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Development of Solar Energy Lamp Using Arduino Uno

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Abstract– This study aims to design an electronic system from solar energy lamps using Arduino Uno and then implement it into a prototype circuit. This solar energy lighting system supports the green energy ecosystem in the implementation of solar cells in the design of cost-effective electronic systems. This automatic solar energy lamp system consists of solar panels and batteries as inputs, LDR and voltage sensors as references and sensors, Arduino Uno and relays as controllers, and LCD and LED lights as output circuits. The implementation results show that solar energy lamps using Arduino Uno can function properly. The solar energy stored in the battery can be used automatically as lighting at night without using electricity from PLN. It can automate the light in the room, eliminating the need to turn them off and on manually.

Keywords: solar energy lamp, LDR, Arduino Uno

I. INTRODUCTION

Air pollution, global warming, climate change, and the destruction of the earth continue, causing us to continue to support all efforts to save the earth (Jacobson et al., 2017). Better quality of life, sustainability of life, and environmental sustainability are considerations in developing technology and its application. Energy sources that do not pollute the environment, be it air, water, and soil, are an alternative for us to reduce negative impacts on the environment (Dincer, 2000). Alternative energy sources must be renewable to ensure their continuous availability (Mamahit et al., 2022). These energy sources have long been developed, but their use is still small. These energy sources are wind, water, bioenergy, geothermal, sea heat, sunlight, and others (Ellabban et al., 2014). Part of renewable energy is a new energy that is abundant, free, and easy to apply in every area with unique energy sources. This new clean and renewable energy source is green energy (Keramitsoglou et al., 2016).

Solar energy is energy that utilizes heat radiation from the sun to be absorbed and converted into energy that can be used for life. The intensity of sunlight affects the amount of heat radiation needed. The higher the intensity of sunlight, the greater the amount of heat radiation for solar energy (Sukumaran & Sudhakar, 2018). The position and tilt of the solar panels greatly determine the intensity of the absorbed sunlight. Solar energy can only be obtained during the day and when the sun shines directly on the earth's surface without any clouds or other obstructions. This means that solar energy is not always available, especially at night, there is absolutely no direct sunlight. Thus, energy storage technology is needed in the development of solar energy. It takes an energy storage battery that has been absorbed from the solar panel to be used when there is no direct sunlight radiation (Hill et al., 2012).

In order to control the use of solar energy, the use of rooftop solar power plants (PLTS Roof) that exceeds 500 kVA must have an operation-worthy certificate (SLO) and an operating permit (ESDM Ministerial Regulations Number 12 and 13 of 2019). This means we can utilize solar energy independently if the grid power is not more than 500 kVA. It is easier if we use the State Electricity Company (PLN) services in the installation of a PLTS network that is integrated with the home, office, or factory electricity network. For independent installation without being a PLN customer, it is obligatory to report the construction and installation of PLTS Roof to the Directorate General of New Renewable Energy and Energy Conversion (EBTKE), Ministry of Energy, and Mineral Resources (ESDM) (Permen ESDM Number 11 of 2021). Efficiency or savings in terms of costs can be obtained from the use of PLTS Roof either sourced from the PLN network (Vaicys et al., 2022) or in the form of independent PLTS used for special purposes (Hosenuzzaman et al., 2015).

Solar cells are composed of solar cells arranged in solar panels that function to absorb solar radiation and convert it into electrical energy (Danny Santoso Mintorogo, 2000) (Singh, 2013). Solar cells are made of silicon semiconductor, which functions as an insulator at low temperature and as a conductor in hot conditions (high temperature), as shown in Figure 1 (Danny Santoso Mintorogo, 2000). In the development of solar cells, there are three types, namely: Mono-crystalline Silicon (±24%), Poly-crystalline/Multi-crystalline Silicon (±18%), and Gallium Arsenide (GaAs) with an efficiency of ±25%. The next development is in the form of solar cells in integrated silicon known as a thin film. The types of thin films are Amorphous Silicon (A-Si), Thin Film Silicon (Tf-Si), Cadmium Telluride (CdTe), Copper Indium Diselenide (CulnSe2/CIS), Chalcopyrites [Cu(In,Ga)(S, Se)2], and Electrochemical Cells.

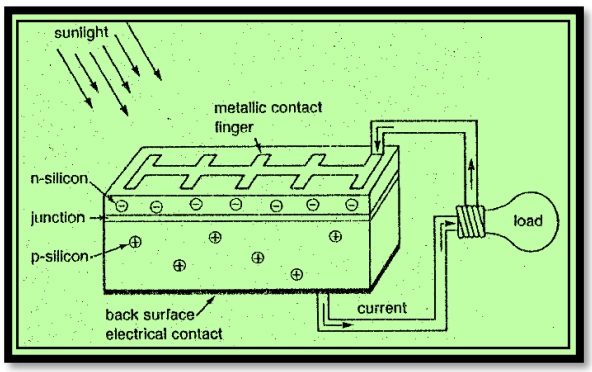

Figure 1. Solar Cell Components (Danny Santoso Mintorogo, 2000)

The solar panel is an integrated circuit of solar cells. The solar panels were tested under standard test conditions, namely at a temperature of 250C, radiation of 1000 W/m2, and an air mass of 1.5 G (El-Tayyan, 2011). The parameters in the output specifications are open-circuit voltage (Voc), short circuit current (Isc), voltage at maximum power (Vmp), current at maximum power (Imp), and maximum power point (Pmax). An example of a 5-volt solar panel specification is in Table 1.

Tabel 1. 5 Volt Solar Panel Specifications

Parameter	Specification
Maximum power (P_{max})	1 Watt
Tolerance	± 10 %
Voltage at maximum power (V_{mp})	6 Volt
Current at maximum power (I_{mp})	0,17 Ampere
Open circuit voltage (V_{oc})	6,9 Volt
Short circuit current (I_{sc})	0,18 Ampere
Cell thickness	0,18mm ± 20 µm
Panel size	125*63*3mm
Number of cells	12
Weight per unit cell	0,12 gram

Light-dependent resistor (LDR) is a resistor whose resistance value or resistance value depends on the intensity of sunlight it receives (Sazol Ahmmed Sourav Kumar Ghosh, Md., 2018). LDR consists of a semi-conducting disc that has two electrodes on its surface. In the dark or dim light, the disc's material produces a relatively small number of free electrons. The LDR resistance value will decrease when the light is bright, and the resistance value will be high when it is dark. The working principle of the LDR is very simple; namely, the LDR is installed in various electronic circuits and can disconnect and connect electricity based on light. The more light that hits the LDR, the resistance value will decrease, and conversely, the less light that hits the LDR, the greater the resistance value (Sarief, 2020).

This voltage sensor is used to measure AC or DC voltage. The voltage sensor module operates on the principle of resistance suppression, it has the ability to reduce input voltage by up to five times the original voltage (Rivani et al., 2019). In this tool, the DC voltage sensor detects how much voltage is in the battery and is displayed on the LCD. The shape of the voltage sensor module is shown in Figure 2.

Figure 2. Voltage Sensor

Batteries are energy storage media capable of converting chemical energy into electrical energy through oxidation-reduction electrochemical reactions or so-called redox reactions. Batteries have a higher efficiency because the energy conversion mechanism takes place electrochemically. Lithium-ion batteries (Li-ion or LIB) belong to the secondary or rechargeable batteries family. It is the most popular energy storage device used, especially portable devices (Bruce et al., 2011). Each Li-ion battery has a voltage of 4 Volts. This battery has a lighter weight than other batteries of the same size because the two electrodes are made of lithium and carbon elements that are lightweight. In addition, lithium is also a very reactive element, so that it can store more energy. This energy is stored in chemical bonds. This is what makes lithium batteries have high energy density characteristics. This battery also has no memory effect, meaning we do not have to drain the battery before recharging. Low self-discharge (1-2% per month). Self-discharge is a battery characteristic where chemical reactions occur in the battery. Longer

charge-discharge cycles mean that lithium-ion batteries last longer even when used continuously (Goriparti et al., 2014).

A relay is an electromechanical component that is an electrically operated switch made up of two main parts: an electromagnet (coil) and a mechanical one (a set of switch contacts) (Romoadhon & Anamisa, 2017). Relays use electromagnetic principles to move the switch contacts, allowing them to conduct higher voltage electricity with a small electric current (low power). A relay powered by a 5V and 50 mA electromagnet, for example, can move the armature relay (which acts as a switch) to conduct 220V 2A electricity. Arduino relays have three inputs, each of which functions as a control to turn on the relay. These pins are GND, VCC, and IN pins. GND for ground or 0 volts (-), VCC for +5v positive voltage, while IN is for input from other sensors that function to move a relay sensor. In simple terms, this electromechanical relay is a device that uses electromagnetic force to close (or open) a switch contact. Switches that are driven (mechanically) by electric power/ energy (Stepanova et al., 2019).

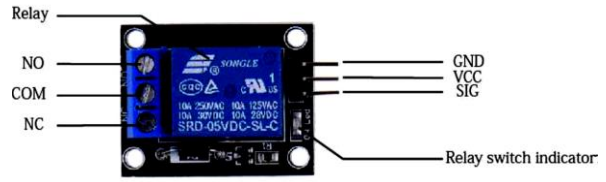

Figure 3. Relay Module

The Arduino Uno microcontroller board is based on the ATmega328 (Cameron, 2019a) (Bell, 2021) (Pan & Zhu, 2018). The Arduino Uno has 14 digital input/output pins (Six of them can be used as PWM outputs), six analog inputs, a crystal oscillator operating at 16 MHz, a USB port, a power jack, an ICSP header, and a reset button. Arduino UNO contains everything required to support the microcontroller. It is easy to connect it to a computer equipped with a USB cable or supply it with an AC to DC converter or start with a battery. The Arduino Uno (Figure 3) differs from all previous Arduino boards in that it lacks a USB-to-serial FTDI driver chip. In contrast, the Atmega16U2 (Atmega8U2 up to version R2) features are programmed as a USB to serial converter (Cameron, 2019b) (Koch, 2020). Revision 2 of the Arduino Uno board has a resistor that draws the 8U2 HWB line to the ground, making it easier to put it into DFU mode. Arduino UNO is the final installment of the Arduino USB board and the reference model for Arduino boards compared to previous versions (Sanggola et al., 2022).

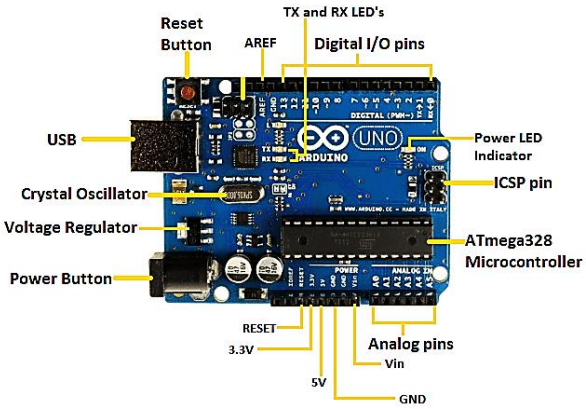

Figure 4. Arduino Uno Controller Board

Inter-integrated circuit (I2C) communication is used between microcontrollers where there are times when in a system we need more than one microcontroller that exchanges data/ communicates (Wootton, 2016). The master and slave principle still applies even though the microcontroller carries out the communication process. Namely, the clock comes from the master as data synchronization. The main problem is that the slave cannot send data directly because the slave also needs time to enter the interrupted service routine, store data into variables, and adjust the address of the data requested by the master. Some of the things above take time, so if the master still sends a clock, then the data received from the slave will have an error/ wrong response. The trick slave can hold the SCL in the low position when it first receives a read command from the master, and then the slave prepares the requested data; once ready, the slave releases the SCL to return to High. Figure I2C can be seen in Figure 4.

Figure 5. I2C Module

An electronic display is a type of electronic component that displays data, such as characters, letters, or graphics. A liquid Crystal Display (LCD) is a type of electronic display that uses CMOS logic technology to work by reflecting the surrounding light against the front-lit or transmitting light from the back-lit rather than producing light (Wardhani et al., 2019). LCDs have been used in various fields, such as electronic devices such as televisions, calculators, or computer screens. In this post, the LCD application used is a dot-matrix LCD with a character count of 2x16. The LCD significantly functions as a viewer,

which will later be used to display the operational status of the tool.

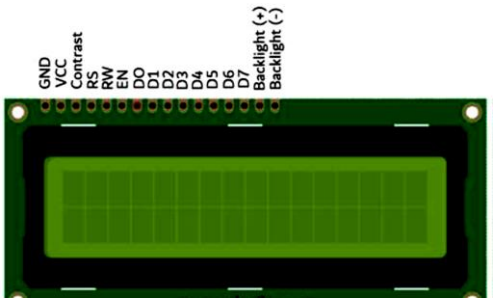

Figure 6. 2x16 LCD Panel

The purpose of this research is for the author will develop an automatic system of solar cell lamps using an Arduino Uno controller. This system is a prototype. Solar energy stored in the battery will be used automatically as lighting at night without electricity from the State Electricity Company (abbreviated in Indonesian as PLN). This system can automate energy-saving lamps in the room, eliminating the need for the lamp to be turned off and on manually.

II. METHOD

This research is an electronic system development research by designing and implementing the design on the hardware assembly. The system design to be made is shown in Figure 7.

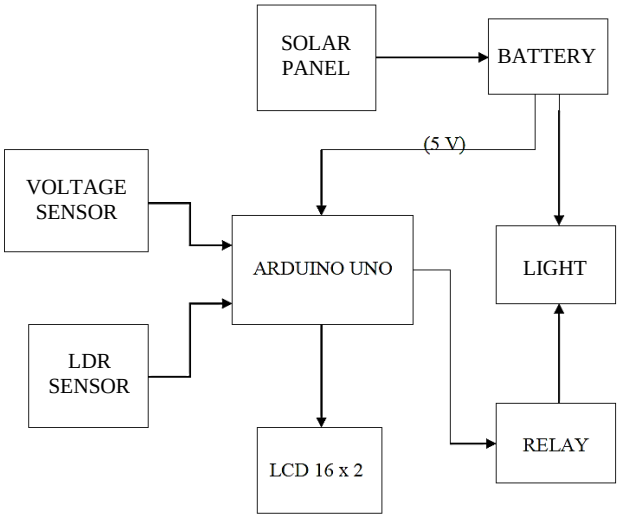

Figure 7. System Design Schematic

The LDR sensor is used to detect light. DC Voltage Sensor serves to detect battery voltage. The ATMega328 microcontroller functions as a data processing medium in sending or receiving signals from other circuit systems. 16x2 LCD serves as a display in displaying the output data. Solar panels function to convert solar energy into electrical energy and as an energy source. The relay is a switch that can be activated when an electric current is applied to the magnetic coil. Batteries function to store energy transferred from solar panels. The lamp serves as a light source for lighting.

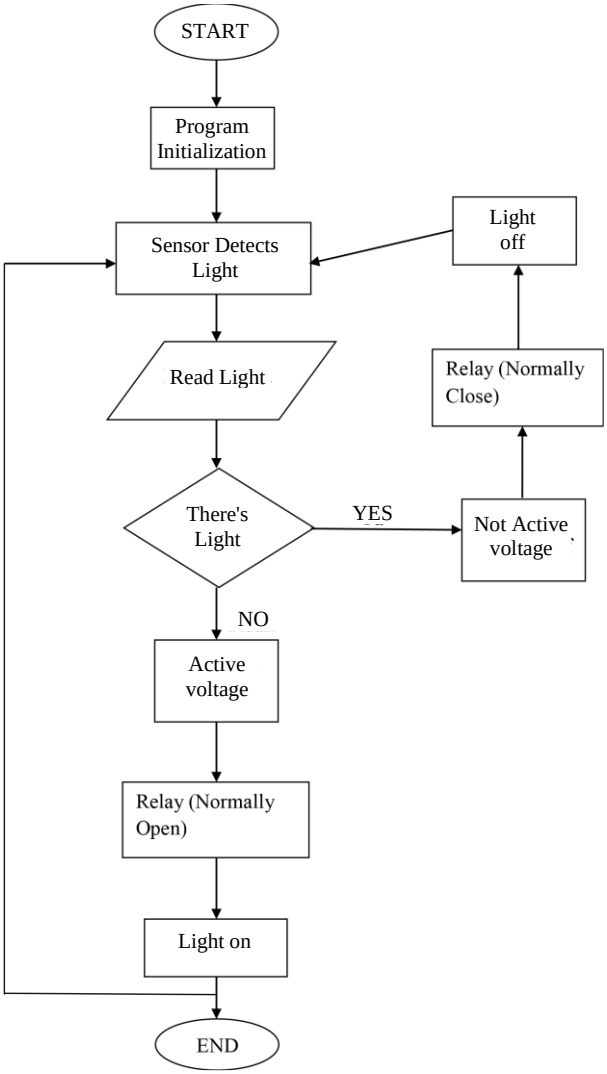

Figure 8. Flowchart System

In this study, a system consisting of several circuit parts will be developed, namely: LDR sensor circuit with Arduino Uno, DC voltage sensor circuit with Arduino Uno, LCD circuit with Arduino Uno, relay circuit with Arduino Uno, and the overall circuit (Arduino Uno, Panel Solar, LCD, Relay, Battery, and Lamp). After the design is made, the next step is to make a PCB layout for the entire circuit.

III. RESULTS AND DISCUSSION

A. LDR Sensor Circuit with Arduino Uno

From Figure 9, it can be seen that the circuit is the input part that functions as a light detector. The LDR sensor is a type of resistor that can change its

resistance when it experiences changes in light reception. Light Dependent Resistor (LDR) is one of the electronic components that can change its resistance when it detects a change in the intensity of the light it receives (Mokalu et al., 2021). The LDR can also be said to be a light sensor; the characteristic of this LDR is that the LDR will change its resistance/resistance when the light changes it detects—with such characteristics, using the principle of a voltage divider in designing a simple sensor (Khujamatov et al., 2019). The resistance of the LDR light sensor will change along with changes in the intensity of light hitting it or those around it. The LDR resistance is about 10 Mega Ohms in the dark, and in the light, it is about 1-kilo ohms or less. LDRs are made of semiconducting materials such as cadmium sulfide.

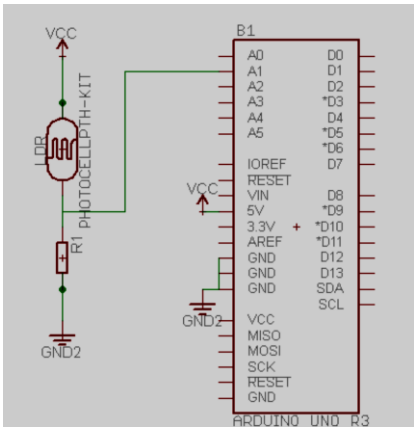

Figure 9. LDR Sensor Input Circuit

B. *DC Voltage Sensor Circuit with Arduino Uno*

From Figure 10, it can be seen that the circuit is the input part which is used as a voltage detector that enters the battery. The voltage sensor module operates on the principle of resistance suppression, and it can reduce the input voltage by up to five times the original voltage. This voltage sensor is programmed in Arduino and calibrated according to the program. This sensor can measure battery voltage up to 25 Volts.

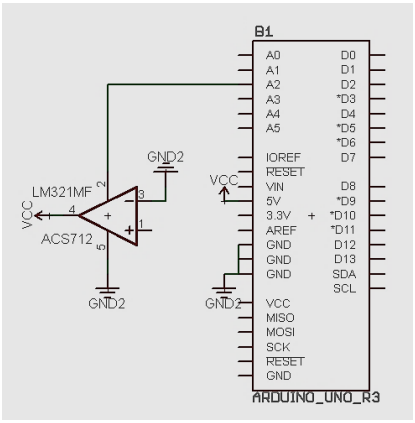

Figure 10. DC Voltage Sensor Circuit

C. *LCD Circuit with Arduino Uno*

From Figure 11, it can be seen that the circuit is part of a 2x16 LCD screen that functions as an output data viewer. An electronic display is a type of electronic component that displays data, such as characters, letters, or graphics. A liquid crystal display (LCD) is a type of electronic display that uses CMOS logic technology to work by reflecting light from its surroundings to the front-lit or transmitting light from the back-lit. The LCD serves as a data viewer, displaying characters, letters, numbers, or graphics. In the picture, the details are that the 16x2 LCD is not directly connected to the Arduino pins but to the I2C module pins, which are serially connected to the Arduino pins, and only use two SCL and SDA pins (Arduino pins A5 and A4) as data instructions from Arduino. The purpose of using this module is to avoid using a lot of Arduino pins that are useful for other circuits.

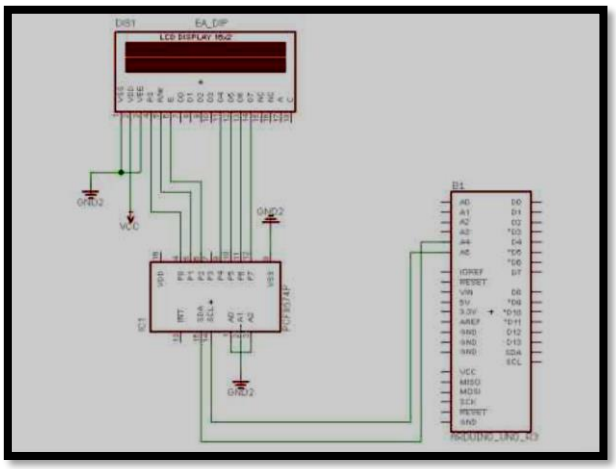

Figure 11. LCD circuit

D. *Relay Circuit with Arduino Uno*

From Figure 12, it can be seen that in making the circuit, the relay is connected to the Arduino digital pin. The output voltage cannot control the relay, and the Arduino will be damaged if it is connected directly. So, with that relay made NPN type transistor circuit. The output voltage on the Arduino pin will turn on the LED on the optocoupler. This lit LED will trigger the phototransistor so that 5 volts will be passed to the base of the transistor. The relay is made up of a coil and a contact. The coil is a wire coil that receives an electric current, whereas the contact is a switch whose movement is determined by the presence or absence of an electric current in the coil. Contacts are classified into two types: normally open (the initial state before being activated) and normally closed (the initial condition before being activated). In layman's terms, this is how a relay

works. When the coil receives electrical energy (is energized), an electromagnetic force is created that attracts the springing armature and causes the contact to close.

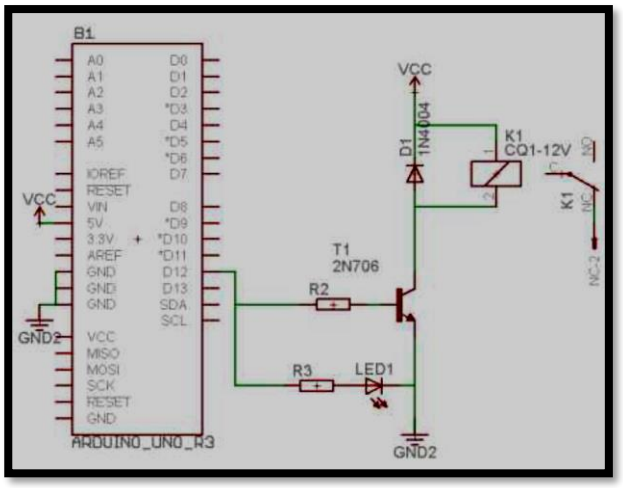

Figure 12. Relay Circuit

E. Arduino Uno Circuit, Solar Panel, LCD, Relay, Battery, and Lamp

From Figure 13, it can be seen that the circuit is an output process from the LCD, Converter Boost, Relay, Battery, and Lamp. The sunlight that enters the solar panel has a maximum voltage of 16 V. The voltage on the battery and lamp is 12 V. The battery can turn on a 12 V lamp. The charge-discharge mechanism for a lithium-ion battery is shown in the image below. The process of charge (when the battery is recharged) and discharge (when the battery is being used) in lithium-ion batteries occur through the transfer of lithium ions between the negative electrode and the positive electrode and the transfer of electrons in the circuit outside the battery. On the LCD, the details are that the 16x2 LCD is not directly connected to the Arduino pins but to the I2C module pins, which are serially connected to the Arduino pins, and only use two SCL and SDA pins (A5 and A4 Arduino pins) as data instructions from Arduino. The purpose of using this module is to avoid using a lot of Arduino pins that are useful for other circuits.

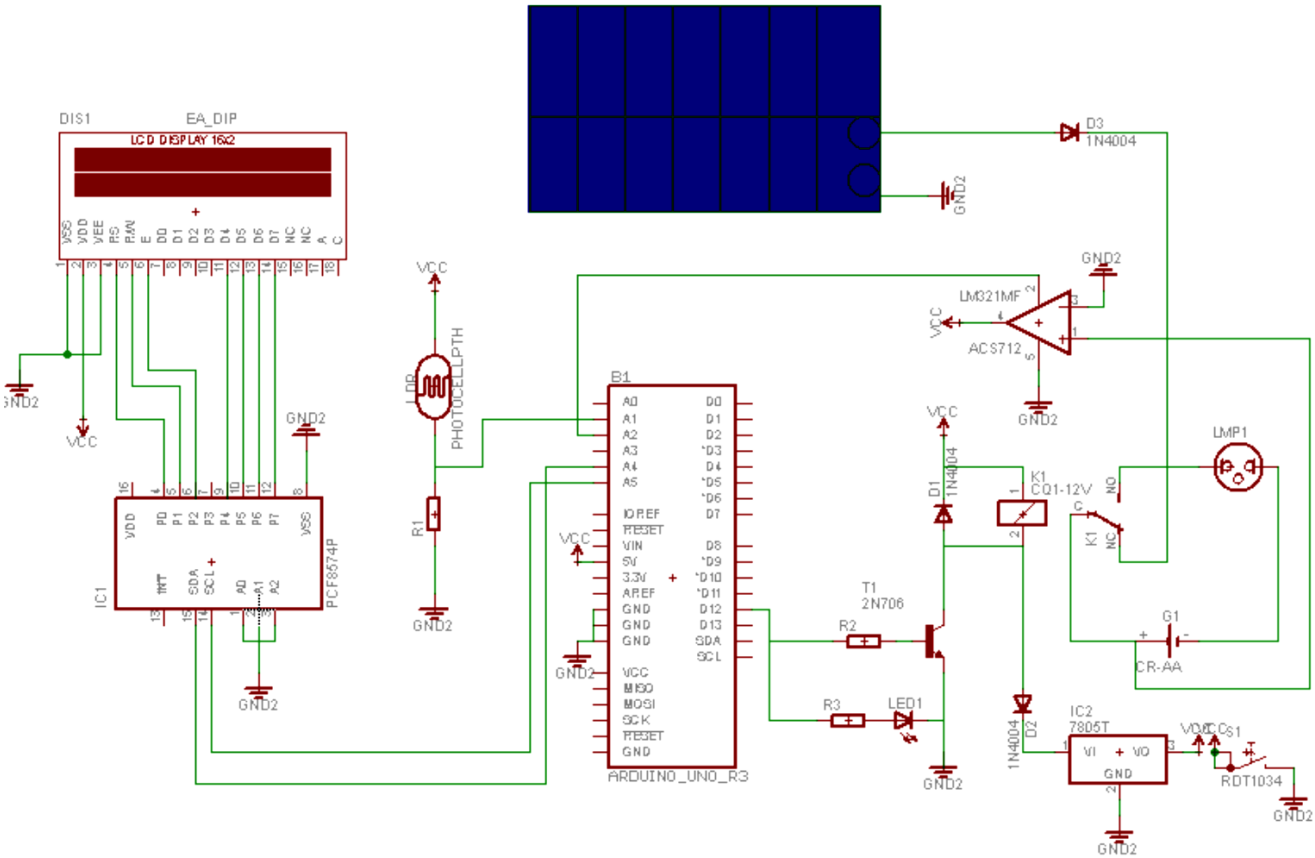

Figure 13. Output Circuit

On the relay, if the LDR sensor detects sunlight and the LCDs (≥500 Lux Light), the relay is in Normally Open (NO), and the lamp is on otherwise when the LDR sensor detects sunlight and the LCDs (<500 Lux) light) the relay is Normally Closed (NC), and the light is off. During the Normally Closed state, the battery will be charged from the solar panel as a voltage source. The output voltage cannot control the relay, and the Arduino will be damaged if it is connected directly. So, with that relay made a series

of NPN transistors. The output voltage on the Arduino pin will turn on the LED on the optocoupler. This lit LED will trigger the phototransistor, so a 5 Volt voltage will be passed to the base of the transistor. A coil and a contact comprise the relay. The coil is a wire coil that receives an electric current, whereas the contact is a switch whose movement is determined by the presence or absence of an electric current in the coil. Contacts are classified into two types: normally open (the initial state before being activated) and normally closed (the initial condition before being activated). The working principle of a relay is simple: when the coil receives electrical energy (is energized), an electromagnetic force is created that attracts the armature.

From Figure 13, it can also be seen that the entire circuit is used to run an automatic system of solar-powered energy-saving lamps. In the circuit, there is an LDR sensor as a bright light sensor that allows the microcontroller to decide whether the lights will be turned on or not. When it is dark, the light will automatically turn on, and when it is bright, the light will automatically turn off. From the test results of this tool, the working system of this tool is that the battery provides a 5 V DC supply to the Arduino Uno. Arduino Uno will read the output from the LDR sensor to instruct the relay to work. On the relay, if the LDR sensor detects sunlight and on the LCD it displays (≥500 Lux), the relay shows it is in Normally Open (NO), and the light is on otherwise when the LDR sensor detects sunlight. On the LCD, it displays (<500 Lux). The relay indicates that it is usually closed (NC), and the light is off. On the LCD, the details are that the 16x2 LCD is not directly connected to the Arduino pins but to the I2C module pins, which are connected serially to the Arduino pins.

F. PCB Layout Drawing on the Overall Circuit

A printed circuit board (PCB) is a copper board that serves to connect components in electronic circuits. Before there were PCB components connected using cables, so it looked very untidy. Each PCB has a different function depending on the product's specifications, so PCBs have different designs. We can design the PCB manually or with the help of software. The design process with software usually begins by creating a schematic from a collection of components and then connecting them. In Figure 14, a series of automatic energy-saving lamp systems using a solar-powered LDR sensor based on Arduino Uno assembled on the PCB Layout. The PCB Layout circuit is arranged based on the overall electronics picture. There is a blue line in the circuit as the PCB circuit line. At the same time, the red line is made as a jumper connecting one component to another.

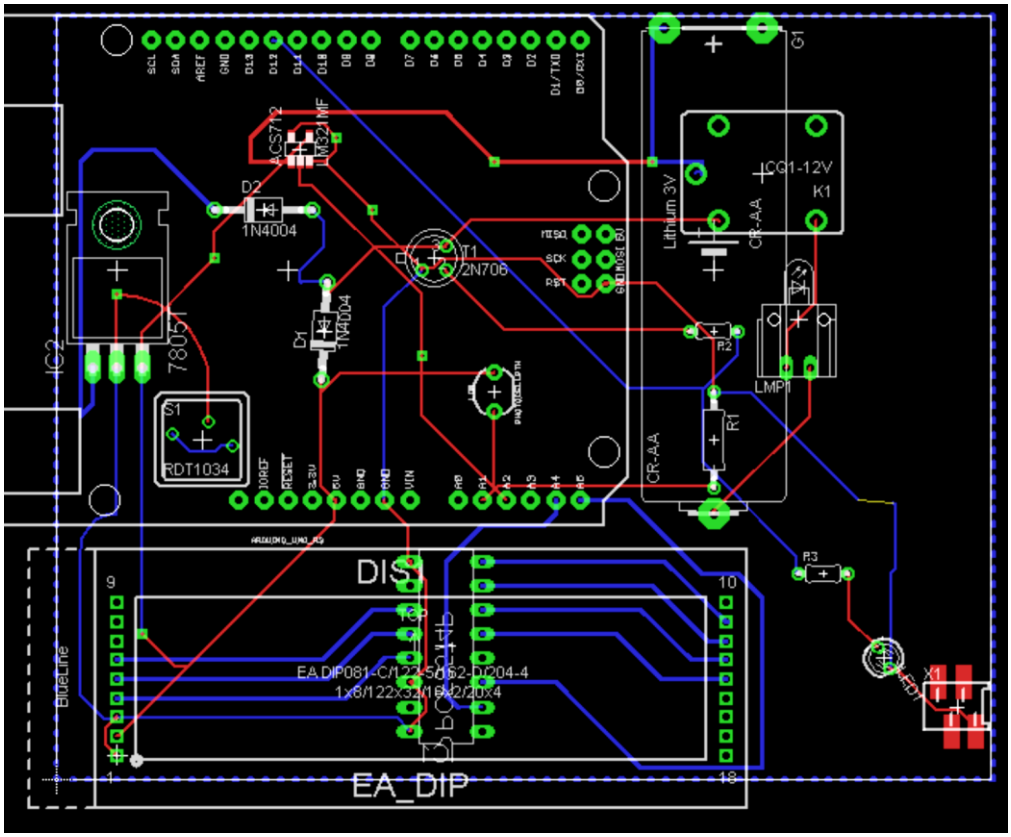

Figure 14. PCB Layout

IV. CONCLUSION

The working principle of Arduino Uno in this study is as a control center, reading the output from the LDR sensor and DC Voltage sensor, instructing to run the relay, and also giving instructions to display the output data on the LCD. In implementing an automatic solar-powered lamp system, it can be concluded that solar panels can produce electrical energy, which will be stored in batteries. Solar energy stored in the battery can be used automatically as lighting at night without using electrical energy from PLN.

REFERENCES

Bell, C. (2021). Introducing the Arduino BT - Beginning IoT Projects: Breadboard-less Electronic Projects. In C. Bell (Ed.), *Beginning IoT Projects* (pp. 31–70). Apress. https://doi.org/10.1007/978-1-4842-7234-3_2

Bruce, D., Haresh, K., & Jean-Marie, T. (2011). Electrical Energy Storage for the Grid: A Battery of Choices. *Science*, *334*(6058), 928–935. https://doi.org/10.1126/science.1212741

Cameron, N. (2019a). *Arduino Applied: Comprehensive Projects for Everyday Electronics* (1st ed.). Apress Berkeley, CA. https://doi.org/https://doi.org/10.1007/978-1-4842-3960-5

Cameron, N. (2019b). Power Saving BT - Arduino Applied: Comprehensive Projects for Everyday Electronics. In N. Cameron (Ed.), *Arduino Applied* (pp. 397–410). Apress. https://doi.org/10.1007/978-1-4842-3960-5_21

Danny Santoso Mintorogo. (2000). Strategi Aplikasi Sel Surya (Photovoltaic Cells) Pada Perumahan Dan Bangunan Komersial. *DIMENSI (Jurnal Teknik Arsitektur)*, *28*(2), 129–141. https://doi.org/ttps://doi.org/10.9744/dimensi.28.2.

Dincer, I. (2000). Renewable energy and sustainable development: a crucial review. *Renewable and Sustainable Energy Reviews*, *4*(2), 157–175. https://doi.org/https://doi.org/10.1016/S1364-0321(99)00011-8

El-Tayyan, A. (2011). PV system behavior based on datasheet. *Journal of Electron Devices*, *9*(20011), 335–341.

Ellabban, O., Abu-Rub, H., & Blaabjerg, F. (2014). Renewable energy resources: Current status, future prospects and their enabling technology. *Renewable and Sustainable Energy Reviews*, *39*, 748–764. https://doi.org/https://doi.org/10.1016/j.rser.2014.07.113

Goriparti, S., Miele, E., De Angelis, F., Di Fabrizio, E., Proietti Zaccaria, R., & Capiglia, C. (2014). Review on recent progress of nanostructured anode materials for Li-ion batteries. *Journal of Power Sources*, *257*, 421–443. https://doi.org/https://doi.org/10.1016/j.jpowsour.2013.11.103

Hill, C. A., Such, M. C., Chen, D., Gonzalez, J., & Grady, W. M. (2012). Battery Energy Storage for Enabling Integration of Distributed Solar Power Generation. *IEEE Transactions on Smart Grid*, *3*(2), 850–857. https://doi.org/10.1109/TSG.2012.2190113

Hosenuzzaman, M., Rahim, N. A., Selvaraj, J., Hasanuzzaman, M., Malek, A. B. M. A., & Nahar, A. (2015). Global prospects, progress, policies, and environmental impact of solar photovoltaic power generation. *Renewable and Sustainable Energy Reviews*, *41*, 284–297. https://doi.org/https://doi.org/10.1016/j.rser.2014.08.046

Jacobson, M. Z., Delucchi, M. A., Bauer, Z. A. F., Goodman, S. C., Chapman, W. E., Cameron, M. A., Bozonnat, C., Chobadi, L., Clonts, H. A., Enevoldsen, P., Erwin, J. R., Fobi, S. N., Goldstrom, O. K., Hennessy, E. M., Liu, J., Lo, J., Meyer, C. B., Morris, S. B., Moy, K. R., … Yachanin, A. S. (2017). 100% Clean and Renewable Wind, Water, and Sunlight All-Sector Energy Roadmaps for 139 Countries of the World. *Joule*, *1*(1), 108–121. https://doi.org/https://doi.org/10.1016/j.joule.2017.07.005

Keramitsoglou, K. M., Mellon, R. C., Tsagkaraki, M. I., & Tsagarakis, K. P. (2016). Clean, not green: The effective representation of renewable energy. *Renewable and Sustainable Energy Reviews*, *59*, 1332–1337. https://doi.org/https://doi.org/10.1016/j.rser.2016.01.005

Khujamatov, K. E., Khasanov, D. T., & Reypnazarov, E. N. (2019). Modeling and Research of Automatic Sun Tracking System on the bases of IoT and Arduino UNO. *2019 International Conference on Information Science and Communications Technologies (ICISCT)*, 1–5. https://doi.org/10.1109/ICISCT47635.2019.9011913

Koch, G. (2020). *Programming the Arduino BT - The LEGO Arduino Cookbook: Expanding the Realm of MINDSTORMS EV3 Invention* (G. Koch (ed.); pp. 25–36). Apress. https://doi.org/10.1007/978-1-4842-6303-7_3

Mamahit, C., Ticoh, J., Sangi, N., & Angmalisang, H. (2022). Studi Sistem Pengisian Cepat Baterai Kendaraan Listrik Berbasis Papan Pengendali OpenEVSE. *JURNAL EDUNITRO*, *2*(1 SE-), 61–70. https://doi.org/10.53682/edunitro.v2i1.3909

Mokalu, A., Mamahit, C., & Sanger, R. (2021). Peningkatan Hasil Belajar dengan Pembelajaran Demonstrasi di Kelas X Jurusan TITL SMKN 2 Manado. *JURNAL EDUNITRO: Jurnal Pendidikan Teknik Elektro*, *1*(2), 19–26. https://doi.org/10.53682/edunitro.v1i2.1045

Pan, T., & Zhu, Y. (2018). *Getting Started with Arduino BT - Designing Embedded Systems with Arduino: A Fundamental Technology for Makers* (T. Pan & Y. Zhu (eds.); pp. 3–16). Springer Singapore. https://doi.org/10.1007/978-981-10-4418-2_1

Rivani, R., Hiendro, A., & Syaifurrahman. (2019). Studi perancangan dan analisis sistem pengisian cerdas (smart charge) baterai. *Jurnal Teknik Elektro Universitas Tanjungpura*, *2*(1). https://jurnal.untan.ac.id/index.php/jteuntan/article/view/35374

Romoadhon, A. S., & Anamisa, D. R. (2017). Sistem Kontrol Peralatan Listrik pada Smart Home Menggunakan Android. *Rekayasa*, *10*(2), 116. https://doi.org/10.21107/rekayasa.v10i2.3613

Sanggola, M., Mamahit, C., & Seke, F. (2022). Pengembangan Sistem Gerak Robot Berkaki Enam. *JURNAL EDUNITRO: Jurnal Pendidikan Teknik Elektro*, *2*(1), 53–60. https://doi.org/10.53682/edunitro.v2i1.3644

Sarief, I. (2020). Pengontrolan Posisi Solar Cell Otomatis Dengan Menggunakan Sensor Cahaya Light Dependent Resistor Untuk Energi Alternatif. *Infotronik : Jurnal Teknologi Informasi Dan Elektronika*, *5*(2), 94. https://doi.org/10.32897/infotronik.2020.5.2.543

Sazol Ahmmed Sourav Kumar Ghosh, Md., T. Z. C. (2018). Automatic Street Light Control System using Light Dependent Resistor and Motion Sensor. *Global Journal of Research In Engineering; Vol 18, No 1-A (2018): The Global Journal of Researches in Engineering*, *18*(1-A). https://www.engineeringresearch.org/index.php/GJRE/article/view/1781

Singh, G. K. (2013). Solar power generation by PV (photovoltaic) technology: A review. *Energy*, *53*, 1–13. https://doi.org/https://doi.org/10.1016/j.energy.2013.02.057

Stepanova, D. A., Naumov, V. A., & Antonov, V. I. (2019). Deep Learning in Relay Protection of Digital Power Industry. *2019 2nd International Youth Scientific and Technical Conference on Relay Protection and Automation (RPA)*, 1–17. https://doi.org/10.1109/RPA47751.2019.8958378

Sukumaran, S., & Sudhakar, K. (2018). Performance analysis of solar powered airport based on energy and exergy analysis. *Energy*, *149*, 1000–1009. https://doi.org/https://doi.org/10.1016/j.energy.2018.02.095

Vaicys, J., Norkevicius, P., Baronas, A., Gudzius, S., Jonaitis, A., & Peftitsis, D. (2022). Efficiency Evaluation of the Dual System Power Inverter for On-Grid Photovoltaic System. In *Energies* (Vol. 15, Issue 1). https://doi.org/10.3390/en15010161

Wardhani, N. V, Aulia, A. M., Yulianto, E., Mak'ruf, M. R., Indrato, T. B., Setioningsih, E. D., Sumber, & Triwiyanto, T. (2019). A Portable Vital Sign Device with Liquid Crystal Display TFT Touchscreen. *2019 International Seminar on Application for Technology of Information and Communication (ISemantic)*, 429–433. https://doi.org/10.1109/ISEMANTIC.2019.8884351

Wootton, C. (2016). *Inter-Integrated Circuit (I2C) BT - Samsung ARTIK Reference: The Definitive Developers Guide* (C. Wootton (ed.); pp. 321–334). Apress. https://doi.org/10.1007/978-1-4842-2322-2_20