Design of a Wirelessly-Updated Digital Clock with Android Interface

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ABSTRACT
This paper presents the design of a digital clock, while providing an easy and convenient means of updating the time, and/or any other message that may be displayed. The aim was to design and also introduce a user-friendly update mechanism through creating input methods – using a 4x4-numeric keypad for data input, establishing communication protocol with Bluetooth and output method using a liquid crystal display. The design incorporated both hardware and software in achieving this aim, with the hardware consisting of LCD, LEDs, RTC, HC-05 Bluetooth module, and a 4x4-numeric keypad. The software is handled by a ubiquitous microcontroller – ATmega16A, programmed in C++, as well as a generic HC-05 Android Bluetooth Application for data input (in addition to the hardware means of update – keypad). Hence, this design introduced convenience (user-friendliness) as compared to clocks which are manually updated. The overall design had percentage accuracy and error of 99.17 and 0.8 respectively.

Keywords
Microcontroller, LCD, Digital Clock, RTC, Android App, Bluetooth.

1. INTRODUCTION
A digital clock is a type of clock that has a digital time base that generally works on frequency pulses (usually 1Hz). Digital watches became popular when microchip LEDs became cheap. It was a great revolution in the watch market because it manufactured watches with less cost and more precision compared to those built based on mechanical operations. The classification of clocks – analog and digital – generally depends on the mechanism of the display, although it is common to think that such classification may be based on the drive mechanism. In recent times, digital clocks have eroded the analog ones due to reasons such as better accuracy, improved readability, additional features such as alarm, calendar (while some even have inbuilt radio), among others. Notwithstanding, the digital clock may not be so different from an analog clock if they both have the same mechanism of time update, i.e. one has to move to the position of the clock, physically touch it (or even open it in some cases) just to update the time. Microcontroller-based digital clocks have, over the years, replaced mechanical and electromechanical clocks with added advantages such as portability, maintenance-free, reduced cost, high reliability, etc. [Pan 2008]. Since clocks must follow a consistent and regular interval, it becomes necessary to either utilize the frequency of the connected power (usually 50 or 60Hz) or use a separate crystal oscillator.

Over the years, publications have been made on the design of digital clocks which, among others, include the design of a calendar clock based on DS12C887 chip [Xiao Chen, 2008], design and development of microcontroller-based digital Bangla clock [V. K. Sarker et al, 2012], development and implementation of microcontroller-based improved timer and alarm systems [Lukman et al, 2016] which used only the keypad to update the time, thus inefficient for multi-purpose displays which, in addition to time, may display other personalized messages. With the advancements in the design of digital clocks so far, it has become necessary to incorporate a wireless method of update. Just like any other design of wireless communication, a protocol must be appropriately chosen from a seemingly increasing list of protocols which include Wi-Fi, Zigbee, NFC, Bluetooth, radio, etc. which all pose threats, though sometimes insignificant, to the safety of mobile data [M. Migliardi et al, 2017]. However, with advantages which include, but not limited to, lower power consumption, relatively inexpensive, no interference with other wireless devices, the bluetooth is a better protocol choice for the realization of wireless communication for this design. In this paper, the design which uses an android phone to communicate with the digital clock also incorporated keypad (4x4), giving the user a variety of options to update the time, especially if such a clock also displays personalized messages. Humans are presently controlling actions within their environment in a programmed and predictable manner [Sarker et al 2012]. Therefore, depending on the user's proximity to the clock, he/she may choose the most convenient of both means of the time update.

More often than not, the need to wirelessly update the time displayed on a clock becomes necessary due to factors such as vibrations, electrical transients, etc. which may result in distortion of the workings, displacement of electronic components, thereby affecting the accuracy of the time. Wirelessly updating the time therefore, reduces the risk of accidental falls, manhandling, etc. as well as incorporating user-friendliness and the overall design achieved this.

The structure of this paper is as follows: Section 2 describes the design methodology; Section 3 demonstrates the design results and Section 4 gives the conclusion.

2. DESIGN METHODOLOGY
The proposed design consists of several sections which include the power supply, microcontroller, timing, display and input sections. Figure 1 is a representation of the sections;

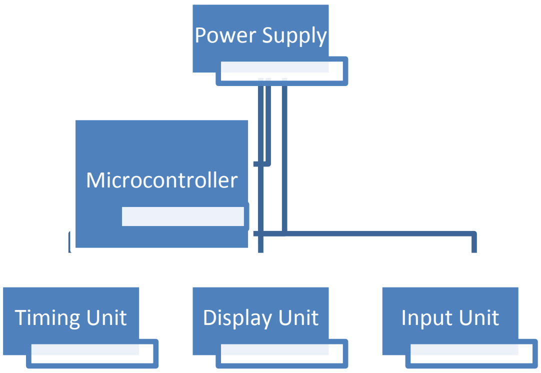

Figure 1: Proposed Block Diagram of the Design

2.1 Power Supply Unit

Speed, cost and power consumption are some of the main parameters considered in the design of electronic systems [Aggarwal et al 2012]. Like any other electronic circuit, the digital clock has a power unit that consists of a 220:12V transformer, diodes in bridge configuration for rectification, filtering capacitors and a voltage regulator. All the components used in the design is rated 5V Vcc, hence, the adjustable voltage regulator is configured (with R1 and RV1 combination) to give 5V. This unit is capable of supplying 1.5A at 5V (7.5W) which is just about what the digital clock requires.

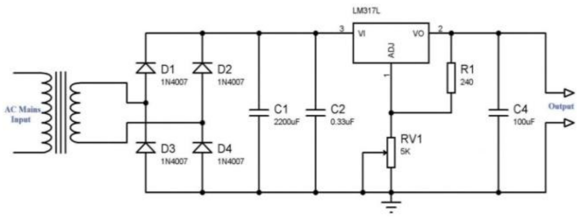

Figure 2: Power Supply Unit

2.2 Microcontroller

One of the difficulties in programming microcontrollers is the limited resources the programmer has to deal with (for instance, speed), in contrast to PCs which have large RAM sizes and high processing speeds. In terms of cost and efficiency, microcontrollers remain a better option. [Aggarwal et al 2012]. The use of several components such as the RTC, keypad, LCD and LEDs for the design of this project necessitated the selection of a microcontroller that has a significant number of digital input and output pins, such as the ATmega16A microcontroller. In addition to the number of pins available for use in the microcontroller (32 programmable I/O pins), it has the features which include two 8-bit timer/counters with compare modes, real time counter with a separate oscillator (necessary for interrupts), Universal Asynchronous Receiver and Transmitter – UART (necessary for bluetooth communication with the android phone), I^2C (used for communication with the RTC), etc. [ATmega16A Datasheet, Atmel Corporation 2001].

The ATmega16A has different communication protocols which it uses to communicate with other components as well as devices such as PC or microcontrollers. Codes with which the microcontroller is programmed are written in C++ language. After writing and compiling these codes in the IDE (Atmel Studio 7), they are transferred to the microcontroller using one of the communication protocols - Serial Peripheral Interface (SPI), with the aid of ProgISP.

2.3 Timing Unit

This section is handled by the RTC – DS1307 which communicates with the microcontroller using the I^2C protocol. It utilizes power from the general supply and also has its alternative power source which is a 3v lithium battery, with a crystal oscillator of 32.768 KHz as its time base. When Vcc drops to a voltage lower than 1.25 xVbat, the device terminates an access in progress and resets the device address counter. At this time, data is no longer sent to the device which helps to prevent false data from being sent. When this occurs, the device switches into a low-current battery-backup mode and switches back to Vcc when it is greater than Vbat +0.2V and recognizes inputs when Vcc is greater than 1.25 x Vbat. [DS1307 Datasheet, Maxim Integrated Products 2015].

In this project, the RTC used is the DS1307 which provides seconds, minutes, hours, day, date, month, and year information, uses only two bidirectional open-collector or open-drain lines, Serial Data Line (SDA) and Serial Clock Line (SCL), pulled-up with resistors. The date at the end of the month is automatically adjusted for months with fewer than 31 days, including corrections for leap year.

2.4 Display Unit

The display for this design uses a 16x2 liquid crystal display which functions by setting the command and data registers appropriately. This is done by the microcontroller by sending a command to the LCD through the command register to, for example, initialize the display; or by sending a data through the data register to display, for example, time in seconds. The LCD which can be configured in 4 or 8-bit mode is configured in 4-bit mode, for the purpose of this design. This configuration helps to reduce the required number of I/O pins of the microcontroller used for the overall design.

2.5 Input Unit

The input unit comprises two methods – using an alphanumeric keypad and updating with an android phone using bluetooth. The 4x4 keypad which is just an arrangement of push buttons in four rows and four columns helps the user send data to set the time of the clock. The keypad provides a means for the user to update the time if the clock is within the user's reach. The microcontroller, which is programmed to accept numbers and characters from the keypad, prompts the user to enter data (in seconds, minutes, hours, day of the week, etc.) and waits for the user to provide all necessary data after which a confirmation is requested. On confirmation, the data is sent to the RTC and eventually displayed on the LCD.

On the other hand, the wireless means, which uses the HC-05 bluetooth module with an android phone, provides a means for the user to update the time if the clock is not within the user's reach. The module operates at a 9600 baud rate which makes it easily interfaced with microcontrollers and other devices that support UART - bluetooth-enabled devices [A. Farooquie at al, 2019]. A connection is established first be established between the clock and the mobile phone after which the user is prompted, on the serial interface of the mobile app, to enter data to update the time (just as using the keypad). The Bluetooth Terminal is an android terminal application with UART serial communication protocol that transmits and receives data wirelessly through bluetooth connection [A. Farooquie et al, 2019].

3. MODE OF OPERATION

Figure 3 shows the circuit diagram of the design. The microcontroller serves to control all the aforementioned components of the design. The design draws power from a 220VAC - 5VDC supply module or 2x18650 cells of 3.7V (auxiliary power, not included in the circuit diagram) each in series with a voltage regulator. When these power sources are unavailable and the clock is down, the RTC which has an on-board 3.0V cell keeps the internal clock functions running, such that when power is restored, the clock displays the accurate time. The reference frequency of the microcontroller is 16.00MHz which is obtained from a crystal oscillator connected between XTAL1 and XTAL2 pins. This frequency serves as the base on which other peripheral functions of the microcontroller such as interrupts, USART synchronization, etc., including the clock timing, are executed. When the device is powered, it takes approximately 500ms for system initialization after which the time data from the RTC is transferred to the microcontroller with the I^2C protocol and subsequently displayed on the LCD. The 16x2 LCD which has its data and control pins connected to PC2 – PC7 of the microcontroller, displays the hour, minute and day-of-the-week data on the first row, while the month, date and year data of the time are displayed on the second row. The microcontroller is programmed to display time in the 12-hour format; therefore, two of the three LEDs connected to PA1, PA2 and PA3 of the microcontroller are used to indicate “AM” and “PM”, while the third represents an ON state of the clock. Once the system is running, the microcontroller constantly “listens” to inputs from either the keypad or the Bluetooth and generates the necessary prompts on the LCD or android phone screen.

At any time the user wishes to update the time, ‘A’ is pressed on the keypad or connection is made with the android phone (with Bluetooth Serial Application installed from Google Play store) with the clock’s Bluetooth, depending on the proximity of the clock to the user or user-convenience. On pressing the key on the keypad or connecting a mobile phone to the clock, the device prompts the user to enter time data (for instance, second, month, etc.), with a final prompt to confirm loading the data and subsequently displaying same.

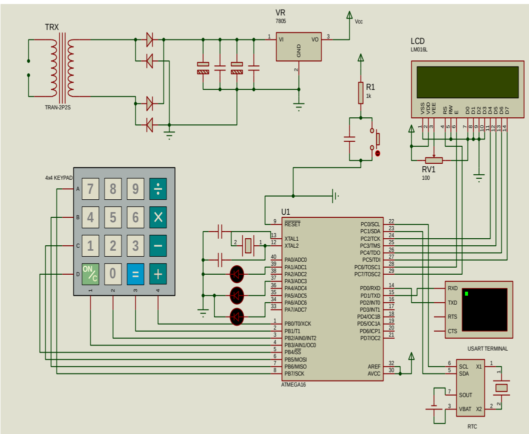

Figure 3: Circuit Diagram of the Design (Zoom-in to enlarge text-labels)

3.1 Assembly and Packaging

The design is contained in an inexpensive plastic casing. Due to the presence of output and input components (keypad and LCD), there had to be cuts made on the casing to allow for easy access to these components, while the other components like the microcontroller and power circuit remain within the casing. The electronic circuit is made with components soldered on a Vero board, with jumper wires making necessary connections.

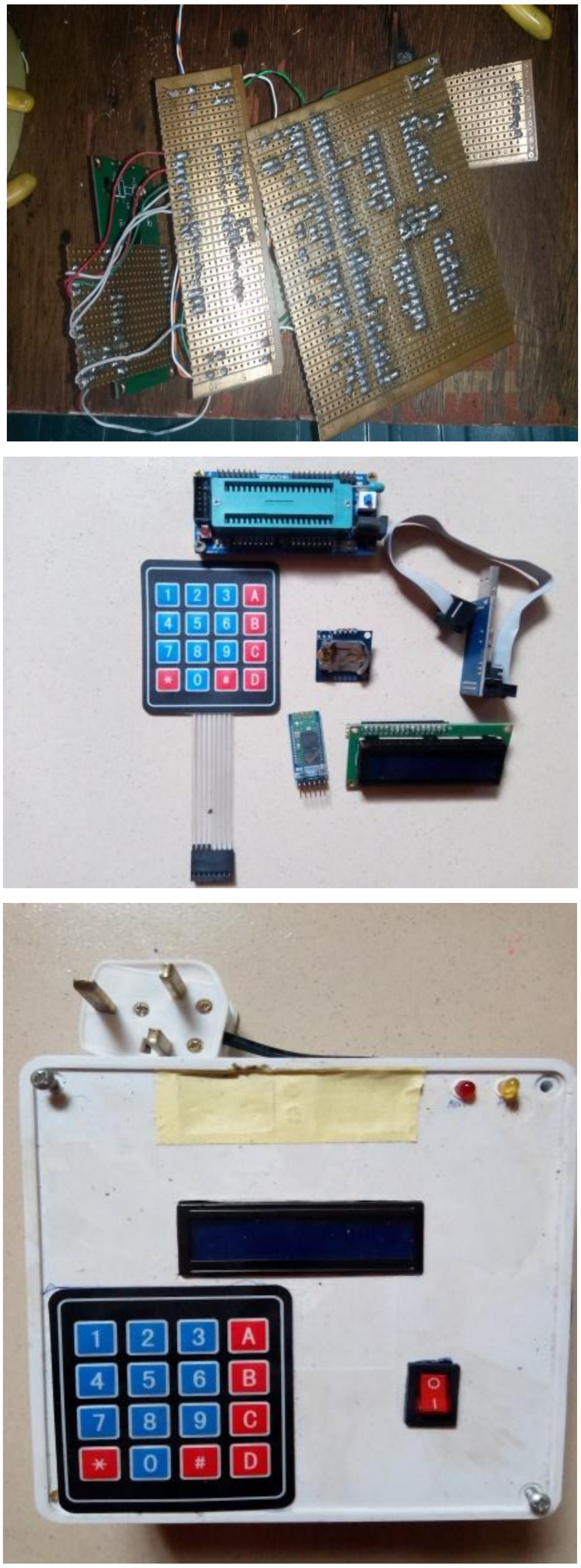

Figure 4: Top: Components on Vero Board; Middle: Showing Components used; Bottom: Packaged Design

3.2 Testing and Result

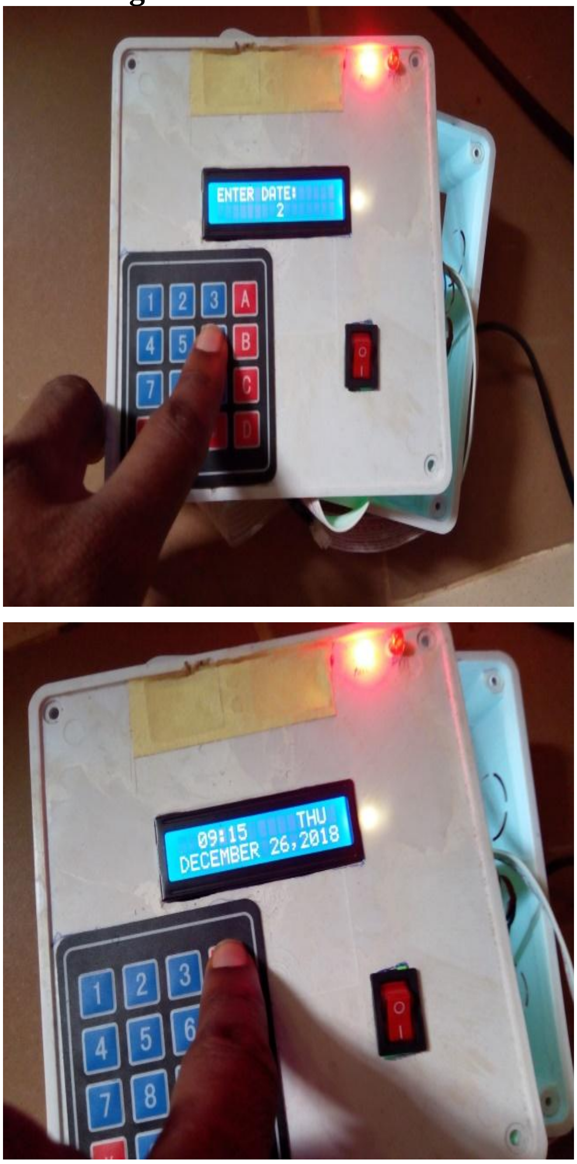

Figure 5: (Top & Bottom) Updating time using Keypad

Testing the design includes the following processes:

a. On connecting to 220VAC mains or providing battery, switch on the circuit and waits for initialization.

b. Press ‘A’ on the keypad to update the clock using the 4x4 keypad (at any time)

c. Enter time data (in second, minutes, etc.) and press ‘#’ to load data

d. Confirm the process and the time is displayed on the clock OR

e. Connect Bluetooth with android phone to update the clock wirelessly and perform steps C and D to load data.

This configuration needs to be done only once, after which the RTC keeps track of the time thereafter (even when the clock is turned off). Figure 5 shows updating the clock using a keypad while figure 6 shows updating the clock with an android phone.

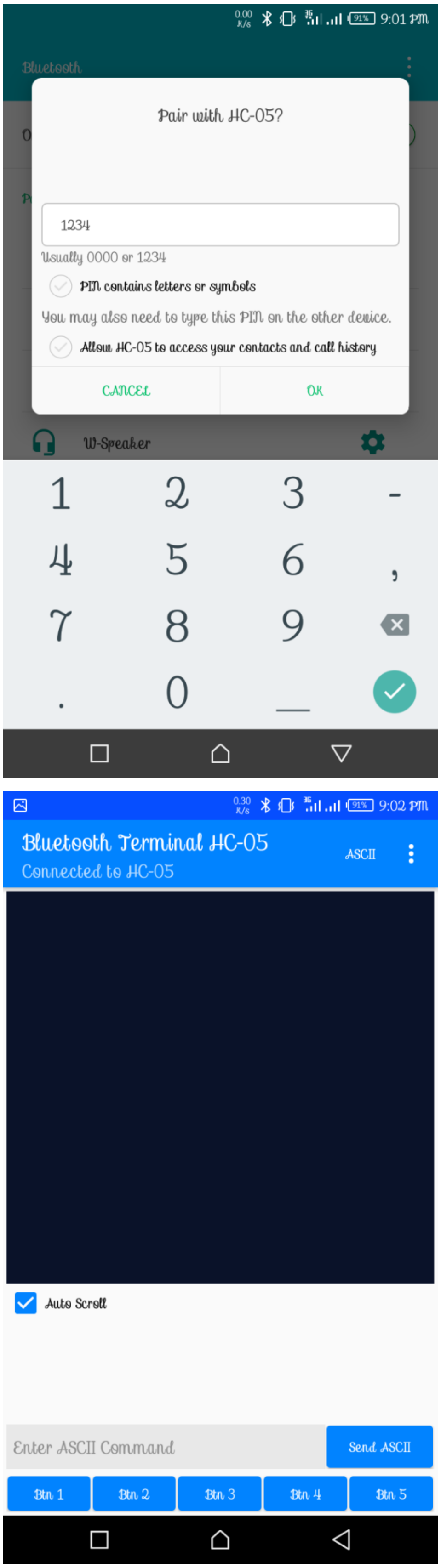

Figure 6 (Top & Bottom): Updating Time Using an Android Phone

In comparison with another digital clock, the time difference was thirty (30) seconds when left to work for an hour. This gives a percentage accuracy and error of: 99.17 and 0.8 respectively.

The table below gives a summary of the performance characteristics;

Table 1: Summary of Design Performance Characteristics

Characteristic	Value
Input Voltage (VDC)	5
Frequency (Hz)	1
Visibility (m)	10
Accuracy (%)	99.17
Error (%)	0.8

Updating the time wirelessly provides a more convenient means of using a digital clock, especially when the clock displays several data other than time. For instance, some digital clocks display personalized messages such as birthday reminders, to-do list, etc. For instance, the display screens in banking halls which display interest and exchange rates could also show information of calendar clock such as year, month, week, etc. [Xiao 2008, p.95-99].

4. CONCLUSION

From the design analysis, wirelessly updating a digital clock introduces user-friendliness and overall customer satisfaction. Although this advantage may not be much desired in clocks that display just time, wireless update would find great application in more advanced digital clocks such as those which, in addition to displaying time, display personalized messages. These types of clocks also act as electronic display boards, displaying important messages as programmed by the user such as birthday messages, notices to visitors at the reception, warning signs, etc. Also, the components used provided a cheap but efficient method of design. Future designs could replace smaller LCDs with bigger ones or LED matrix displays.

5. REFERENCES

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