Development of a Microcontroller Based Countdown Time Reminder with Visual and Aural Indicators

Ponnle A. A., Adedeji K. B., and Udekwe C. N.

Electrical and Electronics Engineering Department, Federal University of Technology, Akure,
Ondo State, Nigeria.
E-mail: ponnleakinlolu@yahoo.co.uk, kezman0474@yahoo.com, charlestheory001@yahoo.com

Abstract— Time management is a very important factor which partly determines the success or failure of students during any written examination. We present the development of a microcontroller based electronic device that takes the role of remaining time reminders during any written examination. It provides a user friendly keypad with which to input the time duration of the examination. It has a large timing visual display which serves as the visual indicator, and an alarm which serves as the aural indicator. Once the start key is pressed, the device starts counting down and alarms are given off at pre-determined intervals throughout the duration of the examination. An alarm is given off when the time duration remains 30 minutes. Another alarm is also given off when the time duration remains 5 minutes, and when the time is up, the alarm beeps continuously for some time signalling the end of the examination.

Keywords— PIC18F4520 microcontroller, programmer, 7-segment display, alarm, interrupt.

I.   Introduction

During examination period, it is the usual practice of the invigilators to issue out general instructions before the commencement of every paper. They make sure that the examination starts at the stipulated time and ensures that the examinations are conducted under a peaceful atmosphere void of examination malpractices as much as possible. One notable role among many that these invigilators play is remaining time reminders. They announce the remaining time stipulated for such examinations at intervals with the intention of alerting every student in managing and maximizing each of their time as judiciously as possible. While such a role is crucial, there are some lapses at the methods by which the role is played by some invigilators. Some announcements are made at irregular intervals, and sometimes with 'accent' of intimidation. It is part of examination rules that examination centres should be as quiet as possible. The effects of these irregular announcements of elapsed/remaining time from the invigilators usually create psychological problems in various degrees to the students writing these papers. It could create an atmosphere of fear especially to students who are not fully prepared or acts as a source of distraction.

Though there could be some large wall clocks in the examination halls which indicate the current time of the day, nevertheless, the necessity of time reminders during examinations cannot be gainsaid. It is the duty of the invigilators to properly manage the time duration for students

writing such examinations by announcing remaining time at suitable intervals, but it is also equally important that the psychological disturbances being created by human invigilators are reduced to the barest minimum. Since mobile devices and other personal high level electronic clocks are prohibited in the examination centres because of the role they play in aiding examination malpractices (FUTA, 2012), it is necessary to provide a device with an alarm that will display the countdown of the duration stipulated for every examination paper as well as take over the duty of the human invigilators as time reminders during examination period. Examination time indicator/alarm is highly recommended for all institute of learning where written examinations are being conducted. It serves as time manager and reminder during examinations, as well as helping the invigilators to concentrate more on active surveillance, and lookout for examination malpractices that could be perpetrated by students in the examination halls.

Different works have been carried out on microcontroller based digital visual display of alphanumeric characters some of which are indicated (Arefin *et al*, 2004; Sabbir and Monira, 2004; Tun, 2008; Sarker *et al*, 2012; Ezeofor and Okafor, 2014). Arefin *et al,* in 2004 designed a 24-segment display for Bangla Characters and Numerals but this design is redundant when it comes to display of numerals. Similarly, Sabbir *et al,* in 2004 designed a 10-segment display for Bangla digits but their segment were not uniform and in addition to it their design has some controversy regarding portraying digits "1", "2", "3" and "7" accurately. Tun, in 2008 designed a digital clock using microcontroller with seven-segment display, however his 7-segments are not the large format types hence may not be visible at far distances. While these past projects are not the same in functionality, the underlying principle in design are somewhat similar, hence a lot of knowledge was drawn from them in the design of our own device.

This work focuses on the development of a microcontroller based electronic device that will enable examination invigilators to input the time duration of every paper with the aid of a keypad, which will be displayed on a large seven segment display board. Once the 'start' key is pressed, the device starts counting down. Alarms will be given off at pre-determined intervals irrespective of the duration of the paper. An alarm is given off when the time duration remains 30 minutes. Another alarm is also given off when the time duration remains 5 minutes, and when the time is up, the alarm beeps continuously for some time signalling that the examiner can collect the examination papers from the

students. It is part of our objective for this work to have a cost effective design with a view to realizing an easy to use device made from locally available materials.

II.   Materials and Methods
A) Brief Description of Device

This section focuses on the methods that were adopted in the design of the countdown time reminder. The developed countdown time reminder in functional block diagram is shown in Figure 1. The entire system is divided into three major parts namely: the User Input Unit, the Processing Unit, and the Output Unit. A programmed microcontroller (PIC18F4520) is at the heart of controlling the actions of the device to ensure reliability.
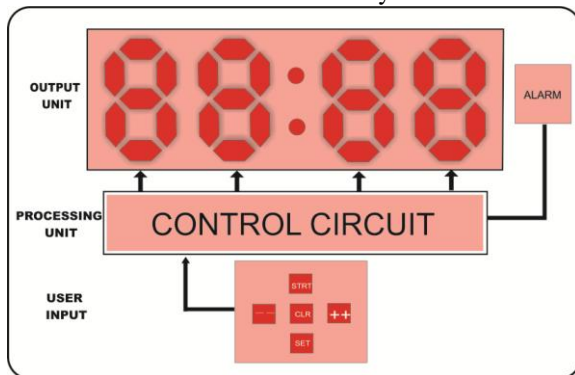

Figure 1: Functional block diagram of the developed Digital Countdown Time Reminder.

The input unit is a keypad with four buttons, and a fifth button serving as the external master clear (MCLR) for the micro-controller. The output unit consists of the visual display and the alarm. The visual display is a large 'hour:minute' format seven-segment display with 118 high-brightness red LEDs to display time and communicate visually with users. The operation of the visual display is controlled by the microcontroller. The purpose of the alarm is to generate a soft sound at pre-determined time intervals to serve as reminders and alert to users.

B) Design Considerations
i) The Microcontroller

At the heart of the processing unit is the PIC18F4520 microcontroller. A microcontroller is a single chip, self-contained computer which incorporates all the basic components of a personal computer on a much smaller scale (Byte Craft Limited, 2002). PIC18F4520 microcontroller is a 40-pin microcontroller housed in a Dual in Line (DIL) package. The PIC18F microcontrollers offer cost-efficient solutions for general purpose applications written in C. It also provides flash program memory in sizes from 8 to 128Kbytes and data memory from 256 to 4Kbytes, operating at a range of 2 to 5 volts, and at speeds from DC to 40MHz. It has program memory addressing up to 2Mbytes; data memory addressing up to 4Kbytes; interrupt priority levels; up to three 16-bit timers/counters; up to four external interrupts; high current (25mA) sink/source capability; fast 10-bit analog-to-digital

converter; power-on reset (POR), power-up timer (PWRT), oscillator start-up timer (OST); and watchdog timer (WDT) with on-chip RC oscillator (Microchip, 2007; Dogan, 2008). The pin configuration of the PIC18F452 microcontroller is shown in Figure 2.
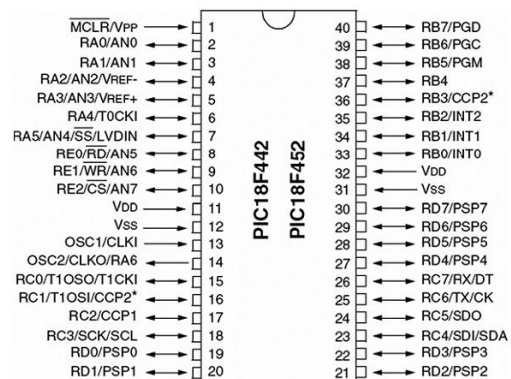

Figure 2: PIC18F4520 microcontroller DIP pin configuration.

The PIC18F4520 microcontroller controls the whole operation of the developed device. Both the input and the output units are properly interfaced to the microcontroller. The PIC18F4520 can operate with a supply voltage of 4.2V to 5.5V at the full speed of 40MHz. In this application where accuracy of timing is important, a crystal oscillator was used. A parallel crystal oscillator was chosen, because series resonant crystals do not oscillate when the system is first powered. It was also ensured that each of the two pins of the oscillator and the ground is having a capacitor of 22pF connected across them.

The reset action puts the microcontroller into a known state. For the purpose of this work, the external reset using the MCLR pin was adopted to ensure greater flexibility. In order to reset externally, the MCLR pin is tied to the supply voltage through a 10KΩ pull-up resistor thereby making the MCLR input to be at logic 1 normally (Dogan, 2008). When the RESET button is pressed, this pin goes to LOW and resets the microcontroller.

ii) The Keypad

The keypad consists of four buttons namely: 'START', 'SET', '++' (advance), and '—' (reduce). In order to determine the state of each button either as a HIGH (pulled to the V_{cc}) or a LOW (pulled to the ground) on the microcontroller, pull-up resistors connected to the V_{cc} were used for each button or else the button will be in a floating state. With a pull-up resistor, the input pin will read a HIGH state when the button is not pressed with a small amount of current flowing between the V_{cc} and the input pin of the microcontroller; thus the input pin reads close to V_{cc}. When the button is pressed, it connects the input pin directly to the ground. Current flows from V_{cc} through the resistor to the ground; thus the input pin reads a LOW state.

In this device, the current was limited to 0.5mA when the button is pressed where $V_{cc} = 5V$. The value of the pull-up resistor was calculated using Ohm's law.

$$V_{cc} = I_1 \times R_1 \tag{1}$$

where I_1, is the current through R_1 (R_1 being the pull-up resistor).

Hence, $R_1 = \dfrac{V_{cc}}{I_1} = \dfrac{5\ V}{0.5\ mA} = 10\ k\Omega$

This is the value of resistor that was used as pull-up resistors for the keypad. The circuit schematic of the keypad is shown in Figure 3.
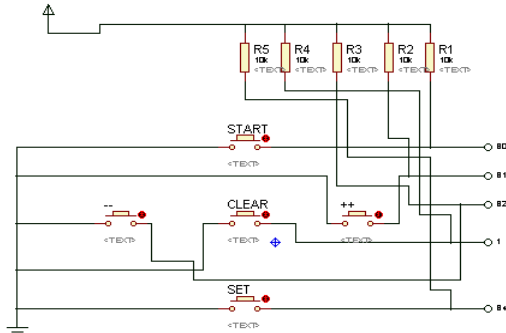

Figure 3: Design schematic of the keypad.

iii)   The Visual Display and the LED Segment Driver

The visual display has four digits; two digits for hours and two digits for minutes, with a colon indicating seconds. Each digit is made up of 7-segments. In each segment of each digit, 4 red LEDs were connected in parallel and a common cathode configuration was used for all the 7 segments. The segments are turned ON by applying logic '1' to the required segment LEDs via current limiting resistors. Connecting LEDs in parallel allows many LEDs to receive the same supply voltage, but the turn-on voltage of one LED may affect the other. This can be greatly minimized by ensuring that all the LEDs used have exactly the same specifications.

Each LED segment is connected to the microcontroller via a transistor driver in current draining mode. BC337 NPN bipolar junction transistor (BJT) was chosen as the LED segment driver (Fairchild Semiconductors, 2002). The transistor operates basically in three modes which are: active mode, saturation mode and the cut off mode (Paul, 2008; Theraja and Theraja, 2009). In this work, the cutoff and saturation modes of the transistor were utilized. Figure 4 shows the LED segment driver circuit. The 7-segment arm was connected to the emitter of the transistor through a current limiting resistor R_E.

The value of R_E was determined using the following expression

$$R_E = \frac{V_o - V_{BEon} - V_{led}}{I_{led}} \qquad (2)$$

where V_o, is the output voltage from the microcontroller which is 5V, V_{BEon} is the transistor's base-emitter turn on voltage which is 0.7V for the BC337 silicon NPN transistor, V_{led} is the voltage drop across the LED which is 1.6V and I_{led}, is the desired current through the LED which is 10mA.
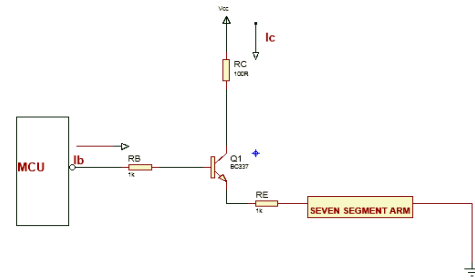

Figure 4: The LED segment driver circuit.

Since 4 LEDs are connected in parallel for each segment, a typical current flowing through the LED segment network will be

$$4 \times 10 = 40\ mA$$

Hence R_E is calculated as

$$R = \frac{5 - 0.7 - 1.6}{40\,mA} = 67.5\ \Omega$$

This value is not readily available, so we chose the nearest possible preferred value which is 100Ω. In Figure 4, resistor R_C helps to reduce the collector-emitter voltage of the transistor when it is in ON state, thereby minimizing the power dissipation of the transistor when it supplies current to light up the LEDs.

Finally, the positive arm of each segment are connected in parallel to form a single arm so that on the whole, seven arms which forms the seven segment of the whole arrangement are obtained ready to be interfaced with the microcontroller. Since a common cathode approach had been adopted for all the segments of each digit, the combined cathode of each digit are then grounded through another set of transistors called the 'control transistors'. This arrangement is shown in Figure 5.
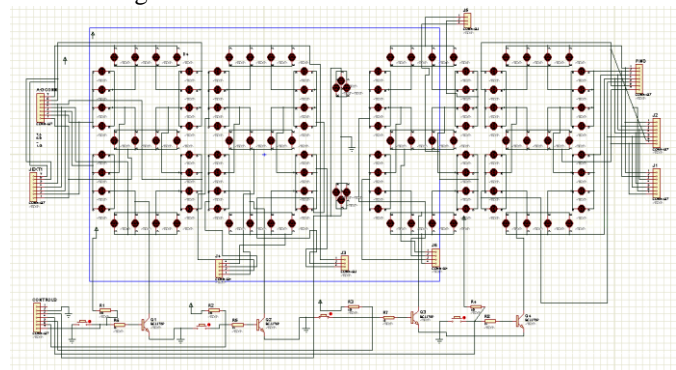

Figure 5: Schematic of the Large Format Seven Segment Display Circuit

iv)   The Alarm Circuit

The alarm was achieved by using a buzzer, driven by a transistor, and controlled by the microcontroller. A piezo buzzer of 9V and sound level of about 80dB was used. BC337 NPN transistor was also chosen to drive the buzzer from the microcontroller, and a diode was connected in reverse bias across the buzzer to protect the transistor.

v)   The Multiplexing Action

The four 7-segments (each digit) are switched 'on' one by one with a very small delay (5ms). Even though only one segment glows at a time, it appears that all the segments are glowing together. Thus the key factor in multiplexing is the switching time of the segments. Each digit is enabled using a BC337 NPN transistor connected to PORTA pins RA0, RA1, RA2 and RA3 of the microcontroller. A segment is turned on when logic 1 is applied to the base of the corresponding segment transistor. Segments 'a' to 'g' of the display are connected to PORTD of the microcontroller through 100Ω current limiting resistors and BC337 transistors. Before driving the display, one has to know the relationship between the numbers to be displayed and the corresponding segments to be turned ON, and this is shown in Table 1. For example, to display number 3 one has to send the hexadecimal number 0X4F to PORTD, which turns ON segments a, b, c, d, and g. Similarly, to display number 9, one has to send the hexadecimal number 0X6F to PORTD which turns ON segments a, b, c, d, f, and g.

Table 1: Displayed number and data sent to PORT

Number	x g f e d c b a	PORTD Data
0	00111111	0x3F
1	00000110	0x06
2	01011011	0x5B
3	01001111	0x4F
4	01100110	0x66
5	01101101	0x6D
6	01111101	0x7D
7	00000111	0x07
8	01111111	0x7F
9	01101111	0x6F

* x *is not used, taken as 0.*

vi) The Interrupt Action

Apart from multiplexing, this device will be required to refresh the displays at a determined time interval. The microcontroller's timer interrupt is used for this purpose. Without this interrupt facility of the microcontroller, it cannot perform two tasks at the same time. In this device, the timer is designed to count from **0** to **59** for the 'minute' and 'seconds' digit; and from **0** to **23** for the 'hour' digit. The display is refreshed every 5ms inside the timer interrupt service routine. The timer 0 interrupt function of the microcontroller is used. Timer 0 has the following basic features: 8-bit or 16-bit operation; 8-bit programmable prescaler; external or internal clock source; and interrupt generation on overflow Timer 0 control register called T0CON (Timer 0 Control).

In this work, the timer mode is selected by clearing the T0CS bit, and in this mode the clock to the timer is derived from Fosc/4. An 8-bit prescaler can be used to change the timer clock rate by a factor of up to 256. The prescaler is selected by bits PSA and T0PS2:T0PS0 register. In this work, Timer 0 was operated in 8-bit mode. Equation 3 was used to calculate the time it will take for the timer to overflow (or to generate an interrupt) given the oscillator period, the value loaded into the timer, and the prescaler value is

$$O_{ft} = 4TP_s(256 - T_{mrol}) \qquad (3)$$

where T, is the clock period , P_s is the selected prescaler value, and T_{mrol} is the value loaded into timer register TMR0L to generate timer interrupts every Time, T period.

The clock frequency is 4MHz, i.e. clock period is 0.25µs, and time is 5ms. Selecting a prescaler value of 32, the number to be loaded into TMR0L was calculated as:

$$T_{mrol} = 256 - \frac{O_{ft}}{4TP_s} \qquad (4)$$

$$Tmrol = 256 - \frac{5000}{4 \times 0.25 \times 32} = 100$$

Thus, TMR0L is loaded with 100. The value to be loaded into TMR0 control register T0CON can then be found as indicated in Figure 6(a). Thus, T0CON register should be loaded with hexadecimal 0XC4.
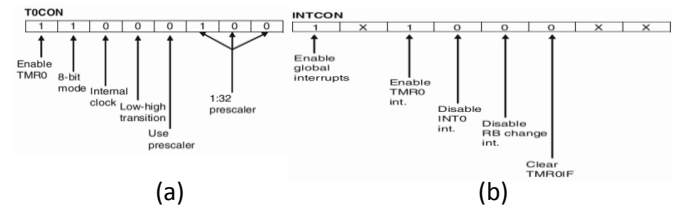

(a)   (b)

Figure 6: (a) T0CON register (b) INTCON register

The next register to be configured is the interrupt control register INTCON, where priority based interrupts are disabled and the global interrupts and TMR0 interrupts are enabled. Taking the don't-care entries (X) as 0, the hexadecimal value to be loaded into register INTCON is 0XA0 as indicated from Figure 6(b). When an interrupt occurs, the program automatically jumps to the interrupt service routine. The operations performed in the main program are summarized as follows:

i. Load TMR0L with 100.
ii. Set T0CON to 0XC4.
iii. Set INTCON to 0XA0.
iv. Increment the counter with 1-second delay.
v. In the interrupt service routine, Re-load TMR0L to 100.
vi. Refresh displays.
vii. Set INTCON to 0X20 (re-enable TMR0 interrupts and clear timer interrupt flag).

vii) The Power Supply

In this device, a +9V power supply is regulated to +5V using a 7805 positive voltage regulator. The power supply circuit is shown in Figure 7. The power supply uses a step down transformer TR_1 to step down the input mains voltage of 220V to a voltage level suitable for the electronics within the device. The output of the secondary winding of the transformer is passed to a bridge rectifier BR_1 for full wave rectification to obtain a pulsating dc voltage. This is followed by a filter, comprising of capacitors C_1 and C_2 to filter out the pulsations (Maddock and Calcutt, 1994; Mehta, 2008). A 'power on' LED indicator D_1 is provided with its current limiting resistor R_1.

After the rectification and smoothening, this voltage ($> +9V$) is unregulated and therefore varies as the input mains voltage varies. The output voltage is then passed to an

LM7805 positive voltage regulator U_1 to provide a regulated +5V supply for the micro-controller. The regulator served to reduce further the ripple and noise in the regulated supply to the microcontroller. The regulator also provides current limiting and protects the power supply and attached circuit from over current (Paul and Winfield, 1989). Also, a provision is made for use of 9V battery in the absence of mains supply with a blocking diode D_2 if there is mains supply while on battery.
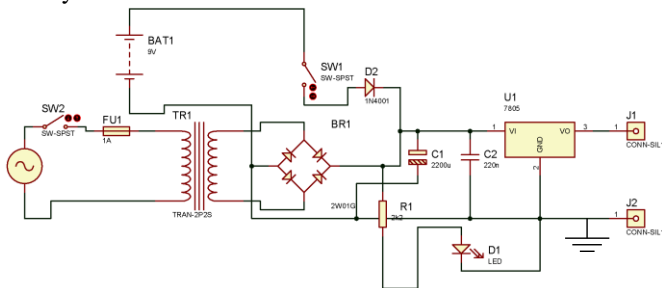

Figure 7: The Power Supply Circuit.

III.   Construction and Performance

For the fabrication of the large "hour:minute" format visual display, a printed circuit board (PCB) was used to aid the connection. ARES (Advanced Routing and Editing Software) which is a PCB package of Proteus was used to design the PCB layout. The display and its mounting panels measure 28cm by 18cm, and comprises of 28 long segments making up four '7-segment digits' and two short segments for the 'Colon'. Narrow-angle, 5mm, high-brightness, red LEDs were chosen because they have a low voltage drop of 1.6V across the anode-cathode junction when compared to other types of LED. The LEDs (128 in number) were soldered on the printed circuit board.

The circuit design of individual section of the entire device was designed using Proteus Circuit Design software. Also the entire circuit diagram was designed and simulated using the software. Figure 8 shows the overall circuit diagram excluding the power supply, as drawn using the Proteus software.
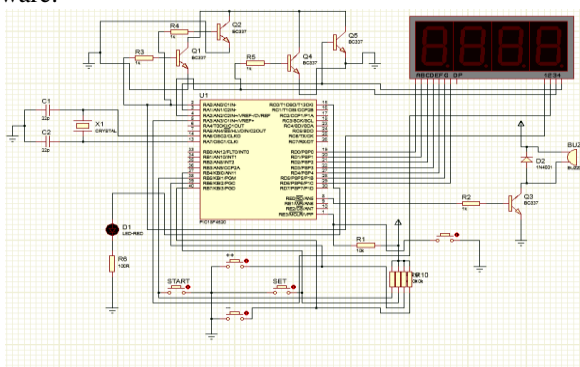

Figure 8: Circuit Diagram of the Countdown Time Reminder.

After the purchase of all the required components for the design based on the designed circuit diagram, effort was made to start developing the program code for the microcontroller using C (Martin, 2008; Julio and Maria, 2007). The design

program was simulated several times on Proteus software until the code for the design performed satisfactorily before the final programming of the microcontroller and assembly of the components. The programming of the microcontroller was done by first writing the program code, and compiled it using MikroC. Then the hex file was burned to the PIC through the EasyProg PIC7 Programmer.

During prototyping, bread-boarding was initially used for effective manipulation of the design. The overall circuit was tested based on each of the stages of the design until effective results was obtained at the output display unit. The control circuit comprising the 18F4520 microcontroller, the pull-up resistors, the buffer transistors, the button terminals and the alarm circuit were all constructed on Vero boards. The constructed device during prototyping is shown in Figure 9 showing all the sections loosely connected together. The device was tested with a test program and was found to perform satisfactorily. The total measured current drain by the device when all the segments of the display, including the colon are lit and the buzzer is sounding with 12V battery operation is about 256mA. This low total current consumption is as a result of the multiplexing action of the microcontroller in operating the visual display.

Figure 9: The device during prototyping.

The different sections of the device were then properly assembled and coupled together inside a black rectangular plastic case. The final appearance of the device in operation is shown in Figure 10 displaying remaining time '**2 hours:27 minutes**'with the 'colon' sign blinking as seconds. The device responded to any user input in any state. Remaining time was displayed on the visual indicator accurately. The buzzer made moderate sound when the alarm is active. The device is safe to use under short term and long term operating conditions.

Figure 10: Final appearance of the Countdown Timer Reminder in operation displaying 02:27.

IV. Conclusion

This paper has shown how a microcontroller based countdown time reminder was developed. The developed device serves as time reminder during any written examination and this ultimately reduces the disturbance from invigilators or time keepers, when trying to announce the remaining time at intervals. The invigilators will be able to monitor other pranks of the students to perpetrate examination malpractices knowing well that this device will take accurate care of time monitoring. When in use, alarms are given off at pre-determined intervals; and an alarm is given off when the time duration remains 30 minutes. Another alarm is also given off when the time duration remains 5 minutes; and when the time is up, the alarm beeps continuously for some time signalling the end of the examination.

The display has four digits; two digits for hours, and two digits for minutes. The developed device has an audible alarm system, ability to set the time in both clockwise and counter clockwise directions, and its operation is stable and convenient such that it will be easy to use. It is completely made from locally available materials.

References

i. Arefin M. S., Dewan M. A., Khan M. I., and Islam M. S. (2004): "Designing a 24-segment display for Bengali Numerical Digits and Characters," in Proceedings of 3rd International Conference on Electrical and Computer Engineering (ICECE), Dhaka, Bangladesh, pp. 549-552.

ii. Byte Craft Limited (2002): "First Steps with Embedded Systems", Ontario, Canada, 2002, p. 5. http://www.bytecraft.com.

iii. Dogan I. (2008): "Advanced PIC Microcontroller Project in C", Newnes, Elsevier Limited, Burlington, MA, USA, p.13.

iv. Ezeofor C. J., and Okafor E. C. (2014): "Design and Simulation of Microcontroller based Electronic Calendar using Multisim Circuit Design Software", International Journal of Engineering Trends and Technology, Vol. 3, No. 18, pp. 396-400.

v. Fairchild Semiconductors (2002): "BC337/BC338 Switching and Amplifying Application", Fairchild Semiconductor Corporation, Great Britain.

vi. Federal University of Technology Akure (2012): "Examination Regulations and Disciplinary Actions", Student Handbook of Information, pp. 56-58.

vii. Julio S. and Maria P. C. (2007): "Microcontroller Programming the Microchip PIC", CRC Press, Boca Raton, Great Britain.

viii. Maddock R. J. and Calcutt D. M. (1994): "Electronics: A Course for Engineers" 2nd Edition; Longman Publishers, Essex, London.

ix. Martin P. B. (2004): "Programming 8-Bit PIC Microcontrollers in C with Interactive Hardware Simulation" 1st Edition, Newnes, ISBN: 978-0-7506-8960-1.

x. Mehta V. K. (2008): "Principles of Electronics", 11th Edition, S. Chand and Companies Limited, Ram Nagar, New Delhi, India, pp. 380-383.

xi. Microchip Inc. (2007): "PIC 18F2420/2520/4420/4520 Data Sheet", Microchip Technology Inc., California, USA, p. 8.

xii. Paul H., and Winfield H. (1989): "The Art of Electronics", Second Edition, Cambridge University Press, Cambridge MA, p. 58, ISBN 0-521-37095-7.

xiii. Paul S. (2000): "Practical Electronics for Inventors", McGraw-Hill Companies, USA, pp. 93-98.

xiv. Sabbir A. and Monira S. (2004): "Designing a 10-segment Display for Bangla and English Numerals," in the Proceedings of 7th International Conference on Computer and Information Technology (ICCIT), Dhaka, Bangladesh, pp. 602-605.

xv. Sarker V. K., Rahman M. A., and Matin M. A. (2012): "Design and Development of Microcontroller based Digital Bangla Clock", International Journal of Computer Theory and Engineering, Vol. 4, No. 6, pp. 935-937.

xvi. Theraja and Theraja (2009): "A Textbook of Electrical Technology", S. Chand and Companies Limited, Ram Nagar, New Delhi, India, pp. 2088-2091.

xvii. Tun P. T. (2008): "Development and Implementation of Microcontroller-based Digital Clock," World Academy of Science, Engineering and Technology, Singapore. Vol. 42.