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Design and Implementation of a Data Acquisition System for Photovoltaic Panels Using Arduino

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Thanks

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General Introduction

General Introduction

In Algeria, there are few functional weather stations. Their problem lies in the high cost of the electronic cards that are the intermediary tools between the majority of the quantities to be measured and their environmental impact, whatever their measurement objectives (weather, marine navigation, air navigation, choice of land for photovoltaic and wind power installations), in this regard, data collection and storage are an integral part of day-to-day lab work[1]:. Researchers and engineers need to constantly monitor machines and systems through a series of sensor information, for this reason; here is a prototype of a low-cost photovoltaic data measurement station. This station can provide us with a set of data to be displayed and data logging and online plotting data in the form of CSV file so that can be used by engineers and researchers wanting regular information on the weather situation and photovoltaic system.

The data is collected using a measurement algorithm implemented in Arduino mega Microcontroller. Furthermore, the parameters identification is one critical step in any system, both in simulation and real-world implementation. A thorough understanding of solar panel parameters is necessary for modelling, quality assurance, and performance assessment, just like with any other system. Indeed, many parameters of the PV panel, which is composed of an assembly of different cells, are typically included in the datasheet, that manufacturer of photovoltaic cells and panels supply. The datasheet does not, however, address all of the factors. In practice, figuring out these unknown characteristics is essential for this reason, The design and implementation of the proposed work can be segmented into two main sections; Parameter identification of 3W PV panel under different climatic conditions followed by real-time data acquisition of operational parameters (current, voltage, temperature, air moisture, solar radiation) of PV panel connected with load that in the data acquisition phase, information is gathered from various sensors, including voltage, current, temperature, humidity, and Light, the processing of these data assisted by Arduino card.

For the presented project, the work has been divided into three chapters, the first of which sets out some general concepts and information about Arduino card and their elements followed by the presentation of used sensors and most important accessories in this work.

The second chapter is devoted to presenting the software used to acquire the data IDE Arduino and data streamer, as well as identifying the different blocks in our system and the components used in the assembly, in particular the power supply, the controller, the sensors used in our system, and the connections between the different parts that make up the work, with a technical reinforcement of a few virtual sub-implementations in the ISIS Proteus environment.

The final chapter will deal withe the implementation of collected the data using a measurement algorithm implemented in Arduino Uno Microcontroller. Furthermore, the parameters identification is one critical step in any system, both in simulation and real-time implementation.

In conclusion, this work presents a design and implementation of multi-sensor real-time data acquisition system and parameter identification for a PV system.

Chapter I

The State of the Art

I.1: Introduction

Renewable energy sources have become one of the main sources of energy due to their abundance. Today, as civilization develops rapidly, various challenges to the energy structure are occurring. This is due to concerns about pollution and global warming and the increasing demand for renewable energy resources.

Therefore, solar energy is the most promising renewable energy source due to its abundance, diversity, and environmentally friendly nature. The development and utilization of this energy not only provides a means to utilize resources, but also produces an effective assessment to modify resources to better overcome the energy resource crisis. There are various environmental and geographical factors affecting resources, so measuring solar resources based on these factors makes the system cost-effective and improves the utilization rate of renewable solar energy.

Data acquisition helps measure the state of solar systems under these factors. The accuracy of the data acquisition system is also important because different tools are used to obtain data from the system [2]. In addition to the above, it is well known that the step of identifying the parameters of any system is a very important step for both simulation and practice.

Arduino is a prototype interactive object tool consisting of an electrical board and a programming environment. [3]

Without any prior knowledge or understanding of electronics, this hardware and software environment allows users to develop their projects through direct experimentation using numerous online resources. Arduino is a bridge between the physical and digital worlds, allowing you to expand the capabilities of sensor or machine-environment relationships.

I.2: Solar energy

Solar energy is the light and heat emitted by the sun, which has been harnessed by humans since ancient times using a range of constantly evolving technologies. Solar energy harnessing techniques include the use of the sun's thermal energy, either for direct heating or as part of a mechanical conversion process for movement or electrical energy, or to generate electricity through photovoltaic phenomena using photovoltaic panels. In addition, architectural designs that rely on harnessing solar energy are techniques that can significantly contribute to solving some of the world's most pressing problems today.

Most renewable energy sources available on the Earth's surface are attributed to solar radiation, in addition to secondary energy sources such as wind power, wave power, hydroelectricity, and biomass. It should be noted that only a small portion of available solar energy has been utilized in our lifetime. Electrical energy is generated from solar energy by heat engines or photovoltaic converters.

Once solar energy is converted into electrical energy, only human ingenuity controls its uses. Applications that utilize solar energy include heating and cooling systems in architectural designs that rely on solar energy, potable water distillation and disinfection, daylight harvesting, water heating, solar cooking, and high temperatures for industrial purposes. [4]

I.2.1: Solar heating energy

Solar thermal energy systems use sunlight to heat a fluid, which can be used to produce steam and drive a turbine to generate electricity. This technique is commonly employed in large-scale solar power plants, like concentrated solar power (CSP) systems, which utilize mirrors or lenses to concentrate sunlight onto a small area.

I.2.2: Solar photovoltaic energy

Solar PV systems convert sunlight directly into electricity using semiconductor materials like silicon. When sunlight hits the solar cells, electrons are set in motion, generating a direct current (DC). This current is then converted into alternating current (AC) using an inverter for use in homes and businesses.

I.3: Data acquisition system

Data acquisition system is a process used to collect information that can be stored and processed by a computer to analyze some special phenomenon. Two main aspects are essential for this system: transmission type in system (serial or parallel) and information exchange mode between system devices.

When system start first of all continuous analog data send to analog to digital converter that accept data over VIN (+) pin and generates data in digital form from pin DO. This generated data is now sending to any pin of controller to allow controller to perform action according incoming value. After processing, data is transmitted to host system through wireless communication module

Zigbee and serial communication RS-232. Now data is collected at host system in a database and graph created in Visual basic module to understand changes. [5]

I.3.1: Interest in acquisition

The importance of data collection lies in providing accurate and reliable information that serves as the basis for statistics, enabling the analysis of trends, identification of patterns, and the making of evidence-based decisions. For example, studies show that organizations that rely on data in their decisions are better able to improve performance and achieve sustainable growth.

- Data acquisition (DAQ) is the process of measuring an electrical or physical phenomenon, such as voltage, current, temperature, pressure, or humidity.
- Electrical or physical data such as voltage, current, temperature, pressure, or sound can be measured using a computer. A DAQ system consists of sensors, DAQ measurement hardware, and a computer with programmable CC+ software.
- Compared to traditional measurement systems, PC-based DAQ systems leverage the processing power, productivity, display, and connectivity capabilities of standard computers.
- Industry-standard display and computer connectivity, providing a more powerful, flexible, and cost-effective measurement solution.

Our country's acquisition systems are very expensive, so we ignored the purchase. As a result of this interest, there are several acquisition problems. Measuring the variation in the current generated by a solar panel and storing the values in a datasheet using an Arduino Uno and a current sensor. To store the values, use the PLX-DAQ datasheet. [6]

I.4: Problem definition

Solar energy is a promising and renewable source; however, it is inherently intermittent due to fluctuations in solar irradiance caused by environmental factors such as clouds, dust, rain, and the angle of sunlight. These variations directly impact the stability and efficiency of solar energy systems.

The manufacturers of PV cells and panels generally provide a datasheet containing some of the parameters of the PV panel made up of an array of several cells. But there are other parameters that are not provided on the datasheet. In practice, determining these unknown parameters is very important.

Furthermore, these systems must be equipped to protect electrical devices from voltage and current fluctuations resulting from sudden changes in solar irradiance.

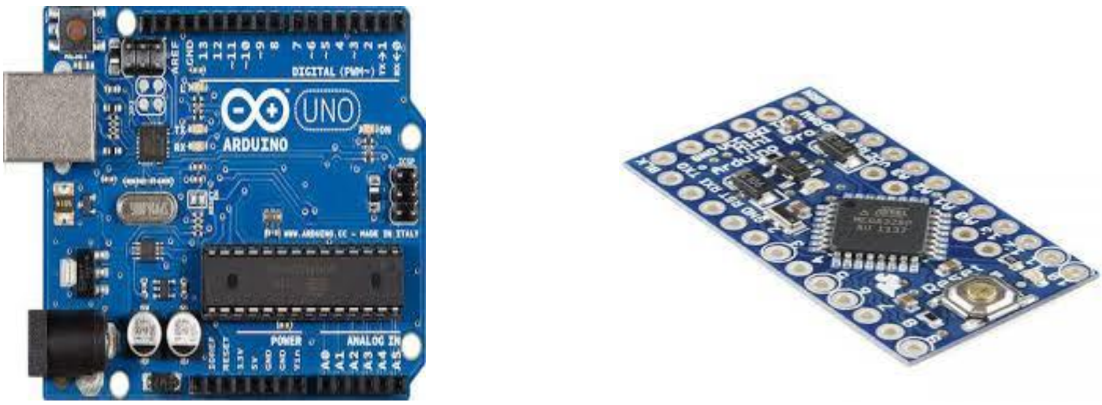
I.4.1: Arduino board

Arduino boards are designed to create prototypes and mock-ups of electronic boards for embedded computing. These boards provide simple and inexpensive access to embedded computing. Furthermore, they are completely open source, both in terms of the source code (Open Source) and the hardware (Open Hardware). This makes it possible to redesign your own Arduino board to improve it or remove unnecessary features from the project. The Arduino language stands out from the languages used in the embedded computing industry due to its simplicity. Indeed, many libraries and basic functionalities obscure certain aspects of embedded software programming in order to simplify the process.

I.4.1.1: Presentation of the Arduino board

The Arduino is an electronic hardware platform for interactive art. It can be used to build small interactive devices, as an interface between sensors and computers, and as a programmer for certain microcontrollers.

An Arduino board, like all microcontroller boards, allows you to control a system interactively using a program that you define and store in its memory. For example, you can automatically open a garage door, send a text message when the garden is too dry, remotely manage the watering system, or even control a new robot. To do this, you need to connect sensors such as light, temperature, and position sensors to the Arduino board. You also need to connect actuators such as motors and a pump, as well as output devices such as a lamp and heater. You can also connect power circuits, a power supply (batteries, solar panels, etc.), dialog interfaces (buttons, LEDs, screen, etc.), and communication interfaces (wired network, wireless network, etc.).



(a) (b)

Figure I. 1:(a) Arduino uno board (b) arduino mini board

I.4.2 History of the Arduino board

The Arduino project was born in the winter of 2005. Massimo Banzi taught at a design school in Ivrea, Italy, and his students often complained about not having access to low-cost solutions to complete their robotics projects. Banzi discussed this with David Cuartielles, a Spanish engineer specializing in microcontrollers. They decided to create their own board, involving one of Benzi students, David Mellis, who was responsible for creating the programming language to go with the board. In two days, David wrote the code; three more days, and the board was ready. Everyone could do something with it very quickly without even having any special knowledge of electronics or computers: responding to sensors, flashing LEDs, controlling motors, etc. They published the schematics and invested €3,000 to create the first batches of boards.

I.4.3: Description of the Arduino UNO board

Arduino is a family of open-source microcontroller electronic boards born in Italy in 2005. These boards are based on a simple input/output interface and a development environment similar to the C language. The Arduino Uno board is the first stable version of the Arduino board. It has all the features of a conventional microcontroller in addition to its ease of use. It uses an ATmega328P chip clocked at 16 MHz. It has 32 KB of flash memory for storing the program, 2 KB of SRAM (random access memory), and 1 KB of EEPROM (read-only memory for data).

It offers 14 digital input/output pins (acceptable data 0 and 1), 6 of which can generate PWM (Pulse Width Modulation). It also allows analog measurements to be measured using these 6 analog inputs. Each pin is capable of delivering a current of 40 mA at a voltage of 5 V. This Arduino board can also be powered and communicate with a computer via its USB port. It can also be powered with a 7 V or 12 V power supply using its Power Jack connector. [7]

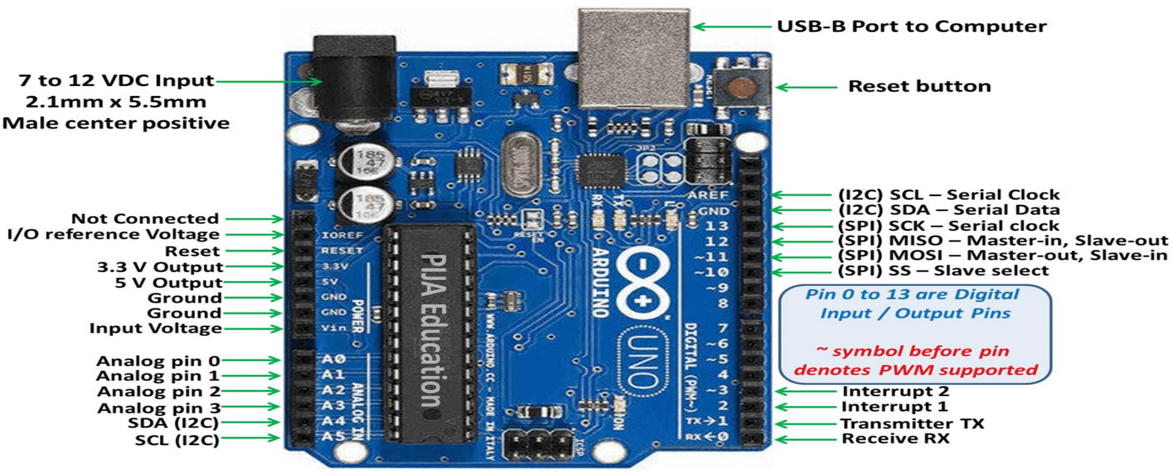


Figure I. 2: Arduino USB port

I.5: SD card reader

The Arduino Micro SD card module is a device based on SPI communication. It can be used to provide external storage for microcontroller and microprocessor-based projects, to store various types of data, images, or videos. SD cards are typically 3.3V logic level devices, but with the Micro SD card module, the signals are converted to 5V via a logic level converter implemented on the SD card module.

Figure I. 3: SD card reader

I.6 Connection wires

Wires for connecting components to each other and to the Arduino are essential for creating our experimental setup. These wires are called jumpers and come in several formats: semi-rigid and stripped at each end, or flexible with a connector at the end (female/female, male/male, male/female).

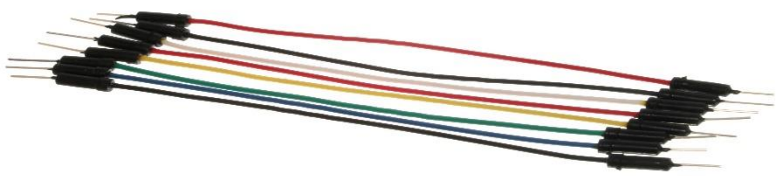


Figure I. 4: Connection wires

I.7: LCD displays

It consists of a 2x16 character alphanumeric LCD display, a contrast adjustment potentiometer, and a series of 6 buttons (up, down, right, left, select, reset). Nothing more, nothing less. The display features white characters on a blue background. It is HD44780 compatible and is used with the Liquid Crystal library included with the Arduino software. No additional installation is therefore required. [8]

I.7.1: Characteristic

The first piece of information to know is the number of characters that can be displayed per line. For this model, it's 16 characters on two lines, for a total of 32 characters. Obviously, this information can be found in the datasheet in the form 16 X 02. But also, in the reference 1602 A. The data transmission mode is also recorded on four (4) or eight (8) bits. In addition, the next information to know is the operating voltages, electrical, and mechanical characteristics of the LCD display.

I.8: Breadboard

It's a flat board used as a base for connecting electronic components to build electronic circuits and prototyping electronic devices. It's solderless and reusable, making it easy to use for creating temporary prototypes and circuit design experiments.

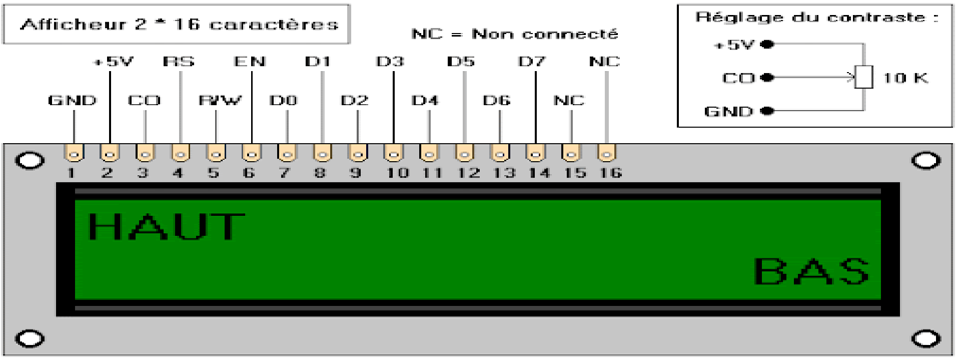


Figure I. 5: LCD displays

The board consists of a flat surface of non-conductive material, mainly plastic, and contains horizontal rows of slots connected horizontally to allow electronic components to be inserted. On both sides, there are several other slots, but they are connected vertically for the purpose of easily powering the circuit. In the middle of the board, there is a slot of a certain width to allow the installation of integrated circuits and divides the board into two similar parts.

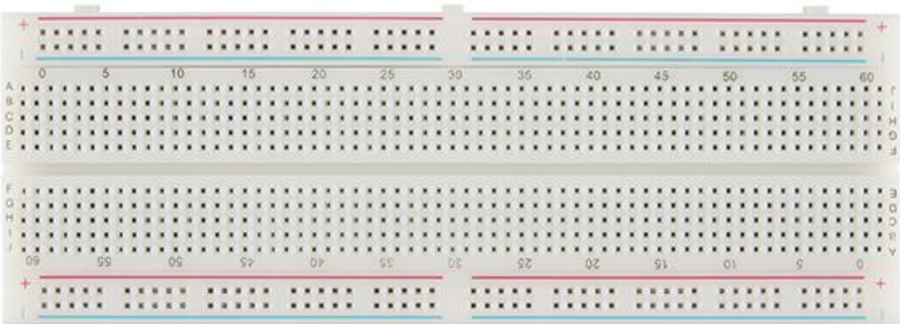


Figure I. 6: Breadboard

I.9: Solar Panel

A device that converts solar energy directly into electrical energy, taking advantage of the photovoltaic effect. It consists of a layer of silicon to which certain impurities are added to give it electrical properties. The element boron in the lower layer gives it the property of absorbing electrons, and this layer is called P. When solar radiation hits the upper layer, the electrons release energy that depends on the intensity of the solar radiation. When there is an electrical conductor between the two layers, the electrons move from the upper layer to the lower layer.

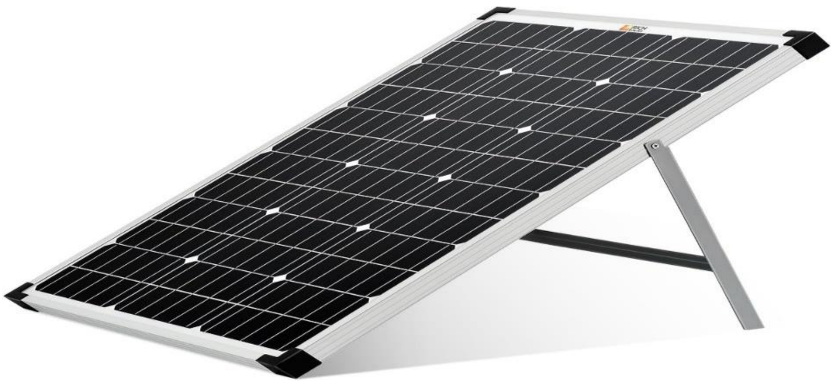


Figure I. 7: Solar panel

I.9.1: Characteristic

- Exceptional low-light performance - Solar cells laminated with TPT/EVA bi-layer for long life.
- High efficiency due to a high-transparency, low-iron tempered glass cover.
- Sealed for protection against harsh environments - Enclosed junction box Enclosed junction box for wired connections.

I.9.2: Applications

- Battery charging applications.
- Surveillance cameras.
- Wireless base stations.
- Outdoor lighting.
- Remote detectors.

I.9.3: Manufacturing of photovoltaic cells

- Silica (raw material for a photovoltaic cell): Silica is a chemical compound also called silicon dioxide, with the chemical formula Si O_2. Silica is the most common element in the Earth's crust after oxygen. It represents 25% of the Earth's crust's mass. Silica occurs as a hard mineral. In nature, it is found in large quantities in detrital sedimentary rocks, metamorphic rocks, and igneous rocks.

- Extraction and purification of silicon: Silicon is a chemical element with the symbol Si. It does not exist in its pure state in nature. Silicon is therefore extracted from silica (Si O_2) using the following simplified chemical reaction:
  - This reaction takes place in an arc furnace because it requires melting the silica.
- Obtaining silicon ingots: Once the purification step is complete, comes the liquid silicon crystallization step. The product resulting from this step is a solid silicon ingot. There are two main crystallization methods. The first produces polycrystalline silicon (composed of several crystals). The second produces monocrystalline silicon (composed of a single crystal). [9]

I.10: ACS712 Current Sensor

The ACS712 30A current sensor can measure electrical current up to 30A. It outputs an analog voltage based on the measured current, allowing for accurate detection of AC or DC signals. The maximum current that can be detected can reach 30A, and the current signal can be read via an analog port. This module can measure positive and negative 30 amps. Its features include:

TABLE I. 1: ACS712 CURRENT SENSOR CHARACTERISTICS

Characteristic	***Value***
Sensitivity	100 mV/A
Logic voltage	4.5 V – 5.5 V
Consumption	10 mA
Deadline for impact on exit	5s
Error	1.5% in 25 C
Internal conduction resistance	1.2 mOhms
Weight	2 gr
Noise	130 mA

Figure I. 8: ACS712 30 current sensor

I.10.1: Benefits

- Low noise analog signal path.
- The device bandwidth is adjusted via the new FILTER pin, which controls the output rise time in response to an input current step.
- 80 kHz bandwidth.
- Total output error 1.5% at TA = 25’C.
- Small footprint, low profile SOIC8 package.
- internal resistance of the conductor.
- 2.1 kVRMS minimum isolation voltage from pins 1-4 to pins 5-8.
- 5.0V, single supply operation.
- 66 to 185 mV/A output sensitivity.

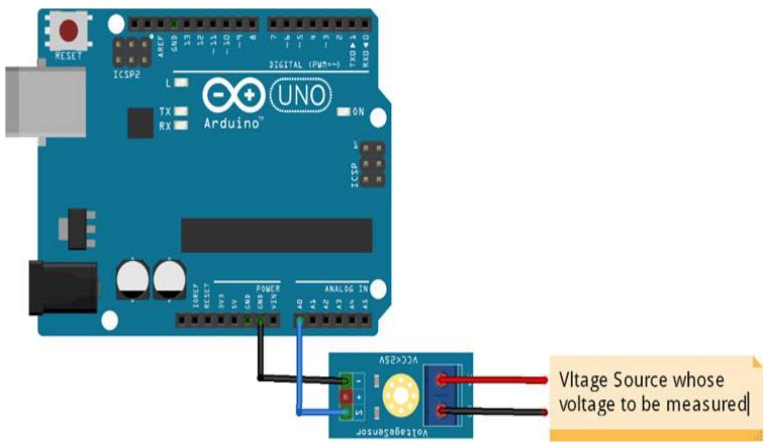


Figure I. 9: Voltage sensor and their mounting

- Output voltage proportional to AC or DC currents
- FAactory adjusted for accuracy
- Extremely stable output offset voltage
- Ratiometric output from supply voltage
- Near-zero magnetic hysteresis

I.11: B25 Voltage Sensor

The B25 Voltage Sensor is a 0 to 25V voltage detector based on the resistor divider principle. The input voltage value is reduced by 5 times; the maximum analog input value of the Arduino is 5 volts [8], so the voltage detection input voltage cannot exceed 5 volts multiplied by 5 = 25 volts (if a 3.3volt system is used, the input voltage cannot exceed 3.3 volts multiplied by 5 = 16.5 volts). Input voltage: DC 0-25V. Measurement range: DC 0.02445V-25V. Measurement resolution: 0.00489V. Pin 9 of the Arduino UNO board is the reference pin for this sensor, as shown in the figure below:

I.12: Type K thermocouple with MAX6675 amplifier module

Type K is the most common type of thermocouple. It is inexpensive, accurate, reliable, and has a wide temperature range. Type K is commonly found in nuclear applications due to its relative radiation hardness. The maximum continuous temperature is approximately 1100°C.

I.12.1 Characteristics

• Operating Voltage: DC 3.0-5V

• Operating Current: 50 mA

• Temperature Measurement Range: 0°C +1024°C

• Temperature Resolution: 0.25°C

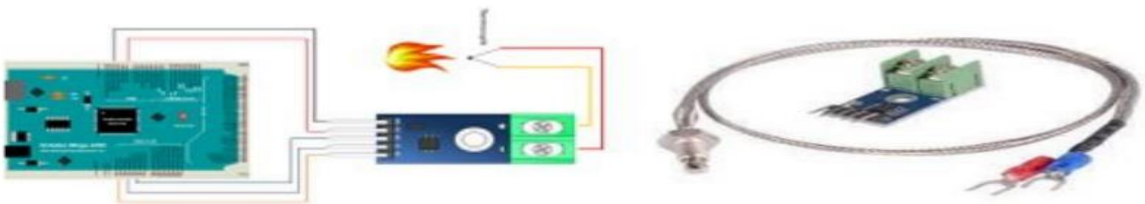


Figure I. 10: Type K thermocouple capture

- K-type precision:

- Default: +/- 2.2 C or +/- 0.75 %
- Special error limits: +/- 1.1 C or 0.4 %
- Output mode: digital signal
- SPI Operating temperature: -20°C +85°C

I.13 Load Regulator

A DC-DC converter is an electrical system (device) that converts sources direct current (DC) from one voltage level to another. In other words, a DC-DC converter takes in a continuous input voltage and delivers a voltage continue different. The output DC voltage can be higher or lower than the voltage CC input. As the name suggests, a DC-DC converter only works with direct current (DC) sources and not with alternating current (AC) sources

I.13.1 Technical sheet

- Voltage rating: 12V/24V/Auto
- Application: Solar System Controller
- Current: 10A / 20A / 30A
- Only for off-grid solar PV system.
- Dimensions: (133 x 70 x 32 mm)

I.14 Resistances

Resistors are electronic components that have an electrical resistance specific, and invariant. The resistance of the resistor limits the flow of electrons in a circuit.

These are passive components, which means they only consume energy (and they cannot generate it). Resistors are usually added to circuits where they complement the active components such as op amps, microcontrollers and other integrated circuits. Resistors are generally used for limit current, divide voltages and remove input/output lines.

Application of the resistor in our project: Limiting the current of the LEDs the resistors are essential to ensure that the LEDs do not explode when they are fed. By connecting a resistor in series with an LED, the current flowing in both components can be limited to a maximum value. across the two components can be limited to a sure value.

Figure I. 11: Resistance

When sizing a current limiting resistor, look for two LED characteristic values: the typical direct voltage and the maximum voltage. characteristics of the DEL: typical direct voltage and maximum direct current. The typical direct voltage is the voltage that is required for an LED to light up, and it varies (usually between 1.7V and 3.4V).

It varies (usually between 1.7 V and 3.4 V) depending on the color of the DEL. The site the maximum direct current is usually of the order of 20mA for LED s basic; The continuous current through the DEL must always be equal to or less than this rated current.

I.15 LED

An electroluminescent diode (ELE) is a semiconductor device that emits visible light when an electric current pass through it. The light is not particularly bright, but in most LEDs, it is monochromatic, occurring at a single wavelength. The output of an LED can go from red (at a length wavelength of about 700 nanometers) to blue-violet (about 400 nanometers). Certainness LEDs emit infrared (IR) energy (830 nanometers or more); such a device is known as infrared emitting diode (IRED).

An LED or IRED consists of two processed material elements called P-type semiconductors and N-type semiconductors. These two elements are placed in direct contact, forming a region called the P-N junction. In this regard, the LED or IRED is similar to most other types of diodes, but there are important differences. The LED or IRED has a transparent housing, allowing visible or IR energy to pass through. In addition, the LED or IRED has a large PN junction area whose shape is suitable for the application. Advantages of LEDs and IREDs over Incandescent and Fixtures fluorescent lighting, in particular:

- Low power consumption: most types can operate with a battery power supply
- High efficiency: most of the power supplied to an LED or IRED is converted to radiation in the desired form, with a minimum of heat production.

- Long lifespan: when properly installed, an LED or IRED can operate for decades.

Figure I. 12: LED

I.16 Conclusion

In this chapter, we talked about solar energy and how it is one of the most important renewable energy sources due to its renewable nature. We also highlighted data acquisition (DAQ), which is the process measurement of an electrical or physical phenomenon such as voltage, current, temperature, pressure or humidity. This part led to the practical realization of a device electronics to measure the different values of the magnitudes collected by the sensors. The set of works reported in this chapter:

- The selection of suitable components for each size.
- The suitable choice of embedded system such as Arduino UNO

The following chapter will be devoted to explaining how this experiment was set up, how it was programmed and prepared, and how data were extracted from it.

Chapter II

Data acquisition system Photovoltaics

II.1 Introduction

Solar photovoltaic systems are installed in different regions. The PV systems are also located in warm and dry places for high efficiency and better performances.

System should be maintained in a timely manner and the PV systems are monitored and evaluated. The purpose of this chapter is to acquire real-time data from the solar panel of measure the parameters of the solar panel set and the load using the data provided by the sensors. In this system, various parameters of solar panels are monitored such as current, voltage, temperature and light intensity.

II.2 System Overview In this system

Designed for the analysis of solar photovoltaic energy at low cost, the objective of this chapter is to obtain real-time data for the panel solar and weather data.

Design of the system is based on a low-cost Arduino board. One source of supply 5 V is supplied using solar panels, which depends on the intensity of the light, the time of day and the season. The light intensity sensor and the temperature sensor is used. to measure their value. One of the sensors of voltage is used to measure the voltage and the other to measure the flowing current during pregnancy.

Acquisition, which allows communication between the Arduino UNO and the computer via a UART bus. Therefore, the properties I-V and P-V, processed in real time, can be directly captured and plotted in an Excel spreadsheet without having to reprogram the microcontroller.

One comparison of these low-cost virtual machines and traditional machines is trained in this work. It was found that our solution offers many advantages compared to the traditional solution such data can be presented under in the form of real-time graphs. Thus, tests to confirm the effectiveness of the system of virtual machines developed are presented in this study.

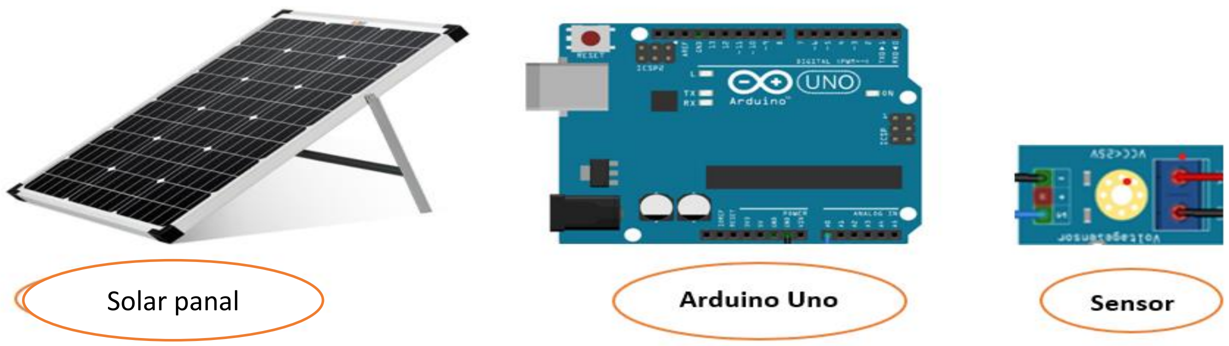


Figure II. 1: The main components of studied photovoltaic system

II.2.1: Characterization of parameters of solar panel.

Table II. 1: Characterization of parameters of solar panel

Module type	GD-35WP
Peak Power (P max)	(W): 3.5
Maximum Power Current (Imp)	(A):0.38
Maximum Power Voltage (Vmp)	(V): 9
Short Circuit Current (Isc)	(A):0.41
Open Circuit Voltage (Voc)	(V): 11.25
Dimensions	(mm): 255*143*15
Maximum System Voltage	(VDC): 1000
Wind Resistance	(pa): 2400

- All technical data at standard test condition:

AM=1.5 E=1000W/M2 IC=25°c

25 Years limited Output Guarantee

II.2.2: Table Connectors of the F031-06 voltage sensor module

Table II. 2: Connectors of the f031-06 voltage sensor module

Pin symbol	Descriptions
VCC	is connected to the high side of the voltage to be meas -ured
GND	is connected to the low side of the voltage to be measured, this is the same electrical point as Arduino ground
S	is connected to an Arduino analog input, this is the meas ured output
+	is not connected
–	is connected to Arduino ground

The voltage sensor is put in parallel with the load as shown in Figure II.2; then, the output of this sensor is transmitted to the analog–digital converter (ADC) of the Arduino microcontroller. The ADC provides a digital value (Vout1) which varies between 0 and 1023, because the latter is encoded in 10 bits. Therefore, the analog voltage resolution of the voltage sensor module is 0.00489 V (5 V/1023), and the minimum input voltage detected by this module is 0.02445 V (0.00489 V×5). Since the voltage range of the sensor module is [0, 25 V], the divider's voltage ratio as shown in Eq. (2) is equal to 0.2. Therefore, the real output voltage of PV panel can be obtained by the equation presented in (3).

$$\boldsymbol{V_d} = \frac{R_2}{(R_1 + R_2)} \times V$$

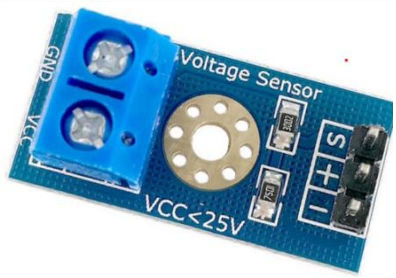


Figure II. 2: F031-06 voltage sensor module

II.2. 3: Table Specifications of the F031-06 voltage sensor module

Table II. 3: Specifications of the f031-06 voltage sensor module [10]

Specifications	FO31-06 voltage sensor module
Input voltage range	DC 0–25 V
Voltage detection range	DC 0.02445–25 V
Analog voltage resolution	0.00489 V

II.2.3.1: The Characteristics of DHT11 Temperature and Humidity sensor module

Table II. 4: Specifications of the DHT11 temperature and humidity sensor module

Pacification	Value
Operating Voltage Range	3.5 V to 5.5 V
Humidity Measurement Range	20% to 80% RH
Humidity Accuracy	±5% RH
Temperature Measurement Range	0°C to 50°C
Temperature Accuracy	±2°C
Response Time	≈2 seconds
Communication Protocol	Single-Wire (One-Wire)
Sampling Interval	≥1 second

Table II. 5: Connectors of the DHT11 sensor module

Pin Symbol	Description
VCC	Connected to Arduino +5V
GND	Connected to Arduino GND
DATA	Connected to a Digital Pin (e.g., D2)

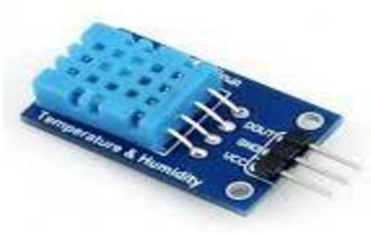


Figure II. 3: DHT11 Temperature and Humidity sensor module

II.2.3.2: Signal Conversion Explanation

The DHT11 sensor does not require an analog-to-digital conversion equation because it transmits digital data directly via the Single-Wire protocol. The digital signal is interpreted as follows:

1. The Arduino sends a start pulse to the sensor, the code of DHT11 sensor in Annex II.

2. The sensor responds with a 40-bit data stream (16 bits for humidity, 16 bits for temperature, 8 bits for checksum).

3. The bits are converted to decimal values using the formula.

$$Value = \frac{\text{Received Data}}{10} (as\ per\ most\ libraries)$$

II.2.4: The Characteristics of the current senser

Table II. 6: Specifications of the current senser

Specification	Value/Details
Common Mode Voltage Range	DC 2.7–60 V
Full-Scale Sense Input Voltage	500 mV
Input Offset Voltage (Max)	±1000 µV
Input Offset Drift (Max)	±1 µV/°C
Nonlinearity Error (Max)	| ±0.1%
Total Output Error (Max)	±2%
Common Mode Rejection Ratio (CMRR)	120 dB (Typ)
Bandwidth	440 kHz

Supply Voltage Range	DC 2.7–60 V
Operating Temperature Range	| -40°C to +85°C
Quiescent Current	60 µA

Table II. 7: Connectors of the current sensor

Pin Symbol	Description
VCC	Connected to the supply voltage (+5V from Arduino) to power the sensor.
GND	Connected to Arduino GND, shared with the low side of the source (e.g., PV panel).
VIN+	Connected to the positive terminal of the source (e.g., solar panel).
VIN	Connected to the positive terminal of the load (e.g., battery or regulator).
VOUT	Connected to an Arduino analog input pin to measure the output current.

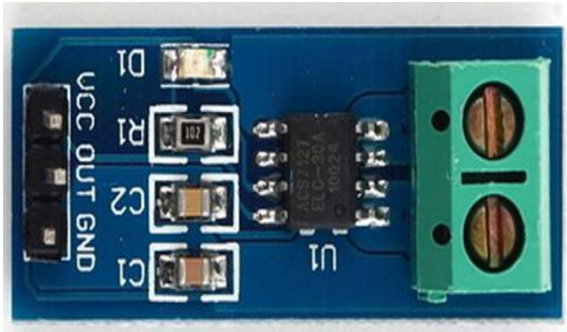


Figure II. 4: Current sensor

The INA169 is a high-side current shunt monitor that measures current by amplifying the voltage drop across a shunt resistor

Key Formula

The relationship between the measured current and the sensor's output

$$I = \frac{V_{out}}{G \times R_{shunt}}$$

- **Step 1:** Calculate the Gain the INA169's gain depends on an external resistor connected between the V+ and VOUT** pins. The formula for gain is:

$$G = \frac{10\text{mA}}{1\text{V}} \times R_{ext} \qquad \text{II. 1}$$

From the datasheet for the gain is typica

$$G = \frac{10\text{mA}}{1\text{V}} \qquad \text{II. 2}$$

- **Step 2**: Measure with Arduino

The Arduino reads as a 10-bit analog value (0–1023). Convert this value to voltage using:

$$V_{out} = \frac{\text{Analog Reading}}{1023} \times 5V \qquad \text{I. 3}$$

- **Step 3**: Calculate Current

$$I = \frac{V_{out}}{\text{G} \times R_{shunt}} \qquad \text{I. 4}$$

II.2.5: The Characteristics of the LDR sensor

Table II. 8: Specifications of the LDR sensor

Specification	Value/Details
Resistance in Darkness	≈1 MΩ to 10 MΩ
Resistance in Light	≈100 Ω to 1 kΩ (depends on light)
Recommended Operating Voltage	3.3 V to 5 V
Spectral Response	Peak sensitivity at ≈550 nm (green)
Response Time	≈15-50 ms (varies by model)
Operating Temperature	-30°C to +70°C
Maximum Power Dissipation	100 mW

Table II. 9: Connectors of the LDR sensor

Component	Description
LDR	One end connected to +5V, the other to a fixed resistor (e.g., 10 kΩ) and GND.
Fixed Resistor	Connected between LDR and an Arduino analog pin (to form a voltage divider).
Arduino Pin	Analog pin (e.g., A0) to read the voltage across the fixed resistor

Figure II. 5: LDR sensor [11]

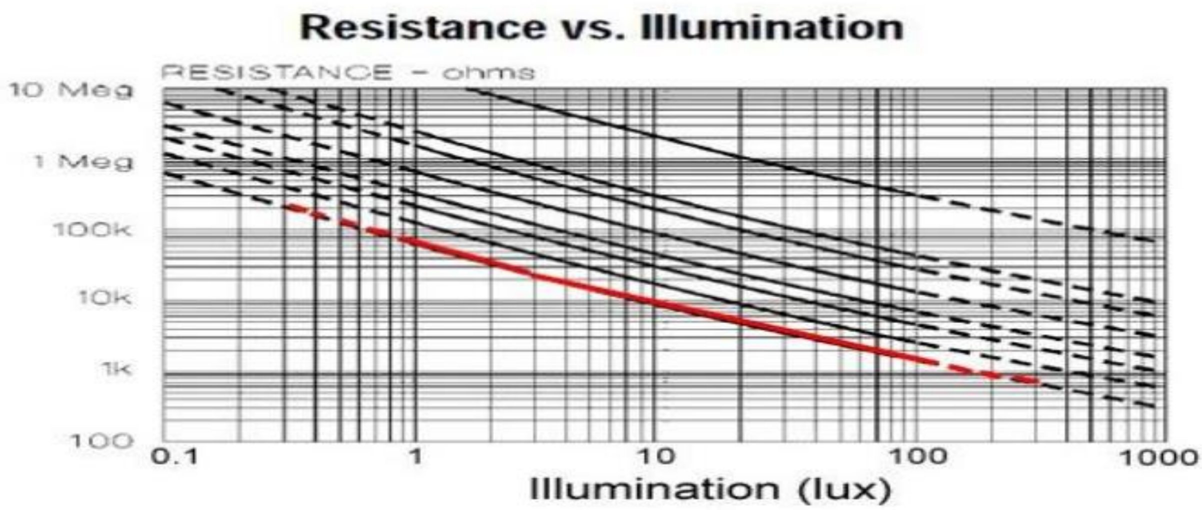


Figure II. 6: LDR response graph under different illumination levels

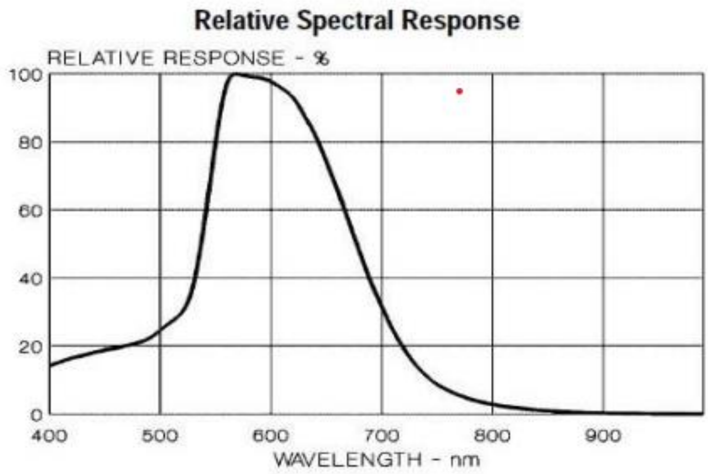


Figure II. 7: Spectral response of an LDR

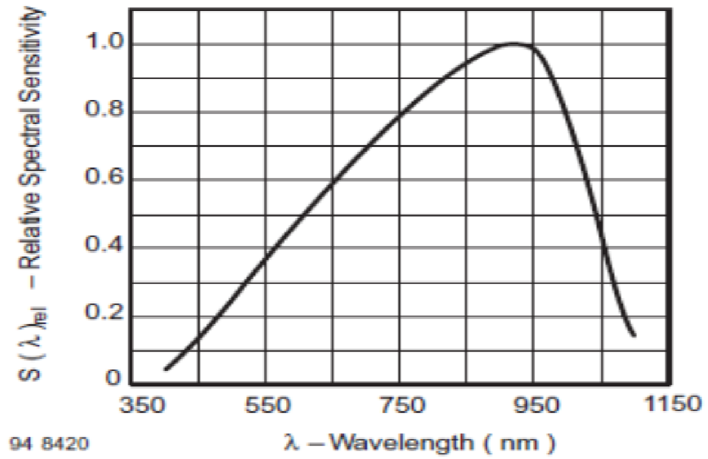


Figure II. 8: Spectral response of BPM34 [12]

II.3 Programming

In the software part, we provide the Arduino code and all the necessary software (PLX-DAQ Excel Macro and Arduino IDE) for a machine system design real-time virtual and a guide to get there. Note that the Arduino IDE and the macro Excel PLX-DAQ are both open sources.

II.4 IDE Arduino UNO

The Arduino IDE allows you to write, edit a program and turn it into a comprehensible series of instructions for the Arduino board microcontroller. THE IDEA can run on windows and linux or mac. Arduino used the card in this work has been programmed by an IDE that serves as a code editor and compiler and the code of the program can be transferred to a microcontroller via a USB cable. [13]

II.4.1: IDE Description

An IDE is a programming software that allows you to write, modify a program and to convert it into a set of comprehensible instructions for the map. The program per code, containing about fifty different commands. By default, the interface visual of the software contains the menu, control buttons at the top, a blank page virgin, a black band at the bottom, like this:

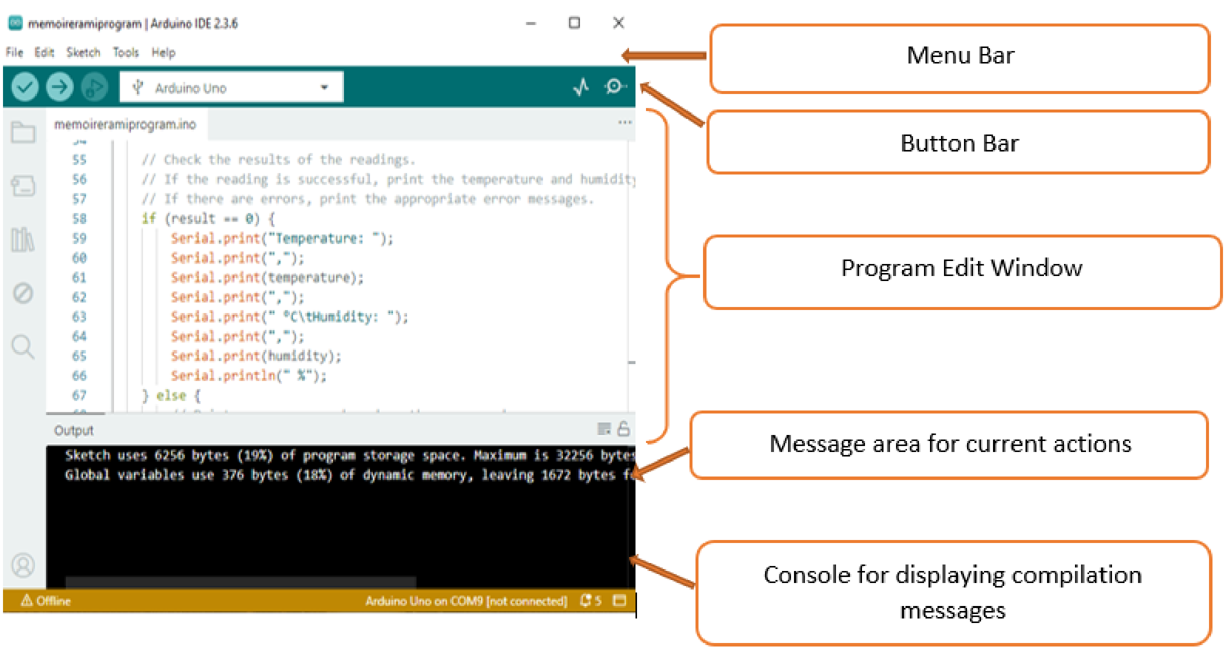


Figure II. 9: Arduino IDE interface

II.4.2 The steps of using the program

• Get an Arduino board and a USB cable.

• Download here the Arduino IDE (Arduino-Software 2018) (version: ARDUINO 1.8.5.2 for Windows) and install it.

• Launch the Arduino IDE application.

• Write the program code in the code area as follows It is illustrated at the figure

• Select the type of board used (Arduino UNO). And we deliver the floor.

• the modification of the program if errors are reported.

• Select the serial port used. Discover the software and download it on your Arduino microcontroller

• checking the assembly if it works

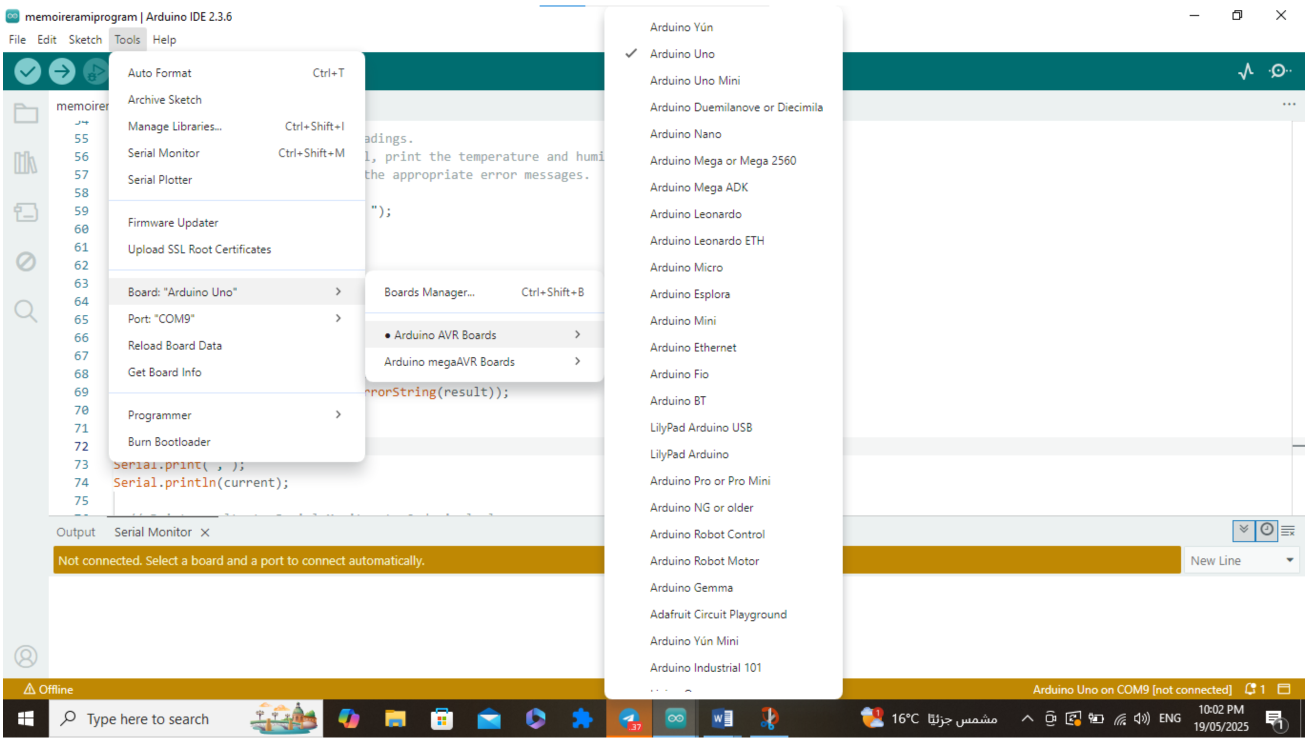


Figure II. 10: Program injection

II.5 PLX-DAQ Spreadsheet

PLX-DAQ is additional microcontroller data acquisition tool parallax for Microsoft Excel. Any of our microcontrollers connected to any sensor and to the serial port of a PC can now send data directly in Excel.

II.5.1 PLX-DAQ has the following features

• Plot or graphically represent data as it arrives in time real using Microsoft Exce.

• Mark data in real time (hh: mm: ss) or in seconds since reset.

• Read/write any cell of a spreadsheet.

• Read/Set one of the 4 check boxes to control the interface.

• Sample code for the BS2, SX (SX/B) and Propeller available.

II.5.2 Steps for using the PLX-DAQ board

• Connect your Arduino as you normally would

• Do not open the serial monitor in the Arduino IDE, this will not work with Excel if you do that.

• Open the shortcut to the PLX-DAQ spreadsheet

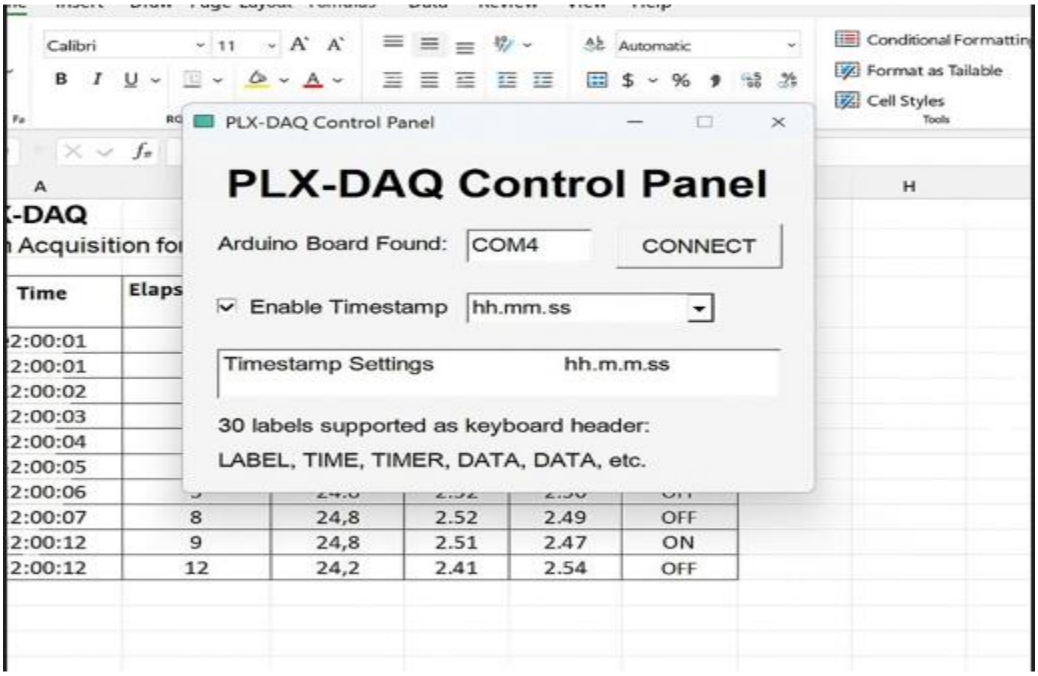


Figure II. 11: PLX-DAQ Spreadsheet

• Excel will say that this application is about to initialize ActiveX. . . click simply on OK

• A new window will appear named Data Acquisition for Excel

• Select the USB port to which the Arduino is connected (if it does not work in first, browse the list of ports)

• Where it says Baud, simply specify the number you entered in your code to Serial.begin (), in my case it will be 9600

• Create an empty graph

• Select the desired data columns on the x and y axis plot (the how to proceed varies slightly depending on your version of Excel, but this it's not hard to say)

• Click Collect Data on PLX-DAX and you should start collecting data

• Excel will plot the information as it is sent by the Arduino to ex cellar in real time

• Depending on the degree of accuracy desired for the plot, you can modify the properties of the graph. You can examine a section of the graph closer by stopping data collection, right-clicking on the x-axis or y et by defining it on a smaller framework. (Usually set to automatic)

• You can also right-click on the curve connecting the points of your graph and select the caller and thickness of the curve. [14]

II.5.3 Arduino Program Code

A program written in Arduino IDE is called Sketch. The sketches are saved on the development computer in the form of text files with the file extension. you. The pre-1.0 Arduino software (IDE) saved sketches with the. pde extension. A minimal Arduino code written in C/C++ consists of only two functions. Configuration {}: This function is called once when a sketch starts after the power down or reset. It is used to initialize variables, modes of input and output pin, and other necessary libraries in the sketch. Loop {}: after the setup {} call, the loop {} function is executed repeatedly in and main programs. It controls the board until the board is turned off or reset the programming code arduino uno board and sensors:

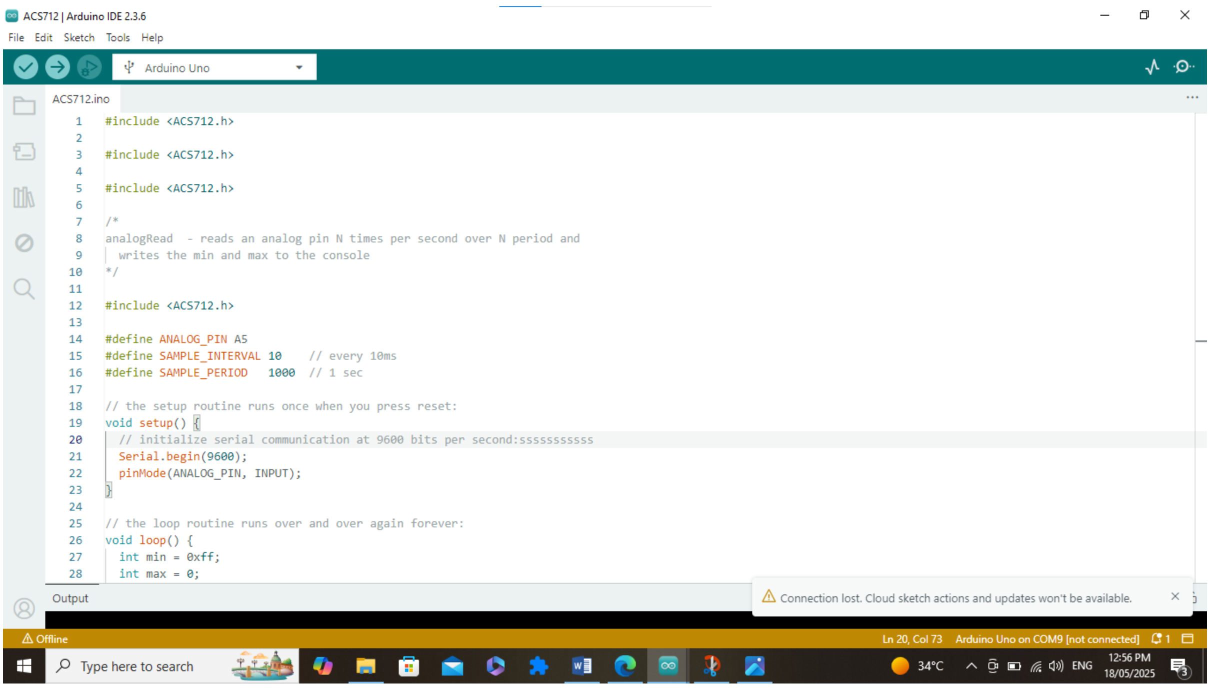


Figure II. 12: Arduino Uno board programming code

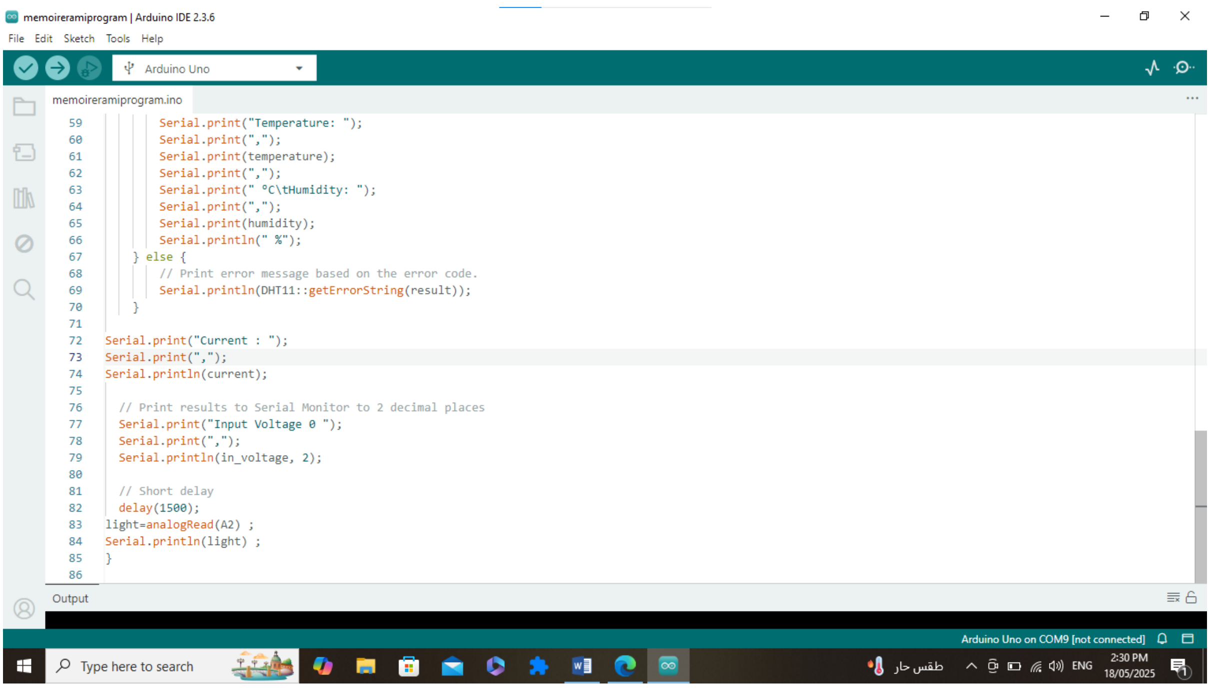


Figure II. 13: Sensor code (current, voltage, temperature)

II.6: Proteus Professional Software

Proteus software is used to create schematics for electronic automation; it's used for simulation of designs and design of PCB. This software as used to draw the system circuit and simulation of results in order to determine any error in the circuit and also to check if the Arduino IDE program code will be used to achieve the objectives of this project. To run the simulation the hex file is applied to the microcontroller schematic, then simulated with any digital or analog electronic. This enables use of broad spectrum of prototyping a project.

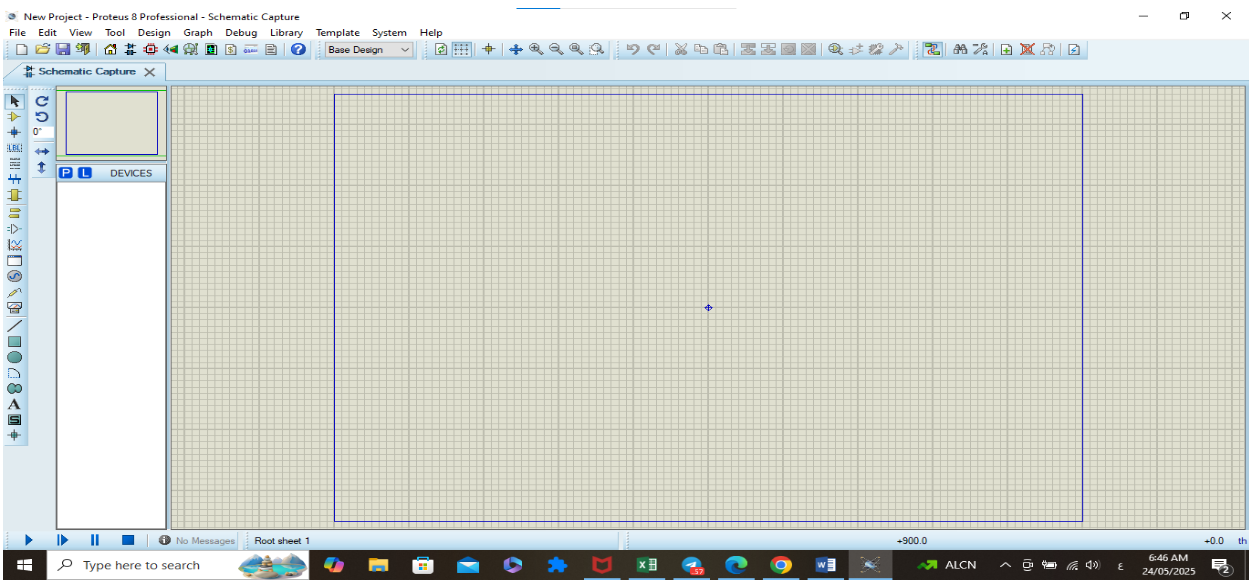


Figure II. 14: Showing the open window of Proteus Professional Software

II.7: How to Add a Library in Proteus 8.

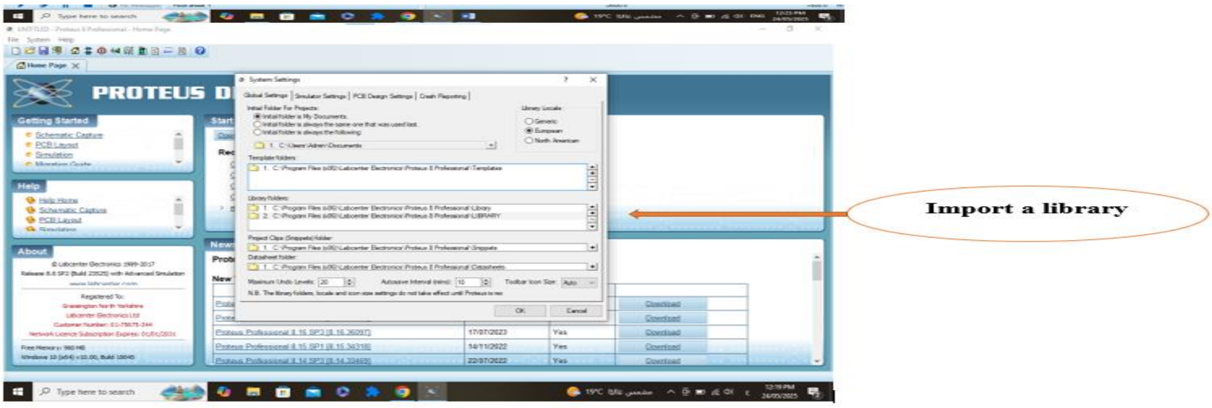


Figure II. 15: import a library

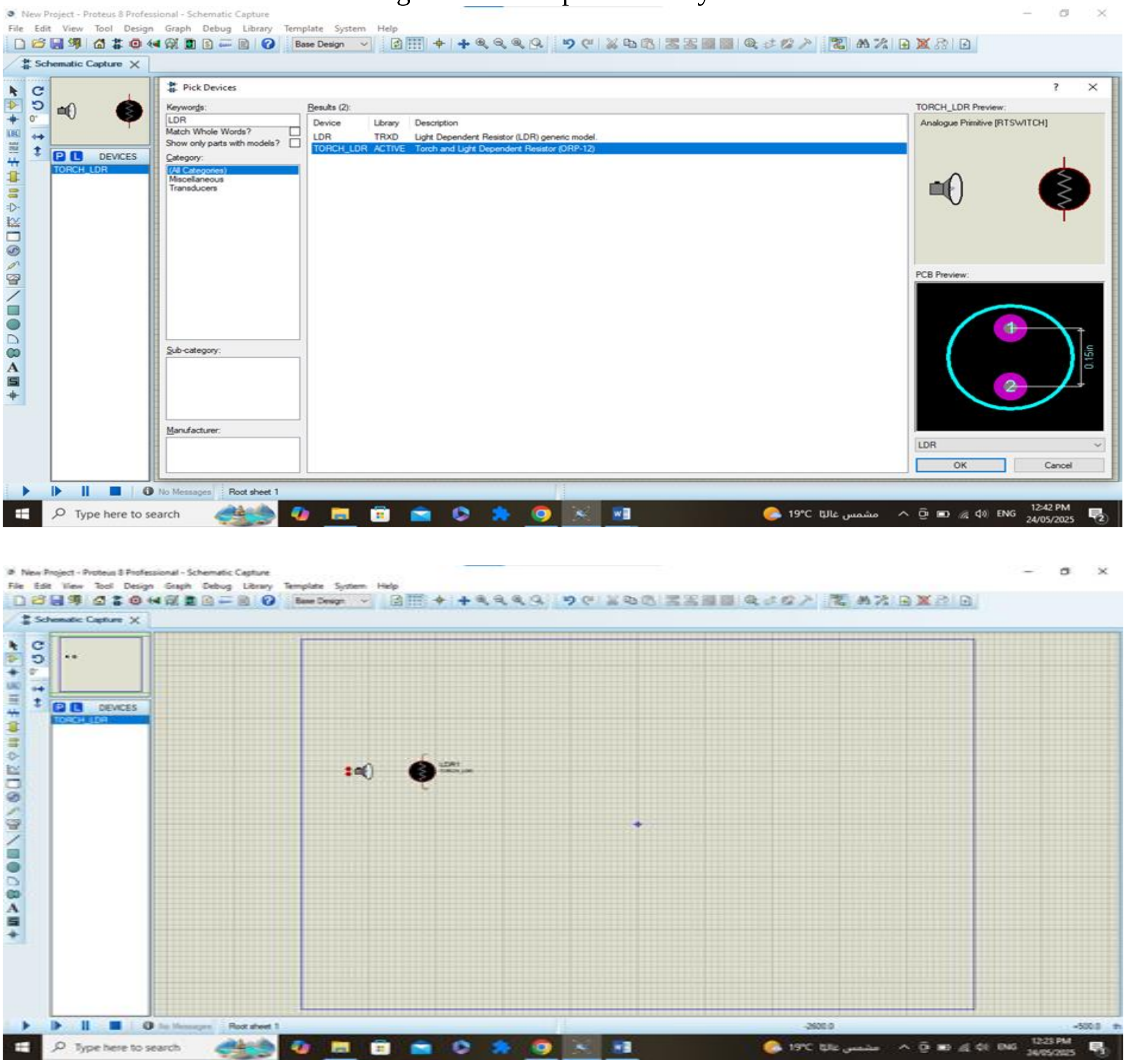


Figure II. 16: LDR library

II.8: Circuit Diagram

The circuit of this system was designed using proteus software the components were connected as in the circuit diagram below for data collection.

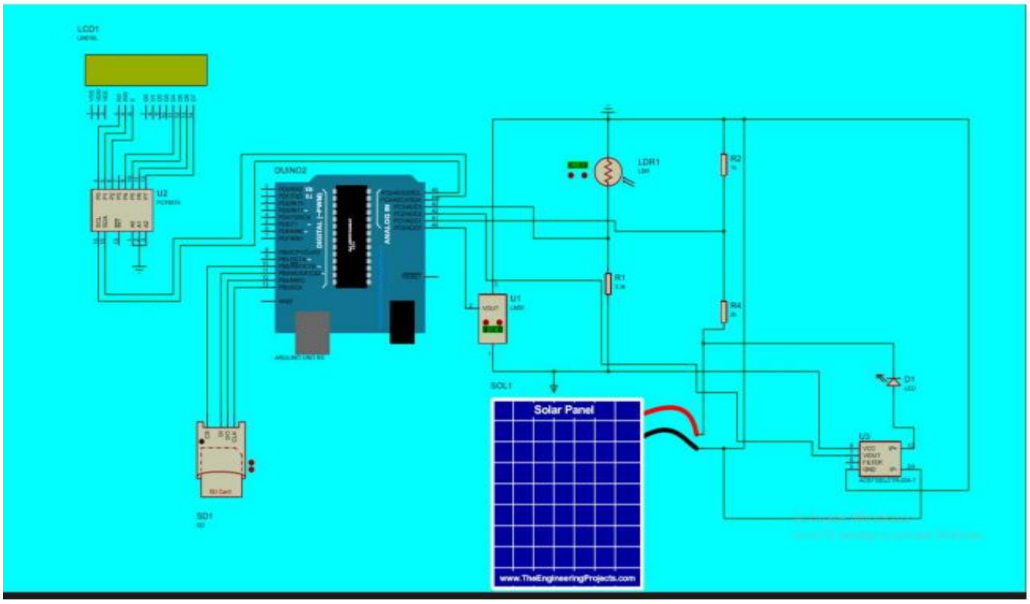


Figure II. 17: The complete Circuit Diagram

From the circuit diagram the voltage is measured by the potential divider R2 AND R4. where you get v=Vmax-5/ (R4/R2+R4) the potential divider is connected to Arduino Analog-Read A1.The current sensor is connected to Arduino Analog-Read A2.the temperature sensor Lm35 is connected to Analog-Read A0, while the irradiation densities sensor is connected to Analog-Read A3.the Arduino microprocessor converts the analog to digital data. The circuit diagram of microcontroller 17 and SD card-based data logging system using SPI and I2C protocol with LCD is shown in the circuit diagram. [15]

II.9 Ways of programming Arduino

II.9.1 Platform lo in VS code

Platform IO is an alternative build system that supports C Make-style projects, unit testing, and library management.

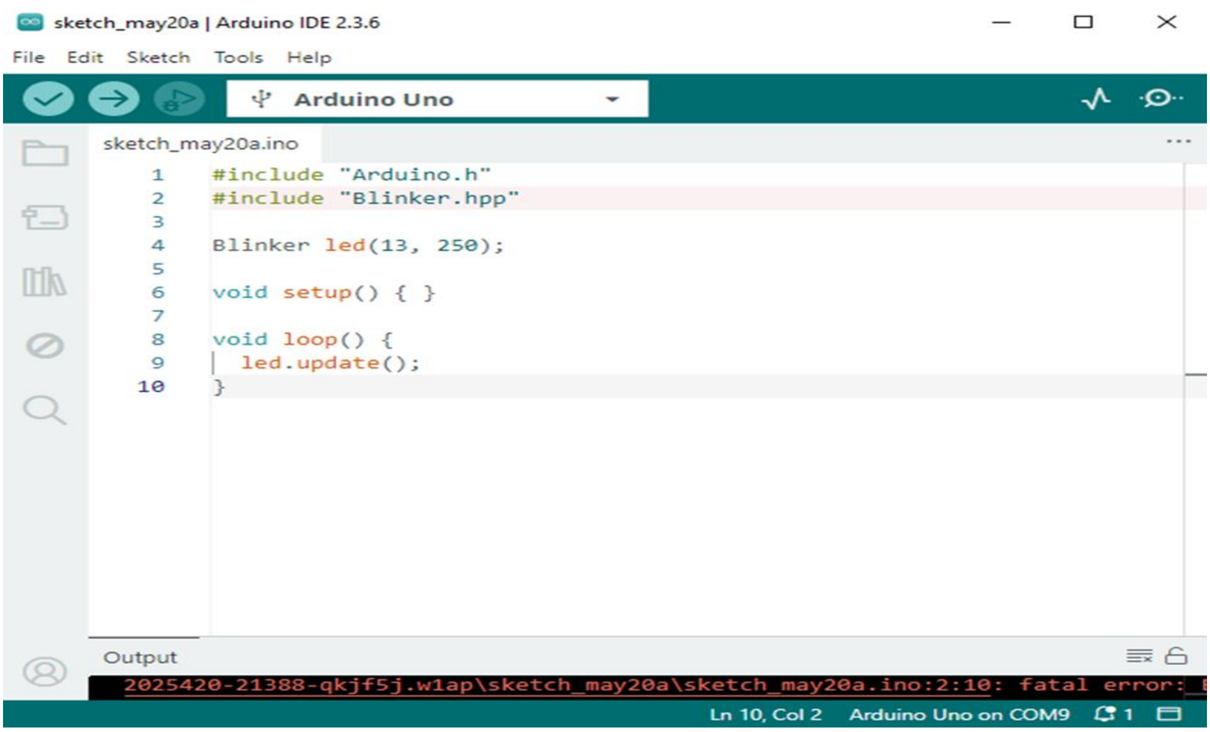


Figure II. 18: Platform lo in VS code for Arduino

II.9.2: Bare-Metal AVR C++ (Atmel Studio or Make-files)

Skip the Arduino core altogether—use pure AVR-GCC and direct register manipulation.

Figure II. 19: Bare-Metal AVR C++ code for Arduino

II.9. 3: State Machines

For deterministic behavior without an RTOS, implement your own finite-state machine.

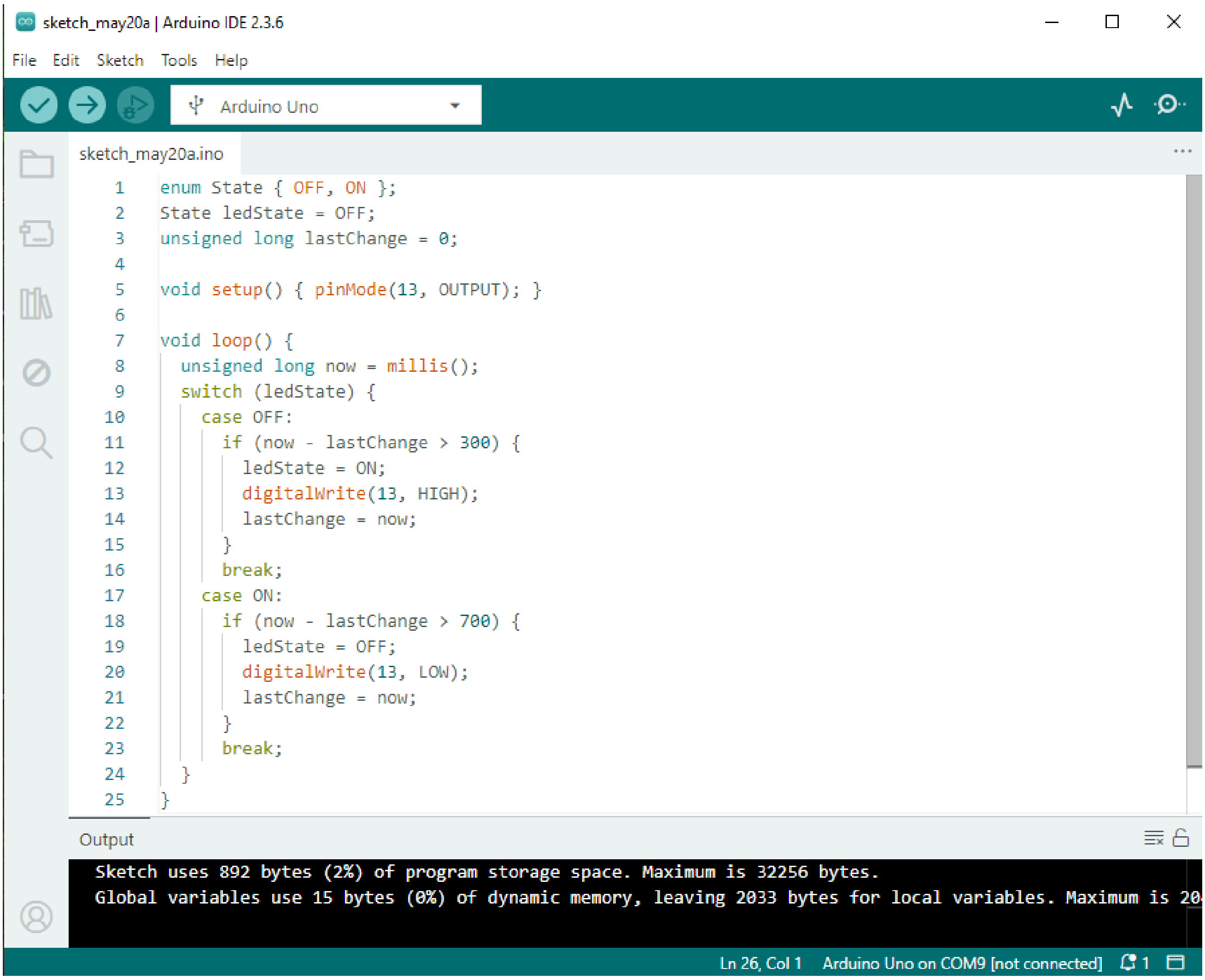


Figure II. 20: State Machines code for arduino

II.10 Applications of Arduino in Photovoltaic Systems

II.10.1: Solar Tracking Systems

- Description: Arduino can control motors to adjust the position of solar panels to follow the sun.
- Benefits: Maximizes solar energy capture throughout the day.
- Components: Arduino, light sensors (e.g., LDRs), servo or stepper motors. [16]

II.10.2: IoT Integration.

- Description: Combine Arduino with Wi-Fi (ESP8266/ESP32) to send PV system data to the cloud.
- Benefits: Remote monitoring via mobile or web dashboards.
- Example Platforms: Blynk, Thing speak, Firebase.

II.11 Conclusion

In this chapter, we explained our system, how to install it and how connect it to the Arduino Uno microcontroller. We also looked at our program code and how the Arduino has a great role in extracting information from the solar panel and the method used for capture and record this data.

Chapter III

Simulation and implementation of the PV system

III.1 Introduction

This chapter will present the implementation of collected the data using a measurement algorithm implemented in Arduino Uno Microcontroller. Furthermore, the parameters identification is one critical step in any system, both in simulation and real-time implementation.

III.2 Photovoltaic panel Simulation in Proteus:

The Proteus simulation of a solar panel is shown in this section. The photovoltaic module, which is made up of connected solar cells, is the most crucial part of any PV installation. To accommodate varying degrees of energy needs, these modules are joined to create fields. A simulated photovoltaic module in a Protues environment is shown in Figure (I.3).

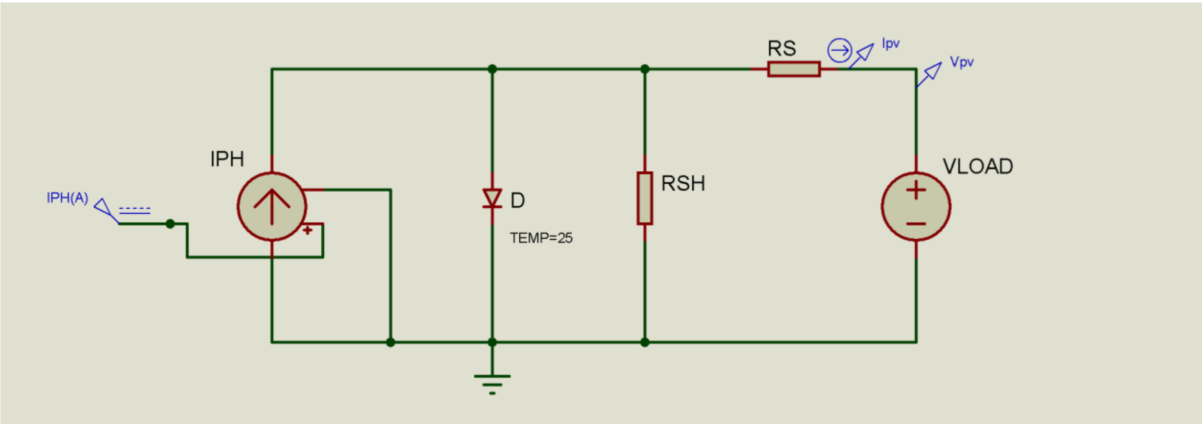


Figure III. 1: Photovoltaic panel simulation diagram under PROTEUS

The general equation of PV cell is

$$I = Iph - I_0 * (exp((V + I * Rs) / (Vt)) - 1) - (V + I * Rs) / Rsh \quad \text{III. 1}$$

Where:

- **I:** Current flowing through the cell (Amperes)
- **I_{ph}:** Photo generated current (Amperes)
- **I_0:** Reverse saturation current (Amperes)

- **V:** Voltage across the cell (Volts)
- **Rs:** Series resistance (Ohms)
- **Rsh:** Shunt resistance (Ohms)
- **V_t:** Thermal voltage (Volts)

III.3 Effects of lighting and temperature

Solar panel efficiency is influenced by a variety of internal and external factors. The weather, temperature, and illumination are the primary environmental elements that have a direct impact on solar panel performance.[17]

Illuminance has a direct impact on the solar cells' I-V and P-V characteristics; in fact, it may be the most significant element influencing I-V and P-V characteristics, particularly short circuit current (Isc).[18] where the intensity of solar illumination directly correlates with the short circuit current Isc. However, the maximum power current varies when the solar irradiation rises or falls since the short-circuit current Isc is entirely and linearly dependent on the irradiation level. Figure III 2 shows how illumination affects I-V and P-V properties.

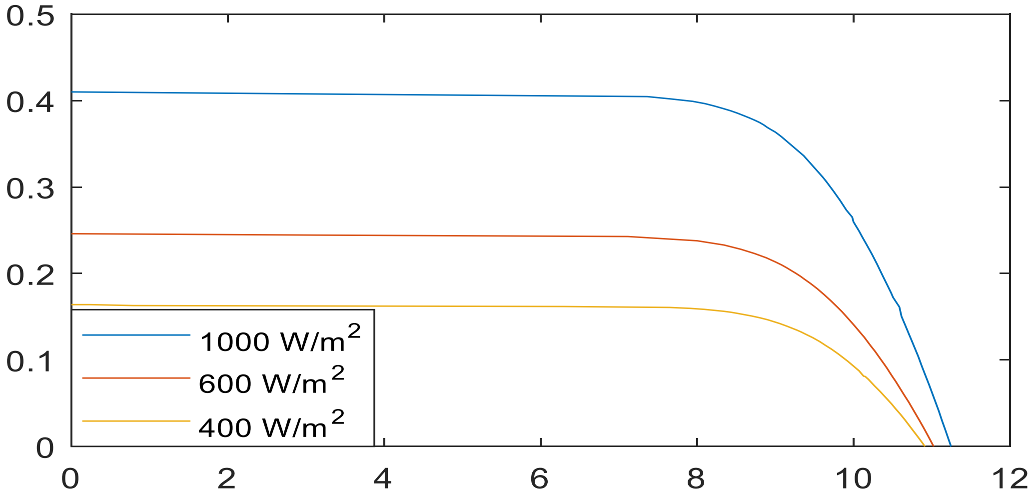


Figure III. 2: Influence of irradiation on I-V characteristics

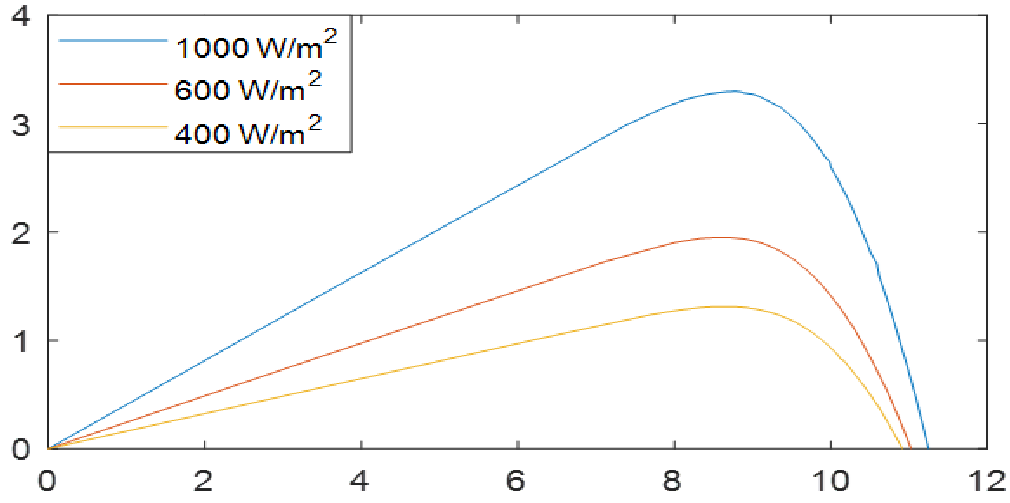


Figure III. 3: Influence of irradiation on P-V characteristics

III.4 Test bench for data acquisition

To validate the functionality and performance of the developed Solar Energy Measurement System , a smal prototype by using real components has been developed as shown in fig.III4, that we aim to record solar panel data through five elements (air temperature, outdoor humidity, PV output current, PV output voltage and light intensity)Note that the same Arduino code used in ISIS Proteus is used in the experiment, and this is the benefit of using ISIS Proteus, it will probably give the same result in the experiment, because we use the same components and Arduino code in simulation and experiment. After testing each sensor alone in small test bench, and real time simulation in ISIS Proteus as first step as presented in the second chaptre, the Arduino uno offers a combination of processing power, memory capacity and connectivity options, which make it well-suited for data acquisition application, in such away arduino board receives the data from connected sensors, for this study; we used the DHT11 for the temperature and humidity sensor, LDR for the light intensity (See Annex I), B26 for DC current measuring ACS712 as DC voltage sensor. To logging these values, we use the MS Excel data streamer icon , which allows recording the received results and storing them in (CSV) file. The solar panel of 3 W is supplied a variable resistor rated 500 ohms and three LED lamps connected in series with the current sensor, the voltage sensor is connected on the branch with parallel way. The arduino card receive the data taken from this montage, which is recorded on the data streamer, this is done using the Arduino code that is uploaded to the Arduino IDE program. This experimental test took place at touggourt region (33° 06′ 30″ N, 6° 03′ 50″ E), for sunny and cloudy day, this study was completed on (Mai, 24^{th} ,2025) , during the recording the sampling time sitted in the IDE program with 1500 ms.

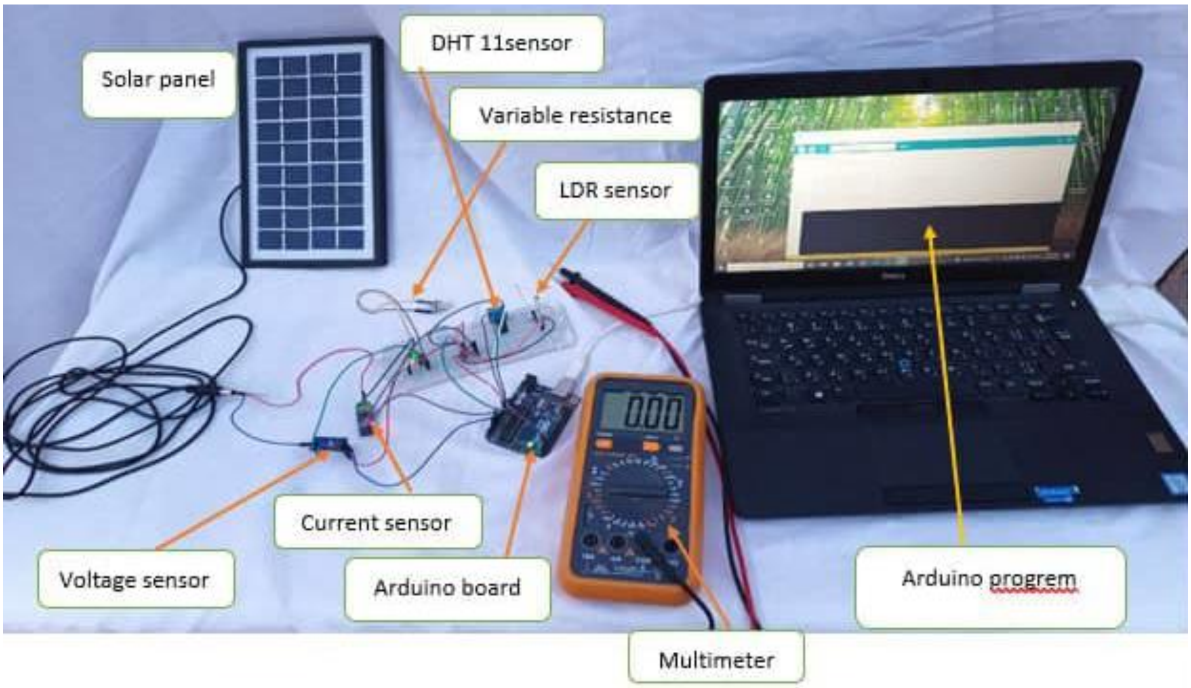


Figure III. 4: Overall test bench for data logging

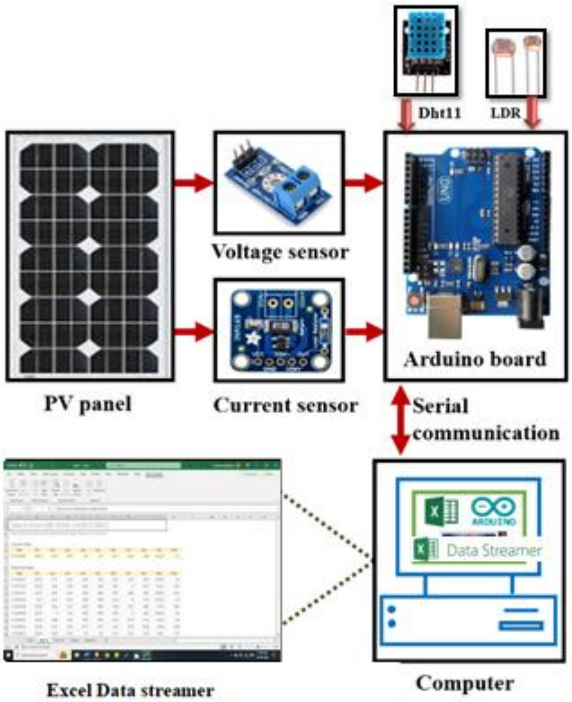


Figure III. 5: Architecture data acquisition system in PV system using multiple sensors

The structure of the equipment used is shown in the Figure below(figIII4). The PV current and voltage are obtained through the current B26 and voltage sensors ACSS7212. The output of the two sensors is transmitted to the ATmega328P microcontroller for Arduino UNO board. During the acquisition process, the data obtained are stored and plotted in real-time in the Excel spreadsheet with little help for curve in matlab.

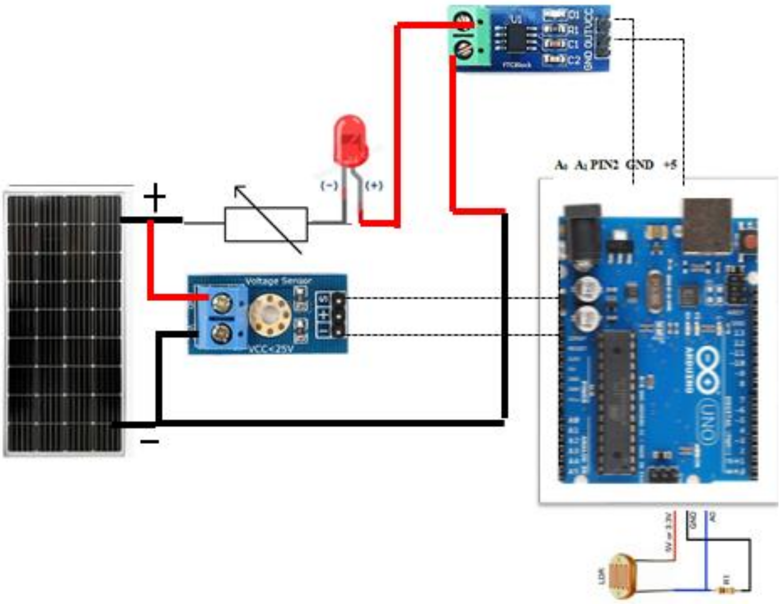


Figure III. 6: Power and single wiring for field test bench

The ATmega328P Arduino microcontroller gets the PV panel output voltage and current which are measured by sensors and then computes the output power in parall with humidty and tempurature . Once the Arduino board is connected to the computer through a USB type A cable, we launch the MS Excel data streamer and by defining in the data streamer icon after its display, the serial port where Arduino board is connected to the computer, and the Baud rate (9600 bit/sec). Note that the Baud rate defined in data streamer window must be the same as that used in the program code embedded in Arduino card. Thereafter, after clicking on "connect" the output data will be collected and displayed in real-time on the Excel Spreadsheet.The microcontroller is programmed to measure successively in each 1.5 second all data.

III .5 Program and data acquistation algorithm :

In order to monitor required data and PV variables at the chosen site, we developed simulation program (Appendix 1) using IDE software, as described in Chapter 2. The program is represented by the following flow chart figIII,3

In the first part of the program, called ‘setup ()’, the program does several things it activates communication with the computer, so that it can display information, it initialise the SD card, so that measurements can be stored on it, and it initializes the temperature and humidity sensor and sets the time and date of the Arduino's clock

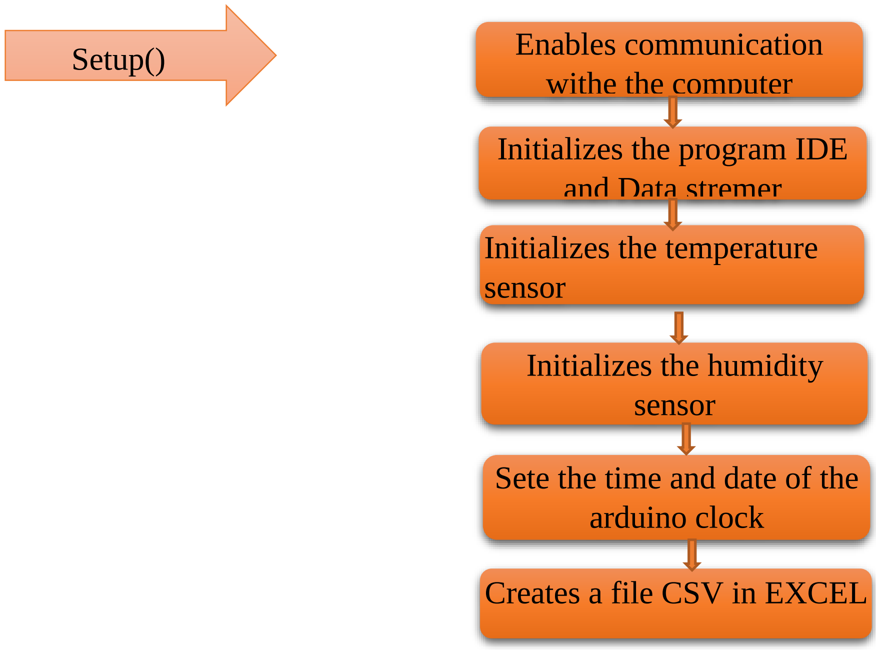


Figure III. 7: flow chart for interfacing arduino data in MS Excel

III.6.LDR processing steps

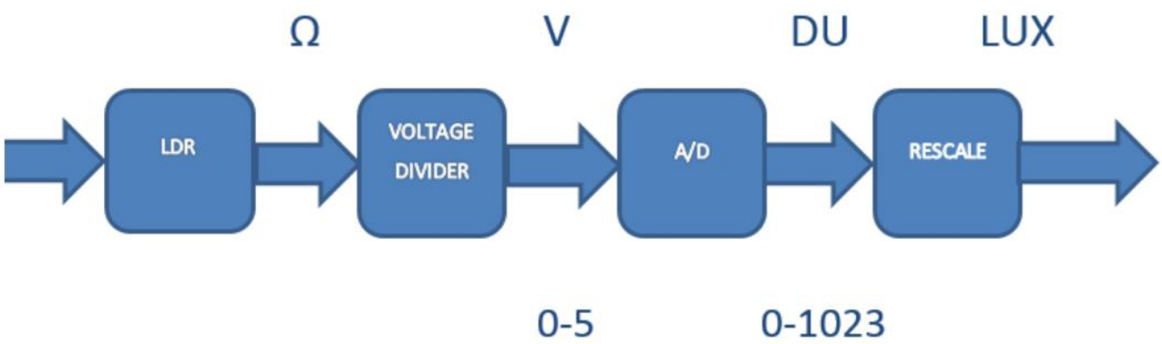


Figure III. 8: Measurements in IDE arduino serial monitor

A serail monitor is very import part in arduion IDE, While the programme was running, we took a close look at the measurements such as air temperature, solar irradiation, humidity, current and voltage related to date and time, that were being displayed on the Arduino's serial; the The data transfer rate wich expressed in the baud rate monitor. This enabled us to check that each sensor was working properly and that the values were logical. Here are some results of the mini recording in the serial monitor:,

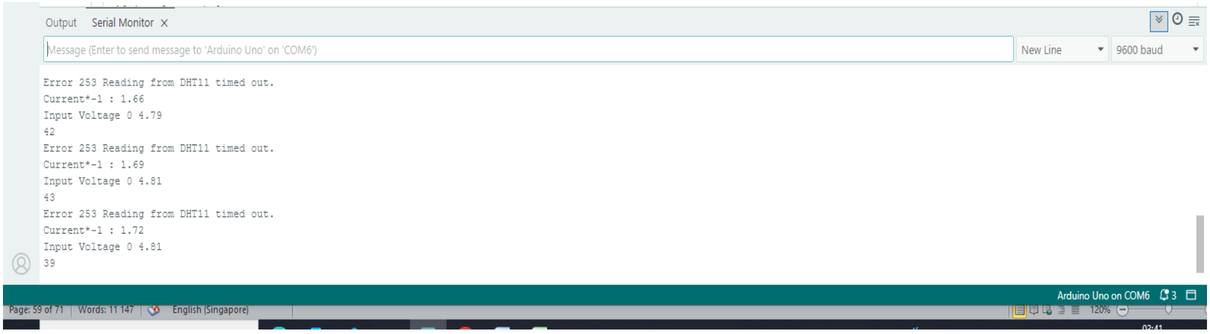


Figure III. 9: Serial monitoring recording data with baud rate of 9600

The achivied program provied the output voltage ranging from 0 to 5 or value of 0 to 1023 but in our case we use LDR to mesure the solar radiation intensity, in this regard a several study achived, that used the an emperical model [19](polynomial regression) based on the observation of the cause and effect relationship between input and output variables. Regression analysis is used as a descriptive method of data analysis. The n order polynomial regression is given by [20]:

for application in our case, we use lux metre, lutron LX-102 light meter serial number 401025 and we measure the voltage through arduino program and simultation nelym some sample measurements are showed in the table:

Table III. 1: voltage and radiation measurement samples

Lux	225	250	300	310	400	700	2500
Voltage	0.1	0.146	0.175	0.243	0.311	0.48	0.85

Through this value we select a polynomial second degree and through Matlab program, we determine the value a_0, a_1 and a_2 and through:

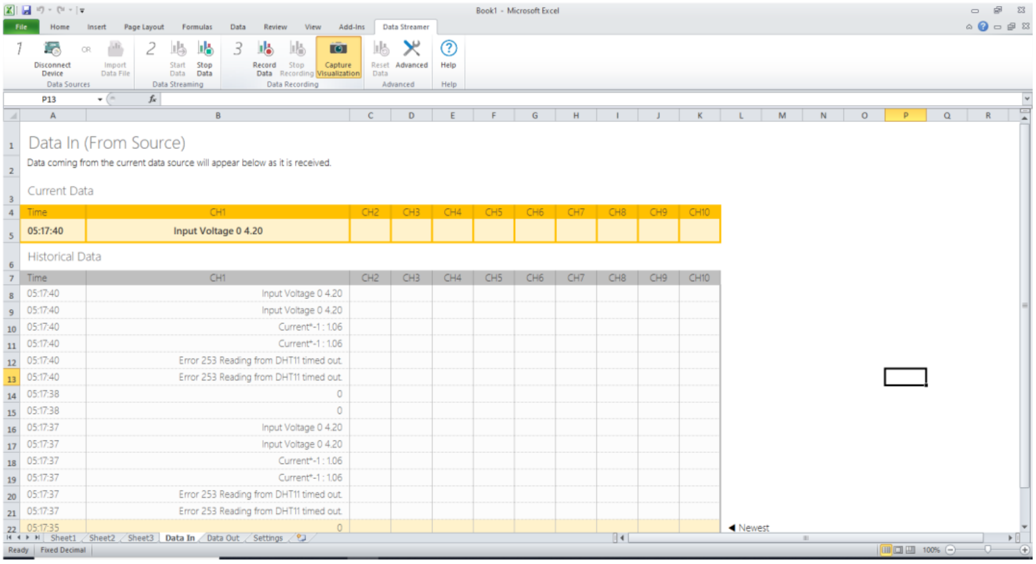
$$Lux(v) = a_0 x^2 + a_1 x + a_2 \qquad \text{III. 2}$$

$$Lux(v) = 1149.6v^2 - 702.5v + 362.93 \qquad \text{III. 3}$$

III.7.Data streamer acquisition

The Data streamer Excel Macro is used for data acquisition from the Arduino AT326 microcontroller to a MS Excel Spreadsheet. We only need to download it. After installation, a folder named " Data streamer " will automatically be created on the Add-ins for excel in which a shortcut named " Data streamer Spreadsheet" is inside. Then, to establish the communication between the board and Excel, we just need to open the Spreadsheet and defining the connections settings (Baud rate and port) in the Data streamer window, in this file we appers these information :

- The first column represents the time.
- The second column represents the illumination.
- The third column represents the temperature.
- The fourth column represents pressure.
- The fifth column represents humidity.



After running the program, the results from the sensors will be stored on the Data streamer as a CSV file Figure (III.4), the results are represented as the measurements were acquired on Mai, 24th , 2025, the graphical interface during data stremer is illustrated in figure III5 The serial port and baud rate should be the same as that used in the sketch code embedded in the Arduino IDE. After clicking connects, the output data will be showed in real time in the Excel sheet. Figure 5 shows the real time Arduino using data streamer data acquisition Excel. All sensors are successfully interfaced with the Arduino Uno and also successfully display on the Excel spreadsheet. The data streamer has the ability to acquire up to 26 columns of data as well as other features such as plot the data in real-time using Microsoft Excel [19].

III.8 Bench adventages in econonomical view

That the prepared bench has a Low-cost way of virtual instrumentation for real-time monitoring of the PV panel characteristics such as voltage, current and power. The system design is based on a low-cost Arduino acquisition board. The acquisition is made through a low-cost current and voltage sensors, and data are presented in Excel by using the Data streamer data acquisition icon .

III.9 Results discussion

We conducted measurements at the field station in Touggourt province (latitude 33° 6.3' N and longitude 6° 4.0' E) over two consecutive days, May 24th , 2025, and May 25th, 2025. Measurements were taken every 1.5 seconds at the station. In this section, we will discuss the obtained results in detail.

This part presents the solar energy measurement results for Touggourt, including data on air temperature, humidity, solar radiation, PV output current, and PV output voltage, which were collected and recorded simultaneously in an MS Excel CSV file. The obtained results are illustrated in Figures III.9a-b, 10a-b, and 11 for the first day, and in Figures III.12a-b, 13a-b, and 14 for the second day. The solar radiation has been measured through Eq III.3.

In this location, data were recorded in both morning and afternoon sessions, capturing variations in temperature and humidity during different time phases.

The first curve (Figure III.9a) illustrates variations in ambient temperature on May 24th , 2025. This data was recorded during daytime, showing an increase in temperature from 37°C, accompanied by a humidity value of 14%. As the temperature continued to rise, reaching approximately 43°C, humidity exhibited an inverse behaviour decreasing as the air temperature increased. This phenomenon was slightly observed at the beginning and middle of the test samples, and the obtained results are consistent with findings reported in [25].

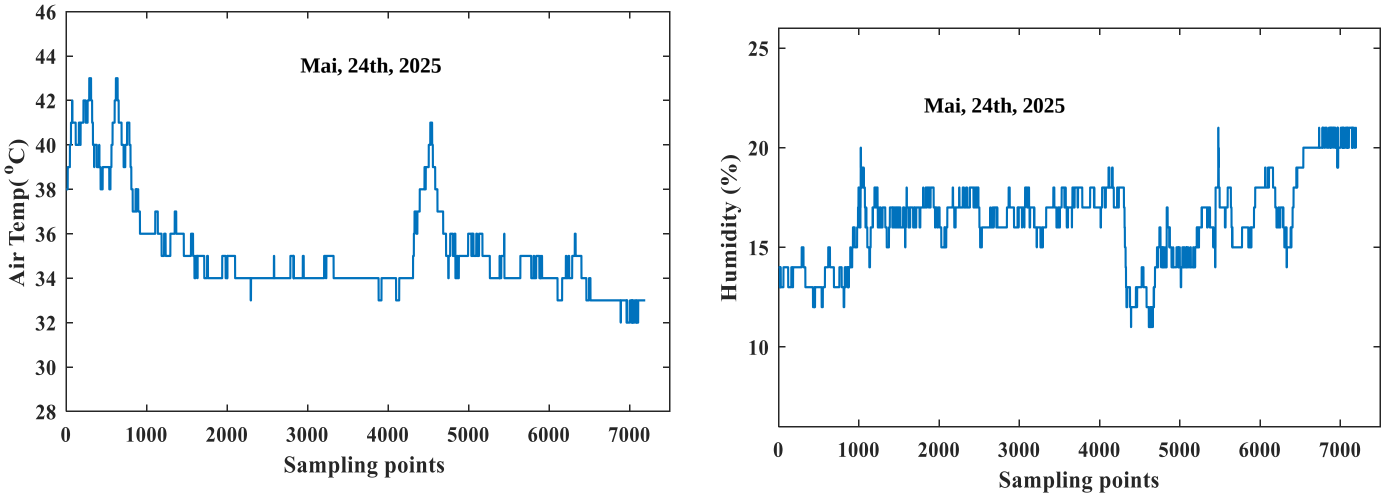


Figure III. 10: a) Typical air temperature (°C) b) Outdoor humidity (%)

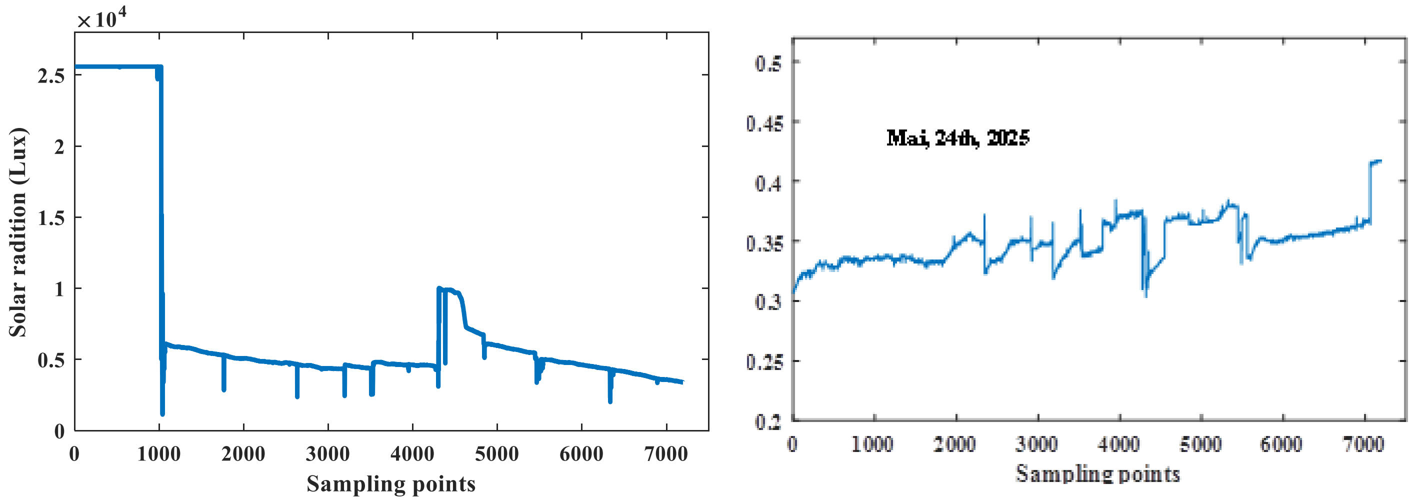


Figure III. 11: a) Solar radiation variation (Lux) b) PV output current (A)

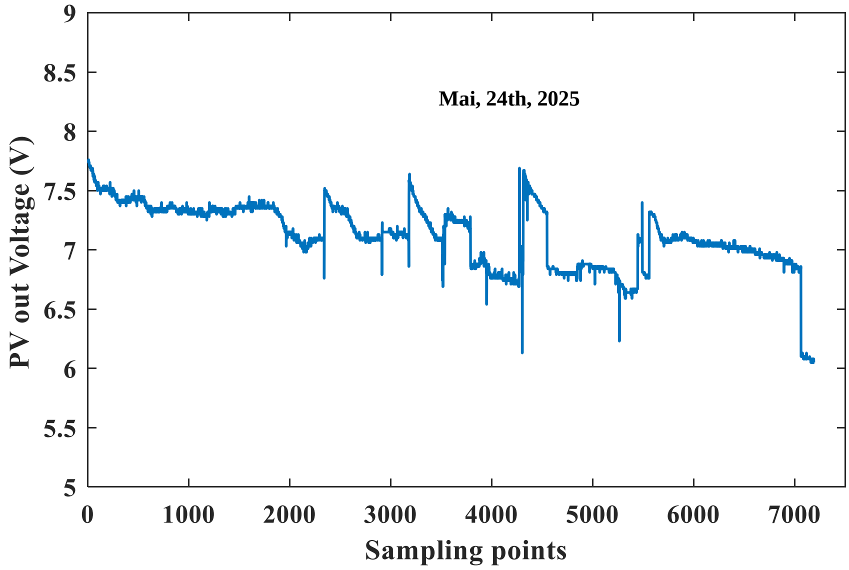


Figure III. 12: PV output Voltage (V)

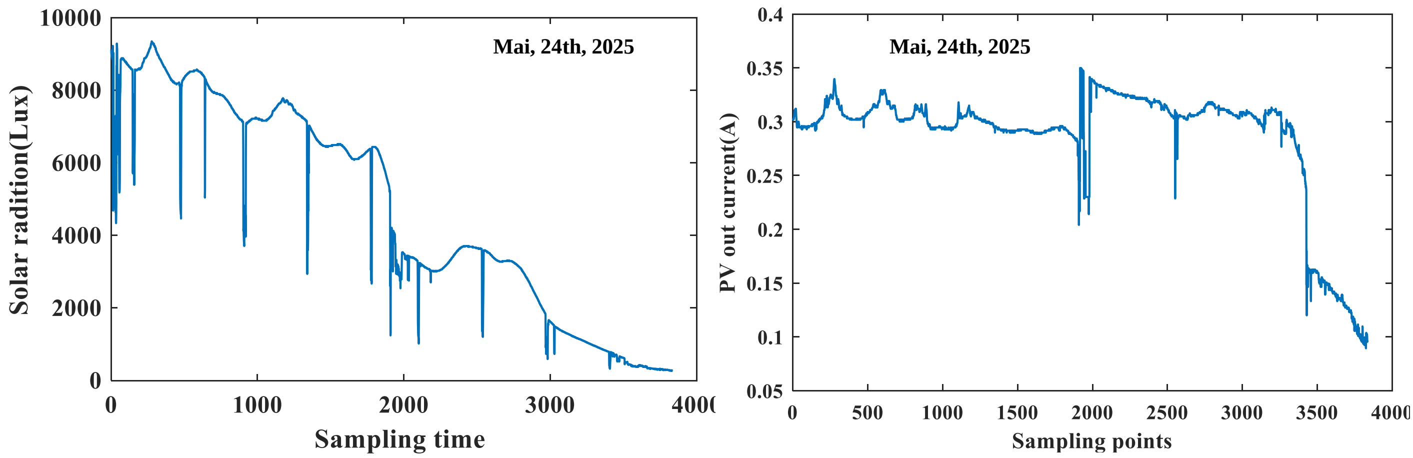


Figure III. 13: a) Typical solar radiation for second day (Lux) b) PV output current **(A)**

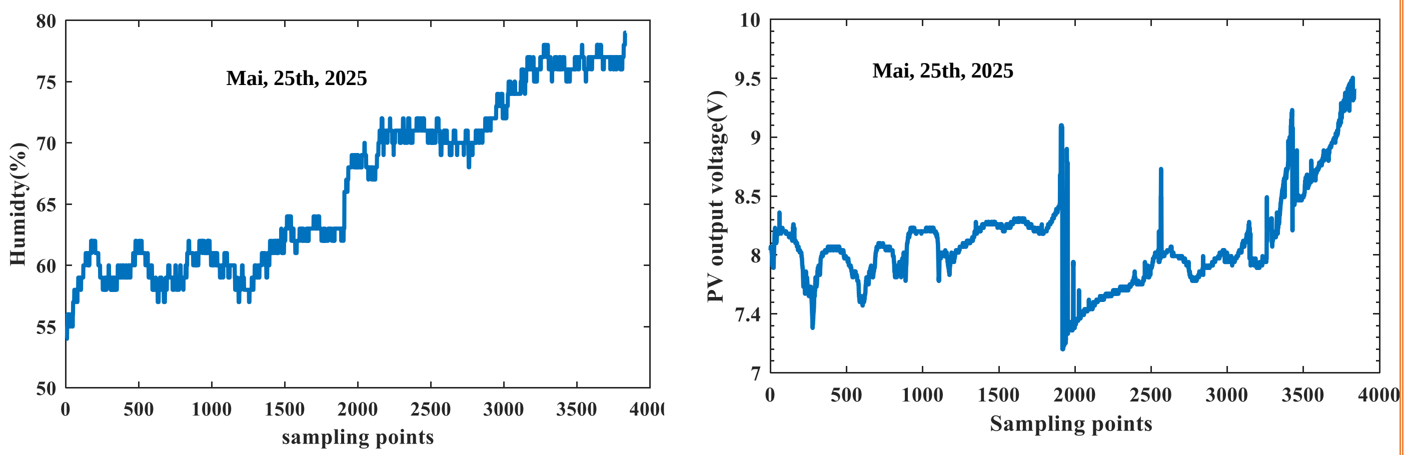


Figure III. 14: Outdoor humidity (%) b) PV output voltage (V)

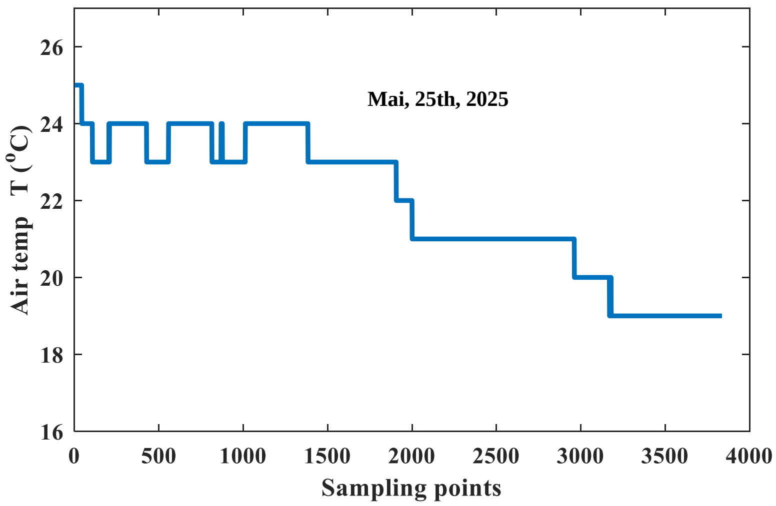


Figure III. 15: Typical air temperature (^{o}C)

As is well known, solar radiation is zero during night hours. However, it gradually increases from morning until noon, reaching its peak close to midday. Afterward, it continuously declines until sunset, where it approaches zero.

Figure III.11a illustrates the variation of solar radiation, starting at 2.6 $*10^4$ Lux and remaining in a steady state. The sensor delivers its maximum value of 5 V, corresponding to 1023 ADC [21]. Towards the end, the radiation decreases to $0.4*10^4$, while the output voltage and current of the panel stabilize at approximately 7.4 V and 0.37 A, respectively. The minor variations in the photovoltaic (PV) output voltage and current are consequences of fluctuations in incident solar radiation and air temperature, as depicted in Figures 10b, III.11 Figures III.12, III.13, and III.14 present data from the second day of testing, conducted on May 25th , 2025. In the first curve (Figure III.14a), the panel's output current is close to 0.36 A during the second day of field testing. However, this value is not constant and decreases towards the end of the day, following a similar trend as observed in Figure III.13a. This graph illustrates variations in humidity, which range between 55.1% and 79.9%. Figure III.14 shows the temperature fluctuations (from 25°C to 18°C) over the sampling acquisition period. Initially, the temperature is approximately 30°C, then gradually declines and stabilizes around 25°C during the day before increasing slightly towards the evening, despite significant fluctuations in temperature and humidity, exhibiting an inverse behavior.

In Figure III.13a, solar radiation drops from 9000 Lux to 940 Lux over a seven-hour period. On the first day, temperature starts at about 30°C, gradually decreases, stabilizes around 25°C during the day, and rises slightly towards the end. Humidity, on the other hand, begins at approximately 55%, gradually increases to peak at 85% in the early morning hours, then declines to about 60%. Notably, an inverse relationship exists between temperature and humidity: as temperature decreases, humidity rises and vice versa.

This result shows that the LDR brightness sensor was saturated during the period of strong sunlight during the day, when it reached its maximum value of $2.5*10^4$ Lux. We can therefore conclude that the LDR light sensor is not suitable for use in a monitoring system for a photovoltaic system, but can used for photovoltaic tracking systeme as mentioned in [22].

Overall, we observed that temperature varies similarly to illuminance, while humidity and temperature exhibit opposite trends. Determining the parameters and characteristics of the solar cell panel was a fundamental challenge in this study. Accordingly, we analyzed specific factors influencing photovoltaic efficiency as achivied in [2gougui3]:

The results confirm that temperature follows the same trend as illuminance, whereas humidity and temperature behave inversely. Throughout the experiment, the system functioned effectively and reliably, demonstrating that our setup is well-designed and dependable.

As perspective, the integration of SD card-based data acquisition systems not only ensures reliable and scalable storage but also enhances the portability and long-term accessibility of critical experimental data, making it an indispensable component in modern data-driven research and development.

III.10 Conclusion

This chapter presented the construction of the prototype used in our study, foucsing on the hardware architecture of the photovoltaic module data acquisition system. The system was implemented using an Arduino board and simulated with ISIS proteus software.

The wark carried out in this chapter represents a real-time simulation of photovoltaic (PV) panel, along with the acquisition of key oprational parameters essential for monitoring and analyzing solar energy systems.

General conclusion

The measured solar energy values can be utilized to develop solar energy system that mathematically relate solar energy to meteorological variables like ambient temperature and humidity for achiving these work, as firest step, we achive performance simulation of the PV panel through this,it provides us with estimates of the characteristics and electrical parameters (I(V), P(V) and verify manufacture parameters. In the second parts, we fouces on PV data acquisition system (DAC) by inexpensive way. The DAC is able to monitor, collect and plot the data of the PV and solar enegy system into Excel sheet and matlab.

In order to good acquire and supervise the photovoltaic voltage, current,power and operating data and to validate the functionality and performance of the developed solar energy measurement system, a prototype using real components has been developed using an open-source Arduino, that systems has structured in three main stages. Firstly, we explored the general generalities about PV system and dataloggers, presenting the different technologies available and the the importance of dataloggers for collecting and storing environmental and solar energy data. Throught, This stage enabled us to familiarise ourselves with the key tools for our project, which will enable us to reliably measure and record various electrical and environmental parameters, using high-quality low coast sensors, we were able to obtain accurate and consistent measurements. The tests and validation of the system confirmed the smooth operation of each component, as well as, the overall reliability and consistency of the mini weather station's performance. The creation of this autonomous mini weather station represents an important step in our learning and mastery of technologies related to embedded systems. Over and above the technical aspects, this work has also made us aware of the importance of environmental measurements and weather monitoring, whether for personal, scientific or educational use. Building this autonomous weather station has been an enriching experience, allowing us to put our theoretical knowledge into practice.We are proud of the result and plan to explore further the possibilities offered by this type of embedded system in future projects. the possibilities offered by this type of embedded system as part of future projects in such an analysis.

In our project, we selected components and sensors compatible with the Arduino Uno and adapted to the types of measurements required.

list of ABREVIATIONS

PV: Photovoltaic

MPPT: Maximum Power Point Tracking

PLX-DAQ: Parallax microcontroller data acquisition add-on tool for Microsoft Excel.

LCD: Liquid crystal display

SD: Secure Digital

LED: Light-emitting diode

SPI: serial peripheral interface

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Document: Datasheet Date: 28-Jul-08 Model #: 3190 Product's Page: www.sunrom.com/p-510.html

Light Dependent Resistor - LDR

Two cadmium sulphide(cds) photoconductive cells with spectral responses similar to that of the human eye. The cell resistance falls with increasing light intensity. Applications include smoke detection, automatic lighting control, batch counting and burglar alarm systems.

Applications

Photoconductive cells are used in many different types of circuits and applications.

Analog Applications

- Camera Exposure Control
- Auto Slide Focus - dual cell
- Photocopy Machines - density of toner
- Colorimetric Test Equipment
- Densitometer
- Electronic Scales - dual cell
- Automatic Gain Control – modulated light source
- Automated Rear View Mirror

Digital Applications

- Automatic Headlight Dimmer
- Night Light Control
- Oil Burner Flame Out
- Street Light Control
- Absence / Presence (beam breaker)
- Position Sensor

Electrical Characteristics

Parameter	Conditions	Min	Typ	Max	Unit
Cell resistance	1000 LUX 10 LUX	- -	400 9	- -	Ohm K Ohm
Dark Resistance	-	-	1	-	M Ohm
Dark Capacitance	-	-	3.5	-	pF
Rise Time	1000 LUX 10 LUX	- -	2.8 18	- -	ms ms
Fall Time	1000 LUX 10 LUX	- -	48 120	- -	ms ms
Voltage AC/DC Peak		-	-	320	V max
Current		-	-	75	mA max
Power Dissipation				100	mW max
Operating Temperature		-60	-	+75	Deg. C

```
// Define analog input
#define ANALOG_IN_PIN A0
 // Include the DHT11 library for interfacing with the sensor.
#include <DHT11.h>

// Create an instance of the DHT11 class.
// - For Arduino: Connect the sensor to Digital I/O Pin 2.
// - For ESP32: Connect the sensor to pin GPIO2 or P2.
// - For ESP8266: Connect the sensor to GPIO2 or D4.
DHT11 dht11(2);

// Floats for ADC voltage & Input voltage
float adc_voltage = 0.0;
float in_voltage = 0.0;

// Floats for resistor values in divider (in ohms)
float R1 = 30000.0;
float R2 = 7500.0;

// Float for Reference Voltage
float ref_voltage = 5.0;

// Integer for ADC value
int adc_value = 0;
int light ;
void setup(){
  // Setup Serial Monitor
  Serial.begin(9600);
}

void loop(){
  // Read the Analog Input
  adc_value = analogRead(ANALOG_IN_PIN);

  // Determine voltage at ADC input
  adc_voltage  = (adc_value * ref_voltage) / 1024.0;

  // Calculate voltage at divider input
  in_voltage = adc_voltage*(R1+R2)/R2;
 int adc = analogRead(A0);
float voltage = adc*5/1023.0;
float current = (voltage-2.5)/0.185;
 int temperature = 0;
    int humidity = 0;

    // Attempt to read the temperature and humidity values from the DHT11 sensor.
    int result = dht11.readTemperatureHumidity(temperature, humidity);
```

```
    // Check the results of the readings.
    // If the reading is successful, print the temperature and humidity values.
    // If there are errors, print the appropriate error messages.
    if (result == 0) {
        Serial.print("Temperature: ");
        Serial.print(temperature);
        Serial.print(" °C\tHumidity: ");
        Serial.print(humidity);
        Serial.println(" %");

    } else {
        // Print error message based on the error code.
        Serial.println(DHT11::getErrorString(result));


    }

Serial.print("Current*-1 : ");
Serial.println(current+10);

  // Print results to Serial Monitor to 2 decimal places
  Serial.print("Input Voltage 0 ");
  Serial.println(in_voltage, 2);

  // Short delay
   delay(1500);
light=analogRead(A2) ;
Serial.println(light) ;
}
```

Abstracte

Solar radiation data provide information on how much of the sun's energy strikes a surface at a location on the earth during a particular time period. These data are needed for effective research in solar-energy utilization. Due to the cost of and difficulty in solar radiation measurements and these data are not readily available, alternative ways of generating these data are needed. In this paper, a review is made on the solar energy modeling techniques which are classified based on the nature of the modeling technique.

The temperature, humidity, atmospheric pressure and altitude are the most important parameters of the environment. If those parameters are known, it will help to select the best crops for specific location which increases the productivity in solar power system. This is very useful for countries like touggourt where the most of people in this prevenous intersted onphotovoltaic systeme and renwable enegry . In this study, an Arduino based device is constructed which measures those parameters and record the data in real time. The DHT11 and LDR sensors are used for measuring those parameters whereas ACS7212 and B26 sensors are used to record PV power data in real time. Data can be displayed on LCD and serial monitor of computer or laptop. The data were collected at tougourt city, with the help of Arduino based device.In this project, the digital portable weather station monitoring system has been designed.

KEY WORDS: Data acquisition. solar panal. Photovoltaic. Arduino uno. Arduino ide.

الملخص

توفر بيانات الإشعاع الشمسي معلومات حول كمية الطاقة الشمسية التي تصل إلى سطح معين في موقع محدد على الأرض خلال فترة زمنية معينة. هذه البيانات ضرورية لإجراء بحوث فعالة في مجال استخدام الطاقة الشمسية. ونظرًا للتكلفة العالية والصعوبة المرتبطة بقياس الإشعاع الشمسي، فضلاً عن محدودية توفر هذه البيانات، هناك حاجة إلى طرق بديلة لتوليدها. في هذه الورقة البحثية، تم استعراض تقنيات نمذجة الطاقة الشمسية وتصنيفها وفقًا لطبيعة منهجية النمذجة المستخدمة. تعد درجة الحرارة، الرطوبة، الضغط الجوي، والارتفاع من أهم العوامل البيئية المؤثرة. توفر معرفة هذه العوامل إمكانية اختيار المحاصيل المناسبة لكل موقع، مما يساعد في تحسين الإنتاجية ضمن أنظمة الطاقة الشمسية. وتكتسب هذه المعلومات أهمية خاصة في مدينة توقرت، حيث يولي معظم السكان اهتمامًا متزايدًا بأنظمة الطاقة الكهروضوئية والطاقة المتجددة.

في هذه الدراسة، تم تطوير جهاز يعتمد على Arduino لقياس هذه العوامل البيئية وتسجيل البيانات في الوقت الفعلي. تم استخدام مستشعرات DHT11 و LDR لقياس درجة الحرارة والرطوبة وشدة الإضاءة، بينما تم استخدام مستشعرات ACS7212و B26 لتسجيل بيانات الطاقة الكهروضوئية. ويمكن عرض البيانات على شاشة LCD أو عبر المراقب التسلسلي لجهاز الكمبيوتر أو الحاسوب المحمول. تم جمع البيانات في مدينة توقرت باستخدام الجهاز المصمم لهذه الدراسة، حيث أثبتت النتائج فعالية النظام في قياس العوامل البيئية بدقة وكفاءة. في هذا المشروع، تم تصميم نظام رقمي محمول لمراقبة الأحوال الجوية، مما يتيح إمكانية تطبيقه في مختلف المجالات البحثية والعملية.

الكلمات المفتاحية . Data acquisition :الألواح الشمسية، الإشعاع الضوئي،**Arduino uno. Arduino ide.**