Lesson Plan: Digital Alarm Clock Using Arduino Learner Kit

Overview:

This lesson use Arduino Learner Kit to make a digital alarm clock. Arduino Learner Kit has onboard DS1307 RTC, Buzzer, Button Switch and LCD display which will be used to make the alarm clock. Students need to connect all the components to Arduino using jumper wires. After making the connection they will write code and upload it the Arduino Kit.

After completing the lesson students will learn:

- About I2C communication protocol and how to implement I2C using Arduino
- About interfacing of DS1307 RTC and LCD Display
- About generating tone using Arduino and Buzzer
- How to use external library in Arduino IDE.
- How to apply conditional statements and loops in a program.

Perquisites:

- Basic knowledge on Arduino digital output (e.g. how to drive led)
- Basic knowledge on Arduino digital input (e.g. how the interface button switch)

Important Questions:

- What are the different communication protocol use in embedded system?
- Difference between serial and parallel communication?
- What are the most common serial protocol used in Arduino?
- Why RTC is used in microcontroller system?

[Teacher will ask students and explain the answer of the questions]

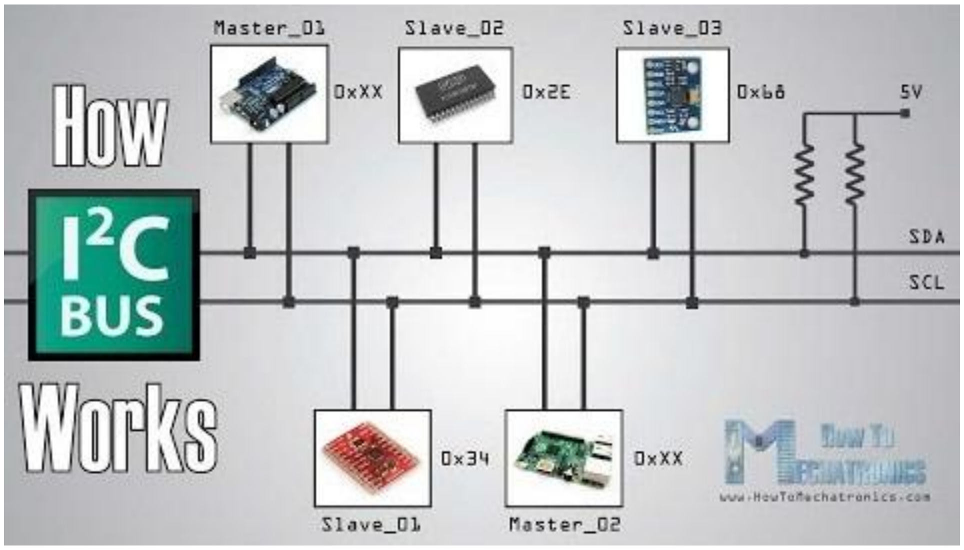
Materials needed:

- 1 Arduino Learner Kit with USB cable
- 12 male to male jumper wires
- 2 male to female jumper wire
- Access to a PC

Background Knowledge:

I2C Serial Communication:

The Inter-integrated Circuit (I2C) Protocol is a protocol intended to allow multiple "slave" digital integrated circuits ("chips") to communicate with one or more "master" chips. The I2C communication bus is very popular and broadly used serial bus by many electronic devices because it can be easily implemented in many electronic designs which require communication between a master and multiple slave devices or even multiple master devices. The easy implementations comes with the fact that only two wires are required for communication between up to almost 128 (112) devices when using 7 bits addressing and up to almost 1024 (1008) devices when using 10 bits addressing. Each device has a preset unique ID called device address so the master can choose with which devices will be communicating.



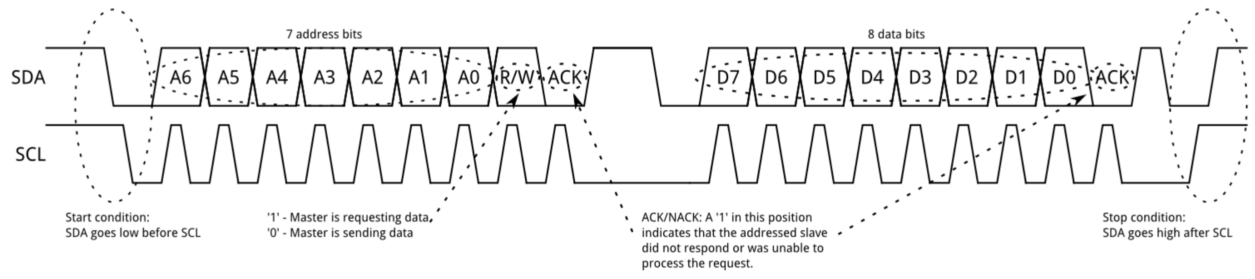
The two wires, or lines are called Serial Clock (or SCL) and Serial Data (or SDA). The SCL line is the clock signal which synchronize the data transfer between the devices on the I2C bus and it’s generated by the master device. The other line is the SDA line which carries the data. The clock signal is always generated by the current bus master; some slave devices may force the clock low at times to delay the master sending more data (or to require more time to prepare data before the master attempts to clock it out).

The two lines are “open-drain” which means that pull up resistors needs to be attached to them so that the lines are high because the devices on the I2C bus are active low. Most I2C devices can communicate at 100kHz or 400kHz. and commonly used values for the resistors are from 2K for higher speeds at about 400 kbps, to 10K for lower speed at about 100 kbps.

The Protocol:

Communication via I2C is more complex than with a UART or SPI solution. The signalling must adhere to a certain protocol for the devices on the bus to recognize it as valid I2C communications. Fortunately, most devices take care of all the fiddly details for you, allowing you to concentrate on the data you wish to exchange.

Basics


7 address bits
8 data bits
SDA
SCL
A6
A5
A4
A3
A2
A1
A0
R/W
ACK
D7
D6
D5
D4
D3
D2
D1
D0
ACK
Start condition: SDA goes low before SCL
'1' - Master is requesting data, '0' - Master is sending data
ACK/NACK: A '1' in this position indicates that the addressed slave did not respond or was unable to process the request.
Stop condition: SDA goes high after SCL

Messages are broken up into two types of frame: an address frame, where the master indicates the slave to which the message is being sent, and one or more data frames, which are 8-bit data messages passed from master to slave or vice versa. Data is placed on the SDA line after SCL goes low, and is sampled after the SCL line goes high. The time between clock edge and data read/write is defined by the devices on the bus and will vary from chip to chip.

Start Condition

To initiate the address frame, the master device leaves SCL high and pulls SDA low. This puts all slave devices on notice that a transmission is about to start. If two master devices wish to take ownership of the bus at one time, whichever device pulls SDA low first wins the race and gains control of the bus. It is possible to issue repeated starts, initiating a new communication sequence without relinquishing control of the bus to other masters; we'll talk about that later.

Address Frame

The address frame is always first in any new communication sequence. For a 7-bit address, the address is clocked out most significant bit (MSB) first, followed by a R/W bit indicating whether this is a read (1) or write (0) operation.

The 9th bit of the frame is the NACK/ACK bit. This is the case for all frames (data or address). Once the first 8 bits of the frame are sent, the receiving device is given control over SDA. If the receiving device does not pull the SDA line low before the 9th clock pulse, it can be inferred that the receiving device either did not receive the data or did not know how to parse the message. In that case, the exchange halts, and it's up to the master of the system to decide how to proceed.

Data Frames

After the address frame has been sent, data can begin being transmitted. The master will simply continue generating clock pulses at a regular interval, and the data will be placed on SDA by either the master or the slave, depending on whether the R/W bit indicated a read or write operation. The number of data frames is arbitrary, and most slave devices will auto-increment the internal register, meaning that subsequent reads or writes will come from the next register in line.

Stop condition

Once all the data frames have been sent, the master will generate a stop condition. Stop conditions are defined by a 0->1 (low to high) transition on SDA after a 0->1 transition on SCL, with SCL remaining high. During normal data writing operation, the value on SDA should not change when SCL is high, to avoid false stop conditions.

The DS1307 RTC:

Real time clocks (RTC), as the name recommends are clock modules. RTC is a system that keeps track of the current time and can be used in any device which needs to keep accurate time even after power failure. DS1307 module is one of the most affordable and common RTCs modules. It can accurately keep track of seconds, minutes, hours, days, months, and years. The DS1307 real time clock (RTC) IC is an 8 pin device using an I2C interface. The DS1307 is a low-power clock/calendar with 56 bytes of battery backup SRAM. The clock/calendar provides seconds, minutes, hours, day, date, month and year qualified data. The end date of each month is automatically adjusted, especially for months with less than 31 days.

The main advantage of RTC is that they have an arrangement of battery backup which keeps the clock/calendar running even if there is power failure. An exceptionally little current is required for keeping the RTC animated. We can find these RTCs in many applications like embedded systems and computer mother boards, etc. In this article we are going to see about one of the real time clock (RTC), i.e. DS1307. The DS1307 module has the capability to install a 3-volt CR2023 backup battery and use a 32.768 kHz crystal oscillator.

Pin-out and Connections:

The DS1307 RTC module has total 8 pins that interface it to the outside world. In the simple circuit the two inputs X1 and X2 are connected to a 32.768 kHz crystal oscillator as the source for the chip. VBAT is connected to positive terminal of a 3V battery chip. Vcc provides power to the I2C interface and 5V can be given using microcontrollers. The data communication with Arduino is performed using SCL and SDA pin. These two pin must be pull up with 4.7KΩ resistor.

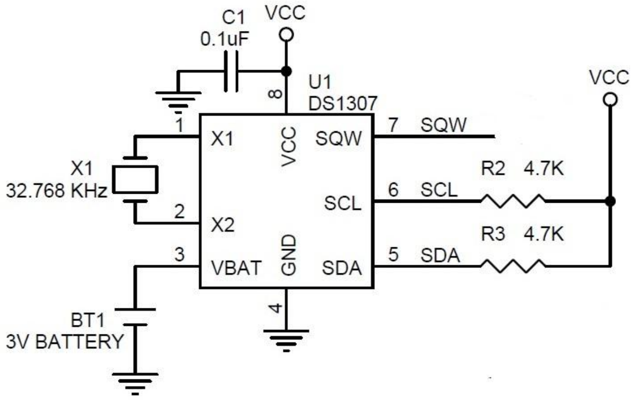


Table 1: Connection with Arduino

LM35	Arduino
VCC	5V
SCL	A5
SDA	A4
GND	GND

The LCD Display:

LCD (Liquid Crystal Display) is very popular and broadly used in electronics projects as they are good for displaying information like sensors data from your project, and also they are very cheap.

The LCD used in the kit has 16 pins and the first one from left to right is the Ground pin. The second pin is the VCC which we connect the 5 volts pin on the Arduino Board. Next is the Vo pin on which we can attach a potentiometer for controlling the contrast of the display.

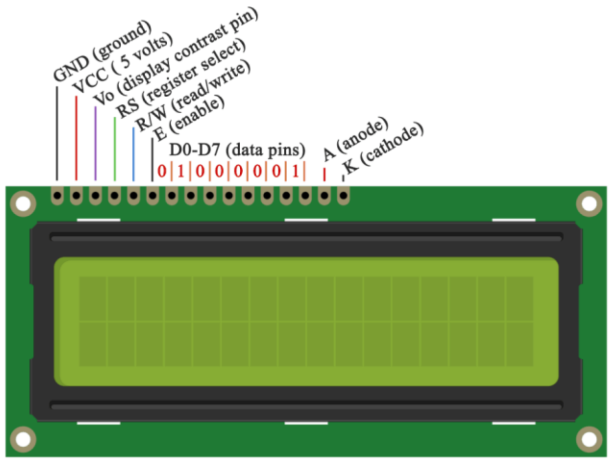
Next, the RS pin or register select pin is used for selecting whether we will send commands or data to the LCD. For example if the RS pin is set on low state or zero volts, then we are sending commands to the LCD like: set the cursor to a specific location, clear the display, turn off the display and so on. And when RS pin is set on High state or 5 volts we are sending data or characters to the LCD.

Next is the E pin which enables the writing to the registers and next 8 data pins from D0 to D7. And the last two pins A and K, or anode and cathode are for the LED back light.

The display can work both 4 bit mode and 8 bit mode. We need to connect D4-D7 to Arduino to work in 4 bit mode. D0-D3 should be unconnected. In the kit GND, VCC, Vo, A, K are already connected to appropriate source. You need to make the following connection only:

Table 2: LCD and Arduino Connection

LCD	Arduino
RS	9
E	8
D4	4
D5	5
D6	6
D7	7



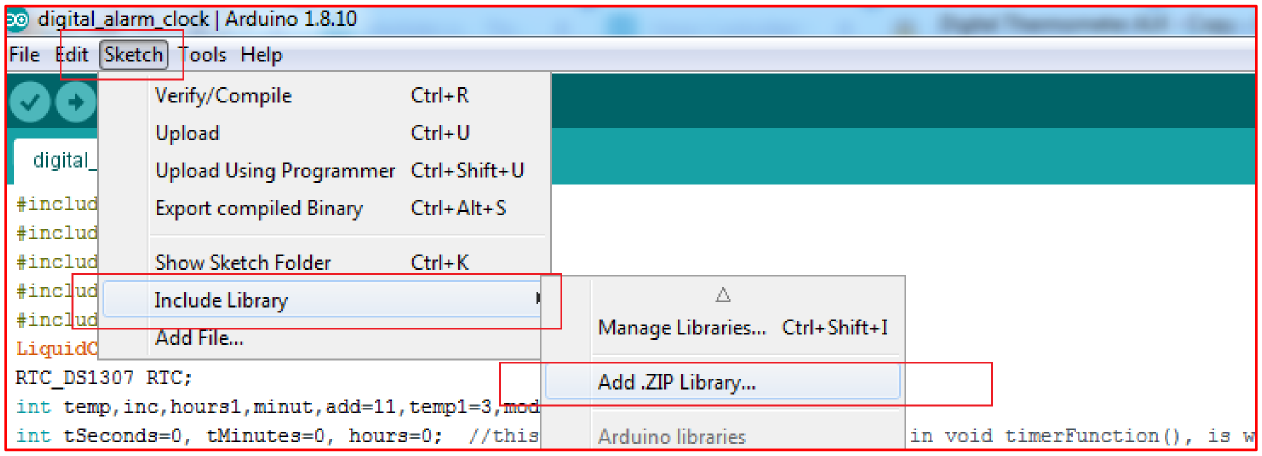
Recommended Procedure:

1. Connect B_CONN (buzzer) pin to D11 pin of the Arduino using a male to female jumper wire.
2. Connect the LCD pins to the Arduino pins according to the table 2 using male to male jumper wires.
3. Connect S1, S2, S3 and S4 pins to A0, A1, A2 and A3 pins of Arduino header respectively .
4. Connect SCL pin to A5 pin of Arduino header and SDA pin to A4 pin of the Arduino header.
5. Open Arduino IDE and copy the provided code in a new sketch and save it.
6. Connect the kit to PC using a the USB cable and upload the provided sketch to the kit.
7. You will see the time and date in the display.
8. Use the buttons to adjust the date and time of the clock.

Installing third party library:

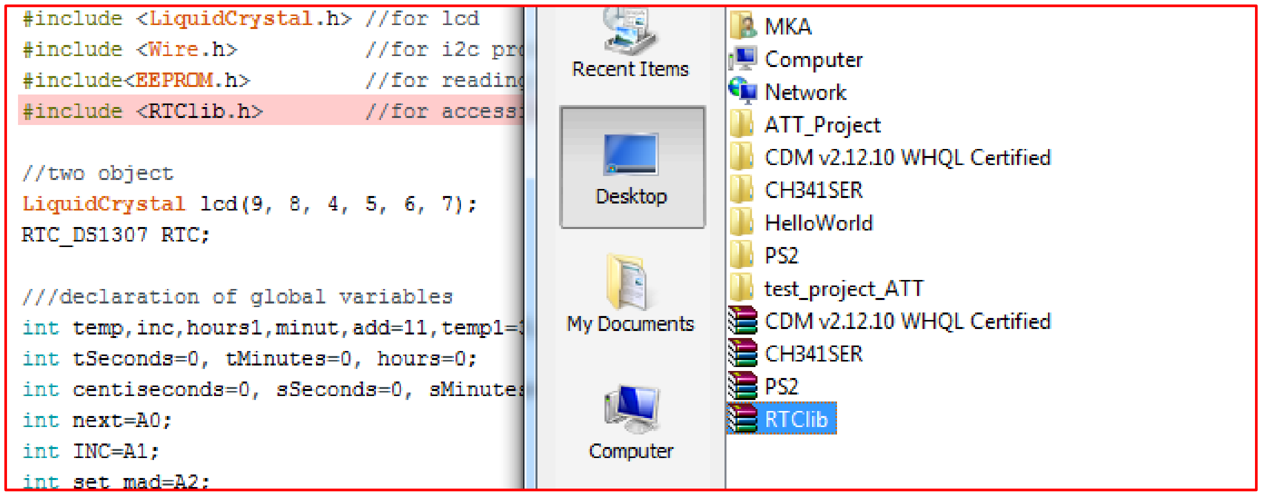
We will use one third party library for DS1307 RTC module in our program. To do that you need to download and add the library to Arduino environment. Go to the link: https://github.com/adafruit/RTClib and download the zip file. Rename the zip file if it contains any - or space in the name. From the Arduino IDE go to Sketch menu and from the dropdown choose Include Library and then Add .zip library. Browse the .zip file you downloaded and press OK. Now you are ready to use the library.

Step 1


digital_alarm_clock | Arduino 1.8.10
File Edit Sketch Tools Help
Verify/Compile Ctrl+R
Upload Ctrl+U
Upload Using Programmer Ctrl+Shift+U
Export compiled Binary Ctrl+Alt+S
Show Sketch Folder Ctrl+K
Include Library
Add File...
Manage Libraries... Ctrl+Shift+I
Add .ZIP Library...
Arduino libraries

```
RTC_DS1307 RTC;
int temp,inc,hours1,minut,add=11,temp1=3,mod
int tSeconds=0, tMinutes=0, hours=0;  //this
in void timerFunction(), is w
```

Step 2

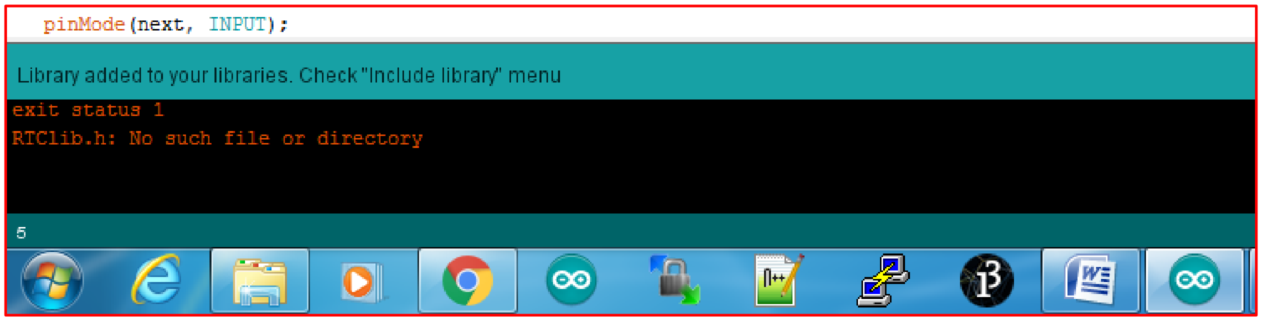


```
#include <LiquidCrystal.h> //for lcd
#include <Wire.h>          //for i2c pr
#include<EEPROM.h>         //for readin
#include <RTClib.h>        //for access

//two object
LiquidCrystal lcd(9, 8, 4, 5, 6, 7);
RTC_DS1307 RTC;

///declaration of global variables
int temp,inc,hours1,minut,add=11,temp1=
int tSeconds=0, tMinutes=0, hours=0;
int centiseconds=0, sSeconds=0, sMinutes
int next=A0;
int INC=A1;
int set_mad=A2;
```

Step 3



```
  pinMode(next, INPUT);
```

Library added to your libraries. Check "Include library" menu

```
exit status 1
RTClib.h: No such file or directory
```

The Sketch:

```
///including the library
#include <LiquidCrystal.h> //for lcd
#include <Wire.h>          //for i2c protocol
#include<EEPROM.h>         //for reading/writing in eeprom
#include <RTClib.h>        //for accessing rtc

//two object
LiquidCrystal lcd(9, 8, 4, 5, 6, 7);
RTC_DS1307 RTC;

///declaration of global variables
int temp,inc,hours1,minut,add=11,temp1=3,mode=0;
int tSeconds=0, tMinutes=0, hours=0;
int centiseconds=0, sSeconds=0, sMinutes=0;
int next=A0;
int INC=A1;
int set_mad=A2;
int shw_dat=A3;
int buzzer=11;
int HOUR,MINUT,SECOND=0;


void setup(){
  Wire.begin(); //initilize i2c module
  RTC.begin();  //initilize rtc module
  lcd.begin(16,2); //initilize lcd
  //buttons pin as input
  pinMode(INC, INPUT);
  pinMode(next, INPUT);
  pinMode(set_mad, INPUT);
  pinMode(shw_dat, INPUT);
  //buzzer pin as output
  pinMode(buzzer, OUTPUT);
  //initilize buttons state high
  digitalWrite(next, HIGH);
  digitalWrite(set_mad, HIGH);
  digitalWrite(INC, HIGH);
  digitalWrite(shw_dat, HIGH);

   lcd.setCursor(0,0);
   lcd.print("Real Time Clock");
   lcd.setCursor(0,1);
   lcd.print("Instructable class");
   delay(3000);
   //if rtc works then set date time ot the rtc as your pc time
   if(!RTC.isrunning())
      {
          RTC.adjust(DateTime(__DATE__,__TIME__));
      }
}

void loop()
{

   int temp=0,val=1,temp4;
   //read current date time
   DateTime now = RTC.now();


   if(digitalRead(shw_dat) == 0)
       {mode++;}

   if(digitalRead(shw_dat) == 0 && mode==1)     //set Alarm time
   {
     lcd.setCursor(0,0);
     lcd.print("    SET ALARM ??    ");
     delay(2000);

     while(1)
       {  if(digitalRead(set_mad) == 0)
         {
            time();
            delay(1000);
            lcd.clear();
            lcd.setCursor(0,0);
            lcd.print(" ALARM TIME SET ");
            lcd.setCursor(9,1);
            lcd.print(HOUR=hours1,DEC);
            lcd.print(":");
            lcd.print(MINUT=minut,DEC);
            lcd.print(":");
            lcd.print(SECOND=now.second(),DEC);
            CheckTime();
            delay(1000);
          }
        if(digitalRead(shw_dat) == 0)
        break;
      }
   }

  if(digitalRead(shw_dat) == 0 && mode==3)      //set CLOCK TIME
```

```
   {
     lcd.clear();
     lcd.setCursor(0,0);
     lcd.print("    SET TIMER     ");
     while(1)
       {
         if(digitalRead(set_mad) == 0)
         {
            timerFunction();
         }
        if(digitalRead(INC) == 0)
            break;
       }
   }

  if(digitalRead(shw_dat) == 0 && mode==4)      //set Stopwatch
   {
     lcd.clear();
     lcd.setCursor(0,0);
     lcd.print("    STOPWATCH     ");

     while(1)
       {
         if(digitalRead(set_mad) == 0)
           {
             stopwatchFunction();
           }
         if(digitalRead(INC) == 0)
            break;
       }

   }


  if(mode>=5)
      {mode=0;}

  lcd.clear();  //refress lcd
  lcd.setCursor(0,0); //write in first line hh:mm:ss
  lcd.print(HOUR=now.hour(),DEC);
  lcd.print(":");
  lcd.print(MINUT=now.minute(),DEC);
  lcd.print(":");
  lcd.print(SECOND=now.second(),DEC);

  lcd.setCursor(0,1);  //write in second line dd/mm/yyyy
  lcd.print(now.day(),DEC);
  lcd.print("/");
  lcd.print(now.month(),DEC);
  lcd.print("/");
  lcd.print(now.year(),DEC);

  delay(1000); //wait some time
}

/*Function to set alarm time and feed time into Internal
eeprom*/
void time()
{
  int temp=1,minuts=0,hours=0,seconds=0;
    while(temp==1)
     {
     if(digitalRead(INC)==0)
       {
        HOUR++;
        if(HOUR==24)
          {
             HOUR=0;
          }
        while(digitalRead(INC)==0);
        }
     lcd.clear();
     lcd.setCursor(0,0);
     lcd.print("Set Alarm Time ");

     lcd.setCursor(0,1);
     lcd.print(HOUR);
     lcd.print(":");
     lcd.print(MINUT);
     lcd.print(":");
     lcd.print(SECOND);
     delay(100);
     if(digitalRead(next)==0)
       {
        hours1=HOUR;
        EEPROM.write(add++,hours1);
        temp=2;
        while(digitalRead(next)==0);
       }
    }
    while(temp==2)
     {
       if(digitalRead(INC)==0)
         {
           MINUT++;
           if(MINUT==60)
             {MINUT=0;}
           while(digitalRead(INC)==0);
          }

      lcd.setCursor(0,1);
      lcd.print(HOUR);
      lcd.print(":");
      lcd.print(MINUT);
      lcd.print(":");
      lcd.print(SECOND);
      delay(100);
      if(digitalRead(next)==0)
        {
         minut=MINUT;
         EEPROM.write(add++, minut);
         temp=0;
         while(digitalRead(next)==0);
        }
    }
    delay(1000);
}
/* Function to chack medication time */
void CheckTime()
{
  int tem[17];
  while(1)
  {
    DateTime now = RTC.now();
    lcd.setCursor(0,1);
    lcd.print(HOUR=now.hour(),DEC);
    lcd.print(":");
    lcd.print(MINUT=now.minute(),DEC);
    lcd.print(":");
    lcd.print(SECOND=now.second(),DEC);
    for(int i=11;i<17;i++)
      {
        tem[i]=EEPROM.read(i);
      }
    if(HOUR == tem[11] && MINUT == tem[12])
     {
       for(int j=0;j<5;j++)
        {
          digitalWrite(buzzer, HIGH);
          delay(500);
          digitalWrite(buzzer, LOW);
          delay(500);
        }
    hours1=0;
    minut=0;
    add=11;
    return;
   }
  }
}

void timerFunction()  //the timer function was made with the
//help of this post: http://pastebin.com/f57045830
{
  int set=0;
    lcd.setCursor(4,1);
    lcd.print("00:00:00");
    while(1)
           {

                   while(digitalRead(shw_dat)==1)
                    {
                      set=1;
                   if(digitalRead(set_mad)==0)  //if
//"Start/Stop" is pressed, the timer counts down
                      {
                        tSeconds++;
                        lcdOutput();
                        delay(300);
                        if(tSeconds==60)
                        {
                        tMinutes++;
                        tSeconds=0;
                        }
                       }
                 if(digitalRead(INC)==0)  //if "Start/Stop" is
//pressed, the timer counts down
                      {
                        tMinutes++;
                        lcdOutput();
                        delay(300);
                        if(tMinutes==60)
                        {
                        hours++;
                        tMinutes=0;
                        }
                      }
                  if(digitalRead(next)==0 )  //if "Start/Stop"
```

```
//is pressed, the timer counts down
                  {
                        hours++;
                        lcdOutput();
                        delay(300);
                        if(hours==24)
                        {
                        hours=0;
                        }
                  }      }
    if(digitalRead(shw_dat)==0 && set==1)
      {
       lcd.clear();
       lcd.setCursor(0,0);
       lcd.print(" TIMER SET FOR  ");
       lcd.setCursor(4,1);

       lcd.print("00:00:00");
            while(digitalRead(INC)==1)
            {
            static unsigned long lastTick = 0;
              if (tSeconds > 0)
                {
                if (millis() - lastTick >= 1000)
                {
                lastTick = millis();
                tSeconds--;
                lcdOutput();
                }
                }
            if (tMinutes > 0)
               {
              if (tSeconds <= 0)
              {
                tMinutes--;
                tSeconds = 60;
              }
              }
            if (hours > 0)
              {
              if (tMinutes <= 0)
              {
                hours--;
                  tMinutes = 60;
                }
              }
              if(hours == 00 && tMinutes == 00 && tSeconds ==
00)  //when timer ends, the alarm goes on
                {
              while(digitalRead(shw_dat) == 1)  //the alarm will
//only go off until "Restart" is pressed
              {
                set=2;
                lcd.setCursor(4, 1);
                lcd.print("00:00:00");
                for(int i=0;i<5;i++)
                {
                digitalWrite(buzzer, HIGH);
                delay(500);
                digitalWrite(buzzer, LOW);
                delay(500);
                }
              }
            }
          }
      }
    if(digitalRead(shw_dat) == 0 && set==2)
               {
                set=0;
                mode=0;
                break;
                }
    }
}

void lcdOutput()  //this is just used to display the timer on
//LCD
{
  lcd.setCursor(4, 1);
  printDigits(hours);
  lcd.setCursor(7, 1);
  printDigits(tMinutes);
  lcd.setCursor(10, 1);
  printDigits(tSeconds);
  delay(100);
}

void printDigits(int digits)  //this void function is really
//useful; it adds a "0" to the beginning of the number, so that
//5 minutes is displayed as "00:05:00", rather than "00:5 :00"
{
  if(digits < 10)
  {
    lcd.print("0");
    lcd.print(digits);
  }
  else
  {
    lcd.print(digits);
  }
}
void stopwatchFunction()
{
int count=1,sMin,sSec,sCen;

    lcd.setCursor(4,1);
    lcd.print("00:00:00");

  while(1)
  {
  if(digitalRead(shw_dat) == LOW )
    {
      count=0;
      loop();

    }
  if(digitalRead(next) == LOW)  //if the "Start/Stop" button is
//pressed, the time begins running
  {

  while(1)
    {
      int count=1;
      delay(6);
  lcd.setCursor(4, 1);
  printDigits(sMinutes);
  lcd.setCursor(7, 1);
  printDigits(sSeconds);
  lcd.setCursor(10, 1);
  printDigits(centiseconds);
    centiseconds++;
    sCen=centiseconds;
    if(centiseconds==100)
    {
      sSeconds++;
      sSec=sSeconds;
      centiseconds=0;
      if(sSeconds==60)
      {
        sMinutes++;
        sMin=sMinutes;
        sSeconds=0;
        }
    }
    if(digitalRead(set_mad) == 0)
      {
        centiseconds = 0;
        sSeconds = 0;
        sMinutes = 0;
        break;
      }
if(digitalRead(INC) == LOW && count ==1)
    {
      while(1)
      {
        lcd.setCursor(4, 1);
        printDigits(sMinutes);
        lcd.setCursor(7, 1);
        printDigits(sSeconds);
        lcd.setCursor(10, 1);
        printDigits(centiseconds);

        if(digitalRead(set_mad) == 0)
          {
            count=2;
            centiseconds = 0;
            sSeconds = 0;
            sMinutes = 0;
            break;
          }
        }
      }
    }
   }
 }
}
```

Assignment:

Add the temperature functionality in you clock. [Note: Use on-board LM35 sensor.]