TSL Primary and Expansion Boards (TSLPB & TSLXB)

Interface Control Document (ICD)

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This document describes the functional, physical, and electrical characteristics of the TSL Primary Board ("TSLPB") and TSL Expansion Board ("TSLXB"). This interface control document is intended to provide the payload developer with the necessary technical information to design, test and integrate these Payload Boards into the Student Payload area of the ThinSat spacecraft. Please refer to the ThinSat ICD for more information about the ThinSat Bus.

1 ThinSat Program

Virginia Commercial Space Flight Authority ("VCSFA"), Twiggs Space Lab, LLC ("TSL") and NearSpace Launch, Inc. have partnered to create an exciting program to advance STEAM education and promote space science research and systems engineering. The three-phase program is designed for students in grades 6th – 12th with research applications for university students and other organizations.

Phase 1: Students are introduced to sensors, software, electronics, and data collection methods. The students design, construct and test various configurations of a desktop satellite ("FlatSat"). The FlatSat provides for student learning opportunities with respect to instruments, satellite subsystems and systems engineering. Students use the FlatSats to collect atmospheric data, implement data collection methods and apply data analytics techniques to interpret the data. The data is displayed on the Space Data Dashboard where students can review chart data received from FlatSat sensors or download the data into a CSV file and import into analytical programs such as Excel or MATLAB. There are online resources and curriculum to assist the teachers and enhance the student learning experience.

Phase 2: The student teams will decide on a final design and build a payload to fly in the engineering model of their ThinSat. Students will have the opportunity to use TSLPB and TSLXB, or custom developed payloads. The engineering model with student payloads will fly on a high-altitude balloon up to approximately 100,000 feet and collect upper-level atmospheric data. The student teams will analyze the data collected from both ground tests and the flight mission. After review and approval of the final design by the student teams, they will submit their payload specification to TSL or deliver the custom-built payloads for integration into the ThinSat flight model bus ("ThinSat Bus") by TSL.

Phase 3: NearSpace Launch, Inc. ("NSL") will manufacture the flight satellites based on specifications provided by TSL. TSL will collect payload requirements from student teams based on the engineering model and integrate standard and custom payloads into the flight models. The satellites will be tested at TSL facilities at Morehead State University Space Science Center and deemed operational prior to integration into the canisterized satellite dispensers. Integration onto the second stage of the Antares rocket will be performed by Northrop Grumman Innovation Systems personnel at the Horizontal Integration Facility at the Mid-Atlantic Regional Spaceport ("MARS"). The flight satellites will be launched into Extremely Low Earth Orbit ("ELEO") and are expected to orbit the Earth and send data (accessible by the students) for approximately 5 days. The student teams will analyze the data collected by their satellite and submit a report detailing their research findings.

2 Research Opportunities and Advantages Using ThinSat Platform

The ThinSat Bus is a satellite platform that can be utilized for countless research and commercial applications, including: (1) developing new sensors, instruments and subsystems for picosatellites; (2) raising the technology readiness level for sensors, electronic boards, and subsystems for future satellite applications; and (3) space science research. Micro-gravity research is a growing area of interest for bio-pharma, material science, semiconductor, and other industries. The ThinSat Bus is an excellent platform for student learning and research applications for NASA agencies, commercial space enterprises and other organizations.

The ThinSat Program addresses many of the challenges encountered with the CubeSat Program and creates new opportunities, including: (1) decreasing the spacecraft development cycle time; (2) reducing the complexity and increase reliability; (3) providing regular launch opportunities, thereby increasing space access; (4) engaging students earlier in their educational training (6th to 12th grade); (5) reducing the burden of paperwork and licensing requirements; (6) mitigating the threat of space debris with a short orbital life; (7) reducing the overall cost of spacecraft development and access to space; (8) creating a precursor program to CubeSat Programs; and (9) creating a smaller spacecraft platform for value space research.

3 TSLPB Overview

The TSLPB is designed to provide a means of interfacing to the ThinSat Engineering Model and ThinSat Bus as "Student Payload".

The TSLPB provides six analogs and two digital signals that can be sent to the ThinSat Bus through the ThinSat Interface connector as Analog/Digital outputs or as a Serial Payload Packet. In addition, the TSLPB has six I^2C digital sensors and one I^2C IMU module that includes an accelerometer, gyroscope and magnetometer in 3 axes.

The TSLPB includes an ATmega328P microcontroller (the Arduino Pro Mini 3.3V is based on this microcontroller) with firmware that can be used for programing or monitoring the TSLPB and TSLXB using the TSL USB Diagnostic Connector. The microcontroller provides the functionality for Serial Communications, use of an Electrically Erasable Programmable Read-Only Memory ("EEPROM") (32K x 8Bits), 5 analog ports (10-bits resolution), I^2C interface and 5 (General-Purpose Input / Output ("GPIOs") that can be used as 1 wire, Serial or SPI interfaces, additionally two GPIOs are connected to LEDs for monitoring purpose. The board can be reset by the implementation of a software reset as well as a hardware reset (if it is implemented by using the TSL Expansion Board).

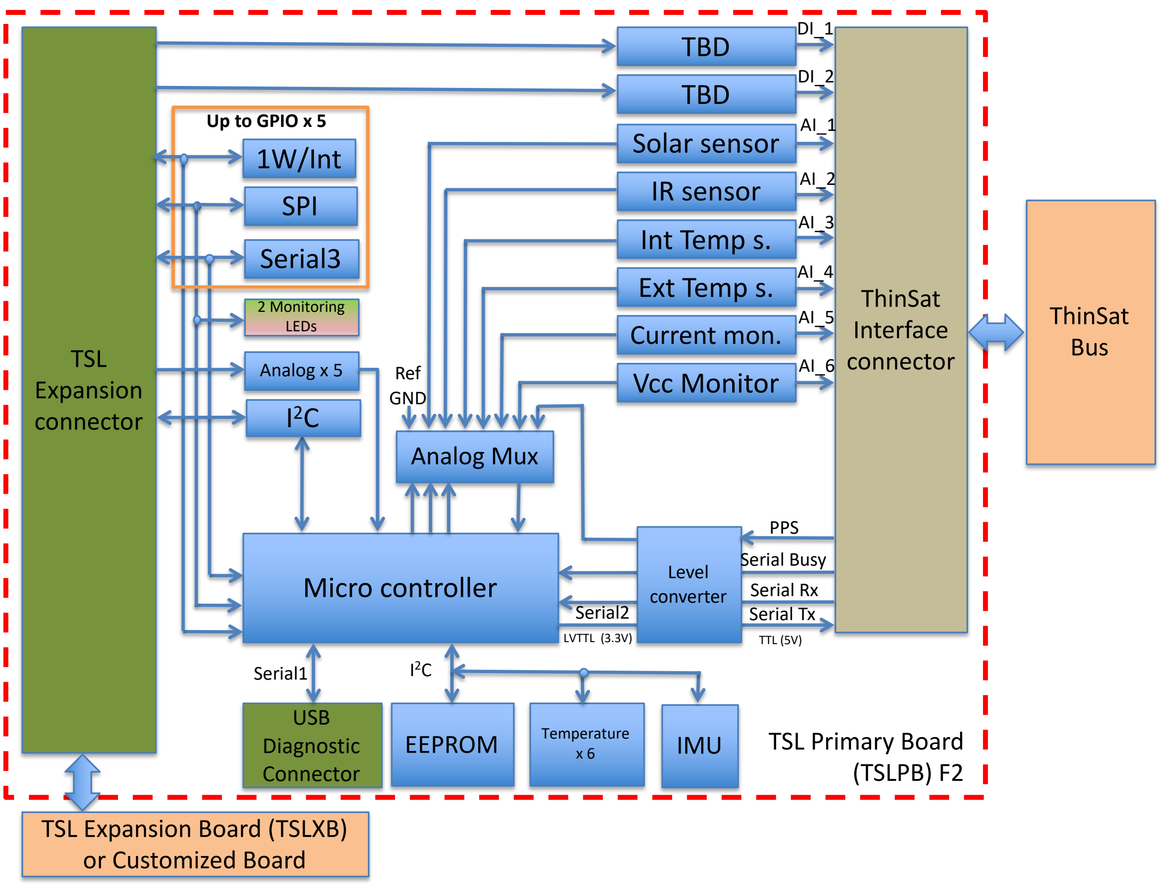

Figure 1 TSLPB Block Diagram

In addition, the TSLPB has the capability of supporting an expansion board, the TSL Expansion Board ("TSLXB") on which additional sensors can be accommodated, or a customized expansion board developed by the user ("USRXB"). A computer with a USB port is required for monitoring and programing the TSLPB by using the TSL USB Diagnostic Connector Board together with a FTDI 3.3V adapter. In order to test the TSLPB connectivity with the ThinSat Bus, a ThinSat Engineering Model (or Flight model) is required.

4 *Sensors Specifications*

The analog signals and the selected sensors in the TSLPB are shown in Table 1. The Analog Sensors operate in the range of 0 to 3.3V. It is recommended that the students calibrate the Analog Signal values to determinate the real value.

The ThinSat Bus has five ports that provide access to the space environment surrounding the exterior of the ThinSat spacecraft for sensors or other instruments on the "Student Payload" area.

The External Temperature and Solar Sensor are located under ThinSat Port 3; the Infra-Red Sensor is located under ThinSat Port 5; the IMU module (Accelerometer, Gyroscope, Magnetometer) is located close to ThinSat Port 4; and the TSLXB has an available area to install a sensor under each of the ThinSat Ports 2 and 1. The location of the sensors is shown on Figure 2 and Figure 3 is showing the location of the ThinSat Bus ports.

Signal	Sensor	I^2C Address
Solar Sensor	SFH2430	NA
Infra-Red Sensor	TSL260-R-LF-ND	NA
Internal Temperature	TMP36GRTZ	NA
External Temperature	TMP36GRTZ	NA
Current Monitor	INA169	NA
Vcc Monitor	NA	NA
DT1 (Temperature)	LM75A	0x4A
DT2 (Temperature)	LM75A	0x4C
DT3 (Temperature)	LM75A	0x4D
DT4 (Temperature)	LM75A	0x48
DT5 (Temperature)	LM75A	0x49
DT6 (Temperature)	LM75A	0x4B
Accelerometer 3 axis	MPU-9250	0x69
Gyroscope 3 axis		
Magnetometer 3 axis		
IMU internal temperature		

Table 1 Sensor Specifications

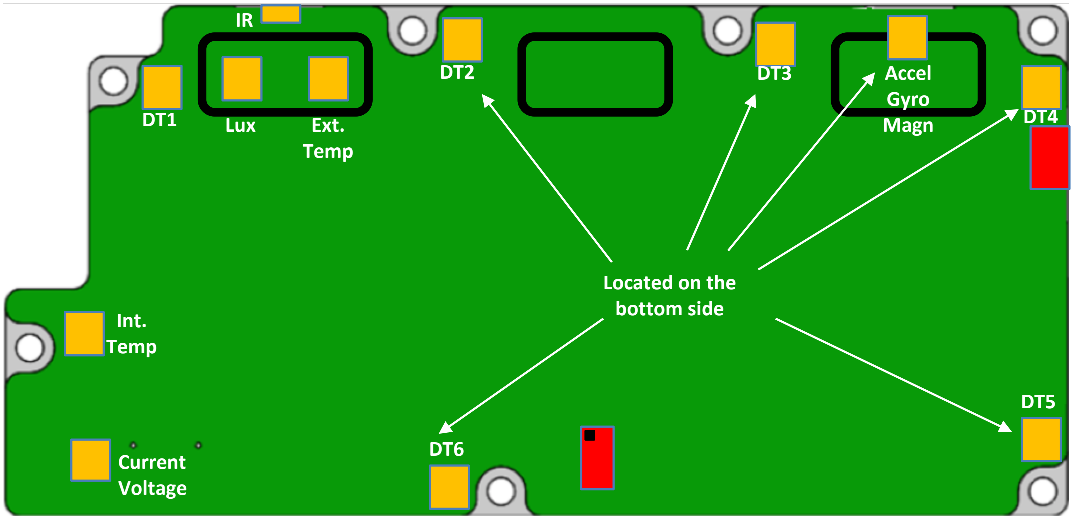

Figure 2 TSLPB Sensors distribution

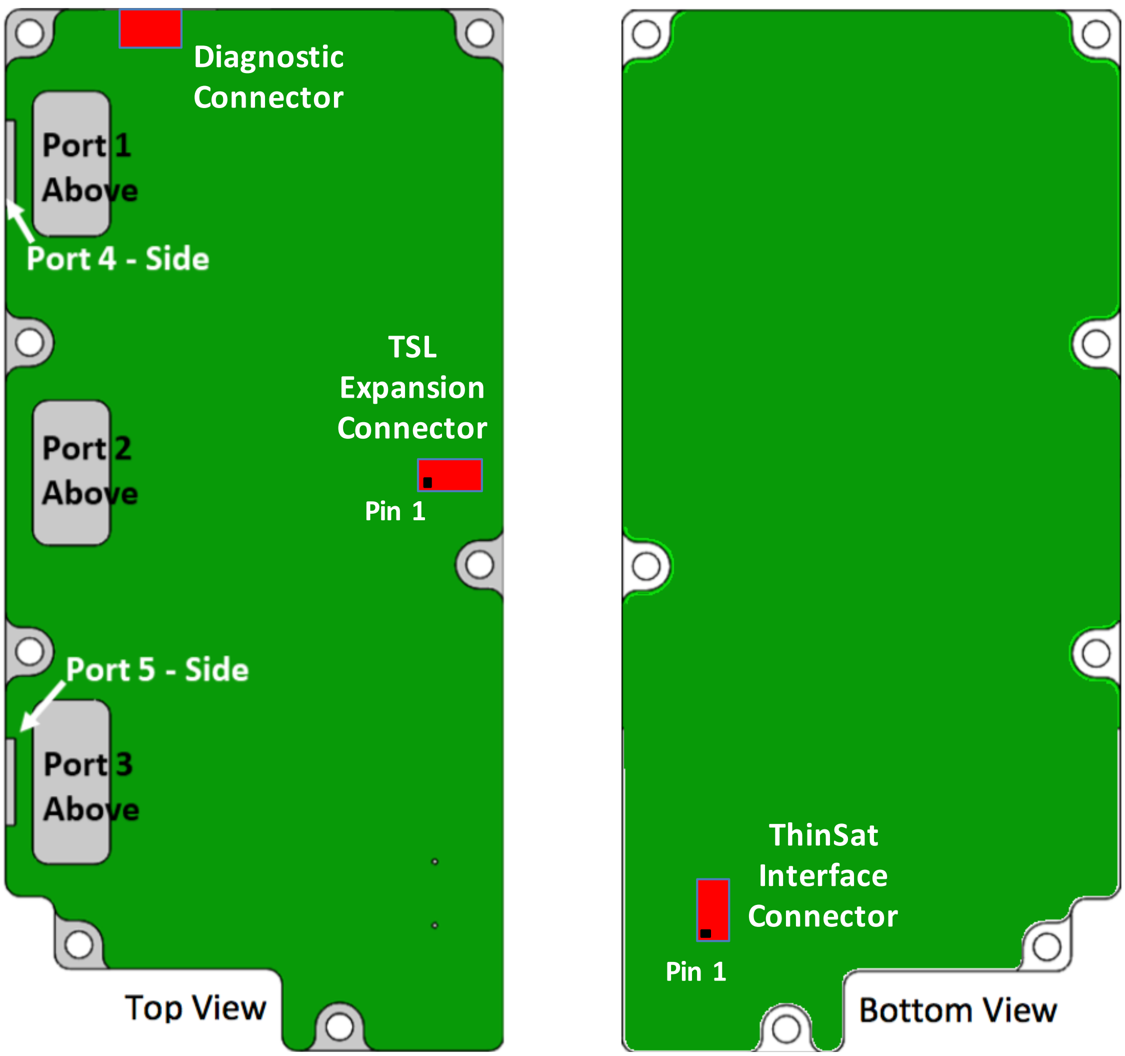

Figure 3 ThinSat Bus Ports and Connectors location

5 Interfaces

The Arduino IDE is used for programming the TSLPB by using the TSL USB Diagnostic Adapter ("TSLDA") and a FTDI 3.3V adapter. See Figure 4 below. The TSLDA also can be used for monitoring the TSLPB. The Arduino IDE is a free open-source software that can be downloaded for different platforms from the following link: https://www.arduino.cc/en/Main/Software

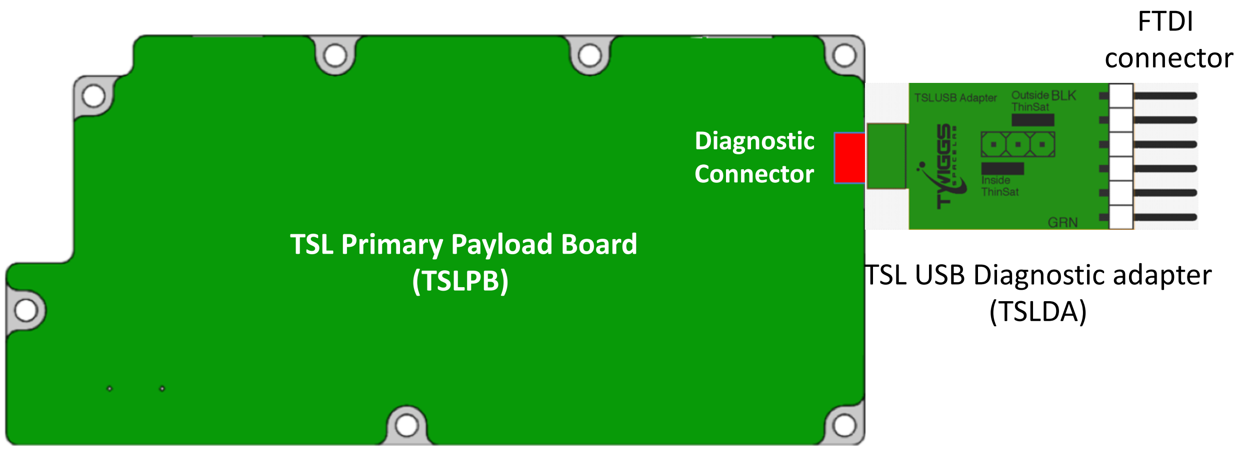

Figure 4 TSL USB Diagnostic Adapter Connection

To program or monitor the TSLPB, the student must connect a FTDI 3.3V adapter with the pinout showed on the Table 2 on the FTDI connector. The FTDI connector is a 6 positions right angle header 0.100" (2.54mm).

FTDI Connector	Signal
BLK (1)	GND
2	CTS
3	VCC
4	TXD
5	RXD
GRN (6)	RST

Table 2 FTDI Connector Pinout

The TSLDA has a "+3.3V" header connector labeled as "Outside ThinSat" and "Inside ThinSat" to supply or not supply the +3.3V from the FTDI. If the TSLPB is installed inside the ThinSat, then the jumper must be installed on the "Inside ThinSat" side where the +3.3V power will be supplied by the ThinSat Bus. If the TSLPB is not installed inside the ThinSat, then the jumper must be installed on the "Outside ThinSat" side where the +3.3V power will be supplied by the FTDI module.

The complete port assignments on the microcontroller (that corresponds to port assignments on the Arduino Pro Mini) are shown on the Table 3.

The EEPROM is a I²C device configured to function with an address considering A0=0, A1=0 and A2=0, (0x50). This device can be used to store data on the TSLPB.

The Analog multiplexor is a SN74HC4851PWR that multiplex eight analog signals. It is used to send the analog signals on the TSLPB to the microcontroller. The multiplexed signals and selector is shown on the Table 4.

Arduino Port	Signal	Comments
A0	Analog Port 0	0 to 3.3V signals
A1	Analog Port 1	0 to 3.3V signals
A2	Analog Port 2	0 to 3.3V signals
A3	Analog Port 3	0 to 3.3V signals
A4	SDA	I²C interface
A5	SCL	
A6	Analog Port 6	0 to 3.3V signals
A7	Multiplexer out	This port receives the signals coming from the Analog multiplexer
D0	RXI	Serial1 RX In
D1	TXO	Serial1 TX out
D2	1W/Int	GPIO or One Wire and Interrupt
D3	Serial2 Rx	Serial2 port Rx for communication with the ThinSat Bus
D4	Serial Busy	Serial Busy signal (from ThinSat Bus)
D5	Serial2 Tx	Serial2 port Tx for communication with the ThinSat Bus
D6	Internal RST	Software reset
D7	Mux A	Multiplexor A selector
D8	Mux B	Multiplexor B selector
D9	Mux C	Multiplexor C selector
D10	SPI CS	GPIO or SPI CS with a Red monitoring LED
D11	SPI MOSI	GPIO or SPI MOSI
D12	SPI MISO	GPIO or SPI MISO
D13	SPI CLK	GPIO or SPI CLK with a Green monitoring LED

Table 3 Microcontroller Port Assignments

Mux C	Mux B	Mux A	Signal
0	0	0	Solar Sensor
0	0	1	Infra-Red Sensor
0	1	0	Internal Temperature
0	1	1	External Temperature
1	0	0	Current Monitor
1	0	1	Vcc Monitor
1	1	0	GND
1	1	1	PPS (from ThinSat Bus)

Table 4 Analog Multiplexer

The TSLXB or the USRXB is connected to the TSLPB through the TSL Expansion Connector. It can be used to add sensors or customized payloads. A maximum of 100mA current consumption is allowed for use in the operation of TSLPB and TSLXB/USRXB on the ThinSat Spacecraft.

The User Expansion Board – USRXB, cannot have dimensions greater than the TSLXB. Figure 5 shows the TSLXB/USRXB and location on the TSLPB.

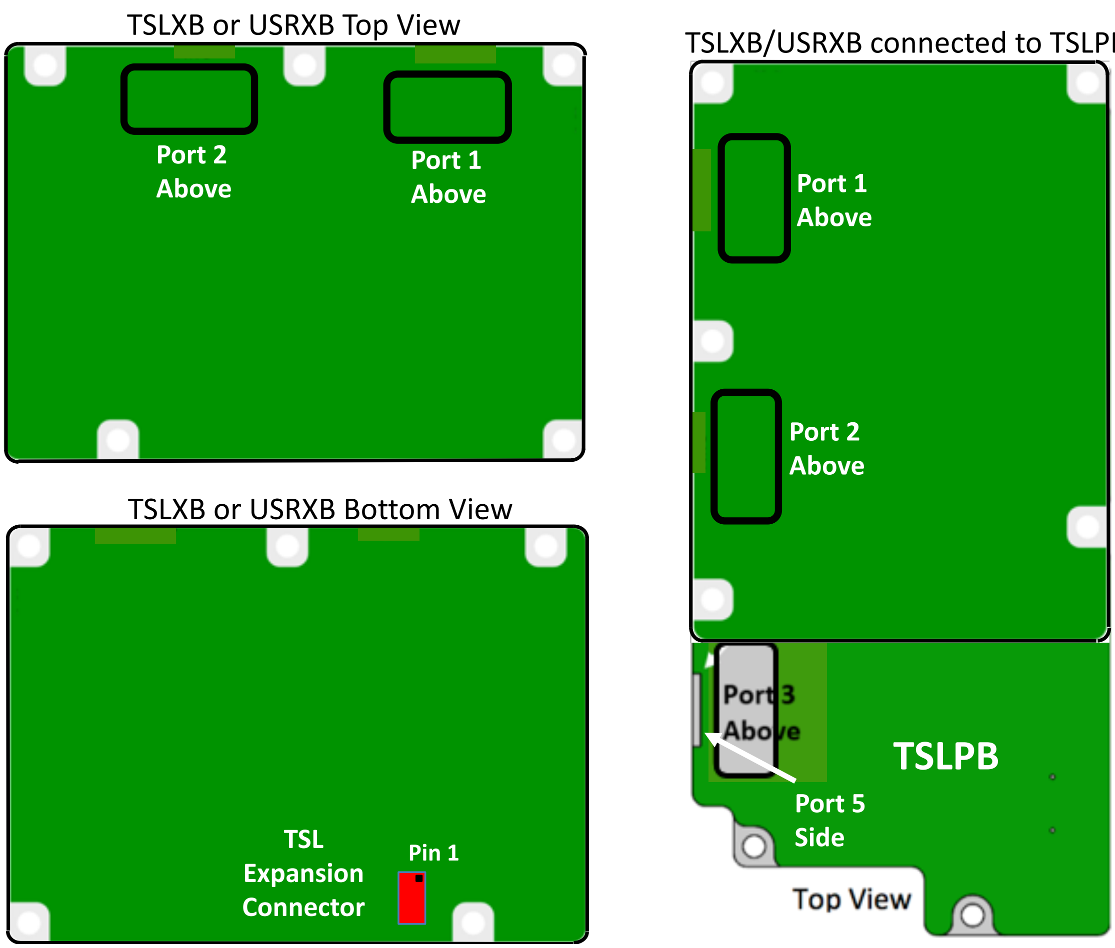

Figure 5 TSLXB/USRXB

The TSL Expansion Connector is used to send and receive multiple signals between the TSLPB and TSLXB/USRXB, its pinout is shown on the Table 5.

TSL Exp Conn	Signal	TSL Exp Conn	Signal
1	5V	2	3.3V
3	PPS_LV	4	RST
5	DI1	6	D2 (1W/INT)
7	DI2	8	A3
9	A0	10	A6
11	A1	12	D13 (SPI_CLK)
13	A2	14	D12 (SPI_MISO)
15	SDA	16	D11 (SPI_MOSI)
17	SCL	18	D10 (SPI_CS)
19	GND	20	GND

Table 5 TSL Expansion Connector pinout

6 *TSL Expansion Board (TSLXB)*

The TSLXB is a TSL Secondary Payload Board that can be used as a general Proto-Board to build a customized secondary payload taking advantage of the design and the pads that it has for that purpose. See Figure 6 below for the TSLXB.

The column of PADs over the GND label are all connected as well as the column of PADs over the VCC (3.3V) label to facilitate the assembly of the customized payloads.

The first PAD over the rest of the labels has the signal indicated on the label.

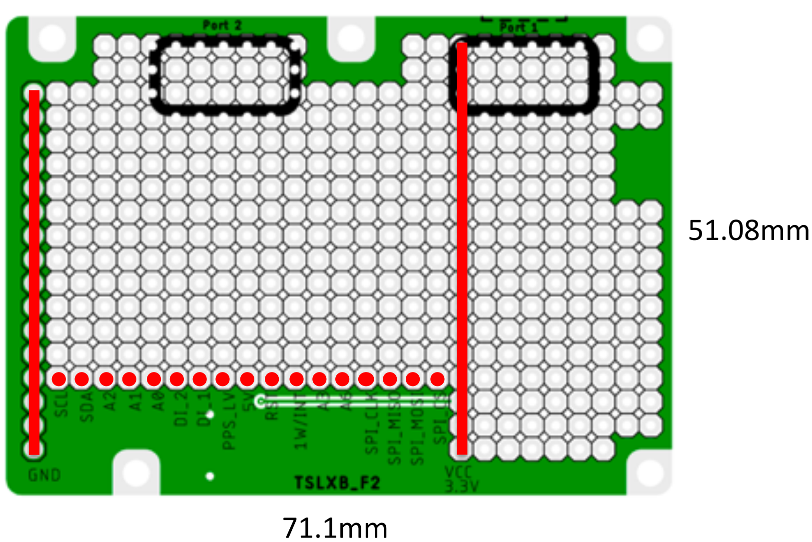

Figure 6 TSLXB

7 *TSL Primary Payload Board Operation*

The TSLPB has two operational modes, Plug & Play and Serial.

The Plug & Play operational mode works when the board is connected to the ThinSat Bus and the six analog signals are read and transmitted as part of the Spacecraft Beacon.

The Serial mode sends a total packet of 38 bytes, three bytes as preamble (hex 50 50 50) and 35 bytes of payload data to the ThinSat Bus serial port through a half-duplex communication with the parameters of 38.4Kbps, 8 data bits, no parity, 1 stop bit.

The ThinSat Bus answers each data packet with an ACK (hex AA 05 00) if the packet is correct or a NAK (hex AA 05 FF) if the packet is not correct.

The Busy Signal provided by the ThinSat Bus is LOW to indicate that the ThinSat Bus can receive data from the TSLPB and is HIGH to indicate that data cannot be received.

Although there is a 5V signal on the TSLPB and TSLXB, the level of signals to be used on both boards is Low Voltage Transistor-Transistor Logic ("LVTTL") (3.3V).

In addition, the available space to place components on the TSLXB/USRXB cannot exceed 3.0mm on the bottom of the board and 2.9mm on the top of the board, as shown in Figure 7.

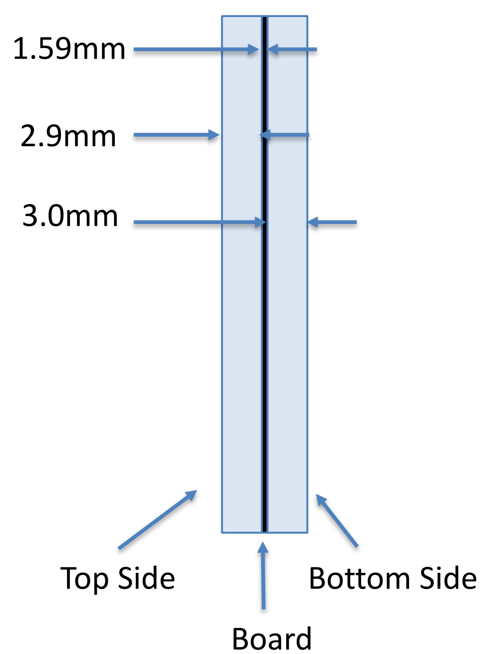

Figure 7 TSLXP/USRXB Available Space

Please refer to the "TSL Testing Procedures F2" package for documentation and example codes to use the TSLPB.