Development of Power Failure Alarm with Auto Generator Starting Device using PIC16F88 as Active Device

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ABSTRACT

Most domestic, industrial and commercial appliances are dependent on power supply and if there is loss of power, serious time is not only wasted but also creates device or machine damage. This project presents the design and construction of a power failure alarm system that can be used in the monitoring of mains power, with automatic generator starting capability. The power failure alert system described in this work provides a feature of signaling the user whenever there is loss of power. In the overall setup, the system allows the measurement of mains input voltage, as well as manual switching of the generator. The described power failure system will incorporate intelligent circuitry based on highly popular PIC16F876 microcontroller to manage and monitor mains power. The controller is programmed to allow the user to decide, either to manually start and off the generator when there is power failure and to set the system to automatically start and off the generator during power failure. Using a 16 by 2-line character LCD, the system will indicate the status and its performance. When the device detects a power outage, it immediately sounds an audible alarm to the user and automatically starts the generator depending on the user setting, and when power is restored, it sounds another audible tone signaling the presence of mains power then delay for a few seconds before turning off the generator. The device has built-in backup power in the form of a battery, to keep the system active and independent of utility power source which may not be present at all times.

Key words: Power Supply, Alternative Power Source, Change-over Switch, Generator, PIC16F88 microconroller

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INTRODUCTION

In underdeveloped and developing countries, for instance, in Nigeria, the supply of power from electricity distributing companies is unstable [1,2]. To meet with high demands of energy, alternative sources of power supply is a necessity [3-5]. The introduction of these alternative sources of supply brings forth the challenge of switching smoothly and timely between the mains supply and the alternative sources whenever there is a failure on the mains source [6]. Hence,a changeover control circuit that will aid the continuous supply of energy without interruption during the loop is required. A review of literature shows that several changeover circuits has been built [7-10].

In this work, an audible Sound Alarm method has been adopted in the design and development of this system. In the development of this system, a simplified approach of combining software and hardware is adopted. This is to allow for the archiving of the project aim and objectives as well as the operational goal. The basic operation of the project is to alert and automatically switch ON an auxiliary power supply (like a generator). This operation eliminates the stress of manually starting and stopping of the generator in the event of power failure. The control logic unit operation is based on sequential timing. The main component of the unit is a PIC microcontroller and a control Relay. This device initiates the starting/stopping of the generator when power supply fails/restores.

This design incorporates proper monitoring measures to avoid equipment damage and ensure efficient delivery of services indata centers, surgery in the hospitals, banking activities, lifts in tall buildings, telecommunication base stations, among others.

PIC16F88 microcontroller

A microcontroller is a single integrated circuit chip that contains a processor, memory storage and input and output ports (I/O), all controlled by software stored within the chip. A microcontroller has the similar function of a Central Processing Unit (CPU) found in home PCs, in that information in the form of instructions are used to control the device. In the design of this work, a PIC16F876 has been used to allow for advance features to be implemented. The PIC16F876 is a 16-bit microcontroller (up to 256 KB Flash and 64 KB SRAM) with USB, advanced analog ports, audio and graphic interfaces. It is a32-bit microcontroller that comes in a28-pin dual inline (DIL) package, 256 KB of flash memory and a 64KB static random-access memory (SRAM).It is an extremely affordable device compared with the numerous features that it contains. The dual-inline-package format in which the controller is produced, is easy to orientate on breadboard and strip board projects, making connections to the pins straightforward. The flash memory it uses has the ability to be electrically programmed and erased without the removal of the chip from the circuit. When selecting a microcontroller for this project, it was important to choose a device with sufficient onboard memory, as the length of the final software code was unknown. The 256KB of 16-bit word instructions was suitable for the estimated length of code that would be generated.
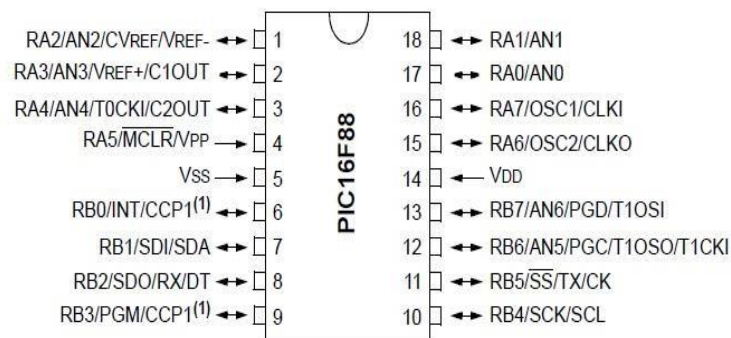
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RA2/AN2/CVREF/VREF-  ◄►  ▯ 1        18 ▯  ◄►  RA1/AN1
RA3/AN3/VREF+/C1OUT  ◄►  ▯ 2        17 ▯  ◄►  RA0/AN0
RA4/AN4/T0CKI/C2OUT  ◄►  ▯ 3        16 ▯  ◄►  RA7/OSC1/CLKI
       RA5/MCLR/VPP   ►  ▯ 4   P    15 ▯  ◄►  RA6/OSC2/CLKO
                VSS   ►  ▯ 5   I    14 ▯   ◄  VDD
                            C
       RB0/INT/CCP1(1) ◄►  ▯ 6  16   13 ▯  ◄►  RB7/AN6/PGD/T1OSI
                            F
         RB1/SDI/SDA  ◄►  ▯ 7  88   12 ▯  ◄►  RB6/AN5/PGC/T1OSO/T1CKI
       RB2/SDO/RX/DT  ◄►  ▯ 8        11 ▯  ◄►  RB5/SS/TX/CK
      RB3/PGM/CCP1(1)  ◄►  ▯ 9        10 ▯  ◄►  RB4/SCK/SCL
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Fig. 1 Pin out diagram for PIC16F88 microcontroller

Material

To achieve this study, various components, devices and modules were used. Each, has specific functions and roles that they play in the design. Some of these components includes an electromagnetic interference (EMI) filter, a 230VAC to 12V plug pack to provide the required power, a 230VAC to 5V DC switch-mode converter, a precision real-time clock and a USB-to-UART serial converter, for both programming and logging of data to personal computer (PC). There are also special purpose ICs for an isolating current-to-voltage conversion and an analogue-to-digital converter (ADC). Others arePIC16F88 microcontroller, PC817 Photocoupler, 16×2 character LCD module and 2 Single Pole Double Throw (SPDT) relay used as a switch.

Power failure Alert for mains electricity was achieved by using the Transmission Control Protocol/internet Control Protocol (TCP/IP) as an alert system when power comes in mains.The figure below shows the block diagram for the power failure alarm with Automatic generator starting capability.

The system consists of mains detector, power supply, Battery backup, microcontroller, switching unit and the LC display. The mains detector monitors the presence of power from PHCN, the power supply provides the needed supply voltage for the microcontroller and the switching unit and at the same time charges the backup battery. The switching unit consist of two single pole double throw (SPDT) relays whose function is to act as the switch in the generator. One of the relays is for ignition and the other is for start. LCD display module provide visual display of the system status. The microcontroller is the heart of the entire system. It monitors signal coming from the mains detector and acts accordingly by flagging off of the alarm and as well as initiating the generator start and stop sequence.
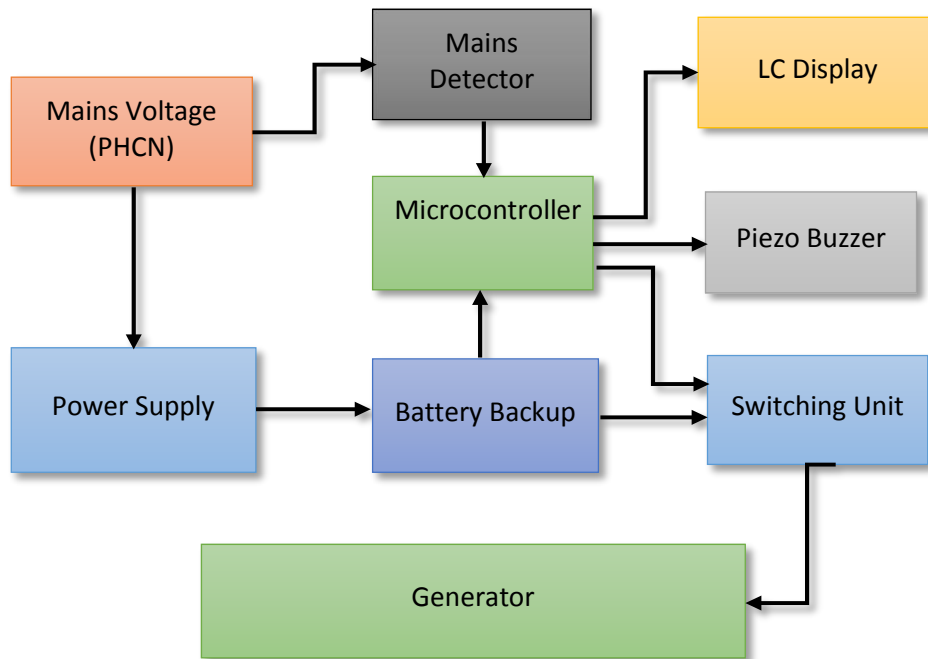
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Fig. 2 Block diagram of Power Failure Alarm system

System Design
General Power supply circuit.
The general power supply circuit powers the entire circuit. The general power supply takes it power from an external 12V power supply which could either be a battery or a raw DC power pack or adapter.

The power supply consists of two power supply modules based on MT3608 DC to DC step up boost converter module and TP4056 3.7V li-ion 18650 battery charger module. The TP4056 3.7V li-ion 18650 battery charger module charges the backup battery to keep power for the system in the event of power failure. The MT3608 DC to DC step up boost converter module provides adjustable output voltage from 5V DC to 28V DC and a voltage regulator, smoothing capacitors and the input, where power is taken in from.
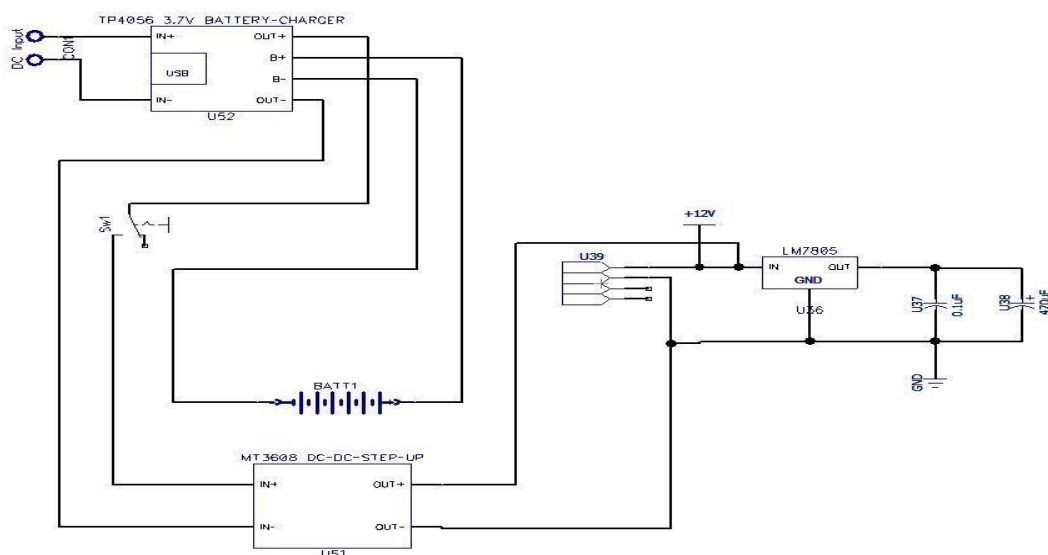

Fig. 3 Circuit diagram for the General power supply section

Phase Voltage monitoring section
The phase voltage monitoring section monitors the incoming phase voltage of the mains feed in. This section monitors the voltage that is present in each phase, and then sends this voltage difference to the microcontroller for onward

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processing before being displayed on the LCD screen. The voltages are displayed according to the phase that it's associated with.
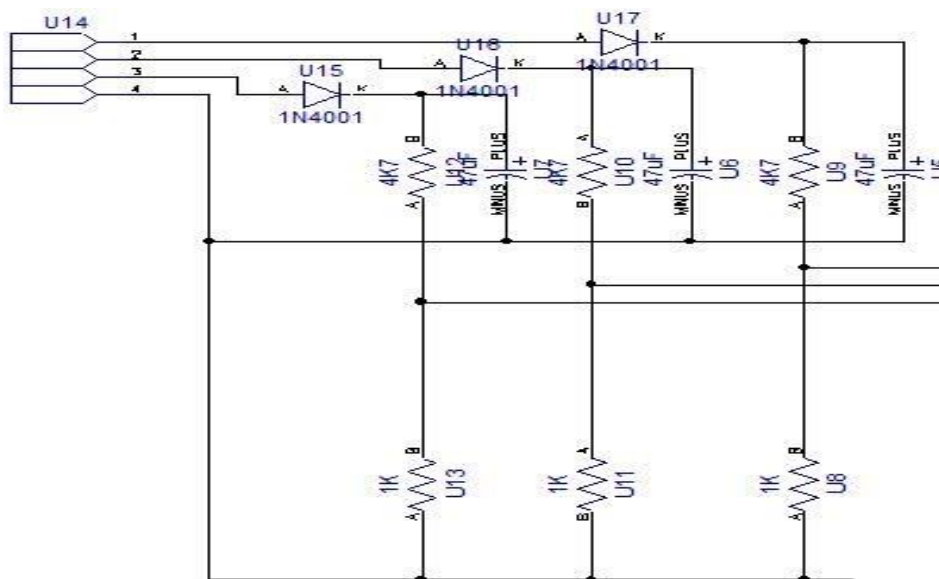

Fig. 4 Circuit diagram for the Phase voltage monitoring section

The Microcontroller unit
The Microcontroller section is the heart and Intelligence of the entire system. It controls every processing and command that the system needs in other to control the external devices. The microcontroller accepts input signal from the opto-coupler, and the Phase voltage monitoring section, then processes it to know if there is power failure or if the generator has successfully started or not.
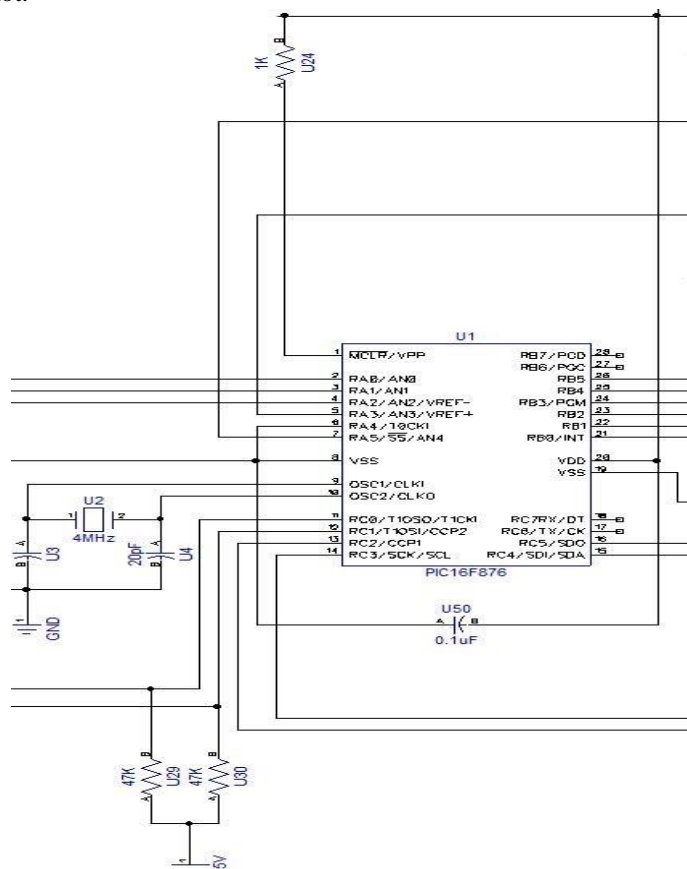

Fig. 5 Circuit diagram for Microcontroller section

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The entire task is done by the microcontroller, a PIC16F876A which is programmed with a dedicated firmware program. In operation, the microcontroller runs from a 4MHz crystal clock and does all of the timing by counting the clock cycles – using a combination of both hardware and software.

Opto-coupler section
The opto-coupler is an optical link between the high and the low voltage section of the entire system. It serves as the sensor to the circuit and isolates the high voltage part of the circuits via its optical link. The optical link is contained within a chip. A Light Emitting Diode inside the chip shines on a photo-transistor. When the photo device illuminates, the resistance between its terminals reduces. This reduced resistance is used by the microcontroller to sense and know if the mainsor the auxiliary power is present thereby activating the start or stop sequence.
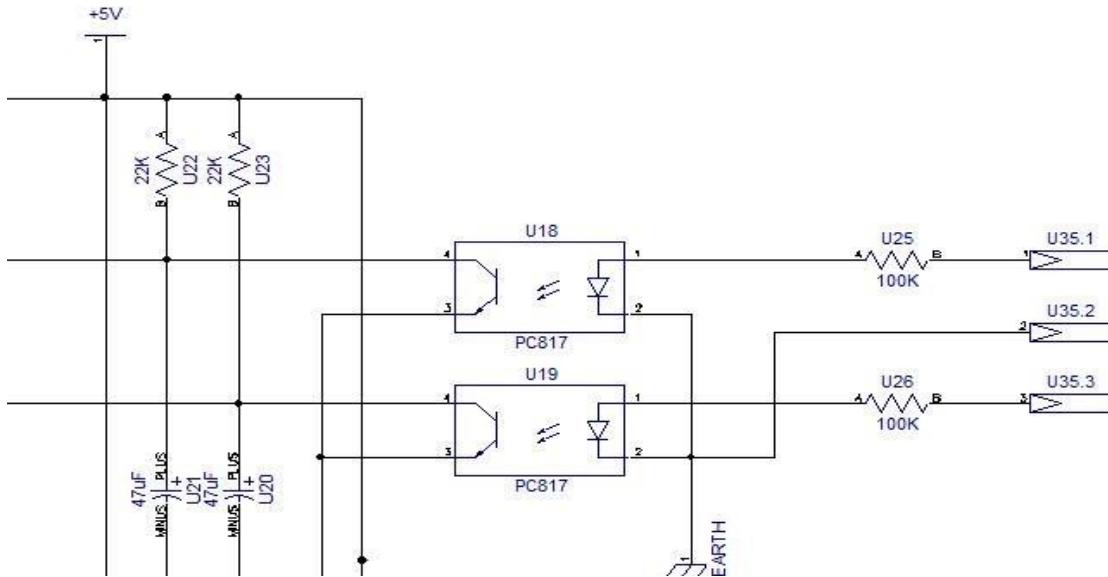
Fig. 6 Circuit diagram for voltage sensing section

Relay Driver and Relay Section
This section of the system handles the switching (starting and stopping sequence) of the generator system. It is designed around a ULN2003 transistor array and three low voltage relays. The transistors inside of the ULN2003 is used in the switching ON/OFF of the relays when the microcontroller receives a signal from the opto-coupler circuit. The signal comes from either one of the two opto-couplers, one for Generator (Auxiliary source) or the other from mains source. These signals are then used by the controller to activate any of the three relays, starter, Ignition or the Contactor control relay through the transistor array.
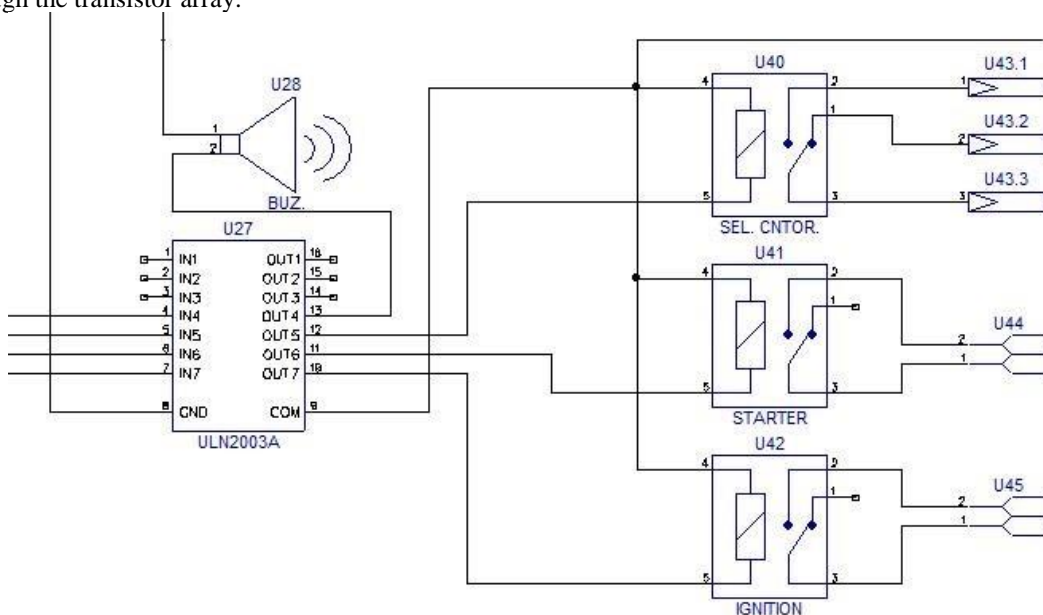
Fig. 7 Circuit diagram for Relay switching section

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Circuit Description

The circuit diagram below shows the complete circuit diagram for the power failure alarm system. The heart of the system is based on the highly popular PIC16F876 microcontroller. Power supply for the circuit is provided through 9V to 12V DC source with support of two power supply modules based on the MT3608 DC to DC step up boost converter module and TP4056 3.7V li-ion 18650 battery charger module. The TP4056 3.7V li-ion 18650 battery charger module, charges the backup battery to power the system in the

event of power failure. MT3608 DC to DC step up boost converter module Provides adjustable Output voltage from 5V DC to 28V DC. This output voltage is set to +5v DC which is used in powering the entire system. Presence and absence of mains voltage, is done by two optocoupler type PC817.
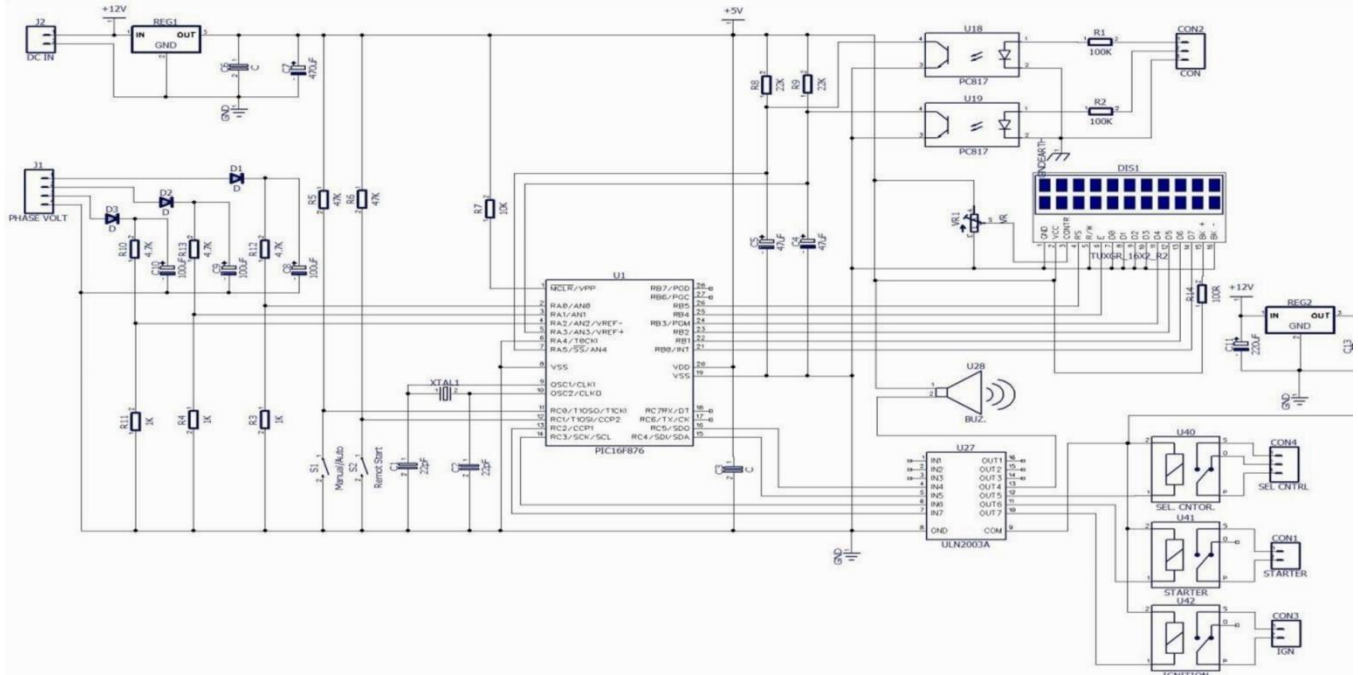

Fig. 8 Complete Circuit Diagram for the power failure alarm system

This optocouplers, provide galvanic isolation for the low voltage side of the system. The positive half-waves of the mains voltage are sensed by this two optocouplers and transferred to Port pins RA3 and RA5 of the microcontroller. The input LED of the optocoupler has a low reverse breakdown voltage, so the negative half-waves are bypassed by diode D1. With a 230V mains voltage, current limiting is provided by two resistors in series (U25 and U26) to avoid exceeding their maximum voltage rating. With a 115V mains voltage, only one of the two resistors is necessary and the other can be replaced by a wire link. This detector configuration is virtually immune to voltage spikes on the mains, except in the very rare event of a direct lightning strike on the building service connection.

The basic operation of the project is to alert and automatically switch ON an auxiliary power supply (like a generator). This operation eliminates the stress of manually starting and stopping the generator in the event of power failure. The control logic unit operation is based on sequential timing. The main component of the unit is a PIC microcontroller and a control Relay. This device initiates the starting of the generator when power supply fails.

In operation, the microcontroller monitors the value of it to Port pins RA3 and RA5 to see if there are any changes in those port. These changes do occur when the opto-couplers sends signal during the presence of power and absence of power. When mains voltage is present at one of the inputs of the optocoupler, the internal transistor inside the optocoupler switches ON thereby sending a logic level low signal to the microcontroller, this low-level logic tells the microcontroller that there is mains present and no action would be taken by the system. When the mains voltage fails, the transistor inside of the optocoupler would be switched off there by allowing logic level high through a pull up resistor to be present in the port of the microcontroller. When the microcontroller senses a logic level high in that port it then sends a positive signal to the transistor Array ULN2003. The ULN2003 then activates the relay for ignition followed by activating the start relay, which eventually starting the generator. The ULN2003 in the design is used as a switch to turn on/off the relays. The Buzzer provides audible alert to the user when there is power failure.

The 4MHz crystal and the two 20pF capacitors provide timing for the microcontroller while the capacitors enable the crystal to start reliably. The PIC16F876A can be operated in four different oscillator modes namely LP Low-Power Crystal, XTCrystal/Resonator, High-Speed Crystal/Resonator and RC mode. In this design it is program to operate in XT Crystal/Resonator operating mode using two configuration bits (FOSC1 and FOSC0) to select one of these four modes.

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In XT mode, a crystal or ceramic resonator is connected to the OSC1/CLKI and OSC2/CLKO pins to establish oscillation as shown in the diagram below. The PIC16F876A oscillator design requires the use of a parallel cutcrystal.
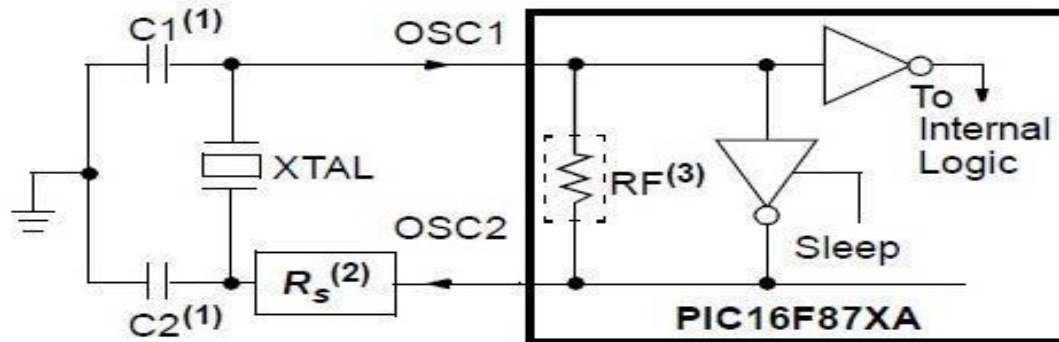

Fig. 9 Oscillator configuration diagram for the Microcontroller

Use of a series cut crystal may give a frequency out of the crystal manufacturer's specifications. When in XT, LP or HS modes, the device can Have an external clock source to drive the OSC1/CLKI pin. In summary the system is designed to sound an alert and automatically start the generator once the mains power supply fails, then turn off the generator moments after the A.C. mains are restored. The device removes the stress of manually switching from generator to mains or from mains to generator when there is power failure.

Construction

The construction and implementation were done using step to step approach in other to achieve the hardware. These steps include; designing the schematic and layout diagram, tools and equipment use, mounting and soldering of the components and construction of casing.

Software and Programming

Fig 10 shows screen shot of application that was used in the development of the microcontroller Firmware code. Here, MickrocPro integrated development environment (IDE) was used in writing the required firmware for the microcontroller. The firmware program allows control command to be sent to the relay board through the receipt of PHCN and Generator status. The Firmware program was written in C using the above stated IDE.

MikrocPro provide library for microcontroller and the LCD display, this makes writing, compiling and programing the microcontroller easy. In the code, libraries for the microcontroller and the LCD display were first included. These libraries contain the core initialization functions that enable the system communicate with the various components attached to it. The microcontroller digital pins were initialized and declared as output and input were necessary.
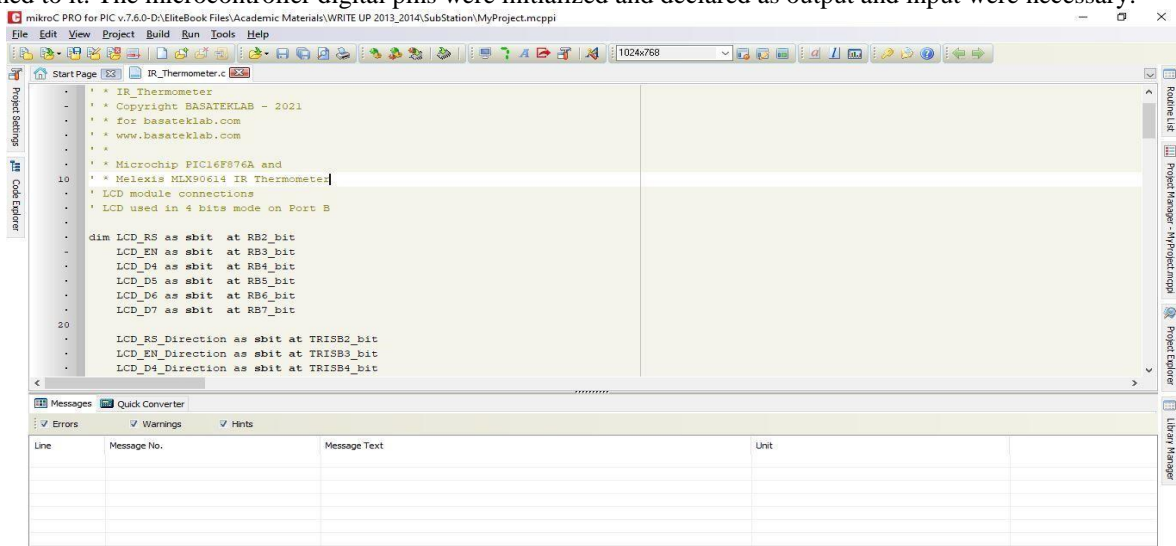

Fig. 10 MikrocPro integrated development environment

Testing and result

Testing of the system was one of the paramount things that was done, before putting it into use. A digital multimeter was used in the testing and troubleshooting of the circuit. Before applying power to the circuit, the ICs were first removed

from their respective sockets in the circuit to avoid short circuit damage or PCB track during the construction. Short circuit test was first carried out to ensure that there was no short circuit between the PCB connections and other components on the board. Next, was an open circuit test to ensure that no components were left unconnected and broken PCB tracks were left open. Finally, a voltage test was carried out to ensure that the correct and maximum allowable voltage was passed to the circuit from the internal power supply. This test also helps to make sure that the ICs and other circuit components received the correct voltage to avoid damage during operation and testing.

Before installing the microcontroller, the power supply to the microcontroller was checked. A 9V to 12V DC was connected to the system. Voltage between pin 14 and pin 5 of the microcontroller IC socket was checked. Pin 14 should be at +5V with respect to pin 5 (GND). With the result of this test, the microcontroller was finally installed in place and the two boards were connected together through their respective connecting cables. Power was reapplied and the system LCD came on to indicate that the system was working as expected. a faint click was also observed from the corresponding relay as the completed system turns on. Changing the input selection was done using the switches. It was observed that each time the system senses power outage, the relay corresponding to the particular appliance switched on to initiate the starting of the generator.

Problems Encountered

Problem was encountered during the planning stage of this project. This involved decision making in terms of the components to be used and writing of the microcontroller firmware. Designing of the schematic and the printed circuit board layout was also challenging as different designs were made and improved upon before arriving on what has been presented in this work.

CONCLUSION

Automatic mains failure (AMF) system with alarm and auto generator starting has been designed to help provide constant reliable power for operations and activities that are power dependent. The integrated auto generator starting gives an added advantage as it enables the secondary power source to be switched on automatically during the event of power failure. Additionally, the system allows the generator to be started automatically when an urgent need for electrical power supply and public mains supply is still unavailable.

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