



Design and Implementation of a Digital Run-Time Meter for Electric Power Generating System

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ABSTRACT

This paper present the design and implementation of a digital run-time meter for electric power generating system. A run-time meter is connected directly to the output of the generator terminals to measure the elapsed time of equipment while running. It helps users of electric power generating system to keep accurate track of maintenance interval thereby leading to increased reliability and maximized availability of the generating system. It was designed using the ATmega328P-PU microcontroller. The microcontroller senses when the generator is put ON and records its operating time. The elapsed time is displayed on an LCD screen. The run-time meter designed and implemented in this paper was able to record the operating time of a generator when it is put ON, pause recording when the generator is turned OFF and continue from previous count whenever the generator is put ON again with reading equivalent to real time.

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INTRODUCTION

Maintenance is the combination of actions carried out to retain an item in or restore it to normal operational standard [1]. Nothing last forever and all equipment have associated with them some predefined life expectancy or operational life. Ideally, maintenance is performed to keep an item running efficiently for at least its design life span. As such, the practical operation of a component is a timed-based function [2].

The design life span of most equipment requires periodic maintenance. Any time we fail to carryout maintenance activities intended by the equipment's designers, we shorten the operating life of the equipment [2]. We have observed that all the domestic generators (i.e. small and medium generators) imported into Nigeria and around the world do not have pre-installed hour meters in them, and as such, it becomes difficult to keep accurate track of maintenance interval thereby leading to abrupt breakdown of generator set far before its design life.

Over the last three decades, different approaches to how maintenance can be performed to ensure equipment reaches or exceeds its design life have been developed. These approaches can generally be divided into Reactive, Preventive and Conditioned-based (Predictive) maintenance [3]. Reactive maintenance is basically the 'run it till it breaks down' maintenance mode. No actions or

effort are taken to maintain the equipment as the designer originally intended to ensure design life is reached. In conditioned-based maintenance, it is the actual current conditions of equipment or system that determines the form and frequency of maintenance. Condition monitoring of equipment can be carried out by using human sense, portable test instrument and/or fixed monitoring systems. Preventive maintenance is the practice of maintaining equipment on a regular schedule based on elapsed time or meter readings. This approach has proofed to deliver maximum availability and least operational life cycle cost. The intent of preventive maintenance is to prevent failures before they take place by following routine and comprehensive maintenance procedures [3].

Electric generators, like any other piece of machinery, need routine maintenance. This helps to ensure the generator set will work properly and optimally when it is needed. Regular maintenance also extends the useful life of the generator. It is generally a good idea to establish and adhere to a schedule of maintenance and service based on the specific power application and the condition of the environment.

The oil in an engine acts not only as a lubricant, but also as a cooling agent and a method of pulling nasty tiny and possibly damaging particles caused by wear into the filter and boiling of harmful chemicals caused by combustion. Those particles or chemicals might

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retain in the oil of an engine. Oil and other fluid can as well breakdown over a period of time, losing their effectiveness. It is recommended to change generator oil after the first month or 20-25 hours of use. After the initial oil change, every 3 months or 1,000 hours of use is recommended. Oil changes that are done on a regular scheduled basis can prolong the life of generator engine and keep it running properly [3].

To keep track of maintenance interval of a generator set, one method usually employed is the use of an Hour Meter also called Run-Time meter. The primary reason for using a run-time meter is for maintenance. If you rely on the actual running time of an engine to schedule maintenance from the last service, rather than calendar days or miles driven, there is less guesswork and greater correlation to the true operating life of the equipment.

REVIEW OF RELATED WORK

A special type of clock for measuring time intervals are referred to as timers. By function timers can be categorized into two main types, viz., timers that count upwards from zero for measuring elapsed time (e.g. stopwatch) and timers that count down from a specified time interval- usually referred to as countdown timers e.g. hourglass [4].

An hour meter is basically a type of timer. Honeywell International, Inc. makers of Honeywell hour meters defines hour meter as a gauge or instrument that tracks and records elapsed time, normally displayed in hours and tenth of hours. The majority of hour meters are used to log running time of equipment to assure proper maintenance of expensive machine or systems according to [5].

Over time, hour meter has been called several names depending on the field it finds application. In aviation, it is generally referred to as Hobbs meter- named after John Weston Hobbs who in 1938 founded the company which manufactured the first electrically wound clocks for vehicle use [6]. In marine and automobile it is generally referred to as engine hour meter, which records the time a boat or car engine has been running. If used in electric generators it is mainly referred to as running time meter or run hour meter. Virtually all large industrial, construction and agricultural equipment such as bulldozers, cranes, trenchers, forklifts, graders, compactors, tractors, combines, shredders and the like are sold "used" based on age, condition and logged hours. A generator set with 1,000 hours, for example, will be worth more than a comparable one with 2,500 hours. Having an accurate accounting of

elapsed time can make a big difference in price when selling used equipment. This is one important area of application of the digital run time meter.

III Methodology

The method adopted in this design involves the use of a microcontroller as a counter and storage medium to record the elapsed time of the generator set and is displayed on a Liquid Crystal Display (LCD) system. The counter increases only when the generator set is ON and stops when the generator set is switched off. Fig.1 shows the block diagram of the proposed system.

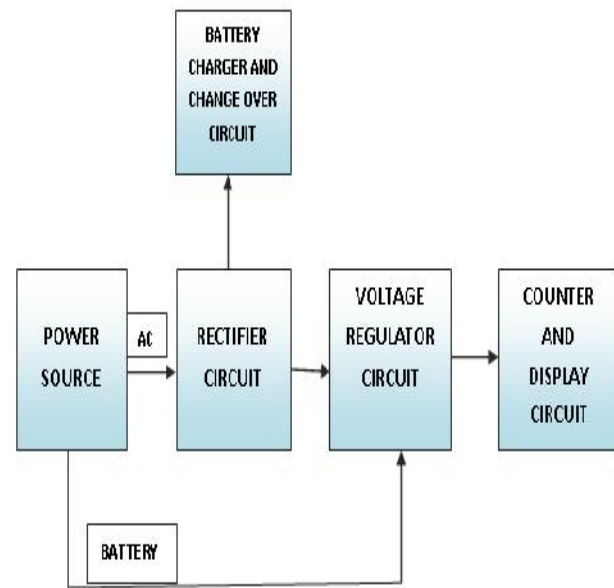


Fig. 1: Block diagram of the Digital Run- Time Meter

As shown in Fig. 1 the design consists of a main power source which is an AC power from the generator terminals that serves the circuit. An auxiliary power source which is a rechargeable battery acts as a backup power source for the design. It powers the counter and display circuit when the generator set is OFF and as such enables one to read the measured count at a glance without turning on the generator set.

The microcontroller unit in Fig.2 was wired up to form a cloned or stand-alone Arduino Uno Rev3; an ATMEGA microcontroller board built around the ATmega328P-PU microcontroller. It consists of ATmega328P-PU chip, 16MHz crystal oscillator (X1), two 22pf capacitors (C₄ and C₅) and a 10kΩ resistor (R₂). The ATmega328P-PU was programmed to count only when the generator is turned on and to control what is displayed on display unit. Resistor R₂ is used to limit the amount of current flowing into pin1 of the

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microcontroller to avoid damaging it. Capacitor C_4 and C_5 acts as load resonant capacitors for the crystal oscillator. The measured elapsed time is displayed on a Liquid Crystal Display (LCD) screen, an electronic display module. The display used is the 1602 LCD screen.

Push buttons PB1 and PB2 were connected to the microcontroller unit as control buttons. Push button PB1 when pressed displays the Total Run time of the generator set while PB2 resets the Current run time of the generator set.

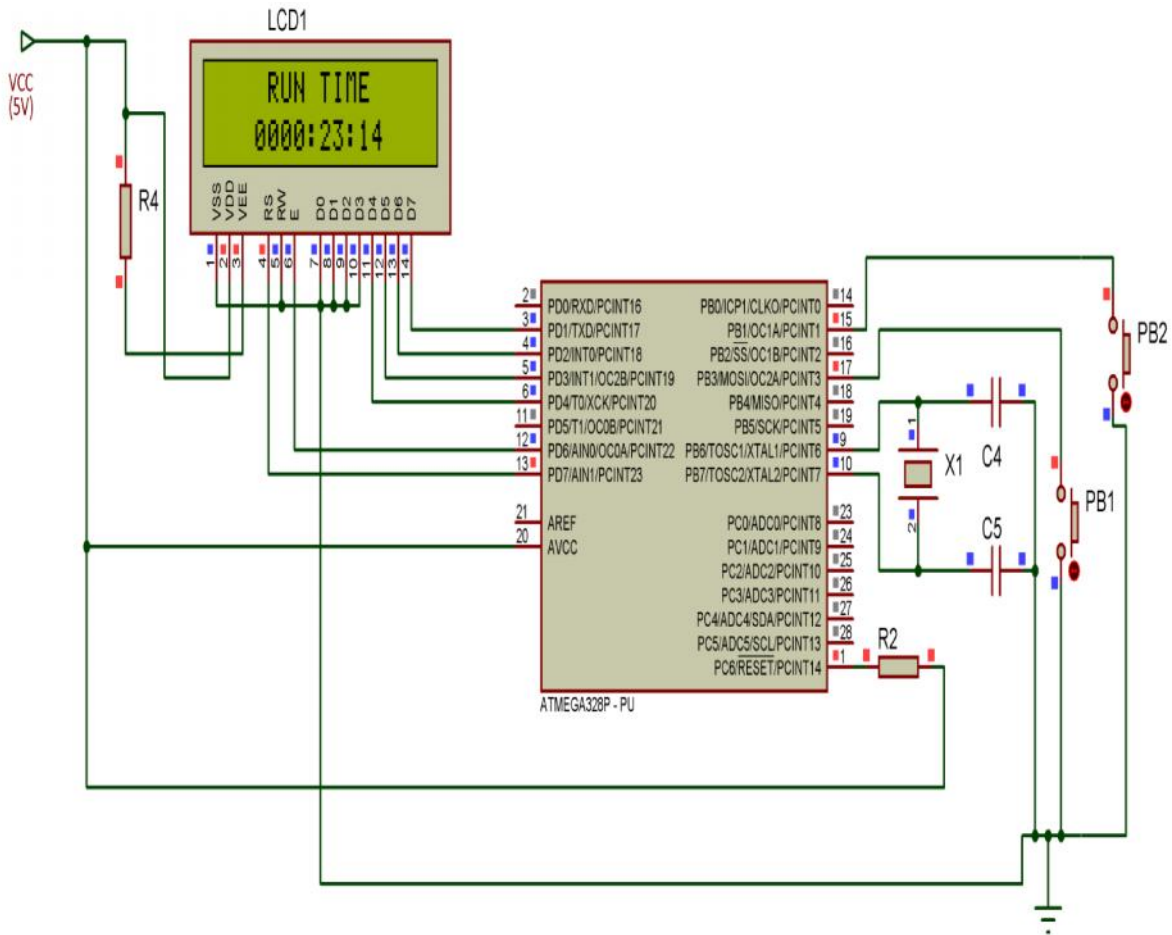


Fig.2: Counter and Display Unit.

The microcontroller was programmed to use the Arduino C derived programming language to follow the sequence of operation as shown in the system flow chart of Fig.3. The counter unit checks the status of the generator set and the push buttons simultaneously. If the generator is ON, it records the time of operation which is continuously updated on the display unit. If the generator is put OFF, the

counter unit pauses and displays the accumulated operating time of the generator on the display screen. When push button 1 (PB1) is pressed, the counter unit resets the current run time to zero and when Push Button 2 (PB2) is pressed, the total run time measured by the hour meter is displayed for five (5) seconds.

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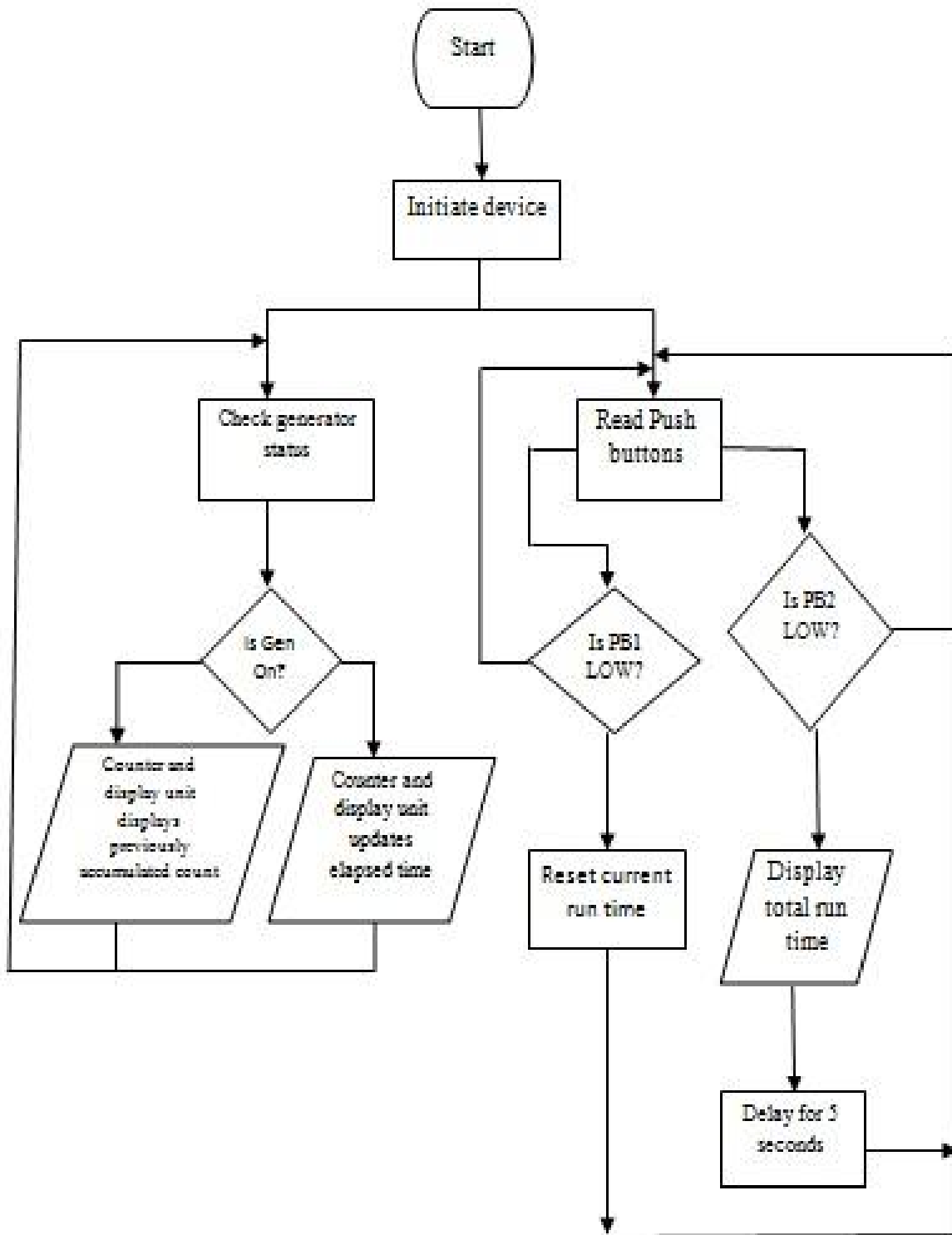


Fig.3: System Flow Chart

MODE OF OPERATION

The complete circuit of the proposed system is shown in Figure 4. The system measures the elapsed time of a generator set.

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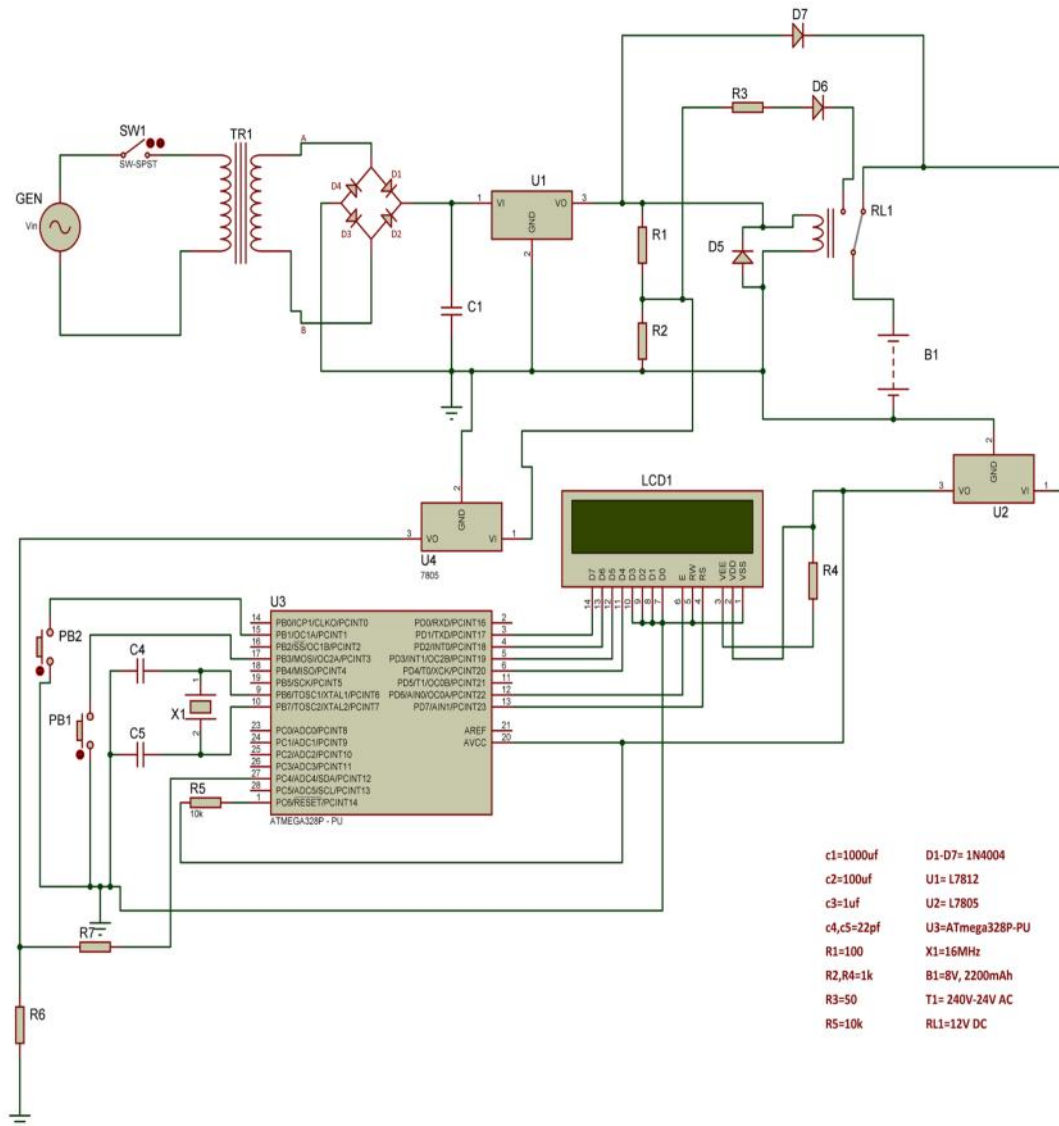


Fig. 4: Complete Circuit Diagram of the digital Run-Time Meter

When the generator is turned ON, the relay (RL₁) is energized causing the battery (B₁) to switch from NC pin of the relay to NO pin and thus start charging. The microcontroller (U₃) keeps track of the duration of operation of the generator set in hours, minutes and seconds. The measured elapsed time is displayed on LCD1.

When the generator set is turned OFF, the relay de-energizes and the battery switches back to the NC pin thereby powering the counter and display unit. This switching is very fast such that the counter and display unit doesn't go OFF. The Microcontroller senses that the generator is OFF and pauses counting. The operating time of the generator is displayed on

the LCD screen. The counting continues when the generator is turned ON again.

The hour meter designed in this paper measures two different times viz. total run time and Current run time. The total run time is the total time the generator set has operated since purchased or the total elapsed time measured by the hour meter since it was installed on the generator set. The total run time is non-resettable. The current run time is the time since when services or maintenance was performed on the generator set. The current time can be reset after servicing the generator or any time desired by the user.

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Push button PB1 when pressed displays the total run time of the generator set for a period of 5secs. Push button PB2 when pressed resets the current run time.

Design Calculations

Calculations For Rectifier Circuit

(a) Average DC Output Voltage of Rectifier Circuit

Rating of transformer used was 220V to 22 V AC.

This implies that secondary output voltage (V_s) of the transformer is 22V

Peak output voltage of the transformer is given by equ.1.

$$V_{s(p)} = V_s \times \sqrt{2} \quad (1)$$

$$V_{s(p)} = 22 \times \sqrt{2} = 31.11V$$

At any instant in the bridge rectifier, two diodes in series are conducting, each having a forward voltage drop of 0.7V,

Hence peak output voltage is

$$V_{o(p)} = 31.11 - 2(0.7) = 29.71V$$

Average DC output voltage (V_d) is calculated using equ.2.

$$V_d = \frac{2V_{o(p)}}{\pi} \quad (2)$$

$$V_d = \frac{2 \times 29.71}{3.142}$$

$$V_d = 18.91V$$

(b) Selection of Diode for the Bridge Rectifier

The bridge rectifier circuit was designed with four diodes. For efficiency, the peak inverse voltage (PIV) was determined. Peak inverse voltage is the maximum reverse voltage a diode can withstand without destroying the junction. It is given in equ.3.

$$P = \frac{V_{s(p)}}{2} \quad (3)$$

$$P = 31.11 \times 2 = 62.22V$$

From the above result, the diode used was 1N4004 which have a peak inverse voltage of 70V.

Calculations for Battery Charging Circuit

(a) Charging Voltage for Battery

The type of rechargeable battery used is the Lithium-ion (Li-ion) kind. Two (2) Li-ion battery rated 3.7V, 2200mAh were connected in series to form a 7.4V, 2200mAh battery bank. A charging voltage of 10V was used. This was achieved by the voltage divider network formed by resistor R_1 and R_2 . Knowing that the forward voltage drop across the diode is 0.7V, to obtain 10V charging voltage, values of R_1 and R_2 were chosen to obtain an output voltage of 10.7V using equ.4.

$$V_o = V_{i_i} \times \frac{R_2}{R_2 + R_1} \quad (4)$$

Where V_{i_i} = voltage to be divided, 12V

$$V_o = 10.7V$$

Let $R_2 = 1K\Omega$, then equ.(4) in terms of R_1 becomes

$$R_1 = \frac{V_{i_i}}{V_o} R_2 \left(1 - \frac{V_o}{V_{i_i}} \right)$$

$$R_1 = \frac{12}{10.7} \times 1000 \left(1 - \frac{10.7}{12} \right) = 1121.5 \times 0.108$$

$$R_1 = 121\Omega$$

Preferred value for $R_1 = 100 \Omega$.

(b) Charging Current

The battery charger employed in this design is a simple battery charger. To avoid overcharging and damaging the battery, slow charging which involves charging of battery at low current was employed.

Minimum charging current of battery is 10% of battery Ampere hour rating

$$10\% \text{ of } 2200m = 0.1 \times 2200 = 220m$$

From Ohm's law, $V = I$

Resistance required to give out a current of 220mA from 10V voltage is

$$R_3 = \frac{V}{I} = \frac{10}{220 \times 10^{-3}}$$

$$R_3 = 45\Omega$$

A resistor of 46 Ω preferred in the design.

Calculations for Microcontroller Unit

(a) Selection Of Crystal Oscillator

For Asynchronous normal mode;

$$F_o = (UBRR + 1)16 \times B \quad (5)$$

Where F_o is frequency of oscillation in Hz,

UBRR is the USART Baud Rate Register,

BAUD is the Baud rate in bit per seconds.

For UBRR = 100 and BAUD = 9600bps,

$$F_o = (100 + 1)16 \times 9600$$

$$F_o = 101 \times 153600$$

$$F_o = 15513600 \approx 16M$$

(b) Selection of Resonating Capacitor

The value of the resonating capacitor employed is calculated as given by equ.6.

$$C_L = \frac{(C_1 \times C_2)}{(C_1 + C_2)} + C_s \quad (6)$$

C_L = the crystal load capacitance

C_s = the stray capacitance in the oscillator circuit

C_1, C_2 = the required capacitor values of capacitor

Let $C_1 = C_2$, then equ (6) becomes

$$C_L = \frac{(C_1 \times C_1)}{(2 \times C_1)} + C_s \quad [6]$$

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$$C_L = \frac{C_1}{2} + C_s$$

$$C_1 = 2(C_L - C_s)$$

Given from the data sheet, $C_L = 14p$

Let $C_s = 3p$,

$$C_1 = 2(14 - 3) = 22p$$

$$\therefore C_1 = C_2 = 22p$$

Implementation

The implementation of this design was carried out in three phases. These phases were

- (a) Simulation
- (b) Bread-boarding and
- (c) Prototype

(a) Simulation

The original idea of the design was first tested on PROTEUS, a Virtual System Modelling (VSM) and circuit simulation application developed by Labcenter Electronics. Adjustments were made till the circuit worked as expected when simulated.

(b) Bread-Boarding

The refined circuit of the design was first tested on the bread board to see if the design will work as expected before building a prototype. The Arduino Uno R3 microcontroller board was also used in the bread boarding. Fig 5 shows a section of the project on Bread Board.

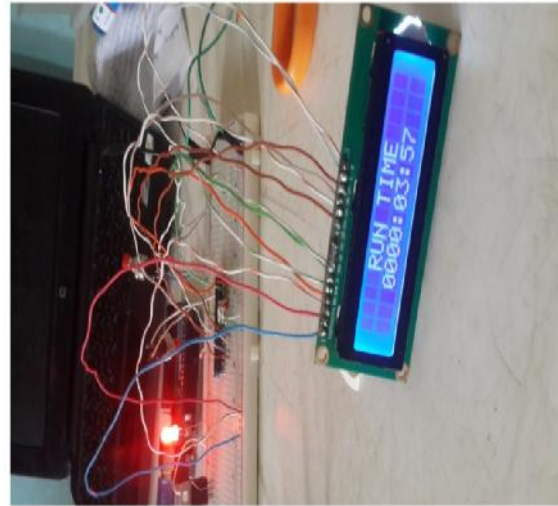


Fig.5: Testing on Bread Board

(c) Prototype

This is the final implementation phase. The circuit was built on a strip board (or Vero board). The necessary components were soldered in stages to form a permanent connection on the strip board. The order of soldering started from the power source, change over and battery charger unit to the counter and display unit. Fig 6 shows some of the components soldered on the strip board during construction.

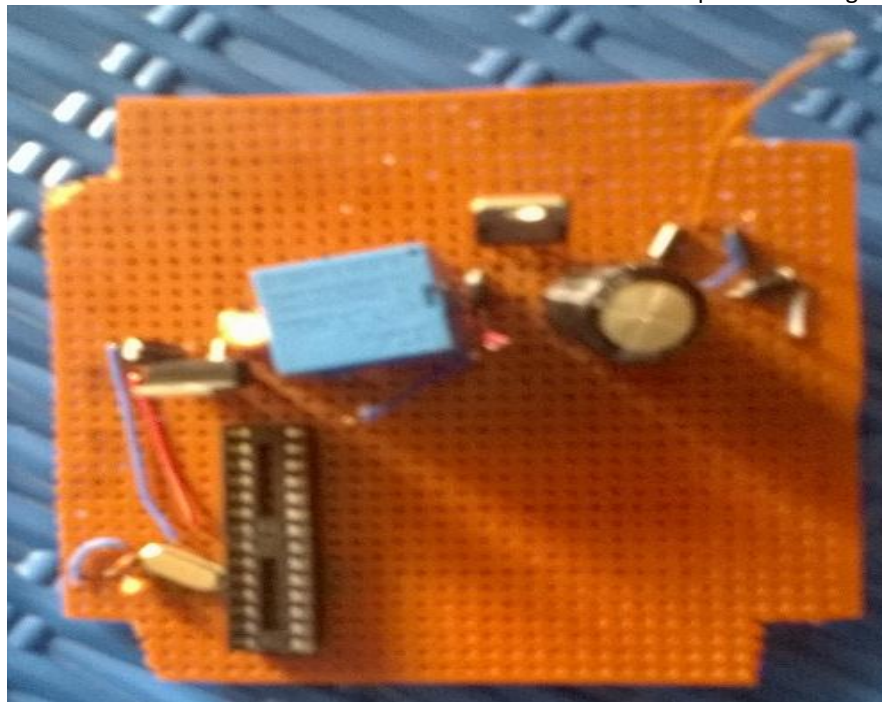


Fig.6: Construction in Progress

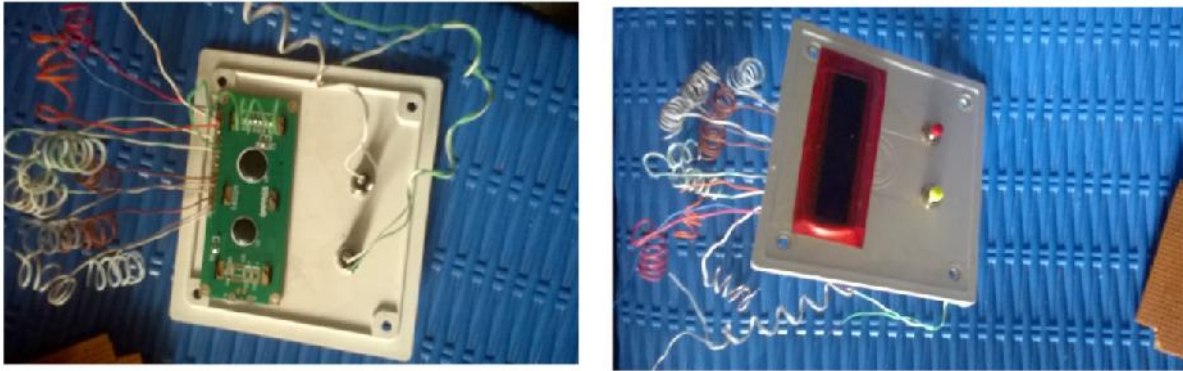


Fig.7: Fitting the LCD and Push Buttons

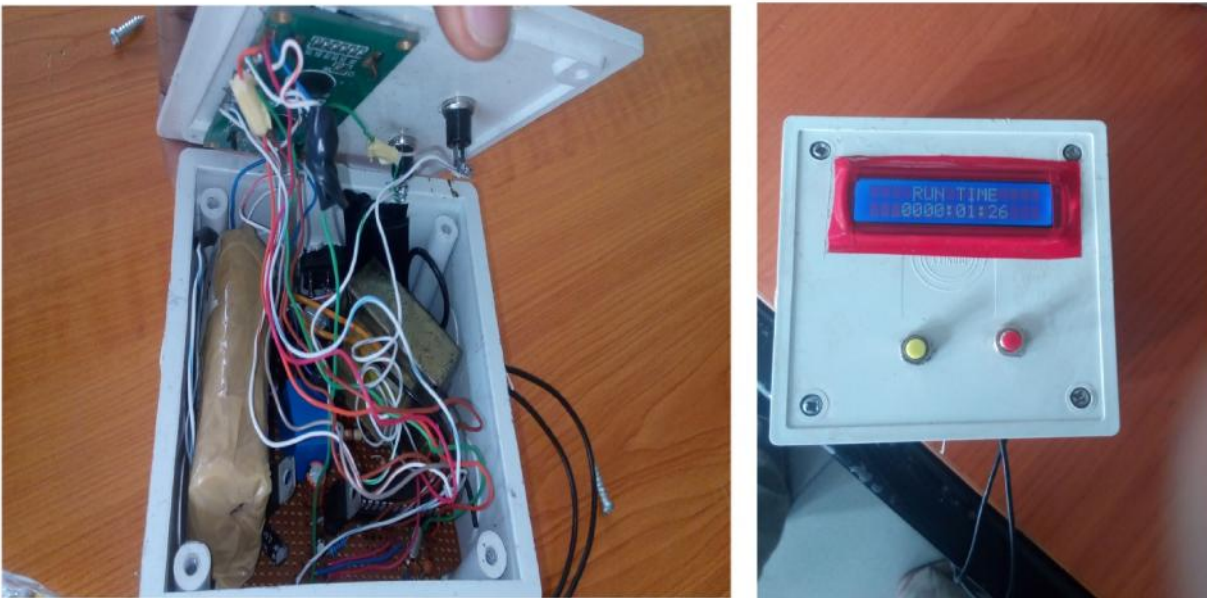


Fig.8: Constructed Digital Run-Time Meter

CONCLUSION

The run-time meter designed and implemented in this paper can help prevent early failure and increase the availability of an electrical power generating system by enabling users of these generators keep accurate log of maintenance interval. It should however be noted that a run-time meter in itself does not perform maintenance on the generator but rather a tool that makes maintenance more productive.

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