PROGRAMMABLE ENERGY CONTROLLER FOR HOUSEHOLD APPLIANCES

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ABSTRACT *This project presents an alternative approach to controlling household electric bill consumption by utilizing a programmable energy controller for household appliances. The study uses developmental research to design and develop an instructional program for the energy controller. It uses the Proteus 7, Arduino Uno microcontroller, and other electronic components and devices for data analysis. Additionally, statistical analysis techniques such as mean, frequency count, and standard deviation are utilized. The study's findings reveal that televisions and light bulbs are the most commonly utilized items in households with an average of four occupants. The monthly electric bill ranges from P500 to P1000. The programmable energy controller for household appliances can control the devices by setting specified times. A source code is uploaded from the computer to implement the system's desired functions. It is a programmable household energy controller because it may be set to turn on and off the appliances automatically at predetermined times of the day. The overall results show 61.35% energy savings due to the developed energy controller for household appliances. Likewise, it controls four specific devices with different usage times and provides data logging for total time calculation. It performed very satisfactorily based on the assessments of the practitioners and users.*

Keywords: Energy-efficiency, AutomationMicrocontroller, Consumption Programmable, Appliances, Data-logging, Timers, Arduino UnoProteus 7

1. INTRODUCTION

Today, having access to electricity is necessary because it powers gadgets and serves as an essential element in homes by providing light [1]. Hydropower, often known as hydroelectric power, is one of the many ways to produce energy [2]. In Lanao and Iligan, the Agus and Pulangi Hydropower Complexes provide hydropower for Surigao, respectively [3]. However, Mindanao endures power interruptions and expensive electricity when hydropower sources deplete [4, 5]. Microcontrollers are tiny integrated circuits that are being used increasingly in building automation in various industries, including manufacturing, robotics, and the Internet of Things (IoT) [6].

Accordingly, a programmable project is created to manage appliances and conserve energy [7]. A real-time clock shows the passing of time, and the system uses a programmable household energy controller to turn on and off the appliances at predetermined periods [8]. The microcontroller-equipped Arduino, an open-source electronics platform, reads the source code and manages the appliances [9]. Due to its affordability, compatibility, small size, and ease of interface with other controllers like Field Programmable Gate Arrays (FPGAs), Programmable Logic Controllers (P.L.C.s), and Programmable Integrated Circuits, the Arduino U.N.O. Atmega328 are utilized in an automatic street lighting proposal (P.I.C.s) [10]. This resulted in significant power savings and reduced operational and maintenance costs [11].

Other programs concentrate on retrofitting older buildings with energy-saving measures [12]. The artificially intelligent Smart Building Automation Controller (A.I.B.S.B.A.C.), which automates building systems for maximum energy efficiency and user comfort [13], is an example of such project. U.I.R.I.M. [14], a brand-new wireless communication technology [15], was introduced with A.I.B.S.B.A.C. [16] to create wireless connections between the controller and electrical appliances [17]. The market demand for smart home systems is nevertheless constrained by their high production costs, notwithstanding the potential for energy savings [18]. This was addressed by developing a compact, affordable smart home system that uses an Arduino microcontroller for its wireless local area network [19]. This enables simple monitoring and management of household amenities, ultimately promoting energy efficiency and lowering electricity costs [20].

This research aims to develop a programmable household energy controller to regulate household power consumption, to test and evaluate the system performance and implement the development in actual settings.

Objectives of the Study

This project aims to develop a programmable household energy controller for regulating household power consumption. It is likely to provide consumer with an opportunity to reduce their electric bill and charges at the same time.

1. To design a block diagram of programmable energy controller for household appliances.
2. To implement the programmable energy controller for household appliances.
3. To test the programmable energy controller for household appliances.
4. To evaluate programmable energy controllers for household appliances as to accuracy and efficiency.

2. MATERIALS AND METHODS

2.1 Materials

This section presents the components of the developed programmable energy controller for household appliances. There are six basic parts: a power supply, an Arduino Uno, an LCD screen, an R.T.C., an S.D. card, and relays [21]. The materials used to create the system are listed below.

1. Arduino Uno is the project's core because it handles practically all internal and external operations. It accepts computer input and uses the LCD to display messages.
2. The power supply provides the energy needed by the system. These power supplies provide an active form for the Arduino microcontroller.
3. LCD is used to display the time and the number of hours used by all appliances. The following are the materials

used to develop the system.

4. A real-time clock is used for the system's date and time and the time management to control the appliances.
5. The computer creates source codes, which are then uploaded to the programmable home energy controller.
6. A low-power signal uses a relay on the appliances' on and off states.
7. SD Card stores data, calculates the total number of hours spent, and terminates the system.

2.2 Methods of the Study

This section presents the methods for developing programmable energy controllers for household appliances.

1. Design a block diagram of the study.
2. Implementation of the programmable energy controller for household appliances.
3. Integration of the programmable energy controller for household appliances.
4. Testing of the programmable energy controller for household appliances.
5. Evaluation of the programmable energy controller for household appliances.

3. RESULTS AND DISCUSSION

This section presents the results of developing a programmable energy controller for household appliances.

3.1 Block diagram of the programmable energy controller for household appliances

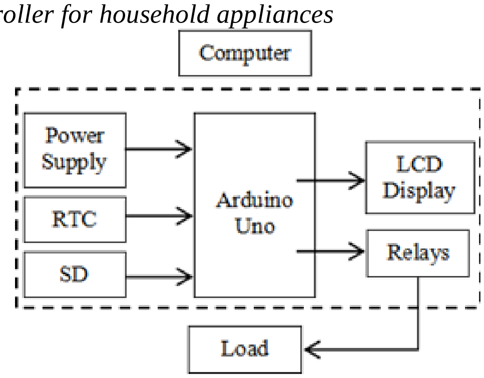

Figure 1. Block Diagram of the programmable energy controller for household appliances

Figure 1 illustrates the block diagram of the energy controller. If the source code of a computer is uploaded, the project is transformed into a programmable household energy controller. The system of the project is contained within the dashed line. It comprises six fundamental parts: a power supply, an Arduino Uno, an LCD screen, an R.T.C., an S.D. card, and relays.

3.2 Implementation of the programmable energy controller for household appliances

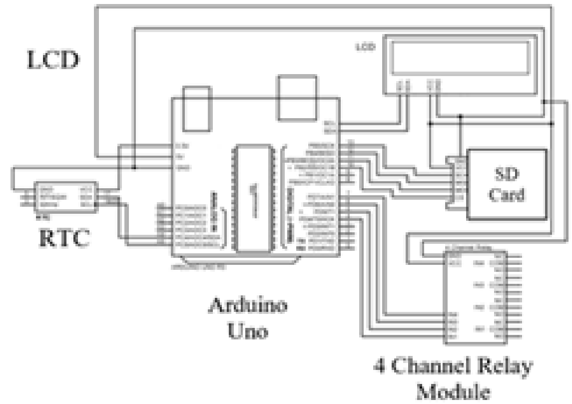

Figure 2. Schematic Diagram of the programmable energy controller for household appliances.

The four modules are powered by the Arduino Uno, which serves as the system's central component [22]. The Arduino's A4 and A5 pins are linked to the S.D.A. and S.C.L. pins of the real-time clock module. Because it can operate between 3.3V and 5V, its VCC is connected to 3.3V. The S.D.A. and S.C.L. pins of the Arduino Uno are connected to the S.D.A. and S.C.L. of the LCD module, which has only four pins. VCC and GND are located on the LCD's additional two pins. The Arduino is attached to the SD Card module's six pins. The D12, D11, D13, D10, 5V, and GND are connected to the MISO, M.O.S.I., S.C.K., C.S., VCC, and GND, respectively [23]. The Arduino's VCC and GND are linked to its 5V and GND, respectively, while its In1, In2, In3, and In4 are connected to D4 and D5, respectively D6, and D7.

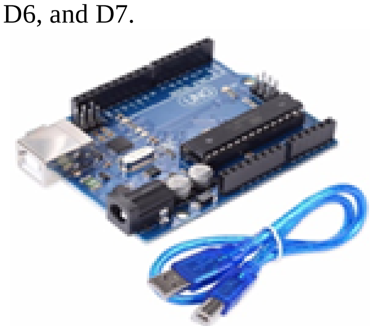

Figure 3. The Arduino Uno

Based on the ATmega328P, the Arduino Uno R3 microcontroller contains six analog inputs, 14 digital input/output pins (of which six can be used as P.W.M. outputs), a 16 MHz quartz crystal, a USB connection, a power jack, an I.C.S.P. header, and a reset button.

Figure 4. The LCD Display with I2C Adapter

The LCD module's backlight is blue. With a built-in LCD controller that is industry standard (HD44780 equivalent), it provides a wide viewing angle and great contrast. It can display two lines by 16 characters with a 5V D.C. voltage. This module may save 5 I.O. ports while driving the original 1602 screen, which required 7 I.O. ports.

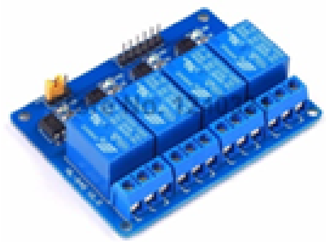

Figure 5. The 4-Channel Relay Module

The 4-channel relay interface board on this 5V active low relay module can be directly controlled by various microcontrollers, including Arduino, A.V.R., P.I.C., A.R.M., and P.L.C.

Figure 6. The R.T.C. Module

The Real time clock generates seconds, minutes, hours, days, dates, months, and year timing. It validates until the year 2100 leap year compensation. The memory chip is AT24C32 (storage capacity 32K. It has an I.I.C. bus interface with a maximum transmission speed of 400 KHz (working voltage of 5V).

Figure 7. SD Card Module

Through its onboard voltage level conversion, the Micro SD Card Module for data storage or logging procedures enables a simple interface with 3V or 5V devices for communication. The operational voltage of the S.P.I. interface is 4.5V to 5.5V.

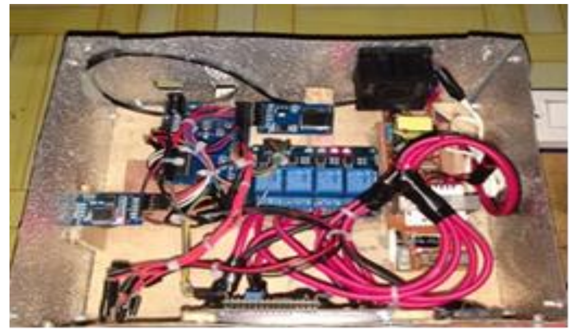

Figure 8. Actual image of the complete set-up

Figure 8 displays the system's actual image. It includes an R.T.C., an Arduino Uno, an S.D. card module, an LCD, relays, a fan, L.E.D. lights, and a power supply.

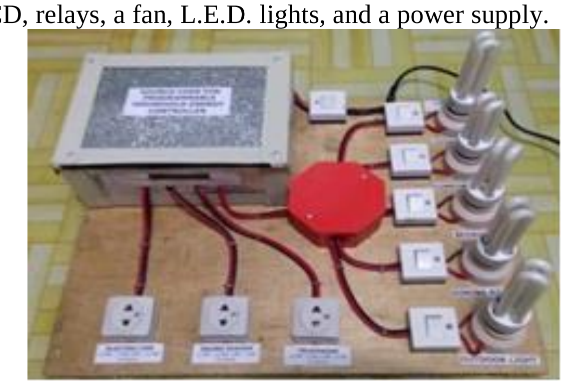

Figure 9. Development of the programmable energy controller for household appliances

The project's actual image is depicted in Figure 9. It contains three outlets and five lights wired to the four-channel relays. The project's system is in the box.

3.3 These sections include integrating the development of a programmable energy controller for household appliances.

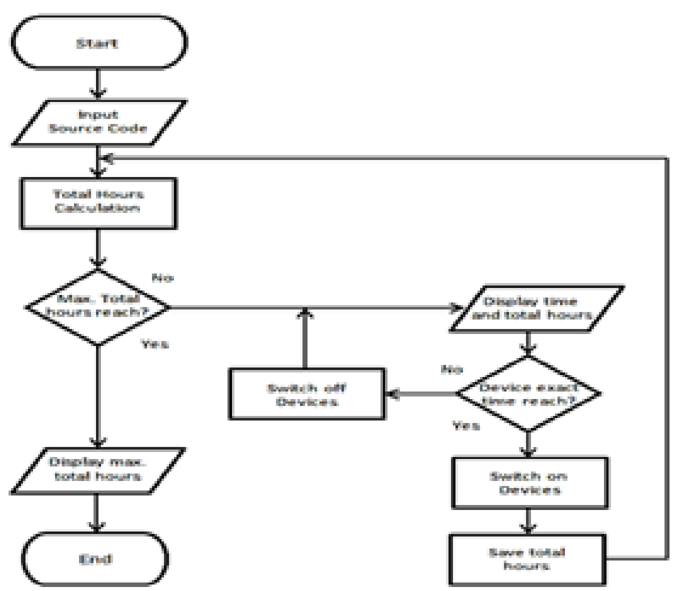

Figure 10. Flowchart of the Source Code

Figure 10 displays the source code flowchart. Every time the device starts up, the source code calculates the number of hours on the S.D. card. The LCD's current time and number of hours are constantly visible. When time has passed, the devices turn on and save the total number of hours to an S.D. card. The system will indicate this and turn off the relays if the maximum total hours are reached.

3.4 These sections are the location of the testing.

This section shows the testing of the programmable energy controller for household appliances.

Figure 11. Image of the Community

Figure 11 depicts the community's image. It illustrates the barangay hall of Barangay Balite, San Francisco, in Surigao del Norte.

Figure 12. Map Location of the Community

Figure 12 displays the community's location on a map. It displays the most recent photograph taken by Google Maps of Barangay Balite in San Francisco, Surigao del Norte.

Table 1. Average results of the survey

VARIABLES	AVERAGES
No. of the person living in the household	Four people
Quantity of devices in the household	Four devices
Devices used in the household	Bulb/Fluorescent, Television, Sound System, Electric Fan
Monthly electric bill of the household	500.00-1,000.00 pesos per month

The survey's average results were shown in Table 1 above. Most appliances are bulbs and televisions used in households with an average of four people. The average number of devices is four.

Table 2. Device Usage

Device	Time Frame	Usage	Usage/ Month
Bulb/Fluorescent	6 PM-12 AM	6 HRS	180 HRS
Television	12 PM-2 PM & 6 PM-9 PM	5 HRS	150 HRS
Sound System	11 AM-12 PM	2 H.R.S.	60 H.R.S.
Electric Fan	12 PM-1 PM & 9 PM-12 AM	4 HRS	120 HRS
TOTAL USAGE/MONTH			510 HRS

Table 2 displays monthly device usage. The time of day each device was used varies. The devices were used for a total of 510 hours per month.

Table 3. Test Results in using the programmable energy controller for household appliances

Time	Appliances	Results (Total Hours)	Usage/ Month
11 AM–12 PM	Sound System	0.996 HRS	29.88
12 PM –1 PM	Television Electric Fan	2.988 HRS	89.64
1 PM – 2 PM	Television	1.98 HRS	59.4
3 PM – 4 PM	Sound System		
6 PM – 9 PM	Bulbs/Fluorescent Television	5.2 HRS & 4.1 HRS	279.0
9 PM – 1 AM	Electric Fan	3.5 HRS	105
	Total	**22.748** HRS	**312.92**

The test results for the project are displayed in Table 3. The first column lists the specific time of day, and the second lists the appliances turned on or off at that same moment. The third column displays the total number of hours every hour or two. The result shows 22.748, which equates to roughly 23 hours. The actual number of hours that all the appliances use in a day is around 23 hours. The system's accuracy in computing the combined hours of all the appliances is less than 1% error. In comparison, its accuracy in time management is 100%. The overall results show 61.35% energy savings due to the developed programmable energy controller for household appliances.

Table 4. Evaluation Results

Variable	M	SD	QD
Accuracy			
1. Calculation of total hours used	**3.35**	**0.167**	**Very Satisfied**
2. Time of the system	**3.4**	**0.152**	**Very Satisfied**
3. Appropriate delay used to minimize the effect of a power surge	**3.15**	**0.182**	**Satisfied**
Total Mean	**3.3**	**0.167**	**Very Satisfied**
Efficiency			
1. Storage space used by the source code	**3.35**	**0.11**	**Very Satisfied**
2. Minimal computing resources	**3.3**	**0.128**	**Very Satisfied**
3. Overall performance	**3.7**	**0.128**	**Very Satisfied**
Total Mean	**3.45**	**0.122**	**Very Satisfied**
Grand Mean	**3.38**	**0.145**	**Very Satisfied**

Table 4 displays the accuracy and efficiency of the system's performance assessed by Barangay Balite users. Users are highly satisfied with the system, according to the results. With a combined mean of 3.3 for accuracy and 3.45 for efficiency, it receives a very satisfied rating.

4. CONCLUSION

The developed programmable energy controller for household appliances was implemented. Automation to turn devices on and off at set times not only saves energy but also helps prevent power outages. The overall results show 61.35% energy savings due to the developed programmable energy controller for household appliances. This initiative provides an alternative way to automate home appliances. The most used devices are fans, televisions, sound systems, light bulbs, and fluorescent lights.

The main components of the system, Arduino Uno, 4-channel relay module, LCD, R.T.C., and S.D. card module, can control all devices. A good Arduino Uno source code ensures the system works properly. The positive feedback from practitioners and users reflects the system's satisfactory performance. This research contributes to promote energy efficiency and reducing electricity costs in households.

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