Overview

The 4100 Ultra Wideband (UWB) Radio Transceiver/Radar Sensor

The hardware used Ranging and Communications Module & Radar Module is physically identical. Given that there are no differences in the device hardware, this document will refer to the platform as a UWB 4100 when describing hardware characteristics and as a 4100 TIM or 4100 TIMS when describing applications.

The 4100 is an Ultra Wideband (UWB) radio transceiver and/or radar sensor that provides the following functions:

- It accurately and reliably measures the distance between two and provides these measurements at a high update rate.
- It supports two different range measurement techniques (Two-Way Time-of-Flight and Coarse Range Estimation).
- It communicates data between two or more 4100 radios
- It is interoperable with earlier generations
- It allows operation as a monostatic radar also if needed
- It is also possible to operate the as hybrid device that is both a ranging radio and a radar sensor.

The user controls and monitors the 4100 through an Application Programming Interface (API) over USB or Serial connections. USB driver support is provided for Vista 32, Vista 64, Win7 32 and Win7 64 operating systems. The API provides all the commands and capabilities required by a user to design a network tailored for operating multiple 4100s as ranging radios or as individual or systems of radars.

The API has been segregated by application. For details, see the following documents:

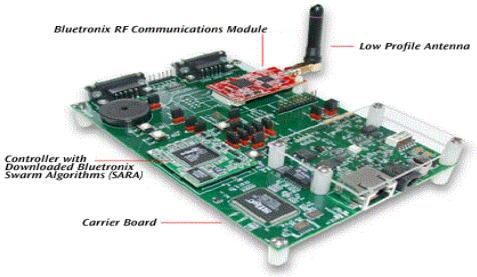
- *Ranging and Communications API Specification,*
- *Monostatic Radar Module API Specification,*
  Using the USB and Serial Interfaces

To assist the user in demonstrating the performance of the 4100 either as a ranging radio or as a radar sensor, Bluetronix Inc. also provides two PC-based Graphical User Interfaces (GUIs). These GUIs exercise all of the API commands and offers the following capabilities:

- They provide programmers with a visual example of a host application which interfaces to the 4100 through the API.
- They allow users to evaluate ranging and communications performance.
- They allow users to evaluate the radar performance through use of a sample Motion Filter, sample Detection Processor, and a graphic display of raw and processed radar scans.
- They allow system analysts to visualize, collect, and log raw ranging and radar data such that it is possible to develop algorithms/strategies tailored to a given application

Bluetronix Inc. can provide sample C and MATLAB code for demonstrating the interface and performance of the hardware.

This document focuses on describing the 4100 UWB radio hardware. This discussion is subdivided into the following subsections.



4100 Ultra Wideband (UWB) Radio Transceiver /Radar Sensor

Key Features of the 4100

- Excellent performance in high multipath and high clutter environments
- Coherent signal processing extends operating range
- Direct sequential pulse sampling allows measurement of received waveform (resultant waveform is available to the user for ranging optimization)
- Two-Way Time-of-Flight (TW-TOF) ranging technique provides highly precise range measurements with industry-leading update rate
- Coarse Range Estimation (CRE) technique estimates the range from a transmitting unit by using the received leading edge signal strength and periodically recalibrating the estimate based on infrequent TW-TOF range measurements
- UWB chipset enables low cost, small size, and low power operation
- UWB waveform and pseudo random encoding ensures noise-like transmissions with a very small RF footprint
- RF transmissions from 3.1 GHz to 5.3 GHz, with center at 4.3 GHz
- Two user-configurable antenna ports for single or dual antenna operation
- RF emissions compliant with FCC limits
- Each unit is a full transceiver
- Single 3” x 3.15” (7.6 x 8.0 x 1.6 cm) board
- USB or Serial interface
- Several sleep modes allow user to reduce power consumption
- Interoperates with P4100s

Typical Applications of the 4100 TIM

- Peer-to-peer ranging with moderate-rate wireless communications (HDR)
- GPS augmentation for multipath resistance
- Inertial augmentation for drift removal
- Robotics navigation and tracking, precision formation
- Autonomous vehicle convoys
- First responder tracking and man-down locator
- Asset tracking, especially in applications that preclude the use of fixed infrastructure or involving moving frames of reference
- Distributed sensor automatic survey and dynamic mapping with fused data communications
- Wireless channel impulse response (CIR) measurements
- Wireless noise-like / covert data communications

Key Features of the 4100 TIMS

- Excellent performance in high multipath and high clutter environments
- Coherent signal processing extends operating range at very low signal power levels
- 4100 MRM provides raw scans for post processing
- UWB chipset enables low cost, small size, and low power operation

- UWB waveform and pseudo random encoding ensures noise-like transmissions with a very small RF footprint
  - Seven separate channels provided, more are possible
  - RF transmissions from 3.1 GHz to 5.3 GHz, with center at 4.3 GHz
  - Two user-configurable antenna ports for dual antenna operation
  - RF emissions compliant with FCC limits
- Single 3"x 3.15" (7.6 x 8.0 x 1.6 cm) board
  - USB or Serial interface
  - Several sleep modes allow user to reduce power consumption
  - Interoperates with P400s

In the very near future it is anticipated that the TIM will also support the following enhancements:

Different integration rates for different distances (segment control) & Operation with a single antenna

Typical Applications 4100 TIMS

- Tagless tracking
- Proximity detection
- Collision avoidance
- Security applications
- Presence/intrusion detection
- Unattended ground sensors
- Surveillance
- Through-wall sensing
- Data Communications

It should also be noted that since the 4100 TIM and 4100 TIMS share the same hardware, it is also possible to construct hybrid systems that combine capabilities to address applications that would benefit from radar, UWB communications, and UWB ranging.

To power the board, the user must supply a maximum of 4.2 Watts at any voltage between 5.75-30V. This can be accomplished either with the provided power supply or from a battery. Indicating lights provide operating status information. The user can interface to the 4100 through either USB (standard USB Micro-B connector) or a Serial connection (header). In addition, the user can request the 4100 to report the board temperature and can command the fan to turn on or off.

The processor controls the UWB front end through a Digital Baseband FPGA interface. More specifically, the FPGA configures the Pulser chip (UWB transmitter) and 4100 Analog Front End (AFE) chip (UWB receiver), provides timing signals and outgoing data, receives incoming data, and controls the position of the transmit/receive (T/R) switch.

There are three RF sections:

˜ Power amplifiers are provided to boost the output of the Pulser. Amplification is adjustable from -32 to -12dBm. A high power option is available which provides -14.5 to 0.7 dBm. ˜ Receive chain consists of gain stages and band pass filter.

˜ T/R switch supports 5 configurations: Transmit/Receive on Port A, Transmit/Receive on Port B, Transmit on A, Receive on B, and Transmit on B, Receive on A and A/B Toggle. The T/R switch supports a configurable default receive position with an optional override when transmitting.

The 4100 is normally powered by a modular power supply (optionally provided by Bluetronix) that plugs directly to the 4100 barrel connector power jack. Alternatively, the user can install alternate SIP connectors using either of two pairs of mounting holes shown in below . The pair of holes on the right is intended for a two position, 0.1 inch pitch header (Digi-Key part number WM8072-ND). The pair of holes on the left is intended for a locking, two position, 3.96 mm connector (Digi-Key part number 455-1648-ND). The round hole is connected to ground. The square hole is for the supply voltage. The input power is specified in below:

Alternate Power Connections (Table 1)

Parameter	Description	Min	Max	Unit
VIN	Input voltage to 4100	5.75	30.0	Volts
IIN	Input current to 4100	0.037 @ 30 Vin	0.73 @ 5.75 Vin	Amps
Win	Power to 4100	1.1W (sleep)	4.2W (Max)	Watts

Indicator Lights

Edge Mount LEDs - The amber LED indicates that power to the board is on. The green LED is off until the 4100 has booted and is running. Once running, the LED will turn on solid. After that, it will toggle every time a packet is transmitted.

FPGA LEDs - The amber LED toggles at 1Hz to indicate that the FPGA has passed Built-In Test (BIT). If the FPGA fails BIT, then the amber LED will blink at approximately 10 Hz. The green LED is initially off indicating that the FPGA has not been loaded. It blinks rapidly to indicate that the FPGA has been loaded and is getting a clock. After that, a steady on or off indicates a failure.

POWER

The P410 is normally powered by a modular power supply (optionally provided by Time Domain) that plugs directly to the P410 barrel connector power jack. Alternatively, the user can install alternate SIP connectors using either of two pairs of mounting holes shown. The pair of holes on the right is intended for a two position, 0.1 inch pitch header (Digi-Key part number WM8072-ND). The pair of holes on the left is intended for a locking, two position, 3.96 mm connector (Digi-Key part number 455-1648-ND). The round hole is connected to ground. The square hole is for the supply voltage.

The input power is specified in **Table 1**.

Parameter	Description	Min	Max	Unit
VIN	Input voltage to P410	5.75	30.0	Volts
IIN	Input current to P410	0.037 @ 30 Vin	0.73 @ 5.75 Vin	Amps
Win	Power to P410	1.1W (sleep)	4.2W (Max)	Watts

USB and Serial Interfaces

The 4100 offers two different interfaces that allow users to control the module according to their specific application needs. The standard interfaces currently supported by the system are: USB 2.0 through a

Antennas

The 4100 has two antenna ports, designated Port A and Port Micro-B USB connector, and a 3.3V TTL-level serial interface through a six pin 0.1" SIP header. (Serial to USB cables compatible with this interface are available from FTDI (TTL-232R3V3) or through Digi-Key (768-1015-ND). **Note** the USB connection does not provide enough power to support the TIM.

The protocol used to communicate with the 4100 is fully defined in the TIM or MRM *API Specification*.

The 4100 board has a 3.3V serial universal asynchronous receiver transmitter (UART) port which customers can also use to communicate with the 4100. Both the Serial and USB interfaces are documented in Bluetronix application note *Using the USB and Serial Interfaces*.

USB is recommended for PC/Laptop hosts, while Serial is intended primarily for embedded hosts. The 4100 also has a number of currently unassigned GPIO pins. One processor GPIO (3.3V) and two FPGA GPIO (2.5V) pins are available for general use. Logic and drivers for these pins can be developed based on specific customer requests.

The connector used on each port is a standard polarity male SMA connector (Digi-Key part number J801-ND). The two ports enable single and dual antenna modes of operation.

An RF transfer switch on the 4100 controls how the RF electronics are connected to the SMA connector. The switch supports 5 configurations: Transmit/Receive on Port A, Transmit/Receive on Port B, Transmit on A/Receive on B, Transmit on B/Receive on A, and Toggle A-B. This fifth state is used only when a 4100 TIM receives a series of range requests. When this occurs, the unit will automatically toggle between the two receive antennas. The user specifies the desired antenna configuration through the API. When operating as 4100 MRM, the user's antenna choices are limited to Transmit on A/ Receive on B and Receive on A/Transmit on B.

While Bluetronix provides its standard Broadspec UWB antenna with the Development Kit, the SMA ports are standard and any third party UWB antenna can be used depending on gain and directionality requirements. Please be aware that using alternate UWB antennas will likely change the RF time-of-flight electrical distance between the antenna port and the phase center of the antenna.

Failure to account for such changes will result in an offset or bias error in range measurements. See the TIM *API Specification* for details on how the electrical distance is defined and calibrated.

Fan

A small fan (2.5CFM) has been provided on the TIM. This fan is located between and above the FPGA and P400 AFE chip. Although these chips are manufactured to operate at high temperatures, the fan is used to provide a modest amount of heat removal required for optimal operation across all specified temperature and performance ranges. The fan can be turned off (through the API) or removed at the factory, but some degradation in maximum distance or accuracy may be encountered at high temperatures.

There are 4 mounting holes. Three are indicated in the drawing, and the fourth is located underneath the RF shield. The board comes with 4 rubber feet, which are removable. All units are English.

Performance

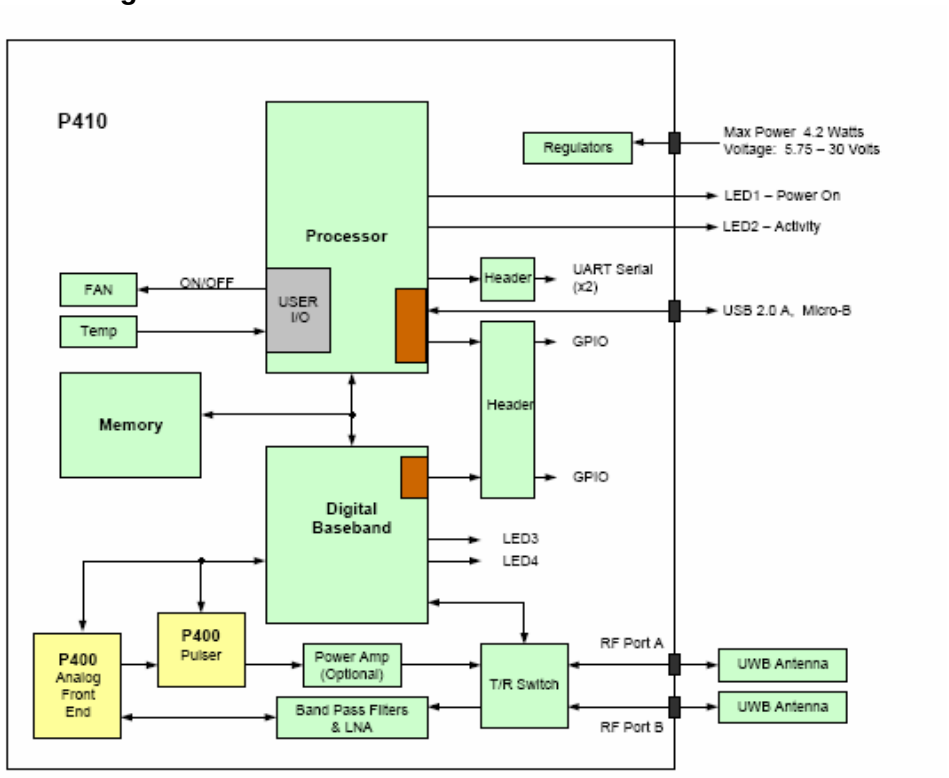
Table 2 summarizes the 4100 specifications and key performance parameters.

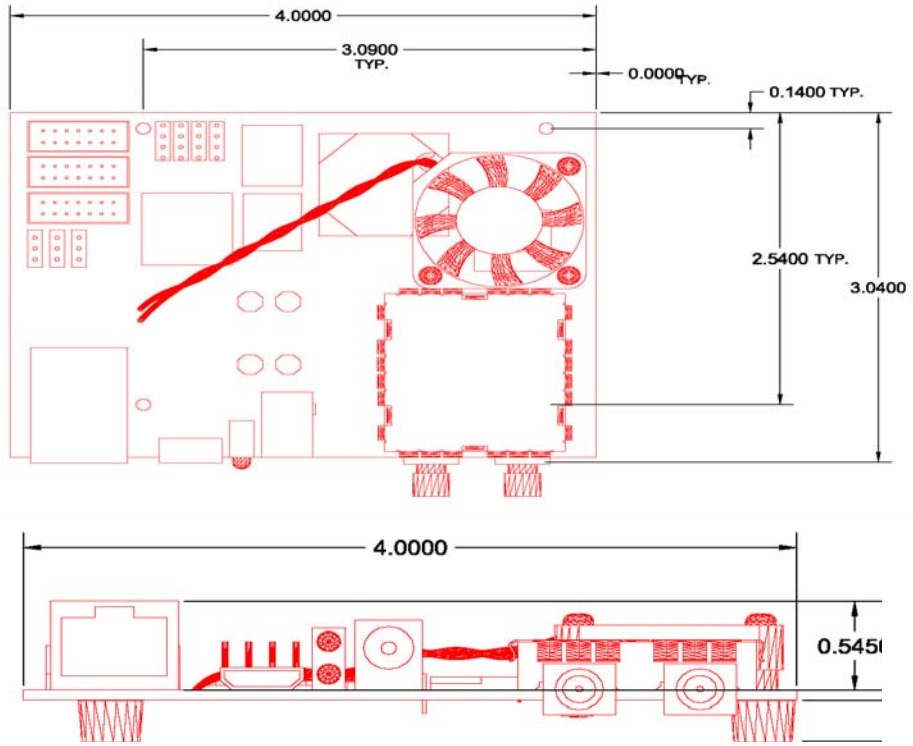
4100 Specs	Value
Physical Parameters	
Dimensions (with mounting feet):	3"x 3.155" x 0.75" (76 x 80 x 19 mm)
Dimensions (without feet):	3"x 3.155" x 0.63" (76 x 80 x 16 mm)
Weight	58 grams
Storage Temperature:	-40°C to 85°C
Operating Temperature range	0°C to 70°C
Max allowable board temperature:	70°C (as reported by on board temp sensor)
Humidity:	Up to 95%, non-condensing
Input Power Range:	5.75V to 30V DC
Input Power Ripple:	100 mV pk-pk
Power/Temp operating as a Ranging Radio	
Maximum Power Consumption:	4.2 Watts
Typical Power Consumption and Transition times (power function of communications interface):	
- Active (requesting)	3.90 Watts
- Active (receiving)	3.88 Watts
- IDLE	2.60 Watts (Enter: 1.2 ms, Exit: 1.2 ms)
- Standby_E	1.10 Watts (Enter: 1.2 ms, Exit: 2.9 ms)
- Standby_S	1.10 Watts (Enter: 1.3 ms, Exit: 2.9 ms)
Operating Temperature range: (on lab bench, with no enclosure) Operating Temperature range: (in	-10°C to 60° C -10°C to
Power/Temp operating as a Radar	
Maximum Power Consumption:	3.9 Watts
Typical Power Consumption and Transition times (power function of communications interface):	
- Active and scanning	3.65 Watts
- Active but not scanning	3.30 Watts
- IDLE	3.30 Watts (Enter: 1.2 ms, Exit: 1.2 ms)
- Standby_E	1.11 Watts (Enter: 1.2 ms, Exit: 2.9 ms)
- Standby_S	1.14 Watts (Enter: 1.3 ms, Exit: 2.9 ms)
Operating Temperature Range: (on lab bench, with no enclosure) Operating Temperature Range: (in	-10°C to 60°C -10°C
User Interfaces/Devices	
Standard PC/Laptop Interface:	USB 2.0A Client – Micro-B connector
Standard embedded host interface:	3.3V TTL Serial UART 115.2kbps, 8, n, 1
Hardware Interfaces available but not currently supported:	˜ 1 Processor GPIO pin (3.3V) ˜ 2 FPGA GPIO pins (2.5V)
On Board Temperature Sensor	-40°C to 125°C, +/- 2.0 °C

RF Characteristics	
Operating Band:	3.1 GHz to 5.3 GHz
Center Freq:	4.3 GHz
Transmit power (Adjustability range) (-14.5dBm is FCC Part 15):	Standard: (-31.6 to -12.64 dBm) High power: (-14.5 to 0.7 dBm) For adjustment control see Note 4
Antenna Ports A&B:	Standard 50 Ohm SMA coaxial connector
Antennas Supported	Compatible with Bluetronix Toroidal Dipole Antenna (0 dB) as well as a wide variety of 3rd party antennas.
Antenna Control:	User cross-bar configured as either Tx/Rx on either, or Transmit on one, Receive on the other
Noise Figure:	4.8 dB
Dynamic Range:	
Integration: 1 (instantaneous)	30 dB
Integration: 16:1 (PII=4)	42 dB (Min Ranging Integration)
Integration: 64:1 (PII=6)	48 dB (Min Radar Integration)
Integration: 1024:1 (PII=10)	60 dB (Max Ranging Integration)
Integration: 32768:1 (PII=15)	75 dB (Max Radar Integration)
Transmit Pulse Repetition Rate	10.1 MHz (default - others available)
RF Communications	
Channelization:	7 user selectable pseudo-random pulse interval channels. Others available for special applications
Raw Data (Symbol) rates:	See Table 3
Max Range (FCC Part 15, standard Broadspec Antennas, free space)	See Table 3
Comms type:	Packet transmission
Max user bytes/packet:	1024
Pulse integration rates (PII):	4 (16:1), 5 (32:1), 6 (64:1), 7 (128:1) 8 (256:1), 9 (512:1), 10(1024:1)
Ranging Performance	
Ranging techniques:	Pulsed Two-Way Time-of-Flight (TW-TOF), Coarse Range Estimation (CRE)
Two-Way Time-of-Flight	
Line of Sight Range Performance	See Note 1
Precision (Standard Deviation)	2.3 cm
Accuracy (Bias error):	2.1 cm
Range Update Rate	See Table 3
Non-Line of Sight Performance	See Note 2
Coarse Range Estimation (LOS only)	See Note 3
Range update rate	See Table 3
Radar Performance	
Approximate Detection Range (high power transmission)	Person Walking: 8 Person Crawling: 0 Vehicle: m See Note 5 4

Table 2: 4100 performance characteristics

Block Diagram





Enclosures