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Microcontroller Based Automatic Power Selection Switch

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Abstract: *The need to protect electrical appliances from electrical power fluctuation cannot be over emphasized. Most homes and office complexes where single-phase supply is needed are supplied with two or three phases of power supply to allow change from one phase to another when there is fluctuation or complete outage of power supply on a particular phase. This action is done manually and results in electric shock and damages. The automatic phase selector system automatically select and switch from one phase to the other in a RED-YELLOW-BLUE sequence and operates within a voltage range of 160V - 220V. When voltage supply on a phase is below 160V or above 220V, this system automatically disconnects the load from the phase and connects to another where the required condition is met. The system was developed using Atmega328P microcontroller, ULN2003AN transistor switch, relays, 78XX series regulators, liquid crystal display and an audio alarm unit that produces a beep sound whenever there is a change from one phase to another. The load is connected on this phase and remains on it when the condition of operation is met. This sequence provides protection and guarantees continuous power supply for single-phase appliances and the designed system performed satisfactorily.*

Keywords: *Appliance protection, phase selector, priority phase, Transistor Switching, microcontroller*

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I. Introduction

In developing countries like Nigeria, power instability and phase failure has posed a serious threat to our economic development. One of the factors that boost the economy of a country is its ability to supply a steady and stable power supply. However, issues such as phase failure, phase imbalance or earth fault are main causes that lead to unstable and erratic power supplies [1-2]. In some cases, the power lines are over loaded leading to power trip-off by the circuit breakers or by the load shading process undertaken by distribution authority**.** Most homes and office complexes where single phase supply is needed are supplied with two or three phases power supply to allow change from one phase to another when there is fluctuation or complete outage of power supply on a particular phase. This action is aimed at making sure that power is always available for use by the appliances, but it is accompanied with its hazard because it is manually controlled; Hence, the need for an automatic control (switching) system. The automatic switching systems can help to eliminate the manual control technique mostly used in developing countries [3]. Several works have been done in this regard, some of which interfaced three-phase supply to generators using various approaches with remarkable success over the years [4-7].

II. Related Works

Automatic power selection switch helps to monitor power from utility to check for phase failure, over or under voltage or power outage. In [8], the authors developed a three-phase automatic change over switch using PIC16F877A microcontroller for changing between generator and utility supply. The authors in [3] developed an automatic three phase changer using LM324 quad integrated circuit to check phase imbalance.

AT89C52 microcontroller was used in the design of smart phase change-over system in [9] where continuous checking of phase was done. In [10], the author designed and implemented an automatic phase changer without the use of a microcontroller. The system only considered under voltage protection for emergency loads. A low cost automatic transfer switch with an over voltage protection was developed in [11] without the use of a microcontroller.

In this paper, a microcontroller based automatic power selection switch is designed and developed to help eliminated the manual method of phase selection and its associated limitations. Under or over voltage protection is considered using ATMEGA328P microcontroller, with audible alarm when phase change occurs.

III. Materials and Method

The materials used in the design and development of an automatic power selection switch are ULN2003AN transistor switch, ATMEGA328P microcontroller, alarm and its control circuit, liquid crystal display, relays, voltage control circuit and load (100W bulb and 13A socket).

The methodology adapted in this work is in several stages. Firstly, phase sensing unit was designed, followed by the control unit. The sensing unit was integrated into a microcontroller and C language was used to program the operation of each unit of the system. Proteus 8 was used to simulate the designed system, after which a prototype of the system was built. Finally, test was carried out on the system to check its functionality. The building blocks for the automatic power selector switch are presented in Fig. 1.

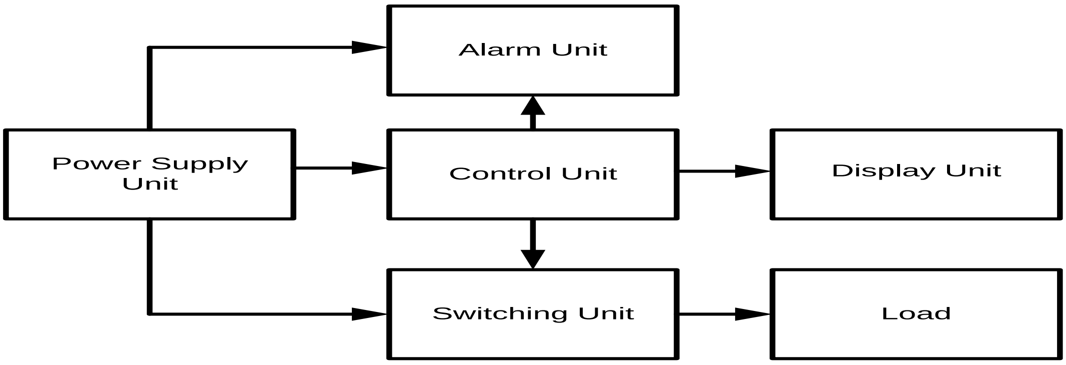


Fig. 1: Block diagram of automatic power selection switch

3.1 System Design and Analysis

The various blocks making up the automatic power selector switch is presented in this section.

3.1.1 Power Supply Unit

This comprises of three-phase power supply from the distribution or utility company to the consumer unit. It is also the source of power to the entire system. It includes the mains, step-down transformer, rectification, filtration and regulation units. Fig. 2 presents the circuit diagram for the three-phase power supply unit.

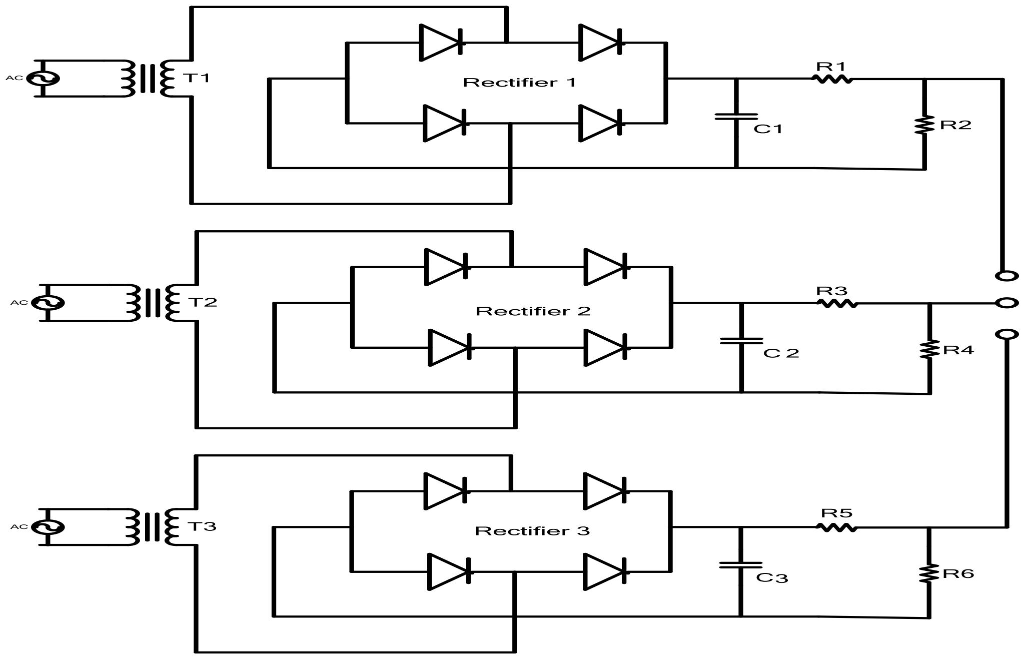


Figure 2: A Three-Phase Power Supply Unit

For the selection of transformer, the design specification is as follows:
Secondary voltage of the transformer, V_2 = 15V
Primary voltage of the transformer, V_1 = 220/240V AC
Secondary current of the transformer, I_2 = 630mA

Primary current of transformer is obtained using (1) [12]:

$$I_1 = \frac{I_2 V_2}{V_1} = \frac{630\times10^{-3}\times15}{240} = 39.4\text{mA} \approx 39\text{mA}. \quad (1)$$

Transformer utilization factor (TUF) is given by (2) [13]:

$$TUF = \frac{\text{POWER DELIVERED } (P_{dl})}{\text{AC RATING } (P_{ac})} \quad (2)$$

where TUF for a bridge diode rectifier is 0.693.

Power delivered $(P_{dl}) = I_2 \times V_2 = 630 \times 10^{-3} \times 15 = 9.45\text{VA}$ (3)

$$\therefore AC\ RATING\ (P_{ac}) = \frac{9.45}{0.693} = 13.64VA \approx 14VA$$

But, $P_{ac} = I_{ac} \times V_2$ (4)

where I_{ac} is the source current of the transformer.

$$\therefore I_{ac} = \frac{P_{ac}}{V_2} = \frac{14}{15} = 933\text{mA}.$$

Thus, we select a transformer of rating 240/15V, 50Hz, 2A.

For a full wave bridge rectifier [14], $PIV = 2V_{max}$ (5)

$$V_{max} = V_{rms} \times \sqrt{2} = 15 \times \sqrt{2} = 21.21V$$

$$\therefore PIV = 2 \times 21.21 = 42.42V.$$

Thus, a full wave bridge rectifier chip that can withstand 42.42V was selected.

For selection of the filter capacitor, ripple factor is given by (6) [15]:

$$\gamma = \frac{\text{rms value of component}}{\text{dc value of load voltage}} = \frac{1}{4\sqrt{3}FCR_L} \quad (6)$$

For a bridge rectifier, $R_L = \frac{V_L}{I_L} = \frac{V_2}{I_2}$ (7)

where V_L is the load voltage and I_L is the load current respectively.

$$\therefore R_L = \frac{15}{0.63} = 23.81\Omega.$$

Assuming γ of 10%,

$$\therefore C = \frac{1}{4\sqrt{3}F\gamma R_L} = \frac{1}{4\sqrt{3}\times50\times23.81\times0.1} = 1212.14\mu\text{F}.$$

Thus, a standard capacitor value of 1500µF was selected for the design.

For the voltage dividers connected across the capacitor, the resistors values were determined thus:

The mathematical expression for voltage divider operation is given as [16]:

$$V_o = \frac{R_1}{R_1 + R_2} V_i \quad (8)$$

where V_o is the output DC voltage to the microcontroller (5V DC), V_i is the input DC voltage and R_2 = 10kΩ.

$$\therefore R_1 = \frac{V_o R_2}{V_i - V_o} = \frac{5\times10\times10^3}{15-5} = 5k\Omega.$$

Thus a standard value of 5.4kΩ was chosen for the design.

The LM78XX series regulator family was used. For this design, LM7805 and 7812 IC regulators were selected to give 5V and 12V output voltages for the entire components used for the circuit.

3.1.2 Control Unit

The control unit consists of an ATMEGA328P clocked by a 16MHz crystal oscillator. The design values for this unit were gotten from the datasheet of the microcontroller. The program (logical instruction set) of the microcontroller were coded in Arduino programming language and uploaded into the component (ATMEGA328P) using an Arduino board. In this circuit design, the microcontroller is programmed to carry out the following functions: (1) Phase Selection (2) Over voltage control (3) Under voltage control (4) LCD display control (5) Alarm control. The predetermined safe limits of operation for the phase selection system as programmed into the microcontroller is between 160V and 220V AC supply.

The three phases of the power supply are prioritized in the following order: Red, Yellow and Blue. When the voltage supply is within the range of 160-220V on the Red phase, the Red phase will be active above all others. But if the condition is not satisfied in the Red phase, the control switches to the yellow phase. If condition is as in Red phase, then control circuit switches to the Blue phase. The microcontroller is interfaced with the switching, alarm and display units.

3.1.3 Switching Unit

The switching unit comprises of transistor chip (ULN2003A) and three relays (12-28V DC, 30A, 240V AC), each of the relays is connected to each of the phase of the power supply. The major function of the switching unit is to alternate between the three phases as controlled by the microcontroller which monitors the voltage supply changes.

3.1.4 Display Unit

The primary aim of using a liquid crystal display (LCD) in this work is to display the status of the system in a text form which can be read by the user. The LCD used is a 4 by 16 character display. The LCD displays the voltage level of each phase in percentage. It also displays the active phase, which is the phase feeding the load at that instance. In a case of total power outage from the three phases, the LCD goes off.

3.1.5 Alarm Unit

The alarm unit basically is for notification of any form of change in the phases of the circuit except for when the power is off (power outage). Whenever the system switches from one phase to the other as a result of over or under voltage, the microcontroller sends a signal to the alarm unit and the alarm sound comes ON for a minute (as predetermined in the microcontroller program).

3.1.6 Load Design

For effective design, the value of load current must be determined. In this work, the load considered in the design was a 100W bulb and a 13A socket. To get the design value of the relay, minimum current rating of the relay was considered with respect to the load being powered.
Therefore total load current is the sum of the current rating of the bulb and the current rating of the socket.

$$Current\ rating\ of\ the\ bulb = \frac{100W}{240V} = 0.4167A$$

$$\therefore current\ rating\ of\ the\ load = (13 + 0.4167) = 13.4167A \approx 13.5A$$

Thus, a 30A relay was chosen for each phase. For safe operation, the relay contact current should be greater than the AC input current on that line, hence 30A (I_R) > 13.5A (I_L).

Fig. 3 presents the complete circuit diagram for the automatic power selection switch.

3.2 System Operation

The sequence of operation of the automatic power selection switch based on microcontroller ATMEGA328P is as shown in Figure 4.

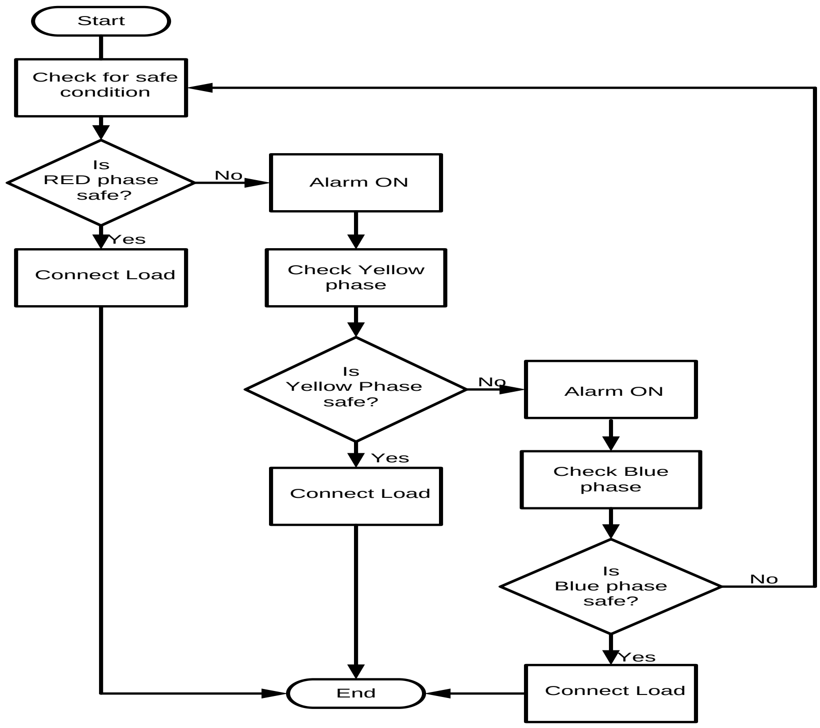


Figure 4: Flowchart of the automatic power selection switch

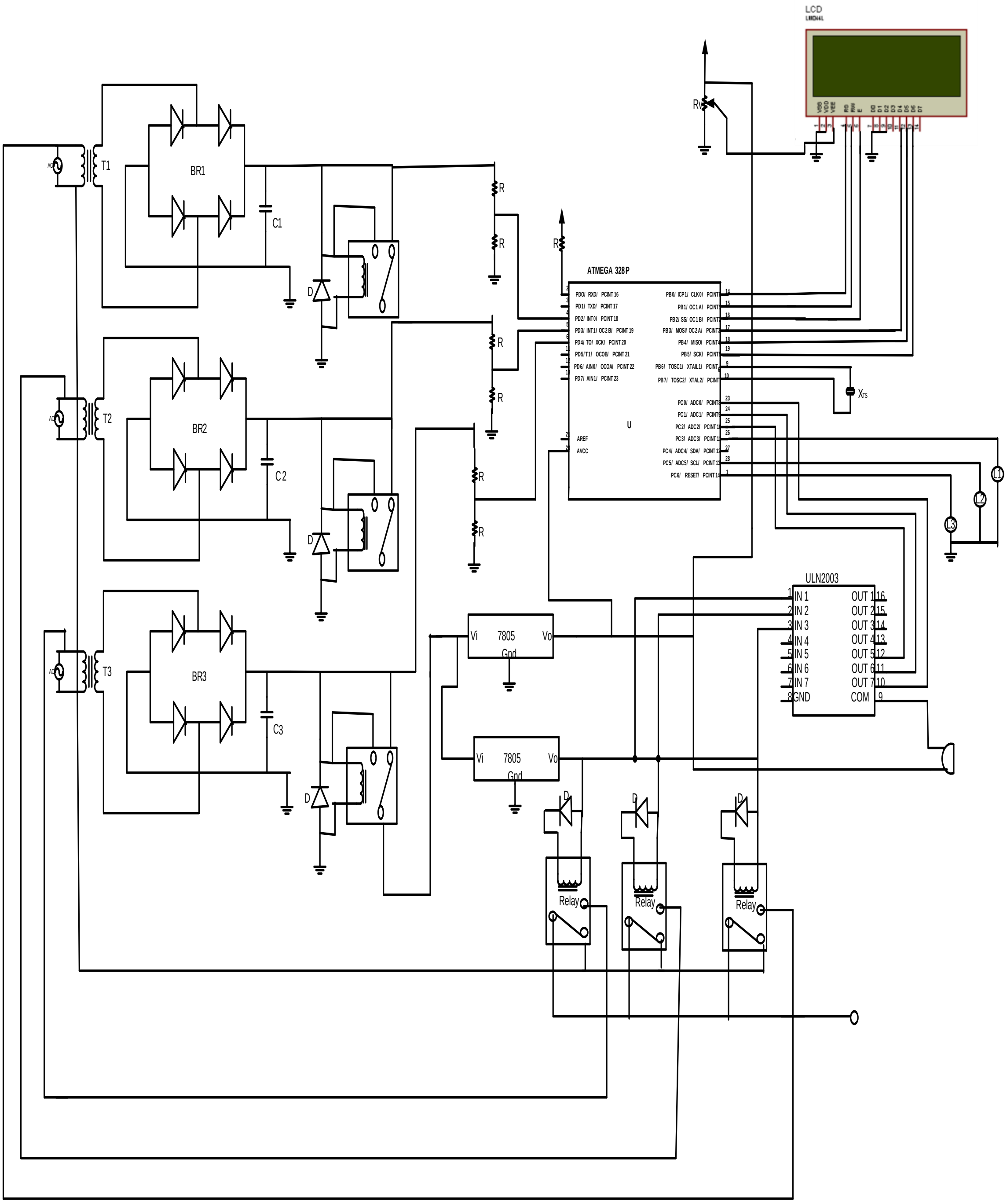
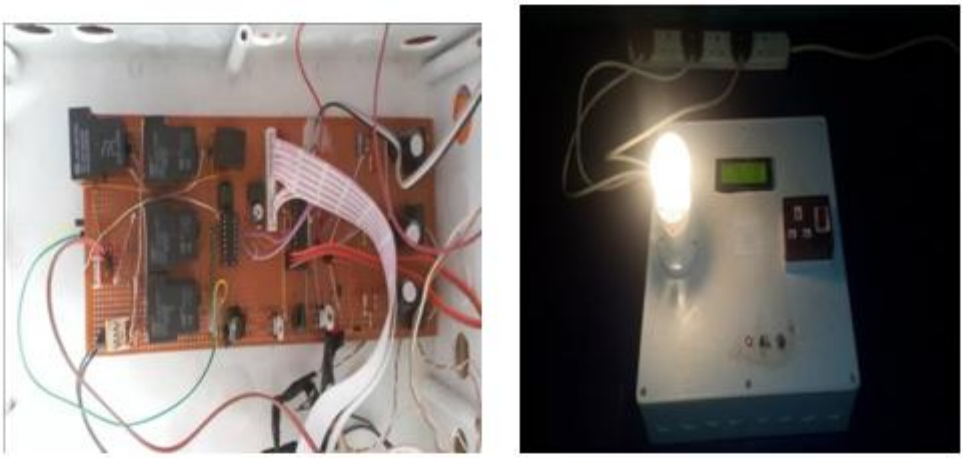


Figure 3: Complete circuit diagram for the automatic power selection switch.

IV. System Development

The designed circuit of the automatic power selector switch presented in Fig. 3 was first simulated on Proteus, after which the circuit was wired and a model developed as shown in Fig. 5.



(a) Wired system (b) Control circuit in operation
Figure 5: Developed automatic power selection switch

4.1 Test

Phase priority test was performed on the developed work to determine the efficiency of the design. This test was done by first, supplying power to all phases and sequentially removing the supply from each phase. Table 1 is a logical table showing the result of the test where “1” indicates power availability in the phase or the phase is operating between 160V to 220V AC. While “0” indicates power outage in the phase or the phase is operating below 160V or above 220V AC supply.

Table 1: Result of priority test on the three phases

Red Phase	Yellow Phase	Blue Phase	Output	Active Phase
0	0	0	**OFF**	None
0	0	1	**ON**	Blue Phase
0	1	0	**ON**	Yellow Phase
0	1	1	**ON**	Yellow Phase
1	0	0	**ON**	Red Phase
1	0	1	**ON**	Red Phase
1	1	0	**ON**	Red Phase
1	1	1	**ON**	Red Phase

4.2 Evaluation

The circuit of the automatic power selection switch is desired to switch from one phase of power supply to another in an event of power outage in the serving phase or in the event of under or over voltage (as specified in the microcontroller program codes). From Table 1, it is obvious that the Red phase is chosen over the other phases when operating in the safe mode (i.e.160-220V). But when the Red is out of the safe condition, the yellow phase takes the lead, and when the yellow phase drops out of the safe condition, the blue phase takes the lead. When all the phases are not in the safe operating condition, the load is cut off from the power supply terminals. However, the alarm comes on whenever there is a change in phase.

V. Conclusion

In this paper, an automatic power selection switch was designed and developed to help control power supply to electrical equipment, with the aim of preventing the equipment from damage as a result of under and over voltage supply. The performance of the designed work as demonstrated by the prototype shows high efficiency of operation with respect to the desired aim. It is to be used on single-phase loads that have opportunity of interfacing with two or three phases of power supply. The system is applicable to electrical equipment operating within 160V and 220V power supply in homes, offices and workshops. This system with little modification can be converted into an automatic changeover from utility to generator or another source of power supply. There is need to include a back-up dc supply to allow for continuous operation of the control and display units, so that users can have true information about the power situation.

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