

Project SHIELD: Iterative System Design

Stage 1: Basic MCU and Sensor Integration

Objective:

Establish foundational hardware communication and sensor interfacing.

Hardware Components:

- MCU: STM32F411
- Sensors: MPU-6050 (IMU), BMP280 (Pressure)
- Communication: USB-C via CP2102N USB-UART
- Power: USB power (no battery) via 3.3V LDO regulator
- Interfaces: Single I²C bus, SWD header for debugging/programming
- User Interface:
 - Power LED (Green)
 - Reset button
- PCB:
 - 2-layer, 50mm x 70mm, mounting holes, clear labeling

Algorithm Implementation:

- Basic sensor data acquisition
- Data streaming over USB-serial, No predictive capabilities

Detailed Component Specifications

This table specifies the key components for the schematic. Package types are suggested for PCB layout considerations.

Component	Part Number / Example	Package	Function
Microcontroller (MCU)	STM32F411CEU6	UFQFPN-48	ARM Cortex-M4 core for running the SHIELD prognostic algorithm.
IMU Sensor	MPU-6050	QFN-24	6-axis Inertial Measurement Unit (accelerometer +

			gyroscope) for motion data.
Pressure Sensor	BMP280	LGA-8	Barometric pressure and temperature sensor for environmental data.
USB-UART Bridge	CP2102N-A02-GQ FN24	QFN-24	Manages USB communication for programming and data streaming.
3.3V LDO Regulator	AMS1117-3.3	SOT-223	Steps down 5V USB power to a stable 3.3V for all onboard components.
USB Connector	USB Type-C	SMD	Primary port for power and data.

STM32F411CEU6 Pin Assignments

The following table maps the peripherals to the specific pins on the STM32F411 MCU. This is the core guide for the schematic design.

MCU Pin	Function	Peripheral / Net Name	Connected To	Notes
PA0	GPIO_Input	USER_BTN	User Button	Pulled-up to 3.3V; button press pulls to GND. (Stage 2 Feature)
PA9	USART1_TX	UART_TX	CP2102N (RXD)	Serial data output from MCU to PC.
PA10	USART1_RX	UART_RX	CP2102N (TXD)	Serial data input to MCU from PC.
PA13	SWD	SWDIO	SWD Header (Pin 2)	Serial Wire Debug I/O.
PA14	SWD	SWCLK	SWD Header (Pin 4)	Serial Wire Debug Clock.

PB6	I2C1_SCL	I2C_SCL	MPU-6050 (SCL), BMP280 (SCL)	I2C Clock line. Requires 4.7kΩ pull-up resistor to 3.3V.
PB7	I2C1_SDA	I2C_SDA	MPU-6050 (SDA), BMP280 (SDA)	I2C Data line. Requires 4.7kΩ pull-up resistor to 3.3V.
PC13	GPIO_Output	STATUS_LED	Blue LED	For programmable status indication. (Stage 2 Feature)
PC14	GPIO_Output	ALERT_LED	Red LED	For programmable alert indication (Stage 3 Feature).
NRST	Reset	RESET	Reset Button, SWD Header (Pin 5)	System reset pin.
VDD Pins	Power	+3.3V	LDO Output	All VDD pins must be connected to 3.3V with decoupling capacitors.
VSS Pins	Ground	GND	System Ground	All VSS/GND pins must be connected to the ground plane.

Schematic Block Details

Power Block:

- USB-C VBUS (5V) feeds the input of the AMS1117-3.3 LDO.
- The LDO output (3.3V) powers the VDD pins of the STM32F411, the CP2102N, the MPU-6050, and the BMP280.
- A green Power LED should be connected to the 3.3V rail via a current-limiting resistor to provide a constant power-on indication.

- Place 0.1 μ F ceramic decoupling capacitors close to the power pins of every integrated circuit.

Sensor Block (I²C Bus):

- The MPU-6050 and BMP280 will share the I²C1 bus.
- Connect the SCL and SDA lines from both sensors to the MCU pins PB6 and PB7, respectively.
- Ensure both SCL and SDA lines have their own 4.7k Ω pull-up resistor connected to the 3.3V rail.

USB-to-Serial Block:

- Connect the D+ and D- pins of the USB-C connector to the corresponding D+ and D- pins on the CP2102N.
- Cross-connect the UART lines: CP2102N TXD connects to MCU RX (PA10), and CP2102N RXD connects to MCU TX (PA9).

Debug Block (SWD):

- Create a standard 4 or 5-pin 0.1" header for the ST-Link programmer.
- The header should provide connections for SWDIO, SWCLK, GND, 3.3V, and RESET.

Stage 2: Expanded Sensor Suite and Battery Management

Objective:

Integrate enhanced sensors, accurate timestamps, and portable battery power.

Hardware Upgrades (Additions to Stage 1):

- Sensors:
 - Replace MPU-6050 with ICM-20948 IMU (advanced accuracy)
 - Replace BMP280 with BME280 (Temperature, Humidity, Pressure)
- Real-Time Clock (RTC): DS3231 (timestamping)
- Power Management: MCP73831 LiPo battery charger with battery indicators.
Battery Connector: JST-PH for single-cell LiPo battery
- Expansion Header: 8-pin basic (GPIO, I²C expansion)
- User Interface (enhanced):
 - Programmable status LED (Blue)

Algorithm Implementation:

- Basic sensor fusion to get timestamped data\
- No predictive capabilities

Stage 3: Electrical Diagnostics & Enhanced Safety Monitoring

Objective:

Implement electrical health monitoring to detect voltage/current anomalies.

Hardware Upgrades (Additions to Stage 2):

- Electrical Diagnostics:
 - ADC monitoring for sensor power lines
 - Current-sense resistor footprints (optional)
 - Overvoltage/undervoltage detection circuitry
- Expansion Header: Upgrade to 10-pin with additional ADC-capable GPIO pins
- Thermal Management: Thermal pads for MCU and regulator
- User Interface: Alert LED (Red) for electrical anomalies

Algorithm/Software Implementation:

- Threshold-based electrical diagnostics
- Real-time streaming of diagnostic data