

# CubeSat ML Fault Detection System Hardware Design Specification

Hardware Team

Updated for STM32H735GT

## Document Overview

This document provides complete hardware specifications for the CubeSat ML Fault Detection System PCB, including all components, interfaces, and LED indicator systems. Updated for STM32H735GT microcontroller.

## 1 PCB Architecture

### 1.1 Core Components List

Table 1: Complete BOM - Main Components

Component	Part Number	Qty	Purpose
MCU	STM32H735GT	1	ML inference and control
External Watchdog	TPL5010	1	Monitor the monitor
Power Supervisor	MAX809L	1	Brown-out reset
RS-422 Transceiver	ADM3491	1	Robust OBC comms
HSE Crystal	25 MHz	1	Main clock source
LSE Crystal	32.768 kHz	1	RTC clock
I <sup>2</sup> C Multiplexer	TCA9548A	1	Sensor management
Current Sensor	INA260AIDR	2	3.3V/5V rail monitoring
Temp Sensor	TMP117	1	Board temperature
Buck Converter	TPS62321	1	3.3V generation
MOSFET	IRLR8743	4	Load switching
TVS Diode	SMAJ15A	4	Input protection
PTC Fuse	1812L010	2	Overcurrent protection
OR Gate	SN7432N	2	Reset logic and signal conditioning
RGB LED	WS2812B	1	Multi-status display
Green LED	160-114-1-ND	3	Power/Status
Red LED	160-116-1-ND	2	Fault indicators
Blue LED	160-118-1-ND	2	ML/Comm activity
Yellow LED	160-117-1-ND	1	Warning indicator
220 Resistor	RC1206FR-07220RL	12	LED current limiting
Level Shifter	TXS0108	1	UART interface
Connector	Hirose DF13	2	OBC interface
SWD Header	10-pin	1	Programming

### 1.2 SN7432N OR Gate Application

The SN7432N quad 2-input OR gates are used for:

- **U1:** Combines watchdog reset and manual reset signals

- **U2:** Combines power supervisor reset and software reset signals
- Provides glitch-free reset signal conditioning
- Ensures reliable system initialization under all fault conditions

## 2 LED Indicator System

### 2.1 LED Layout and Purpose

Table 2: LED Indicator Configuration

LED	Color	GPIO Pin	Pattern	Logic and Purpose
PWR	Green	3V3 Rail	Steady	Direct power rail indication. Always on when 3.3V rail present.
SYS_OK	Green	PC9	Steady	System operational. Lit after successful MCU initialization.
ML_ACTIVE	Blue	PC0	Blink 1Hz	ML inference running. Toggles during each inference cycle.
FAULT_OBC	Red	PC1	Solid	OBC fault detected. Lit solid when OBC heartbeat loss.
FAULT_TTC	Red	PC2	Solid	TTC fault detected. Lit solid when UART timeout or CRC errors.
WARNING	Yellow	PC3	Blink 2Hz	Predictive warning. Fast blink when ML detects anomalies.
HEARTBEAT	Green	PC4	Blink 1Hz	OBC heartbeat mirror. Synchronized with actual OBC heartbeat.
COMM_ACTIVE	Blue	PC5	Blink 5Hz	UART activity. Fast blink on RS-422 data transmission.
RGB_STATUS	RGB	PC6,7,8	Multi-pattern	Comprehensive status display. Color codes system status.

### 2.2 RGB LED Status Coding Logic

Table 3: RGB LED Color Coding System

Color	Pattern	System Logic and Meaning
Green	Solid	Normal Operation: All systems nominal, ML confidence >90%, no warnings
Blue	Slow blink (1Hz)	ML Active: Model running normally, processing sensor data
Cyan	Breathe	Data Collection: Gathering training data or calibration in progress
Yellow	Fast blink (4Hz)	Predictive Warning: ML detected anomaly but confidence <70%, monitor closely
Orange	Double blink	OBC Degradation: Heartbeat becoming irregular or power consumption trending high
Red	Solid	OBC Fault: No heartbeat detected or overcurrent condition confirmed
Purple	Solid	TTC Fault: UART timeout or excessive CRC errors detected
Red	Fast blink	CRITICAL: Multiple simultaneous faults or system integrity compromised
White	Chase pattern	System Boot: Initialization sequence in progress
Rainbow	Cycle	Demo Mode: System in demonstration/showcase mode

### 2.3 LED Circuit Design

#### 2.3.1 Single Color LED Circuits

- **Current Limiting:** 220 resistors provide 5.5mA at 3.3V:  $(3.3V - 2.1V \text{ forward voltage})/220\Omega$
- **GPIO Drive:** STM32H735GT GPIO pins configured as push-pull output
- **Visibility:** 5mA provides excellent visibility for lab environments

#### 2.3.2 WS2812B RGB LED Circuit

- **Single Wire Control:** Uses SPI or bit-banged protocol, only one GPIO needed
- **Addressable:** Can chain multiple LEDs if needed for expansion
- **Integrated Driver:** No external current limiting resistors required
- **High Visibility:** Very bright, suitable for well-lit environments

## 3 PCB Layout and Mechanical

### 3.1 3U CubeSat Compliance

- **Board Size:** 100mm × 100mm × 1.6mm
- **Mounting:** 4× M3 holes at corners, 3.2mm diameter
- **Keep-out:** 5mm border on all edges for CubeSat rails
- **Connector Edge:** All external interfaces on one side
- **LED Placement:** All status LEDs on opposite edge for visibility

### 3.2 LED Placement Strategy

- **Status LEDs:** Along top edge for easy viewing during bench testing
- **RGB LED:** Centered for maximum visibility
- **Power LED:** Near power input connector
- **Test Points:** Adjacent to LEDs for oscilloscope probing
- **SN7432N Placement:** Near reset circuitry and power management section

## 4 Power Distribution

### 4.1 Power Rails and Budget

#### LED Power Calculation:

- **Single LEDs:**  $8 \times 5.5\text{mA} = 44\text{mA}$
- **RGB LED:**  $3 \times 8\text{mA} = 24\text{mA}$  (per color, typical)
- **SN7432N:**  $2 \times 20\text{mA} = 40\text{mA}$  (typical per IC)
- **Total:** 108mA worst case (all LEDs on maximum brightness + logic ICs)
- **Budget:** Well within 3.3V rail capacity (300mA max)

Table 4: Power Distribution Analysis

Rail	Voltage	Max Current	Components	Load
Primary Input	7-18V	500mA	Buck converter	-
3.3V Digital	3.3V ±5%	300mA	STM32H735GT, Logic	66mA (12 LEDs)
3.3V Analog	3.3V ±1%	50mA	Sensors	-
Logic Power	3.3V	40mA	SN7432N (x2)	40mA total
LED Power	3.3V	70mA	All indicators	70mA total

## 5 Interface Connections

### 5.1 OBC Interface Connector (J1 - Hirose DF13-20P)

### 5.2 Internal Signal Routing

## 6 Design for Testability

### 6.1 Test Points and Debug Features

- Test points on all LED drive signals for oscilloscope monitoring

Table 5: OBC Interface Pinout

Pin	Signal	Type	STM32H735GT Pin	Remarks
1	VCC_INPUT	PWR	-	7-18V from CubeSat
2	GND	PWR	-	Power return
3	3V3_BACKUP	PWR	-	To OBC (optional)
4	RS422_A	Diff	-	RS-422 differential A
5	RS422_B	Diff	-	RS-422 differential B
6	RS422_Y	Diff	-	RS-422 differential Y
7	RS422_Z	Diff	-	RS-422 differential Z
8	HEARTBEAT_IN	GPIO	PC13	OBC heartbeat monitor
9	ML_FAULT	GPIO	PA5	Fault indication to OBC
10	RESET_OUT	GPIO	PA8	Preventive reset control
11	SWDIO	Debug	PA13	Programming interface
12	SWDCLK	Debug	PA14	Programming interface
13	WDOG_WAKE	GPIO	PA6	Watchdog keep-alive
14	WDOG_DONE	GPIO	PA7	Watchdog interrupt
15-16	SPARE	GPIO	-	Future expansion
17-18	NC	-	-	No connect
19	ADC_TEMP	Analog	PA0	External temp sense
20	GND	PWR	-	Signal ground

Table 6: Internal Component Connections

Component	Interface	STM32H735GT Pins	Remarks
INA260 #1	I <sup>2</sup> C1 + Mux Ch0	PB8(SCL), PB9(SDA)	3.3V rail monitor
INA260 #2	I <sup>2</sup> C1 + Mux Ch1	PB8(SCL), PB9(SDA)	5V rail monitor
TMP117	I <sup>2</sup> C1 + Mux Ch2	PB8(SCL), PB9(SDA)	Temp sensor
I <sup>2</sup> C Mux	I <sup>2</sup> C1	PB8(SCL), PB9(SDA)	TCA9548A control
RS-422 Transceiver	UART1	PA9(TX), PA10(RX)	Differential comms
External Watchdog	GPIO	PA6, PA7, NRST	TPL5010 interface
Power Supervisor	Reset	NRST	MAX809L reset control
SN7432N #1	GPIO	Multiple	Reset logic combination
SN7432N #2	GPIO	Multiple	Signal conditioning
MOSFET 1-4	GPIO	PA1-PA4	High-side switches
Status LEDs	GPIO	PC0-PC5, PC9	Individual indicators
RGB LED	GPIO	PC6	WS2812B data line

- Current sense resistors (20m) on power rails for validation
- SWD header for programming and real-time debugging
- UART console output for development messages
- LED disable jumpers for power consumption testing
- Reset test points for SN7432N signal monitoring
- Logic analyzer headers for SN7432N input/output verification

## 6.2 Prototyping Considerations

- All LEDs can be populated selectively to save space/power
- RGB LED can replace multiple single-color LEDs if space constrained
- Brightness can be reduced via PWM to save power
- Test points allow LED signals to be monitored during operation

- SN7432N sockets for easy replacement during development
- Reset circuit can be bypassed for debugging purposes

## 7 STM32H735GT Specific Configuration

### 7.1 Key Differences from STM32H743

- **Enhanced Security:** H735 includes additional security features
- **Power Efficiency:** Improved power management unit
- **Pin Compatibility:** Similar pinout with minor differences in alternate functions
- **Memory:** Adjusted memory configuration (check specific variant)

### 7.2 Reset Circuit with SN7432N

The SN7432N OR gates implement the following reset logic:

- **Global Reset** = (Power Supervisor Reset) OR (Watchdog Reset) OR (Manual Reset)
- **Controlled Reset** = (Software Reset) OR (External Command)
- Provides redundant reset paths for enhanced reliability
- Ensures clean reset signals under noisy conditions