Digital Clock using Arduino and 7-Segment Displays

Contents

1 Introduction

A digital clock is a very useful device used to display time in 24-hour format. This aim of the project is to make a digital clock using Arduino.

2 Components used

The following components were used:

- Arduino Uno
- Breadboard
- Six 7-segment displays
- A 7447 BCD to 7-segment decoders
- Push buttons for setting time
- Resistors(220Ω) and wiring
- Power source

3 Circuit Design

The 7-segment displays are connected to each other and then one of them is connected to the pins of the 7447 according to the table below

7447	$\bar{a}$	$\bar{b}$	$\bar{c}$	$\bar{d}$	$\bar{e}$	$\bar{f}$	$\bar{g}$
Display	a	b	c	d	e	f	g

The remaining pins of 7447 which are to be connected to the arduino are as follows

7447	D	C	B	A
Arduino	5	4	3	2

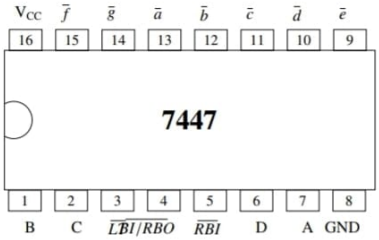


Fig. 3.1: 7447 IC

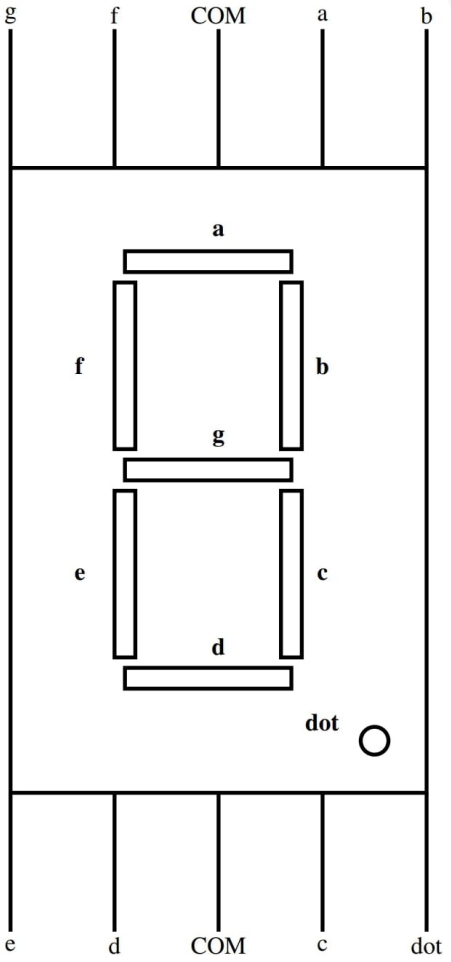


Fig. 2.2: Seven Segment pins

$5v$ pin of Arduino is connected to v_{cc} of 7447 while their grounds are connected to each other.

The COM pins of the 7-seg displays are connected to 220Ω which are connected to analogue pins on the Arduino.

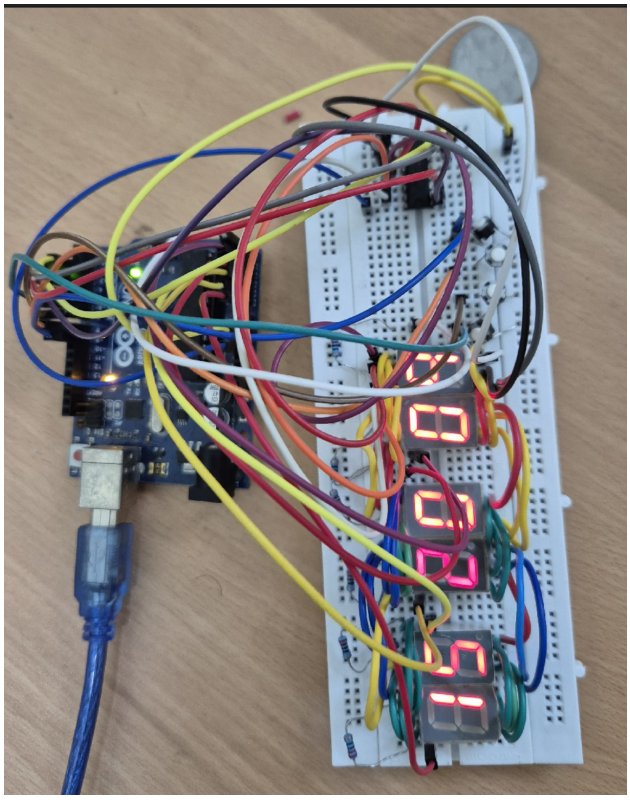
There are also 4 push buttons which are connected to 6,7,8 and 9 pins in the Arduino . They have the following uses

- The first is used to adjust the hours of the clock by incrementing till 23 and then reset to zero.
- The second is used the adjust the minutes by incrementing till 59 then

reset to zero.

- The third switches the clock between showing the time and being used as a stopwatch.
- The fourth is used to stop time or the stop watch.

The following is the picture of the fully functioning circuit



4 Code

The following is the code implemented

```
#define F_CPU 16000000UL
#include <avr/io.h>
#include <util/delay.h>
#include <avr/interrupt.h>

#define BCD_PORT PORTD
#define BCD_DDR DDRD
#define BCD_MASK 0b00111100  // PD2 to PD5
```

```
9
10 #define COMMON_PORT PORTC
11 #define COMMON_DDR DDRC
12
13 #define MODE_BUTTON PB0 // Switch between Clock, Timer, and
       Stopwatch
14 #define STOPWATCH_BUTTON PB1 // Start/Stop Stopwatch and
       Timer
15
16 volatile int seconds = 0, minutes = 0, hours = 15;
17 volatile int timer_seconds = 0, timer_minutes = 0,
       timer_hours = 0;
18 volatile int stopwatch_seconds = 0, stopwatch_minutes = 0,
       stopwatch_hours = 0;
19 volatile int mode = 0; // 0 = Clock, 1 = Timer, 2 = Stopwatch
20 volatile int stopwatch_running = 0; // 1 = Running, 0 =
       Stopped
21
22 void setup() {
23     // Set BCD display pins (PD2-PD5) as output
24     BCD_DDR |= BCD_MASK;
25     BCD_PORT &= ~BCD_MASK;
26
27     // Set digit selector pins (PORTC) as output
28     COMMON_DDR = 0xFF;
29     COMMON_PORT = 0x00;
30
31     // Enable pull-up resistors for buttons
32     PORTD |= (1 << PD6) | (1 << PD7);
33     PORTB |= (1 << MODE_BUTTON) | (1 << STOPWATCH_BUTTON);
34
35     // Timer1 Setup: CTC Mode, 1-second interval
36     TCCR1B |= (1 << WGM12) | (1 << CS12) | (1 << CS10);
37     OCR1A = 15625; // 1-second interrupt
38     TIMSK1 |= (1 << OCIE1A);
39
40     // Debug LED on PC7 (Bit 7 of PORTC) to check if ISR is
           running
41     DDRC |= (1 << 7);  // Set PC7 as output
42     PORTC &= ~(1 << 7); // Initially turn it off
43
44     sei(); // Enable global interrupts
45 }
46
47 ISR(TIMER1_COMPA_vect) {
48     PORTC ^= (1 << 7); // Toggle PC7 to check ISR is running
49
50     // Clock Mode Updates
51     if (mode == 0) {
```

```
52          seconds++;
53          if (seconds == 60) {
54              seconds = 0;
55              minutes++;
56              if (minutes == 60) {
57                  minutes = 0;
58                  hours = (hours + 1) % 24;
59              }
60          }
61      }
62
63      // Timer Countdown (only when running)
64      if (mode == 1 && stopwatch_running) {
65          if (timer_seconds > 0 || timer_minutes > 0 ||
                timer_hours > 0) {
66              if (timer_seconds == 0) {
67                  if (timer_minutes > 0) {
68                      timer_minutes--;
69                      timer_seconds = 59;
70                  } else if (timer_hours > 0) {
71                      timer_hours--;
72                      timer_minutes = 59;
73                      timer_seconds = 59;
74                  }
75              } else {
76                  timer_seconds--;
77              }
78          }
79      }
80
81      // Stopwatch Increment
82      if (mode == 2 && stopwatch_running) {
83          stopwatch_seconds++;
84          if (stopwatch_seconds == 60) {
85              stopwatch_seconds = 0;
86              stopwatch_minutes++;
87              if (stopwatch_minutes == 60) {
88                  stopwatch_minutes = 0;
89                  stopwatch_hours = (stopwatch_hours + 1) % 24;
90              }
91          }
92      }
93  }
94
95  void displayTime();
96  void setBCD(int value);
97  void checkButtons();
98
99  int main() {
```

```
    setup();
    while (1) {
        checkButtons();
        displayTime();
    }
}

// Function to display time on a 6-digit 7-segment display
void displayTime() {
    int digits[6];

    if (mode == 0) { // Clock Mode
        digits[0] = hours / 10;
        digits[1] = hours % 10;
        digits[2] = minutes / 10;
        digits[3] = minutes % 10;
        digits[4] = seconds / 10;
        digits[5] = seconds % 10;
    } else if (mode == 1) { // Timer Mode
        digits[0] = timer_hours / 10;
        digits[1] = timer_hours % 10;
        digits[2] = timer_minutes / 10;
        digits[3] = timer_minutes % 10;
        digits[4] = timer_seconds / 10;
        digits[5] = timer_seconds % 10;
    } else { // Stopwatch Mode
        digits[0] = stopwatch_hours / 10;
        digits[1] = stopwatch_hours % 10;
        digits[2] = stopwatch_minutes / 10;
        digits[3] = stopwatch_minutes % 10;
        digits[4] = stopwatch_seconds / 10;
        digits[5] = stopwatch_seconds % 10;
    }

    // Multiplex 7-segment display
    for (int i = 0; i < 6; i++) {
        setBCD(digits[i]); // Send the BCD value first
        COMMON_PORT = (1 << i); // Enable the corresponding
           digit
        _delay_us(500); // Short delay for smooth display
    }
}

// Function to set BCD output for 7-segment display
void setBCD(int value) {
    BCD_PORT = (BCD_PORT & ~BCD_MASK) | ((value << 2) &
       BCD_MASK);
}

```

```
147 // Function to check button inputs and update mode/settings
148 void checkButtons() {
149     if (!(PIND & (1 << PD6))) {
150         _delay_ms(50);
151         if (!(PIND & (1 << PD6))) {
152             if (mode == 0) {
153                 hours = (hours + 1) % 24;
154                 seconds = 0;
155             } else if (mode == 1) {
156                 timer_hours = (timer_hours + 1) % 24;
157                 seconds = 0;
158             }
159             while (!(PIND & (1 << PD6))); // Wait for release
160         }
161     }
162 
163     if (!(PIND & (1 << PD7))) {
164         _delay_ms(50);
165         if (!(PIND & (1 << PD7))) {
166             if (mode == 0) {
167                 minutes = (minutes + 1) % 60;
168                 seconds = 0;
169             } else if (mode == 1) {
170                 timer_minutes = (timer_minutes + 1) % 60;
171                 seconds = 0;
172             }
173             while (!(PIND & (1 << PD7))); // Wait for release
174         }
175     }
176 
177     if (!(PINB & (1 << MODE_BUTTON))) {
178         _delay_ms(50);
179         if (!(PINB & (1 << MODE_BUTTON))) {
180             mode = (mode + 1) % 3; // Cycle through Clock,
                Timer, and Stopwatch
181             while (!(PINB & (1 << MODE_BUTTON))); // Wait for
                release
182         }
183     }
184 
185     // Modified section: Stopwatch button controls both Timer
        and Stopwatch
186     if (!(PINB & (1 << STOPWATCH_BUTTON))) {
187         _delay_ms(50);
188         if (!(PINB & (1 << STOPWATCH_BUTTON))) {
189             if (mode == 2) {  // Toggle Stopwatch running
190                 stopwatch_running = !stopwatch_running;
191             } else if (mode == 1) {  // Toggle Timer running
192                 stopwatch_running = !stopwatch_running;  //
```

```
                    Reuse the same flag
            }
            while (!(PINB & (1 << STOPWATCH_BUTTON))) {
                _delay_ms(10);
            }
        }
    }
}
```

5 Working of circuit based on the code

- **Clock Mode:** Displays and updates the current time in a 24-hour format.
- **Timer Mode:** Allows countdown from a set time.
- **Stopwatch Mode:** Tracks elapsed time when running.

A six-digit 7-segment display is used for output, and push buttons provide user interaction to switch modes and start/stop timing operations.

Pin Configuration and Display Control

The system uses Binary-Coded Decimal (BCD) representation for displaying digits on the 7-segment display. The display is multiplexed, meaning only one digit is active at a time, and the microcontroller rapidly cycles through them to create a persistent visual effect.

BCD and Digit Selection

```
#define BCD_PORT PORTD
#define BCD_DDR DDRD
#define BCD_MASK 0b00111100  // PD2 to PD5

#define COMMON_PORT PORTC
#define COMMON_DDR DDRC
```

- **BCD_PORT (PORTD, PD2-PD5)** controls the segment encoding.
- **COMMON_PORT (PORTC, PC0-PC5)** selects which digit to activate.

All these pins are set as outputs:

```
BCD_DDR |= BCD_MASK;
COMMON_DDR = 0xFF;
```

Button Configuration

Two push buttons are used for user input:

- **Mode Button (PB0)** - Switches between Clock, Timer, and Stopwatch modes.
- **Start/Stop Button (PB1)** - Starts and stops the stopwatch or timer.

The buttons are connected with internal pull-up resistors to avoid floating states:

```
PORTB |= (1 << MODE_BUTTON) | (1 << STOPWATCH_BUTTON);
```

Time Tracking Variables

Three sets of time variables store hours, minutes, and seconds for each mode:

```
volatile int seconds = 0, minutes = 0, hours = 15;
volatile int timer_seconds = 0, timer_minutes = 0,
    timer_hours = 0;
volatile int stopwatch_seconds = 0, stopwatch_minutes = 0,
    stopwatch_hours = 0;
```

- **Clock mode** starts with an initial time (e.g., 15:00:00).
- **Timer mode** counts down when started.
- **Stopwatch mode** increments when running.

Interrupt-Driven Time Updates

A hardware timer (Timer1) generates an interrupt every second to update time values.

Timer1 Configuration

```
TCCR1B |= (1 << WGM12) | (1 << CS12) | (1 << CS10);
OCR1A = 15625;
TIMSK1 |= (1 << OCIE1A);
```

- Configures Timer1 in **CTC mode** (Clear Timer on Compare Match).
- Uses a prescaler of 1024 to achieve a 1-second interval.
- Triggers an interrupt when the timer reaches 15625 counts.

Interrupt Service Routine (ISR)

Every second, the ISR updates the appropriate time variables based on the active mode.

Clock Mode

```
if (mode == 0) {
    seconds++;
    if (seconds == 60) {
        seconds = 0;
        minutes++;
        if (minutes == 60) {
            minutes = 0;
            hours = (hours + 1) % 24;
        }
    }
}
```

- Increments seconds.
- Rolls over to minutes and hours when necessary.

Timer Mode

```
if (mode == 1 && stopwatch_running) {
    if (timer_seconds == 0) {
        if (timer_minutes > 0) {
            timer_minutes--;
            timer_seconds = 59;
        } else if (timer_hours > 0) {
            timer_hours--;
            timer_minutes = 59;
            timer_seconds = 59;
        } } else {
```

```
        timer_seconds--;
    }
}
```

Stopwatch Mode

```
if (mode == 2 && stopwatch_running) {
    stopwatch_seconds++;
    if (stopwatch_seconds == 60) {
        stopwatch_seconds = 0;
        stopwatch_minutes++;
        if (stopwatch_minutes == 60) {
            stopwatch_minutes = 0;
            stopwatch_hours = (stopwatch_hours + 1) % 24;
            }
    }
}
```

- Increments time while running.
- Rolls over when needed.

7-Segment Display Multiplexing

The function `displayTime()` handles time display:

```
void displayTime() {
    int digits[6];

    if (mode == 0) {
        digits[0] = hours / 10;
        digits[1] = hours % 10;
        digits[2] = minutes / 10;
        digits[3] = minutes % 10;
        digits[4] = seconds / 10;
        digits[5] = seconds % 10;
    }
    ...
    for (int i = 0; i < 6; i++) {
        setBCD(digits[i]);
        COMMON_PORT = (1 << i);
        _delay_us(500);
    }
}
```

- Converts the current mode's time into six digits.

- Updates one digit at a time using BCD.
- Uses a short delay to ensure smooth display.

Button Handling

The function `checkButtons()` reads button inputs and updates settings accordingly.

```
if (!(PINB & (1 << MODE_BUTTON))) {
    _delay_ms(50);
    if (!(PINB & (1 << MODE_BUTTON))) {
        mode = (mode + 1) % 3;
        while (!(PINB & (1 << MODE_BUTTON)));
    }
}
```

- Checks if the mode button is pressed.
- Debounces input using a delay.
- Cycles through Clock, Timer, and Stopwatch.

The start/stop button toggles operation:

```
if (!(PINB & (1 << STOPWATCH_BUTTON))) {
    _delay_ms(50);
    if (!(PINB & (1 << STOPWATCH_BUTTON))) {
        stopwatch_running = !stopwatch_running;
        while (!(PINB & (1 << STOPWATCH_BUTTON))) {
            _delay_ms(10);
        }
    }
}
```

6 Results

- The clock is successfully able to display time.
- Stopwatch is also functioning correctly.
- Countdown timer also works perfectly.
- The push helps in easy controlling and adjustment of time in clock as well as the others

7 Conclusion

This project implements a functional digital clock with help from Arduino. Although its simple, easy and functioning but there is still room for improvement.