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Design and Modeling of an Automated Solar Powered Irrigation and Water Pumping System with Time Regulation

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Abstract

The automatic solar powered time regulated water pumping and irrigation system was designed in such a way that the system function as a source of artificial irrigation mechanism for a farm land and also to pump water from the ground into a storage tank. The system was designed to operate using solar power and it was also be time based. In order to achieve this feat, a microcontroller was programmed to receive signal from input switches and respond by collecting data from a real time clocking integrated circuit, the data t sent by the input switches to the microcontroller was digital. Using pull up resistors, the state of the switch to the microcontroller is a high state. However when the switch is pressed, the signal turns to low, this signifies to the controller that a valid signal is sent. The program written into the ROM of the microcontroller set the screen in such a way that the user will make sense out of the data. The content of the data is basically to set time. Time for pump operation, time for pump in-operation duration and time for deactivation of the pump, meanwhile, the data displayed on the screen was sent by the microcontroller, into a real time clock integrated circuit, DS1307. This real time clock has the ability to store time in a format that corresponds to seconds, hours, minutes, days, months, years. It stored these data in its ROM and it ready to output this stored data upon command. The pump was controlled by the use of an electromechanical relay which is driven by a transistor with resistor biased. When the system desires the pump to start to work, it will send a high signal to the transistor to switch on the relay and when it desires the pump to stop, it will send a low signal to the transistor to shut down the relay. The circuit is powered by a solar panel which also doubles as charger for a rechargeable battery. This battery is necessary for power storage when the sun is set.

1. Introduction

Water scarcity is a pressing global issue, particularly in arid and semi-arid regions, where agricultural practices are significantly impacted. The reliance on traditional irrigation methods often leads to inefficient water use and increased labor costs, hindering agricultural productivity. In response to these challenges, there is a growing interest in sustainable and efficient irrigation systems that utilize renewable energy sources [1-3]. This study presents the design of an automatic powered time-regulated water pumping and irrigation system, aimed at optimizing water usage while minimizing environmental impact.

Water scarcity has emerged as one of the most critical challenges in global agriculture, particularly in arid and semi-arid regions where conventional irrigation practices often fall short in efficiency and sustainability. According to the Food and Agriculture Organization [1], over 1.2 billion people live in areas with physical water scarcity, which necessitates innovative solutions for effective water management in agriculture. Traditional irrigation methods frequently result in excessive water use, leading to waste and increased operational costs [2-6]. As a result, there is an urgent need for sustainable irrigation systems that optimize water usage while minimizing environmental impact.
Automatic irrigation systems present a promising alternative, utilizing renewable energy to enhance efficiency and reduce dependence on fossil fuels. The integration of solar energy into irrigation practices has been shown to significantly lower operational costs and reduce greenhouse gas emissions [7-8].

These systems operate water pumps using photovoltaic panels, which can provide a consistent and sustainable power source, especially in remote areas where electricity supply is limited or unavailable. Moreover, the automation of irrigation processes through time-regulated systems enhances water application efficiency. Automation technologies, such as timers and sensors, allow for precise control over water delivery, ensuring that crops receive the optimal amount of water at the right times [5]. This not only conserves water but also contributes to improved crop yields and reduced labor requirements[10-11]. As emphasized by [12], automated irrigation systems can adapt to changing environmental conditions, making them a vital tool in modern agriculture.
Despite the advantages of solar-powered and automated irrigation systems, challenges remain regarding their implementation and design. Economic feasibility, technical reliability, and the suitability of technology for specific agricultural contexts must be carefully considered [13]. Understanding these factors is crucial for the successful adoption of such systems, particularly in regions most affected by water scarcity.

The proposed system leverages solar energy to operate water pumps, reducing dependence on fossil fuels and contributing to a more sustainable agricultural framework. Additionally, by integrating time-regulated mechanisms, the system ensures that crops receive the optimal amount of water at the right intervals, thereby enhancing growth and yield [14]. This approach not only addresses the immediate need for efficient water management but also aligns with broader goals of sustainable agriculture and climate resilience.

The design of an automatic powered time-regulated water pumping and irrigation system focuses on integrating renewable energy sources with modern technology to enhance agricultural efficiency**.** The increasing demand for sustainable agricultural practices necessitates innovative solutions for irrigation. Solar-powered systems offer a clean alternative to fossil fuels, reducing operational costs and environmental impact. This research aims to develop a comprehensive design for an automatic irrigation system that utilizes solar energy, thereby minimizing human intervention while optimizing water usage.

2. Methodology

Design and simulation of the automatic solar powered time regulated water pumping and irrigation system was done, the circuitry of the system is broken down and few circuits were opened and analyzed. This research method is on the mode of operation and the complete circuit diagram. Figure 1 is the schematic diagram for the complete circuit.

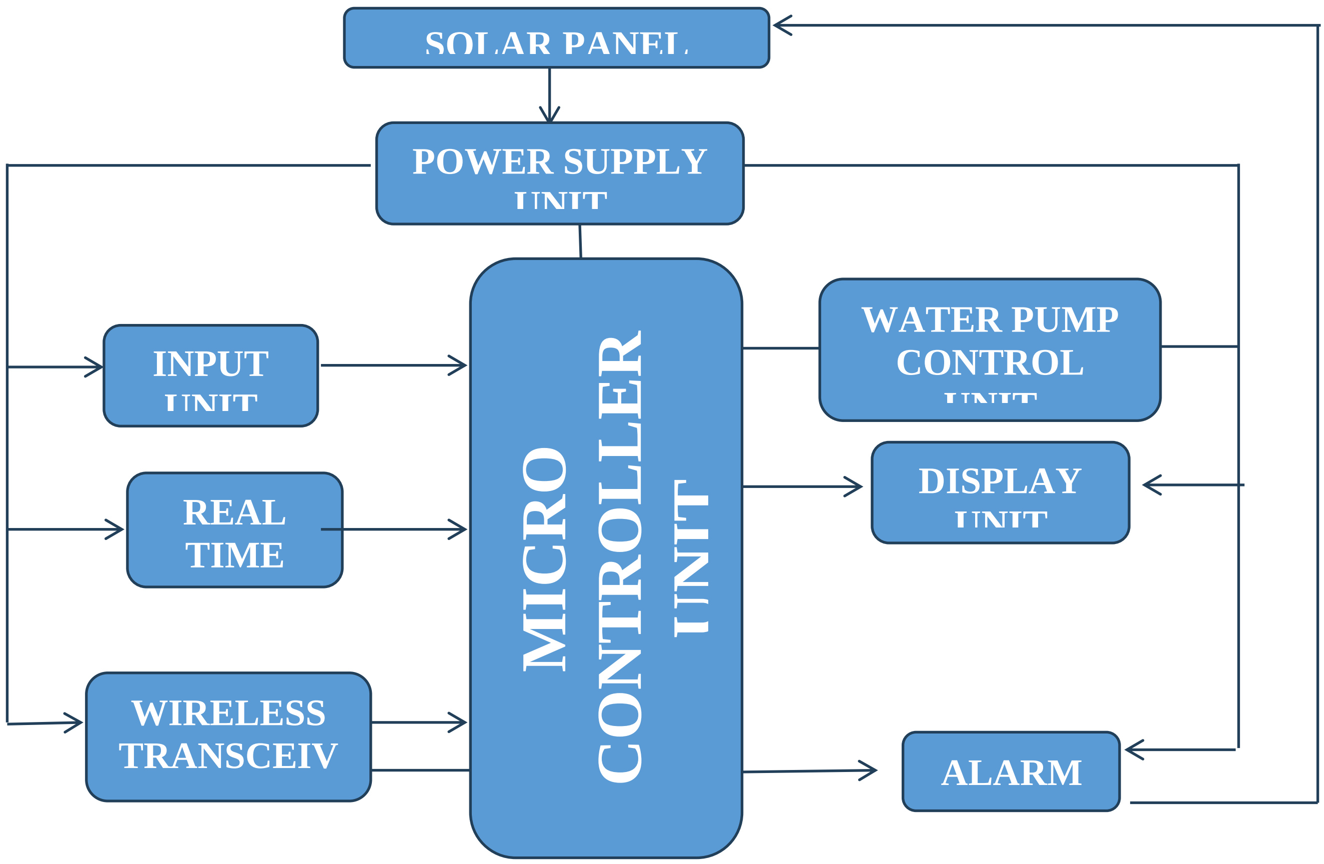

Fig. 1 Schematic diagram of the complete system

2.1 Power Supply Circuit

The typical diagram for this power supply circuit is as shown fig 2.1

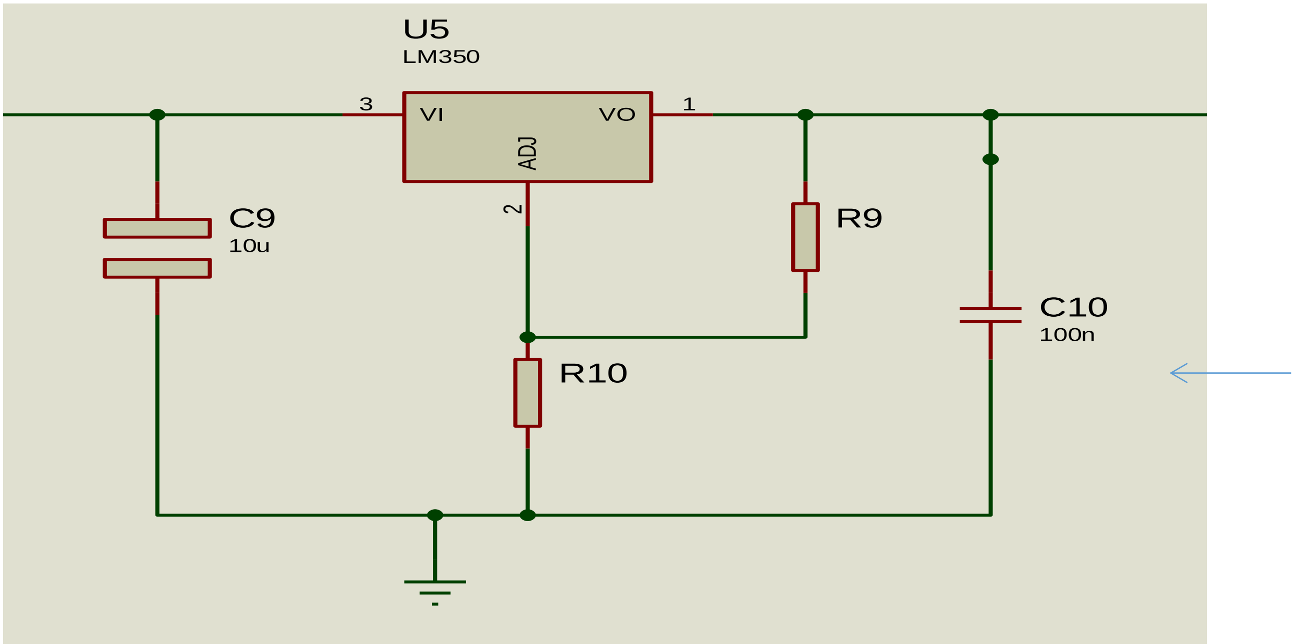

Fig. 2 diagram of the Power Supply Unit

The LM350 is an adjustable three terminal positive voltage regulator capable of supplying in excess of 3.0A over an output voltage range of 1.2 V to 33 V. This voltage regulator is exceptionally easy to use and requires only two external resistors to set the output voltage. Further, it employs internal current limiting, thermal shutdown and safe area compensation, making it essentially blow−out proof. The LM350 serves a wide variety of applications including local, on card regulation. This device also makes an especially simple adjustable switching regulator, a programmable output regulator, or by connecting a fixed resistor between the adjustment and output, the LM350 can be used as a precision current regulator.

The formulae to obtain various voltage outputs are given as;

V_{OUT} = 1.25V $\left(1 + \frac{R_2}{R_1}\right) + I_{ADJ}R_2$……………………… …………………………..1

$I_{ADJ}R_2 = 0$

Therefore the equation becomes

V_{OUT} = 1.25V $\left(1 + \frac{R_2}{R_1}\right) + 0$……………………………………………………... 2

To obtain 5volts output,

$5 = 1.25V\left(1 + \frac{R_2}{240}\right) + 0$

$\frac{5}{1.25} = \left(1 + \frac{R_2}{240}\right) + 0$

$\frac{R_2}{240} = \frac{5}{1.25} - 1$

$\frac{R_2}{240} = 4 - 1$

$R_2 = 240 \text{ x } 3$

$R_2 = 720\Omega$

2.2 Display Circuit

The solar powered irrigation system uses a display unit that interfaces between the user and the device. This is where the time is set and adjusted to suit the required function. The display also ensures that the status of the system is known always.

The display circuit diagram is illustrated by figure 3

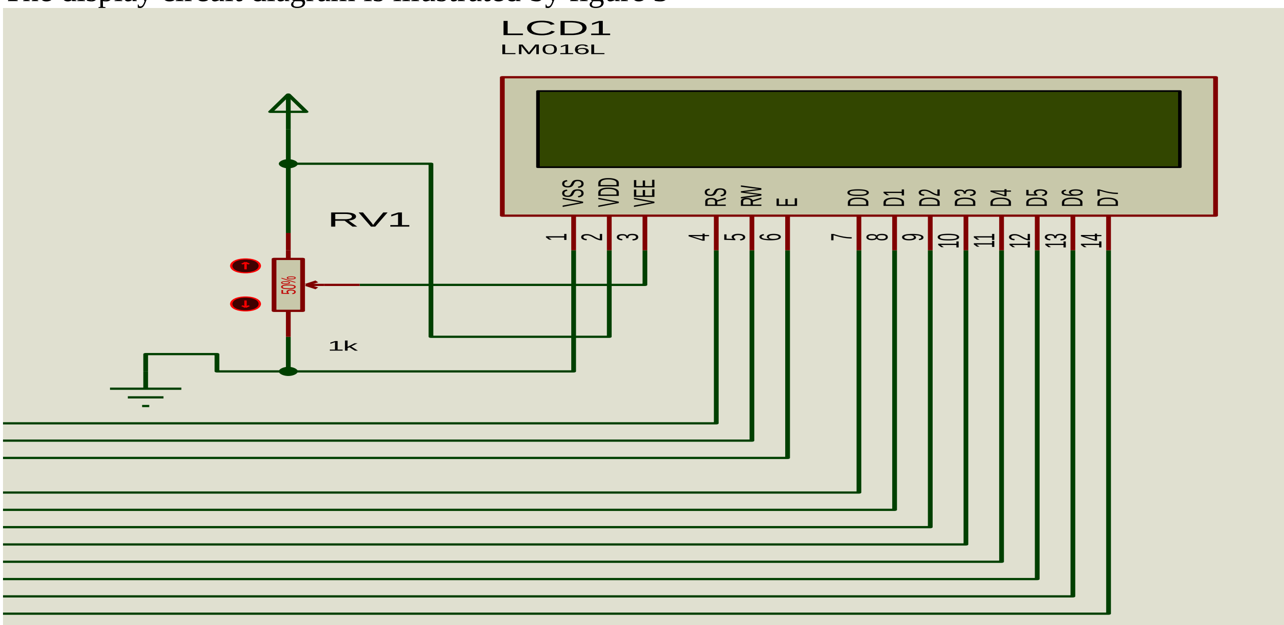

Fig. 3 diagram of the Display circuit

The LCD is 16 x 2 screen display. This means that it can display 16 alphanumeric characters on 2 lines. RV2: is a resistor to set the contrast of the display. A 1kΩ variable resistor is the usual value used

2.3 Alarm Circuit

The system utilizes an alarm system whereby the user is notified each time the farm land is fully irrigated. The alarm is also activated when an alteration to the set time is scheduled and finally, this alarm is activated when the time duration is set. The alarm is activated by the microcontroller via an Astable mode connected multivibrator integrated circuit, the 555 timer.
The schematic diagram of the alarm circuit is illustrated in figure 4. The calculation procedure is as follows.

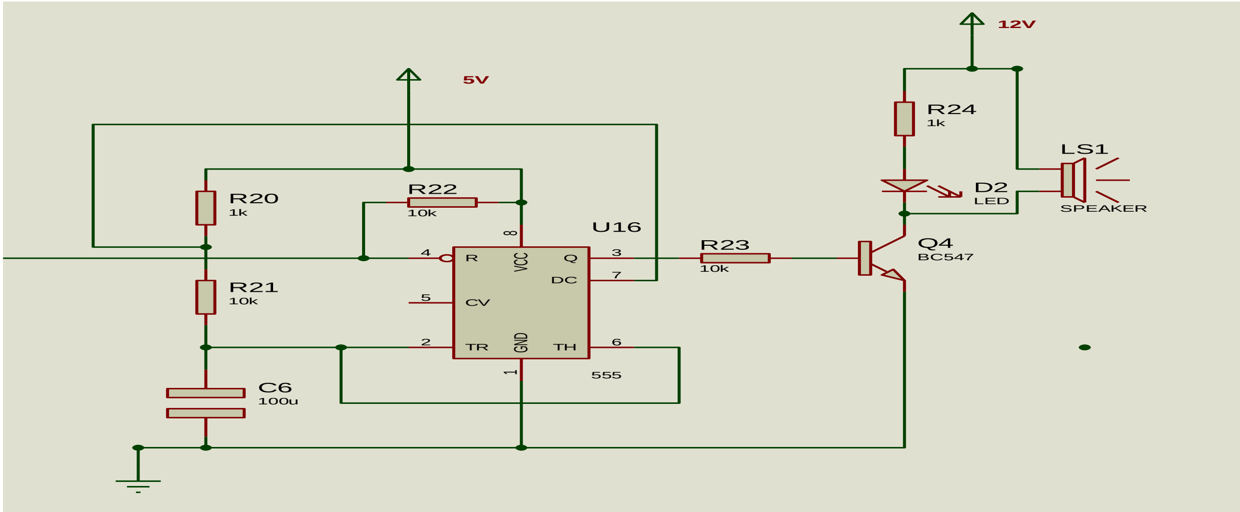

Fig. 4 Diagram of the Alarm circuit

The outputs of the multivibrator is set to a frequency of 1Hz such that the alarm connected to it will turn on for one second and off for another one second continuously as long as the microcontroller allows it to.
U16 - This is a 555 timer biased in an Astable multivibrator mode. R_{20}, R_{21} and C_6 are used to set the output frequency. The relationship is given thus;

$$f = \frac{1.44}{(2R_{21} + R_{20})C6} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

A frequency of 1 Hz is desired. Since we are looking for three unknown, we chose values for two and calculate for the third one. Choosing;
$C_6 = 47\mu F$ and $R_{21} = 10K\Omega$

Calculating R_{20} as follows

$$f\,(2R_{21} + R_{20})\,C_6 = 1.44$$
$$(2fR_{21} + Fr_{20})\,C_6 = 1.44$$
$$2fR_{21}\,C_6 + fR_{20}C_6 = 1.44$$
$$f\,R_{20}C_6 = 1.44 - 2fR_{21}C_6$$
$$R_{20} = \frac{1.44 - 2R_{21}C_6}{f \text{ x } C_6}$$
$$R_{20} = \frac{1.44 - (2 \text{ x } 1 \text{ x } 10000 \text{ x } 47 \text{ x } 10^{-6})}{1 \text{ x } 47 \text{ x } 10^{-6}}$$
$$R_{20} = 10638.29\Omega$$

This value of resistor is not in the market, so the value of the resistor used is
R_{20} = 12KΩ

R_{24}: this is a current limiting resistor for the LED and the value is given as thus

$$R_x = \frac{Vs - Vir}{Iir} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 4$$

Where

V_{ir} = voltage drop of the LED: 2V
I_{ir} = current of the LED: taken as 10mA
V_s = voltage from the source: 12v

$$R_x = \frac{12-2}{10mA}$$

$$R_x = \frac{10}{10 \text{ x } 10^{-3}}$$

$$R_x = 1000\Omega$$

∴ R_{24} = 1kΩ
In this circuit, this resistor is also known as the collector resistor: R_C

R_{23} is the base resistor for the transistor R_C. For effective switching, the collector current should be about 10 times the base current.

$Ic = 10 \text{ x } I_B$
∴ $R_B = 10 \text{ x } Rc$
Rc = 1000Ω (from previous calculations)
∴ $R_B = 10 \text{ x } 1000$
$= 10000$
$R_{23} = 10k\Omega$

2.4 Water Pump Control Circuit

The system employs a DC powered water pump for the irrigation purposes. This pump is controlled via a relay. The relay receives signals from the microcontroller via transistors and resistors.

The schematic diagram of the water pump circuit is illustrated in figure 5 and the calculations are as follows:

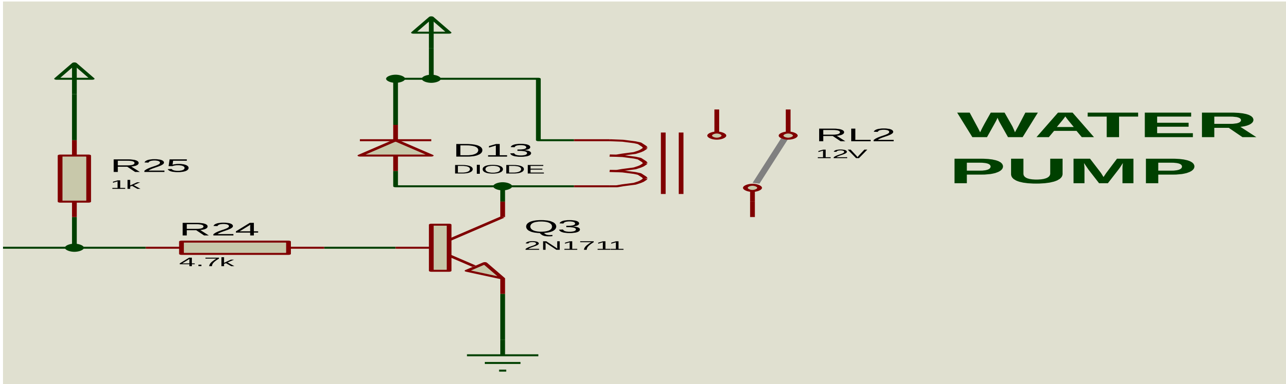

Fig. 5 Diagram of the Water Pump Control Circuit

R_{25} = This is a pull up resistor . This is a resistor that is basically used to set a terminal temporarily high. The value is usually from a range of

470Ω to 10,000Ω

For this circuit, the value of 1,000Ω was used.

R_{24} = this is the base resistor to the relay switching transistor. To enable the transistor operate in the switch mode, the following formulae is used.
R_B = 10 x R_C
Where R_B is base resistor R_{24}, and R_C is collector resistor. in this circuit, the collector resistor is the impedance of the coil of the switching relay. From measurement using a multimeter, the resistance of this coil is 400Ω.
Therefore;
R_c = 400Ω
Substituting

$$R_B = 10 \text{ x } 400\Omega$$
$$R_{24} = 4000\Omega$$

But this resistor value cannot be obtained in the market so the next available value will be used. 4700Ω
Therefore

$$R_{24} = 4.7\text{k}\Omega$$

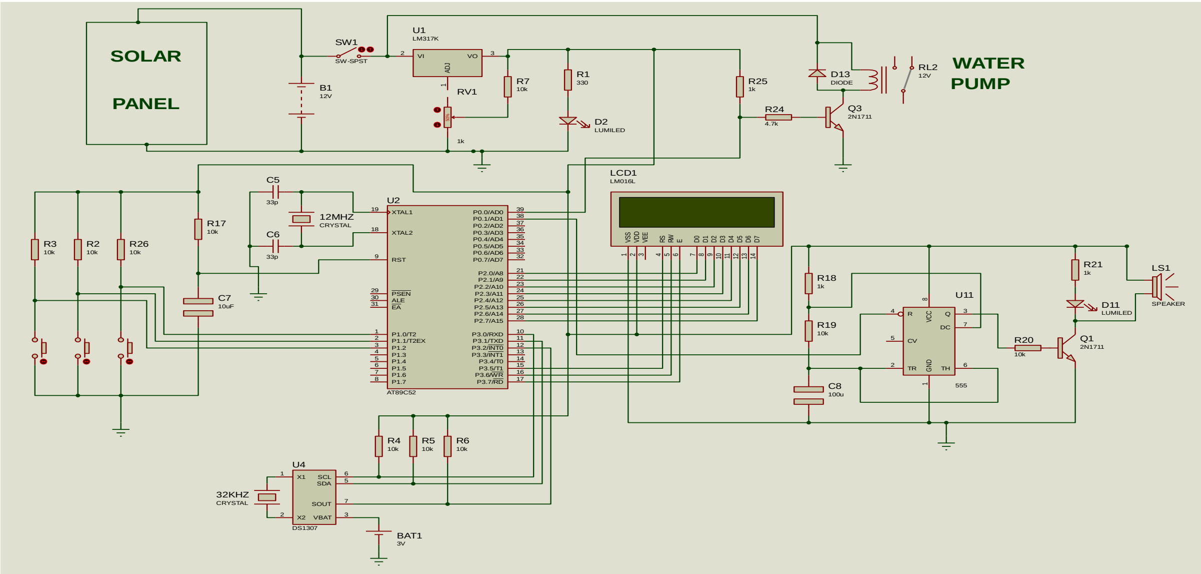

Fig. 6 Diagram of the Complete Circuit

3. Results and Discussion

The mode of operation for the automatic solar powered time regulated water pumping and irrigation system is such that a system will be designed and implemented to function as a source of artificial irrigation mechanism for a farm land and also to pump water from the ground into a storage tank. This system will be designed to operate using solar power and it will also be time based.

In order to achieve this feat, a microcontroller will be programmed to receive signal from input switches and respond by collecting data from a real time clocking integrated circuit, display the data on a 16 by 2 liquid crystal display screen and use same data to control a relay driven water pump.
The data to be sent by the input switches to the microcontroller will be digital. Using pull up resistors, the state of the switch to the microcontroller is a HIGH state. However when the switch is pressed, the signal turns to LOW. This signifies to the controller that a valid signal is sent. Using ASCII codes, the microcontroller will display the data that it receives from the input, into the screen which the user van now read and interpret. The program written into the read only memory of the microcontroller will set the screen in such a way that the user will make sense out of the data. The

content of the data is basically to set time. Time for pump operation, time for pump in-operation duration and time for deactivation of the pump

Meanwhile, the data displayed on the screen will also be sent by the microcontroller, into a real time clock integrated circuit, DS1307. This real time clock has the ability to store time of the day in BCD in a format that corresponds to seconds, hours, minutes, days, months, years. It stored these data in its ROM and it's ready to output this stored data upon command. It uses the I^2C communication protocol.

Finally, the pump is controlled by the use of an electromechanical relay which is driven by a transistor with resistor biased. When the system desires the pump to start to work, it will send a high signal to the transistor to switch on the relay and when it desires the pump to stop, it will send a low signal to the transistor to shut down the relay.

The circuit is powered by a solar panel which also doubles a charger for a rechargeable battery. This battery is necessary for power storage when the sun is set.

4. Conclusion

The developed system enables the solar powered irrigation system that optimized water usage in agricultural practices, promote the use of renewable energy resources in irrigation to reduce reliance on non-renewable energy and minimize environmental impact, the system also enable consistent and adequate water supply to crops enhancing the overall agricultural productivity, the circuit enable a time regulated control that automate the irrigation process based on preset schedules.

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