Here’s the **detailed component list** with **technical specifications, purpose, and theoretical explanation** for each component required in our project:

**🔩 Detailed Component List with Explanation**

| **Component** | **Specifications** | **Purpose** | **Theoretical Explanation** | **Where It's Used in Project** |
| --- | --- | --- | --- | --- |
| **ESP32 Dev Board** | - 2.4 GHz Wi-Fi and Bluetooth- 12-bit ADC channels- Multiple GPIO pins | Central controller | ESP32 is used for reading analog sensor data, processing, and sending it to AWS Lambda over Wi-Fi. It has a powerful processor and multiple ADC channels suitable for real-time IoT projects. | Reads all sensor inputs and sends data to the cloud. |
| **ACS712 Current Sensor (5A version)** | - 5A current sensing- Sensitivity: 185 mV/A- Operating Voltage: 5V | Measures current | Based on Hall Effect. Outputs voltage proportional to the current passing through the sensor. Can measure both DC and AC currents. | Measures both battery discharge current and load current. |
| **Voltage Divider Circuit (Resistors)** | Example:R1 = 10 kΩ, R2 = 10 kΩ | Measures battery & load voltage | Direct battery voltage cannot be connected to ESP32 ADC as it may exceed 3.3V. The voltage divider scales down the voltage within ESP32's readable range. | Battery and load voltage measurement. |
| **NTC Thermistor (Eaton NRG3105H3950B1H)** | - Resistance: 10 kΩ at 25°C- Beta value: 3950 K- Max voltage: 3.3V compatible via divider | Measures battery temperature | Negative Temperature Coefficient (NTC) thermistors decrease resistance as temperature increases. The resistance change is mapped to temperature using a mathematical formula. | Measures battery temperature. |
| **Fixed Resistor (for NTC Thermistor)** | 10 kΩ | Forms voltage divider with NTC | Helps in converting thermistor's resistance to a measurable voltage range for ESP32 ADC. | Part of the temperature sensing circuit. |
| **DC Motor (Load)** | Low power DC motor | Simulated load | Provides a variable (non-constant) load for battery discharge, which matches your planned scaling approach. | Acts as a real-world load connected to the battery. |
| **Battery Holder for 18650 Battery** | Suitable for 1x 18650 | Battery mounting | Safely holds the battery and provides electrical connections. | Power source for the system and load. |
| **18650 Rechargeable Battery (Li-ion)** | - Nominal Voltage: 3.7V- Max Charge Voltage: 4.2V- Capacity: typically 1800 - 2500 mAh | Power source | Provides power to load (motor) and is the main battery under health monitoring. | The battery whose discharge characteristics are being analyzed. |
| **Breadboard + Jumper Wires** | Standard prototyping accessories | Circuit building | Provides easy and temporary connections for all components. | Connects all sensors and modules to ESP32. |
| **Optional: 5V Regulated Power Supply** | Provides stable 5V | Stable power | Ensures sensors like ACS712 operate reliably. | Powers ACS712 sensors and ESP32 if needed. |

**📖 Explanation of Key Components and Theory**

**1. ESP32**

* **Why?** ESP32 is chosen because it has inbuilt Wi-Fi, multiple ADCs, and enough computational power for real-time IoT tasks.
* **Configuration:** 3.3V logic level, requires stable power.

**2. ACS712 Current Sensor**

* **Why?** Measures both DC and AC currents precisely.
* **Configuration:** Output voltage is centered at 2.5V when no current flows. For the 5A version, the scale is **185 mV per Ampere.**
* **Theory:** Based on Hall Effect — a magnetic field produced by the current generates a voltage proportional to that current.

**3. Voltage Divider (Resistor Network)**

* **Why?** ESP32 ADC can read up to 3.3V maximum.
* **Configuration:** Using 10kΩ : 10kΩ resistors will scale 0-4.2V (battery voltage) to a safe 0-2.1V range.
* **Theory:** Divides input voltage into a smaller output voltage proportionally.

**4. NTC Thermistor (Temperature Sensor)**

* **Why?** Provides temperature-dependent resistance to monitor battery temperature.
* **Configuration:** 10kΩ thermistor with a 10kΩ fixed resistor connected to ESP32 ADC.
* **Theory:** Resistance drops as temperature increases. Using the Beta parameter, temperature can be derived mathematically.

**5. DC Motor (Load)**

* **Why?** You are planning a **variable load** setup (non-constant discharge), matching real-life inverter battery usage.
* **Theory:** The motor’s current draw varies with load torque and voltage fluctuations, simulating real-world battery stress.

**6. Battery (18650)**

* **Why?** Compact, rechargeable, commonly used in battery research.
* **Charging Profile:** CCCV — constant current followed by constant voltage.
* **Discharging Profile:** Current-dependent on load (here, a DC motor).

**🔌 Detailed Connections Summary**

| **ESP32 Pin** | **Sensor/Component** | **Description** |
| --- | --- | --- |
| GPIO34 | Battery Voltage Divider Output | Scaled battery voltage |
| GPIO35 | Load Voltage Divider Output | Scaled load voltage |
| GPIO32 | ACS712 Battery Current Sensor | Battery discharge current |
| GPIO33 | ACS712 Load Current Sensor | Load current |
| GPIO36 | Thermistor Voltage Divider | Battery temperature |
| 5V Pin | ACS712 VCC | Sensor power supply |
| GND | Common Ground | Connect all grounds together |

**🛠️ Process Summary**

1. **Circuit Building:**
   * Connect sensors to ESP32 as per the table above.
   * Setup voltage dividers correctly to ensure safe ADC readings.
   * Power the ESP32 and sensors.
2. **Firmware Upload:**
   * Flash the ESP32 with the final provided code.
   * Update your Wi-Fi credentials and AWS API Gateway URL.
3. **AWS Lambda Setup:**
   * Host your ML model in AWS Lambda.
   * Setup API Gateway to receive POST requests from ESP32.
4. **Testing:**
   * Monitor sensor readings via serial monitor.
   * Ensure real-time predictions are returned from AWS.
5. **Scaling:**
   * For inverter battery applications, replace the motor with a real-life inverter load.
   * Update resistor divider values if battery voltage range increases.

| **#** | **Component** | **Purpose** | **Quantity** |
| --- | --- | --- | --- |
| 1 | ESP32 Dev Board | Core processing, Wi-Fi for AWS connection | 1 |
| 2 | ACS712 Current Sensor (5A) | Measure battery current & load current | 2 |
| 3 | NTC Thermistor (10kΩ, Beta 3950) | Measure battery temperature | 1 |
| 4 | Fixed Resistor 20kΩ, 0.25W | Voltage divider for battery/load voltage | 2 |
| 5 | Fixed Resistor 10kΩ, 0.25W | Voltage divider for battery/load voltage, NTC divider | 3 |
| 6 | DC Motor (3-6V, 150mA-300mA) [TT Gearbox Motor (Yellow Motor)] | Simulated load | 1 |
| 7 | 18650 Rechargeable Battery | Power source under test | 1 |
| 8 | Battery Holder (18650) | Safely hold battery | 1 |
| 9 | Breadboard | Prototyping platform | 1 |
| 10 | Jumper Wires | Circuit connections | 30-40 |
| 11 | 5V Regulated Power Supply | External power source for ESP32 & sensors | 1 |
| 12 | Capacitors (100nF (0.1µF), 50V, Ceramic (X7R preferred)) [optional] | Noise filtering for sensors | 4 |

**Detailed Connection Explanation (Step by Step)**

**1. ESP32 Dev Board**

* Central controller.
* Connect to Wi-Fi for sending data to AWS Lambda.
* Analog pins (ADC) will read sensor values.

**2. ACS712 Current Sensors (2 units)**

* **Sensor 1:** Battery current measurement
* **Sensor 2:** Load current measurement

**Connections:**

* VCC → 5V Power Supply
* GND → Common Ground
* OUT → Connect to ESP32 ADC Pin (e.g. GPIO 34 for battery current, GPIO 35 for load current)
* Place a **100nF capacitor** across VCC and GND (close to sensor)

**3. NTC Thermistor (10kΩ, Beta 3950)**

* Measures battery temperature using voltage divider.

**Connections:**

* One leg → 3.3V
* Second leg → Connect to ESP32 ADC Pin (e.g. GPIO 32) and also to one side of 10kΩ resistor.
* Other side of 10kΩ resistor → Ground
* Place a **100nF capacitor** across the analog pin and GND for noise filtering.

**4. Voltage Divider for Battery & Load Voltage (Resistors: 20kΩ & 10kΩ)**

* Reduces battery/load voltage to safe ADC range (0-3.3V).

**For Battery Voltage:**

* Connect 20kΩ resistor between battery positive terminal and ESP32 ADC Pin (e.g. GPIO 33).
* Connect 10kΩ resistor between ESP32 ADC pin and GND.

**For Load Voltage:**

* Same voltage divider configuration on load side.
* Connect 20kΩ resistor between load positive terminal and ESP32 ADC Pin (e.g. GPIO 36).
* Connect 10kΩ resistor between ESP32 ADC pin and GND.

**5. DC Motor (Load)**

* Connect in series with load current sensor (ACS712 #2).
* The motor will discharge the battery at varying loads.

**6. Battery Setup**

* 18650 battery mounted in holder.
* Connect battery:
  + Positive → Current Sensor 1 → Voltage divider → Load path → Load current sensor → Motor → Ground

**7. Capacitors (100nF, 0.1µF)**

* 2 × Across each ACS712 (near VCC and GND)
* 1 × Across ESP32 3.3V and GND
* 1 × Across NTC Thermistor input and GND

**8. 5V Regulated Power Supply**

* Powers ESP32 and ACS712 sensors.