Design and Construction of an Automatic Power Changeover Switch

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Abstract

Power failure or outage in general does not promote development to public and private sector. The investors do not feel secure to come into a country with constant or frequent power failure. These limit the development of industries. In addition there are processes that cannot be interrupted because of their importance, for instance surgery operation in hospitals, transfer of money between banks and lots more. This paper presents the design and construction of an automatic power changeover switch that switches power supply from public supply to generator once there is public power supply outage and it does this automatically. This is achieved by the use of integrated circuits that have timing abilities and relays to effect switching.

Keywords: *Switching, relay, generator, motor, public power supply, transistor.*

Introduction

The project is designed for power supply applications. It involves automatic changeover between the main power supply and an auxiliary power supply, such as a generator. The project implements an automatic switching or starting of the power generator whenever the main power fails. The circuit of the project consists of logical control unit and relay switches. The design of the project takes into consideration practical or real life situations, even though it is a prototype design. Irrespective of that fact, a lot of precautions were put in place to make its performance acceptable.

The basic operation of the project is to switch ON an auxiliary power supply (like a generator). This operation connects the power supply from the generator to the load after a predetermined time interval. This is intended to normalize the current from the generator. Switching is possible through the use of the relays.

The system was designed to automatically change power supply back to the main supply moments after the A.C. mains are restored and to switch OFF the generator. The device removes the stress of manually switching ON the generator when power failure occurs.

Whenever public power supply is available, relay 3 in Fig. 4 is energized and terminals C_3 and B_3 of the relay are connected together. Whenever public power supply is cut off from the transformer, C_3 and A_3 of the relay are connected together and the power circuit is then powered through the 12V battery.

The first important action as related to the circuit is the automatic resetting of both latches through Schmitt trigger AND gate (4093B) whenever public power supply is available. The gate allows Q and Q^- of the latches to be at logical zero and one respectively, this is required for normal starting state. For the motor control latch Q is connected to Q_1 (transistor 1) through the base. The NPN device controls the relay. For Q at logical 1, Q_1 is saturated and relay 1 is energized. Terminals C_1 and B_1 of the relay is connected together. The operation allows electric current to flow through the motor/starter. It is noted that one of the motors terminals is already connected to 12V+ terminals. The switching of the relay allows the other terminal to be grounded thereby completing the circuit of the electric motor.

The control oscillator starts timing immediately relay 3 supplies electric current to the logic control unit. Pin 2 of the control oscillator is related to 1.6Hz or 0.6sec signal. Therefore, the motor control latch is set by the control oscillator around 0.62 sec.

Signal from pin 3 of the control oscillator is used for setting the changeover latch. The initial condition of the latch's output after reset by the Schmitt trigger AND gate is Q logical zero and Q^- logical 1. The Q output is connected to the base of Q_2 (transistor 2). Therefore, the transistor is cut off. The result is that terminals A_2 and C_2 of relay 2 are connected together.

Relay 2 supplies power supply to the output load from two sources, G and M. M represent public power supply and G represents power supply from the generator.

Therefore the initial condition is the supply of power to the load through the normal A.C. mains. The control oscillator through its pin 3 sets the changeover latch for the Q output to change from logical zero to 1 for Q_2 to be saturated in reversing the output condition of relay 2. The switching time of the changeover operation is the period of the signal from pin 3 (1.23 sec). The fact is that timing is quite longer than the calculated values due to internal capacitance of the circuit and variations of frequency.

Methodology

The operation of the power unit was well organized and coordinated for an efficient performance. The operational process is outlined below:

(i) The power circuit is not active when there is A.C. mains supply.

(ii) Its response to A.C. mains supply power failure is by switching on the starting mechanism of the generator.

(iii) There is a delay in the loading of the generator so as to attain stability for a while. After the said delay, the generator is loaded.

(iv) Power supply from the generator is interchanged the moment the A.C. mains are restored. Immediately after this the generator is switched off.

The circuit contains some integrated circuits (IC) more especially the CMOS (complimentary metallic oxide silicon) type. The CMOS consumes less power from the battery. That is why it was incorporated into the circuit. The circuit also consists of relays that provide external switching. These devices are quite robust for efficiency and reliability. Fig. 1 is the functional block diagram of the system.

Control Logic Unit

The control logic unit operation is based on sequential timing. The main component of the unit is a control oscillator (4060B). This device initiates the required switching in the circuit. Although, the device has ten control terminals, only two are used in the circuit for controlling two latches.

The 4060B in Fig. 2 is a CMOS RC/crystals oscillator/divider integrated circuit. It is usually configured in the RC mode. Its pin 12 is required logic zero or ground for normal operation. Pin 9, 10 and 11 are output 1, output 2 and clock terminals, respectively (Theraja and Theraja 2002). They are needed for the RC oscillator mode. The device works within 3-18 volts power supply.

The 10 output signals are derived from a main frequency. The main frequency of oscillation is given by (Horowitz and Hill 1995; Thomas 1997; Theraja and Theraja 2002):

$$F_m = 1/(2.3R_{tc}*C_{tc}), \quad (1)$$

where $10R_{tc} \geq R_5 \geq 2R_{tc}$.

The typical values of R_5, R_{tc} and C_{tc} are 100 kilo ohms, 33 kilo ohms and 0.001 microfarad. Therefore,

$$F_m = 1/(2.3*33*10^3*0.001*10^{-6}),$$

$$F_m = 13.2 \text{ KHz}.$$

The output frequencies are based on the following formula:

$$F_{qx} = F_m/2^X. \quad (2)$$

Frequency output from pin 2 is given by

$$(F_{q13} = F_m/2^{13}) = 13.2*10^3/2^{13},$$

$$F_{q13} = 1.61\text{Hz},$$

$$T_{q13} = 1/F_{q13},$$

$$T_{q13} = 1/1.61 = 0.62\text{sec}.$$

Frequency output from pin 3 is given by

$$F_{q14} = F_m/2^{14} = 13.2*10^3/2^{14},$$

$$F_{q14} = 0.81\text{Hz},$$

$T_{q14} = 1/F_{q14}$,
$T_{q14} = 1/0.81$,
$T_{q14} = 1.23$sec.

These signals are used for switching or controlling two latches which deal with motor and changeover control. 4013B integrated circuit contains two independent latches. They work with active high input signals.

Although the 4013B is really designed for *D* type application, the latches in the circuit are configured in the *SR* mode by grounding the corresponding clock and *D* inputs as shown in Fig. 3. As earlier stated, two of such latches are required for the circuit. One controls relay 1 that switches ON and OFF the motor/starter. The other latch handles the changeover operation between the public power supply and the auxiliary power source to a particular load.

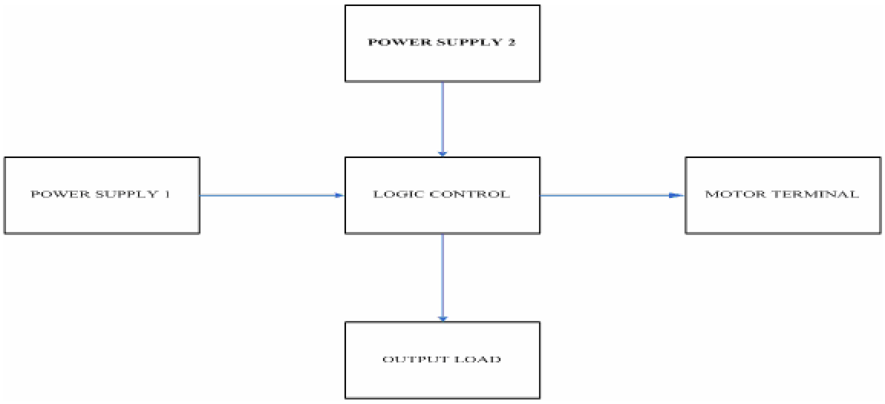

Fig. 1. Block diagram of the circuit.

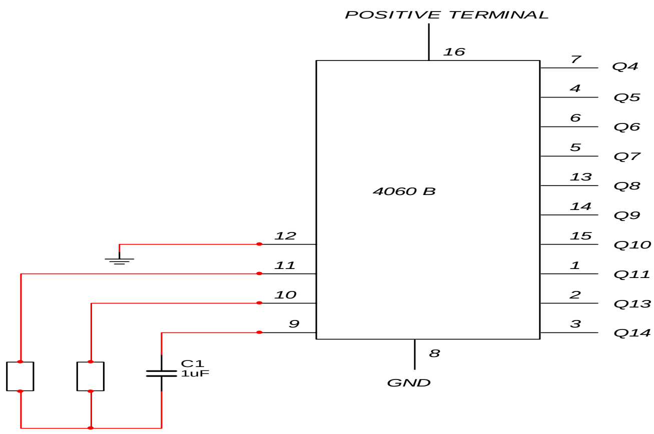

Fig. 2. Normal *RC* mode of the 4060B showing its pin configuration.

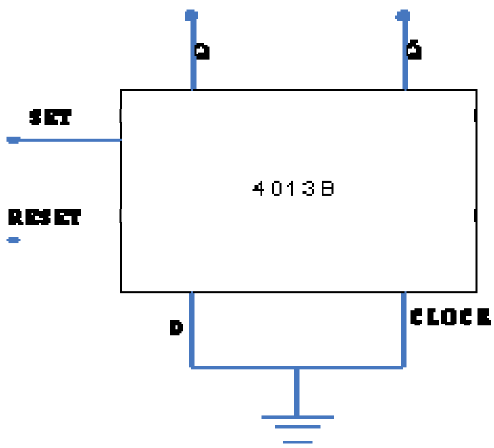

Fig. 3. A D-type latch at SR mode.

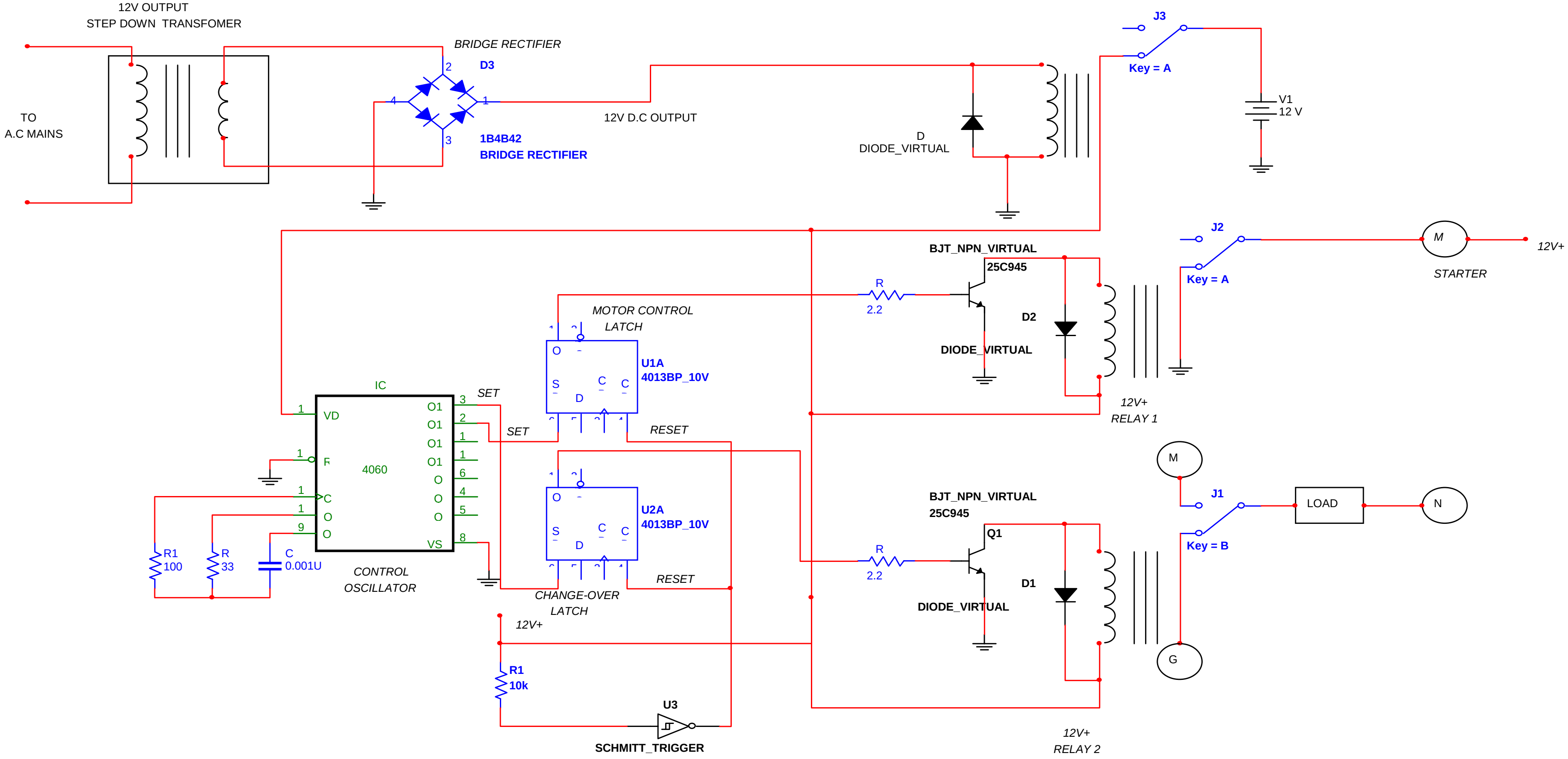

Fig. 4. System circuit diagram.

Motor Terminal

The motor terminal is intended for an electric motor (kick-starter), which starts an internal combustion engine that powers an alternator. Because the project is a prototype, this terminal is connected to a 12V electric motor that represents a kick-starter. When electricity is supplied to terminal of the motor, the engine switches on.

Output Load Terminal

This is the terminal that supplies the wiring of a building with electricity from either the normal A.C. mains power supply or auxiliary power supply, such as a generator. For clarity, the expected power supply from the generator is intended as back up to the normal A.C. mains power supply. A 60w light bulb is connected to this terminal as the load.

Relay Switching Circuit

A relay is an electromagnetic device that is used by varying the input in order to get a desired output. Relays are of two types, the normally closed and normally open (from Texas Instruments data sheets, Anon. 2003-2007). The type used in this project is the normally open relay.

It is a good and common practice to switch a relay with a transistor. The transistor is set in the common emitter configuration.

The switching transistor used is 25C945. It is an NPN device with maximum current and voltage ratings of 100 milliamperes and 50 Volts. It possesses a typical current gain of 100. The resultant load or resistance of the relay in the transistors collector is 400 ohms (Amos and James 1981; Anon. 2003-2007). Therefore for full saturation of the transistors, the bases of the switching transistors are connected to the latches through a 2.2 Kohm resistor.

Performance Evaluation

In other to test the performance of the system, Switch *A* is inserted in series into the circuit immediately after the bridge rectifier and another Switch *B* is inserted in series next to the battery supply. During this test the public supply is available and the battery is fully charged. A 60 W bulb is used as the load and a 12 Volts motor is used as the kick-starter. Also during the test, one of the phases of the public supply is used in place of the generator supply.

The following steps were involved in the operation of the circuit:

- Switch *A* opened (OFF) simulates public supply outage.
- Switch *A* closed (ON) simulates public supply availability.
- Switch *B* opened (OFF) simulates a bad battery or battery unavailability or faulty generator.
- Switch *B* closed (ON) simulates battery availability.
- Motor ON means the 12V motor rotates for about 4 sec.
- Bulb ON means the 60W bulb lights.

The results of the performance evaluation are summarized in Table 1.

Table 1. Summary of performance evaluation.

Step	Switch *A*	Switch *B*	Motor	Bulb	Comments/Observations
1	OFF	OFF	OFF	OFF	No supply gets to the load since there is public supply outage and the generator/battery are in bad condition
2	OFF	ON	ON	ON	The bulb light up after about 8 sec powered by the generator. During the first 4 sec the motor rotates and stops. During the next 4 sec the generator builds up voltage after which the load is connected
3	ON	ON	OFF	ON	The bulb light up powered by the public supply
4	ON	OFF	OFF	ON	The bulb light up powered by the public supply

Conclusion

An automatic power changeover switch has been designed and constructed. The prototype of the automatic power changeover switch worked according to the specification and quite satisfactorily. The device is quite cheap, reliable and easy to operate. Whenever there is power outage, it reduces stress for manpower changeover.

References

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