Workshop VII

Interrupts, Timers, and TM1637

SECTION I

Interrupts

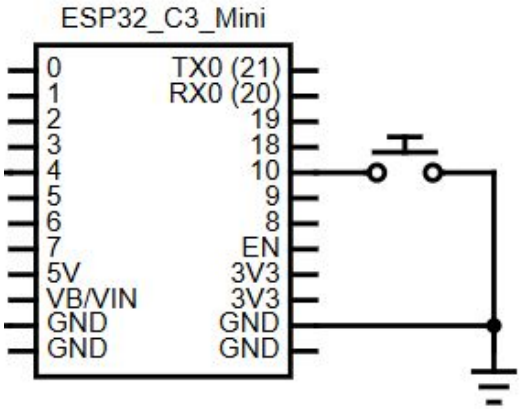
Interrupts

- An **interrupt** is a request for the CPU to **halt the currently executing code** when an event occurs
- In other words, the current code is paused, and a different block of code runs
  - The CPU suspends the current program to *handle* the event by executing a function called an **interrupt handler** or **interrupt service routine** (**ISR**)
  - When the interrupt handler finishes execution, the CPU returns to the old program

Interrupts

- Interrupts on ESP32 are triggered by the signal at a pin

- We can use pull-up resistors for this!
  - When we press the button, the voltage at the pin changes from HIGH to LOW. This would be considered a *falling edge*

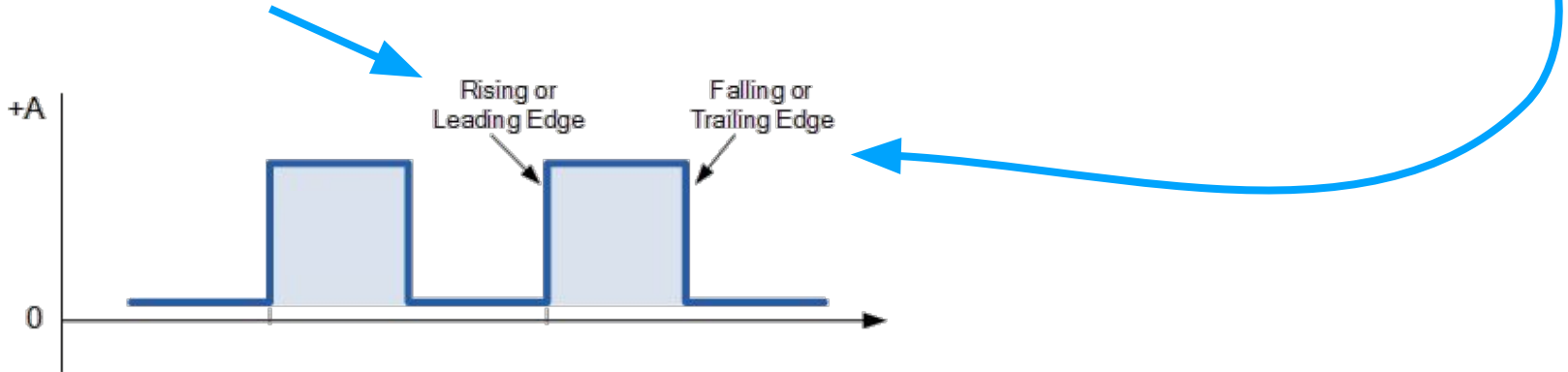


Setting Interrupts

- Interrupts are configured in the `void setup()` block
- `attachInterrupt(interrupt, ISR, mode)`
  - Initializes an interrupt
  - *`interrupt`* - the interrupt number (**not a pin number**)
  - *`ISR`* - the name of the function to call as the interrupt handler
    - This function must be defined beforehand
  - *`mode`* - configures the timing of the IRQ
    - You will set the mode to one of the following constants…

Setting Interrupts (Cont'd)

- The options for ***mode*** are…
  - **`LOW`** - when the pin is a LOW voltage
  - **`CHANGE`** - when the pin changes value
  - **`FALLING`** - when the pin voltage changes from HIGH to LOW
  - **`RISING`** - when the pin voltage changes from LOW to HIGH



Setting Interrupts (Cont'd)

- `digitalPinToInterrupt(pin)`
  - This function converts a digital pin number to its corresponding interrupt number
- It is **recommended that you call `attachInterrupt` as follows:**
  - `attachInterrupt(digitalPinToInterrupt(pin), ISR, mode)`
  - This approach avoids confusion involving digital pin and interrupt numbers

Onboard LED Exercise

Write a program that satisfies the following requirements:

- You must breadboard a circuit in which **one pushbutton turns on the ESP32's onboard LED and the other pushbutton turns it off**.
- The LED should only turn on **when you let go** of the ON button (it should stay on afterwards as well!).
- The LED should only turn off **immediately** when you press the OFF button.
- The ESP32 should **print a message** whenever a button is pressed.
- Onboard LED is pin 8 (built-in)
    - **Reverse enabled**: turned on by writing LOW and off by writing HIGH

Onboard LED Exercise Code

```
const int on_btn = 3;
const int off_btn = 4;
const int led = 8;

void turnOn() {
  digitalWrite(led, LOW);
  Serial.println("ON");
}

void turnOff() {
  digitalWrite(led, HIGH);
  Serial.println("OFF");
}

void setup() {
  Serial.begin(115200);
  pinMode(on_btn, INPUT_PULLUP);
  pinMode(off_btn, INPUT_PULLUP);
  pinMode(led, OUTPUT);
  attachInterrupt(digitalPinToInterrupt(on_btn), turnOn, RISING);
  attachInterrupt(digitalPinToInterrupt(off_btn), turnOff, FALLING);
}

void loop() {

}
```

SECTION II

Timers

Arduino Timer Library

- We will use one of the Arduino's internal timers to **measure time**
  - To do so, we will enlist the help of the Timer library, which will need to be downloaded and installed to the Arduino IDE
  - Make sure to use `#include <Timer.h>`

Arduino Timer Library (Cont'd)

- First, instantiate a `Timer` object as `Timer timer;`
  - Time is **measured in milliseconds**
  - A timer has 3 states: `RUNNING`, `PAUSED`, or `STOPPED`
    - `STOPPED` is default state
- `timer.start()` starts the timer and puts it in the `RUNNING` state
- `timer.pause()` pauses the timer and puts it in the `PAUSED` state
- `timer.resume()` resumes the timer from the `PAUSED` state, putting it back in the `RUNNING` state

Arduino Timer Library (Cont'd)

- `timer.stop()` stops the timer and put it in the `STOPPED` state
  - The time recorded since the last `timer.start()` is **reset** the next time the `timer.start()` is called
- `timer.read()` returns the time recorded since the last `timer.start()`
- `timer.state()` returns a byte value indicating the timer's current state
  - `0 - STOPPED`
  - `1 - RUNNING`
  - `2 - PAUSED`

Timer Exercise

Write a program that satisfies the following requirements:

- You must write a program in which the ESP32 **continuously runs a timer and converts the current timer value to minutes and seconds,** printing all three values to the serial monitor
- Example output:
  - Time (ms): 301000
  - Minutes: 5
  - Seconds: 1

Timer Exercise Code

```
#include <Timer.h>

Timer timer;

void setup() {
  Serial.begin(115200);
  timer.start();
}

void loop() {
  int time = timer.read();
  int min = time / 60000;
  int sec = time % 60000 / 1000;

  Serial.print("Time (ms):\t");
  Serial.print(time);
  Serial.println();

  Serial.print("Minutes:\t");
  Serial.print(min);
  Serial.println();
  Serial.print("Seconds:\t");
  Serial.print(sec);
  Serial.println();

  delay(207);
}
```

SECTION III

TM1637

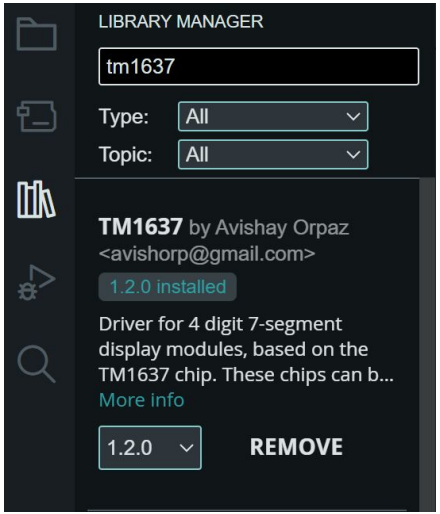
TM1637 Display

- The TM1637 is a 7-segment display
  - Shows 4 digits, each with 7 LED segments

- Pinout
  - CLK - I^{2}C SCL
  - DIO - I^{2}C SDA
  - GND - ground
  - VCC - 5V power

TM1637 Display Library

- Install the TM1637 library via the Arduino IDE library manager
  - Author is Avishay Orpaz



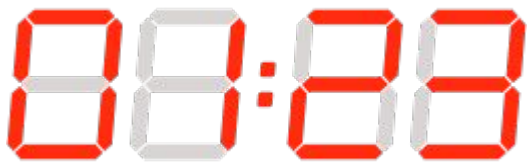
- Include this library with `#include <TM1637Display.h>`

TM1637 Library Functions

- `TM1637Display display(int CLK, int DIO);`
  - Initializes a display object using two ESP32 pin numbers for I^2C
- `display.clear()` clears the display
- `display.setBrightness(int brightness)`
  - sets segment brightness from a value 0 to 7 (7 being the brightest)
- `display.showNumberDecEx(int num, 0x40, bool leading_zero)`
  - `num` - exact number to display
  - `0x40` - enables colon in middle of display
  - `leading_zero` - turns on a leading 0 for numbers less than 4 digits if true

Example

```
display.showNumberDecEx(123, 0x40, true);
```



- Number displayed is 123
- Colon is enabled
- Last parameter turns on a 0 before the number

Display Exercise

Add to the previous timer exercise code:

- You must write a program in which the ESP32 **continuously runs a timer and displays the current time in minutes and seconds to the TM1637**

- Hint: You will need to do some math to convert the time in minutes and seconds to a number to display on the TM1637

Display Exercise Code

I/A

```ino
#include <Timer.h>
#include <TM1637Display.h>

const int CLK = 4;
const int DIO = 6;

Timer timer;
TM1637Display display(CLK, DIO);

void setup() {
  Serial.begin(115200);
  timer.start();

  display.clear();
  display.setBrightness(7);
}

void loop() {
  int time = timer.read();
  int min = time / 60000;
  int sec = time % 60000 / 1000;

  Serial.print("Time (ms):\t");
  Serial.print(time);
  Serial.println();

  Serial.print("Minutes:\t");
  Serial.print(min);
  Serial.println();
  Serial.print("Seconds:\t");
  Serial.print(sec);
  Serial.println();

  int result = min * 100 + sec;

  display.showNumberDecEx(result, 0x40, true);

  delay(207);
}
```

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