

Data Sheet / User Guide **Draft**

PulsON[®] 330

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Document Information

Time Domain reserves the right to change product specifications without notice. Any changes to the functionality or specifications will be issued as specific errata sheets or will be incorporated in new versions of this document. The latest version of this document and future documents can be found on the Time Domain website. The name/number and date of this document can be found on the left side of the cover page.

Regulatory Approvals

The P330, as supplied by Time Domain, has been designed to be compliant with both the US FCC regulations as well as Europe’s ETSI EN 302 065 standard. As of this publication date, Time Domain is in the process of applying for FCC certification and expects approval early in 2017. Certification to the ETSI standard is expected later in 2017.

Regardless, the user is free to buy the equipment for evaluation and demonstration purposes (but not for resale) in most countries. When in doubt, the user should confirm with the relevant authority governing radio emissions.

All final products developed by the user which incorporate the P330 must be approved by the relevant authority governing radio emissions for the target market country(s). The User bears all responsibility for obtaining such approval(s).

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1 Summary

Time Domain is dedicated to providing industry with a wide variety of UWB platforms for use as ranging radios, radars, multi-static radars and communications devices. The P330 is the latest addition and joins the P400 family of devices.

The P400 family is based on Time Domain's FIFE UWB chip while the P330 uses the Decawave DW1000 UWB chip. While both chips support Two Way Time of Flight, the approaches used to implement this capability were accomplished in very different manners. As a result, both chips have significant advantages and disadvantages relative to each other. Consequently, there are applications for which the P330 is ideally suited and others for which the P440 is perfect. For a detailed discussion of these differences see the document *Comparison of P330 and P440*.

The P330 was developed by

- Leveraging the P000 software interface and RangeNet GUI with
- the network and localization capability of the P400
- and the Decawave DW1000 ranging chip.

The result is a powerful development platform which will allow the user to build, test and demonstrate rapid prototypes of end products without needing to first develop the basic hardware and software necessary to demonstrate the ranging, network or localization capability of the end product.

With the P330 the user will be able to

- Quickly demonstrate and quantify the performance of UWB ranging in a target environment
- Organize a group of P330s as a self-localizing, network in which each member of the group computes its own location and report this location and the location of the other P330s in the area to a host controller
- Quickly interface the P330 with virtually any hardware because the P330
 - Accepts any voltage from 5.5 to 48volts
 - Interfaces to a Host Controller through Serial, SPI, CAN, USB or Ethernet
 - Operates from -40 to +85c
 - Has excellent performance in high vibration environments
 - Has emissions which are compliant with both the FCC regulations and the European ETSI standards
- Easily monitor and control a P330 system through the RangeNet GUI (or use the sample MATLAB or C code provided with the P330 to develop your own monitor and control system)

Once a proof of concept has successfully concluded, the user can move to the next step in the product cycle either by using the P330s as is or by designing a low cost version of the P330 that contains only the hardware necessary to fulfill the requirements of the project.

The P330 has the following additional features:

- It is a coherent Ultra Wideband (UWB) radio transceiver optimized for measuring the distance between two radios.
- It uses the DW1000 UWB chip to measure distance by the Two-Way Time-of-Flight (TW-TOF) method. These measurements have a precision of 10 cm (3 standard deviations) and a bias error of +/-2 cm. Ranging rates of 180Hz are possible.

- It operates in both the low band 3.1-4.8GHz and the high band 6.0-7.0 GHz.
- It communicates data between two or more P330s.
- A wide range of settings allow ranging performance to be optimized for high ranging update rates or long range operation.
- It is provided with a network (RangeNet) which has been optimized for TW-TOF measurement. This network can be operated using either the ALOHA (randomized) or TDMA (Time Division Multiple Access) protocols.
- It supports up to 4 independent communications channels thus allowing operation as a CDMA (Code Division Multiple Access) network.
- The network is provided with a localization engine which can be used to determine the location of the unit in the X, Y and Z dimensions.
- The RF emissions are compliant with the United States Federal Communications Commission (FCC) per Rule Part 15.519.
- The RF emissions are compliant with the European Union ETSI EN 302 065 standard mask.
- The user monitors and controls the P330 through an Application Programming Interface (API) over USB, Serial, SPI, Ethernet or CAN connections. USB driver support is provided for Windows Vista 32/64, Windows 7 32/64, Windows 8 32/64, and Windows 10 operating systems. Unix and OS X systems do not need a special driver for USB. The P330 automatically appears as a serial device.
- The API provides all the commands and capabilities required by a user to design a network tailored for operating multiple P330s as ranging radios.

To assist the user in demonstrating the performance of the P330, Time Domain also provides RangeNet GUI, a PC-based Graphical User Interface, which exercises all of the API commands and offers the following capabilities:

- It provides programmers with a visual example of a host application which interfaces to the P330 through the API.
- It allows users to evaluate ranging, communications, network and localization performance.
- It allows system analysts to visualize, collect, and log raw ranging data such that it is possible to develop algorithms/strategies optimized for the chosen product application.
- It allows users to operate multiple P330s to form a network of ranging radios which self locate and report positions to the host.

Time Domain also provides sample C and MATLAB code for demonstrating the interface and performance of the hardware.

The objective of providing the GUI, sample C and sample MATLAB code is to supply programmers with several example interfaces and implementations which the user may then replace or tailor with custom code optimized for their particular needs and applications.

This document describes the P330 hardware and software. This discussion is subdivided into the following subsections.

- Section 2 P330 Software*
- Section 3 Hardware Block Diagram*
- Section 4 Electrical Interfaces*
- Section 5 Mechanical Interface*
- Section 6 Technical Specifications*
- Section 7 Broadspec Antenna*

Section 8 Regulatory Compliance

Section 9 Import/Export Considerations

Section 10 Configuration and Ordering Information

Additional information including all of the documents referenced in this section can be found on the web at www.timedomain.com. This includes: the API, software manuals, application notes, white papers, examples, published papers, sample C code, sample MATLAB code, and more.

2 P330 Software

The P330 software consists of five elements:

- Embedded software operating on the P330 module
- The Application Programming Interface (API) which defines the interface between the P330 and a Host processor
- The RangeNet GUI which (1) illustrates operation of the P330 and (2) provides an analytical tool for characterizing performance
- Sample C and MATLAB code to assist the user in developing custom applications
- The RangeNet network and localizer to enable systems of P330s to range, communicate efficiently and determine their location

In addition, Time Domain is committed to periodically adding new features and capabilities through software upgrades.

2.1 P330 Embedded Software

The P330 is a microprocessor-based UWB platform. The embedded software driving the onboard processor has three principal functions:

- It is responsible for controlling and monitoring the operation of the Decawave DW1000 UWB ranging chip.
- It handles all communications (Ethernet, USB, SPI, Serial, and CAN) with the user's Host processor (typically a PC or single-board computer). It also controls 15 GPIO pins.
- When instructed to act as a network, the onboard processor:
 - Assumes all responsibilities for scheduling communications and range requests
 - Provides the Host with status update information
 - Handles supervisory commands sent by the Host

This increases the ranging update rate and significantly offloads the Host processor.

- When instructed to compute node locations, the onboard processor will monitor reported ranges and, based on input from the user, employ either a Kalman Filter based algorithm or a Geometric solver to compute and report the location of device.
- The processor can also monitor communications traffic and report ranges between other units as well as the location of other units.

2.2 Application Programming Interfaces (APIs)

The communications between the P330 and the Host processor is defined in document *320-0336 P300 RangeNet API Specification*. The API consists of a set of commands which allow the user to initialize, control and monitor the P330 and the DW1000 chip. For example, these commands allow

the user to:

- Define the DW1000 operating properties (RF bands of operation, communications characteristics and preamble code)
- Generate individual range measurements
- Collect statistics on those range measurements
- Define a network based on either the ALOHA or TDMA protocol
- Define behavior of units in a network. For example, the behavior of a static anchor/reference node could be different from that of a mobile. It is also possible to allow or prohibit some units from communicating in the network with other units.
- Direct the P330 to compute its location based on ranges generated by the network.
- Maintain a data base of all units in the network. Information includes range and location data as well as other performance statistics.
- Upload the contents of the data base to the host on a periodic or automatic basis.
- Cause the unit to transition between operating as ranging only device, to operation as part of a network, to operation as part of a network which localizes.
- Buffer and control the flow of communications data between the Host and network
- Collect and report various statistics including P330 node id, software versions, and network performance statistics.

2.3 Graphical User Interfaces (GUIs) and Sample Code

Mastering all of the commands in an API can be a time-consuming task. To accelerate this learning process, Time Domain provides an example Graphical User Interface (GUI) called the RangeNet GUI which operates on a PC and exercises all of the API commands. The RangeNet GUI will also display received data and allow the user to log all received data or API messages sent or received by the Host.

In addition, Time Domain also provides sample C and sample MATLAB code. The sample C code enables embedded programmers to quickly interface to the P330. The sample MATLAB code enables system analysts to quickly construct experiments to investigate and evaluate performance or to build rapid prototypes. The sample code also includes parsers for extracting information from the logfiles.

The sample code includes the following:

Ranging and Network (RangeNet)

- *150-0117 – RangeNet Sample C Applications*
- *150-0118 – RangeNet Sample MATLAB Applications*
- *150-0103 – Ranging Sample C Applications*
- *150-0104 – Ranging Sample MATLAB Applications*

The RangeNet GUI is provided with a User Guide (*320-0338 P300 RangeNet User Guide*) and a Quick Start Guide (*320-0337 P300 Ranging and Location Quick Start Guide*) that illustrate operation of the equipment. Within 1 hour of receiving the equipment, the user will be able to measure range, operate a network and localize.

2.4 API and GUI as Development Tools

This section provides a high level summary of the API and discusses how the RangeNet GUI can be used as a development tool.

In general, the RangeNet GUI performs as one would expect. It allows the user to configure the P330s, initiate range requests, move in and out of a network, calculate location, move to and from different sleep states, measure the P330 temperature, display status, hardware and software version numbers as well as other useful information. In addition, the RangeNet GUI allows the user to display and log collected data as well as all communications between the Host and the P330.

2.4.1 Ranging Measurement with RangeNet

The RangeNet GUI allows the user to configure the P330 and take range measurements. The P330 supports the following two forms of range measurement.

Precision Range Measurements (PRM) are taken using the TW-TOF ranging technique. These readings typically have high accuracy and are provided with estimates of range error as well as flags that warn of possible errors. The user can use these range error estimates to drive a Kalman Filter. The flags can be used to disregard inaccurate readings.

Echo Last Range (ELR) measurements are Precision Range Measurements which have been taken between two other radios in the system. In other words, any time a unit takes a PRM it will broadcast the last range measurement it took to any other radios in the area. For example, if Unit A measures the distance between Unit A and Unit B, it will broadcast this range measurement to Units C, D, E, etc., whenever it next initiates a range measurement. This is an alternate way of automatically distributing range information through a system.

The RangeNet GUI allows the user to configure the unit and take range measurements. It also adds an extra level of system software in that it will allow the user to:

- Request a single range measurement, a fixed number of measurements, or a continuous series of range measurements.
- Display various DW1000 sources performance statistics including: Max Noise, STD Noise, First Path, First Path Amplitude 1, First Path Amplitude 2, First Path Amplitude 3, RX Preamble Count, and Max Growth CIR.
- Compute and display P330 statistics including: Range Error Estimate, First Path Power and RX Power (according to Decawave's published algorithm), Range Status, and the number of milliseconds required to take a measurement.
- Display quality metrics that provide a warning if the reading is suspect.
- Calculate performance statistics. For example, if the user requests a finite number of ranges, the RangeNet GUI will compute the range success rate, the average range, the standard deviation of the range measurements, and the average First Path Power.
- Recalibrate a given link such that the bias or offset inherent in a range measurement can be compensated.

- Allow the user to easily enter and transmit data.
- Allow the user to receive and display data.
- Log all messages exchanged between the Host and connected P330.
- Display range measurements taken between other units in the area for which the connected P330 is not a direct participant.

The ability to log data also allows the user to plot performance as a function of range. This is an excellent tool for evaluating signal propagation in a given area. For example, the information shown in **Figure 2-1** was collected as the distance between two units was increased. Basically, data was logged with one unit held stationary while the second unit was driven away. **Figure 2-1** is a plot of the received signal strength (First Path Power) as a function of separation distance. In this figure one can observe several items of note:

- There is a major Fresnel cancellation at 60 and 130 meters as well as minor ones between 20 and 40 meters.
- The minimum sensitivity of this unit is -105db.

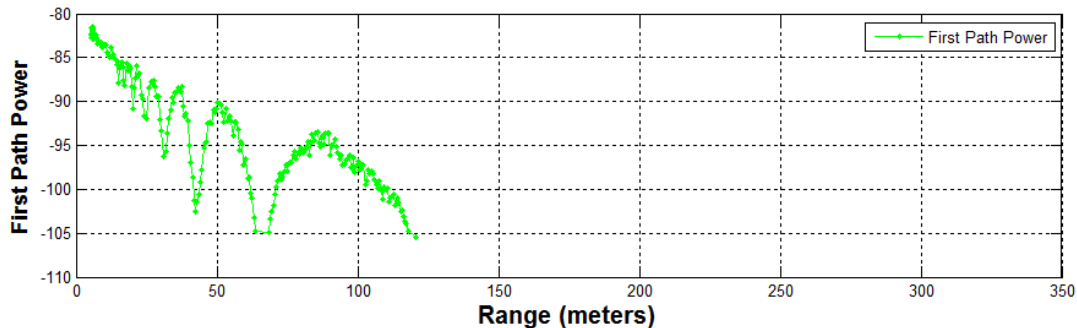


Fig. 2-1: Received signal strength (First Path Power) as function of separation distance.

2.4.2 Networking and Localization with RangeNet

Operating a system that consists of only two units is very simple. Operating with more than two units starts to introduce significant complexity which is increased even further when the need to determine location is added. For example:

- There needs to be a way to prevent units from interfering with each other.
- The number of radios in the system may vary with time. Units that enter the system need to be discovered. Units that exit the system need to be removed from the network.
- Not all units need to behave the same way. Some units might initiate and respond to range measurement requests. Some might only initiate requests. Some might only respond. Some units might only communicate with a subset of the system.
- Before you can convert range into location it is necessary to define a coordinate system and measure the position of anchor (fixed reference) units relative to that system.
- The X,Y,Z location of the references needs to be communicated with all of the anchors.
- Since ranges are taken while a unit is moving, simple trilateration may not produce valid locations. It is therefore necessary to include in the location solving engine a Kalman Filter to both filter out noise and better compute locations.

The RangeNet API allows the user to define a network and to define the behavior of the radios in the system. Operation of the network is controlled by the P330. In particular, the P330 is responsible for scheduling range requests, maintaining all of the neighbors in a database, and passing data between the Host and the network. The Host computer function is thereby limited to monitoring and supervision, thus significantly offloading its responsibilities.

The RangeNet API provides the user with tools to define and monitor the network. For example:

- The network can be defined using two different time-sharing protocols: ALOHA (randomized) or TDMA (Time Division Multiple Access).
- If the ALOHA protocol is used, then the average interval and the random variation of that interval can both be defined. The average interval can be manually or automatically throttled based on the number of units in the system. Radio behavior can be limited on a per unit basis such that some units initiate and respond to range requests, while others initiate-only or respond-only. In addition, some units can be instructed to limit their interactions to a subset of the network members. While most ALOHA networks have an efficiency of 19%, the efficiency of this ALOHA network is approximately 38%, making it equivalent to the performance of a Slotted ALOHA system.
- If the TDMA protocol is used, then the user can define a slot map that provides each radio with instructions on when and to whom and with what parameters it should communicate.
- Because the P330 supports multiple communications channels, it is possible to operate either the ALOHA or TDMA protocol with a CDMA overlay.
- Because the P330 network schedules range requests, it avoids the overhead of Host to P330 communications and can therefore run at a higher ranging rate.
- The P330 network maintains a neighbor database. Besides noting all of the members of the network and their ranges, this database also contains a large body of statistics and other useful information. For example, the database includes received signal strength, approach velocity, effective ranging rate, and signal quality.

The RangeNet API also provides the user with the ability to enable the P330s to compute their location based on ranges generated by the network. This capability does not limit the user's ability to independently construct a Host based localizer.

- The P330 API supports three localization modes: IDLE (awaiting instructions), Autosurvey (anchors use UWB ranging to self locate) and Tracking (P330s compute position in the system and report)
- The API allows the Host to connect to any unit and use that connection to report the location of any unit in the system as well as all of the range measurements taken in the system.
- Based on instructions from the user, the P330 will compute either X and Y locations or X, Y and Z locations, variance and covariance information and report those values through the API.

While these are all powerful network tools, the complexity inherent in this richness can make it difficult to visualize operation through just the API. The RangeNet GUI fills this gap. Not only does the RangeNet GUI allow the user to configure the system, but it also provides a means for easily maintaining different configurations, monitoring results, evaluating the performance of individual links in the network, monitoring the neighbor database, reporting location information and quality statistics from all units in the system. For example, the RangeNet GUI allows the user to:

- Define all types of configuration information (including TDMA slot map, ranging

configuration details, ALOHA setup information, neighbor database characteristics), download it to the P330, store that configuration to disk, and recover from disk any given configuration.

- Monitor the database at whatever update rate the user finds useful.
- Send, receive, and display data.
- Display waveform scans, range measurements and location measurements as well as relevant metrics and statistics associated with a particular links.

While all the functions mentioned so far are performed by the P330 processor and reported to the GUI, additional location related capabilities have been included in the RangeNet GUI. For example:

- The Autosurvey capability has been implemented through the RangeNet GUI. When engaged, the units in the system will be ordered to range to each other and these ranges will be reported to the GUI. The GUI will compute anchor locations until such time that the standard deviation of the location measurements has achieved a user defined threshold.
- Once the locations of the anchors have been defined (either through Autosurvey or manual survey with a laser theodolite) the GUI will then broad cast locations information to all of the units in the system. The P330 based network uses a flooding algorithm to distribute this information through the system and an active confirmation system to verify that the information has been successfully distributed..
- Once the system transitions to Tracking Mode, the GUI will display, in real time, the location of all of the units in the system.
- The GUI also allows the user to define, display and add GPS like waypoints to the system.

2.5 Networking: RangeNet vs. RangeNet Lite

RangeNet Lite is a node-limited version of RangeNet and is intended to allow users to evaluate and test before considering licensing or purchasing the unrestricted version. RangeNet Lite is provided with all Ranging and Localization Development Kits, as well as the PulsON Lab and MegaLab packages. It is node-locked in that the Lite version will support all of the features of RangeNet as long as the system size is limited to 10 nodes or less. More specifically, the first 10 nodes that join the system will operate normally. They can join and leave the network normally, but the 11th unit and all subsequent units will not be recognized by the system. These units will still operate but will likely interfere with the first 10 units and significantly degrade network performance for the first 10 units.

For information on upgrading from RangeNet Lite, please contact Time Domain directly at sales@timedomain.com.

2.6 Software & Hardware Support

Time Domain is committed to maintaining full-featured software support for the hardware platforms. We believe that the success of UWB will be largely determined not by the capability of the hardware but by the richness of the software which drives the hardware. This includes improvements to both the embedded software (where the basic functionality of the UWB technology can be changed) and the API interface (where upper layers can be added).

It is Time Domain's intention to continue increasing the capability of UWB by adding new and

significant software functionality.

For example, consider recent releases:

- 2010 – Ranging capability demonstrated with P400
- 2011 – Monostatic radar functionality added
- 2012 – Ranging performance enhanced
- 2013 – Channel analysis and bistatic / multistatic radar functionality added
- 2014 – RangeNet, a networking capability based on the ALOHA and TDMA protocol, added
- 2015 – RangeNet Lite added
- 2016 - Localization layer added to RangeNet
Support for Decawave DW1000 added to Rangenet

It is Time Domain's intention to continually increase the capability of UWB by adding new and significant software functionality.

3 Hardware Block Diagram

This section provides and discusses at a high level the P330 functional hardware block diagram shown in **Figure 3-1**. Additional detail on the various interfaces is provided in **Section 4**.

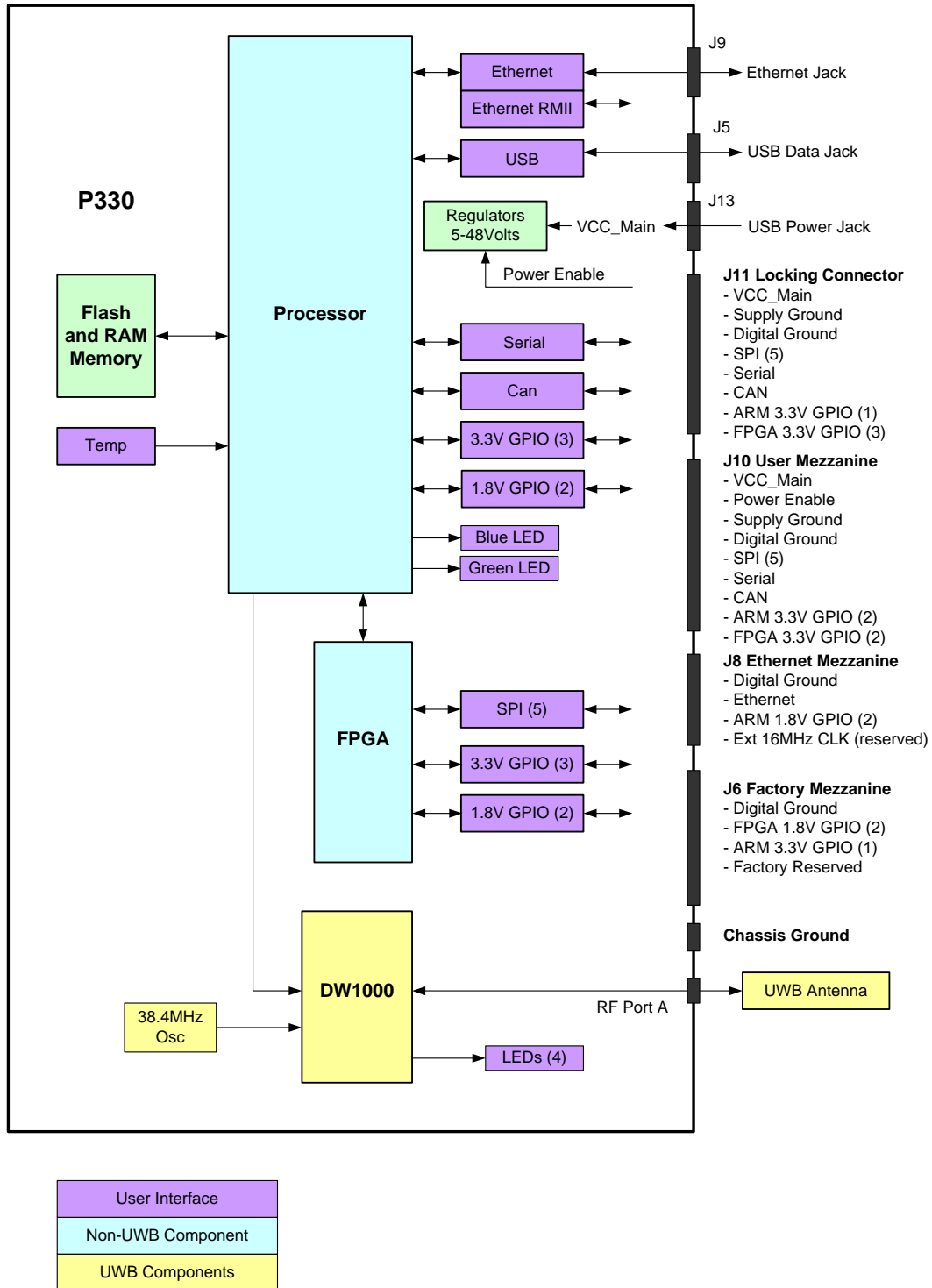


Fig. 3-1: P330 hardware functional block diagram

The P330 requires less than a Watt of power from a DC supply that provides any voltage between 5.5 and 48 volts. This power can be provided through Time Domain's standard external power supply, a battery, or a user-supplied power source. Indicator lights provide operating status information.

The processor monitors and controls the DW1000, initiates range requests, controls the flow of data to and from the DW1000, operates the network, computes locations and handles the interface with the host/user.

The DW1000 is a full UWB transceiver. It transmits and receives packets, sends data, initiates Two Way Time of Flight Range measurements and reports the range measurements as well as several statistics related to the measurement.

The user can interface to the P330 through Ethernet, USB, SPI, Serial, or CAN. Ten GPIO pins are available. If the SPI interface is not used, then these pins can be reassigned yielding an additional five GPIOs for a total of 15.

In addition, the user can request that the P330 report the board temperature.

A variety of means have been provided to physically interface to the P330. These means include two USB connectors, an Ethernet RJ45 connector, a locking connector, and three mezzanine connectors. See **Section 4** for details. The mezzanine connectors are suitable for mating directly with a customer-provided board. Mating mezzanine connectors can be ordered with a variety of mated heights, thereby allowing the user to mount low profile devices on their carrier board underneath the P330. See **Section 5** for details.

4 Electrical Interfaces

This section provides a detailed description of the various P330 electrical interfaces. A standard P330 has the following connections:

- One antenna port
- Communications for Low Speed Serial, USB 2.0, Ethernet, CAN, SPI
- Connections for up to 15 GPIO pins
- Connections for power (5 to 48V), Ground, and Chassis Ground

There are also eight indicator LEDs, six on the board and two on the RJ45 jack.

The physical interface to Communications, GPIO, and Power are through a mix of connectors (see **Figure 4-1**) including the following:

- Three mezzanine connectors
- One locking connector
- One Ethernet RJ45 connector
- Two USB connectors (one power-only, one for data-only)
- Two 0.1" DIP header, (one for the user and one for Factory checkout)

This arrangement provides the user with a maximum of flexibility for evaluating the technology and demonstrating product proofs of concept. This flexibility of course comes with a monetary cost and at some point in time the user will need to consider a stripped down implementation which provides the required performance at a fraction of the cost. For further details on reducing the cost, contact Time Domain directly at sales@timedomain.com.

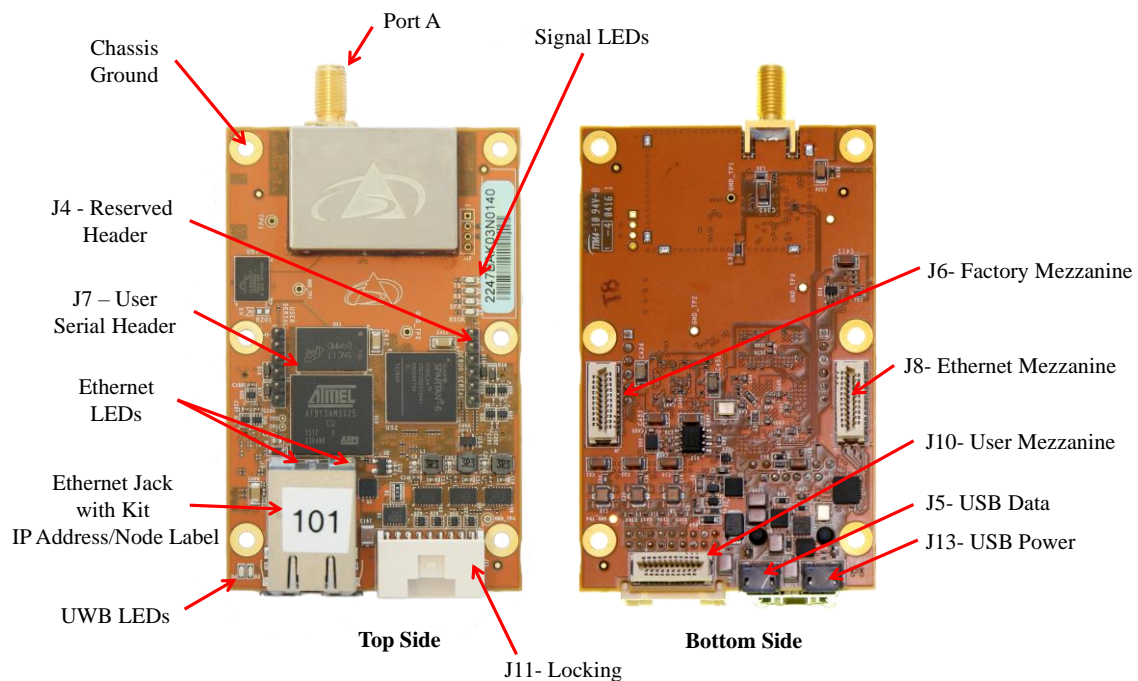


Fig. 4-1: Top and Bottom assembly drawing of the P330 highlighting key interfaces

Finally, the physical interface for the Chassis Ground is through the designated mounting screw hole shown in **Figure 4-1**. (For additional details, see **Section 4.3 – Powering and Grounding the Unit**).

4.1 Connecting to the P330

The user can connect to the P330 in a number of different ways. For example, it is possible to:

- Connect directly to the USB or Ethernet connectors
- Build a special purpose cable and connect through the locking connector
- Mount the P330 on a carrier board and communicate through one or more mezzanine connectors

The following are examples of the electrical connections:

Option 1: USB. The user can connect to the board via the USB Data jack (J5) and power the unit through the USB Power jack (J13).

Option 2: Ethernet. The user can connect to the P330 via the Ethernet RJ45 jack and then power the unit through the USB Power jack (J13). Details on how the Ethernet IP address is assigned can be found in **Section 4.4.5 – Ethernet and IP Addressing**.

Option 3: Locking Connector. The user can use the locking connector to connect via SPI, User Serial, or CAN. This connector also provides power and ground. Details on the pinouts for the locking connector and the part number for mating connector are provided in the following section.

Option 4: User Mezzanine Connector. The User Mezzanine connector supports SPI, User Serial, and CAN. It also provides power and ground. See the following section for details.

Option 5: Ethernet Mezzanine Connector. This connector provides power, ground, and all of the Ethernet MAC signal lines necessary to communicate with the unit. However this requires that the user provide an Ethernet PHY chip on a carrier board.

Several of these connection approaches offer access to the GPIO pins. See the following section for details.

4.2 Connector Pinouts

The pinouts of the various connectors are shown in **Figures 4-2, 4-3, 4-4, 4-5, and 4-6**. The connector pin numbering conventions are shown on **Figures 4-7, 4-8 and 4-9**.

All signal lines are provided with Electrostatic Discharge (ESD) protection (+/- 8 kV contact discharge and +/-15 kV air-gap discharge). The signal line voltage levels are 3.3 Vdc, 1.8 Vdc, or (in the case of CAN) are differential. These inputs are not tolerant to other voltages. Overdriving these lines with too large a voltage or requiring them to source too much current will cause damage to the P330. Please take care to avoid damage. Not only will this compromise or damage the performance of the system but this class of damage is not covered by warranty.

Some of the mezzanine connector pins are marked as “Reserved.” The function of these pins may change with time. If the user intends to mount the P330 on a carrier board, then it is advisable to connect any pin marked “Reserved” to a landing point but to NOT connect the landing point to any other trace on the carrier board.

The part numbers of all of the connectors and their mates can be found in **Section 5 – Mechanicals**.

Finally, it may be useful to clarify the directions associated with the Serial transmit (TX) and receive (RX) lines. “User Serial TX” means transmitted by the P330 to the Host. “User Serial RX” means received by the P330 from the Host. All user serial lines operate at 3.3v.

Pin	Name	Function
1	SPI_MOSI	SPI Master Out Slave In
2	SPI_INT	SPI interrupt
3	SPI_MISO	SPI Master In Slave Out
4	FPGA_GPIO_1_3.3V	FPGA General Purpose IO #1, 3.3VDC
5	Digital Ground	Digital Ground
6	FPGA_GPIO_2_3.3V	FPGA General Purpose IO #2, 3.3VDC
7	SPI_CLK	SPI Clock
8	Digital Ground	Digital Ground
9	SPI_CS	SPI Chip Select
10	User_Serial_TX	User serial transmit
11	ARM_GPIO_0_3.3V	ARM General Purpose IO #0, 3.3VDC
12	User_Serial_RX	User serial receive
13	Supply_Ground	Ground
14	Digital Ground	Digital Ground
15	FPGA_GPIO_3_3.3V	FPGA General Purpose IO #3, 3.3VDC
16	CAN_HIGH	CAN differential high
17	VCC_Main	Input Power
18	CAN_LOW	CAN differential low

Fig. 4-2: J11 - Locking connector

Pin	Name	Function
1	SPI_MOSI	SPI Master Out, Slave In
2	Digital Ground	Digital Ground
3	SPI_MISO	SPI Master In, Slave Out
4	SPI_INT	SPI interrupt
5	Digital Ground	Digital Ground
6	FPGA_GPIO_1_3.3V	FPGA General Purpose IO #1, 3.3VDC
7	SPI_CLK	SPI clock
8	FPGA_GPIO_2_3.3V	FPGA General Purpose IO #2, 3.3VDC
9	SPI_CS	SPI Chip Select
10	Digital Ground	Digital Ground
11	ARM_GPIO_0_3.3V	ARM General Purpose IO #0, 3.3VDC
12	User_Serial_TX	User serial transmit
13	Digital Ground	Digital Ground
14	User_Serial_Rx	User serial receive
15	ARM_GPIO_1_3.3V	ARM General Purpose IO #1, 3.3VDC
16	Digital Ground	Digital Ground
17	Power_Enable_H	Signal line to enable/disable on-board regulators. This allows the user to turn power to the board on and off with a single digital control line. 0-2.1Vdc = off, 2.1Vdc to VCC_Main = on
18	CAN_HIGH	CAN differential high
19	Supply_Ground	Ground
20	CAN_LOW	CAN differential low
21	VCC_MAIN	Input power (4.5 to 48v)

Fig. 4-3: J10 – User Mezzanine connector

SPI users should take note that the SPI interrupt line is pin 4 on the User Mezzanine and pin 2 on the locking connector.

Pin	Name	Function
1	Digital_GND	Digital Ground
2	E_Rx1	Ethernet Rx1
3	E_Rxer	Ethernet Rxer
4	E_TxEn	Ethernet TxEn
5	E_Tx0	Ethernet Tx0
6	Digital_GND	Digital Ground
7	E_Tx1	Ethernet Tx1
8	E_CrsDv	Ethernet CrsDv
9	Digital_GND	Digital Ground
10	E_TxCk	Ethernet TxCk
11	E_Rx0	Ethernet Rx0
12	Digital_GND	Digital Ground
13	E_MDIO	Ethernet MDIO
14	E_MDC	Ethernet MDC
15	Digital_GND	Digital Ground
16	Digital_GND	Digital Ground
17	ARM_GPIO_0_1.8V	ARM General Purpose IO #0, 1.8VDC
18	ARM_GPIO_1_1.8V	ARM General Purpose IO #1, 1.8VDC
19	Digital_GND	Digital Ground
20	Digital_GND	Digital Ground
21	Ext_16MHz_In	Reserved

Fig. 4-4: J8 – Ethernet Mezzanine connector

Pin	Name	Function
1		Reserved
2		Reserved
3		Reserved
4		Reserved
5	Digital_GND	Digital Ground
6	Digital_GND	Digital Ground
7		Reserved
8		Reserved
9		Reserved
10		Reserved
11	Digital_GND	Digital Ground
12	FPGA_GPIO_1_1.8V	FPGA General Purpose IO # 1, 1.8VDC
13		Reserved
14		Reserved
15		Reserved
16		Reserved
17		Reserved
18	FPGA_GPIO_0_1.8V	FPGA General Purpose IO #0, 1.8VDC
19		Reserved
20	ARM_GPIO_2_3.3V	ARM General Purpose IO #2, 3.3VDC
21	Digital_GND	Digital Ground

Fig. 4-5: J6 – Factory Mezzanine connector

The Factory Mezzanine connector has a number of GPIO pins and grounds which the user is free to use. However the remaining lines are NOT available for use. All of these lines are active and are used by the factory to test the unit as it moves through production. This connector can be used by the customer but it is critical that the reserved pins should never be connected to any signal, ground, or power lines. This can result in extreme damage to the unit.

Pin	Name	Function
1	Digital_GND	Digital ground
2	No Connection	Reserved
3	No Connection	Reserved
4	User_Serial_RX	User serial receive
5	User_Serial_TX	User serial transmit
6	No Connection	Reserved

Fig. 4-6: J7 – User Serial 0.1” Header

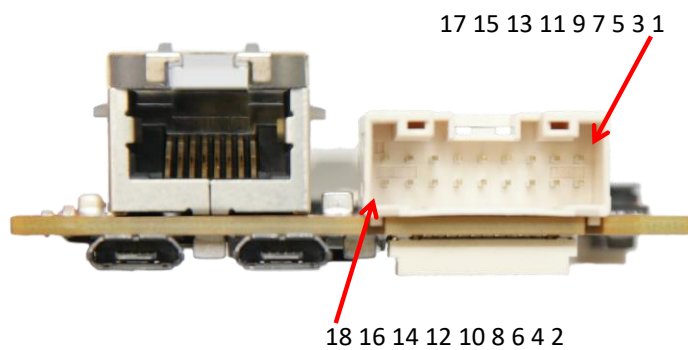


Fig. 4-7: J11 Locking connector pinouts

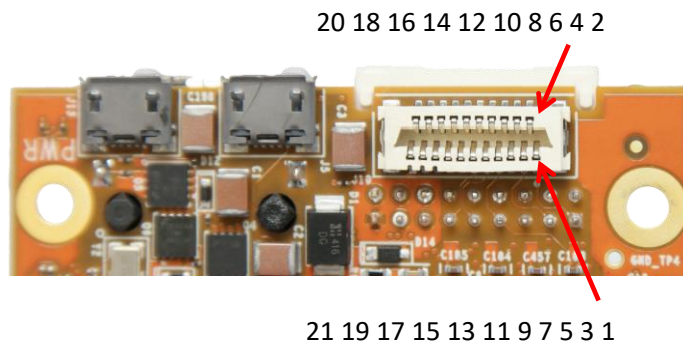


Fig. 4-8: J10 Mezzanine connector pinouts



Fig. 4-9: J7 User Serial pinouts

4.3 Powering and Grounding the Unit

4.3.1 Powering the P330 through the USB Power Jack vs Locking & Mezzanine Connectors

The P330 can be powered in three different ways: through the USB power jack, through the Locking Connector or through the mezzanine connectors. The user should select one and only one means of powering the unit. While it is physically possible to power the unit through all three means simultaneously, this is a very bad practice and should be avoided. Connecting multiple power sources at different voltages can result in damage.

Two different Grounds are provided: Digital Ground and Supply Ground. In principle Digital Ground should be used for signal lines and Supply Ground should be used for main power ground. In practice, the main value of the multiple ground lines is to guarantee a low impedance path to ground.

4.3.2 Reverse polarity protection

The power input (VCC_Main) is reverse polarity-protected and can be driven by any voltage between 5.0 and 48 volts.

4.3.3 Two means of Powering the P330

There are two techniques for supplying power to the P330. One can connect and disconnect the power connectors or one can power the board continuously and use the Power_Enable_H pin on the J10 User Mezzanine connector to turn on and off the P330 main power regulators. This capability gives the user the opportunity to do a hard reboot of the P330 board without needing to physically break a supply connection.

4.3.4 Chassis Ground

The P330 is provided with a chassis ground through one of the six mounting holes. Each of the six mounting holes is copper plated on the top, bottom, and inside of the hole. The mounting holes are not covered with silk screen. These holes are not connected to any ground planes or signals of any sort. The one exception to this rule is connected to Digital_Ground through the parallel combination

of a 0.01 μ F capacitor and 1.0 MegOhm resistor. This mounting hole provides the Chassis Ground. The position of this hole is shown in **Figure 4-1**.

4.4 Host to P330 Interface Options

The P330 supports five different host interfaces: USB, Serial, SPI, Ethernet, and CAN. This wide choice of interfaces provides the user with the freedom to experiment with and to optimize for their specific application the means by which the overall system (P330 plus the user Host) communicates. The characteristics of these interfaces are summarized below. For information on pin assignments see **Section 4.2 – Connector Pinouts**.

The protocol used to communicate with the P330 is fully defined in the Time Domain RangeNet API Specifications, various C and MATLAB examples, and in the document “*Using the USB and Serial specifications*”. All of these resources are provided on the delivery disks and are also available on the Time Domain website, www.timedomain.com.

4.4.1 USB 2.0 High Speed Device

The P330 supports USB 2.0 High Speed Device connection through the USB Data microUSB jack (J5). When connecting through J5 it is important to remember that this jack only provides the data communications lines to the P330. To power the board, the user should apply power to the board either through the USB Power microUSB jack (J13), through the locking connector (J11) or through pin 21 on the User Mezzanine connector.

The maximum data rate for the USB is 480 Mbps. However, the maximum effective throughput will be limited by many factors, including the speed of the Host computer, the specific implementation of the USB driver, processing overhead at the P330, and processor overhead at the Host computer. The effective transfer rate is on the order of 5-10% of the maximum data rate.

4.4.2 User Serial

The User Serial interface is RS-232 Universal Asynchronous Receiver/Transmitter (UART) Serial link operating at 3.3V TTL logic levels. The maximum speed of the interface is 115.2 kbps. Lower rates of 9.6, 19.2, 38.4, and 57.6 kbps are also supported. The default rate is 115.2 kbps.

However, the maximum rate is largely a function of the ability of the system to drive the cable capacitance. If a shorter cable is used or if the user provides an external line driver, then the communications rate can be increased by factors of 2 up to 921.6 kbps. Operation at these higher ranges is also limited by the serial interface circuit on the user-provided Host computer. The maximum length of cable must be determined empirically. Time Domain has found that a cable length of 1 foot (30 cm) or less will support the 460.8 kbps rate quite reliably.

User Serial is provided on the Locking connector (J11), the User Mezzanine connector (J10), and the User Header (J7).

The Serial interface uses 3.3 volt logic. Do not connect 5 volt serial cables to the P330. In fact, do not connect any serial cables that operate at greater than 3.3 volts. The increased voltage will physically damage the P330.

While most users will connect to the serial port through either J11 or J10 doing so requires the construction of a dedicated cable or interface. To use the serial interface directly, the user can connect directly to J7 using a standard cable available from a number of sources including the following:

- FTDI (part number TTL-232R-3v3) or
- Digikey (part number 768-1015-ND www.digikey.com).

4.4.3 SPI

The SPI interface is designed to operate at a maximum clock rate of 16.0 MHz with signals operating at 3.3V TTL levels. The actual throughput of the link is limited by the various communications overheads. However, transfer rates of 6-7 Mbps have been achieved using an un-optimized system.

The SPI interface allows the user to control the P330 with a co-located single board computer. Since the operating speed of the link is subject to noise and line capacitance, the length of the SPI wiring should be kept as short as possible. When operating the SPI interface at a maximum rate of 16Mhz, the cable length should be no longer than a few inches (10-15cm). The exact length needs to be confirmed empirically. If, for a given length of cable, the link experiences communications problems, then the user should reduce the SPI clock rate.

The SPI port consists of five signals. Four of these are the typical SPI signals: CLK, CSn, MOSI, and MISO, each with a 100k pull-up resistor to 3.3 V. The fifth signal (INT) is active-high and is used to indicate that data exists in the slave output FIFO. The INT signal does not have a pull-up resistor and is not driven during initial power-up. The signals are illustrated in **Figure 4-10**. The SPI slave RX and TX FIFOs are 4k x 8.

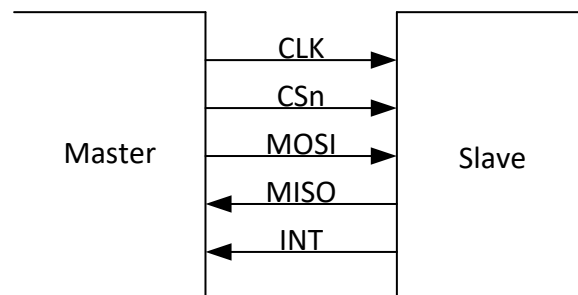


Fig. 4-10: SPI interconnect signals

The SPI port uses 8-bit bytes sent MSb first. The CLK idle state is high. The data is propagated on the falling-edge (leading-edge) of clock and sampled on the rising-edge (trailing-edge) of clock as shown below in **Figure 4-11**:

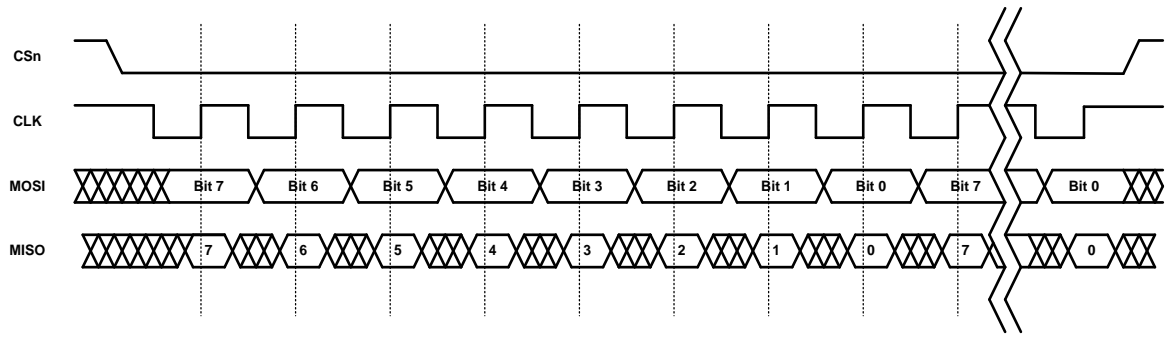


Fig. 4-11: Signaling timing diagram

The master drives the SPI chip-select low (CSn in above figure) and shifts an 8-bit command, possibly followed by data. The first bit (MSb) of a command is always set. If the second bit is set, then it is a read command, otherwise it is a write command. The commands are listed below in **Figure 4-12**. The chip-select must stay active-low for the entire transaction, which is required to be on 8-bit boundaries. This and other timing diagrams are shown in **Figure 4-13**. Timing constraints are shown in **Figure 4-14**.

Command	Function	Command Format	Response Format
0x80	Write to slave input FIFO	Command followed by data	N/A
0xC0	Read from slave output FIFO	Command	Slave output FIFO data
0xC2	Read slave output FIFO byte count	Command	Two bytes: MSB followed by LSB

Fig. 4-12: SPI command structure

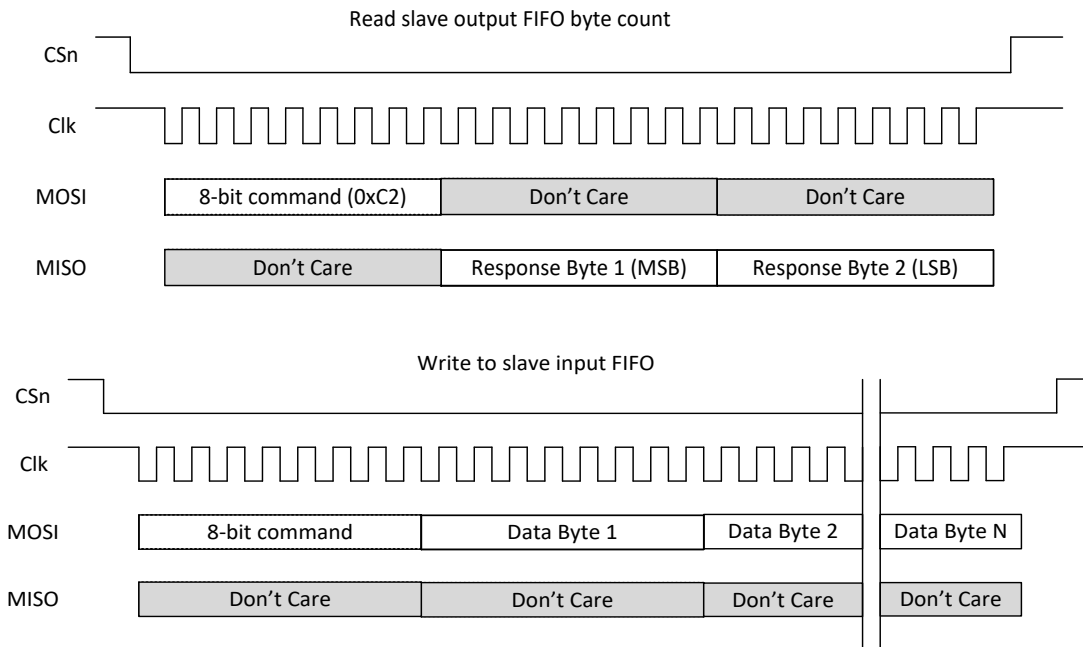
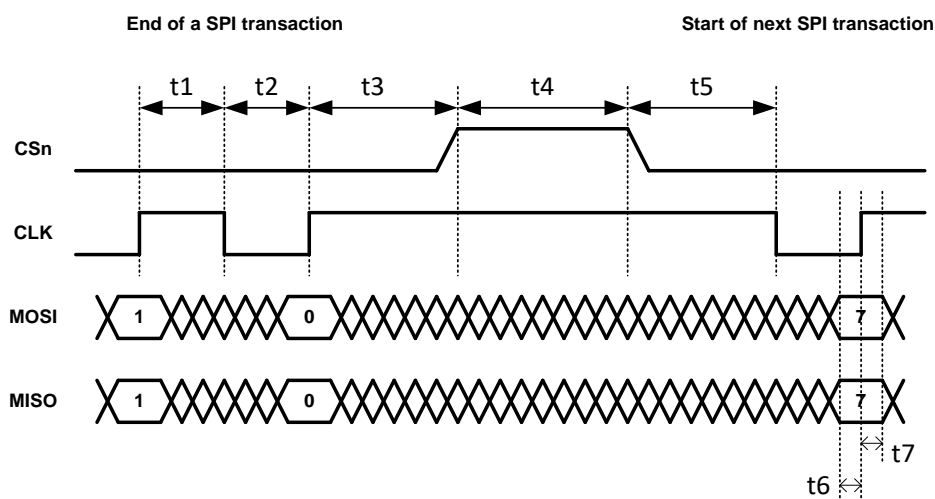


Fig. 4-13: Timing diagrams



Timing	Function	Minimum
t1	CLK high to CLK low (high pulse)	30 ns
t2	CLK low to CLK high (low pulse)	30 ns
t3	CLK rising-edge to CSn rising-edge (inactive)	50 ns
t4	CSn rising-edge (inactive) to CSn falling-edge (active) or time between transactions	60 ns
t5	CSn falling-edge (active) to CLK falling-edge	50 ns
t6	Data setup to CLK rising-edge	12 ns
t7	Data hold from CLK rising-edge	12 ns

Fig. 4-14: Timing constraints

4.4.4 Ethernet and IP Addressing

Ethernet 10/100 is provided either through the standard Ethernet RJ45 Jack or as Ethernet RMII signal lines through the Ethernet Mezzanine Connector (J8). As such, the RMII signals cannot be interfaced to directly. The user must provide a carrier board and an Ethernet PHY chip. The PHY chip should be configured for Address 1.

The communications rate through this interface is limited not only by the Ethernet 10/100 protocol but also by the processing capability of the connected computer and various system overheads.

The IP address of a unit is assigned in one of two ways. If the P330 came as part of a Development Kit then the IP addresses will be set at the factory to 192.168.1.x, where “x” is indicated on a label mounted on the P330’s RJ45 jack. If the P330 was ordered as an “Industrial Module” then the IP address is normally set to 192.168.1.100. The RangeNet GUI gives the user the ability to change the IP address or to select the Dynamic Host Configuration Protocol (DHCP). Upon special request and in conjunction with volume orders, Industrial Modules can alternatively be shipped using DHCP.

As a side note, the Node ID of the P330 is set in a similar fashion. If the P330 came as part of a Kit then the Node ID will be set to “x.” If the P330 came as an Industrial Module, then the Node ID is set at the factory and can be determined through the API or the RangeNet GUI provided with the system. When using the GUI, the Serial Number shown on the Status Info Tab will be identical in value to the Node ID. However, the Status Info Tab shows the value in hexadecimal while the Node ID is shown in decimal.

Instructions on how to connect to the P330 via Ethernet or change the IP address and Node ID are provided in the documents *320-0338 P330 RangeNet User Guide*.

4.4.5 CAN

The CAN interface is provided with a TI SN65HVD231 CAN line driver. That driver provides a 5 volt differential signal. For additional details on the driver, a link is provided to the TI part. The maximum data rate is 1 Mbps. <http://www.ti.com/lit/ds/symlink/sn65hvd231.pdf>

Time Domain's application note *320-0326 CAN Interface Application Note* provides additional information on the software interface. This document is available on the Time Domain website.

4.4.6 Detection of Failures

When the P330 is powered, it will boot and execute a series of self-diagnostic checks. This process takes approximately 10 seconds. At the end of this process the unit will respond to commands issued by the Host. If the unit has failed to boot, then there will be no communications. If the unit has failed self-diagnostics, it will set the "BIT Results" parameter to a non-zero number and attempt to function normally. "Attempting" to function normally does not guarantee that the unit will actually function properly. Therefore, it is a good practice for the Host computer to initiate communications with the P330 by first checking the BIT Results. (This is accomplished with the Status Info Message. See the API for details.) If the returned parameter is not zero, the unit should be power-cycled.

4.5 GPIO

The P330 has fifteen user-definable general purpose input/output (GPIO) pins. Most of these pins operate on 3.3 Vdc but there are several that operate at 1.8 Vdc. Approximately half come from the ARM processor and the remaining ones are connected to the FPGA. These pins can be defined as inputs, outputs, or as having a special function. The SPI pins are special function pins. If the user chooses not to use the SPI interface, then the SPI pins can be reallocated for general use. The state and direction of these pins are controlled through the software API.

GPIO output pins can be used to source 1mA of current per pin. Do not exceed this limit. Exceeding this limit will damage the P330.

The GPIO pins are not associated with a specific connector but are instead distributed through the various connectors. Some GPIO pins are available from multiple connectors. **Figure 4-15** lists the various GPIO pins and their associated connector and pin number.

As of this date, there is currently no software support (i.e. API commands) for controlling the state of the GPIOs. Similarly, the function of the SPI lines is currently fixed such that these lines can only be used for SPI. Time Domain expects to provide expanded support for GPIOs in an upcoming software release.

J11 - Locking	1	SPI_MOSI
	2	SPI_INT
	3	SPI_MISO
	7	SPI_CLK
	9	SPI_CS
	4	FPGA_GPIO_1_3.3V
	6	FPGA_GPIO_2_3.3V
	11	ARM_GPIO_0_3.3V
15	FPGA_GPIO_3_3.3V	
J10 - User Mezzanine	1	SPI_MOSI
	3	SPI_MISO
	4	SPI_INT
	6	FPGA_GPIO_1_3.3V
	7	SPI_CLK
	8	FPGA_GPIO_2_3.3V
	9	SPI_CS
	11	ARM_GPIO_0_3.3V
15	ARM_GPIO_1_3.3V	
J8 - Ethernet Mezzanine	17	ARM_GPIO_0_1.8V
	18	ARM_GPIO_1_1.8V
J6 - Factory Mezzanine	12	FPGA_GPIO_1_1.8V
	18	FPGA_GPIO_0_1.8V
	20	ARM_GPIO_2_3.3V

Fig.4-15: GPIO and associated connector and pin locations

4.6 Antenna Port

The P330 has one antenna port. It is designated as Port A. The connector used is a standard polarity female SMA connector (Digi-Key part number J801-ND).

When connecting the port to an SMA cable or antenna, be careful not to overtighten the connection. This can cause damage to the board. Beware of loose connections. They can degrade performance. As long as the connectors are “finger-tight,” the system will work well. To insure an optimal connection, the user should use a calibrated SMA torque wrench. They cost <\$100.

The P330 is intended to be used with Time Domain’s Broadspec antenna. Using any other antenna will require recertification to confirm compliance with the relevant emissions regulations. However, it is possible to add passive extension cables between the antenna port and the antenna. Be aware that using alternate UWB antennas, additional fixed attenuators, additional cabling and/or connectors will 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 a bias error in range measurements.

4.7 RF Transmit and Receive Characteristics

The RF transmit and receive characteristics are determined by the Decawave DW1000 chip. Given that, the most logical source of detailed technical information on the DW1000 can be found in the documents DW1000 User Manual and DW1000 Data Sheet. While these data sheets are posted on the Time Domain website, the best place for the most recent information is on the Decawave website.

However, the DW1000 has a great many different settings. Since the standard was developed largely before regulations were put in place, some of these settings are either unwise to use or offer marginal utility. For example, some of the RF Channel band edges fall outside the legal limits. If used,

designers must add filtering to bring transmissions within legal limits. Furthermore, one of the high band channels overlaps with 5.8 GHz making its use dependent on the absence of ubiquitous 1 watt, 5.8GHz WIFI. Also, the 900MHz bands offer little improvement over the 500MHz channels.

Therefore the P330 limits operation of the DW1000 chip to the 20 combinations shown in **Table 4-1**.

Combinations	RF Channel	PRF	Data Rate	Preamb Length	Preamble Code
1	2 (4.0/500MHz)	16	110	1024	3 or 4
2	2	16	850	256	3 or 4
3	2	16	850	512	3 or 4
4	2	16	850	1024	3 or 4
5	2	16	6.8	128	3 or 4
6	2	64	110	1024	9,10,11,12
7	2	64	850	256	9,10,11,12
8	2	64	850	512	9,10,11,12
9	2	64	850	1024	9,10,11,12
10	2	64	6.8	128	9,10,11,12
11	5 (6.5/500MHz)	16	110	1024	3 or 4
12	5	16	850	256	3 or 4
13	5	16	850	512	3 or 4
14	5	16	850	1024	3 or 4
15	5	16	6.8	128	3 or 4
16	5	64	110	1024	9,10,11,12
17	5	64	850	256	9,10,11,12
18	5	64	850	512	9,10,11,12
19	5	64	850	1024	9,10,11,12
20	5	64	6.8	128	9,10,11,12

Table 4-1: DW1000 configurations supported by the P330.

These setting combinations are all in compliance with both the FCC and EU (ETSI) regulations. The user has access to one additional DW1000 control and that is the transmit power. If the user accepts the default P330 settings then the transmit power will be at or, slightly below, the regulatory limit. The user also has the ability through the P330 API or GUI to set the transmit power up to 10db below or above the regulatory limit. There are no issues with setting the transmit lower than the regulator limit. Setting the transmit power to greater than the default value is useful in overcoming cable or antenna losses and can be useful for development and evaluation purposes. However, using a higher value (or using a different cabling or antenna combination) in a final product without recertification for compliance with the regulations is expressly forbidden.

Of these, we have found that combinations highlighted in yellow are the most useful. They support the largest number of communications channels and offer either the fastest ranging rate or the longest operating range in both the high and low bands.

While Time Domain has found these 20 to be the most useful, we are open to increasing the number of combinations supported if a compelling reason can be made for such additions.

4.8 Indicator Lights

The P330 is provided with eight indicator LEDs. See **Figure 4-1** for exact locations. The following is an explanation of the LED functions.

Ethernet LEDs (located on the back of the RJ45 connector)

- Green: Lit indicates operation at 100 Mbps, off means the link is operating at 10 Mbps.
- Yellow: Lit indicates the link is available, flashing indicates activity, and off means no link.

UWB LEDs (located adjacent to the RJ45 connector)

- Blue (Built in Test – BIT): flashing slowly (approximately 0.5 Hz) indicates that the unit is operating normally. Flashing quickly (approximately 10 Hz) or solidly on or solidly off indicates a failure.
- Green (UWB activity): Toggles (if off, turns on – if on, turns off) as follows:
 - On initiation of a Range or Network Request packet transmission
 - On initiation of a Range or Network Response packet transmission
 - On initiation of a Range or Network Data packet transmission
 - On initiation of a Network Beacon transmission

The following is a description of the LED activity when the unit powers up. When power is applied to the P330, the Green UWB LED will turn off and the Blue LED will turn on. The Blue LED will stay on for approximately 8 seconds. During this time, the unit will boot and execute a Built in Test (BIT) of the system. Once the unit has successfully booted and has passed BIT, then the Blue LED will blink approximately every 2 seconds. Any behavior other than what is described above should be considered to be a fault.

DW1000 LEDS (located adjacent to the barcode)

These LEDs (TX, RX, SFD and RXOK) are copied from and provide the same functions as the signal LEDS found on the Decawave EVK. They have been included for the convenience of those users familiar with operation of the EVK.

4.9 Heat Management

The P330 consumes approximately 1 watt. While this isn't very much power, this energy is sufficient to warm the board. In some extreme cases, this can cause issues. For example, if the board is operated in a sealed enclosure, in a high ambient temperature, with solar heating then the resulting thermal rise can raise the board temperature above its rated limit.

The P330 is equipped with a built in temperature sensor which will report the board temperature. The user should monitor this temperature sensor and insure that the unit is not operated in excess of the maximum rated temperature.

The following examples are provided to illustrate the effect of self heating on temperature rise.

Case 1: Ambient 23°C, bare P330 sitting on a table in still air. Board Temp: 34°C

Case 2: Ambient 23°C, P330 mounted in Time Domain enclosure accessory. Board Temp: 38°C

4.10 Accessories

When the P330 is ordered as part of a Development Kit, it is provided with a number of accessories. These accessories include: a custom plastic enclosure, a power supply, USB battery and cabling and antenna. Units shipped outside the US are typically provided with a power plug adapter to ensure compatibility with the user's AC power plugs. This is illustrated in **Figure 4-16**.



Fig. 4-16: P330 with full set of accessories

4.10.1 Enclosure

The enclosure is intended to provide a modest level of protection for the boards. The primary goal is to avoid damage from light handling, accidental drops on the floor, coffee spills, and the like. The enclosures also make it easy to safely and conveniently take measurements in buildings and outdoors. The enclosures are NOT waterproof or rain proof. A photo of the enclosure is shown in **Figure 4-17**. Note that underneath the enclosure are 4 rubber feet which conceal four 4-40 (not metric) mounting holes. Those holes are suitable for attaching the unit to a fixed object.



Fig. 4-17: P330 in standard enclosure (left) and view of enclosure bottom showing feet and mounting holes for 4-40 screw

4.10.2 Power Supply/Charger with Battery and Cables

P330s provided with Kits and Labs are normally powered through the USB Power jack. The easiest (but not most reliable) way to communicate to the P330 is through the USB Data jack. Accordingly, Time Domain provides each P330 with a USB Power Supply/battery charger, two USB cables (1.8 m for communications and 15 cm for supplying power) and at least a 4000mAh USB battery. (USB batteries change model numbers and capabilities almost continuously. As a result, the battery provided with your kit may not be described in this data sheet, but it will drive the unit and supply at least 4000mAh.

Power supply: The power supply is intended for use with the standard North American wall plugs. For units shipped outside North America, the power supply is also provided with an interface plug (see **Figure 4-18**). Every attempt is made to provide an adapter compatible with the end user's power system, but this cannot be guaranteed. Please indicate your preference when ordering your equipment.



Fig. 4-18: USB Power Supply and interface plug

Cables: The 1.8 m (6 ft) cable is a standard USB cable and can be used to power the unit or communicate through the USB data port. The 15 cm (6 in) cable is intended to connect the unit to the USB battery but it can also support USB data communications.

In principle, there is nothing special about these components and they are almost universally available. The user is free to provide substitutes and replacements for units that are lost or damaged. While Time Domain does stock the USB battery all of these components are available on the web from a variety of sources. **Table 4-2** shown below provides source information for these components. Where possible it includes specific suppliers and part numbers. Entering the product description into your favorite internet search engine will lead you to any number of suppliers.

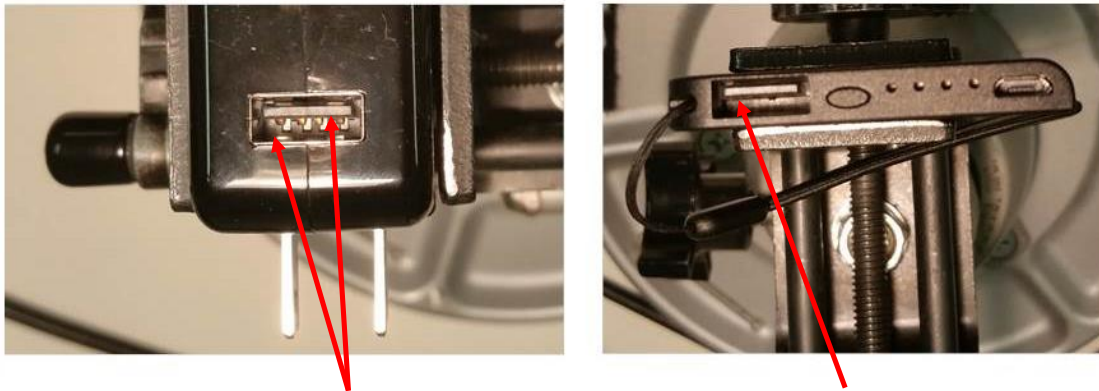
Description	Searchable description	Source and part number
USB battery	AFENDO 4000mah External Portable Rechargeable Battery	
6 ft/ 1.7 m USB cable	6ft USB 2.0 A Male to Micro 5pin Male 28/28AWG Cable	Monoprice product number 12002
6 in /15 cm USB cable	Premium USB to Micro USB Charge & Sync Cable 0.5 ft –Black	Monoprice Product Number: 4868

Charger/supply	Anker 10W (2A) Home and Travel USB Wall Charger Adapter	
----------------	---	--

Table 4-2: Accessory source information

WARNING: In practice, USB devices are not provided with a uniform level of quality. The devices listed above work well and are recommended. The same cannot be said about other USB devices. Some suppliers of cables use undersized wiring that is so small that it is not capable of providing sufficient power to the P330s. Some produce power with a great deal of ripple. We have even seen outputs with 1v spikes on a 5 volt signal! This is not acceptable for driving the P330s.

Some batteries and power supplies have very poor connectors. These connections are so flimsy that they provide power only intermittently. Consider the devices shown in **Figure 4-19**. The connector on the left provides a high quality connection with multiple contact points. The one on the right has few contact points and will cause endless problems. Nothing will ruin a multiday measurement campaign more completely than a few cheap, worthless USB cables and connections.



Two sets of pins guarantee a good connection

Nothing to insure a proper connection

Fig. 4-19: Superior connections (left) and inadequate product (right)

When providing power from USB devices do NOT use USB extension cables. There is sufficient voltage drop across these cables that they will not provide sufficient power to drive a P330.

5 Mechanical Interface

Figures 5-1, 5-2, 5-3, 5-4 and 5-5 provide the information which defines the board size, the height of key components, as well as the location and dimensions of all connectors. Dimensions are shown in British Imperial units (inches). Dimensions shown in [brackets] are in metric (millimeters). Table 5-1 lists the part numbers of all connectors and their respective mating pair.

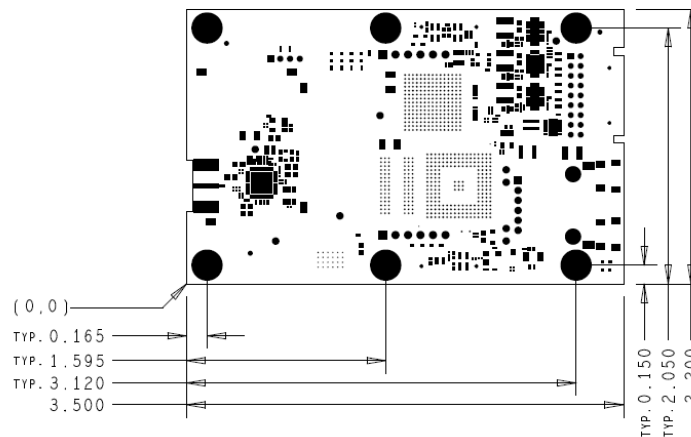


Fig. 5-1: P330 board dimensions

The six mounting holes have an inside diameter of 0.125 inches (3.175 mm) and are sized for a #4 screw. The pads have an outside diameter of 0.250 inches (6.35 mm). The minimum distance between the center of the hole and the closest component or circuit trace is 0.140" (3.556 mm).

It is anticipated that the number of mounting holes, size of the holes and placement separations are sufficient to satisfy most vibration requirements. Several customers have already satisfactorily tested the vibration performance of the P330 in extremely challenging end applications.

The P330 board is built to IPC Class 2 standards. The tolerances associated with hole size and centering are consistent with this standard.

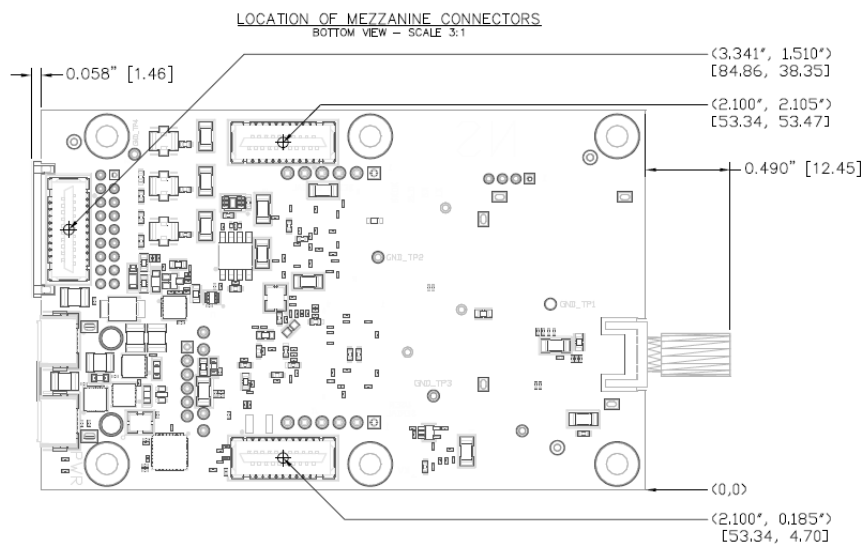


Fig. 5-2: Locations of Mezzanine connectors

DRAFT

Shown in **Figures 5-2 and 5-3** are all of the parts which extend out beyond the board dimensions. This includes the RF SMA connectors, the Locking connector, the USB micro connectors, and the RJ45 jack.

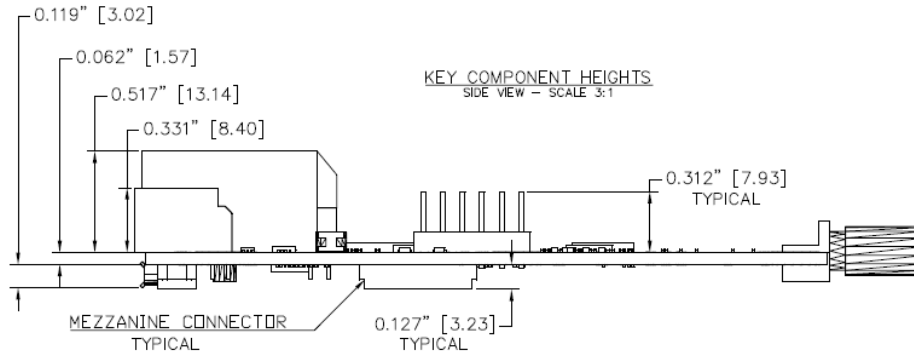


Fig. 5-3: Components which limit vertical height

When the P330 is mounted on a carrier board, the designer should be careful not to place any components within 0.125" (3.17 mm) of the bottom of the board. This is a keep-out area and it is reserved for components on the bottom side of the P330 board. Note that mating parts for the mezzanine connectors are available with different lengths. By selecting a suitably tall mating connector, the user can accommodate a wide variety of parts under the P330 without compromising the keep-out area.

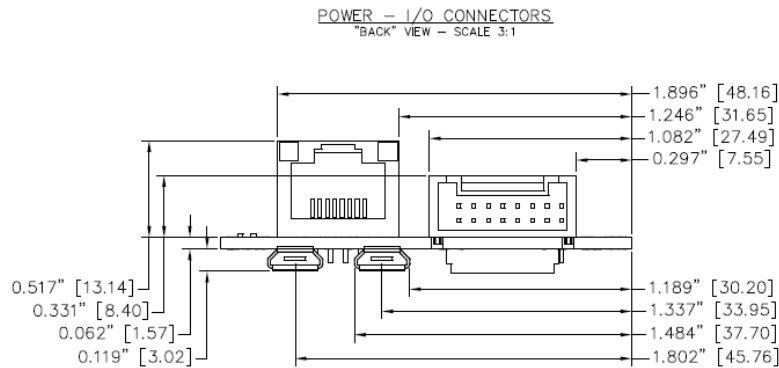


Fig. 5-4 Locations and dimensions of Power and I/O connectors at the rear of the P330

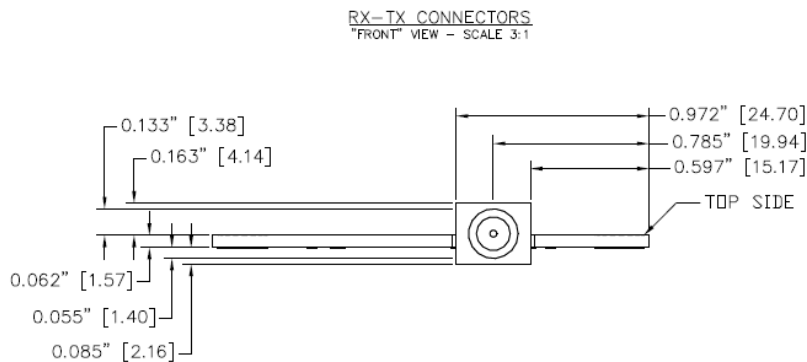


Fig. 5-5: Location and dimensions of RF SMA connector

The part numbers for the P330 connectors and their mating pair are shown in **Table 5-1**.

Name and Number	P330 Connector Part Number	Mating Connector Part Number
J2 - SMA Port A	Cinch Connectivity# 142-0701-871, Digikey# J610-ND	Many different choices. *
J5 - USB Data	FCI# 10103594-0001LF, Digikey# 609-4050-1-ND	Many different choices. *
J6 - Factory Mezzanine	FCI# 91931-31121LF, Digikey# 609-3520-2-ND	FCI# 91911-31321LF, Digikey# 609-3424-2-ND
J7 - User Header	3M# 961106-6404-AR, Digikey# 3M9451-ND	Many different choices. *
J8 - Ethernet Mezzanine	FCI# 91931-31121LF, Digikey# 609-3520-2-ND	FCI# 91911-31321LF, Digikey# 609-3424-2-ND
J10 - User Mezzanine	FCI# 91931-31121LF, Digikey# 609-3520-2-ND	FCI# 91911-31321LF, Digikey# 609-3424-2-ND
J11 - Locking	JST Sales America: S18B-PUDSS-1(LF)(SN), Digikey# 455-2490-ND	JST Sales America: PUDP-(18)V-S, Digikey# 455-2473-ND
J13 - USB Power	FCI# 10103594-0001LF, Digikey# 609-4050-1-ND	Many different choices. *

Table 5-1: Connector part numbers

* These are standard SMA, USB, or 0.1” headers, for which the user has a very large number of choices. The right choice is application-specific. Fortunately, there is an option for almost every conceivable application.

6 Technical Specifications

6.1 Summary of Key Performance Parameters

Table 6-1 summarizes the P330 specifications and key performance parameters. For additional detail on the performance of the DW1000 UWB chip see Decawave's DW1000 User Manual and Data Sheet. Note that the P330 uses a subset of the DW1000 RF channels. For a discussion on which channels were implemented see Section 4.7 RF Transmit and Receive.

P330 Specs	Value
Physical Parameters	
Board Dimensions (without SMAs):	3.5 x 2.2 inches (89 x 56 mm)
Assembly height (bottom to top connectors):	0.703 inches (17.9 mm)
Weight:	1.6 ounces (45 grams)
Storage Temperature:	-40°C to 85°C
Operating Temperature range: Industrial units:	-40°C to 85°C
Max allowable board temperature:	85c as reported by on board temp sensor
Humidity:	Up to 95%, non-condensing
Vibration:	Designed to meet most vibration specs. Existing customers have already tested the P330 for operation in extreme vibration environments.
Power & Ground & Boot Times	
Input Power Range:	5.0 V to 48 V DC
Input Power Ripple:	100 mV pk-pk
Power Protection:	Reverse voltage
Electrostatic Discharge Protection:	+/-8kV contact discharge and +/-15kV air-gap discharge
Chassis Ground:	Available. See Section 4.3.4 for details
Time from power on to completion of boot:	11 seconds (no cables connected, with Serial connected or USB connected, or no cables connected) 7 seconds (Ethernet connected)
Minimum time the power must be turned off to force the processor to reboot:	1 second
Power & Temperature when Operating as a Ranging Radio	
Typical Power Consumption (board temp 40°C, Vin= 5.0 V with state transition times shown)	
- Active (transmitting)	1.0 Watts
- Active (receiving)	1.0 Watts
- IDLE, Standby_E, Standby_S	0.5 Watts (Enter: 1.2 ms, Exit: 1.2 ms)
Operating Temp at ambient 23°C: - On flat surface, receiving, no air	34°C (11° over ambient)

circulation - In Time Domain standard enclosure	38°C (15° over ambient)
User Interfaces/Devices	
USB:	USB 2.0 Client – Micro-B connector Maximum rate: 480 Mbps See Section 4.4.2 for more details
Serial:	3.3V TTL Serial UART (8, n, 1) 115.2kbps (typical) 921.6kbps (over short, ~15cm cable) See Section 4.4.3 for more details
Ethernet:	10/100 See Section 4.4.5 for more details
SPI:	3.3V TTL levels 16Mbps maximum clock rate See Section 4.4.4 for more details
CAN:	See Section 4.4.6 for details
GPIO available:	<ul style="list-style-type: none"> • 3 Processor GPIO pin (3.3V) • 2 Processor GPIO pin (1.8V) • 8 FPGA GPIO pins (3.3V), 5 of which can be used for SPI • 2 FPGA GPIO pins (1.8V) See Section 4.5 for more details
On Board Temperature Sensor:	-40°C to 125°C, +/- 2.0°C
RF Characteristics	
Transmit Operating Band:	Chan 2 (4.0GHz center, 500MHz bandwidth) and Chan 5 (6.5GHz center, 500MHz bandwidth)
Average Transmit Power:	Max power spectral density: -41 dBm/MHz (This spectral density equates to approximately ~50 uW or -13 dBm with an adjustability range: ~ -33 to -13 dBm)
Receive Sensitivity: At 110Kbps: At 6.8Mbps:	- 95 dB -105 dB
Antenna Port	Standard 50 Ohm SMA coaxial
Antennas Supported:	Compatible with Time Domain Broadspec™ Toroidal Dipole Antenna (0 dB) as well as a wide variety of 3 rd party antennas. Standard 50 Ohm SMA coaxial connector
Communications	
Channels per RF channel:	2 channels at PRF 16MHz, 4 at PRF 64MHz
Data Rate supported:	110,850, 6800 Kbps
Preamble Lengths:	128, 256, 512, 1024
Communications Type:	Packet transmission
Ranging Performance	
Ranging Techniques:	Pulsed Two-Way Time-of-Flight (TW-TOF)

Two-Way Time-of-Flight	
Max Range:	30-400 meters (See Section 6.2)
Precision (3 Standard Deviations)	10.0 cm (See Section 6.4)
Unit to Unit bias error (uncalibrated):	~30 cm (See Section 6.4)
Bias error (-40 to 85) (uncalibrated):	~20 cm (See Section 6.4)
Bias error (if fully calibrated):	+/-2cm (See Section 6.4)
Range Measurement Rate	20-182 Hz (See Section 6.3)

Table 6-1: P330 performance characteristics

From time to time changes will be made to the P330 design. **Section 6.8** describes how the version number of any given board can be determined and describes the version to version differences.

6.2 Maximum Operating Range of a P330 Radio

Operating range in any given application will be a function of parameters the user can control and ones that are beyond control. Controllable parameters include transmit power (normally set to the maximum value that the regulations allow), the antenna height, and the RF channel/message configuration parameters (such as PRF, data rate and preamble length). The channel and parameters are usually set either for maximum ranging rate (which provides a shorter operating range) or the maximum operating range (which results in a slower ranging rate).

Parameters which affect range but which are not controllable include blockages from RF reflective or impenetrable structures and attenuation due to propagation through foliage and walls. Interference from other RF systems operating in the area is also a possibility but in practice it rarely happens.

While all of these factors are well understood (if not obvious) the most important parameter to consider (and the one most frequently overlooked) is constructive and destructive Fresnel cancellation and enhancement.

Section 6.2.1 will describe why Fresnel is such an important factor and Section 6.2.2 will offer empirical data to illustrate operational range performance and Fresnel effects under a wide variety of conditions.

6.2.1 Fresnel – Key Limit to Operational Range

Basically, when operating over open ground, transmissions will be received from the direct path as well as from the forward scattered reflections from the ground. Since the ground reflection will arrive at the receiver a bit later than the signal following the direct path, the summation of the two signals can be either destructive or constructive. Destructive cancellation can be so severe that at some separation distances the signal will not be received. At some distances constructive interference will significantly increase the received signal, in which case the operating range will be increased. At other distances the delay time between the two signals could be so large that neither has a meaningful effect on the other.

While the Fresnel effect is frequently overlooked, in most outdoor applications it will be the primary factor limiting the operating range. To illustrate this phenomenon consider **Figure 6-1**. In this example, two radios were placed approximately 1.7 meters above the ground and data was taken while the distance between the units was increased. The first unit was mounted on a tripod and the second mounting above the roof of a small car. The test started with a separation distance of 8 meters and the car slowly drove off until the signal disappeared. **Figure 6-1** shows the results as a plot of First Path Power (a measure of the received signal strength) as a function of the distance.

There are several items to note. First, the received signal has serrated look. Every 5-10 meters the signal strength diminishes. As the separation distance increases the spacing between minima increases. At the same time the depth of the minima also increases. These serrations are destructive cancellation due to the Fresnel effect.

Second, at some point the received signal strength will drop to the point that the receiver will not be able to acquire. For these settings (RF Channel 5, 64 MHz PRF, preamble length of 64 and 6.8Mbps) will link failed at -94dB. This level is indicated by the red line.

Finally, the -94dB value that defines the location of this red line will vary from unit to unit by a few dB. A prudent system designer will incorporate additional margin to insure that all of the units will meet the system operational requirement.

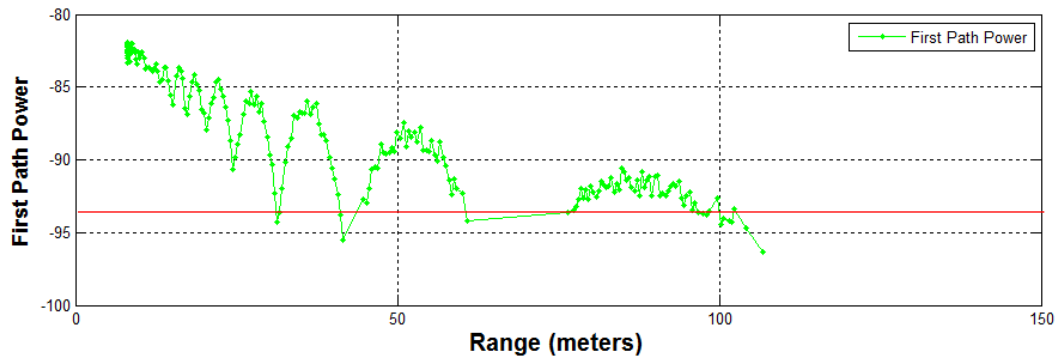


Fig. 6-1: Plot of received signal strength (First Path Power) vs separation distance (range in meters)

Defining a maximum operating range is ambiguous. While it is clear that ranges were measured out to 100m, it is equally clear that no range measurements were possible between 60 and 75m. In fact, the signal was marginal at 30 meters and again at 40 meters. Depending on the requirements of the application, the correct specification for maximum operating range could be anything from 30-100 meters, perhaps less if an allowance for margin was added. The correct answer for most applications is probably 65 meters, but users who need a higher quality of service would argue for 30 meters.

It is also possible to mitigate the Fresnel effects at the cost of increasing the complexity of the overall system. For example, assume it is necessary to monitor the location of many units as they move through a fixed area. Furthermore, assume that the location of the units is determined by measuring their distance to a set of fixed references mounted on the walls of the area. Since the Fresnel effects are largely due to geometry, their effects can be mitigated in several ways. First, the infrastructure of fixed references could be doubled such that all units would have at least three references which were not at ranges that corresponded to Fresnel minima. Second, the fixed infrastructure could be outfitted with multiple antennas each a different height. This would change the geometry such that one antenna would be affected by the a Fresnel while the second could be counted on to have an acceptable signal.

It becomes more difficult to define a maximum operating range if the units in the link are also allowed to vary their height. In this a case, the location of the Fresnel nulls will move quite dramatically. Suppose you were designing a system for tracking the location of miners in an open area. Suppose further that the location tag was mounted on the miner's helmet. In this case, the location of the Fresnel nulls would be considerably different between tall miners and short ones. The Fresnel nulls would change if any miner sat down or climbed on a tall vehicle.

While this can get complicated, the goal of this section is not complication. The objective is to illustrate this phenomenon in a way that a system engineer can understand the issue and work to define an appropriate solution. One approach is to require that the operating distances to limited to a

very short value, in this case, to less than 30 meters. Another approach would be to add a significant number of references to the system. Intermediate solutions are also possible. But failing to consider propagation performance in the system design will result in a very unhappy customer.

6.2.2 Examples of Operational Range

The figures in this section illustrate operational performance of distance of 4 standard radio configurations for each of three deployment scenarios. These figures are followed by a table summarizing performance.

The four standard configurations are:

- RF Channel 5 (High Ranging Rate) PRF 64M, Preamble 128, Data Rate 6.8Mbps
- RF Channel 5 (Low Ranging Rate) PRF 64M, Preamble 1024, Data Rate 110kbps
- RF Channel 5 (High Ranging Rate) PRF 64M, Preamble 128, Data Rate 6.8Mbps
- RF Channel 5 (Low Ranging Rate) PRF 64M, Preamble 1024, Data Rate 110kbps

The three scenarios are

- 1.7m to 2.3m (tag mounted on a person's helmet or on a robot to a wall mounted reference)
- 1.7m to 1.7m (tags mounted on helmets)
- 1.0m to 1.0m (tags on pallets or attached to a person's belt).

Performance statistics are shown in Red in the lower right hand corner of the following figures. The values to the left of the / indicate the range of values for the minimum and maximum reliable operating range while the number to the right indicates the maximum range achieved. These are subjective values based on the author's opinion. The reader is encouraged to consider this data in the context of a specific application and suggest better values.

As a side note, the Matlab used to collect and produce these figures is provided with the equipment and can normally be found on the Time Domain website.

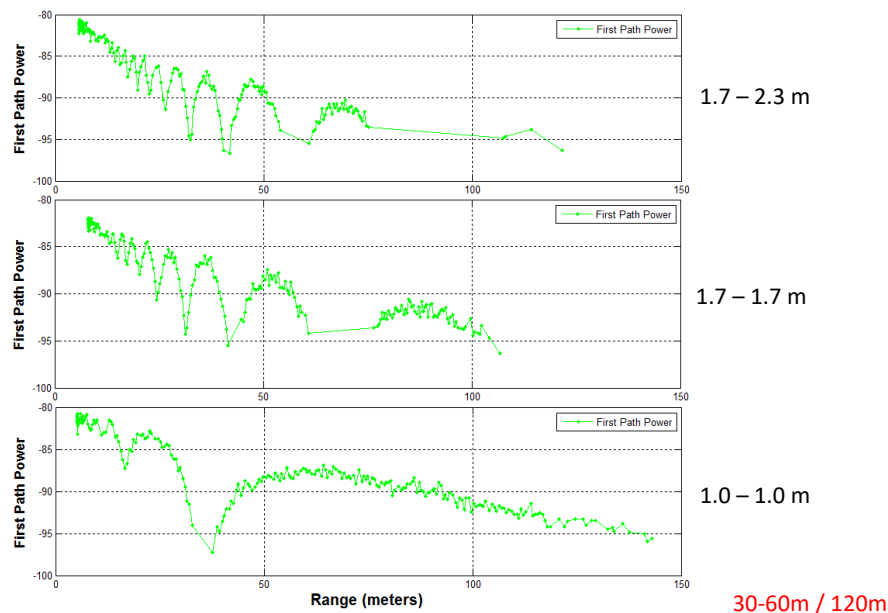


Fig. 6-2: RF Channel 5 (High Ranging Rate) Received Signal Strength vs Range for 3 scenarios

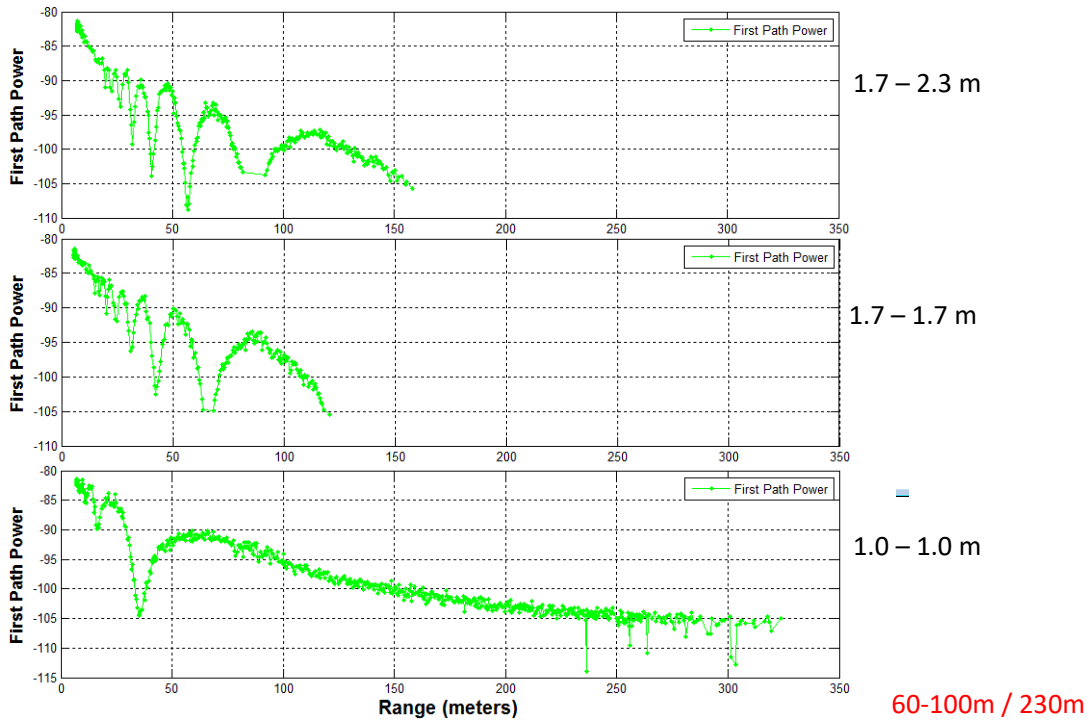


Fig. 6-3: RF Channel 5 (Low Ranging Rate) Received Signal Strength vs Range for 3 scenarios

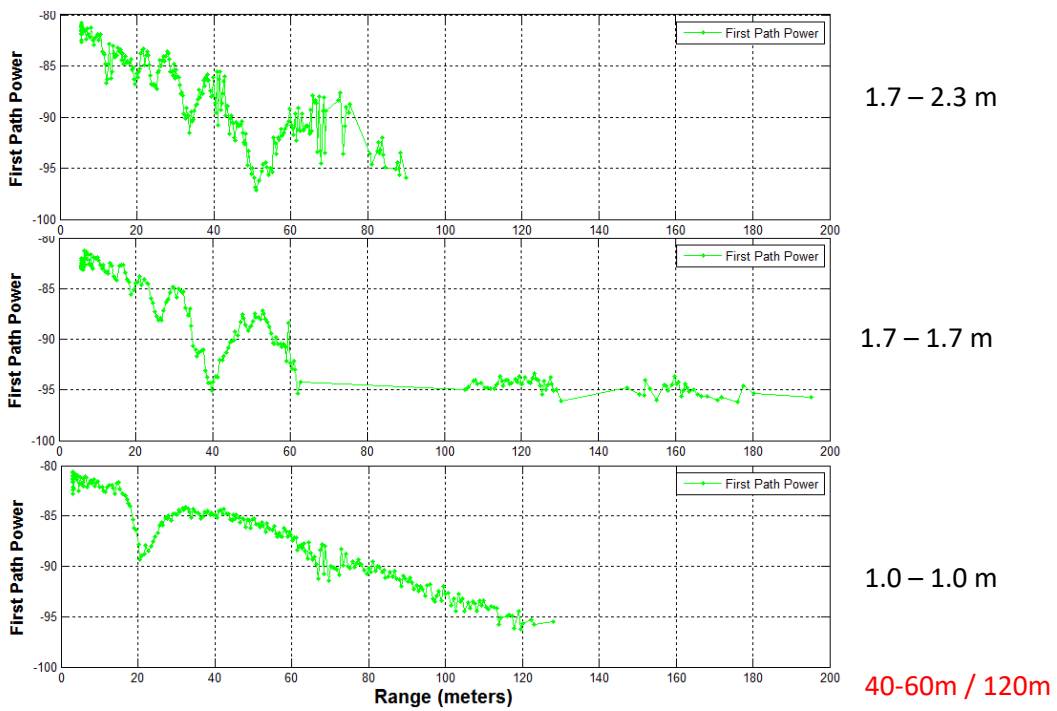


Fig. 6-4: RF Channel 2 (High Ranging Rate) Received Signal Strength vs Range for 3 scenarios

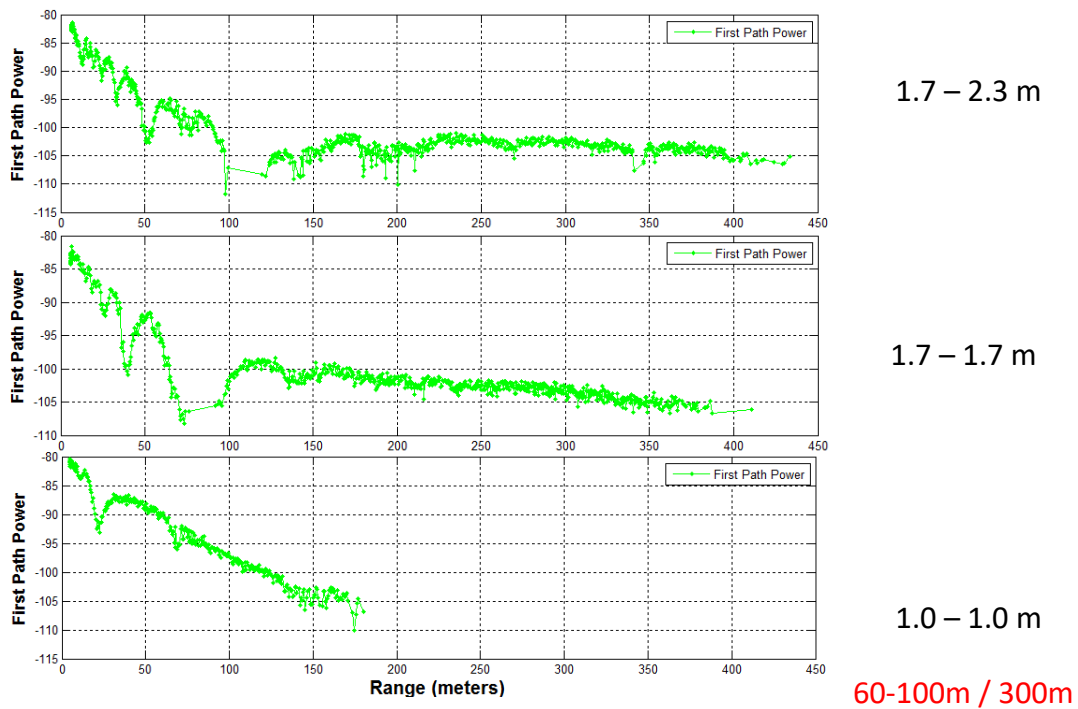


Fig. 6-5: RF Channel 2 (High Ranging Rate) Received Signal Strength vs Range for 3 scenarios

These results are summarized in the following table.

RF Channel	Low Rate (Max Range)	High Rate
Chan 2 (Low band)	60-100/300	40-60/120
Chan 5 (High band)	60-100/230	30-60/120

Table 6-2: Maximum Operational Range for 4 radio configurations

6.3 Range Measurement Rate

Ranging Conversation Time is the amount of time required to take a single TW-TOF range measurement. The maximum measurement rate is limited by the Host to P330 overhead conversation time required to initiate a range request. This overhead will limit the measurement by approximately 30% of the values shown in the table below. This overhead is eliminated when the range requests are handled through RangeNet.

The **Maximum Range Measurement Rate** is shown in **Table 6-3** and is achieved when two radios are operated as a network consisting of a single requester unit and a single responder unit.

Configuration: Chan 2 (low band) or 5 (high band), PRF=64MHz, Preamble (128 or 1024), Data Rate = (110KHz or 6.8Mbps)	Range Conversation Time (milliseconds)	Maximum Range Measurement Rate (Hz)
Chan 2: High Rate (64MHz, 128, 6.8MHz)	5.5	181.8
Chan 2: Low Rate (64MHz, 1024, 110KHz)	48.0	20.8
Chan 5: High Rate (64MHz, 128, 6.8MHz)	5.5	181.8
Chan 5: Low Rate (64MHz, 1024, 110KHz)	48.0	20.8

Table 6-3: Ranging performance characteristics at maximum legal transmit power

6.4 Range Measurement Precision, Bias and Accuracy

The Range Precision, Accuracy and Bias are defined by the performance of the Decawave DW1000 chip all of which is described in the Decawave product documentation. For more detail, the reader is encouraged to review the product information provided by Decawave.

This section will focus on discussing the precision, accuracy and bias of the DW1000 based on empirical data and experience gathered to date.

6.4.1 Precision in LOS and NLOS Conditions

The DW1000 has a precision (standard deviation) of 10cm. This is a 3 sigma value and has been verified both in a lab environment and in the field. Note that this is a line of sight measurement and it assumes that the antennas of the units are clearly visible to each other that there are no obstructions or partial blockages of the direct path and that is very little reflective surfaces which will cause “undo” amounts of multipath. These conditions are typical of operation outdoors and are also typical inside large areas inside building.

Operating inside buildings frequently requires transmissions through walls as well as operation in the presence of significant reflectors. These factors will attenuate and distort the signal in a variety of ways that will compromise the precision and bias of the resulting readings. This degradation is generally modest, largely because serious degradation will normally be significant enough to prevent a link from being completed. For logistical reasons, it is very difficult to quantify this degradation especially over a wide enough number of RF environments to be statistically significant. Even so, one can expect the precision to be generally acceptable and consistent with the chip specification.

6.4.2 Precision in Fresnel Nulls

Bal blah blah blah

6.4.3 Bias and Calibration

The DW1000 does not report range measurements with a bias of zero. This is to be expected because the bias is a function various electrical delays in the chip, on the board, in cabling to the antenna and in the antenna itself.

This bias needs to be calibrated out and a procedure for doing so is described in the RangeNet User’s Guide.

The user can expect each unit to have a different bias error. The variation for most of the units is

approximately 150mm although it is not unusual to find individuals which are different by more than 300mm. It is also important to note that the bias also varies over temperature. Furthermore, this is slightly nonlinear and even with a single order compensation, the user can expect residual bias errors on the order of +/- 2 to 3 cm.

An example of bias performance over temperature of nine units is provided in **Figure 6-6** below.

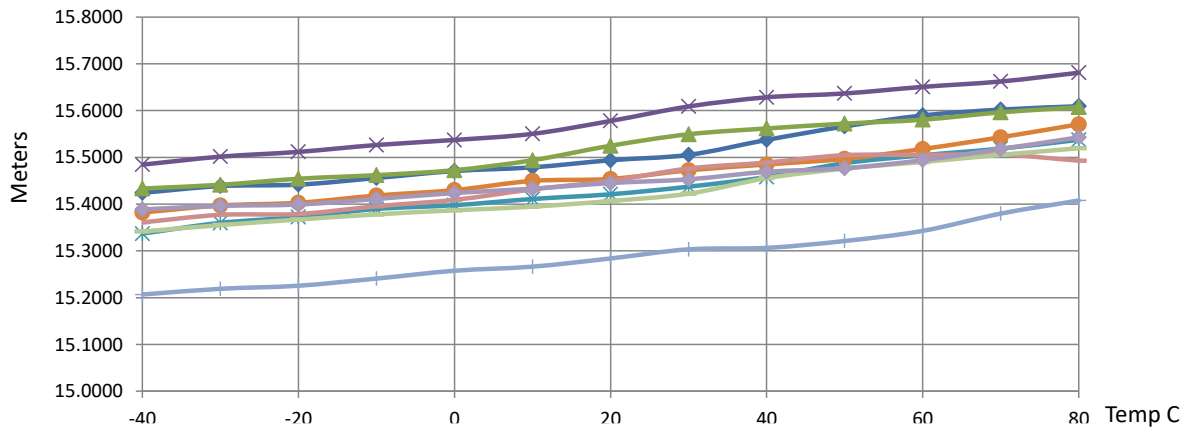


Fig. 6-6: DW1000 Bias performance over temperature.

While bias calibration is relatively straightforward it is very important that it is handled appropriately. If not, then the user will experience significant errors when attempting to localize.

Decawave's documentation and application notes provide several suggestions as to how these changes in bias with temperature can be best accommodated.

Once Time Domain has completely characterized the behavior of a few hundred units, it is our intention to provide temperature compensated range measurement. In the meantime, the P330 provides the user with a means of measuring the board temperature. This allows the user the opportunity to implement a temperature compensation routine.

6.4.4 Accuracy

Range accuracy is a function of precision and bias. If ranges are used to determine location, then the location accuracy will be a function of the accuracy of the constituent range measurements. To a first order, the accuracy of the DW1000 will be approximately 5-10cm. For many applications this will be more than sufficient.

For applications that require more accuracy, it will be necessary to do a more complete analysis. Such an analysis would include evaluation of the environment in which the equipment is to be used, determination of the maximum rate at which a P330 would move, and consider the effects of averaging. Basically, a "bad" environment and "fast" moving mobiles will degrade accuracy. On the other hand, most errors are Gaussian so any form of averaging will improve accuracy. Averaging can be the result of taking many range readings on a particular link and averaging them over time or it could come in the form of taking many range readings to a large infrastructure of anchors (reference units). Other forms of averaging are also possible.

Finally, the accuracy and reliability of a system can be greatly increased if the system relies on the combined outputs of multiple types of sensors. For example, integrating measurements from a UWB ranging, inertial sensors and, if the device is a robot, wheel odometry will greatly improve the overall system performance.

6.5 P330 Revisions and Differences

From time to time slight changes or improvements are made to the P330 design. This section explains how the user can identify the revision level of any P330 device and provides a location for listing the differences between one revision level and another. This is also where any documentation errors will be reported.

Version/Revision Level: The version or revision level of any given P330 is indicated in the bar code of that particular P330 (See **Figure 35** below).

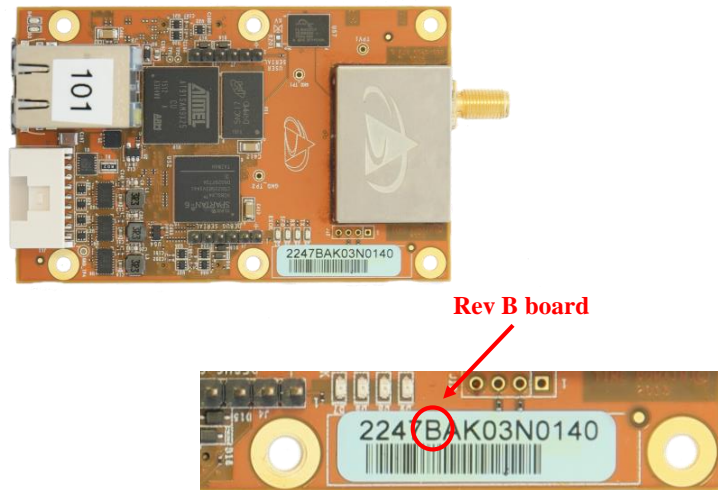


Fig. 6-7: P330 Version indicated in bar code. Unit shown is a Rev B board.

To be more complete, the number 2247BAK03N0055 in the example shown above can be decoded as follows:

2247: board type
 B: board revision
 A: board sub version
 K: year of manufacture (for example J = 2015, K = 2016)
 03: week of the year assembled
 N: contract house
 0140: serial number.

Note that when the user electronically polls the unit for its serial number, the returned value will be a multi-digit number. These two values are linked in such a way that any board can be referenced by either number.

Differences from previous versions: The B revision of the P330 is the first generally released version. Had there been a previous version, then differences, improvements and corrections would be summarized here.

7 Broadspec Antenna

The P330 is designed to operate with the Broadspec antennas shown in **Figure 7-1**. While this is the antenna provided with the P330, the unit can accommodate a wide variety of standard and custom antennas. The only electrical requirement is that the antenna used has a 50 ohm SMA connection.

Using a different antenna will likely change the beam pattern and gain, either of which will affect certification. Using a different antenna may change the phase linearity and compromise the pulse shape and integrity. This can affect the performance of the range measurement algorithms.

However, all of the transmit settings have been set assuming that the P330 is connected to the Broadspec. In fact, the pending US certification effort will require use with the Broadspec antenna. Using any other antenna (or even adding cabling between the P330 and the antenna) will require recertification of the equipment.

For example, as per FCC 15.203, the Broadspec antenna must be professionally installed and the installer has the responsibility to insure that the Broadspec antenna is used. EU regulations have similar restrictions.

The Broadspec antenna (~3 dBi) provides an omni-directional transmit/receive pattern supporting a frequency range of 3.1-5.3 GHz. It has a standard SMA male connector and measures 1.2" x 2.5" x 0.063" (3.0 x 63.5 x 1.6 mm). When ordered with a Kit it is also provided with a 90-degree connector as shown in **Figure 7-1**.

The connector can also be ordered with a standard SMA female connector. See **Section 10** for ordering details.

Specifications are available on the web at:

http://www.timedomain.com/datasheets/TD_Broadspec_Antenna.pdf

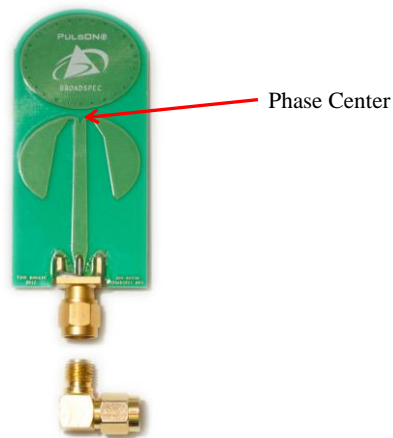


Fig. 7-1: Broadspec antenna with phase center indicated

8 Regulatory Compliance

The P330 with the Broadspec antenna has been designed to be in compliance with both the U.S. FCC Part 15 subpart F regulations, sections 15.519 and 15.521 and with the European Union ETSI EN 302 065 standards.

Integration of the P330 into other user equipment will require certification of the resultant system. While that certification is the responsibility of the end user, Time Domain will be happy to assist in this process.

The P330 is currently undergoing testing for compliance with FCC regulations and Time Domain expects to receive a formal FCC Grant of Equipment Authorization in early Spring 2017. Until then, the user is free to use the equipment for evaluation and demonstration. After that authorization, the equipment will be available for distribution and use in end products.

8.1 Compliance with the U.S. FCC Regulations

The standard P330 has been designed to be in compliance with the FCC regulations governing UWB hand-held systems (Part 15.519) also known as “battery powered devices” or “mobile devices.” This means that the device can be incorporated in a wide variety of products including mobile tracking systems, mobile locators, radar-based locators, guidance and position systems, and communication devices. Note that there are other applications which are specifically forbidden, such as use of the devices in toys. See FCC Parts 15.519 and 15.521 for more details.

More specifically:

This device complies with 47 CFR Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Furthermore:

The user is cautioned that changes or modifications not expressly approved by the party responsible for compliance could void the user’s authority to operate the equipment.

The label which provides the certification number is shown below in **Figure 8-1**.

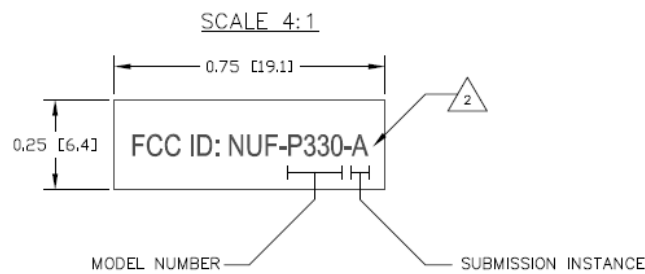


Figure 8-1: FCC ID number

This label will be located on the back or bottom side of the P330. See **Figure 8-2**.

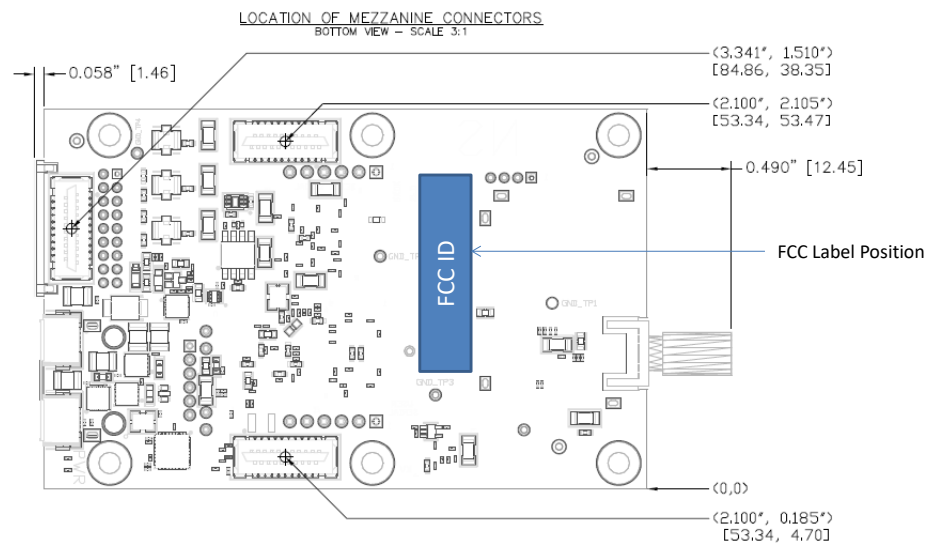


Fig. 8-2: Planned location for certification number

If the P330 is incorporated into a different enclosure it is possible that the enclosure can alter the unintentional and intentional emissions respectively.

The P330 is capable of transmitting at power levels in excess of the FCC limits for enhanced performance. In order to use these higher powers in final applications, please consult and seek authorization from the appropriate regulatory agencies. Time Domain has expertise in working with regulatory agencies and can help as needed. However, the responsibility for obtaining such authorization rests with the end user.

Additionally, the FCC regulations do not apply for US government or military applications. Proper governmental use is described in “Government Regulations for Non-Licensed UWB Systems - Annex K.” Developers interested in building a device for a particular government agency should discuss their application and Annex K with that agency’s spectrum manager.

Time Domain is available to assist you with the certification process.

8.2 Compliance with the EU ETSI Standards

The standard P330 has been designed to be in compliance with the emissions mask defined in the ETSI EN 302 065 standard.

The user is free to buy the equipment for evaluation and demonstration purposes. But before the device can be generally marketed as an end product, its operation must be compliant with the ETSI standard. The ETSI standard places additional requirements on operation of UWB devices beyond just the emission mask. These requirements are related to the specific end application. For example, depending on the user’s intended application, there can be additional limitations (or flexibilities) on the location of fixed and mobile transmitters as well as on the rate at which transmissions can be

generated. There are also alternate mitigation strategies which can be used to accomplish the intent of the standard. These strategies need to be considered in the context of the target application.

The ETSI regulations also evolve over time with changes being introduced periodically. Product developers need to keep this in mind as they evaluate applications and target products.

Finally, the P330 by itself cannot be certified. The P330 must be certified by the relevant body in the context of the final product in which it is to be used.

Time Domain is available to assist you with the certification process.

9 Import/Export Considerations

Time Domain has self-certified the P330 in all its variations under Export Commodity Control Number (ECCN) 5A001b.4 pending formal classification from the U.S. Department of Commerce's Bureau of Industry and Security. This self-certification is based upon the Bureau's previous assignment of ECCN 5A001b.4 to the company's P400 modules.

Products falling under ECCN 5A001b.4 are controlled for export purposes pursuant to the Commerce Control List for National Security and Antiterrorism. For the latest information from the Commerce Department on Export, please go to: <http://www.bis.doc.gov/licensing/exportingbasics.htm>.

While Time Domain has shipped products to more than twenty countries (and takes pride in doing so) there are a small number of countries for which export license approval may be required. Furthermore, these rules change with time. Therefore, the company reluctantly reserves the right to refrain from selling P330s if there is a significant export concern.

10 Configuration and Ordering Information

The P330 is available either as a single board (OEM Module) or as part of a Ranging and Localization Development Kit. When ordered as part of a Kit, the P330 module is provided with a number of hardware and software accessories.

The hardware accessories include the following:

- **Enclosure for P330 module:** Housing made of damage-resistant plastic with clear polycarbonate cover. Provides protection from improper handling during evaluation, testing, and development activities.
- **Broadspec antenna:** Time Domain’s standard UWB antenna as described in **Section 7**.
- **USB wall charger, battery, and cables:** The USB battery can drive the P330 directly for approximately 10.0 hours. The USB wall charger can drive the P330 directly from an AC power source or can be used to recharge the battery. A short USB cable is provided for connecting the battery to the P330 USB power port and a longer cable is provided for driving the P330 either through the USB power port or for communicating to the P330 through the USB communications. Most (but not all) commercially available USB battery packs will drive the unit, so the user has the freedom to experiment with alternate battery approaches.

The P330 software offerings include the following:

- **RangeNet / RangeNet Lite:** RangeNet is Time Domain’s GUI for demonstrating two different ranging and localization capabilities. First, it allows the user to measure the distance between two P330 units using TW-TOF ranging. Second, it allows the user to define a network of P330s. More importantly, this network has been optimized for use with TW-TOF ranging. RangeNet supports both the ALOHA and TDMA network protocols. It can also be configured to transfer data. RangeNet “Lite” is a node-locked version of RangeNet in that it is limited to operation with a maximum of 10 nodes. RangeNet Lite is provided to allow the user to easily experiment with units both as standalone pairs and as members of a network. Users interested in unrestricted operation of RangeNet should contact the factory for information on purchase and licensing options.

All of the software packages come with sample C code and sample MATLAB code to illustrate the API interface from a Host computer to the P330.

Table 10-1 provides the name of the part or kit, a part number, and short description of the part or kit.

KIT Series	Part number	Description
P330 Ranging and Localization Development Kit	430RL01	Contains <ul style="list-style-type: none"> • 5 P330 modules (130RM01) • 5 Broadspec antennas (100ANR4) • 5 enclosures (330EN01) • 5 rechargeable USB batteries (340RB01) • 5 USB wall chargers

		<ul style="list-style-type: none"> • 5 long USB cables (6 ft./1.8 m) • 5 short USB cables (6 in./15cm) • RangeNet Lite (ranging and network software, node-locked to 10 nodes) • 5 hours of technical support
OEM Module Series		
P330 UWB Module	130RM01	Single P330 Module (board only, no accessories). Integratable printed circuit assembly designed to provide precision ranging and wireless communications with multiband (4 and 6.5 GHz) operation. Supports Ethernet, USB, SPI, Serial, or CAN interface.
Antenna Series		
Broadspec Antenna (Male SMA Connector)	100ANR2	UWB Antenna (3-7 GHz) with male SMA connector. Omnidirectional antenna for use with P300 and P400 series platforms.
Broadspec Antenna (Male SMA Connector) with Right Angle Adapter	100ANR4	UWB Antenna (3-7 GHz) male SMA connector and right angle SMA connector. Omnidirectional antenna for use with P300 and P400 series platforms.
Accessory Series		
P330 Enclosure	330EN01	Single P330 Enclosure. Made of damage resistant ABS plastic with clear polycarbonate cover. Suitable for lab use and light field testing.
Rechargeable Battery	340RB01	Rechargeable 300mAh USB battery. Provides 10 hours of continuous operation for P330.
Technical Services		
Technical Support Block (10 hours)	910TS01	Ten hours of Time Domain remote engineering technical support (phone or e-mail) for integration and testing. Valid for one year from date of purchase.
Technical Support Block (25 hours)	925TS01	Twenty five hours of Time Domain remote engineering technical support (phone or e-mail) for integration and testing. Valid for one year from date of purchase.

Table 10-1: P330 Ordering Information

For pricing and ordering information, please contact sales@timedomain.com