

Design of Microcontroller-Based Automatic School Bell

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Abstract

The world over the decades has made considerable advancement in automation; automation is employed in homes, industries, commercial and educational sectors. In this work, a microcontroller-based automatic school bell is designed. This circuit uses a programmed microcontroller chip to schedule the school teaching and break periods so that for every start or end of a period a bell is automatically rang. This design finds a tremendous use at primary and secondary school levels where the teaching sections can span over eight periods including breaks. The advantage here is that the bell rings at the start of each period without any human intervention to a great degree of accuracy. The time schedule results are compared with that obtained with a clock, however, some drift is noticed, which is negligible.

Keywords: Automation, break period, time-select switching unit, pull-up resistors, oscillator characteristics.

1. Introduction

A bell is a percussion instrument used in schools that tells the students when it is time to go to class in the morning and when it is time to change classes during the day. Typically, the first bell tells the students that it is time to report to class. The bell is an important instrument in both primary and secondary schools and even in the industries and other businesses where the bell timer plays a critical role in running the day (Wikipedia 2011). Bells are also associated with clocks indicating the hour by ringing. Clock towers or bell towers can be heard over long distances which was especially important in the time when clocks were too expensive for widespread use. The bell shape is usually an open-ended hollow drum which resonates upon being struck.

Bells were known in China before 2000 BC and in Egypt, India, Greece, Rome, and other ancient cultures. From earliest times, they were used as signaling devices, as ritual objects, and as magical, often protective, amulets (often hung in doorways or around the necks of animals). The use of bells in churches spread through Europe from the 6th to 11th centuries and were first used in Eastern Christian

churches in the 9th century (Encyclopedia 2011).

2. Design

The entire circuit is designed in blocks of different modules as shown in Fig. 1. The subsequent sessions describe the various modules that are included in the microcontroller based automatic school bell.

2.1 Design of Power Supply Unit

Most of the electronic devices and circuits require a *dc* source for their operation (Theraja and Theraja 2003). The *dc* power supply converts the standard 230 V, 50 Hz *ac* available on wall outlets into a constant *dc* voltage. It is one of the most common electronic circuits that one will find and an emphasis will not be laid on its circuit design, however, the power supply circuit diagram is shown in Fig. 2.

2.2 Design of Time-Select Switching Unit

This unit is responsible for the selection of timing suitable for a particular school. This

is done by pressing the switch that corresponds to the school schedule on the timetable. The unit comprises of 11 switches from S1 to S11. Each switch from S1 to S10 represents a single schedule and the set of ten switches gives a total of ten different timing schedules as shown in Fig. 3. A single schedule has a total of eight periods with a breakfast after the fourth period. The eleventh switch, S11, provides a room for any emergency that arises which will lead to the bell ringing, thus called an emergency switch. This emergency switch is common for every schedule selected and active at any point in time during the school hours.

2.2.1 Calculation of Pull-up Resistors:

Each switch is connected from the pins of microcontroller to the ground. Every microcontroller has ability to sink or source current. The type of microcontroller used in this design is AT89S51.

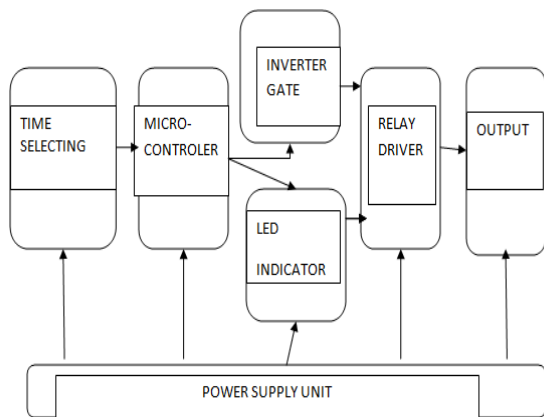


Fig. 1. Functional block diagram of the microcontroller based automatic school bell.

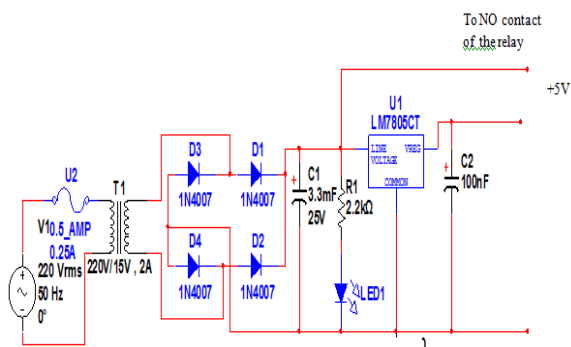


Fig. 2. Circuit diagram of power supply unit.

Table 1 shows some different possible timing schedules available for this design.

Table 1. Different timing schedules.

	Schedule	Switch Symbol	Duration Per Period (In minutes)	Duration of the Break (In minutes)
1.	1	S1	45	40
2.	2	S2	45	30
3.	3	S3	45	20
4.	4	S4	40	40
5.	5	S5	40	30
6.	6	S6	40	20
7.	7	S7	35	40
8.	8	S8	35	30

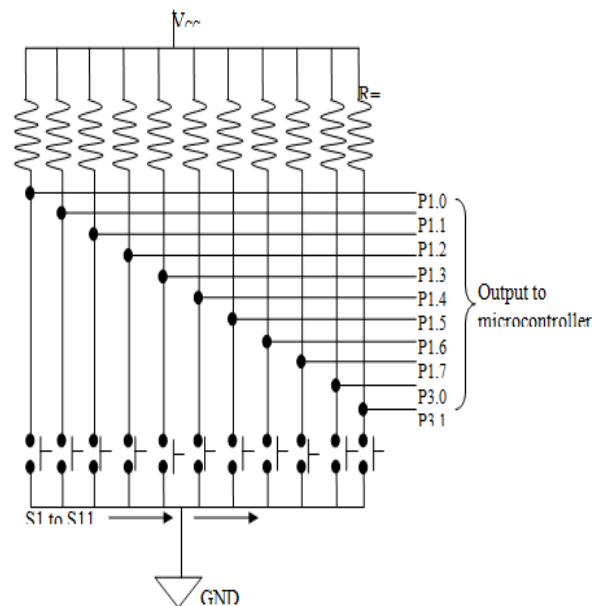


Fig. 3. Circuit diagram of the time-select switching unit.

From the datasheet of AT89S51 (2011), ports 1, 2 and 3 can sink current of about 1.6 mA. Therefore, by taking the sinking current to be 0.5 mA, the pull-up resistors can be calculated.

From Fig. 3, $V_{CC} = IR$, where $V_{CC} = +5\text{ V}$, $I = 1.5\text{ mA}$, $R = \text{pull-up resistor}$. Therefore, $R = V_{CC} / I = 5\text{ V} / 0.5\text{ mA} = 10\text{ k}\Omega$.

The pins that were connected to the switches are held HIGH by the pull-up resistors. The I/O ports of the 8051 microcontroller can be both read and written to (bidirectional), therefore, if any of the switches, after being powered, is pressed to select the schedule, the concerned pin of the microcontroller will be pulled down to ground which serves as the input to the microcontroller. When the microcontroller senses a signal from that pin, it will start executing some specific instructions as directed by the software programming.

Note: The emergency switch is always active at every point in time once the schedule has been chosen.

2.3 Design of Microcontroller Unit

The major component in this project design is the AT89S51 microcontroller which controls, coordinates and directs all the activities and behaviors of this design. Most control application require extensive I/O and need to work with individual bits. The AT89S51 addresses both of these needs by having 32 I/O, bit manipulation and bit checking.

The input from the timing unit to the microcontroller automatically selects the corresponding timing programmed within the microcontroller chip. The output of this goes to the LED indicator and inverter units as shown in Fig. 4.

2.3.1 Oscillator Characteristics: In this design, a quartz crystal was used. From the datasheet of AT89S51 (2011), it is noted that the capacitors C1 and C2 are $30\text{ pF} \pm 10\text{ pF}$ for crystals. Therefore, since a crystal was used, 33 pF was chosen for both capacitors C1 and C2 as shown in Fig. 4.

2.3.2 The Programming: The instructions that execute the timing were written on the microcontroller read/write memory using the flow chart shown in Fig. 5.

2.4 Design of LED Indicators Unit

The circuit diagram of this unit is as shown in Fig. 6. The limiting resistance can be calculated as follows. According to Boylestad and Nashesky (2007), the voltage across the LED is 1.7 V . From the datasheet of AT89S51 (2011), the sinking current of port 0.1 and port 0.2 is 3.2 mA .

For LED to glow, 1.7 V must drop across its terminal. Therefore,

$$V_{CC} = V_{LED} + IR,$$

where $V_{CC} = +5\text{V}$, $R = \text{limiting resistance for an LED}$, and

$$R = (V_{CC} - V_{LED}) / I = (5 - 1.7) / (3.2 \times 10^{-3}) = 1.03\text{ k}\Omega.$$

Therefore, the commercial value of $1\text{ k}\Omega$ was used in the design.

LED1, which has green color, glows immediately after a schedule has been selected, indicating that the school bell is active. It remains ON throughout the school periods.

LED2, which has red background, is oscillating at every second after the last period of the school hour is over. It indicates the end of the school periods.

2.5 Inverter (NOT) Gate

The inverter is used to complement or invert a digital signal. It has a single input and a single output. The symbol and truth table for the inverter gate are shown in Fig. 7(a) and (b), respectively.

In this design, the 7404 hex inverter is used, which is a single TTL integrated circuit (IC) package. It has six complete logic circuits fabricated into a single silicon chip. The 7404 has 14 metallic pins connected to the outside of a plastic case containing the silicon chip. The pin configuration of the 7404 is shown in Fig. 8. The power supply connections to the IC are made to pin 14 (+5V) and pin 7 (ground), which supplies power to all six logic circuits. In the case of the 7404, the logic circuits are called inverters.

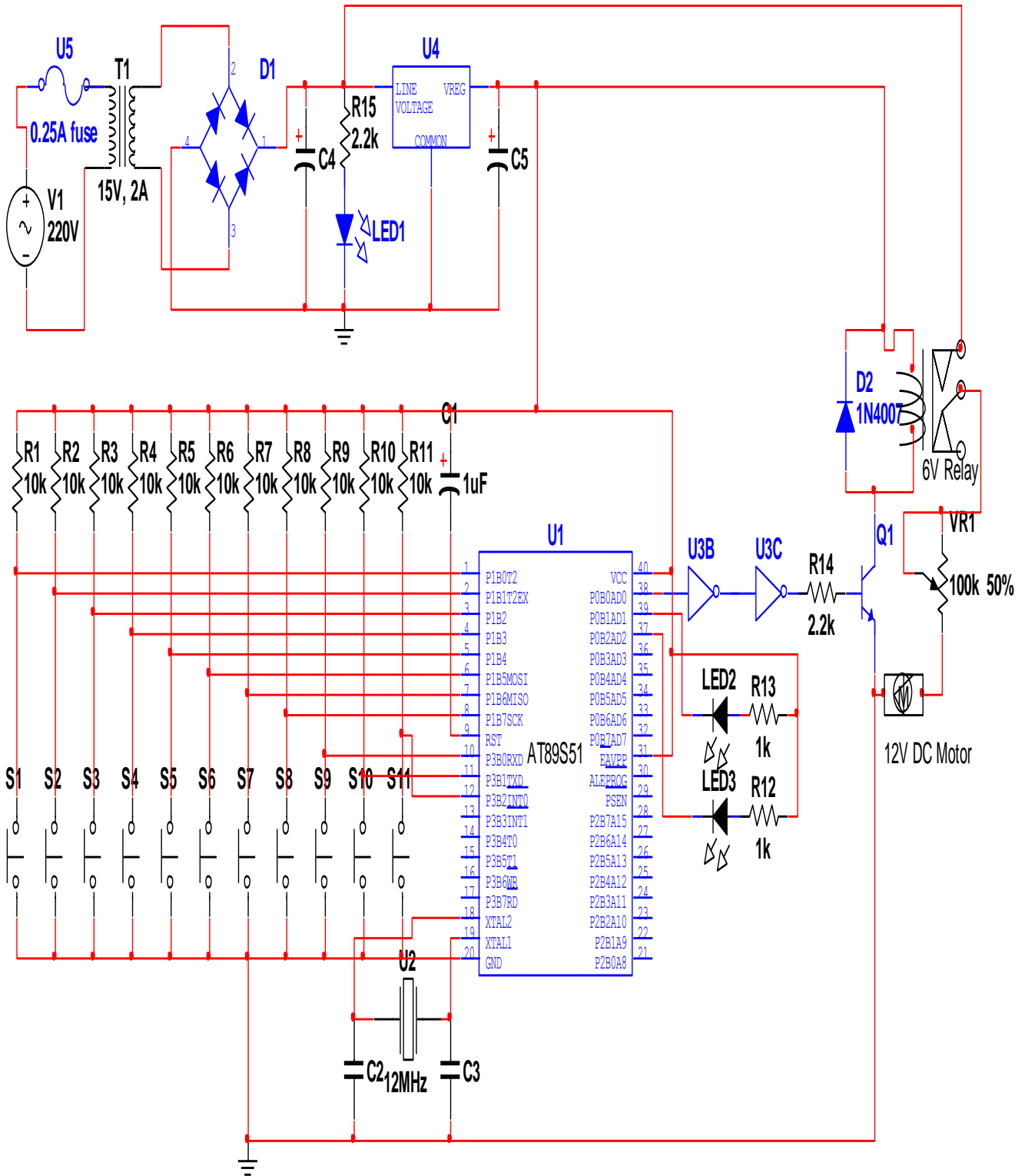


Fig. 4. Complete circuit diagram of an automatic school bell.

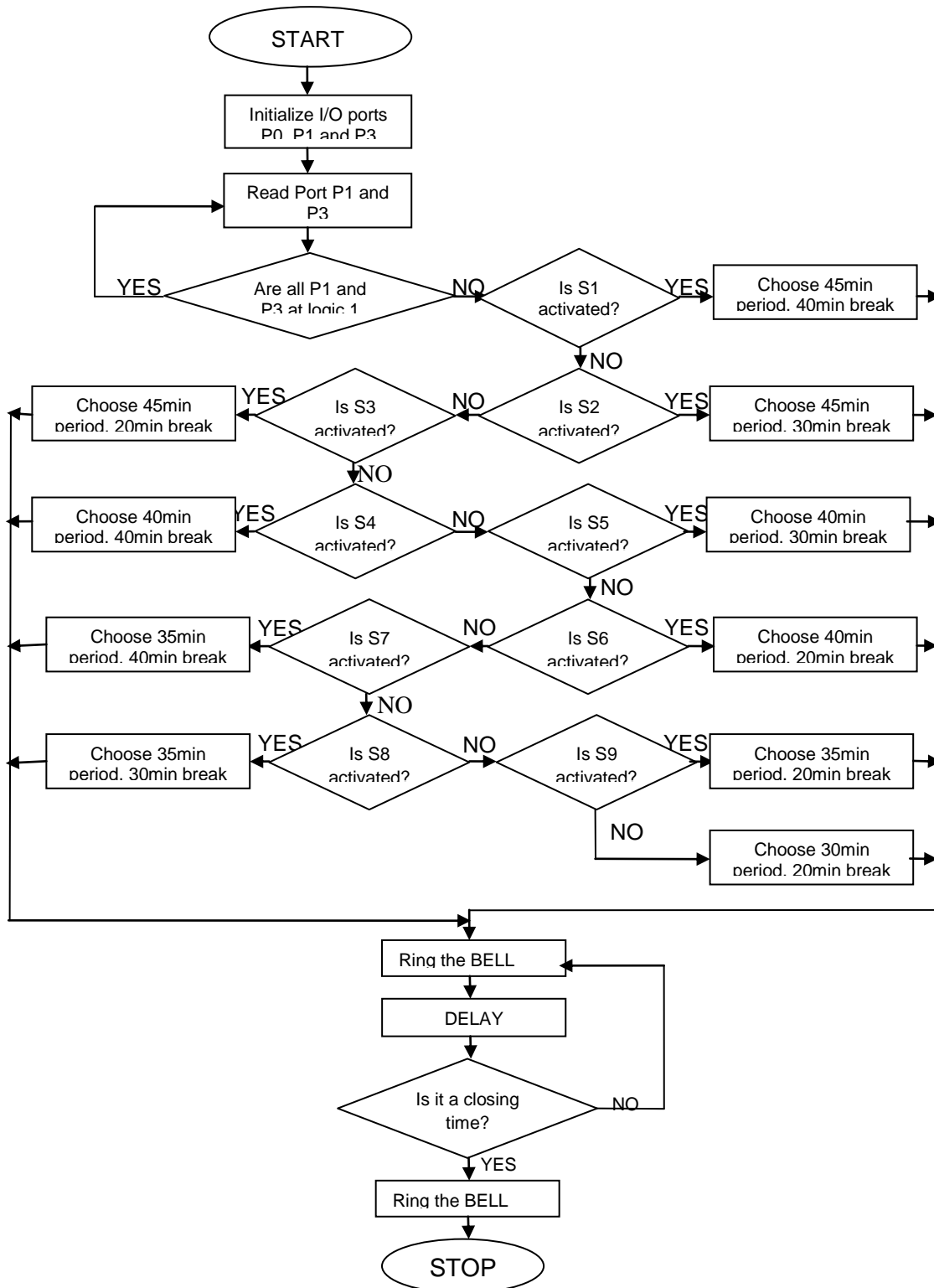


Fig. 5. Flow chart for the instructions that execute the timing.

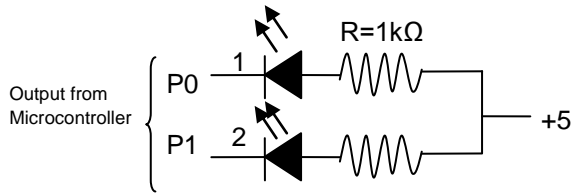
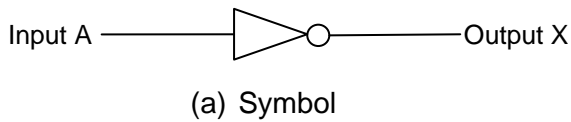


Fig. 6. LED Indicator Circuit Diagram.



(a) Symbol

Input A	Output X
0	1
1	0

(b) Truth table

Fig. 7. Inverter symbol and truth table.

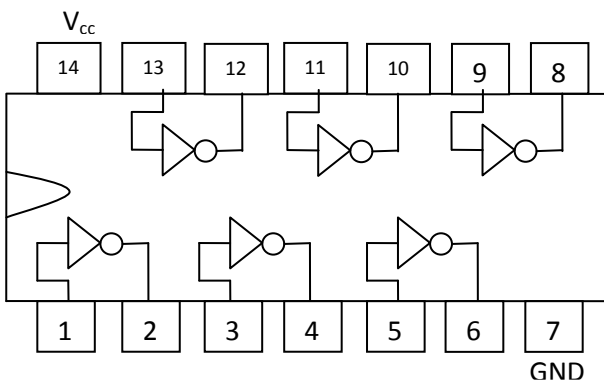


Fig. 8. A 7404 hex inverter pin configuration.

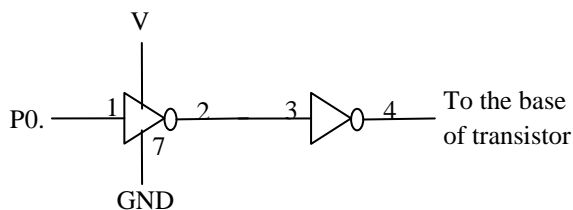


Fig. 9. A 7404 hex inverter pin configuration.

The output of the microcontroller goes to pin 1 of 7404 which is inverted and comes out of pin 2 as shown in Fig. 9. The output of pin 2 then goes to pin 3 which is also inverted and comes out of pin 4 as the input to the base of the switching transistor. This means that whatever comes out of P0.0 of the microcontroller, it is amplified through the two inverters looped together and serving as the input to the switching transistor. The inverter was used since AT89S51 does not source the sufficient current to trigger the base of the transistor.

2.6 Relay Driver Unit

2.6.1 Transistor as a Switch: In an electronic circuit, the input signal (1 or 0) is usually applied to the base of the transistor, which causes the collector-emitter junction to become a short or an open circuit. When a transistor is used as a switch it must be either OFF or fully ON. In the fully ON state, the voltage V_{CE} across the transistor is almost zero and the transistor is said to be saturated because it cannot pass any more collector current I_C . The output device switched by the transistor is usually called the 'load'.

2.6.2 Calculation of Base Resistance, R_B : The load resistance, which is the collector resistance, is the resistance of the relay coil as shown in Fig. 10.

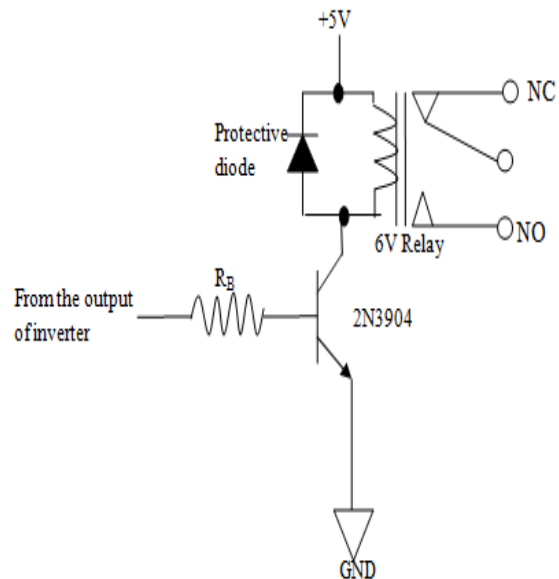


Fig. 10. Circuit diagram of the relay driver unit.

The 6 V relay used has the coil resistance of 100 Ω. Therefore, $R_C = 100 \Omega$. The NPN transistor used is 2N3904. Thus, from the datasheet of 2N3904:

$$I_{C(max)} = 200 \text{ mA}, h_{FE(max)} = 300.$$

Taking h_{FE} to be 100, implies that

$$h_{FE} = 100, R_C = 100 \Omega, V_{CC} = +5 \text{ V}.$$

But when the transistor is saturated (Mehta and Mehta 2008),

$$V_{CE(sat)} = 0.2 \text{ V}, V_{BE(sat)} = 0.7 \text{ V}.$$

Thus, at saturation (Mehta and Mehta 2008),

$$I_{C(sat)} = (V_{CC} - V_{CE})/R_C = (5 - 0.2)/100 = 0.048 \text{ A} = 48 \text{ mA}.$$

The minimum value of base current (Mehta and Mehta 2008) is then obtained,

$$I_{B(min)} = I_{C(sat)} / h_{FE} = 48 \text{ mA} / 100 = 0.48 \text{ mA}.$$

Therefore, the voltage across the base resistance R_B is (Mehta and Mehta 2008),

$$V_B = V_{in} - V_{BE(sat)},$$

where V_{in} is the output voltage of the inverter gate which is approximately equal to V_{CC} (+5V).

As a result, $V_B = 5 - 0.7 = 4.3\text{V}$, thus the maximum value of R_B is

$$R_{B(max)} = V_B / I_B = 4.3/0.48 \text{ mA} = 8.96 \text{ k}\Omega.$$

The maximum value of R_B that will allow a minimum I_B of 0.48 mA to flow was calculated by Ohm's Law. The actual value used should be much less. Therefore, the base resistance, R_B was chosen to be 2.2 kΩ to ensure saturation which will give base current of

$$(5 - 0.7) \text{ V} / 2.2 \text{ k}\Omega = 1.95 \text{ mA} > I_C/h_{FE} \text{ (i.e., } 0.48 \text{ mA)}.$$

2.6.3 Relay as a Switch: A relay provides total isolation between the triggering source applied to the terminal and the output. This total isolation is important in many digital

applications and it is a feature that certain semiconductor switches (e.g. transistors, diodes and integrated circuits) cannot provide. Also, the contacts are normally rated for currents much higher than the current rating of semiconductor switches (Boylestad and Nashlesky 2007).

2.6.4 Protective Diode: If the load is a motor, relay, or solenoid (or any other device with a coil), a diode must be connected across the load to protect the transistor from the brief high voltage produced when the load is switched OFF. The diagram in Fig. 11 shows how a protection diode is connected 'backwards' across the load, in this case a relay coil.

The circuit in Fig. 4 uses a relay to isolate an electric motor from the logic devices. Notice that the logic circuit and *dc* motor have separate power supplies. When the output of the inverter goes HIGH, the transistor is turned on and the NO contacts of the relay snap are closed. The *dc* motor operates by providing a rotary motion, which drives the mechanical devices that result in bell ringing. The bell keeps on ringing for long as the *dc* motor rotates. When the output of the inverter goes LOW, the transistor stops conducting and the relay contacts spring back to their NC position. This turns off the motor, thereby stopping the bell from ringing. The 560 kΩ variable resistor connected in series with the motor is used to regulate the rpm of the motor, thereby setting the ringing frequency of the bell.

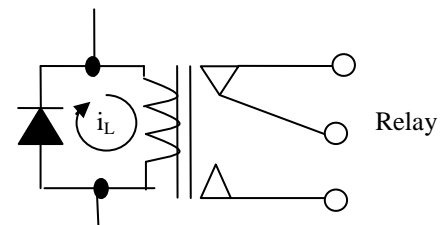


Fig. 11. Illustration of a protection diode.

2.7 Complete Circuit Diagram

The circuit in Fig. 4 shows the complete circuit diagram of the design.

3. Results

After testing the bell, the following tabulated results shown in Table 2 were obtained.

Table 2. Results obtained from the test.

S/NO.	DURATION PER PERIOD		DRIFT PER PERIOD (In seconds)	TOTAL DRIFT AFTER THE LAST PERIOD (8*drift) (In seconds)
	SELECTED (In minutes)	MEASURED		
1.	45	45min 2sec	2	16
2.	40	40min 1sec	1	8
3.	35	35min 0sec	0	0
4.	30	30min 0sec	0	0

Note: Total drift = 8 * drift per period, since every schedule has maximum number of eight periods.

Various deductions can be made from the results shown in Table 2. The drift in 45 min is more than that of 40 min by 1 sec while in 35 min and 30 min there is no drift. This means that the higher the time schedule is, the more is the drift in it. This might occur due to accumulation of the execution of some microsecond instructions that were not taken into consideration during the programming.

According to the results in Table 2, it was observed that at the end of the school periods 45 min periods have increased by at least 16 sec while that of 40 min have increased by 8 sec. This implies that the seconds' increment can be negligible since an individual timer clock varies. Thus, this is accurate enough for most applications.

4. Conclusion

The basic design of the Automatic School Bell (mainly for Primary and Secondary Schools) in this work remains the same though extra functions can be included. This will ring the School Bell at pre-scheduled times of periods on each day. There are different times per period varying from one school to the other. The basic design provides an opportunity of selecting the suitable time schedule for every school by momentarily pressing one of the push-to-on switches. This signals the microcontroller to carry out the specific task, thereby ringing the bell at a regular time interval.

Therefore, from the results obtained, it can be concluded that the aim of this work has been practically and theoretically achieved.

5. References

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