9. **WF-MSO Close** - Remove the session and reset all values for scope.
10. **WF-PS Initialize** - this VI initializes the power supply.
11. **WF-PS Enable All Outputs** - this VI enables all outputs for power supply.
12. **WF-PS Configure Voltage Outputs** - this VI configures voltage outputs for power supply.
13. **WF-PS Close** - 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. **PS Channel** - specify your **Device PS** channel. Use **Table 2** for your **Device**.

2.2. Modify the front panel shown in **Figure 10**. Inside **Device name** String Control write your corresponding **Device** name from **Table 2**.

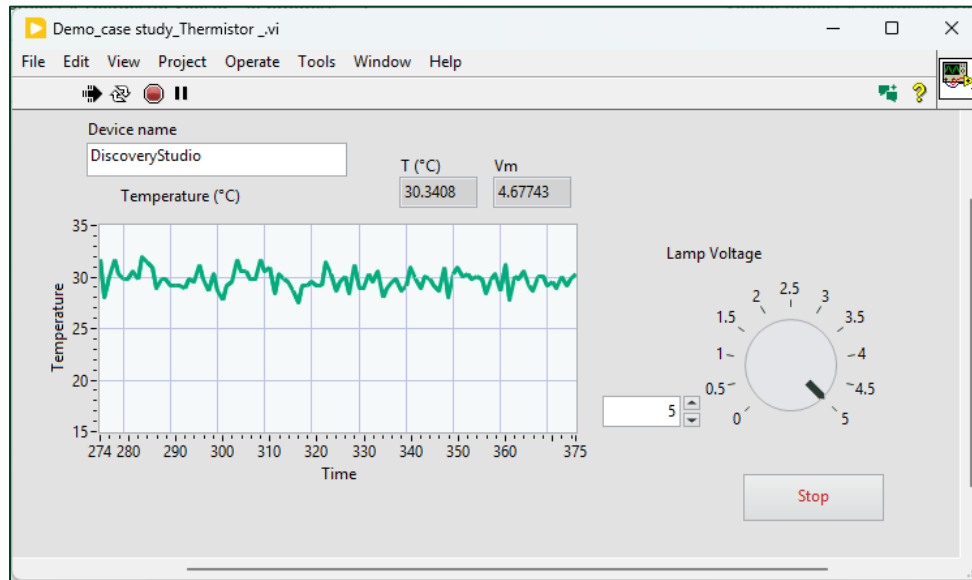


Figure 10. VI Front Panel

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. Turn on the **Lamp**.
 - for AD 3 use external battery
 - for ADS or ADS Max use Lamp Voltage control to set the voltage for **Lamp**.
- 3.3. Observe temperature changes.