FLORIPASAT - TTC-DOC - REV1

Telemetry, Tracking and Command Module of the FloripaSat Project

Module Documentation
GSE, Federal University of Santa Catarina, Florianópolis - Brazil

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Abstract

This document...

Keywords: Cubesats. Embedded systems. Telecomunications.

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Nomenclature

ADC	Analog-To-Digital Converter.
BSL	Bootstrap Loader.
CDS	CubeSat Design Specification.
CPU	Central Processing Unit.
DMA	Direct Memory Access.
GFSK	Gaussian Frequency-Shift Keyring.
GPIO	General Purpose Input/Output.
HAL	Hardware Abstraction Layer.
I^{2}C	Inter-Integrated Circuit.
ISR	Interruption Service Routine.
P-POD	Poly-Picosatellite Orbital Deployer.
PCB	Printed Circuit Board.
RAM	Random Access Memory.
RF	Radio Frequency.
SPI	Serial Peripheral Interface.
TMR	Telemetry, Tracking and Command Module Requirements.
TTC	Telemetry, Tracking and Command.
UART	Universal Asynchronous Receiver/Transmitter.
USB	Universal Serial Bus.

CHAPTER 1

Introduction

INTRODUCTION...
[1].

1.1 Module Requirements

In the list below, the TTC module requirements for the mission are described. These requirements are nominated as TMR, or Telemetry, Tracking and Command Module Requirements.

TMR 1 The FloripaSat shall have a physical device to inhibit radio frequency (RF) transmission.

Compliance with CDS 3.3.9: The use of three independent inhibits is highly recommended and can reduce required documentation and analysis.

TMR 2 The CubeSat will have the RF power output to the transmitting antenna input no greater than 1,5 W.

Compliance with CDS 3.3.9.1.

TMR 3 The CubeSat will have the RF power output to the transmitting antenna input no less than 1,0 W (or 30 dBm).

Defined by team analysis.

TMR 4 No CubeSats shall generate or transmit any RF signal from the time of integration into the P-POD through 45 minutes after on-orbit deployment from the P-POD.

Compliance with CDS.

TMR 5 TTC transceiver shall transmit and receive on the frequency of 437,9 Mhz.

Defined by the team, based on available spectrum allocation to Amateur communication.

TMR 6 TTC beacon shall transmit on the frequency of 145,9 Mhz.

Defined by the team, based on available spectrum allocation to Amateur communication.

TMR 7 TTC shall modulate and demodulate information using GFSK.

Defined by the team.

TMR 8 TTC Beacon must transmit periodic beacon messages at an interval of 10 seconds, except when in hibernation or shutdown mode. Allows ground stations to track and receive satellite data even if telecommand was not sent to the satellite.

TMR 9 TTC transceiver must receive signals from ground stations and demodulate them.

TMR 10 TTC must interface with OBDH, exchanging encoded raw data received or to be transmitted.

TMR 11 TTC must interface with OBDH using the SPI protocol (@2 KHz).

Defined by the team.

TMR 12 TTC radio must modulate raw data received from OBDH using GFSK, prior to transmission, and demodulate received data and forward raw data to OBDH.

TMR 13 TTC transceiver shall transmit and receive data at a baud rate of 2400 bps. Defined by the team, based on link budget analysis.

TMR 14 TTC beacon shall transmit data at a baud rate of 1200 bps.

Defined by the team, based on link budget analysis.

TMR 15 TTC beacon shall transmit packets using the NGHam and AX.25 protocols.

Defined by the team.

TMR 16 A same beacon packet must be transmitted in both NGHam and AX.25 protocols.

Defined by the team.

TMR 17 TTC must receive the batteries voltages from the EPS module at every 10 seconds.

Defined by the team.

TMR 18 The payload from the packets transmitted by the beacon must contain at least the satellite ID (”FLORIPASAT”) and batteries voltages (received from the EPS module at every 10 seconds).

TMR 19 TTC uC must perform the antenna deployment of the VHF band antenna.

Defined by the team.

TMR 20 Between the beacon packets transmissions, the beacon MCU and radio must operate in low power mode, to save energy.

Defined by the team.

TMR 21 TTC PAs (Power amplifiers) must just only be activated during transmissions. When they are not in operation, they must be turned off.

Defined by the team.

TMR 22 All the beacon critical data, like time control and antenna deployment status, must be stored in a non-volatile memory.

Defined by the team.

TMR 23 TTC beacon must be able to receive a 24 hour shutdown command from the OBDH module.

Compliance with AMSAT/IARU regulations.

CHAPTER 2

Hardware

THE TTC board is composed by the following main components:

- MSP430F6659, as the beacon microcontroller.
- RF4463F30, as the radio module for the beacon and the telemetry link.

In the figure 2.1, ...

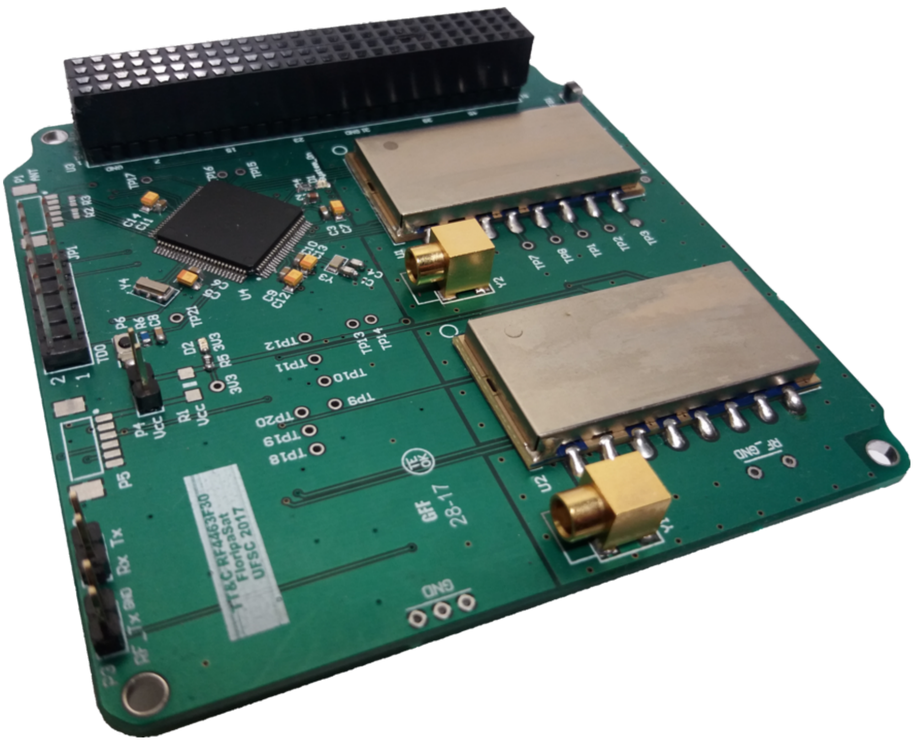

Figure 2.1: TTC PCB.

2.1 General Diagram

In the figure 2.2, a general hardware diagram can be seen.

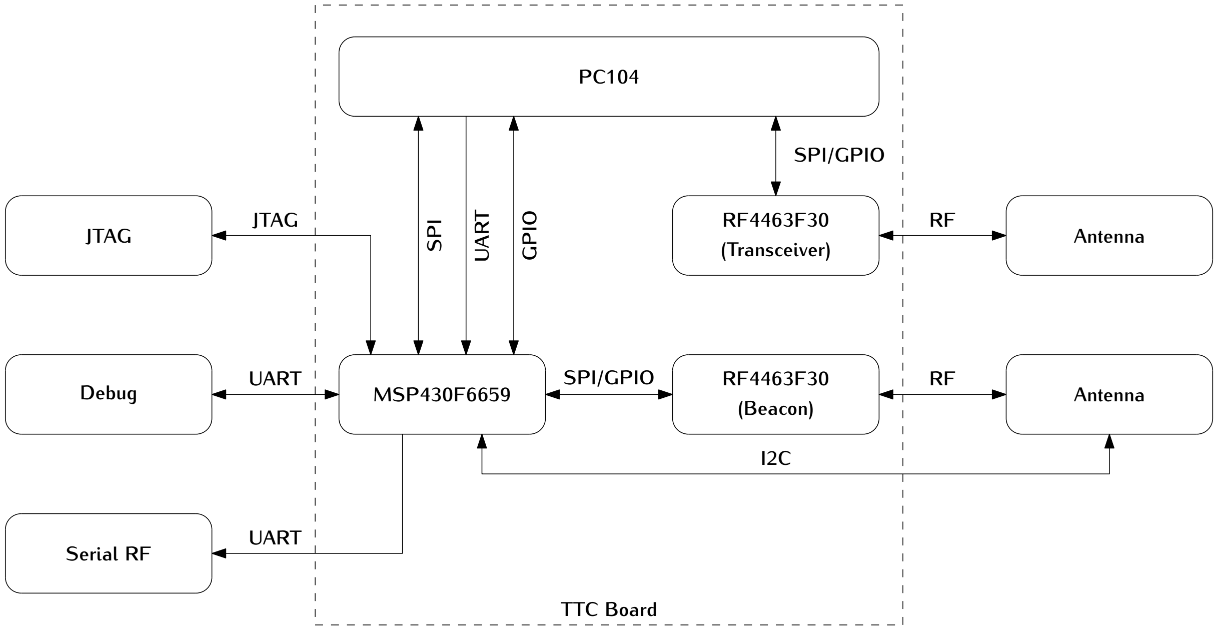

Figure 2.2: Hardware diagram of the TTC module.

2.2 Main Components

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2.2.1 Microcontroller

The beacon microcontroller is the MSP430F6659IPZR [?]. Its main characteristics can be found in the table 2.1.

2.2.2 Radio Modules

The NiceRF RF4463F30 [?] is a transceiver module based on the Silicon Labs Si4463 [?] radio. This module also contains a PA module to increase the output power up to 31 dBm.

Si4463

2.3 External Connections

This section describes the external available connections of the TTC module.

In the figure 2.3, all the external connections are enumerated.

A brief description of each connection is presented in the table 2.3.

The connections 1, 2, 4 and 6 were designed to be used during the software development stage, and not during the satellite operation.

Characteristic	*Value*
CPU	MSP430
Frequency	Up to 20 MHz
Non-volatile memory	512 kB
RAM	66 kB
GPIO pins	74
I^2C	3
SPI	6
UART	3
DMA	6
ADC	ADC12-12ch
Comparators	12 inputs
Timers - 16-bit	4
Multiplier	32 × 32
BSL	USB
Min V_{cc}	1,8 V
Max V_{cc}	3,6 V
Active Power	360 $\mu A/MHz$
Standby Power (LMP3)	$2,6\ \mu A$
Wakeup Time	3 μs
Operating Temperature Range	-40 to 80 $°C$

Table 2.1: MSP430F6659 features.

Characteristic	*Value*	*Unit*
Frequency range	119-1050	MHz
Receiver sensitivity	-126	dBm
Modulation	(G)FSK, 4(G)FSK, (G)MSK and OOK	-
Max. output power	+20	dBm
PA support	+27 to 30	dBm
Ultra low current powerdown modes	30 (shutdown), 50 (standby)	nA
Data rate	100 bps to 1 Mbps	-
Power supply	1,8 to 3,6	V
TX and RX FIFOs	64 bytes for each or 129 bytes shared	-

Table 2.2: Si4463 features.

2.3.1 PCI-104 Pins

The table 2.4 describes the PCI-104 connector used pins. The first column is the row number of the connector, and the remaining columns are the respective columns (Named as H1A, H1B, H2A and H2B respectively). If the pin has no description, it is not connected to the TTC board.

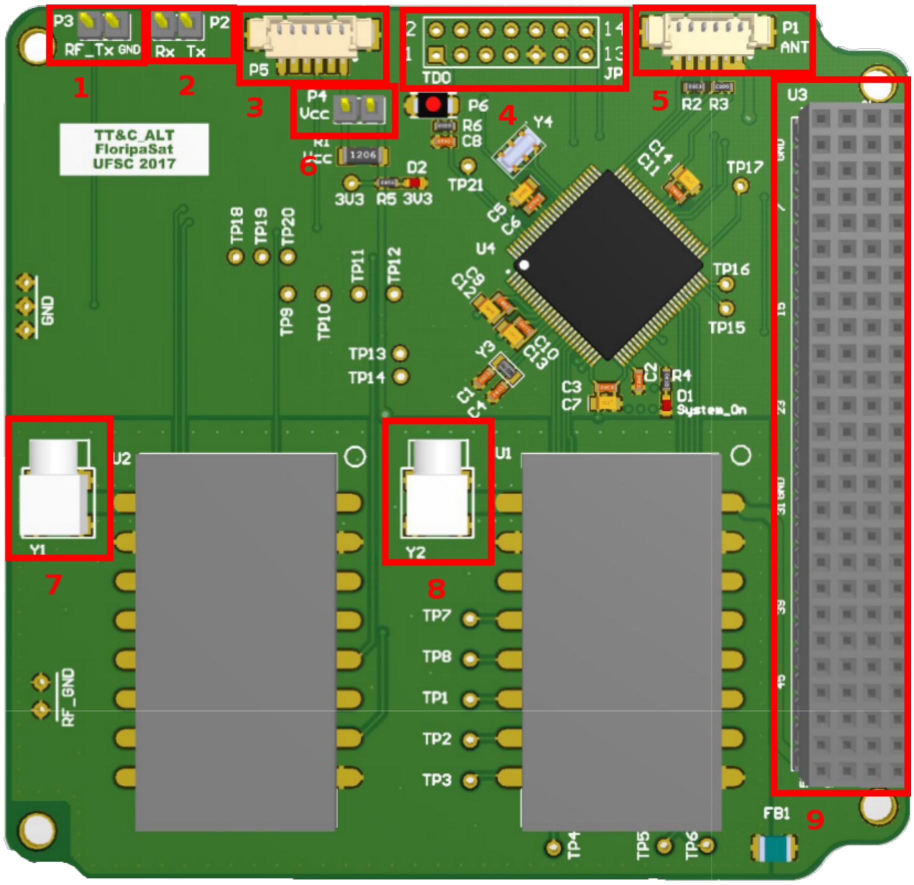


Figure 2.3: External connections on the board.

Number	*Connector*	*Description*
1	Male pin header (1 × 2)	UART TX @4800 bps. These pins transmit the beacon packets over a serial connection (It is enable in the configuration file, setting the BEACON_RADIO variable as UART_SIM).
2	Male pin header (1 × 2)	Debug UART TX/RX @115200 bps. These pins transmit a description of the main events of the beacon software during it's execution. This feature is only available in DEBUG_MODE.
3	Male PicoBlade^{TM} (×6)	JTAG and Debug. This connection contains the relevant pins of the connectors 2 and 4.
4	Male pin header (2 × 2)	MSP430 JTAG. This connection is for programming the uC code, using a MSP-FET debugger.
5	Male PicoBlade^{TM} (×6)	Antenna I2C. I2C bus for a communication channel with the antenna module.
6	Male pin header (1 × 2)	Power supply jumper. With a jumper, the beacon microcontroller power source comes from the JTAG connector. Without a jumper, the uC power supply comes from a pin of the PC104 connector.
7	Female Angled MCX	437 MHz band RF signal (Goes to the antenna module).
8	Female Angled MCX	145 MHz band RF signal (Goes to the antenna module).
9	Male/Female PCI-104	PCI-104. Power supply and communication buses with others stacked up modules.

Table 2.3: External connections description.

Row	*H1A*	*H1B*	*H2A*	*H2B*
1	GND	GND	GND	GND
2	GND	GND	GND	GND
3	-	-	UART RX @4800 bps from the EPS module.	-
4	Telemetry radio GPIO0	Telemetry radio GPIO1	-	-
5	Telemetry radio GPIO2	Enable beacon radio power supply	-	-
6	Telemetry radio SDN	-	OBDH communication (SPI MOSI)	OBDH communication (SPI clock)
7	-	-	OBDH communication (SPI chip select)	OBDH communication (SPI MISO)
8	-	-	-	-
9	-	-	-	-
10	-	-	-	-
11	-	-	-	-
12	-	-	-	-
13	-	-	-	-
14	-	-	Beacon uC power supply (3,3 V/50 mA)	3,3 V beacon uC power supply (3,3 V/50 mA)
15	GND	GND	GND	GND
16	GND	GND	GND	GND
17	-	-	-	-
18	Telemetry radio SPI clock	-	-	-
19	Telemetry radio SPI MISO	-	-	-
20	Telemetry radio SPI MOSI	Telemetry radio SPI chip select	-	-
21	-	-	-	-
22	-	-	-	-
23	-	-	-	-
24	-	-	-	-
25	Telemetry radio power supply (5 V/500 mA)	-	-	-
26	Beacon radio power supply (5 V/500 mA)	-	-	-

Table 2.4: PCI-104 connector reference.

CHAPTER 3

Software

SOFTWARE...

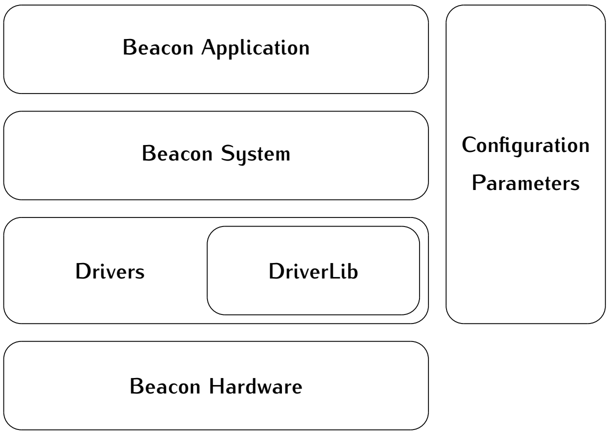


Figure 3.1: Beacon software stack-up.

3.1 Flowcharts

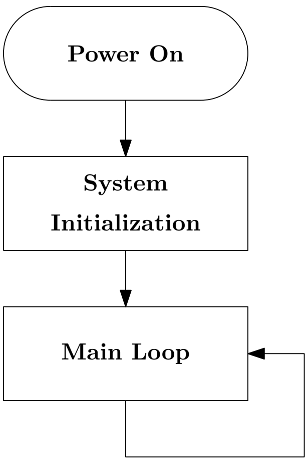
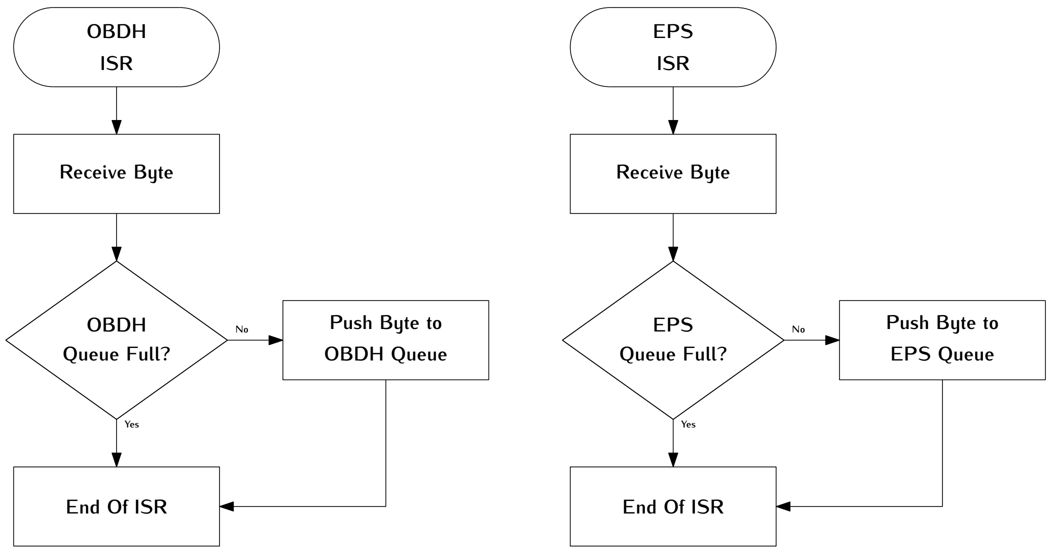


Figure 3.2: Main flowchart of the beacon software.



(a) OBDH communication ISR flowchart. (b) EPS communication ISR flowchart.

Figure 3.3: OBDH and EPS modules comunication ISRs routines.

CHAPTER 4

Tests

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4.1 RF Signal Power

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CHAPTER 5

Conclusion

CONCLUSION...

Bibliography

[1] Rafael P. Alevato. Floripasat project, 2017.