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GLOBAL ACADEMIC EXCELLENCE

DEVELOPMENT OF DATA ACQUISITION SYSTEM FOR MOBILE ULTRAVIOLET (UV) MONITORING DEVICE

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Abstract:

In this age of modernization, smart or self-sufficient frameworks in all domains of work are becoming increasingly important as innovation advances. This involves improving data collecting for UV monitoring system using metal oxide sensors, an underdeveloped market niche. The Data Acquisition (DAQ) system available at the moment is antiquated and frustrating. This project aims to establish a framework for acquiring information about UV monitoring devices using metal oxide sensors. Metal oxide-based sensor uses titanium dioxide nanorod arrays (TNAs). Self-powered UV photosensor creates electricity when exposed to UV light. UV photosensors are photoelectrochemical (PEC). Monitoring the sensor's real-time output voltage in relation to UV intensity evaluates the data acquisition system's performance. A Raspberry Pi is used to evaluate the data security architecture for the Cytron-UNO development board. The sensor's data gathering system detected the current produced and stamped the date and time on it. This paper discusses trait formation and experimental data.

Keywords:

Ultraviolet, Data Acquisition (DAQ), TNAs UV Photo Sensor, Photoelectrochemical (PEC), Fluoride Tin Oxide (FTO)

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Introduction

The data acquisition (DAQ) system is playing a vital part in the development of new inventions at the moment. According to H. F. Zhang and W. Kang, a variety of study has been done addressing data acquisition as a vital technology for monitoring equipment. This was stated in the aforementioned article. Data Acquisition (DAQ) systems are the primary instruments used in laboratory research by scientists and engineers; they are utilized for testing and measurement, as well as automation. The acronyms DAS and DAQ are two names that are occasionally used to refer to this data acquisition system. According to F. Carena et al., the DAQ system comes with a software package that monitors and evaluates both the data's quality and the system's overall performance. Generally, DAQ systems are all-purpose DAQ devices that do well in measuring voltage or current signals. The basic elements of DAQ are sensors and transducers, field wiring, signal conditioning, DAQ hardware, DAQ software, and PC (with operating system).

Transducers are capable of detecting a broad variety of physical phenomena, including motion, electrical signals, radiant energy, and thermal, magnetic, or mechanical energy. They are used to transform one type of energy into another type of energy. The transducer's input or output configuration is determined by the type of signal recorded, or process regulated; in other words, a transducer is a device that transforms one physical phenomenon to another.

There have been many different suggestions made on possible DAQ approaches. One of them makes use of an STM32 controller with an A/D converter module, which has a resolution of 12 bits. The portability, low cost, and low power consumption of this gadget make it an attractive option. The European Organization for Nuclear Research (CERN) created a Data Acquisition System (DAQ) and an Experiment Control System (ECS) for the ALICE experiment that is housed at the CERN Large Hadron Collider (LHC). These systems are two different types of computing systems, each consisting of hundreds of personal computers and data storage devices that are connected to each other by two separate networks. Several hundreds of high-speed optical cables are utilised in order to acquire the experimental data from the detectors. In addition to this, there is a way that is based on the internet and may be used for real-time applications. According to A. Z. Alkar and M. A. Karaca, interactive internet-based systems give users the ability to monitor and alter their settings by utilising a personal computer and a regular web browser. Because regular web browsers may be used on the client side, the target systems are able to be watched and controlled regardless of their location or the platform they are running on.

Problem Statement, Objectives and Methodology

The researches in developing dual system of UV monitoring using metal oxide-based sensor is very rare. Hence, this project this is to develop dual system of UV monitoring using TiO2 UV photo sensor and DAQ system. The development of the TiO2 based UV photosensor is based on the photoelectrochemical (PEC) design in which its components consist of an electrode, a counter electrode and electrolyte. Based on the previous project research papers, in the data acquisition system, the real-time data received was presented from a recorded data in graphical content without any effort to store it and no real-time presentation of data. This data is very precious especially if it was to be used to train an artificial intelligence (AI) system. Thus, data storing, and management system is needed in order to preserve the data recorded by the system.

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The objectives of this project is to design a UV monitoring device using TNAs type metal oxide. Then, we want to develop a data storage and management system on the voltage generated by the TNAs UV photo sensor. Lastly is to evaluate the performance of the developed mobile UV monitoring system by comparing it with digital multimeter (DMM).

Methodology

This ultimate goal of this research is to develop a UV monitoring system using metal TiO2 UV photo sensor and collect the data automatically by using DAQ system. The first item needs to be prepared is TiO2 before execute the experiment. Flouorine tin oxide (FTO has been deposited to TiO2 photo sensor) coated glass subtract react as the electrode and the designed is based on PEC cell structure. After that, sandwiched together platinized FTO-coated glass substrate and the deposited TiO2 on FTO-coated glass substrate as electrode as counter electrode with a spacer (a thin film) in between the electrodes.

In this research, the Sodium Chloride (NaCl) with molarity of 0.25M will be the electrolyte that acts as a solvent were filled in the inner side of the sealing material between the two electrodes. The molarity is calculated by using this formula:

$$\text{Molarity} = \frac{\text{mass of solute}}{\text{molar mass of solute}} \times \frac{1}{\text{volume of solution}}$$

Figure 1: Molarity Formula

Figure 1 shows the device structure design of the TiO2 / electrolyte PEC-based UV photo sensor. The effective area was designed approximately at 1.0 cm2 for the detection of UV radiation.

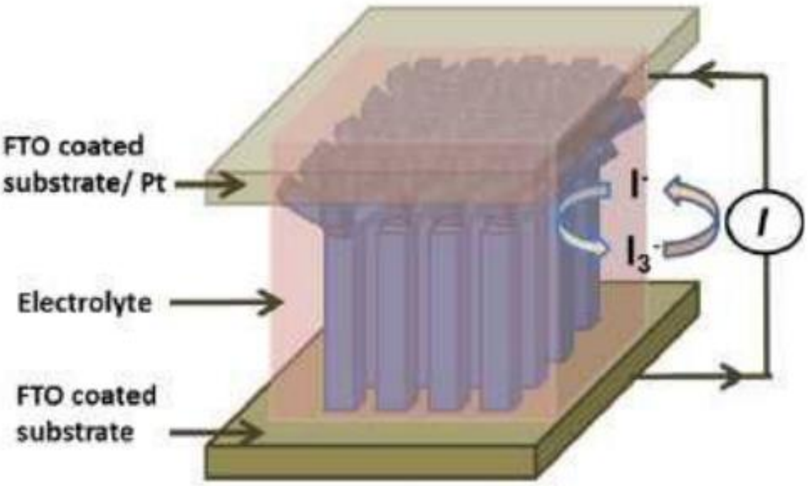

Figure 2: Layout of TIO$_2$ UV Photo Sensor

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Circuit Setup

Figure 2 shows the circuit design for the project. The 2- channel relay is connected to the boost converter, which steps up the 12V power supply to 24V before getting fed to the 24V linear actuator. The sensor is connected to the Cytron-UNO for the ADC process. The Cytron-UNO then sends the measured voltage value to the Raspberry Pi 4 by serial UART communication via a micro-USB cable. The infrared (IR) receiver is connected to the Cytron-UNO and is used to control the linear actuator by the signal received from the IR remote. The linear extender's end is attached to the UV flashlight. The IR receiver reads IR signals, then the Cytron-UNO decodes them and controls the linear actuator through the 2-channel relay. This way, we can manipulate the distance between the UV flashlight to the TNAs UV photo sensor by the specified range which is 4 cm to 20 cm. The Raspberry Pi will further process the data sent by the Cytron-UNO to generate the real-time graph and the .csv file export.

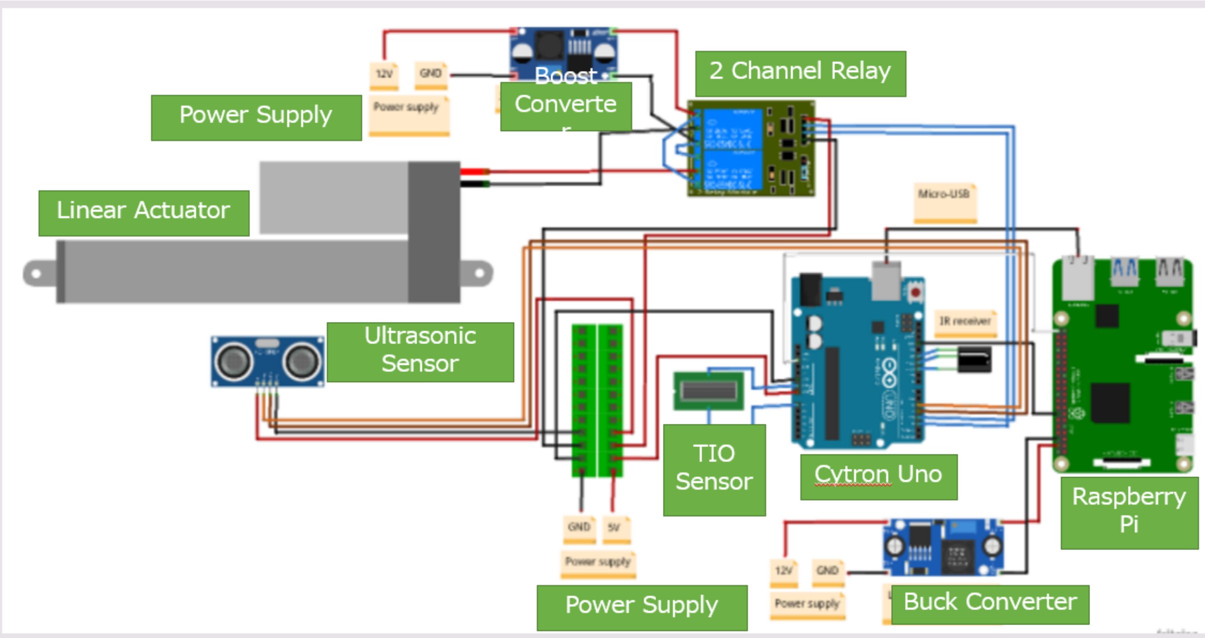

Figure 3: The Proposed Circuit Setup

Platform Design

The proposed design of the platform is as in Figure 3. The design is created based on the specifications so that the experiments on the TNAs UV photo sensor can be done properly. Firstly, the platform has a space for the sensor to be placed due to its sensitive connection that can cause misreading of the generated voltage. Secondly, the platform can adjust the distance between the sensor and the UV flashlight. Lastly, the platform has a space to place all the electronic components to ensure the UV monitoring can be operated.

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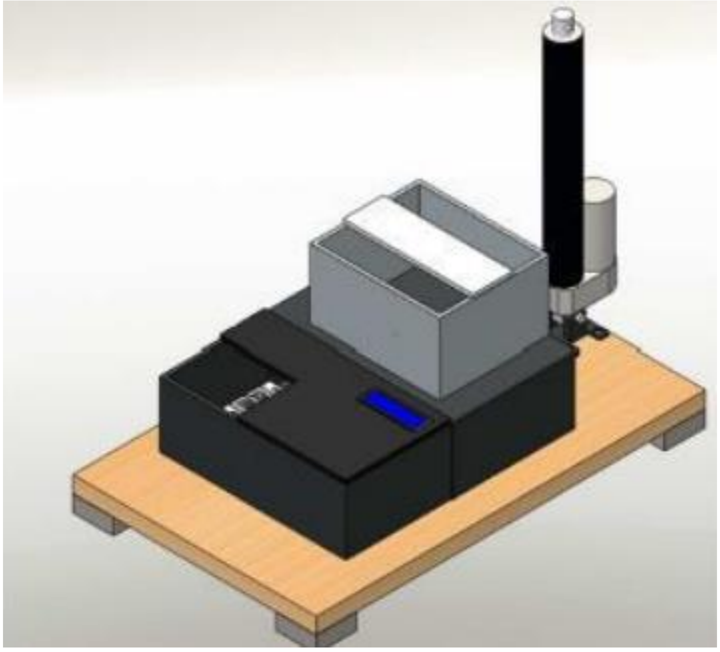

Figure 4: The Proposed Design of The UV Monitoring Device

In this research, we will be executing the experiments on the data acquisition system for portable low power UV detection using TNAs UV photo sensor. The experiment included in this chapter are the generated output voltage in Volts from the TNAs UV photo sensor for every distance set between the sensor and the UV flashlight; 4 cm to 20 cm. In addition, this chapter delves into the redox reaction that takes place between the TiO2 nanostructure material and the electrolytes that were put to use in the tests, which ultimately results in the output voltage being produced. The finalized platform for the project is depicted in figure 4 below.

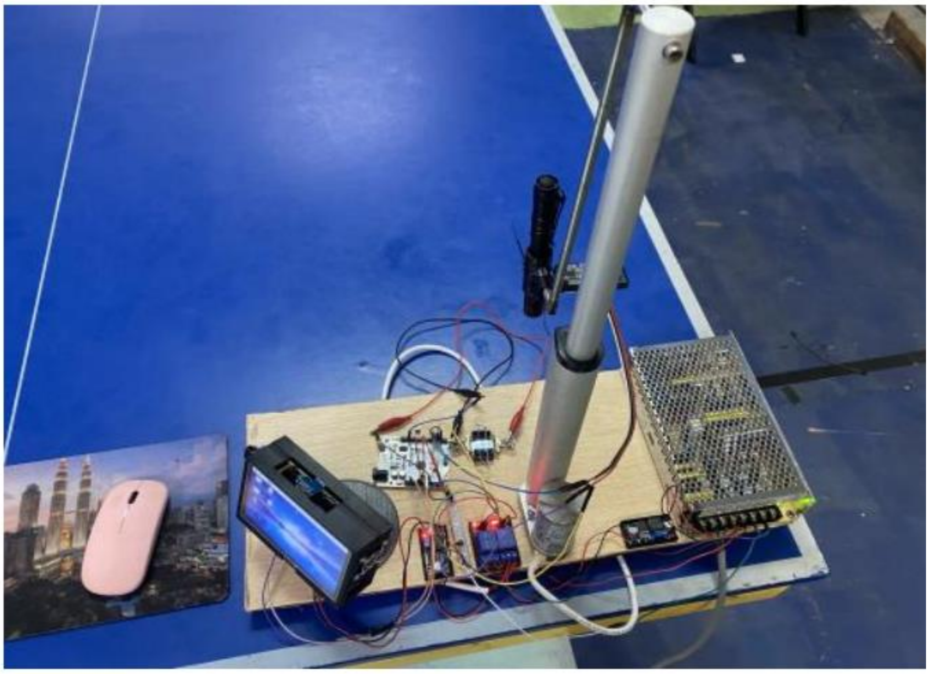

Figure 5: The Finalized Platform for DAQ System on Tnas UV Photo Sensor

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Result

Voltage Measurement Analysis using Digital Multimeter (DMM)

The voltage measurement was also performed using the digital multimeter (DMM) in this exploratory experiment. This type of measurement was used to verify the validity of the voltage readings taken by the Cytron-UNO. To validate the developed DAQ system, the sensor deposited with 0.25M of NaCl was connected to the DAQ system and a DMM for comparison purpose. The percentage error has been calculated using (6) in order to determine how close the voltages measured with the Cytron-UNO are to the voltages measured with the DMM. It is critical to do this computation in order to acquire accurate voltage readings using CytronUNO for the UV monitoring system's future growth. The percentage inaccuracy may be determined using the following formula:

$$\%\ \text{Error} = \left| \frac{\text{measured votlage UNO} - \text{measured voltage DMM}}{\text{measured voltage DMM}} \right| \times 100$$

Figure 6: Error Percentages

Table 1. The Comparison of The Measured Voltage Between the Cytron-Uno and DMM

Distance (cm)	Readings (mV)		%Error (%)
	Cytron-UNO	*DMM*	
4	352	340	3.53
6	331	340	2.65
8	313	310	0.97
10	303	300	1.00
12	301	290	3.79
14	290	280	3.57
16	272	270	0.74
18	258	260	0.77
20	247	230	2.92

As shown in Table 1, the percentage error readings produced are <5%, indicating that the voltage reading from the Cytron-UNO is almost accurate when compared to the voltage reading using the DMM. Thus, it can be concluded that voltage measurements made using Cytron-UNO are accurate when compared to voltage readings taken with a DMM as a reference and may be utilized as a voltage measurement reference when building a UV monitoring system.

Discussion

The Performance of The TNA UV Photo Sensor

The UV flashlight lights the TNA UV photo sensor, allowing redox reaction to take place in the sensor's electrons (Yusoff et al., 2019a). This is because the TNA UV photo sensor is essentially a compound of TiO2, which is an n-type material that dissociates to form Ti3+ and

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oxygen vacancies (VO) when exposed to UV light (Yusoff et al., 2019a). The expression is as follows:

$$Ti^{4+}O^{2-} \rightarrow Ti^{4+}_{1-2x}Ti^{3+}_{2x}Ti^{2-}_{2-x} + xV_O + 0.5xO_2 \quad (5)$$

Figure 7: Redox Reaction

Excitonic charge carriers were formed as a result of UV light exposure using the following equation (Yusoff et al., 2018):

$$hv \rightarrow e^- + h^+ \quad (6)$$

Figure 8: Excitonic Charge

Where hv denotes the photon energy, $e-$ denotes an electron, and $h+$ denotes a hole. The photon energy displaces O2 in the TNA UV photo sensor, creating oxygen vacancies. Through the nanorods, the photogenerated electrons diffuse toward the FTO glass substrate, whereas the photogenerated holes diffuse toward the TNA / electrolyte interface. The photocurrent is created by the passage of photogenerated electrons via the external circuit, while photogenerated holes diffuse into electrolytes and oxidize iodide ions in the process. Following that, the photogenerated electrons react with the oxidized iodide ions (tri-iodide ions) to complete the closed circuit (Yusoff et al., 2019b).

The manufactured UV photosensor's performance is mostly determined by the mobility of photogenerated electron hole pairs. During the "on" state, the produced photocurrent lowered the total resistance and instantly restored it to its initial value during the "off" state. The photocurrent generated by rutile TNAs' photoconductivity effect is dependent on a light-trapping and hole-trapping mechanism (Yusoff et al., 2020). Additionally, to the presence of oxygen molecules on the TNA UV photo sensor's surface. Due to the presence of free electrons in the n-type TiO2 material collected by the absorbed oxygen molecules in the initial state without irradiation, a high-resistance carrier depletion zone forms at the TNA UV photo sensor's interface. As demonstrated by the following process in equation (Yusoff et al., 2018), oxygen molecules from the atmosphere tend to be adsorbed on the TNAs surface by the capture of a free electron to create adsorbed oxygen ions:

$$O_2 + e^- \rightarrow O_2^- \quad (7)$$

Figure 9: Free Electron

As a result, a depletion zone close to the TNAs' surface is produced. The electron-hole pairs are formed when the developed photo sensor is illuminated with UV light with an energy greater than the energy gap of the synthesized material. As a result, oxygen is desorbed from the surface of this location. Due to the built-in electric field, the photogenerated holes travel

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towards the surface, where they combine with adsorbed oxygen ions to form oxygen molecules. Equation below (Yusoff et al., 2018) may be used to explain this reaction:

$$O_2^- + h^+ \rightarrow O_2 \tag{8}$$

Figure 10Fdmm: Oxygen Molecule

The Performance of TNAs UV Photo Sensor Based on The Distance of UV Ray and TiO2.
From TABLE I, it can be observed that shorter distance will generates higher electricity. At 4 cm position of UV flashlight, it generated higher voltage at 352 mV (Cytron-Uno) and 340 (DMM) which is the highest value while at the distance 20 cm it generates electricity at 247 mV (Cytron-Uno) and 230 mV (DMM) which is the lowest value. The setup of the experiment is same for Cytron-Uno and DMM. The difference is the device to measure the electricity. For both of them, it gives the same result which is shorter the distance will generate higher electricity. This is because shorter distance will give higher intensity of UV ray that will give higher reaction and at the end will produce higher amount of electricity.

The Performance of TNAs UV Photo Sensor Measure by Cytron-Uno and DMM
To know the accuracy, we need to compare the measurement with the current device establish device. From that, we can know the percentage of differences. If the percentage is big, it is a sign that the device is not accurate. From this research, we can observe that the percentage of difference is less than 5%. The percentage is small and can be neglected. It show that this device has a high accuracy.

Conclusion
It is concluded that all of the UV monitoring system's objectives have been successfully accomplished, and that the system has accumulated sufficient. With the use of the TNAs UV photo sensor, this research describes and examines in detail the operation and technique of Data Acquisition (DAQ) system in great detail. The experiment was carried out, and the output voltage reading was acquired by utilizing Cytron-UNO in proportion to the distance between the TNAs UV photo sensor and the UV light. The experiment in this research is compared the results to voltage measurements recorded with a digital multimeter, which exhibited a small percentage error of less than 5%. Additionally, the concept is accepted due to the fact that the output voltage generated is proportional to the intensity of the UV light. With the help of these references, the fabrication of the UV monitoring system may be simplified. During the course of this project's continuation, the findings of the data analysis presented in this report will be compared to the results of future experiments conducted during the fabrication of the UV monitoring system.

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