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RESEARCH ARTICLE

# A NodeMCU Based Low-Cost Portable Device for Change Indication in Multiple Financial Commodities of Various Market Paradigms

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**ABSTRACT** Online trading has become an important component of the portfolio of investors as it provides an attractive and profitable investment option in spite of the risk involved. Many individuals embraced diversified financial portfolios and started investing in Stocks, Cryptocurrencies, Bonds, Metals, and Commodities through online portals. It needs constant attention to the price of the financial commodities to obtain profits. However, the majority of the investors are landing in losses because of the lack of continual monitoring of the prices to ascertain the changes in the prices of financial commodities all the time. In this work, to assist users in order to avoid this tiresome task of continual monitoring, a prototype of a low-cost portable device for change indication in the price of multiple financial commodities of various trading paradigms based on NodeMCU is proposed. The device includes a Data retrieval and processing (DRP) unit in the form of nodeMCU, control unit, and notification unit. The DRP unit initially obtains the list of the financial commodities and control parameters including sampling rate, threshold, and time delay from the Google Firebase real-time database which are collected from user through a mobile application. Further, it fetches the real-time price data of the financial commodities to compute the percentage change in the given time duration and obtain the prioritized list i.e., the list of financial commodities as per the descending order of absolute percentage change and instructs the notification unit to generate alarm through an audio buzzer in case at least if one of the financial commodity exhibits an absolute percentage change greater than a predefined threshold. The notification unit also contains Red and Green LEDs corresponding to each of the financial commodities to indicate negative and positive changes that exceed the threshold. Further, an LCD displays the details of the first financial quantity in the prioritized list. The control unit comprises two designated switches to change the financial quantity whose details are to be displayed on the LCD and a silent mode switch to disable the audio notifications for the sake of convenience of the user. A prototype of the proposed device is realized with 16 cryptocurrencies, a sampling rate of one sample per minute, and a time delay of one hour for the purpose of testing the device. A maximum of 0.20 % of the mean error rate is observed in the price of Dogecoin, and 0% of the mean error rate is observed in the percentage change of price corresponding to all cryptocurrencies. Further, the number of notifications using RED and GREEN LEDs are computed for all cryptocurrencies which are found to be exactly in match with the original data with various threshold values of 1%,2%,5%, and 10%. The total number of notifications including both Red and Green LEDs is found to be higher in HBAR. The proposed device assists investors in making timely decisions for profitable trading and provides valuable insights about the momentum of various markets to readjust the investments and balance the portfolios accordingly.

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**INDEX TERMS** NodeMCU, shift register, financial commodity, data retrieval and processing unit, notification unit, control unit.

## I. INTRODUCTION

In the past decade, because of improved literacy, ease of access, and improved financial conditions number of investors in various market paradigms has increased significantly. The investors are careful enough to design their portfolios with a diversified spectrum of investments in various markets including stocks, commodities, bonds, and cryptocurrencies. Achieving profits by trading in these markets needs continuous monitoring of the price of the financial commodities. A significant fraction of these investors are considering online trading a part-time option, and they lack time and concentration in continuous monitoring of the key movements in the price of the financial commodities resulting in huge losses. There are several mobile applications and websites that provide notifications of the change in the price of the individual market/financial commodity. For example, Zerodha, Groww, NerdWallet, etc. are websites and mobile applications that provide notifications on changes in selected stock prices. CoinGecko [19], Coinmarketcap [20], Wazrix [18] are mobile applications and websites that provide notifications on changes in price of the cryptocurrencies. Similar websites and mobile applications can be listed in each of the market paradigms. All these websites and mobile applications need a mobile or a computer as a platform for running these applications. Buying and maintaining costly mobile phones and computers can become a hurdle and financial burden to investors with limited financial assets. Further, simultaneous operation of financial applications and other mobile applications in mobile can be a potential threat to the lifespan of mobile batteries. In some of these websites/applications, there is a delay in updating the price of the financial commodities which can prove fatal to the investments of the traders. Although, there are few paid/rental mobile applications like SoFi invest, Ally invest, and Vangaurd [17], that provide notification services to investors for multiple financial commodities, monitoring multiple financial commodities is still mobile/Computer dependent, and further costly affair due to the paid services. Most of these websites and mobile applications are not customizable as per the user requirement. For example, most of the mobile applications provide percentage change over 24*Hrs* and are not customizable to the requirement making it suitable for day traders. A low-cost portable dedicated customizable hardware device that provides notifications regarding the changes in the price of financial commodities can solve the issue. There are few patents granted/published in the field of financial technologies. The inventors in [1], developed a system that involves computer connected to the web server of a given stock trading platform and monitors the price to send this information to a client device via the internet. It employs a computer to perform the simple task of an information transfer system that displays and reads out the current price. In [2], a computer-based system is proposed for defining the stop laws manually and further providing notifications to the user through email, phone call, or a phone message whenever the stop laws are satisfied. Ronca et al. [3], developed a system for optimal exchange of the currencies with each other. Seung-Wook [5], uses a wireless/wired connection to a client selling portal to update the price of a given commodity based on the prices of the competitive goods in the open market. The inventors of [6], developed an electronic device for generating the key prices of financial commodities for current trading based on historical price data. Chheda in [7], developed a mobile application which communicates with a central server that sends real time price data to alert modules in the form of feed packets,and generates notifications based on conditional parameters. Lei and Jin [10], developed an automatic price-updating system of commodities in the shopping carts based on two user-defined verification rules to update four thresholds that are useful in determining the price. The researchers in [12], proposed a computer/mobile phone based system that predicts the price of cryptocurrency based on the transactions using artificial intelligence techniques. However, these systems except [6] involve usage of a computer hence it is costly for a trader with limited financial assets. Table 1 provides a comparative statement of various solutions with similar objectives with estimated cost. It indicates that there are very few works in literature with objective of monitoring of price of different financial commodities that are corresponding to various market paradigms. The existing works are mostly mobile applications/websites which require either a mobile or a computer to access. Further these solutions are not customizable to user's choice. It is humbly submitted that it is the first time that an attempt is made to design and prototype of a customizable solution in low cost in the form of a device for change indication in price of financial commodities.

The authors of [4], used two NodeMCUs one as an access point and the other one as a station to find out the distance between two points using the Received Signal Strength Indicator (RSSI) methods. On [14], NodeMCU along with Arduino is used for patient health monitoring systems. Vamseekrishna et al. [8], used nodeMCU which is connected with internet to switch on and off the PIN diodes to reconfigure the frequency range of multi band antenna to one of eight bands. A nodeMCU based home automation system using IOT is proposed in [9], in which the nodeMCU is connected with the sensors and devices to collect data and send it to the central server so that the user can access this data anywhere and take appropriate action from remote location through nodeMCU which instruct the devices that are equipped with relays to switch on and off. Jabbar et al. in [9], nodeMCU is used to collect the data from sensors and upload it to AdaFruit MQTT server so that the parents can check the vitals and mood of the baby

**TABLE 1.** Related works with estimated costs.

| Reference | Type | Objective | Need of computer | Need of mobile | Need of dedicated server | Need of external server | Cost |
|---|---|---|---|---|---|---|---|
| U. Kawasaki [1] | Computer based system | Price monitoring and alert system | ✓ | ✗ | ✗ | ✓ | 18000 |
| X WANG [2] | Computer based system along with dedicated hardware | Stop laws implementation | ✓ | ✗ | ✗ | ✓ | 18000 |
| J Ronca et al [3] | Computer based system | Currency exchange | ✓ | ✗ | ✗ | ✓ | 18000 |
| S Lee et al [5] | Computer based system | Price updating system | ✓ | ✗ | ✗ | ✓ | 18000 |
| R Elisa [6] | Embedded system | Key price calculation | ✗ | ✗ | ✗ | ✓ | 5000 |
| S D Chadda [7] | Computer and mobile based system | Alerting system based on control parameters | ✓ | ✓ | ✓ | ✓ | 23000 |
| D Lei et al [10] | Computer based system | Threshold based Price updating | ✓ | ✗ | ✗ | ✓ | 18000 |
| Oo ki Young et al [12] | Mobile application | Cryptocurrency price prediction | ✗ | ✓ | ✗ | ✓ | 8000 |
| CoinMarketcap [20] | Mobile application | Cryptocurrency price monitoring | ✗ | ✓ | ✗ | ✓ | 8000 |
| Proposed device | Embedded system | Notification system for dominant changes in financial commodities | ✗ | ✗ | ✗ | ✓ | 974 |

from remote location. NodeMCU integrated with a PID temperature controller is used as a portable thermal device to control, monitor, and manipulate the cartridge heater in the process of synthesis of ZnO in [13]. The Ammonium content in water is monitored through an innovative sensor that is connected through nodeMCU through webserver in [15]. In [16], Djehaiche et al. proposed a adaptive control of IoT devices in smart buildings using heterogenous wireless networks using nodeMCU and Arduino boards. There are several such research works where nodeMCU is used for Data processing, collection, transmission, and reception. Inspired by such applications of nodeMCU in various fields and as it is a low cost WiFi enabled microcontroller which can be easily programmable, in the current work nodeMCU is selected for data retrieval and processing.

## II. MATERIALS AND METHODS

### A. KEY FEATURES OF THE DEVICE

- A low-cost portable dedicated device for change indication in the price of financial commodities is proposed. The device can be switched by connecting it to a USB Micro B cable.
- The list of financial commodities provided by the user through a secured mobile application is uploaded to Google fire-base cloud hosted real-time database, which is further obtained by the DRP unit of the device.
- The NodeMCU/DRP unit in the device iteratively fetches the price data of the financial commodities at two time stamps with a predefined differences i.e., at the current time stamp and at a preceding time stamp whose difference with the current timestamp is a predefined constant.
- The device provides automatic notification of substantial changes in the price of financial commodities through a Notification unit that comprises audio intervention and Visual inspection.
- The user is provided notification by an audio intervention which is facilitated by using a Buzzer when the absolute percentage change in at least one of the financial commodities in a selected time frame is greater than a predefined threshold.
- Further, the user can easily perceive the changes in the price of financial commodities during the given time duration by visually inspecting the series of LEDs which indicate that the absolute percentage change in the respective cryptocurrency in the given time duration greater than the threshold.
- The Red LEDs indicate a substantial change in the price of the cryptocurrency in a negative direction whereas the Green LEDs indicate a positive change. The LCD display shows the details of financial commodities including the name of the commodity,the current price of the commodity, and percentage change in the selected time period as per the descending order of absolute percentage change in the financial commodities.
- The device further includes a control unit which comprises designated push buttons to facilitate the change of financial commodity to the next and to reset to the first in the descending order, and a switch for enabling silent mode for the comfort of the user.

### B. KEY HARDWARE COMPONENTS OF THE DEVICE

The proposed device is expected to be an inexpensive, portable device, hence the hardware is supposed to be minimal and optimal both in size and cost. The device uses NodeMCU, Shift registers, Red and Green Light Emitting Diodes (LEDs), a Buzzer, a $16 \times 2$ Liquid crystal display, Push Buttons, and a Push ON/Push OFF switch. The purpose of each of the components in the device along with the specifications are given in Table 2.

**TABLE 2.** Specifications and purpose of each of the component in the proposed device.

| Component | Type | Specification and Purpose |
|---|---|---|
| NodeMCU | WiFi enabled Microcontroller | NodeMCU is a low cost open source platform developed by Espressif systems. It comprises of ESP8266 System On Chip micro controller with $2.4GHz$ WiFi capability and popularly used for IoT applications. NodeMCU has 4MB flash memory, 64KB SRAM and operates with 3.3V and accepts input voltages of 7-12V. It contains 30 pins out of which 17 General Purpose Input and Output (GPIO) pins, 4 power pins including three 3.3V out, and one $V_{in}$ pin, 4 Ground ($GND$) pins, two control pins, 1 ADC pin and two reserve pins. The GPIO pins are to be used carefully as some of these pins are meant for specific tasks. For example, $GPIO_i, 6 \leq i \leq 11$ are connected to the flash memory, and $GPIO_1$ and $GPIO_3$ are used as $UART\ TX$ and $RX$ pins. The remaining pins are marked as digital pins $D_i, 0 \leq i \leq 8$. $D_1, D_2, D_5, D_6, D_7$ are available for the users for both input and output operations whereas the remaining data pins are to be used with caution for input and output operations as these pins are also assigned with other specific tasks. There are 4 designated pins that generate Pulse Width Modulation (PWM) outputs. However all GPIO pins can be programmed to generate PWM outputs. It is used for the purpose of data retrieval from internet through WiFi connection, processing and decision making. |
| 16X2 LCD | Actuator | A $16X2$ LCD can display 2 lines with 16 characters each, and each character is displayed in 5X7 pixel matrix and capable of displaying 224 different characters and symbols. It is one of the cost effective solution for communicating information by means of visual inspection. It has two registers namely command register, and data register wherein the command register stores instructions of commands and data register store the data in the form of binary equivalents of ASCII values to be displayed on LCD. The LCD has 16 pins out of which 8 pins are data pins $D_i, i = 0 \ldots 7$, two power supply pins (VSS, VCC), two back light power pins (LED+, LED-), a contrast adjustment pin (VEE), one register select pin, Enable pin and one Read/Write pin. In the current work, LCD is used for visual inspection of the details of the financial commodity. |
| I2C adapter | Module | $I2C$ is Inter Integrated circuit provides half duplex hardware protocol by means of which serial data transfer happens via SDA line, between the master and one or more slave devices that are synchronised to same clock through the SCL line. In order to connect such $16X2$ LCD with an Arduino/NodeMCU at least 11 pins of the microcontroller are required which makes it difficult for the user to use the other input/output devices. In order to over come this challenge, an I2C interface is used along with LCD so that the number of pin connections will be reduced to 4 pins, out of which two are for power supply and two are for data transfer. |
| Buzzer | Actuator | A buzzer is a sound signalling device, which has two power pins ($V_{CC}$ and $GND$) operates with DC voltage of range 3-24V (typically 5V is used). It generates an audio signal when powered, and generally used as an audio notification/alarm device. In the proposed device buzzer is used for audio intervention as it is a compact cost effective audio device. |
| LED | Actuator | LED is a transducer of electricity into light. It is a semiconductor diode that generates light of specific wavelength, when enough current flows through it, because of the energy released due to the recombination of holes with electrons. The proposed device uses Red LEDs for indicating negative substantial change in the price of financial commodity where as the Green LEDs are used for indicating substantial positive change. |
| Shift register | Serial in Parallel out interfacing module | Shift register is a digital device comprises of cascaded flipflops operating at same clock frequency and popularly used for serial to parallel and parallel to serial data conversion. The IC has 16 pins, out of which 8 pins are data pins, two power supply pins ($V_{CC}$ and $GND$), one master clear, one clock pin, one latch pin, one output enable, and one serial data input. In the current work, the proposed device uses 8 bit shift register IC 74HC595 for serial to parallel data conversion through which multiple LEDs are provided inputs by the nodeMCU through the shift register. |
| Push ON/ Push OFF switch | Actuator | Push ON/Push OFF is a mechanical arrangement where an electric circuit will be closed when there is an external force is applied on the switch and it get's latched to that position until external force is applied one more time to break the electric circuit to make the switch to return to the actual position. It is used for activating silent mode operation of proposed device. |
| Push Button | Actuator | Push button switch is a mechanical in out actuation mechanism which should be triggered by the user by pressing the push button in order to break (OFF) or initiate (ON) an electric circuit. This is typically used for triggering/controlling an action in a process. In the current work, two push buttons are used for iterating through the list of the financial commodity that is displayed on the LCD. |

### C. MOBILE APPLICATION

A mobile application is developed using the Google firebase application development framework to assist the user in providing the necessary inputs for customization of control parameters including the list of symbols of the financial commodities, the time delay between the time stamps, sampling rate, and threshold. Fig. 1 shows the flow of the steps in the Graphical User Interface (GUI) to the user at different stages of using the mobile application. The device is preloaded with a default set of control parameters i.e., a list of predefined financial commodities, a sampling rate of one sample per minute, a threshold of 1%, and a time delay of one hour. In order to change these control parameters, the application requests the user to initially register to the mobile application through the interface, in order to create a personalized list of financial commodities and a set of control parameters. The user further needs to login to his account whenever a change of commodities or set of control parameters is required. Currently, a mobile application is developed to provide a choice of combination of cryptocurrencies and stocks, which can be easily extended to the generalization of the remaining commodities. The mobile application displays the list of financial commodities, for confirmation before generating a pdf file containing the names of the financial commodities which may be pasted on the device. Fig. 2, depicts the data stored in the user account on Google firebase real time database.

### COST ESTIMATION

The cost of each individual component is listed in Indian rupees in Table 3, to estimate the total approximate cost

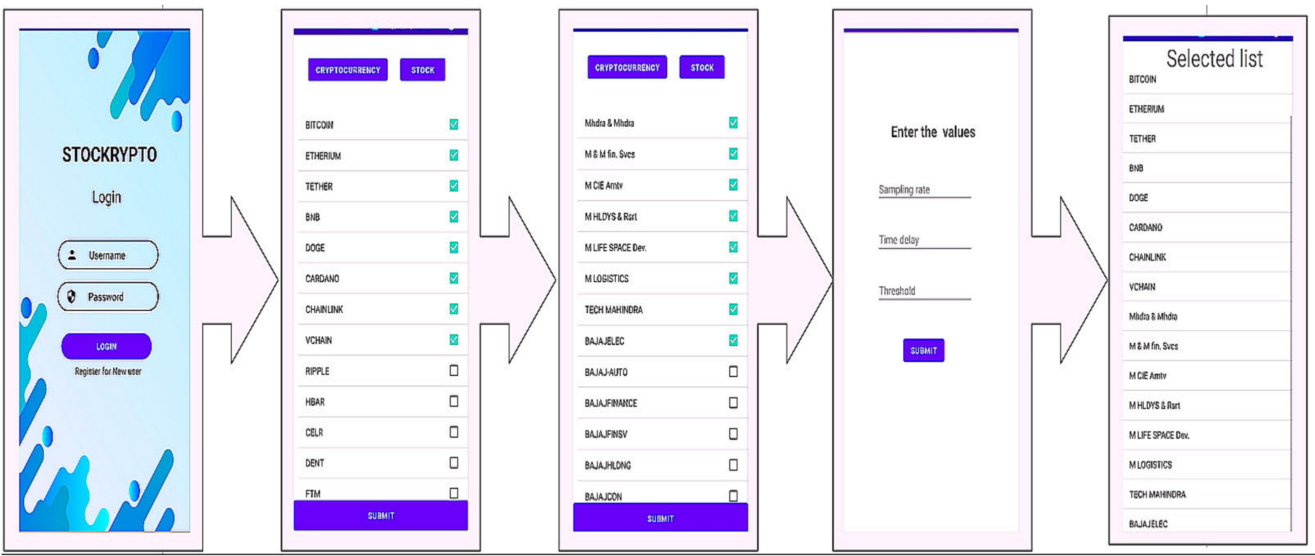



**FIGURE 1.** Demonstration of use of mobile application.

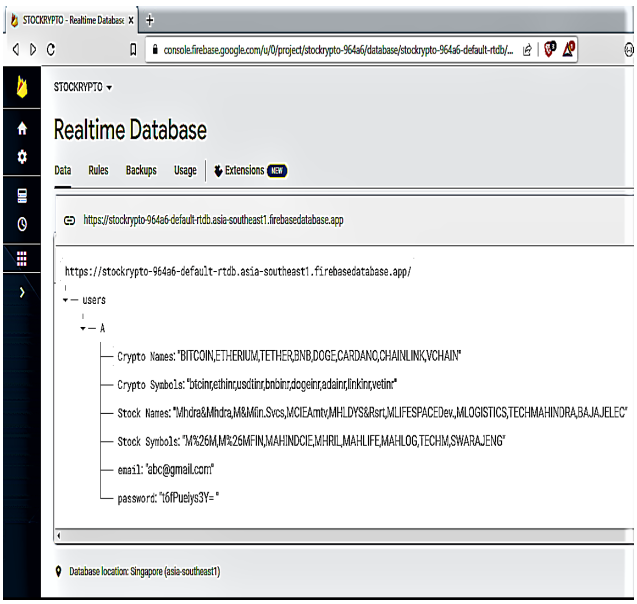



**FIGURE 2.** List of symbols in user account in Google firebase.

**TABLE 3.** Cost estimation of the proposed device.

| Component | Quantity | Cost per 1 (INR) | Total (INR) |
|---|---|---|---|
| NodeMcu | 1 | 200 | 200 |
| 16x2 LCD display | 1 | 170 | 170 |
| I2C module | 1 | 150 | 150 |
| Shift Register | 4 | 20 | 80 |
| Buzzer | 1 | 20 | 20 |
| Push Buttons | 2 | 10 | 20 |
| LED | 32 | 1 | 32 |
| Switch | 1 | 10 | 10 |
| PCB | 1 | 20 | 20 |
| Outer case | 172gm | 1 per gram | 172 |
| Miscellaneous | – | – | 100 |
| Total Approximate cost | | | 974 (INR) |

of the proposed device. The total cost of the device is approximately 974 INR i.e. about 12 $.

### D. SYSTEM DESIGN

The architecture of the proposed device is shown in Fig. 3. It contains Control unit, Data retrieval and processing unit, and a Notification unit. Data retrieval and Processing (DRP) is the major component of the device that loads the symbols of the selected financial commodities from the Google firebase real time database that are uploaded by the user through the mobile application, fetches the current time stamp, and price data of the financial commodities at the current time stamp, and at a past time stamp preceded to the current time stamp by a given delay, from internet. Further, the DRP unit computes the Percentage Change (PC) and Absolute Percentage Change (APC) in all financial commodities using Equation 1.

$$PC = \frac{FC_i(t) - FC_i(t-\tau)}{FC_i(t-\tau)} \times 100 \tag{1}$$

$$APC = |PC| \tag{2}$$

where $FC_i(t)$, is the price of the $i^{th}$ financial commodity at the time stamp $t$ and $\tau$ is the selected time delay. Subsequently, the DRP unit sorts the financial commodities as per the descending order of the absolute percentage change in the time duration $\tau$ to obtain the prioritized list of the financial commodities. To achieve this a microcontroller having the ability to connect with the internet is needed. NodeMCU which is a compact and low cost microcontroller with built-in WiFi capability, is appropriate as a DRP unit. The DRP unit instructs the notification unit that contains $16 \times 2$ LCD, Red and Green LEDs equal in number to that of the financial commodities, and an audio buzzer to notify the user. The audio buzzer generates a sound signal in the form of a pure sinusoidal tone if the absolute percentage change in at least one of the financial commodities is greater than the pre defined threshold. The LCD displays the details including name, percentage change, and current price of the

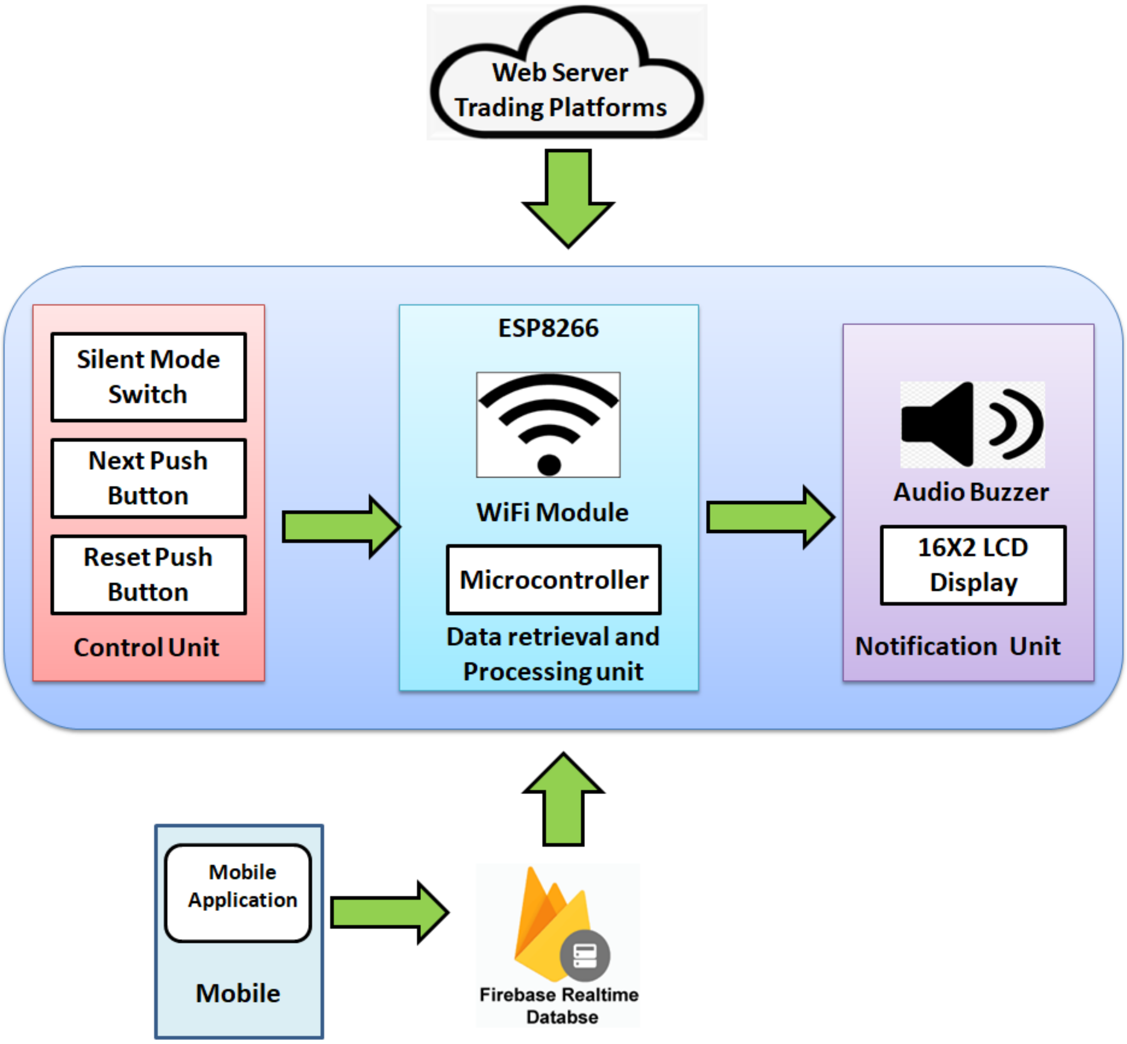



**FIGURE 3.** System architecture.

first financial commodity in the prioritized list. The Red LED switches on if there is a substantial negative change in the price of the corresponding financial commodity with respect to the predefined threshold, and similarly, Green LED switches if there is a substantial positive change in the price of the corresponding financial commodity during the predefined time duration $\tau$.

The control unit consists of two push-button switches which are used to change the financial commodity whose details are displayed on the LCD. The first push-button switch changes the details displayed on the LCD to the next financial commodity to the next one in the prioritized list and the other switch triggers the details displayed on the LCD to the first one of the priority list. The control unit also consists of a ON/OFF switch in the form of silent mode switch that disables the audio intervention by the buzzer, when switched off to avoid disturbance to the user for convenience.

In the current work, a prototype of the proposed device with 16 financial commodities is considered. In such case, 16 green LEDs, 16 Red LEDs i.e. a total of 32 pins are needed. For the connection of the LCD at least 11 pins are required. For two push buttons, one ON/OFF switch, one audio buzzer 4 pins are required. Hence a total of 47 pins are required where as nodeMCU offers 5 digital pins for both input and output operations ($D_i$, $i = 1, 2, 5, 6, 7$), two digital pins for output operations ($D_3, D_4$), and an analog input. To overcome this shortcoming of pins, an I2C is used along with the LCD display which reduces the pin requirement of LCD pins to 2 pins (one clock SCL, and one data pins SDA). Further 32 LEDs can be driven by the nodeMCU using two pins by serial to parallel data conversion by employing cascaded shift registers. As 32 LEDs to be driven 4 shift registers (IC74HC595) are cascaded. Reference [11] demonstrates the use of shift registers to drive multiple LEDs. With this, the requirement of the input-output pins drops to 8 pins and hence the problem of short-coming of the pins is solved. In addition to $D_i, i = 1, 2, 3, 4, 5, 6, 7$, $D_8$ is used as input by connecting a pull-down transistor to ground. The schematic of the proposed device with 16 financial commodities is shown in Fig. 4.

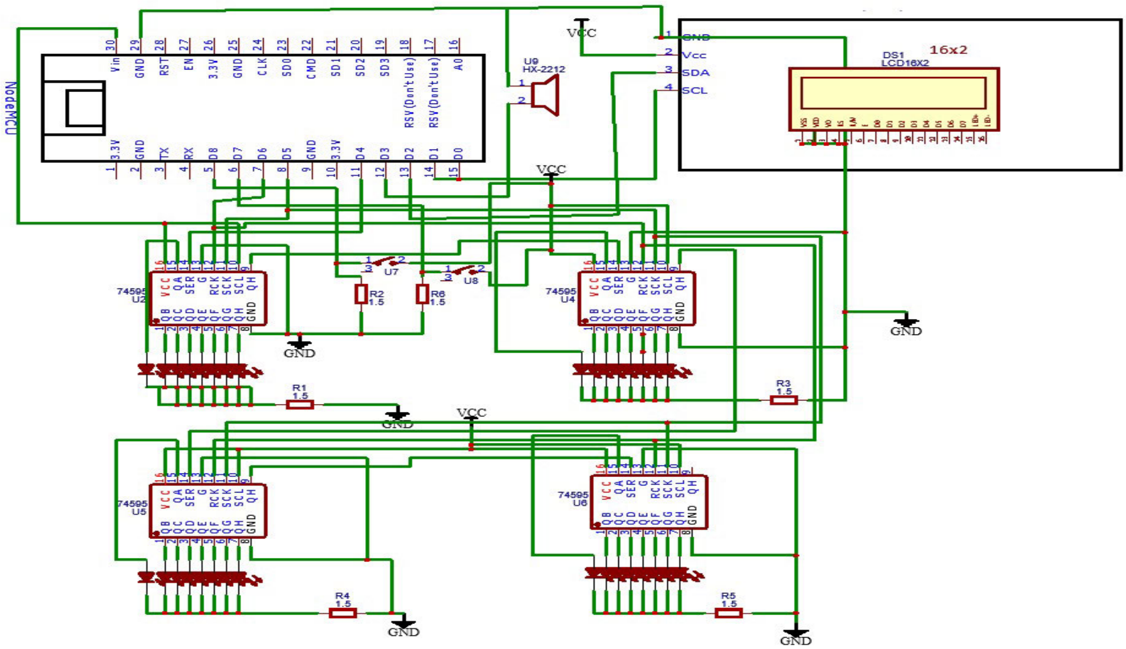



**FIGURE 4.** Schematic of the proposed device.

The flowchart of the implemented algorithm using the device is shown in Fig. 5. The algorithm includes four modules namely, Initialization, Data retrieval and processing, Notification module, and Control module. The initialization module involves including the libraries required for various input/output peripherals, and reading the list of financial commodities and control parameters from the Google Firebase real-time database of the user account. The reading list includes usrCmdlst, an array of commodities selected by user. usrSmb, an array of symbols of commodities selected by the user. The other definitions are audioEnbl, used to switch the device to silent mode whenever needed. audioIn, used to give the buzzer sound when the percentage change is greater than threshold and the audioEnbl is high. redList, an array of red LEDs in which each LED is allocated to each commodity given by user respectively. The LED glows whenever the percentage change of respective commodity is greater than the threshold and is negative. greenList, an array of red LEDs in which each LED is allocated to each commodity given by user respectively. The LED glows whenever the percentage change of respective commodity is greater than the threshold and is positive. absPrcntgChng, indicates Equation 2. PrcntgChng, indicates Equation 1. SmplPrd, the time duration between two consecutive samples. timeDelay, the time diff between two timestamps at which the price is being compared. Thrshd, the threshold of percentage change set by the user. The objective of the data retrieval and processing module is to establish a secure WiFi connection through which internet is connected, error handling for WiFi and internet connection lost issues, parsing the weblinks/APIs of the trading websites for fetching the price at the current time stamp and previous time stamp to calculate the percentage and absolute percentage changes to obtain the priority list of the financial commodities. The notification module generates the necessary inputs for LCD, audio buzzer, and LEDs. The control unit is implemented using interrupts. Separate interrupt service routines are implemented for each of the components in control unit i.e., for silent mode switch as ISR1, push button1 as ISR2, and push button 2 ISR3.

**TABLE 4.** The power consumption in each of the component in the device.

| S.No | Component Name | Qty | Current per one | Total Current | Avg Power |
|---|---|---|---|---|---|
| 1 | Node MCU | 1 | 150mA | 150 mA | 750mW |
| 2 | 16X2LCD Display | 1 | 21mA | 21 mA | 105mW |
| 3 | Shift Register | 4 | 8mA | 32mA | 160mW |
| 4 | LEDs' | 16 | 10mA | 160mA | 800mW |
| 5 | Buzzer | 1 | 10mA | 10mA | 50mW |
| Total Power | | | | | 1.815 W |

### *POWER CALCULATIONS*

A typical mobile charger which consists of an adapter along with USB micro B cable which is capable of driving more than 5WH, is used for operation of the device. The maximum possible power consumption of the device is determined by the summation of the maximum power consumed in each of the individual components using the specified rating of the components which are listed in Table 4. For the current realization with 16 cryptocurrencies the maximum power consumed is 1.815WH (1.815W in one hour) which is far below the rating of the adapter and USB micro B cable.

## III. PROTOTYPING

The prototyping of the device is carried out in two phases namely PCB designing and printing and housing design and

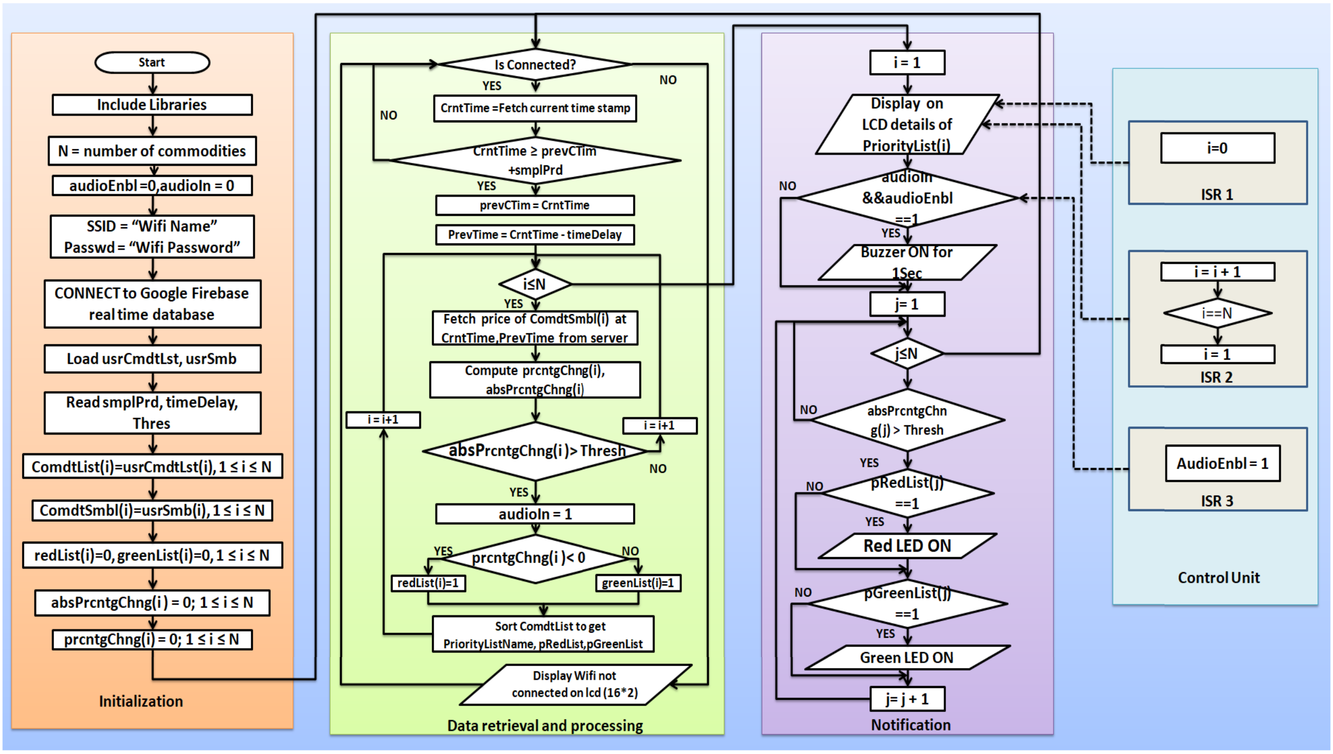


**FIGURE 5.** Flow chart of implemented algorithm.

3D printing. The PCB is designed using EasyEDA software which generates Gerber files that are converted into G-codes using FlatCam and are further used for PCB printing which is carried out using NVIS72 machine and NVIS72 software. The components are soldered to the PCB and the components are connected to the PCB to external wires where ever required. The housing is designed using TinkerCAD software which generates ''.stl'' file which is further converted into G-code using simplify3D and printed using the Pratham 3.0 3D printer. The PCB along with the components is mounted in the housing to complete the prototyping.

### *A. PCB DESIGNING AND PRINTING*

The flowchart of the PCB designing and designing is shown in Fig. 6 and the outcomes at different phases are shown in Fig. 7. It involves the use of three software namely EasyEDA, FlatCam, and NVIS72 interfacing software. As shown in Fig. 6, PCB design is accomplished using two software namely EasyEDA, and FlatCam. The PCB printing using a CNC plotter involves four processes namely Milling, Engraving, Drilling, and Routing generally performed in the same order. Milling is the process of removing an area of copper in order to recreate the signal traces and pattern according to the circuit diagram and Engraving is the process of removing the unwanted copper from PCB. Drilling is a process of creating holes, slots and other cavities of various diameter or same diameter and routing involves cutting the outer border of the circuit board. The schematic of the circuit design is built in the workspace of the EasyEDA by selecting a ''New Project'', importing components from the library, Wiring, followed by Netlist check. Further, once the netlist check is passed, the schematic is exported to the PCB layout. Rearrange the wires to traces and settings including width, hole dimensions, and isolation settings for each of the traces are defined, followed by the Design Rule Check (DRC). After the DRC test is successful the Gerber files are generated through EasyEDA software. The Gerber files generated by the EasyEDA software are imported into FlatCam software where the customized control parameters for Milling, Engraving, Drilling, and Routing are defined to generate the individual G-code files. The control parameters for each of the operations varies depending on the requirement of the operation. For example, Milling, Engraving, and Routing needs a definition of CNC job which includes corresponding tool bit types and step sizes. The drilling control parameters include various tool bit types (diameters), and spindle speed as inputs to the FlatCam which generates G-code for each of the tool bits. The visualization of the Milling of PCB and drilling of the PCB are shown in Figs. 7a, 7b. The G-code files generated by FlatCam for milling, engraving, drilling, and routing in the same order are imported into NVIS72 software which is communicated by the computer to the NVIS72 machine for printing the PCB. To initiate the process of PCB printing PCB plate is placed on the base of the NVIS 72 machine and contact is made with the base through connecting wire. A conductivity test between the base plate and PCB is performed using a multi meter to ensure that the electrical

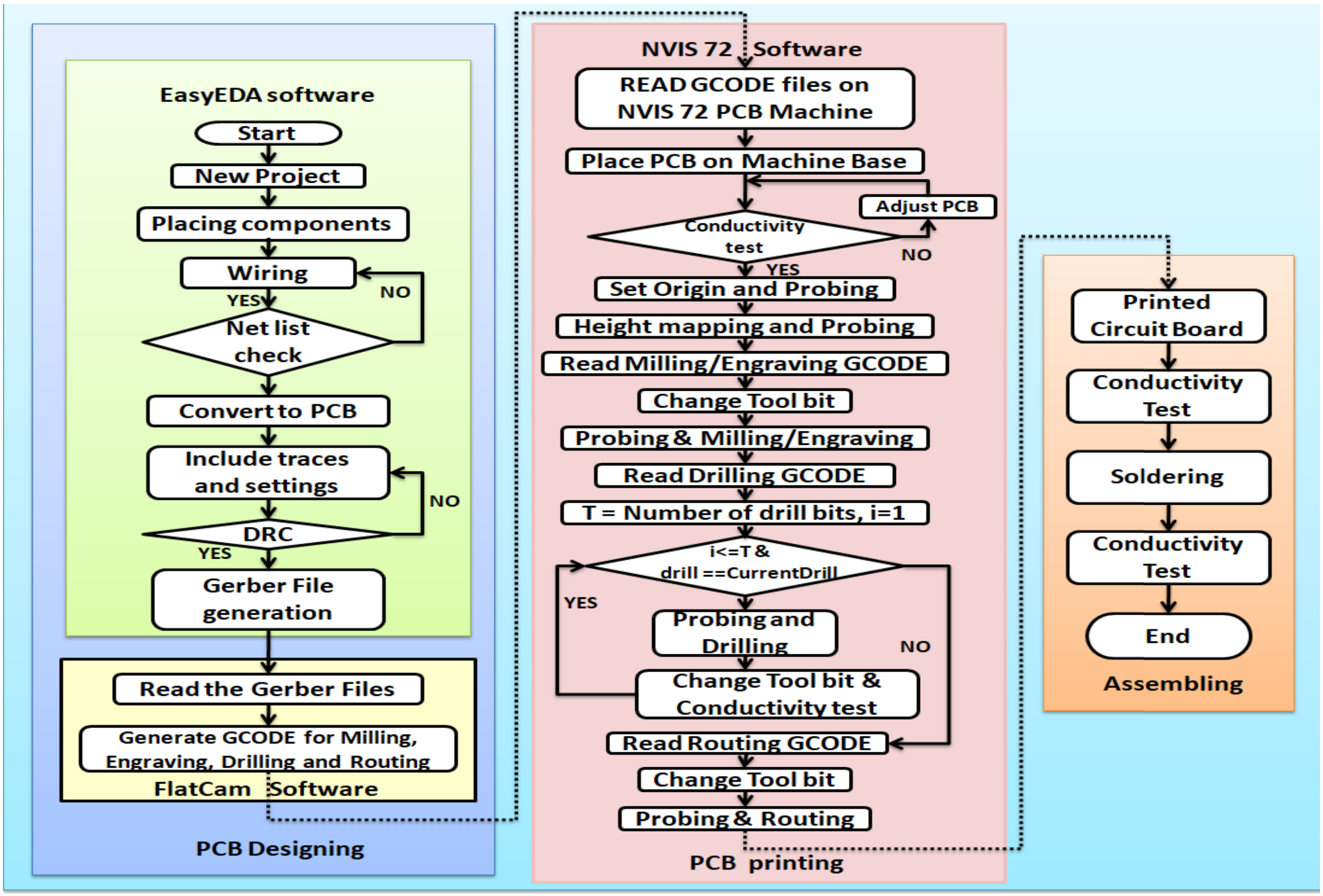



**FIGURE 6.** Flow chart for PCB design and printing with NVIS 72 PCB prototyping machine.

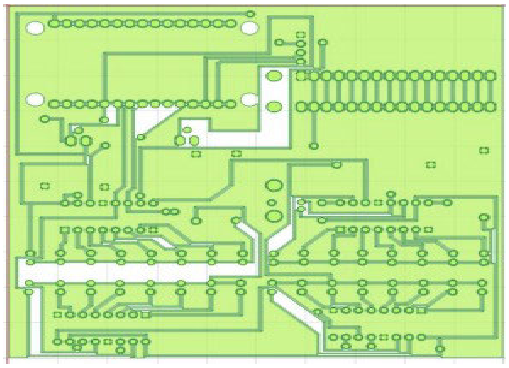
contact is properly established to avoid damage to the tool bit, PCB, and machine. This conductivity test should be performed whenever the tool bit is changed. The reference point or Origin is fixed in the workspace of NVIS72 and after the tool bit corresponding to the operation is fixed to the spindle, conductivity test and probing are performed to fix the Z-axis of the tool. After probing height mapping/surface inspection is performed to adjust the machine to minor irregularities in the plate surface. The G-code corresponding to the operation is imported to NVIS72 to perform milling, engraving, drilling, and routing with corresponding tool bits. After completion of the four operations, the PCB is tested for conductivity for all traces and further, the components are soldered and assembled onto the PCB. Fig. 8, depicts the PCB after soldering the components onto it, and assembling the remaining components through wires wherever required.

### *B. DESIGN AND 3D PRINTING OF HOUSING*

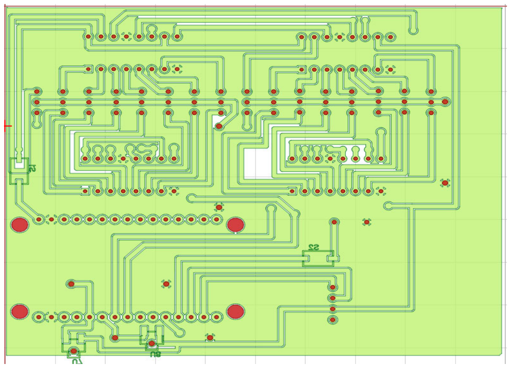
A housing for placing the PCB along with the components is designed using TinkerCAD and printed using PLA filament of 1.75 mm by using Pratham 3.0 of 0.4mm nozzle. TinkerCAD is a software used for designing 3D designs, electronics, and coding. It generates a ".stl" file which is to be converted into G-code by using software like simplify3D. The simplify3D also enables the user to re-scale, rotate, and set the control parameters including infill percentage, infill structure, adjusting the supports, choice of support material, etc. The G-code files are saved to a memory device which needs to be connected to the 3D printer i.e., Pratham 3.0. The housing is printed using the 3D printer further undergoes post process for removal of support material and smoothing. Fig. 9a and Fig. 9b show the top and bottom of the 3D printing case which are designed and printed separately.

## IV. RESULTS AND DISCUSSIONS

In the current work, a prototype of the proposed device is prepared where the user has selected 16 cryptocurrencies as financial commodities and provided the control parameters as $\tau = 86400S$, a threshold of 1%, and sampling period equal to one sample per minute through the mobile application. The time delay is selected as 86400 i.e., 24*Hrs* to verify the result with respect to the Wazrix website as it gives a percentage change over 24*Hrs* only. Some of the cryptocurrencies selected may easily be replaced with other financial commodities of different types by modifying the API keys/web links of the trading platforms. Hence for the sake of simplifying the verification of the result and without loss of generality, 16 cryptocurrencies are considered. For these cryptocurrencies, the corresponding API keys related to Wazrix are used. Fig. 10b shows the



(a) PCB viewed in FlatCam software



(b) Stock drill view in FlatCam

**FIGURE 7.** Outcomes from FlatCam software.

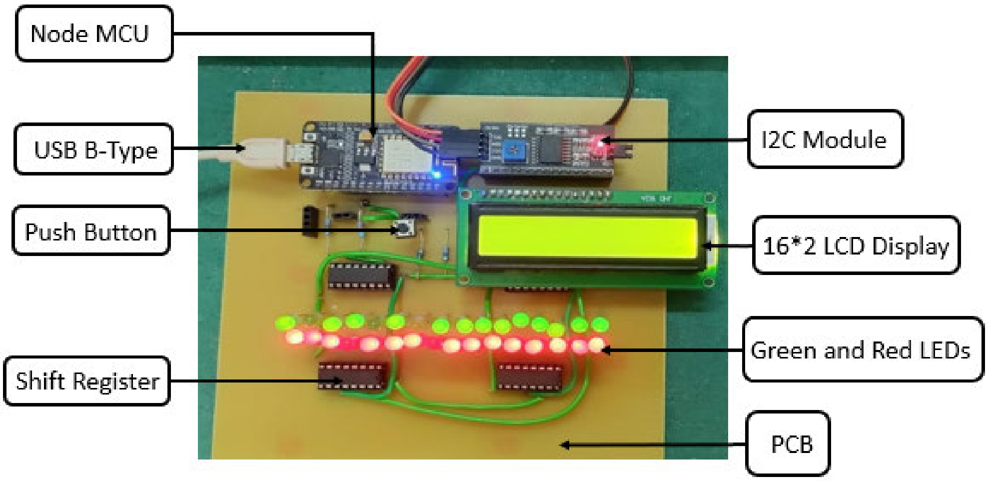
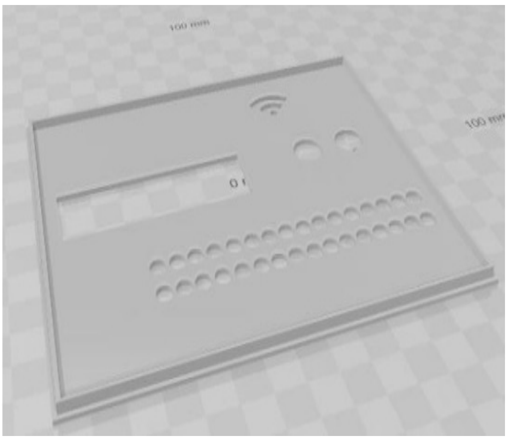
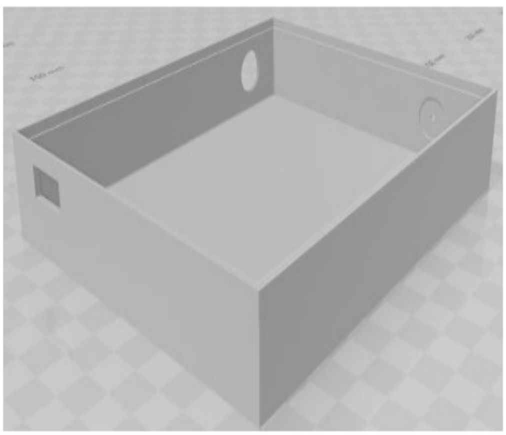



**FIGURE 8.** Components assembled on PCB.



(a) ".stl" file of top of housing

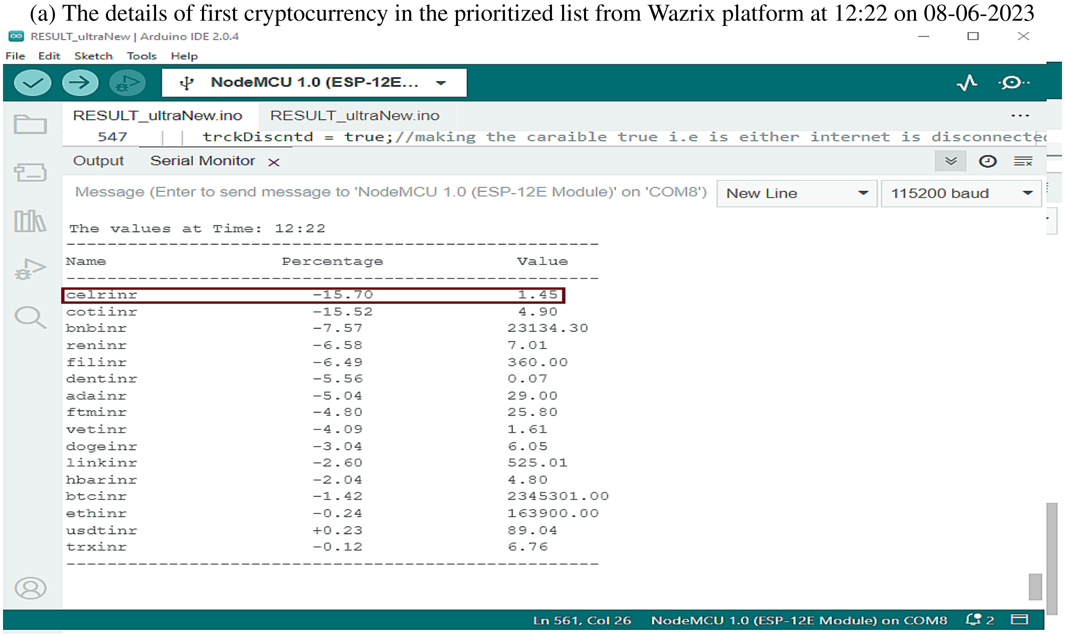


(b) ".stl" file of base of housing

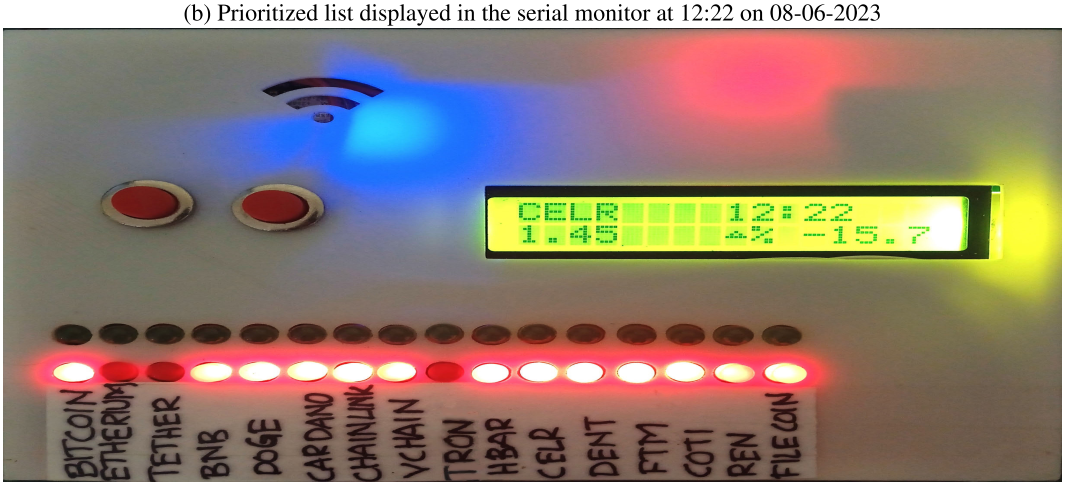
**FIGURE 9.** STL files of housing.

prioritized list of the selected cryptocurrencies obtained using the device and displayed in the serial monitor of the Arduino IDE. The prioritized list is obtained by sorting the 16 cryptocurrencies as per the descending order of their absolute percentage change in the past 24*Hrs*. From the prioritized list displayed it can be easily verified that it indeed contains the cryptocurrencies in descending order of their absolute percentage change in their prices. In fact, majority of the mobile applications/ and websites don't provide such a prioritized list with respect to the absolute percentage. The details of the first cryptocurrency in the priority list displayed on the $16 \times 2$ LCD of the device are shown in Fig. 10c.


(a) The details of first cryptocurrency in the prioritized list from Wazrix platform at 12:22 on 08-06-2023




(b) Prioritized list displayed in the serial monitor at 12:22 on 08-06-2023




(c) Results displayed in 16$X$2 LCD of the device at 12:22 on 08-06-2023

**FIGURE 10. Results obtained using the device, displayed on serial monitor, and verified with Wazrix.**

Further the details of the first cryptocurrency in the prioritized list on the Wazrix trading platform are depicted in Fig. 10a. The details of the first cryptocurrency in the prioritized list displayed on the LCD are matching with the details from the Wazrix trading platform. The 0.01 error in the percentage change is due to truncation performed to display on the LCD. Fig. 10b indicates that there is a positive change in only USDT (Tether) and in all the remaining coins negative change is observed. However, the LEDs will be switched on only if the absolute percentage change is greater than the threshold i.e., 1 %. Hence, except for Ethereum, USDT, and Tron there is substantial negative change and should be indicated by the corresponding Red LEDs. No coin exhibits substantial positive change, so no Green LED should be switched ON. Fig. 10c indicates the same scenario where Red LEDs are switched ON corresponding to all the coins except for the three coins mentioned earlier.

Further the price of the cryptocurrency and the percentage change in the price of the crypto coins retrieved and computed using the proposed system are compared with the original data from Wazrix website over one day with a sampling period of 1 sample per minute, a time delay of one hour from 08$^{th}$ Jan 2024 6.00Am to 09$^{th}$ Jan 2024 5:59Am, using the Mean Error Rate in Price ($e_P$), and Mean Error Rate in Percentage Change ($e_{PC}$) that are defined in Equations 3, and 4.

$$e_P = \frac{|MFC_{ps} - MFC_{od}|}{MFC_{od}} \times 100 \tag{3}$$

$$e_{PC} = \frac{|MPC_{ps} - MPC_{od}|}{MPC_{od}} \times 100 \tag{4}$$

$$MFC_{ps} = \frac{\sum_{k=1}^{N} FC_{ps,k}}{N} \tag{5}$$

$$MPC_{ps} = \frac{\sum_{k=1}^{N} PC_{ps,k}}{N} \tag{6}$$

$$MFC_{od} = \frac{\sum_{k=1}^{N} FC_{od,k}}{N} \tag{7}$$

$$MPC_{od} = \frac{\sum_{k=1}^{N} PC_{od,k}}{N} \tag{8}$$

Where, $FC_{ps,k}$, $FC_{od,k}$ are the price of financial commodity retrieved using proposed system, original data respectively, and $PC_{ps,k}$, $PC_{od,k}$ are percentage change in price of the financial commodity computed using the proposed system and the original data respectively at $k^{th}$ sample using the proposed system. $MFC_{ps}$, $MPC_{ps}$ are the mean price of financial commodity and the Mean of percentage change in price of the financial commodities retrieved using proposed system while, $MFC_{od}$, $MPC_{od}$ are the mean price of financial commodity and Mean of percentage change in price of financial commodities using the original data. Fig. 11, shows the Mean error rate ($e_P$) in price of various cryptocurrencies, from which it can be inferred that the mean error rate is zero in most of cryptocurrencies. A maximum of 0.20 % is observed in DENT followed by CELR with 0.025 %. The price of DENT is usually small and in the range of 0.01 to 1.10, and hence the relative error in DENT is observed to be noticeable when compared with remaining cryptocurrencies. The mean error rate in the price of all cryptocurrencies is less than 0.2 % is within the tolerance range. The mean error rate in percentage change of price of all cryptocurrencies under consideration is 0%, which indicates the accuracy of the device.

Further, the proposed system is used to obtain the notifications from 8$^{th}$ Jan 2024 6:00Am to 9$^{th}$ Jan 2024 5:59Am with various threshold values including 1%,2%,5%, and 10 %. The number of notifications for significant positive and negative changes in the price of cryptocurrencies which are communicated to the user by the device are recorded using Coolterm software and illustrated in Fig. 12 for four different thresholds mentioned earlier. Fig. 12, shows that the number of notifications using Red LEDs i.e., notifications of significant negative changes is higher when compared to notifications using Green LEDs in all the cryptocurrencies except Bitcoin (BTC), Ethereum (ETH), and USDT (Tether) coins. It indicates that the market is low in meme coins. In Bitcoin, there are only notifications through Green LEDs, indicating that the price of Bitcoin at a given time is higher than the price of Bitcoin at the same time on the previous day. However, it does not mean that the price of Bitcoin is increasing throughout the day. The number of notifications in all coins is decreasing as the threshold increases. With a threshold of 1%, the number of notifications are high in all coins with a maximum number of total notifications of 1424 in HBAR, and a minimum of total notifications of 301 are observed in TRX (Tron) coins. For HBAR, almost one notification for each minute is observed. This calls for the need of activation of the silent mode of the device, as the device is notified through audio signal to Buzzer every minute, which might be uncomfortable for the user. A change of 1 % in one hour in any coin is usual, and trading with 1% change in price of coins is not advisable, since in crypto market the transaction fee is at least 1%. With a threshold of 2 %, the total number of notifications in USDT (Tether), and TRX(Tron), decreased significantly from 301 to 21, and 384 to 3 respectively. It shows that the price of these coins are flat with out much of a variation and these coins may not be suitable for day trading on that day, where as the total number of notifications in other coins sustained. A higher threshold value for these coins may be suitable. When the threshold is increased to 5%, the number of notifications in eight currencies remained over 500, where as in the remaining it remained below 300. With further increment in the threshold to 10 % the number of notifications in all the coins is 350 which is almost 1 notification every seven minutes. This analysis shows that customization of the thresholds is needed for each of the coin with which the number of notifications can be significantly decreased which saves good amount of time of the user as it is avoiding for the continuous monitoring.

### A. COMPUTATIONAL ISSUES

There is no limit on the number of financial commodities to be selected as there is no limit on the number of shift registers that can be cascaded in principle apart from the memory limitations. However, as the number of financial commodities increases the device needs more time to fetch the details of the financial commodities, and also more loading time is required for the shift out. This loading time may cause the

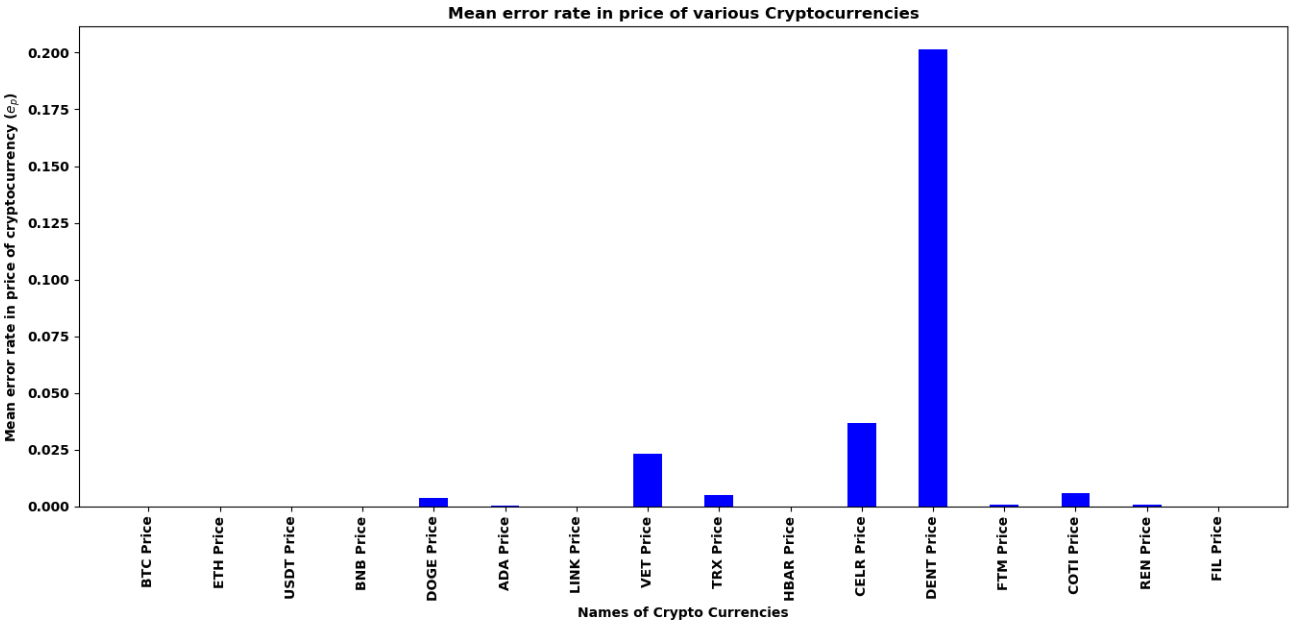



**FIGURE 11.** Mean error rate in prices of various cryptocurrencies.

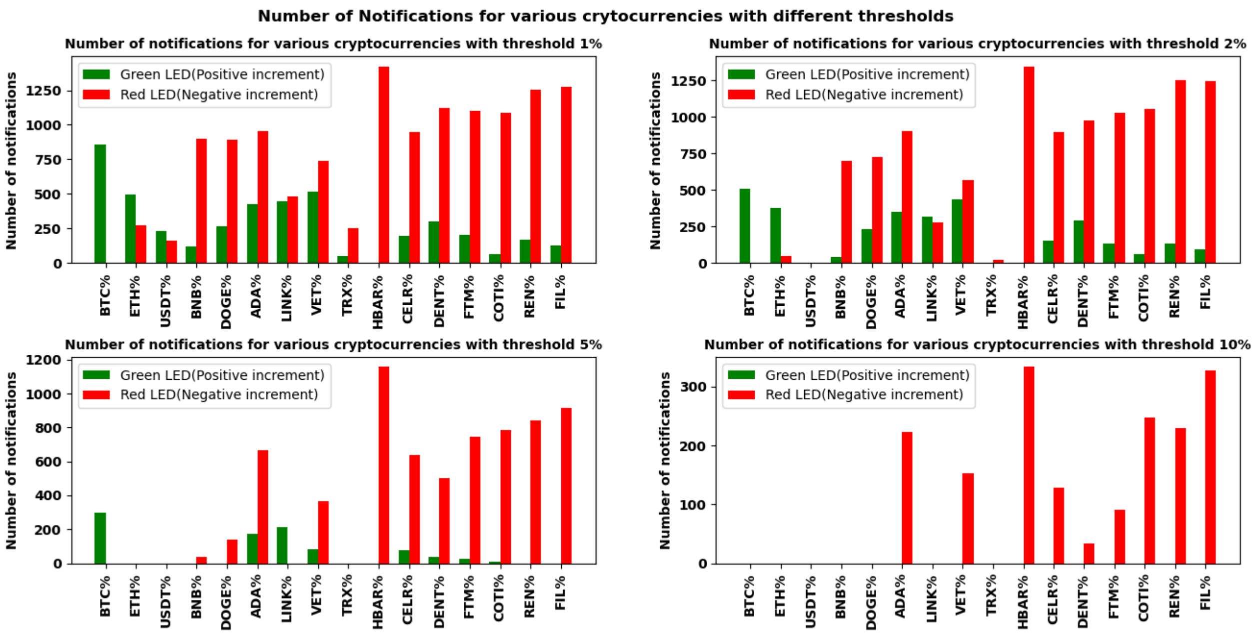



**FIGURE 12.** Notifications based on percentage changes in price of cryptocurrencies with different thresholds.

time for completion of one cycle of fetching, and processing the details of all financial commodities to obtain the priority list to go beyond the sampling period. In such case, the device will be lagging with respect to the current time stamp, and the actual purpose of the device to help the investors to take timely action can be severely affected. One can not actually entirely attribute the delay in processing to this loading time. Infact, the processing time highly depends on the internet speed and operating frequency of microcontroller as well. For the current prototype with 16 cryptocurrencies, implemented using NodeMcU ESP8266-12E of 80MHz operating frequency, it is taking an average delay of 53 seconds to complete one cycle of cryptocurrencies. Hence the sampling period is chosen to be one sample per minute, after considering a buffer time of 7 seconds. It is important to note that the sampling period of one sample per one minute is the minimum sampling period allowed on the proposed device which can be further customizable to one of the user trading choices of one sample per 5minute /15minute /30minute /1hour /2hour /4hour /6hour /12hour/ 1day /1week.

### B. ADVANTAGES OF THE DEVICE

- The device fetches the price data periodically at the given sampling rate hence it assists the investors to make timely decisions for profitable trading.
- The change indication using LEDs simultaneously not only helps in easily monitoring the price fluctuations but also in understanding the trend in the entire market scenario.
- Creating the priority list and showing the details of the first financial commodity in the prioritized list facilitates the user to track down the important changes at that instant time effortlessly and to make prompt and appropriate decisions.
- The device can be customized with the relevant set of control parameters i.e., the sampling period, the time delay between time stamps, threshold, and selection of the financial commodities. Further, the control parameters can also be customized with respect to each of the financial commodity individually.
- Unlike existing solutions in the literature, the device allows customization to the utmost level. The mobile application developed in this work, is need to be used only when a change of parameter or financial commodity is needed. However, the use of mobile applications may be avoided by performing the customization through updating the code, compiling using the Arduino IDE, and uploading the generated binary file to the nodeMCU using Over the Air Update. This needs a bit of technical knowledge and patience.
- The device can provide notifications of various financial commodities of different market paradigms to enable the user to understand the interdependencies of the markets and assist the user for timely action.
- The operation of the device is simple and can easily be operated by a layman.
- The device provides the choice to the user to silence the audio interventions.
- The device is of low cost and mobile/computer independent.

### C. DISADVANTAGES OF THE DEVICE

- The number of financial commodities needs to be fixed before prototyping whereas the mobile dependent software solution does not suffer such a limitation.
- If the number of financial commodities is too high, it may slow down the device, and making the device compact can be an issue as each financial commodity needs two LEDs.
- The performance of the device hugely depends on external factors including the trading platforms and availability the of internet as it doesn't involve a dedicated server.

## V. CONCLUSION

A low-cost portable device for change indication in the price of multiple financial commodities of various market paradigms has been proposed and a prototype of the device has been implemented in the current work. The device has been designed to provide notifications via audio intervention through the audio buzzer and visual inspection through $16 \times 2$ LCD display, and Red and Green LEDs for indication of decrement and increment in the price of the financial commodity. The device comprises of control unit, data retrieval and processing unit, and notification unit. A customised mobile application is developed to collect the list of financial commodities and control parameters to store them in Google Firebase database. The data retrieval and processing unit obtains the list of financial commodities and the control parameters from the Google Firebase database when the device is switched and connected to the internet. The data retrieval and processing unit iteratively fetches the current time stamp and prices of the selected financial commodities at the current time stamp, and at a preceding time stamp delayed by a predefined value to compute the percentage change and absolute percentage change in price of financial commodities and sort the financial commodities as per the descending order of absolute percentage change to obtain the prioritized list of financial commodities. The notification unit in the device is instructed by the DRP unit and is responsible for generating notifications through an audio buzzer, $16 \times 2$ LCD and Red and Green LEDs. The audio buzzer is triggered if the absolute percentage change in at least one of the financial commodity is greater than the predefined threshold. The Green and Red LEDs indicates substantial increment and decrement in the price of the financial commodity respectively, i.e., the corresponding LED to the financial commodity is switched on if the absolute percentage change in the price of the financial commodity is greater than the threshold. The LCD displays the details of the first financial commodity in the prioritized list including the name of the financial commodity, current time, current price, and percentage change in the price of the financial commodity. The details of the remaining financial commodities can be accessed by triggering interrupts through the control unit. The control unit consists of two push-button wherein the first push-button changes the financial commodity on the LCD to the next commodity in the prioritized list and the other push button resets the display to the first of the priority list. The control unit also includes a Push ON/Push OFF switch to enable the silent mode by deactivating the audio button for the convenience of the user. A prototype of the proposed device with a sampling frequency of 1 sample per minute, threshold 1%, time delay 24 hours, and 16 cryptocurrencies have been implemented by PCB design using EasyEDA, and Flatcam software, further, PCB printed using NVIS 72 PCB prototype machine, and NVIS 72 software. Subsequently place the PCB inside 3D printed housing for completion of prototyping. The performance of the system is verified by using the proposed device in cryptocurrency framework by comparing the data retrieved and computed using the proposed system with the original data, wherein the mean error rate in percentage change $e_{PC}$ in the prices of all coins has been obtained as 0, and a maximum of mean error rate in price of cryptocurrency has been found to be 0.2% for DENT. Further, the usefulness of the proposed system is demonstrated by using the device with various threshold values to determine significant percentage change.

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