KiCad PCB Design Checklist - ESP32-S3 Industrial IoT

Pre-Design Setup

KiCad Installation & Configuration

- [ ] Install KiCad 7.0 or later
- [ ] Download ESP32-S3 symbol and footprint libraries
- [ ] Configure design rules for 4-layer PCB
- [ ] Set up component libraries (Digikey, Mouser, etc.)
- [ ] Configure 3D model libraries for visualization

Project Setup

- [ ] Create new KiCad project
- [ ] Set up Git repository for version control
- [ ] Create project folder structure
- [ ] Configure project-specific libraries
- [ ] Set up design rule check (DRC) rules

Schematic Design Checklist

1. ESP32-S3 Module Section

Components:

- [ ] ESP32-S3-WROOM-1 module (or ESP32-S3-WROOM-1U for external antenna)
- [ ] 10µF + 100nF decoupling capacitors on VDD
- [ ] 10kΩ pull-up on EN (enable) pin
- [ ] 470Ω series resistor on USB D+/D- if using USB
- [ ] Boot mode resistors (10kΩ pull-up on GPIO0, pull-down on GPIO46)

Schematic Requirements:

- [ ] All power pins connected to appropriate rails
- [ ] Proper decoupling capacitor placement
- [ ] Boot and reset circuitry
- [ ] Programming interface (USB-C or UART)
- [ ] Unused pins properly handled (pulled up/down or left floating per datasheet)

2. Power Management System

Battery Charging Circuit (MCP73831):

- [ ] MCP73831T-2ACI/OT Li-Po charging IC
- [ ] 2kΩ resistor (PROG pin) for 500mA charge current
- [ ] 4.7µF input capacitor
- [ ] 4.7µF output capacitor
- [ ] Status LED with 470Ω resistor
- [ ] Thermal pad connection to ground plane

3.3V Regulation (AMS1117-3.3):

- [ ] AMS1117-3.3 linear regulator
- [ ] 10µF input capacitor (tantalum or ceramic)
- [ ] 22µF output capacitor
- [ ] Power LED with 1kΩ resistor
- [ ] Thermal considerations for continuous operation

Power Distribution:

- [ ] Battery voltage rail (VBAT) - 3.7V nominal
- [ ] Regulated 3.3V rail (VDD) - main system power
- [ ] Sensor power rail (VSENSOR) - switchable sensor power
- [ ] Load switches (AP2112K) for sensor power control
- [ ] Power selection circuit (battery vs USB)

3. Sensor Interface Circuits

I2C Interface (BME280 Environmental Sensor):

- [ ] BME280 or SHT30 sensor footprint
- [ ] 4.7kΩ pull-up resistors on SDA and SCL
- [ ] 100nF bypass capacitor on sensor VDD
- [ ] ESD protection diodes (optional)
- [ ] Address selection jumper (if applicable)

SPI Interface (ADXL345 Accelerometer):

- [ ] ADXL345 or ICM-20948 sensor footprint
- [ ] 100nF bypass capacitor on sensor VDD
- [ ] Series resistors on SPI lines (22Ω) for signal integrity
- [ ] Chip select pull-up resistor (10kΩ)
- [ ] Interrupt pins routed to ESP32-S3 GPIO

ADC Interface (ACS712 Current Sensor):

- [ ] ACS712-05B current sensor IC
- [ ] 100nF bypass capacitor
- [ ] 1µF filter capacitor on output
- [ ] Voltage divider for ADC scaling (if needed)
- [ ] TVS diode for input protection

4. Industrial I/O Section

Connectors:

- [ ] USB-C connector for programming and charging
- [ ] 3.5mm screw terminals for sensor connections
- [ ] 2.54mm header for GPIO expansion
- [ ] SWD programming header (Tag-Connect or standard)

User Interface:

- [ ] Power LED (green) with 1kΩ resistor
- [ ] Status LED (blue) with 470Ω resistor
- [ ] Error LED (red) with 470Ω resistor
- [ ] Reset button (tactile switch) with 10kΩ pull-up
- [ ] Boot button (tactile switch) with 10kΩ pull-up

Protection Circuits:

- [ ] Reverse polarity protection (P-channel MOSFET)
- [ ] Overcurrent protection (PTC fuse, 1A)
- [ ] ESD protection on all external interfaces
- [ ] TVS diodes on power inputs

5. Schematic Review Checklist

Power System:

- [ ] All ICs have proper power connections
- [ ] Decoupling capacitors on all power pins
- [ ] Power-on reset circuits properly implemented
- [ ] Current consumption calculated and within limits

Signal Integrity:

- [ ] High-speed signals kept short

- [ ] Proper impedance matching considered
- [ ] Clock signals properly routed
- [ ] Unused pins properly handled

Component Selection:

- [ ] All components available from reliable suppliers
- [ ] Temperature ratings suitable for application
- [ ] Package sizes suitable for hand assembly
- [ ] Cost optimization completed

Design Rules:

- [ ] Electrical Rules Check (ERC) passed
- [ ] All nets properly named
- [ ] Component values and part numbers specified
- [ ] Footprint assignments completed

PCB Layout Design Checklist

1. PCB Stackup Configuration

4-Layer Stackup:

```
Layer 1 (Top):    Signal + Components  [0.035mm Cu]
Layer 2 (GND):    Ground Plane         [0.035mm Cu]
Layer 3 (PWR):    Power Planes         [0.035mm Cu]
Layer 4 (Bottom): Signal + Components  [0.035mm Cu]
Core: 1.53mm, Total: 1.6mm
```

Stackup Parameters:

- [ ] Impedance: 50Ω single-ended, 100Ω differential
- [ ] Via size: 0.2mm drill, 0.5mm pad
- [ ] Minimum trace: 0.1mm width, 0.1mm spacing
- [ ] Minimum via: 0.15mm drill, 0.35mm pad

2. Component Placement Strategy

Critical Component Placement:

- [ ] ESP32-S3 module placed first (center of board)
- [ ] Decoupling capacitors as close as possible to power pins

- [ ] Crystal/oscillator components close to IC pins
- [ ] Power management ICs near power input
- [ ] Heat-sensitive components away from power ICs

Placement Rules:

- [ ] Components oriented for easy hand assembly
- [ ] Test points accessible for debugging
- [ ] Connectors at board edges
- [ ] LEDs visible when assembled
- [ ] Buttons accessible for user interaction

3. Power and Ground Plane Design

Ground Plane (Layer 2):

- [ ] Solid ground plane with minimal splits
- [ ] Ground plane connected to all ground pins
- [ ] Thermal relief on ground connections
- [ ] Via stitching between ground planes
- [ ] Ground plane extends under all ICs

Power Plane (Layer 3):

- [ ] Separate power islands: +3.3V, +VBAT, +VSENSOR
- [ ] Power planes sized for current requirements
- [ ] Thermal vias under power ICs
- [ ] Power plane clearance from ground plane
- [ ] Power plane connected via multiple vias

4. High-Speed Signal Routing

ESP32-S3 Critical Signals:

- [ ] SPI flash signals kept short (<10mm)
- [ ] USB differential pair routed as 90Ω differential
- [ ] High-speed GPIO signals have controlled impedance
- [ ] Clock signals routed with guard traces
- [ ] Length matching on critical signal pairs

Signal Integrity Rules:

- [ ] Avoid via stubs on high-speed signals

- [ ] Minimize layer changes on critical signals
- [ ] Proper termination on long traces
- [ ] Avoid routing under crystal/oscillator
- [ ] Ground return path provided for all signals

5. Sensor Interface Routing

I2C Bus Routing:

- [ ] SDA and SCL routed parallel with same length
- [ ] Pull-up resistors close to bus master (ESP32-S3)
- [ ] Bus traces away from switching circuits
- [ ] Proper ground return path
- [ ] ESD protection at connector interfaces

SPI Bus Routing:

- [ ] Clock signal routed first with shortest path
- [ ] Data signals length-matched to clock
- [ ] Chip select signals properly routed
- [ ] Ground plane under SPI traces
- [ ] Series termination resistors if needed

ADC Signal Routing:

- [ ] Analog signals away from switching circuits
- [ ] Proper ground plane separation (analog/digital)
- [ ] Filter capacitors close to ADC inputs
- [ ] Shielded or differential routing if needed
- [ ] Reference voltage properly filtered

6. Power Distribution Network

Power Routing:

- [ ] Power traces sized for current requirements
- [ ] Multiple vias for power connections
- [ ] Decoupling capacitors optimally placed
- [ ] Power and ground planes properly connected
- [ ] Thermal management for power ICs

Current Calculations:

- [ ] Trace width calculated for maximum current
- [ ] Via current capacity verified
- [ ] Thermal rise calculated for power dissipation
- [ ] Voltage drop analysis completed
- [ ] Power budget analysis documented

7. EMI/EMC Considerations

EMI Reduction:

- [ ] Proper ground plane coverage (>80%)
- [ ] High-frequency bypass capacitors
- [ ] Ferrite beads on power lines
- [ ] Avoid antenna-like trace structures
- [ ] Proper shielding of high-speed signals

EMC Compliance:

- [ ] All external cables properly filtered
- [ ] ESD protection on all interfaces
- [ ] Proper ground connection strategy
- [ ] Avoid ground loops
- [ ] Clock signals properly contained

8. Manufacturing Considerations

Design for Manufacturing (DFM):

- [ ] Minimum trace width: 0.1mm (4 mil)
- [ ] Minimum via size: 0.2mm (8 mil) drill
- [ ] Minimum spacing: 0.1mm (4 mil)
- [ ] Solder mask sliver: >0.1mm
- [ ] Silkscreen text: >0.15mm height

Assembly Considerations:

- [ ] Components oriented for pick-and-place
- [ ] Fiducial markers for automated assembly
- [ ] Panel design for multiple PCBs
- [ ] Test points for automated testing
- [ ] Proper solder mask openings

9. Testing and Debug Features

Test Points:

- [ ] Power rail test points (VDD, VBAT, etc.)
- [ ] Critical signal test points
- [ ] Ground test points
- [ ] ADC reference test points
- [ ] Communication bus test points

Debug Features:

- [ ] SWD programming header accessible
- [ ] UART debug pins available
- [ ] LED indicators for system status
- [ ] Jumpers for configuration changes
- [ ] Spare GPIO pins brought out for expansion

10. Final Design Verification

Design Rule Check (DRC):

- [ ] All DRC violations resolved
- [ ] Minimum trace width/spacing verified
- [ ] Via size and drill size verified
- [ ] Solder mask clearance verified
- [ ] Component clearance verified

Electrical Verification:

- [ ] Net connectivity verified
- [ ] Power and ground connections verified
- [ ] Signal integrity analysis completed
- [ ] Impedance calculations verified
- [ ] Thermal analysis completed

Manufacturing Files:

- [ ] Gerber files generated and verified
- [ ] Drill files generated and verified
- [ ] Pick-and-place files generated
- [ ] Bill of materials (BOM) finalized
- [ ] Assembly drawings created

Component Selection Database

ESP32-S3 Module Options:

- **ESP32-S3-WROOM-1**: PCB antenna, 16MB Flash, 8MB PSRAM
- **ESP32-S3-WROOM-1U**: U.FL connector, 16MB Flash, 8MB PSRAM
- **ESP32-S3-MINI-1**: Smaller footprint, 8MB Flash, 8MB PSRAM

Power Management ICs:

- **MCP73831T-2ACI/OT**: 500mA Li-Po charger, SOT-23-5
- **AMS1117-3.3**: 1A LDO regulator, SOT-223
- **AP2112K-3.3**: 600mA LDO regulator, SOT-23-5
- **TPS63070**: Buck-boost converter for battery operation

Sensor Components:

- **BME280**: Environmental sensor (temp/humidity/pressure)
- **SHT30**: High-accuracy temperature/humidity sensor
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