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Application of a microcontroller in automatic electrical domestic changeover system

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ABSTRACT

The design, development, and simulation of an automatic Electrical Mains Changeover System (EMCS) using a PIC microcontroller (µC) has been presented in this study. The system consists of an 18-pin DIP package enhanced flash microcontroller PIC16F84A with a 4 MHz crystal used as the main processor, two switching transistors, two relays, and a Low Voltage Power Supply (LVPS). The electrical mains control signal output at RB0 and RB2 of PortB actuate two switching transistors which drive two relays to operate the loads depending on the availability of mains or backup power source. An assembly language program based on MPLAB IDE has been developed to control the operation of the system. The design and verification of the PIC µC based EMCS in the Proteus 8 simulation platform have been completed successfully.

1. Introduction

Electrical Mains Changeover System (EMCS) is an Automatic Transfer Switch (ATS) that switches a load between two power sources. Some transfer switches are manual in that case operator affects the transfer by throwing a switch. While others are automatic and trigger when they sense one of the sources has lost or gained power. No matter what type of power source is selected for backup power protection, a reliable electrical device is needed to automatically sense the unacceptability of the primary power source and transfer the load to the secondary. Although the backup power source may be functional only when the primary source fails, the transfer switch is the only link between the two power sources (ASCO, 2017). In this regard, the researcher aimed at designing and constructing a workable automatic change-over switch with generator start/shut down functions. This switch turns ON the generator automatically in cases of a mains power failure and connects the load to the generator output, alternatively, it switches OFF the generator automatically once power is restored and returns the load to the mains power (Ezema et al., 2012). In Kelechi et al. (2015); the design and implementation of a Microcontroller-based power change-over switching system with generator shutdown disconnects the load from its power source and transfers it to a standby power source in the advent of a power failure. Thereafter, an Automatic Transfer Switch (ATS) for a single-phase power generator has been designed to enable the automatic operation and transfer of power supply between a public utility supply and a power generator (Agbetuyi et al., 2011). In the current research, the design, development, and simulation of a PIC microcontroller (µC) based automatic Electrical Mains Changeover System (EMCS) has been presented. The 18-pin DIP Package Enhanced Flash Microcontroller PIC16F84A based on an assembly language program developed in MPLAB IDE actuates the switching transistors which drive the relays to operate the loads depending on the availability of mains or backup power source.

2. Materials and methods

The design, development, and simulation of an automatic Electrical Mains Changeover System (EMCS) using a PIC Microcontroller (µC) have been presented in this research. The system consists of the microcontroller PIC16F84A with a 4 MHz crystal used as the main processor, two switching transistors, two relays and Low Voltage Power Supply (LVPS). Block diagram, schematic diagram, circuit description, functional description and program flowchart for the designed EMCS have been presented accordingly:

- **Block diagram:** The block diagram of the Microcontroller-based automatic Electrical Mains Changeover System (EMCS) with Mains Sensing,

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PIC Microcontroller P16F84A, switching transistors, and Relays have been shown in Fig. 1.

- **Schematic diagram:** Complete simulation model of the µC based automatic electrical mains changeover system has been shown in Fig. 2. The description of the individual circuit has been given.
- **Low voltage power supply:** A power supply must provide stable and ripple-free DC output voltage independent of line and load variations (Islam et al., 2012). Therefore, the low voltage power supply is essential for the system and a built-in 5V DC power supply has been used in Proteus 8 simulation platform.

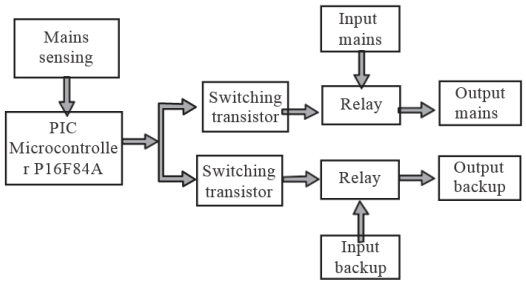

Fig. 1: Shows the block diagram of the µC based automatic electrical mains changeover system

- **Mains sensing circuit:** The mains sensing circuit's function is to detect whether electrical mains present or not consists of an SPST Switch SW1, Variable Resistor RV1, bridge rectifier BR1, filter capacitor C1, discharge Resistor R1, bias Resistor R2, collector Resistor R3, transistor Q1, NOT gate U1 and Resistor R4.
- **Mains indicator circuit:** The mains indicator circuit comprises Resistor R5, R6, Transistor Q2, and LED-RED D1.
- **Processor input circuit:** The processor input circuit consists of Resistor R4, the processor PIC16F84A I/O pin RA2 of portA, and Resistor R12.
- **Processor circuit:** The processor circuit is the heart of the developed system and comprises of PIC16F84A 18 pin DIP Package Enhanced Flash Microcontrollers. It consists of CPU, memory for data and program, Special Function Registers (SFRs), General Purpose Registers (GPRs), 2-port (PortA&PortB), active low MCLR, and interrupts and free-run timer TMR0 and so on (Islam et al., 2012). An assembly language program has been developed by using MPLAB IDE to control the function of the processor as well as the system.
- **Mains switching circuit:** The function of the mains switching circuit is to receive the mains sensing signal from the mains sensing circuit that the electrical mains are present. Then the electrical mains control signal output at the processor PIC16F84A I/O pin RB0 of PortB actuates the switching transistor Q3 which drives the relay RL1 to operate the loads connected with the mains power source. The following components constitute this circuit such as Resistor R9, Relay RL1, Transistor Q3, and LED-RED D2.

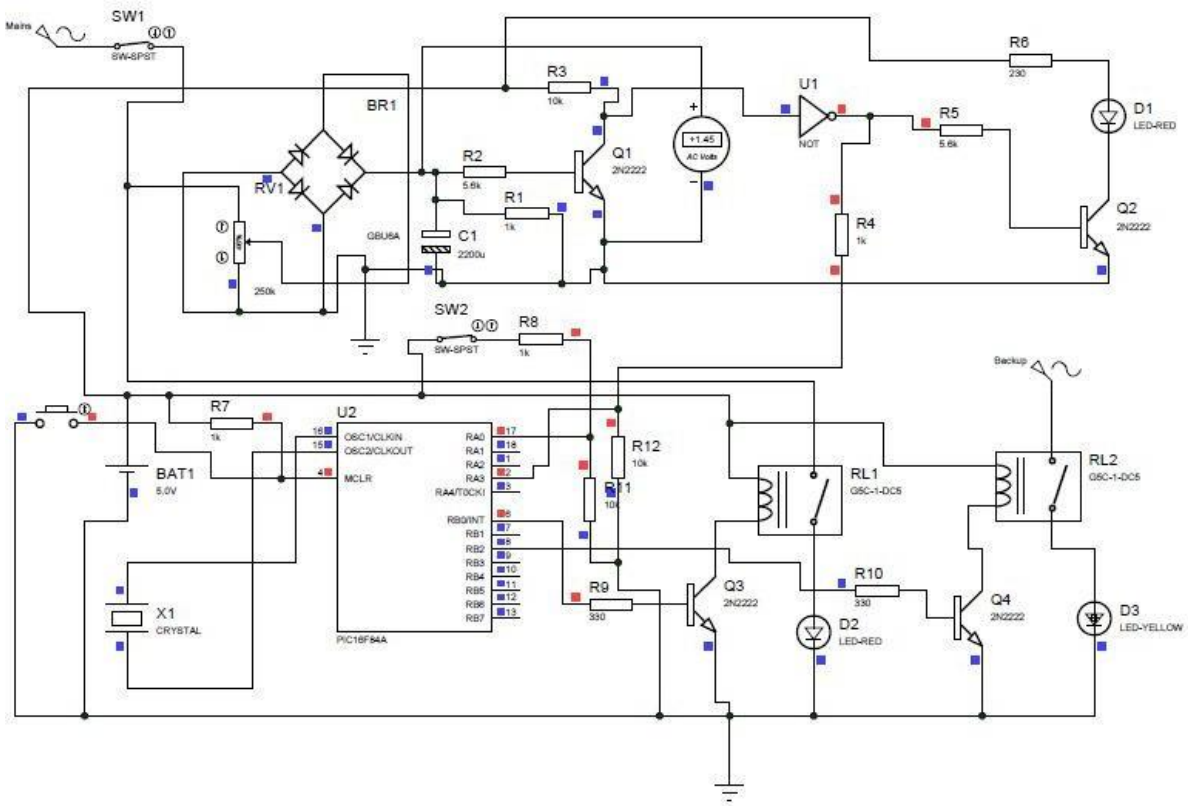

Fig. 2: Complete schematic diagram of µC based automatic electrical mains changeover system

- **Backup switching circuit:** The function of the backup switching circuit is to receive the mains sensing signal from the mains sensing circuit that the electrical mains are not present. Then the electrical mains control signal output at the processor PIC16F84A I/O pins RB2 of PortB

actuates the switching transistor Q4 which drives the relay RL2 to operate the loads connected with the backup power source. The following components constitute this circuit such as Resistor R10, Relay RL2, transistor Q4, and LED-YELLOW D3.

- **Start/stop circuit:** The start/stop circuit consists of SPST switch SW2 and Resistor R8 and R11.
- **Reset circuit:** The reset circuit has the Microcontroller PIC16F84A I/O pin active low MCLR is tied to Vdd through a Resistor R7 and grounded via a push switch.

3. Results and discussion

Electricity (energy) plays a major role in the socio-economic development of a nation with an interest in human, infrastructural, industrial, and economic development. In most developing and Least Developed Countries (LDCs) of the world, the supply of electricity for household, commercial and industrial use is highly unstable. This gives rise to the frequent use of alternative sources of power supply to meet up with the energy demands. 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 (Ezema et al., 2012). Therefore, an automatic Electrical Mains Changeover System (EMCS) based on PIC Microcontroller (µC) has been designed, developed, and tested in Proteus 8 simulation platform. Thus, for finding the solution to switching over to the alternative sources of supply without any delay with an unattended operation that affects the change to the alternative sources comes the importance of the research work. In this study, at first, the mains sensing circuit detect whether the public utility service, i.e., electrical mains present or not. Depending on the availability of mains this circuit generates a signal which is suitable for input into a microcontroller I/O pin. Thereafter, the processor PIC16F84A 18 pin DIP Package Enhanced Flash Microcontroller processes the assembly language program code developed in MPLAB IDE. According to this program µC generate signals to actuate two switching transistors to drive two relays for mains or backup power supply. If the mains is present then the system will run the same otherwise it will act for a backup power source as shown in Fig. 3. The system consists of a few front panel controls such as start, stop, and reset. It has also a mains indicator. The power indicator can be added as required.

4. Conclusion

In this research, the design, development, and simulation of a PIC microcontroller (µC) based automatic Electrical Mains Changeover System (EMCS) has been presented. The design and verification of the PIC µC based Electrical Mains Changeover System (EMCS) in the Proteus 8 simulation platform have been completed successfully. The designed system is cost-effective, simple, and reliable in operation. The EMCS has been tested repeatedly and its performance was found satisfactory.

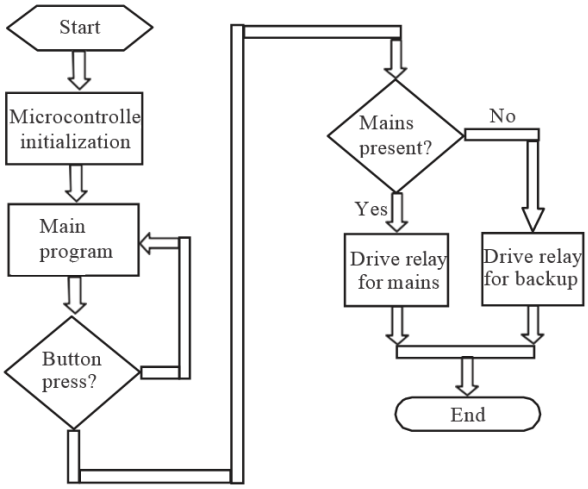

Fig. 3: Shows the program flowchart for the developed system

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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