BTTM

Codename: Flavona

Brake & Tire Temperature Monitor

Product Manual

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1. Introduction

The BTTM (Brake & Tire Temperature Monitor) is a comprehensive motorsport telemetry system designed to provide real-time temperature monitoring of brake rotors and tires during track sessions. The system enables drivers and engineers to optimize brake bias, tire pressures, and driving technique based on actual thermal data.

This system combines infrared temperature sensing, CAN bus networking, GNSS positioning, and wireless connectivity to deliver actionable data both during and after each session.

1.1 Key Features

- 8-node CAN bus network for temperature sensing (4 tires + 4 brakes)
- 50 Hz sampling rate per sensor (400 messages/second total)
- Real-time display with color-coded temperature visualization for driver
- WiFi web interface with live charts and statistics for pit crew
- 5 Hz GNSS positioning with speed tracking
- SD card data logging in CSV format
- Wide input voltage range (3-36V DC)

1.2 System Components

The BTTM system consists of two primary hardware components:

- **BTTM Central Unit: The main controller with display, storage, and connectivity**
- **IR CAN Node Sensors: Eight distributed temperature sensors mounted at each wheel**

2. System Architecture

The BTTM system uses a distributed architecture where eight IR CAN Node sensors communicate with a central controller over a CAN bus network. This design provides several advantages including reduced wiring complexity, noise immunity, and nearly endless expansion.

2.1 Network Topology

All eight IR CAN Node sensors connect to a shared CAN bus operating at 500 kbps. The central BTTM unit receives temperature data from each node and correlates it with GNSS position data for logging and display.

Component	Role	Communication
BTTM Central Unit	Data aggregation, display, logging	CAN RX, WiFi AP, UART (GNSS)
IR CAN Node (x8)	Temperature measurement	CAN TX @ 50Hz
MLX90614 Sensor	IR temperature sensing	I2C @ 100kHz

2.2 Data Flow

Temperature data flows through the system as follows:

1. MLX90614 IR sensor measures object temperature via I2C
2. ESP32-C3 node encodes data as 16-bit signed integer (temp × 100)
3. CAN frame transmitted with unique message ID per sensor
4. BTTM central unit receives and decodes all 8 sensor streams
5. Data correlated with GNSS timestamp and logged to SD card
6. TFT display and web interface updated in real-time

3. Hardware Specifications

3.1 BTTM Central Unit

The BTTM central unit is based on the ESP32-S3 microcontroller with the following specifications:

Parameter	Specification
MCU	ESP32-S3-WROOM-2-N16R8 (16MB Flash, 8MB PSRAM)
Display	320×240 ILI9341 TFT (SPI @ 32MHz)
GNSS Module	u-blox NEO-M8M (5Hz update rate)
CAN Transceiver	TCAN3413DR (500 kbps)
Power Regulator	MAX25223ATPB/VY+ (3.3V @ 3.5A)
Input Voltage	3-36V DC (automotive compatible)
Storage	MicroSD card (SPI @ 25MHz)
WiFi	2.4GHz 802.11 b/g/n (Access Point mode)
Protection	SMBJ18A TVS, MF-SMDF050-2 PTC fuse

3.1.1 BTTM Pin Assignments

GPIO	Function	Notes
GPIO4	CAN TX	To TCAN3413 TXD
GPIO15	CAN RX	From TCAN3413 RXD
GPIO17	GNSS TX	ESP32 → NEO-M8 RX (Pin 21)
GPIO18	GNSS RX	NEO-M8 TX (Pin 20) → ESP32
GPIO40	TFT SCLK	SPI Clock
GPIO41	TFT MISO	SPI Data In
GPIO42	TFT MOSI	SPI Data Out
GPIO14	TFT CS	TFT Chip Select
GPIO47	TFT DC	Data/Command
GPIO21	TFT RST	Display Reset
GPIO10	SD CS	SD Card Chip Select
GPIO48	Heartbeat LED	Status indicator

3.2 IR CAN Node Sensors

Each IR CAN Node sensor is based on the ESP32-C3 microcontroller with an MLX90614 infrared thermometer:

Parameter	Specification
MCU	ESP32-C3FH4 (RISC-V, 4MB Flash)
IR Sensor	MLX90614 (I2C @ 100kHz)
Temperature Range	-50°C to +400°C (object)
Accuracy	±0.5°C (typical)
CAN Transceiver	TCAN3413DR (500 kbps)
Update Rate	50 Hz (20ms interval)
Operating Voltage	3.3V (from CAN bus power)
ESD Protection	ESD2CAN24DCKRQ1 (24V TVS)

3.2.1 IR CAN Node Pin Assignments

GPIO	Function	Notes
GPIO8	I2C SDA	MLX90614 Data
GPIO9	I2C SCL	MLX90614 Clock
GPIO3	CAN TX	To TCAN3413 TXD
GPIO2	CAN RX	From TCAN3413 RXD
GPIO10	Status LED	Health indicator

4. CAN Bus Protocol

4.1 Message IDs

Each sensor node transmits on a unique CAN message ID. The BTTM central unit filters and processes all messages in the defined ID range.

CAN ID	Sensor Type	Position	Description
0x451	Tire	Front Left	TIRE_FL
0x452	Tire	Front Right	TIRE_FR
0x453	Tire	Rear Left	TIRE_RL
0x454	Tire	Rear Right	TIRE_RR
0x455	Brake	Front Left	BRAKE_FL
0x456	Brake	Front Right	BRAKE_FR
0x457	Brake	Rear Left	BRAKE_RL
0x458	Brake	Rear Right	BRAKE_RR

4.2 Message Format

Temperature data is transmitted as a 2-byte CAN frame:

Byte	Content	Description
0	High byte	Temperature × 100 (MSB)
1	Low byte	Temperature × 100 (LSB)

Example: A temperature of 125.5°C is encoded as:

- 125.5 × 100 = 12550 decimal = 0x3106
- Byte 0 (MSB) = 0x31
- Byte 1 (LSB) = 0x06

5. Software Features

5.1 TFT Display

The 320×240 TFT display provides a 4×4 grid layout showing all eight temperature readings with color-coded backgrounds:

Temperature	Color	Indication
≤50°C	Blue	Cold / underutilized
51-100°C	Green	Optimal operating range
101-200°C	Yellow/Orange	Elevated - monitor closely
201-300°C	Red	High temperature warning
>300°C	Flashing Red/Black	Critical - reduce load immediately

The display layout shows front sensors at the top and rear sensors at the bottom, with tire temperatures on the outside columns and brake temperatures on the inside columns.

5.2 Web Interface

The WiFi web interface provides comprehensive monitoring and analysis capabilities:

- **Real-time temperature cards for all 8 sensors**
- **Live scrolling graphs with selectable time ranges (10s/20s/60s/120s)**
- **Individual sensor line visibility toggles**
- **Statistics tables (average, min, max, standard deviation)**
- **GNSS data display (satellites, speed, position, PDOP)**
- **SD card log file browser with download capability**
- **System reboot control**

5.3 SD Card Logging

Data is logged to CSV files on the SD card at 5 Hz (synchronized with GNSS updates). Each log file contains:

Column	Description
Date	YYYY-MM-DD format from GNSS
Timestamp	HH:MM:SS.mmm from GNSS
BrakeFR/FL/RR/RL	Brake temperatures (°C)
TireFR/FL/RR/RL	Tire temperatures (°C)
Latitude/Longitude	GNSS position (decimal degrees)
SpeedKPH	Ground speed (km/h)
Satellites	Number of GNSS satellites in view
PDOP	Position Dilution of Precision

6. Installation Guide

6.1 Wiring Connections

The CAN bus uses a 4-wire connection to each sensor node:

Wire	Color (Suggested)	Function
+	Red	3.3V Power (from BTTM unit)
-	Black	Ground
H	Yellow	CAN High (CANH)
L	Green	CAN Low (CANL)

6.2 Sensor Mounting

1. Mount tire sensors to aim at the tire sidewall or tread surface, approximately 50-100mm from the tire
2. Mount brake sensors to aim at the brake rotor through the wheel spokes, if possible
3. Ensure sensors have clear line-of-sight to the measurement surface
4. Protect sensor wiring from wheel rotation and suspension movement
5. Use heat-resistant sleeving near brake components

6.3 CAN Bus Termination

The CAN bus requires 120Ω termination resistors at each end of the bus. The BTTM central unit includes a switchable termination resistor. If using a daisy-chain topology, enable termination at both ends of the chain.

7. Configuration

7.1 IR CAN Node Configuration

Each IR CAN Node must be programmed with its unique channel assignment. Edit the following line in the firmware before flashing:

```
static const Channel THIS_NODE_CHANNEL = TIRE_FL;
```

Valid channel values:

- TIRE_FL, TIRE_FR, TIRE_RL, TIRE_RR (for tire sensors)
- BRAKE_FL, BRAKE_FR, BRAKE_RL, BRAKE_RR (for brake sensors)

7.2 WiFi Configuration

The BTTM WiFi credentials are configured in the firmware:

```
const char* ssid = "YourNetworkName";

const char* password = "YourPassword";
```

After connecting to the WiFi network, access the web interface at the IP address displayed on the TFT screen.

8. Troubleshooting

8.1 IR CAN Node LED Indicators

The status LED on each IR CAN Node indicates the current health state:

Pattern	State	Meaning
Brief pulse (3ms/497ms)	**HEALTHY**	Normal operation
Slow blink (50ms/150ms)	**DEGRADED**	Some failures detected
Fast blink (100ms/100ms)	**CRITICAL**	Multiple failures or bus errors
Very fast blink (200ms/200ms)	**HALTED**	CAN bus initialization failed

8.2 Common Issues

No temperature readings displayed:

- Check CAN bus wiring (CANH to CANH, CANL to CANL)
- Verify 120Ω termination at bus ends
- Confirm sensor nodes are powered (3.3V present)

Erratic or noisy readings:

- Check for damaged lenses on IR sensors
- Verify sensor is aimed correctly at target surface
- Shield wiring from electromagnetic interference sources

GNSS not acquiring fix:

- Ensure clear sky view for the antenna (or BTTM enclosure)
- Wait up to 60 seconds for cold start acquisition
- Check UART connections (GPIO17 TX, GPIO18 RX)

9. Technical Specifications Summary

Parameter	Value
Number of Sensors	8 (4 tire + 4 brake)
Temperature Range	-50°C to +400°C
Temperature Resolution	0.01°C
Sensor Update Rate	50 Hz per sensor
Total CAN Bandwidth	400 messages/second
CAN Bus Speed	500 kbps
GNSS Update Rate	5 Hz
SD Logging Rate	5 Hz
Display Refresh Rate	4 Hz
Web Interface Update	2 Hz
Input Voltage Range	3-36V DC
BTTM Operating Temperature	-20°C to +85°C

10. Revision History

Version	Date	Changes
v1.9.1	Dec 2025	Second field test release – Corrected Brakes IDs from 0x461–0x464 to 0x455-0x458
v1.9.0	Nov 2025	First field test release - GNSS pin fix, optimized task stacks, cleaned code
v1.8.1	Oct 2025	New TFT layout with inverted rear row, WiFi status display
v1.7.12	Sept 2025	Time range selection, individual sensor line toggles, web UI improvements

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