Design and Implementation of a Generator Power Sensor and Shutdown Timer

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Abstract
This research is on the design and construction of a generator shutdown timer; an electronic device that automatically turns off electric generator after a specified period of duty hours. A microcontroller Atmega8 is used, which makes the entire circuitry compact, more flexible, efficient and reliable. The microcontroller program is written in C programming language using AVR studio4 and the circuit simulation using Proteus. This circuitry does not only control the timing operation of electric generators, but also possesses the ability to sense power restoration (from the utility power supply) and respond by switching off the generator. Power handling capacity of the circuit is estimated to be 1760W.
Keywords: Power Sensor, Shutdown Timer, Atmega8, AVR Studio, Proteus VSM.

1. Introduction

A timer is a specialized type of clock. A timer can be used to control the sequence of processes. A stopwatch counts upward from zero or reference point for measuring elapsed time, whereas, a timer counts down from a specified time interval to zero. When the set period expires, some timers indicates so (e.g. by an audible signal), while others operate electric switches, which cuts electric power. The interest of this research is in the time switching, where a countdown timer is employed to switch off an electric generator after a specified time interval.

Programming countdown timers can be realized using discrete electronic components, such as logic gates, RC oscillators, Light Emitting Diodes (LED's) for the indication, and few Integrated Circuits (ICs) like counters and so on. Timers of this kind suffer many drawbacks. The RC oscillator, which serves as the heart of the entire system may itself not be precise, due to variation in the component ratings or due to capacitor charge leakages, which is associated with more electrolytic capacitors. Another problem is that, it can only have few settable starting times (i.e. not all time intervals can be set). Also the circuit is bulky, and this increases its failure tendencies [1].

Advancement in large scale integration of semiconductor devices results in the availability of microcontroller. The microcontroller is simply a computer on a chip. It is one of the most important developments in electronics since the invention of the microprocessor itself [2].

To take care of all the shortcomings aforementioned, the microcontroller would be employed in this project. Due to its flexibility, the starting time can be varied for all time intervals. The time period is set by the use of operator interface which consists of push buttons and liquid crystal display (LCD). Also, timing ranges from minute to several hours. The use of microcontroller makes the device more compact, more reliable and much more precise.

An additional feature in this device is its ability to sense a power interruption such as when power is restored. The device responds to this kind of situation by switching from generator power to the public utility power supply, and while doing so the countdown timer stops since normalcy is restored.

There are several researches on programmable countdown timers and related applications. In those researches, the timers were normally realized using discrete electronics components such as logic gates, RC oscillators, LEDs for indication, and few ICs like counters, and timers of this kind suffer many drawbacks. The RC oscillator, which serves as the heart of the entire system may itself not be precise due to variation in the component ratings or due to capacitor charge leakages, which is associated with more electrolytic capacitors. Another problem is that, it can only have few settable starting times (i.e. not all time intervals can be set). Also, the circuitry is too complex and it increases the risk of failure [1].

In a work by Olatinwo et al [3], an attempt was made to design and implement an automatic changeover with remote control. The design and construction of an automatic changeover with remote control will ease the use of an electrical power generating system. The paper focuses on the design of an automatic changeover that will enhance user control over a power generating set. It is intended for use with a single phase power generating set operating at 220V AC.

Clive Maxted and Winston Walter (2005), developed an intelligent embedded system for high power industrial generator in replacement of the existing discrete logic design. This system could support automatic main failure start-up and shutdown, multi-channel graphical annunciation control, and monitoring of generator temperature and pressure. With the new controller, of reduced size, used in this research, there were great advantages in terms of reduced cost, increased functionality and flexibility [4].

Jonathan Kolo (2007) designed and constructed an automatic power changeover switch, with control logic (with timing abilities) and relay, to automatically switch between public power supply and generator power supply in the event of power outage. This work proved to be reliable, cheap and reduce human stress [5].

Abd Wahab, Abdullah, Johari and Abdul Kadir (2010) developed a GSM-based control for electrical appliances in order to reduce electricity wastage. The researchers were able to switch ON and OFF appliances by sending SMS through a GSM network. This work has proven to be energy saving- effective, though no provision for notification in case there is power failure [6].

Thiyagaragan and Palanivel (2010) designed an AVR microcontroller that could shut down a transformer in a distribution substation in case of open-circuit, short-circuit, overload and over-temperature, in order to prevent further damages. This proposed system would make distribution system more secure, reliable and efficient [7].

J. Datta, J. Datta, S. Chowdhuri and J. Bera (2012) developed a dedicated microcontroller-based hardware unit (DHU) meant to report any abnormal running conditions installed at different geographical location, and shut down the motors in case of extreme fault or abnormality in operation of each motor [8].

Ezema, Peter and Harris (2012) designed and constructed an automatic change-over switch with generator start/shut down functions. The automatic switching mechanism ensured that consumer loads are transferred to the generator supply in case of mains power failure. Conversely, the switch automatically detects power restoration from the mains, returns the load to the mains power supply and then shut down the generator set. This work has help immensely to reduce human stress and loss time associated with switching power supply from one source to another [9].

In the current research, the timing procedure was reviewed critically and appropriate modifications were made to ensure better performance of generator power sensor and shutdown timer. This is done with a microcontroller together with an LCD display, in order to ensure good precision, compatibility and flexibility.

2. Design

The hardware component of the generator power sensor and shutdown timer consists of display unit, reset configuration, generator power feedback (utility supply sensor), processing unit (microcontroller) and switching circuit.

Power Supply Unit: voltage rating of ATmega8L microcontrollers is between 4.5V to 5.5V DC, the LCD requires a voltage range from 3V to 6V DC while, the relay and the buzzer required voltage of 12V DC each.

From the above consideration, it was concluded that a power supply of two different voltage levels was needed. The microcontroller, push button and the LCD can be operated with a 5V supply, while the relay and a buzzer can be operated at 12V DC. Therefore, 12V rechargeable battery was chosen because of the fact that the device consume less power and the battery gives a clear DC output without any ripples. This is in addition to its portability, cheapness and reliability.

Switching Circuit: The generator shutdown timer is supposed to be able to switch off electric generators. A convenient way of achieving this switching is via the use of a relay. In this design, a 12V relay was used with a contact capacity of 12V DC and 10A thus making the maximum switching load 1760W. This can, however, easily be increased by selecting a relay contact with higher rating.

The relay driver circuit is as shown in Figure 4. Each Atmega8 pin can sink and source a maximum current of 25mA but the relay is rated at 50mA, thus the need for a driver transistor to amplify the current output from the microcontroller. From the *fig 3.3*, it can be seen that logic high on pin PC3 and pin PD5 of the Atmega8 microcontroller causes the transistor to saturate thus energizing the relay. This setup allows the control of the relay using the microcontroller.

Processing Unit: The microcontroller serves as the processing unit, and Atmega8 is suitable for it.

Reset Configuration: In Figure 1, a reset capacitor and resistor is used on microcontroller to enable normal operation, while allowing the programming voltage (about 5V) to be applied without damaging the target. When the switch is open, the current flowing through the resistor charges the capacitor. The microcontroller continues to operate normally as long as the reset pin is at logic high. When the switch is pressed, the capacitor gets discharged and the reset pin becomes low. This condition forces the microcontroller to restart its operation from the beginning again. A resistor ranges from 5kΩ to 10kΩ and a capacitor of 10uF is specified by the manufacturer of the microcontroller.

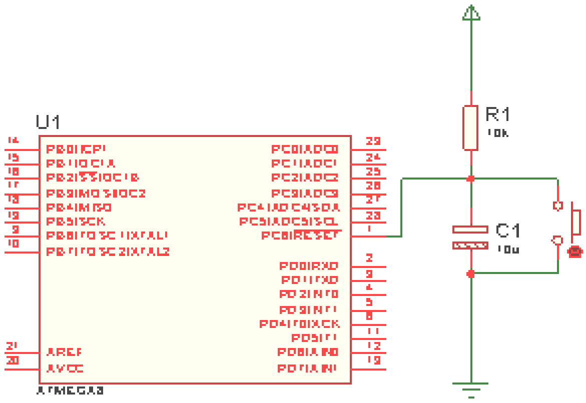

Figure 1: Reset Pin Configuration

Display Unit: The display unit is composed of a liquid crystal display (LCD). The LM016L LCD can be interfaced directly with the Atmega8 microcontroller, because of the fact that they almost have the same voltage and current requirements for both sourcing and sinking.

Generator Power Feedback (Utility Power Sensor): This is where the device senses the generator's power status and the utility power supply. When there is a power failure, this section sends logic high to the microcontroller which enables the controller to prepare the generator for starting. If a generator is running (i.e. the timer is set) and if utility power supply system is restored, it sends a logic zero to the controller. This power down the generator automatically and connect the load to utility power supply system.

In this design, it is assumed that, Ic_{max} > load current

and $$h_{fe\,max} = \frac{5I_L}{I_{c\,max}} \quad (1)$$

Therefore, BCC 337 transistor was selected because it has $I_{C\,max} = 200\,mA$ and $h_{fe} = 100$.

For relay transistor,

$R_L = 358\Omega$, and $V_L = 12V$

$$I_c = \frac{12\,V}{358\,\Omega} = 33.5\,\text{mA}$$
$$I_c = \alpha I_B \quad (2)$$
$$\Rightarrow \quad I_b = \frac{I_c}{\alpha} = \frac{33.5\text{mA}}{100} = 0.335\,\text{mA}$$

In other to operate the transistor on saturation:

$$I_b = 0.335\,\text{mA} \times 2 = 0.67\,\text{mA}$$

The base resistance of the transistor is calculated as follows:

$$R = \frac{V}{I} = \frac{1\,V}{0.67\text{mA}} = 1.49 \simeq 1.5\text{k}\Omega$$

And the voltage at the base is given as

$$V_{TTL} = 5V$$

The value of resistor to be used to limit the amount of current in a LED is calculated as thus:

The LED require 2V at 20mA, and $V_{TTL} = 5V$

$$R = \frac{V_{TTL} - V_{LED}}{I_{LED}} = \frac{5\,V - 2\,V}{20\,mA} = 150\,\Omega$$

Therefore, the LED current limiting resistor is 150Ω

Resistance at the base of Buzzer Transistor is calculated as thus:

The buzzer requires 12V, $I_C = 20mA$

$$I_b = \frac{I_c}{h_{fe}} = \frac{20\,\text{mA}}{100} = 0.2\,\text{mA}$$

For transistor to operate in full saturation;

$$I_b = 2 \times 0.2\,\text{mA} = 0.4\,\text{mA}$$
$$\therefore \quad R_B = \frac{V_{TTL} - V_{BE(ON)}}{I_B} = \frac{5\,V - 0.7\,V}{0.4\,mA} = 10.75\,\text{k}\Omega \cong 10\,\text{k}\Omega$$

3. Pin Assignments

Atmega8 microcontroller serves as the control house for generator shutdown timer design generating all the necessary control logic for driving the necessary component in the circuit. The port assignments are done as

follows [10]:
PORT B (1, 2, 3, 4, 6, and 7) pins serve as a data bus for sending display digits to the LCD display. Weak internal pull ups resistors are enabled for its pins.
PORT C (0, 1, 5, 6) pins are the increase, decrease, start and reset buttons respectively.
PORT C (2, 3, 4) pins are set to drive the LED source, the transistor buzzer and the (generator) relay transistor respectively.
PORT D (0, 1, 4) pins are for LCD Register Select (RS) input, Read /write (RW), Enable (E) input respectively
PORT D (2, 5) pins are the Optocoupler sensor and (switching) transistor relay respectively.

4. Coding

The program was written in C language using the AVR Studio4 IDE's embedded editor with the flowcharts (see Figure 2) as guidelines [11].

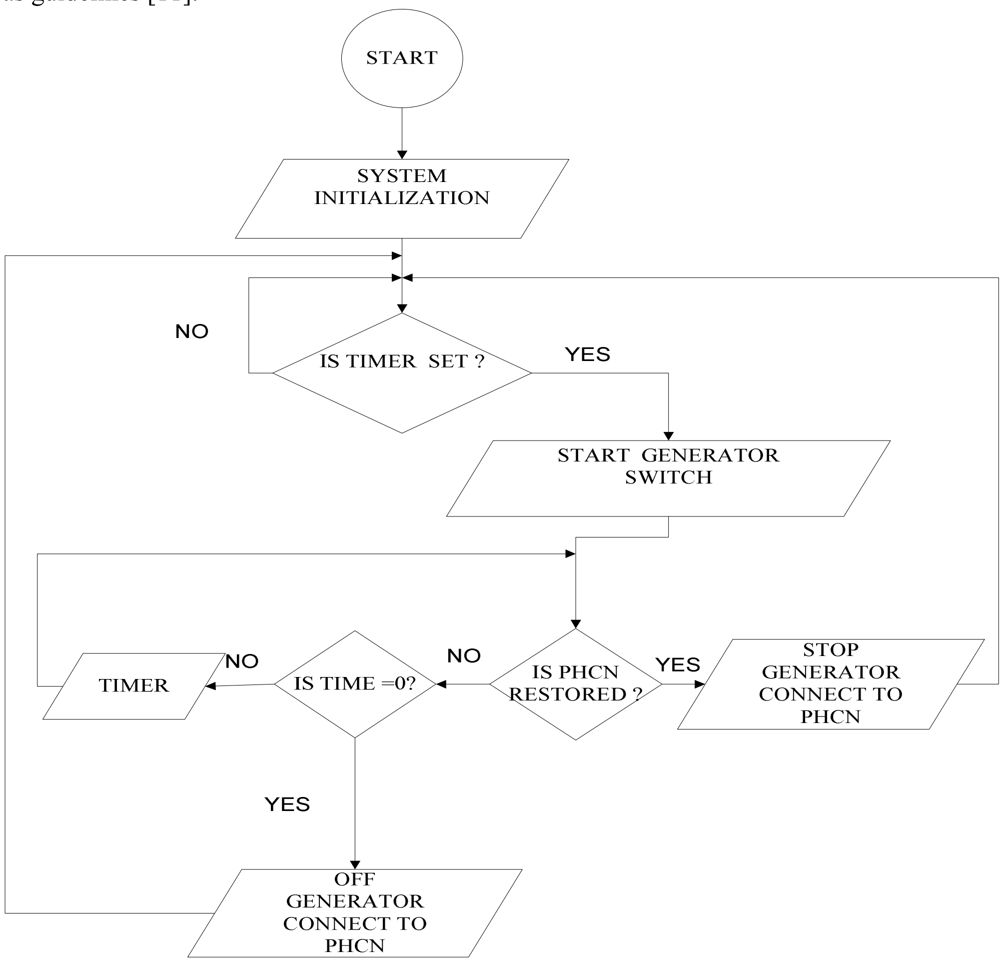

Figure 2: Flowchart of the Main Program

5. Simulation and Debugging

The written program was simulated using Proteus VSM and problems observed, debugged and solved by modifying certain parts of the code. Values of variables, execution of instructions, and status of the port pins (whether set or cleared) were observed in the watch window.
Once this was complete and also from the simulation, it was verified that the program was working, the C program code compiled into hex file using the AVR studio so as it can be loaded into the ATMEGA8L microcontroller chip.

6. Construction

After careful examination of the circuit diagram in Figure 4, all required components were assembled. The circuit was implemented on Vero-board. All components are arranged in close proximity and with an orientation that will effectively minimize the number of links required.

As seen in Figure 3, the main circuit board contains the microcontroller and some of its auxiliary components such as resistor, capacitor, opto-coupler, and so on. Relay is also mounted on the same board.

The Push buttons were mounted on a separate board, but their RESET is placed on the main board and connected with a wire.

A plastic casing was used, because of its resistance to corrosion and some other hazards. It is also cheap compared to the metal case.

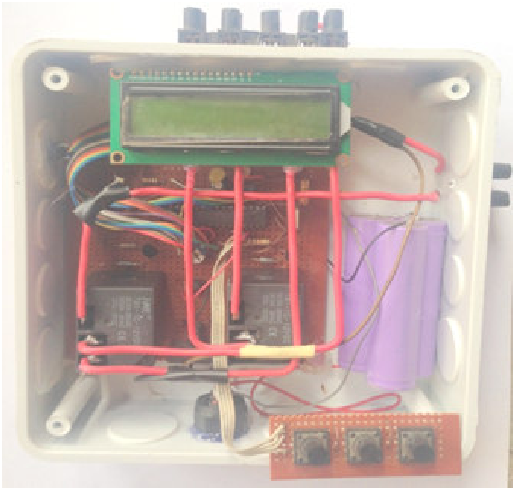

Figure 3: Showing Component in Plastic Casing

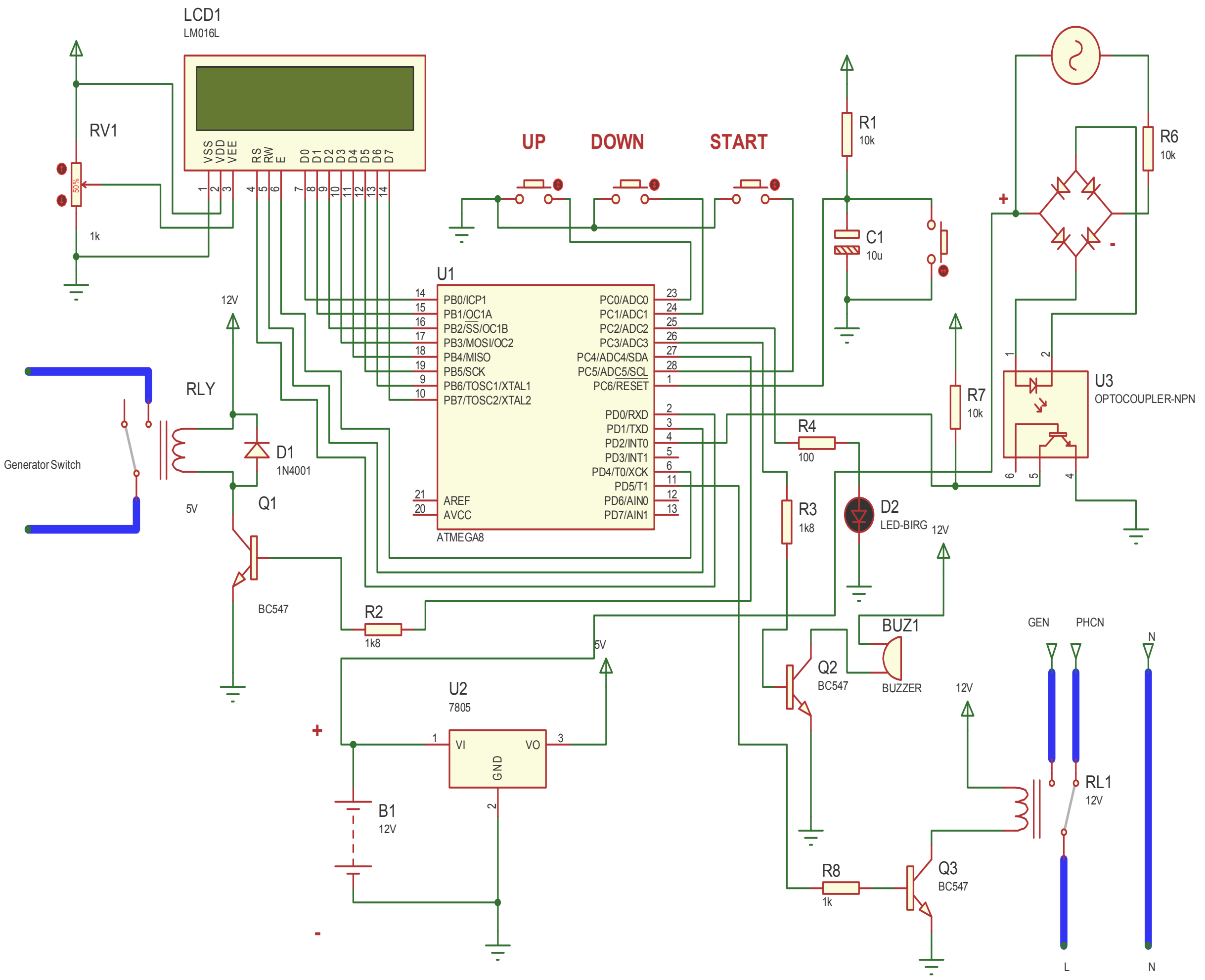

Figure 4: Complete Circuit of the Generator Power Sensor and Shutdown Timer

7. Testing and Results

The programmed chip was mounted in its circuit via an IC socket. The circuit was then powered ON by the power switch. The circuit power supply re-checked to ensure 5V supply to the AVR microcontroller and 12V to the relays. All other connections (resistors, transistors, rectifiers, switches) were ensured. The display was seen to display a text at start up [i.e *enter time*] indicating initialization. We then proceeded to perform the timing test. The timing set was carried out by the increase and decrease buttons accordingly, followed by the start button, and noting the countdown time with a conventional digital stopwatch.

A 100W incandescent light bulb, which represents a load condition for the circuit, was then connected via the relay. The timing test was then carried out again and it was observed that the light bulb powered ON for the duration of time interval, then powered OFF.

After this test, the device was then coupled with an electric generator, and the device was switched ON. The timer was set using the push button (soft touch) to one minute. After the time elapsed, the generator switched OFF.

8. Conclusions

It is seen from this research that the device has maximum operation time of 99 hours and 99 minutes with maximum switchable load (or device power handing capability) of 1760 W. Heavier loads could be handled with higher rating relay.

The constructed shutdown timing circuit does not only control the timing operation of the electric generators, but also possesses the ability to sense power restoration from the public utility supply and respond by switching OFF the generator.

In conclusion, this research provides an easier means of controlling or timing the operation of electric generators used for household appliance, offices, schools and some other establishments. With few modifications, the device can be used in many applications other than generators.

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