

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

### 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:  $(3.3V - 2.1V \text{ forward voltage})/220$
- **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 $\pm 5\%$	300mA	STM32H735GT, Logic	66mA (12 LEDs)
3.3V Analog	3.3V $\pm 1\%$	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