EE351

12212635

1. EE351

EE351“ ”24Fall

4B RaspberryPi OS-64-bit-desktop

- 4B - PCF8591 - - LED - PS2 -

- RPi.GPIO Python - wiringPi C/C++ - python-smbus I2C

1.1

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- PCF8691
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- PS2
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2.

2.1

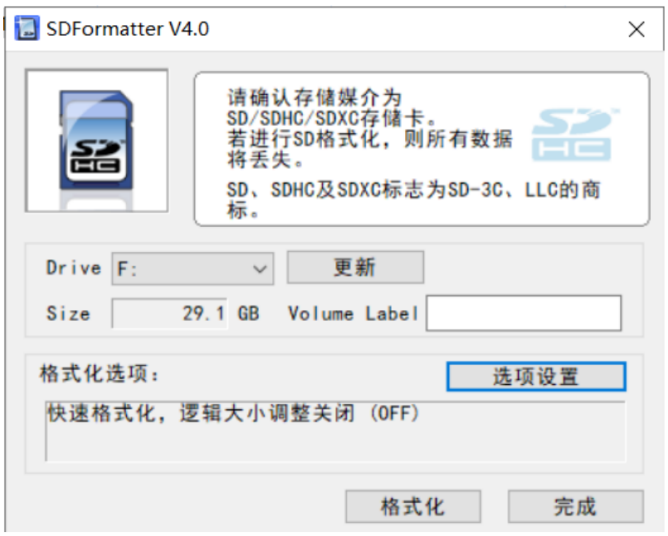
Lab1 Raspberry Pi

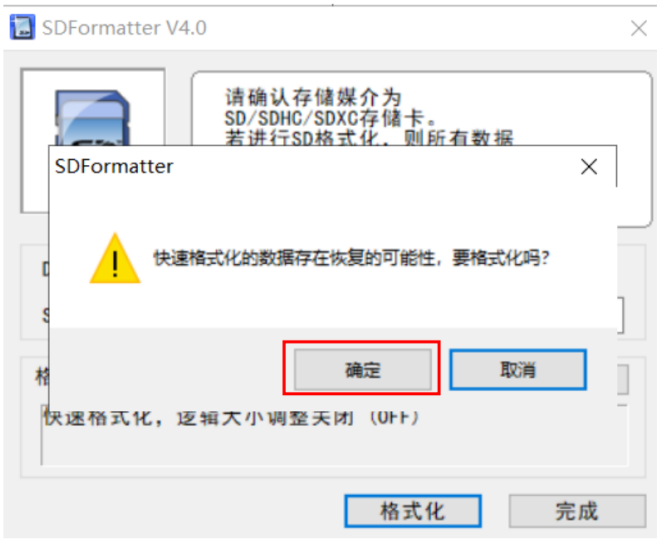
1. Raspberry Pi
2. Raspberry Pi OS
3. Wi-Fi

1

1.
2. Raspberry Pi 4 Model B
3. microSD
4. USB-C ,
5. HDMI HDMI
6.
7.
8. microSD Raspberry Pi

- SDFormatter



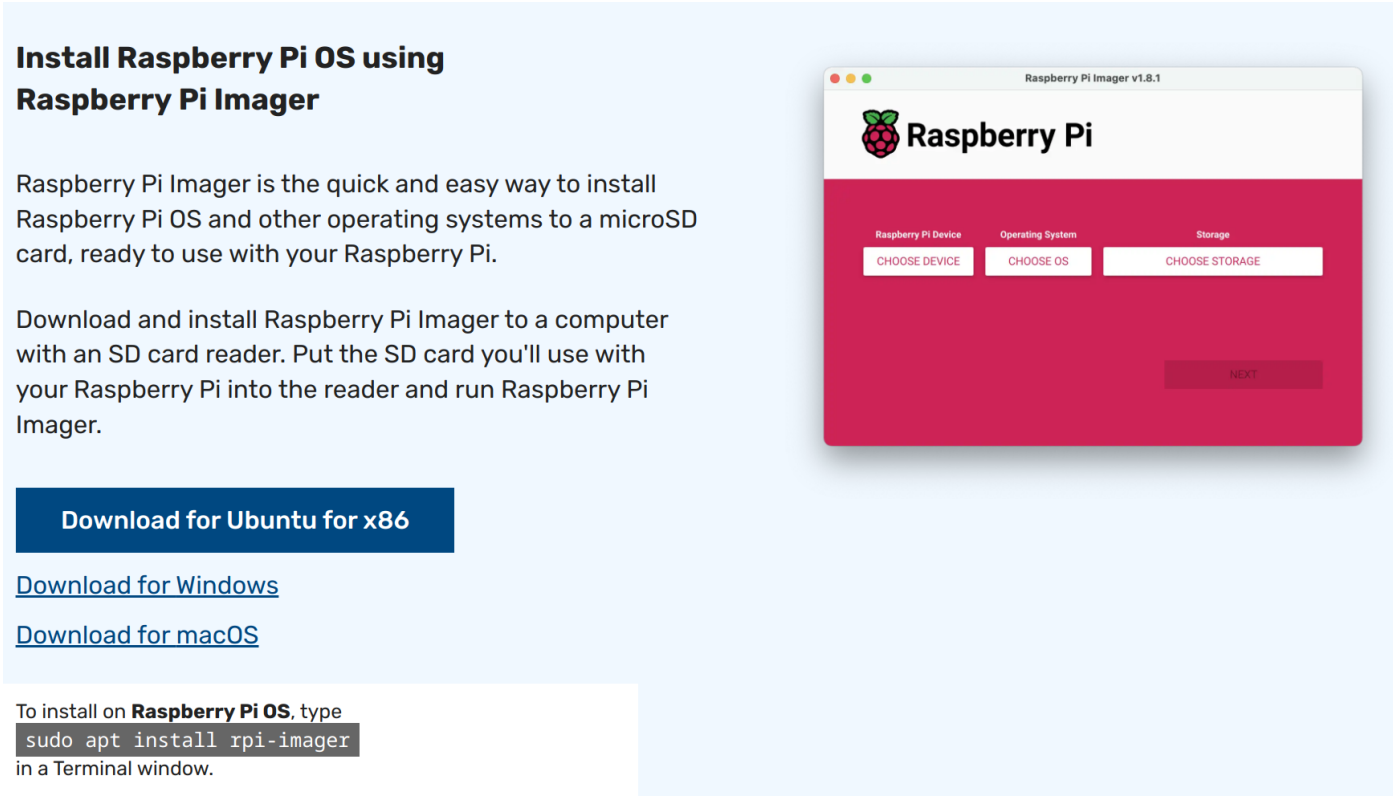


9. GUI
10. Raspberry Pi

2

1. **Raspberry Pi Imager**

2. Raspberry Pi Imager



3. **OS**
4. Raspberry Pi Imager “CHOOSE OS” Raspberry Pi OS (32-bit)
5. “CHOOSE STORAGE” microSD
6. “WRITE”
7.
8. OS microSD Raspberry Pi
9.
10.

3

1. **Wi-Fi**
2. `sudo raspi-config`
3. “Network Options” Wi-Fi SSID
4. `/etc/wpa_supplicant/wpa_supplicant.conf` Wi-Fi
5.
6. `ping www.bing.com`

4

1.
2. `sudo apt-get update`
3.
4. `sudo apt-get upgrade`
5.
6. Python

```
sudo apt-get install python3-pip
pip3 install --upgrade pip
```

7. Git

```
sudo apt-get install git
```

8. Vim `bash`

```
sudo apt-get install vim
```

9.

10. SSH

```
sudo systemctl start ssh
```

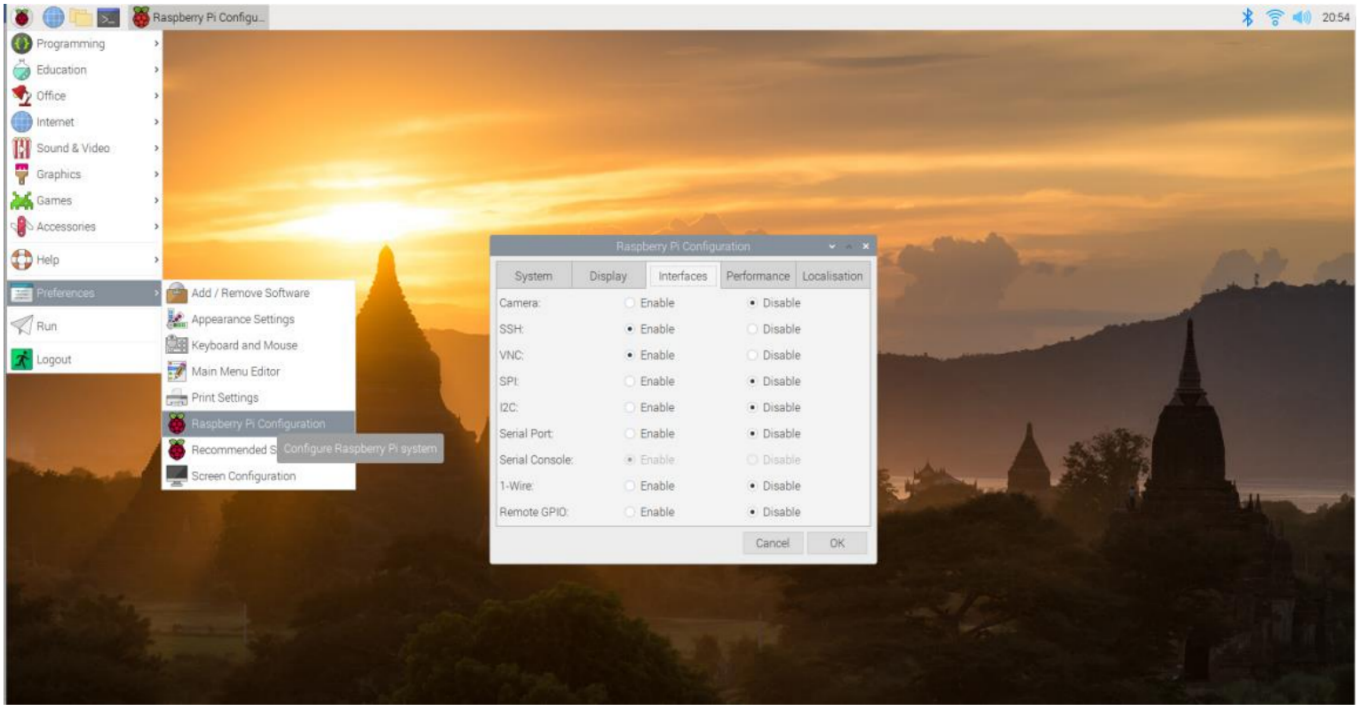
11. SSH

```
sudo systemctl status ssh
```

12. SSH `bash`

```
sudo systemctl enable ssh
```

13. **vscode** **Raspberry Pi**
14. Remote - SSH
15. `ifconfig` IP
16. `Ctrl+Shift+P` `Remote-SSH: Connect to Host` Raspberry Pi IP
17. VSCode Raspberry Pi
18. `ssh-rsa` `~/.ssh/authorized_keys`
19. :
20. VNC Viewer
21. VNC Server



22. Raspberry Raspberry Pi ip
23. Raspberry Pi

Raspberry Pi

2.2

Lab2 LED

Raspberry Pi IO wiringPi RPi.GPIO LED

1. **Raspberry Pi IO**
2. Raspberry Pi 40 GPIO wiringPi BCM2837 SOC
3. BCM
4. **wiringPi**
5. wiringPi C/C++ GPIO Raspberry Pi GPIO GPIO
6. **RPi.GPIO**
7. RPi.GPIO Python Python Raspberry Pi GPIO Raspbian API
8. **Mu Geany IDE**
9. Mu Python IDE
10. Geany IDE C/C++
11. IDE VSCode
12. **LED**
13. LED LED

1.
2. LED S Raspberry Pi GPIO GND Raspberry Pi GPIO BCM GPIO19, GPIO20, GND
3.
4. Mu Python LED GPIO / LED
5. C/C++ Geany GPIO wiringPi
6.
7. Python C/C++ LED
8. T
9.
10. LED

PYTHON

Python LED

```
import RPi.GPIO as GPIO
import time

# Define GPIO pins for the LED (BCM numbering)
RED_PIN = 19  # Red part of the dual-color LED
GREEN_PIN = 20  # Green part of the dual-color LED

# Setup GPIO mode and pin directions
GPIO.setmode(GPIO.BCM)
GPIO.setup(RED_PIN, GPIO.OUT)
GPIO.setup(GREEN_PIN, GPIO.OUT)

try:
```

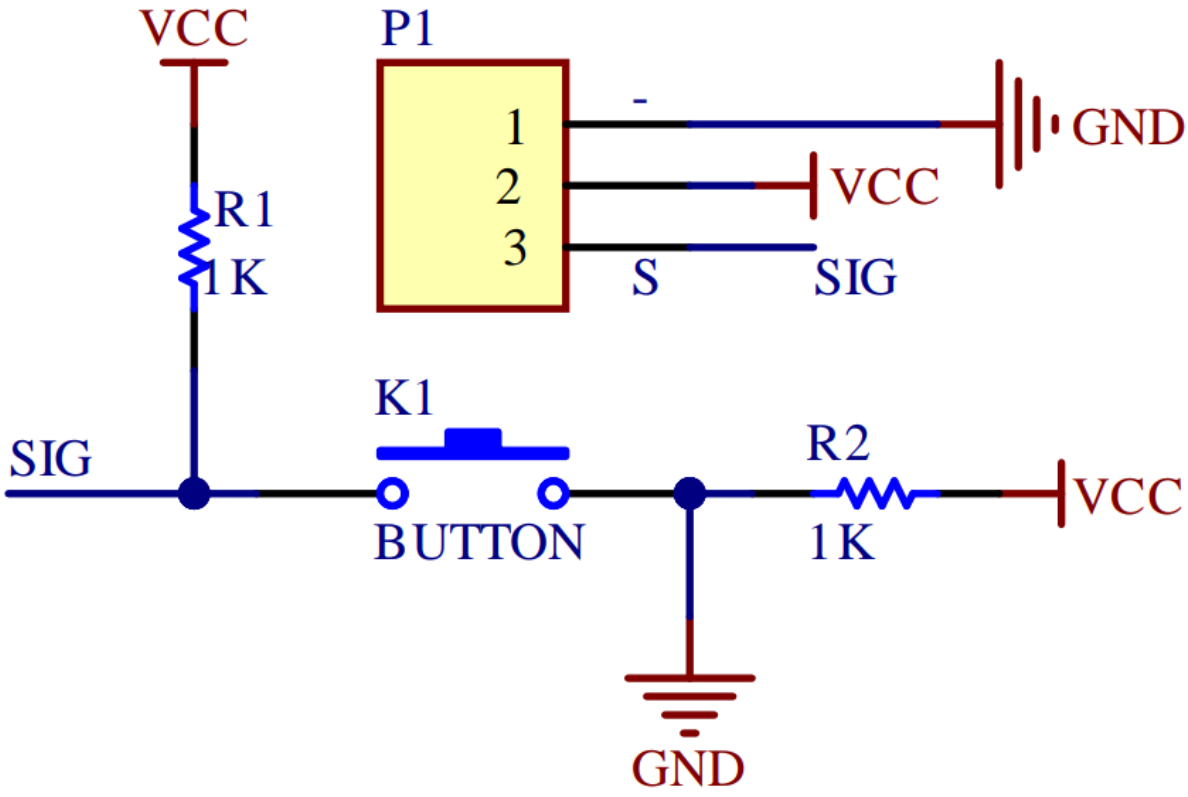
```
    while True:
        # Turn on red LED
        GPIO.output(RED_PIN, GPIO.HIGH)
        GPIO.output(GREEN_PIN, GPIO.LOW)
        print("Red LED is ON")
        time.sleep(1)  # Wait for 1 second

        # Turn on green LED
        GPIO.output(RED_PIN, GPIO.LOW)
        GPIO.output(GREEN_PIN, GPIO.HIGH)
        print("Green LED is ON")
        time.sleep(1)  # Wait for 1 second

except KeyboardInterrupt:
    print("Program stopped by user")

finally:
    # Clean up GPIO settings before exiting
    GPIO.cleanup()
```

LED - - - 1

2.3

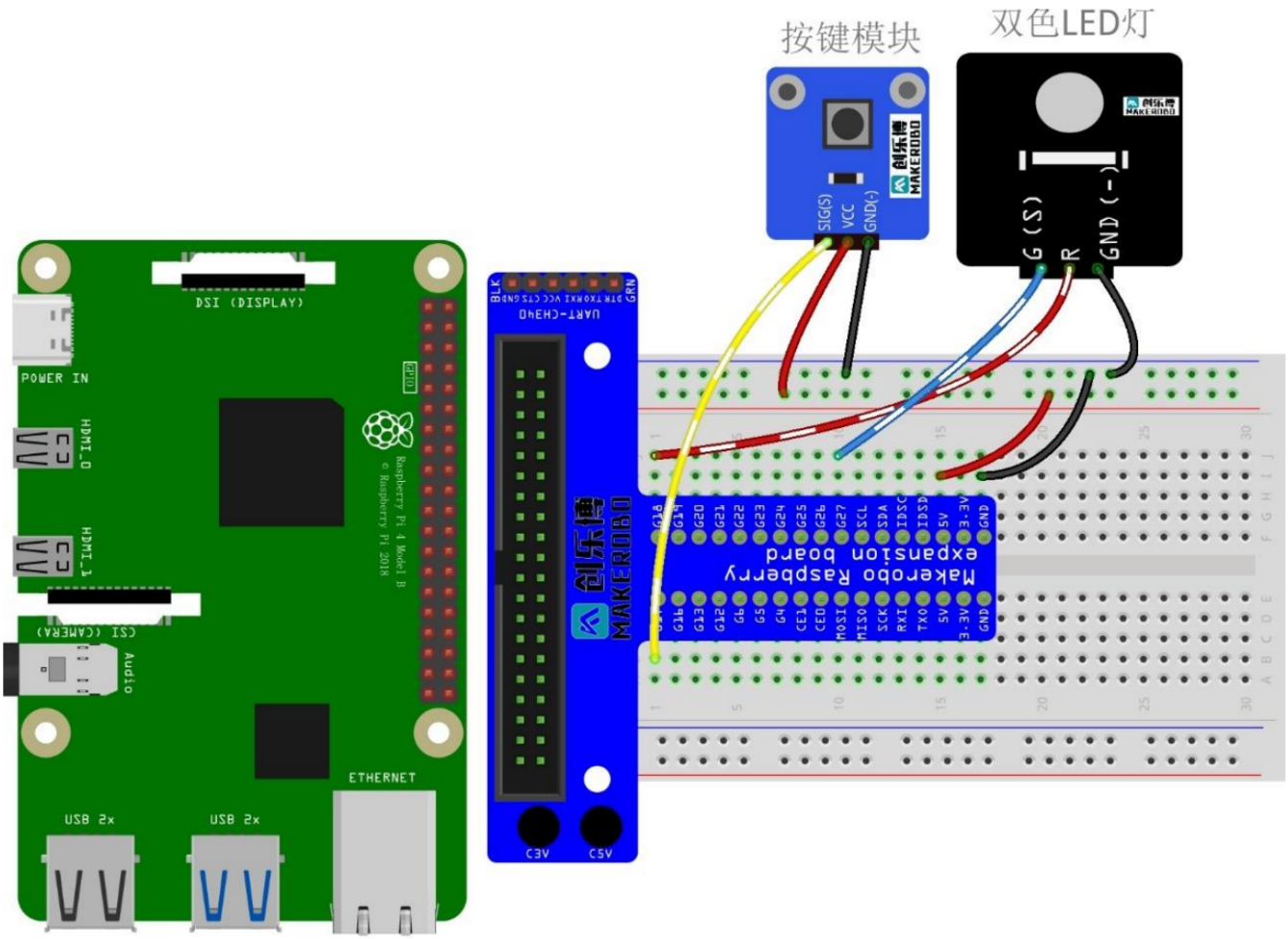
Lab3

- VCC S S



GPIO GPIO S S S LED
LED LED - Python `time.sleep()`
LED

1.



2. Mu VSCode Python LED
3. GPIO /
4. LED
5.

```
import RPi.GPIO as GPIO
import time

# Define GPIO pins for the LED (BCM numbering)
RED_PIN = 19  # Red part of the dual-color LED
GREEN_PIN = 20  # Green part of the dual-color LED
SWITCH_PIN = 21  # GPIO pin for the tactile switch

# Setup GPIO mode and pin directions
GPIO.setmode(GPIO.BCM)
GPIO.setup(RED_PIN, GPIO.OUT)
GPIO.setup(GREEN_PIN, GPIO.OUT)
GPIO.setup(SWITCH_PIN, GPIO.IN, pull_up_down=GPIO.PUD_UP)

def switch_with_delay(pin, delay=0.1):
    state = GPIO.input(pin)
    time.sleep(delay)
    return state == GPIO.input(pin)

try:
   while True:
```

```
      if switch_with_delay(SWITCH_PIN):
            GPIO.output(RED_PIN, GPIO.HIGH)
            GPIO.output(GREEN_PIN, GPIO.LOW)
      else:
            GPIO.output(RED_PIN, GPIO.LOW)
            GPIO.output(GREEN_PIN, GPIO.HIGH)

   except KeyboardInterrupt:
      print("Exiting...")
   finally:
      GPIO.cleanup()
```

1.

LED 1. LED 2. LED 3. LED 4. LED .....

```
import RPi.GPIO as GPIO
import time

# Define GPIO pins for the LED (BCM numbering)
RED_PIN = 19  # Red part of the dual-color LED
GREEN_PIN = 20  # Green part of the dual-color LED
SWITCH_PIN = 21  # GPIO pin for the tactile switch

# Setup GPIO mode and pin directions
GPIO.setmode(GPIO.BCM)
GPIO.setup(RED_PIN, GPIO.OUT)
GPIO.setup(GREEN_PIN, GPIO.OUT)
GPIO.setup(SWITCH_PIN, GPIO.IN, pull_up_down=GPIO.PUD_UP)

def switch_with_delay(pin, delay=0.1):
    state = GPIO.input(pin)
    time.sleep(delay)
    return state == GPIO.input(pin)

def toggle_led(pin):
    GPIO.output(pin, not GPIO.input(pin))

try:
   while True:
      if switch_with_delay(SWITCH_PIN):
            toggle_led(RED_PIN)
            time.sleep(0.5)
            toggle_led(RED_PIN)
      else:
            toggle_led(GREEN_PIN)
            time.sleep(0.5)
            toggle_led(GREEN_PIN)

   except KeyboardInterrupt:
      print("Exiting...")
   finally:
      GPIO.cleanup()
```

2.4 PCF8691

Lab5 PCF8591

PCF8591 8 CMOS I^ 2C A_0 A_1 A_2 8 I ^2C I^ 2C 8 8 I^ 2C PCF8591 LED

1. **PCF8591**
2. PCF8591 CMOS 8 A/D 8 D/A
3. I2C 0x48 A0, A1, A2 8 I2C
4. **I2C**
5. I2C SDA SCL Raspberry Pi PCF8591
6.
7. AIN0 AOUT LED LED
8. NTC

1.
2. Raspberry Pi T PCF8591 SDA SCL VCC GND
3. LED PCF8591 AOUT GND LED GND GPIO GPIO17
4. **I2C**
5. Raspberry Pi Preferences -> Raspberry Pi Configuration
6. Interfaces I2C OK
7.
8. `sudo i2cdetect -y 0` I2C
9. PCF8591 0x48
10.
11. Python `smbus` I2C
12. SMBus PCF8591 AIN0 AOUT LED

```
import smbus
import time

# Define the I2C address of the PCF8591 and control bits
address = 0x48  # Default address for PCF8591
control_bit = 0x40  # Command to start conversion on channel 0 (AIN0)

# Initialize the SMBus library
bus = smbus.SMBus(1)  # Use I2C bus 1

try:
    while True:
        # Write the control byte to initiate an A/D conversion on channel 0
        bus.write_byte(address, control_bit)

        # Read back the converted value from the PCF8591
        analog_value = bus.read_byte(address)

        # Print out the raw analog value
        print("Analog Value:", analog_value)

        # Map the analog value to a range suitable for controlling LED brightness
        led_brightness = int((analog_value / 255.0) * 100)

        print("LED Brightness (%):", led_brightness)
```

```
        time.sleep(0.1)  # Small delay between readings

except KeyboardInterrupt:
    print("Exiting...")
```

1.
2. Python LED
3.
4.
5.

2.5

Lab5

NTC Raspberry Pi PCF8591 Raspberry Pi
/

1. **NTC**
2. NTC
3. Steinhart-Hart -
4.
5. NTC 10kΩ
6. PCF8591 AIN0
7.
8. PCF8591 A/D 5V ADC 8 0 $_{255}$ $_{0}$5V
9. Steinhart-Hart T
10. **Steinhart-Hart**
11. Steinhart-Hart \frac{1}{T} = A + B\ln(R) + C(\ln(R))^3 T R A , B , C
R_0 10kΩ B 3950K

1.
2. Raspberry Pi T PCF8591 SDA SCL VCC GND
3. AO PCF8591 AIN0 DO VCC 5V GND
4. **I2C**
5. Raspberry Pi Preferences -> Raspberry Pi Configuration
6. Interfaces I2C OK
7.
8. Python `smbus` I2C
9. SMBus PCF8591 AIN0
10.

```
import smbus
import math
import time

# Define the I2C address of the PCF8591 and control bits
address = 0x48  # Default address for PCF8591
control_bit = 0x40  # Command to start conversion on channel 0 (AIN0)

# Constants for the thermistor calculation
R0 = 10000  # Resistance at 25°C in ohms
B = 3950  # Thermistor constant in Kelvin
T0 = 298.15  # Standard temperature in Kelvin (25°C)
Vcc = 5.0  # Supply voltage in volts

# Initialize the SMBus library
bus = smbus.SMBus(1)  # Use I2C bus 1

def read_temperature():
    try:
        # Write the control byte to initiate an A/D conversion on channel 0
        bus.write_byte(address, control_bit)

        # Read back the converted value from the PCF8591
```

```
        analog_value = bus.read_byte(address)

        # Calculate the analog voltage
        Vr = (analog_value / 255.0) * Vcc

        # Calculate the resistance of the thermistor
        Rt = R0 * Vr / (Vcc - Vr)

        # Apply the Steinhart-Hart equation to calculate temperature
        temp_kelvin = 1 / (math.log(Rt / R0) / B + 1 / T0)
        temp_celsius = temp_kelvin - 273.15

        return round(temp_celsius, 2)

    except Exception as e:
        print("Error reading temperature:", str(e))
        return None

try:
    while True:
        temperature = read_temperature()
        if temperature is not None:
            print(f"Temperature: {temperature}°C")
        else:
            print("Failed to read temperature.")

        time.sleep(1)  # Small delay between readings

except KeyboardInterrupt:
    pass  # Allow the program to exit cleanly with Ctrl+C
```

1.
2. Python
3.
4.
5.

2.6 Lab 6

2.6.1

2.6.2

2.6.3

Lab6

HC-SR04 Raspberry Pi HC-SR04
Python

1.
2. Trig 10 8 40kHz
3. Echo Echo
4. 343 / 20 Echo
5.
6. **VCC** 5V
7. **Trig**
8. **Echo**
9. **GND**
10.
11. GPIO 3.3V Echo 5V Echo

1.
2. Raspberry Pi T VCC Trig Echo GND
3. Trig Raspberry Pi GPIO17 BCM Echo GPIO18 BCM VCC 5V GND
4.
5. Python RPi.GPIO GPIO
6. `get_distance()` Trig 10 Echo Echo

7.

```
import RPi.GPIO as GPIO
import time

# Define GPIO pins for the ultrasonic sensor
TRIG = 17  # BCM numbering
ECHO = 18  # BCM numbering

# Setup GPIO mode and pin directions
GPIO.setmode(GPIO.BCM)
GPIO.setup(TRIG, GPIO.OUT)
GPIO.setup(ECHO, GPIO.IN)

def get_distance():
    # Ensure TRIG is low initially
    GPIO.output(TRIG, False)
    time.sleep(0.2)

    # Send a 10us pulse to TRIG
    GPIO.output(TRIG, True)
    time.sleep(0.00001)
```

```
    GPIO.output(TRIG, False)

    # Wait for ECHO to go high
    while GPIO.input(ECHO) == 0:
        pulse_start = time.time()

    # Wait for ECHO to go low again
    while GPIO.input(ECHO) == 1:
        pulse_end = time.time()

    # Calculate the duration of the pulse
    pulse_duration = pulse_end - pulse_start

    # Convert pulse duration to distance in centimeters
    distance = pulse_duration * 17150  # Speed of sound in cm/s divided by 2 (round trip)
    distance = round(distance, 2)

    return distance

try:
    print("Measuring distance...")
    while True:
        dist = get_distance()
        print(f"Distance: {dist} cm")
        time.sleep(1)

except KeyboardInterrupt:
    print("Measurement stopped by user")

finally:
    GPIO.cleanup()  # Clean up GPIO settings before exiting
```

1.
2. Python
3.
4.
5.

2.7

Lab7

Raspberry Pi

1.
2.
3. GPIO
4.
5.
6. PFM Pulse-Frequency Modulation /
7. PWM Pulse-Width Modulation
8.
9. GPIO
10. PWM

1

1.
2. Raspberry Pi T I/O VCC GND
3. 3.3V
4.
5. Python RPi.GPIO GPIO
6. `play_tone()` GPIO
7.

```
import RPi.GPIO as GPIO
import time

# Define GPIO pin for the buzzer (BCM numbering)
BUZZER_PIN = 17  # BCM 17, physical pin 11

# Setup GPIO mode and pin direction
GPIO.setmode(GPIO.BCM)
GPIO.setup(BUZZER_PIN, GPIO.OUT)

def play_tone(duration=0.5):
    """Play a tone using the active buzzer."""
    try:
        # Turn on the buzzer (low level trigger)
        GPIO.output(BUZZER_PIN, GPIO.LOW)
        time.sleep(duration)

        # Turn off the buzzer
        GPIO.output(BUZZER_PIN, GPIO.HIGH)
        time.sleep(0.1)  # Short pause between tones

    except KeyboardInterrupt:
        print("Stopped by user")

finally:
    GPIO.cleanup()  # Clean up GPIO settings before exiting

if __name__ == "__main__":
    print("Playing tone...")
    while True:
        play_tone()
```

2

1.
2. Raspberry Pi T I/O VCC GND
3. PWM GPIO GPIO18 BCM
4.
5. Python RPi.GPIO pigpio PWM
6. `play_music()`
7.

```
import RPi.GPIO as GPIO
import pigpio
import time

# Define GPIO pin for the passive buzzer (BCM numbering)
BUZZER_PIN = 18  # BCM 18, physical pin 12

# Initialize pigpio library
pi = pigpio.pi()

# Notes and their frequencies in Hz
NOTES = {
    'C4': 262, 'D4': 294, 'E4': 330, 'F4': 349, 'G4': 392, 'A4': 440, 'B4': 494,
    'C5': 523, 'D5': 587, 'E5': 659, 'F5': 698, 'G5': 784, 'A5': 880, 'B5': 988,
}

# A simple melody to play
MELODY = ['C4', 'D4', 'E4', 'C4', 'E4', 'D4', 'C4']

# Function to set frequency of the passive buzzer
def set_frequency(freq):
    pi.hardware_PWM(BUZZER_PIN, freq, 500000)  # Frequency, Duty cycle (50%)

def play_music(melody):
    try:
        for note in melody:
            if note in NOTES:
                set_frequency(NOTES[note])
                time.sleep(0.5)  # Duration of each note
                set_frequency(0)  # Stop sound between notes
                time.sleep(0.1)  # Short pause between notes

    except KeyboardInterrupt:
        print("Music stopped by user")

finally:
    pi.stop()  # Clean up pigpio resources
    GPIO.cleanup()  # Clean up GPIO settings before exiting

if __name__ == "__main__":
    print("Playing music...")
    play_music(MELODY)
```

1.
2. Python
3.
4.
5.

2.8 PS2

Lab8 PS2

PS2 Raspberry Pi LED PS2 X Y Z
PCF8591 LED

1. **PS2**
2. PS2 X Y 0V 5V 2.5V
3. SW 0V
4.
5. PS2 X VRX Y VRY PCF8591 AIN0 AIN1 SW GPIO
6. PCF8591 Raspberry Pi
7.
8. PCF8591 X Y
9. PCF8591 AOUT LED LED LED

1.
2. Raspberry Pi T PCF8591 PS2 SDA SCL VCC GND VRX VRY SW
3. PS2 VRX PCF8591 AIN0 VRY AIN1 SW GPIO VCC 5V GND
4. **I2C**
5. Raspberry Pi Preferences -> Raspberry Pi Configuration
6. Interfaces I2C OK
7.
8. Python `smbus` I2C
9. SMBus PCF8591 AIN0 AIN1 LED
10.

```python
import smbus
import time

# Define the I2C address of the PCF8591 and control bits
address = 0x48  # Default address for PCF8591
control_bit_x = 0x40  # Command to start conversion on channel 0 (AIN0, X-axis)
control_bit_y = 0x41  # Command to start conversion on channel 1 (AIN1, Y-axis)

# Initialize the SMBus library
bus = smbus.SMBus(1)  # Use I2C bus 1

def read_joystick(axis='x'):
    """Read joystick position from specified axis."""
    if axis.lower() == 'x':
        control_bit = control_bit_x
    elif axis.lower() == 'y':
        control_bit = control_bit_y
    else:
        raise ValueError("Invalid axis. Choose 'x' or 'y'.")

    try:
        # Write the control byte to initiate an A/D conversion on selected channel
        bus.write_byte(address, control_bit)

        # Read back the converted value from the PCF8591
        analog_value = bus.read_byte(address)

        return analog_value
```

```
    except Exception as e:
        print(f"Error reading {axis}-axis:", str(e))
        return None

def map_to_brightness(value, in_min=0, in_max=255, out_min=0, out_max=100):
    """Map joystick value to LED brightness percentage."""
    return int((value - in_min) * (out_max - out_min) / (in_max - in_min) + out_min)

try:
    while True:
        x_value = read_joystick('x')
        y_value = read_joystick('y')

        if x_value is not None and y_value is not None:
            print(f"X-axis: {x_value}, Y-axis: {y_value}")

            # Calculate LED brightness based on joystick position
            led_brightness_x = map_to_brightness(x_value)
            led_brightness_y = map_to_brightness(y_value)

            # Here you would add code to set the LED brightness using PWM or similar method.
            # For demonstration purposes, we'll just print the calculated brightness.
            print(f"LED Brightness X (%): {led_brightness_x}, Y (%): {led_brightness_y}")

        time.sleep(0.1)  # Small delay between readings

except KeyboardInterrupt:
    pass  # Allow the program to exit cleanly with Ctrl+C
```

1.
2. Python LED
3.
4.
5.

2.9

Lab9

LIRC Raspberry Pi
Raspberry Pi

1.
2. LED PIN
3.
4. PIN
5.
6. **LIRC**
7. LIRC Linux Infrared Remote Control LIRC

1. **LIRC**
2. LIRC

```
sudo apt-get update
sudo apt-get install lirc
```

3. `/boot/config.txt` GPIO 22 23

```
dtoverlay=gpio-ir,gpio_pin=22
dtoverlay=gpio-ir-tx,gpio_pin=23
```

4.
5. `/etc/lirc/lirc_options.conf` LIRC

```
sudo nano /etc/lirc/lirc_options.conf
```

```
driver = default
device = /dev/lirc0
```

6.
7. Raspberry Pi

```
sudo reboot
```

8. **IR**
9. `irw`

```
irw
```

10.
11.
12. Python LIRC
13. Python

```
import subprocess
```

```
def listen_to_remote():
    try:
        process = subprocess.Popen(['irw'], stdout=subprocess.PIPE)

        while True:
            line = process.stdout.readline().decode('utf-8').strip()
            if not line:
                break

            print("Received IR command:", line)

    except KeyboardInterrupt:
        print("\nListening stopped.")

if __name__ == "__main__":
    print("Listening for IR commands...")
    listen_to_remote()
```

1.
2. Python
3.
4.
5.

2.10

Lab10

Raspberry Pi GPIO
LED

1.
2. `GPIO.add_event_detect()` GPIO
   - `channel` GPIO
   - `edge` `GPIO.RISING` `GPIO.FALLING` `GPIO.BOTH`
   - `callback`
   - `bouncetime`
3.
4. `GPIO.wait_for_edge()` CPU
5.
6. “ ”

1.
2. Raspberry Pi T SIG(S) VCC GND
3. SIG(S) Raspberry Pi GPIO23 BCM VCC 5V GND
4. LED LED GPIO17 LED GPIO27
5.
6. Python RPi.GPIO GPIO
7. `setup_gpio()` GPIO
8. `button_pressed_callback()` LED
9.

```
import RPi.GPIO as GPIO
import time

# Define GPIO pins for the LED and button (BCM numbering)
RED_LED_PIN = 17  # BCM 17, physical pin 11
GREEN_LED_PIN = 27  # BCM 27, physical pin 13
BUTTON_PIN = 23  # BCM 23, physical pin 16

def setup_gpio():
    """Setup GPIO mode and pin directions."""
    GPIO.setmode(GPIO.BCM)

    # Setup LEDs as output
    GPIO.setup(RED_LED_PIN, GPIO.OUT)
    GPIO.setup(GREEN_LED_PIN, GPIO.OUT)

    # Setup button as input with pull-up resistor
    GPIO.setup(BUTTON_PIN, GPIO.IN, pull_up_down=GPIO.PUD_UP)

def button_pressed_callback(channel):
    """Callback function called when the button is pressed."""
    if channel == BUTTON_PIN:
        print("Button pressed!")

        # Toggle between red and green LED
        if GPIO.input(RED_LED_PIN):
            GPIO.output(RED_LED_PIN, GPIO.LOW)
            GPIO.output(GREEN_LED_PIN, GPIO.HIGH)
        else:
```

```
            GPIO.output(RED_LED_PIN, GPIO.HIGH)
            GPIO.output(GREEN_LED_PIN, GPIO.LOW)

try:
    setup_gpio()

    # Add event detection on the button pin with debouncing
    GPIO.add_event_detect(BUTTON_PIN, GPIO.FALLING, callback=button_pressed_callback, bouncetime=200)

    print("Waiting for button press...")
    while True:
        time.sleep(1)  # Keep script running to allow callbacks to work

except KeyboardInterrupt:
    print("\nProgram stopped by user")

finally:
    GPIO.cleanup()  # Clean up GPIO settings before exiting
```

1.
2. Python LED
3. `bouncetime`
4.
5. ...
6.
7.
8.