Course schedule

- Package lectures: Hybrid lectures and tutorials every week.
  - Monday 9am - 11am E3-06-08
  - Friday 4pm - 6pm E1-06-04
- Lab and Lab test. 8 sessions (3 labs + project 5)
  - Thursday 9am - 12noon, E1-06-03
  - Date TBA
- Makeup session(s) and consultation sessions will be arranged if needed.

Assessments

- Lab and lab test 30%
- Project 30%
- Final exam 40%

Collect boards and tools for labs and project

- Collect in person in Week 2 during the working hours from

  Digital Electronics Lab @ E4-03-07

Chapter 1
Introduction of IoT and Tools

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Internet of things (IoT)

- Network of physical objects embedded with sensors, software, and technologies to connect and exchange data over the internet.
  - Extend the connectivity beyond standard devices to a diverse range of everyday objects.
  - Make them interact in a smart way .

Internet of things (IoT)

- Key Characteristics of IoT.
  - Connectivity
  - Data acquisition through sensors
  - Data processing
  - Automation and control for asset and actuators
  - Scalability

Internet of things (IoT)

- IoT components.
  - Sensors/Devices
  - Connectivity
  - Data Processing
  - User Interface

IoT framework

- Four main components.
  - End nodes: sensor node hardware
  - Network layer: communication protocols
  - Service layer: provide reliable link and data processing.
  - Application layer: integration service for data sharing.

IoT hardware

- Physical devices and components essential for the functioning of IoT systems.
  - Sensors and actuators
  - Processing data
  - Communication

IoT hardware

- IoT hardware
  - Sensors and actuators
  - Microcontrollers and microprocessors
  - Communication module
  - Power Supply
  - Edge Devices
  - Gateways

Example Applications of IoT

- Smart Homes: Connected appliances, lighting, security cameras, thermostats.
- Wearables: Fitness trackers, smartwatches, health monitoring.
- Industrial IoT (IIoT): Manufacturing optimization, equipment monitoring.
- Smart Cities: Traffic management, waste management, energy-efficient buildings.

IoT in Healthcare and Agriculture

- Healthcare: Remote patient monitoring, connected medical devices, telemedicine.
- Agriculture: Soil moisture sensors, automated irrigation, livestock monitoring.

Trends in IoT

- Edge computing
- AI and machine learning
- 5G connectivity
- Enhanced security
- Interoperability and standards
- Increased adoption in industrial IoT

Challenges in IoT

- Security and privacy
- Scalability
- Interoperability
- Data management
- Power consumption
- Standardization

Tools used in this course

- Git and GitHub
  - Refer and share codes
  - Submit and showcase you work in this course
- ESP32-S3 devkit and sensors
- Arduino IDE and supporting packages

Git and GitHub

- Version control, track your coding project progress and showcase.
- Git: local version control tool.
- GitHub: Web-based hosting platform interact with local Git.
- Why and how version control?
- Why web-based GitHub?

Git and GitHub

- Git workflow
  - Working directory
    - Untracked files
  - Staging area
    - Buffer area for files to be committed.
  - Git depository
    - Commit the changes permanently.
  - Master branch and other branches in a repo

Git and GitHub

- Install and configure Git
  - Install Git https://git-scm.com/downloads
  - Configure your Git (in command prompt)
    - User name
    - Email
    - Default editor Create a local Git depo
  - Convert the directory storing code as the project repo

Git and GitHub

- Git operations.

git init	git commit –m “[msg]”
git status	git log --oneline
git ls-files	git branch [branch name]
git add [filename]	git switch [branch name]
git rm --cache [filename]	git merge [branch to merge]
git reset –hard [commit hash]	git checkout [commit hash]

Git and GitHub

- Benefits of GitHub (or other Hubs) provided.
  - Create a repository (repo). Use the repo to store your code, share and collaborate with others.
  - Push your code from you local Git to the repo space on GitHub to share.
  - Showcase your study and work experience and achievement.
  - Evaluate others' work.

Git and GitHub

- Scenarios of GitHub usages.
  - Sign up an account.
  - Create a repository (repo).
  - Push your code from you local Git to GitHub or pull from GitHub to local Git.
  - Merge different branch
  - Collaborate with others
  - Showcase your work with readme.

Git and GitHub

– Push your code from you local Git to GitHub or pull from GitHub to local Git.

Push	Pull
git remote –v	git pull origin master
git remote add origin [url of the GitHub repo]	
git push –u origin master	

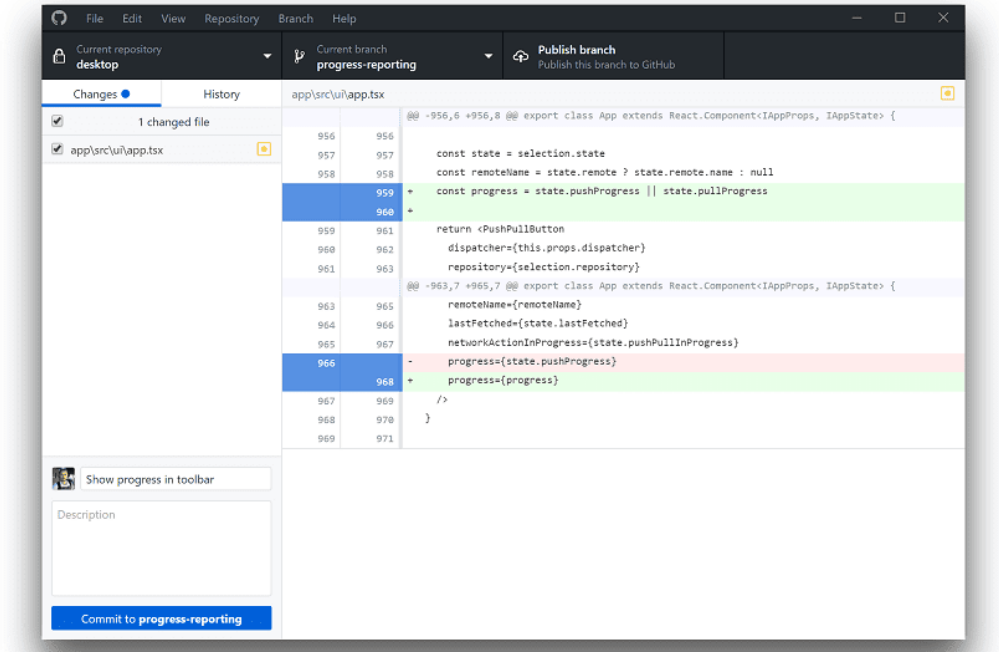
Git and GitHub

- Collaborate with others
  - Collaborator access by invitation as if in one's own GitHub repo

    Clone to local repo git clone [url]
  - Pull request for non-collaborator.
    - Fork to replicate in your own Repo.
    - Clone to local Repo and contribute.
    - Pull to your GitHub Repo.
    - Raise a pull request to merge to the original .
    - Merge the changes to the original Repo.

Use Git and GitHub

- GitHub desktop: Graphical local Git tool for GitHub.
  - https://desktop.github.com/download/



Use Git and GitHub

- Git operations.
- Functions of GitHub provided.
  - Create a repository (repo).

    Use the repo to store your code, share and collaborate with others
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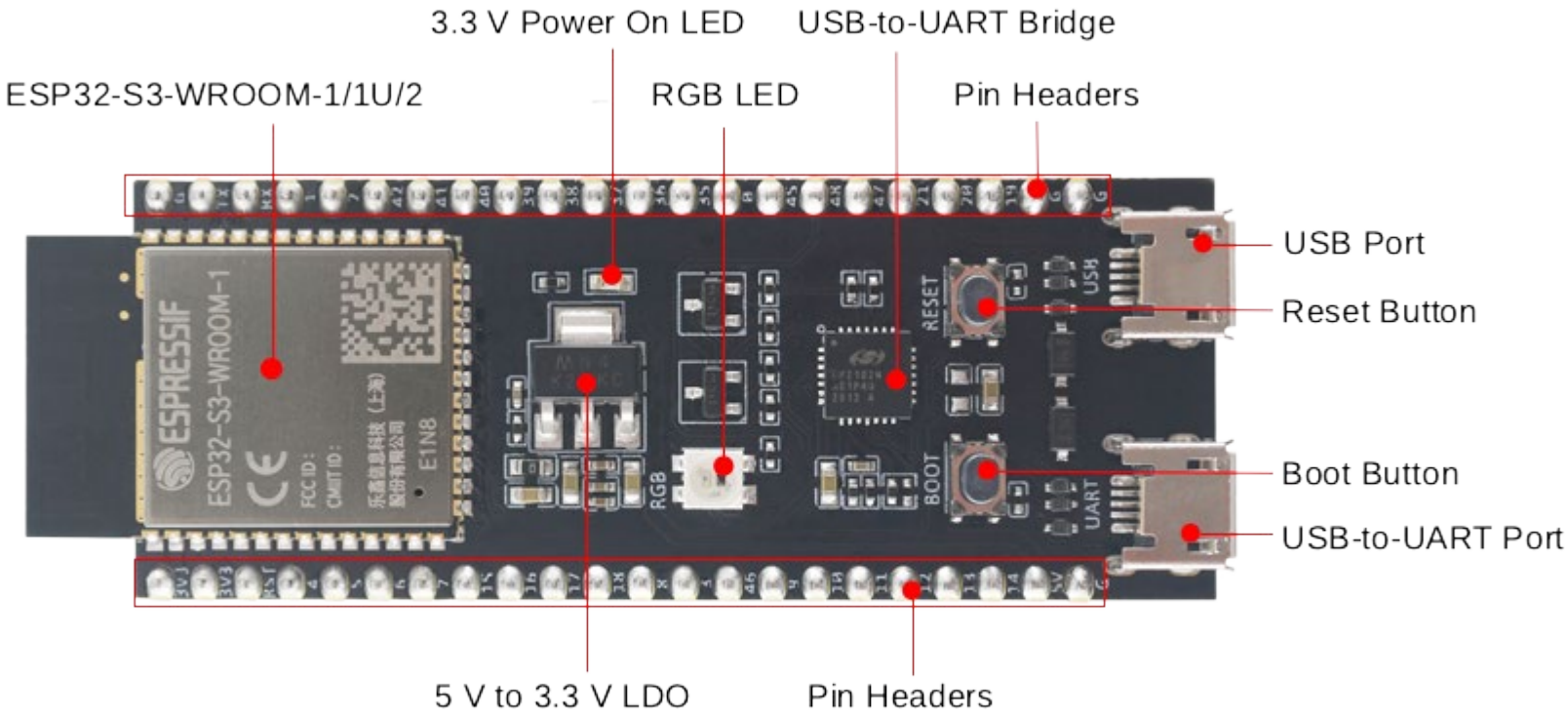
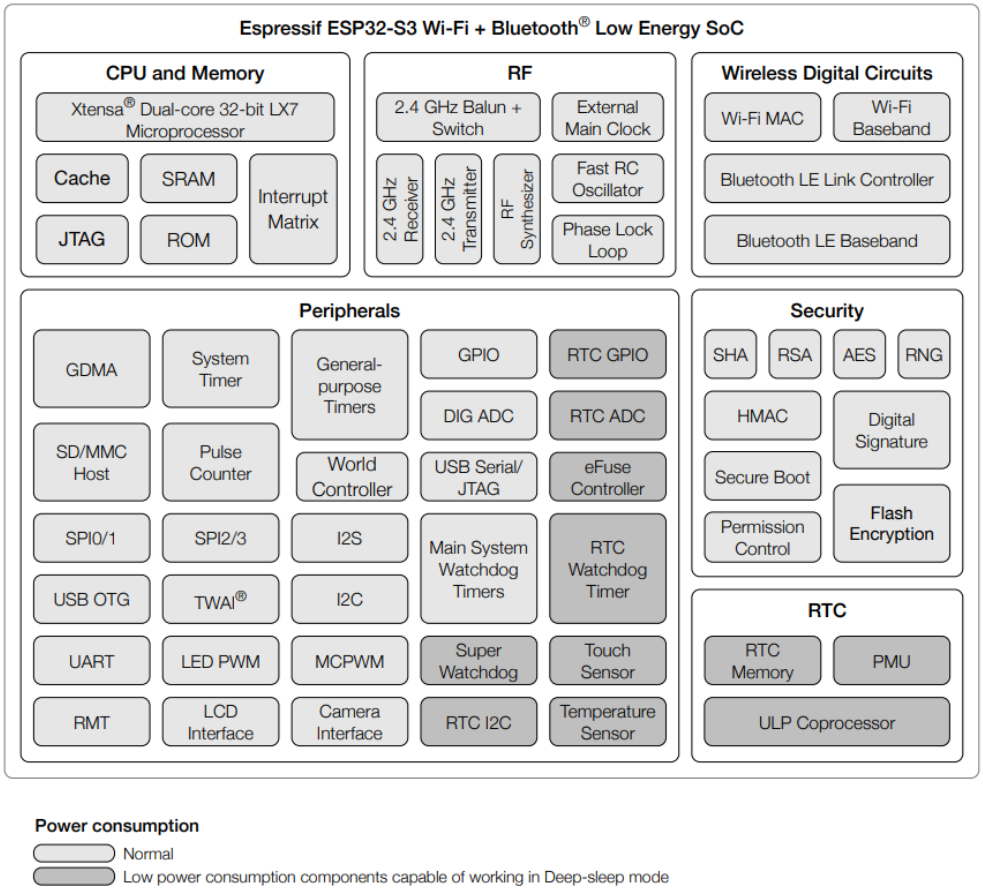
ESP32-S3 develop board

- ESP32-S3-DevKitC-1



ESP32-S3 develop board

- ESP32-S3-WROOM-1/1U/2 MCU module



ESP32-S3 develop board

- Processor cores: Dual core Xtensa LX7 up to 240MHz.
- Power supply: 3.3V and 5V with power regulator on board.
- USB-to-UART port and USB-to-UART bridge
  - UART (Universal Asynchronous Receiver-Transmitter)
    - Minimum 3 wires, TX, RX and GND, and 6 optional wires.
    - Relatively short distance and low rate
    - USB connector connecting to UART interface – CP2102
    - Communicate between MCU to computer and flash applications to MCU.
    - 5V power supply

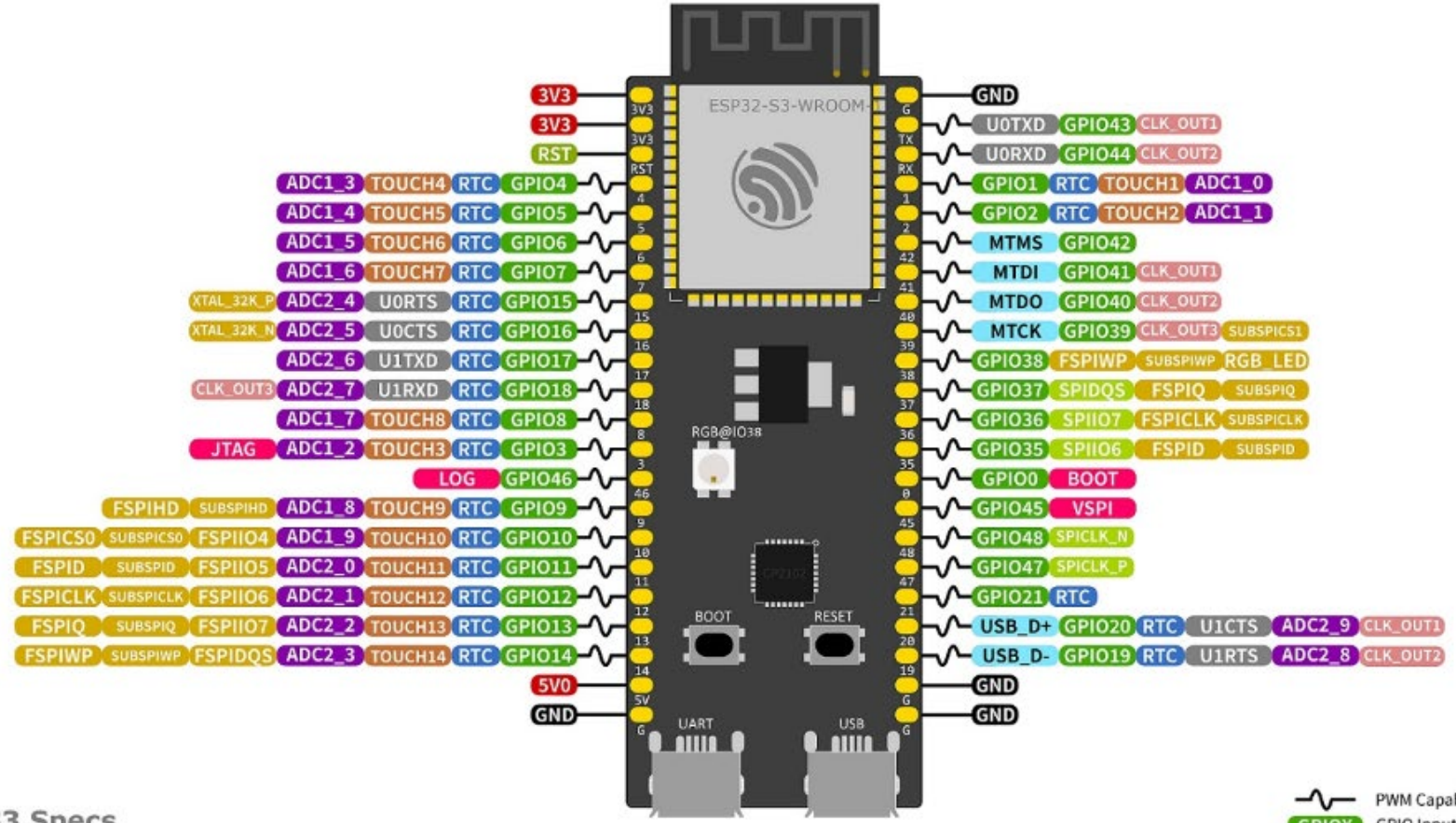
ESP32-S3 develop board

- Boot button
- Reset button
- USB port: USB OTG, power supply, programming and serial communications.
- USB-to-UART: power supply, programming and serial communications (debugging, monitoring and interacting).
- RGB LED: Addressable RGB LED, driven by a GPIO pin.
- GPIO

ESP32-S3 develop board

- ESP32-S3 is a powerful microcontroller with integrated Wi-Fi and Bluetooth (BLE).
- Suitable for IoT applications, embedded systems and edge AI.
- Rich set of hardware resources.

ESP32-S3-DevKitC-1



ESP32-S3 Specs

32-bit Xtensa® dual-core @240MHz
Wi-Fi IEEE 802.11 b/g/n 2.4GHz + BLE 5 Mesh
512 KB SRAM (16 KB SRAM in RTC)
384 KB ROM
45 GPIOs, 4x SPI, 3x UART, 2x I2C,
14x Touch, 2x I2S, RMT, LED PWM, USB-OTG,
TWAI®, 2x 12-bit ADC, 1x LCD interface, DVP

PWM Capable Pin
GPIOX GPIO Input and Output
JTAG/USB JTAG for Debugging and USB
ADCX_CH Analog-to-Digital Converter
TOUCHX Touch Sensor Input Channel
OTHER Other Related Functions
SERIAL Serial for Debug/Programming
STRAP Strapping Pin Functions
RTC RTC Power Domain (VDD3P3_RTC)
GND Ground
PWD Power Rails (3V3 and 5V)

MISC Miscellaneous/SPI functions
CLK_OUTx Clock Output

ESP32-S3 develop board

- Pin functions:
  - GPIO, ADC, I2C, SPI, UART
  - Flexible mapping of pins.

- IDE environemnt, driver and libraries.
  - Arduino IDE + supporting software package
  - ESP-IDF in CLI
  - ESP-IDF plugin + VSC
  - ESP-IDF + PlatformIO

Arduino IDE

- Integrated development environment (IDE) for Arduino boards and other compatible boards
  - Support code editing, compilation, flash and debugging.
  - Community and industry develop various libraries
    - There are drivers for various peripherals
    - Libraries for various developing boards with different MCU, including ESP32-S3-DevKitC-1.
  - Programming language is a simplified C++ → Sketches
    - Support most of the useful features of C++, including pointers.

Why choose Arduino IDE?

- Arduino IDE is a familiar interface to many of us.
- Arduino board family are already used in IoT.
- Arduino IDE supports many other developing board.
- Programming language
  - sketches = mixture of C and C++.

Configuring GPIOs in Arduino IDE

- Use pinMode(), digitalWrite(), and digitalRead() functions.

```
void setup() {
  pinMode(LED_BUILTIN, OUTPUT);
}

void loop() {
  digitalWrite(LED_BUILTIN, HIGH);
  delay(1000);
  digitalWrite(LED_BUILTIN, LOW);
  delay(1000);
}
```

GPIO Interrupts

- Handle asynchronous events.
- Use attachInterrupt() function.

```
void IRAM_ATTR handleInterrupt() {
  // Interrupt service routine
}

void setup() {
  pinMode(2, INPUT_PULLUP);
  attachInterrupt(digitalPinToInterrupt(2), handleInterrupt, FALLING);
}

void loop() {
  // Main loop code
}
```

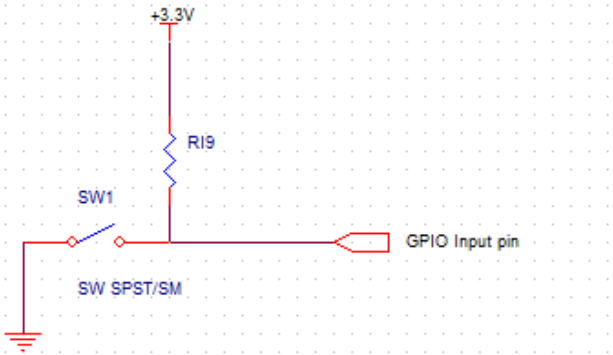
Example: Button Control

- Control an LED with a button press.

```
void setup() {
  pinMode(LED_BUILTIN, OUTPUT);
  pinMode(2, INPUT_PULLUP);
}

void loop() {
  if (digitalRead(2) == LOW) {
    digitalWrite(LED_BUILTIN, HIGH);
  } else {
    digitalWrite(LED_BUILTIN, LOW);
  }

}
```



Configuring I2C in Arduino IDE

- Use Wire.begin(), Wire.requestFrom(), and Wire.write() functions.

```
void setup() {
  Wire.begin();
}

void loop() {
  Wire.beginTransmission(0x68);//device with i2C addr 0x68
  Wire.write(0x00);
  Wire.endTransmission();
  Wire.requestFrom(0x68, 1);
  while (Wire.available()) {
    char c = Wire.read();
  }
}
```

Default:
SDA (Data Line): GPIO 8
SCL (Clock Line): GPIO 9

```
void setup() {
  Serial.begin(115200);
  Wire.begin();
}

void loop() {
  Wire.beginTransmission(0x68);
  Wire.write(0x00);
  Wire.endTransmission();
  Wire.requestFrom(0x68, 2);
  while (Wire.available()) {
    int data = Wire.read() << 8 | Wire.read();
    Serial.println(data);
  }
  delay(1000);
}
```

Configuring SPI in Arduino IDE

- 2 SPI are available: HSPI and VSPI for developers.

```
void setup() {
  SPI.begin();
}

void loop() {
  digitalWrite(SS, LOW);
  SPI.transfer(0x00);
  digitalWrite(SS, HIGH);
  delay(1000);
}
```

MOSI (Master Out Slave In): GPIO 13
MISO (Master In Slave Out): GPIO 12S
CLK (Clock): GPIO 14
SS/CS (Slave Select/Chip Select): GPIO 15

Configuring ADC in Arduino IDE

- Analog-to-Digital Converter.
- Used to read analog signals.
- Multiple ADC channels.

ADC1 Channels:
ADC1_CH0: GPIO 36
ADC1_CH1: GPIO 37
ADC1_CH2: GPIO 38
ADC1_CH3: GPIO 39
ADC1_CH4: GPIO 32
ADC1_CH5: GPIO 33
ADC1_CH6: GPIO 34
ADC1_CH7: GPIO 35

```
void setup() {
  Serial.begin(115200);
}

void loop() {
  int value = analogRead(34);
  float voltage = value * (3.3 / 4095.0);
  float temperature = (voltage - 0.5) * 100;
  Serial.println(temperature);
  delay(1000);
}
```

Configuring PWM in Arduino IDE

- Use ledcSetup(), ledcAttachPin(), and ledcWrite() functions.

```
void setup() {
  ledcSetup(0, 5000, 8);       // Configure LEDC channel 0 with a 5 kHz frequency and 8-bit resolution
  ledcAttachPin(2, 0);          // Attach GPIO 2 to LEDC channel 0
}

void loop() {
  for (int duty = 0; duty <= 255; duty++) {
    ledcWrite(0, duty);        // Set the duty cycle for channel 0 (0 to 255)
    delay(10);                 // Wait for 10 milliseconds
  }
  for (int duty = 255; duty >= 0; duty--) {
    ledcWrite(0, duty);        // Set the duty cycle for channel 0 (255 to 0)
    delay(10);                 // Wait for 10 milliseconds
  }
}
```

Configuring Wi-Fi in Arduino IDE

- Use WiFi.begin(), WiFi.status(), and WiFiClient functions.

```
#include <WiFi.h>

void setup() {
  Serial.begin(115200);
  WiFi.begin("SSID", "PASSWORD");
  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
    Serial.println("Connecting...");
  }
  Serial.println("Connected!");
}

void loop() {
  // Main loop code
}
```