Operation Description/ Theory of Operation

PulsON® 440

TIME DOMAIN®

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Dec 2015

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Overview

This document is a supplement to the P440 Data Sheet and User Manual. The User Manual describes the theory of operation at a high level and is focused on enabling the end user to understand how the P440 is to be used. That document is intended for general release. This document describes details of the theory of operation that are of specific interest to regulatory bodies. The document is not intended for general release.

This document is divided into the following four subsections

Section 1: Summary and Theory of Operation
Section 2: Description of Block Diagram
Section 3: Broadspec Antenna
Section 4: Transmission Specifics Relevant to FCC Certification

1 Summary and Theory of Operation

The P440 is an Ultra Wideband (UWB) radio transceiver that provides the following functions:
- It accurately and reliably measures the distance between two P440s and provides these measurements at a high update rate.
- It supports two different range measurement techniques (Two-Way Time-of-Flight and Coarse Range Estimation).
- It operates as a short range radar.
- It communicates data between two or more P440s.

In addition, a network layer is available to coordinate the operation of multiple ranging radios.

Time Domain's PulsON P440 is a ruggedized, industrial UWB platform. The most obvious and important characteristics of the device relative to industrial operation are listed below:
- The electrical interface to the unit through Ethernet, USB, Serial, SPI or CAN
- All components are rated for industrial temperature (-40C to +85C)
- Fan is not required for cooling.
- The board is provided with six mounting holes that insure that the unit will survive and operate in most high vibration environments
- RF filtering provides superior operation in the presence of 2.4GHz and 5.8GHz
- The UWB emissions have been tested and comply with FCC 15.519 which is the most stringent of the FCC UWB limits.
- The digital emissions have been tested and comply with the FCC 15.109(b) ("Class A digital device") which limits use of the P440 to commercial and industrial uses only.

The P440 is an Ultra Wideband radio that coherently transmits and receives trains of individual RF pulses at a nominal rate of 10 MHz. **Figure 1** provides a notional example of a typical UWB pulse in both the time and frequency domain. Pulses are transmitted as coded trains of pulses. Coding is accomplished either by pseudo-randomly shifting the pulse phase or inter pulse transmission time. By transmitting and receiving pulses coherently, the P440 can integrate multiple pulses and thereby increase the received signal to noise ratio. Integration can therefore be used to increase system robustness and or operational range.
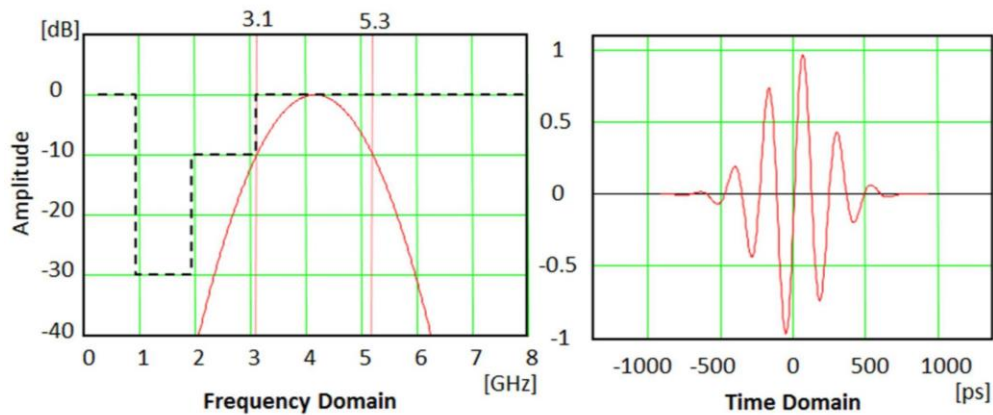
Figure 1: Notional UWB pulse in both time and frequency domain.

The P440 measures distance using a technique called Two Way Time of Flight. In this approach the radio requesting the range measurement (the Requestor) will transmit a packet of pulses that will be received by one or more units (the Responders).   The responder will then measure the leading edge of the waveform relative to the radio lock spot and transmit this information in a return (or responding) packet. The Requestor will then measure the difference in phase between the transmitted and received PN code and compensate this phase measurement by the leading edge measurement. Dividing the result by two and multiplying by the speed of light yields a measurement of the distance between the Requestor and Responder.

The user controls and monitors the P440 through a straight forward Application Programming Interface (API) over Ethernet, USB, Serial, SPI or CAN connections. USB driver support is provided for Vista 32, Vista 64, Win7 32 and Win7 64 operating systems. The API provides all the commands and capabilities required by a user to design a network tailored for operating multiple P440s as ranging radios. For details on the API see the following document:
- *RangeNet API Specification*

The P440 can also be used as a radar. In this case the P440 will transmit on one antenna and receive on the second antenna. Due to the low transmit power the operating range of the radar is limited to a few 10s of meters. For details on the radar API se the following document:
- *Monostatic Radar Module API Specification*

For details on the USB and serial interfaces refer to
- *USB and Serial Interfaces*

To assist the user in demonstrating the performance of the P440 as a ranging radio or as a radar, Time Domain also provides PC based Graphical User Interfaces (GUIs). These GUIs allow the user to exercise all of the API commands and offers the following capabilities:
- They provide <u>programmers</u> with a visual example of a host application which interfaces to the P440 through the API.
- They allow <u>users</u> to evaluate radar, ranging and communications performance.
- They allow <u>system analysts</u> to visualize, collect and log raw ranging data such that it is possible to develop algorithms/strategies tailored to a given application

Time domain also provides sample C and Matlab for demonstrating the interface and performance of the hardware.

For details on these GUIs refer to the following documents:
- *RCM – RangeNet RET User Guide* (Ranging and Network operation)
- *MRM Ret User Guilde* (Monostatic Radar)

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, applications notes, white papers, examples, published papers, sample C code, sample Matlab, etc.

2 Description of Block Diagram

The P440, shown in **Figure 2**, is a small, low power and affordable device which provides accurate, high rate range measurements and has superior operational performance when compared to conventional RFID/RTLS devices. The device is intended for use as an OEM module.
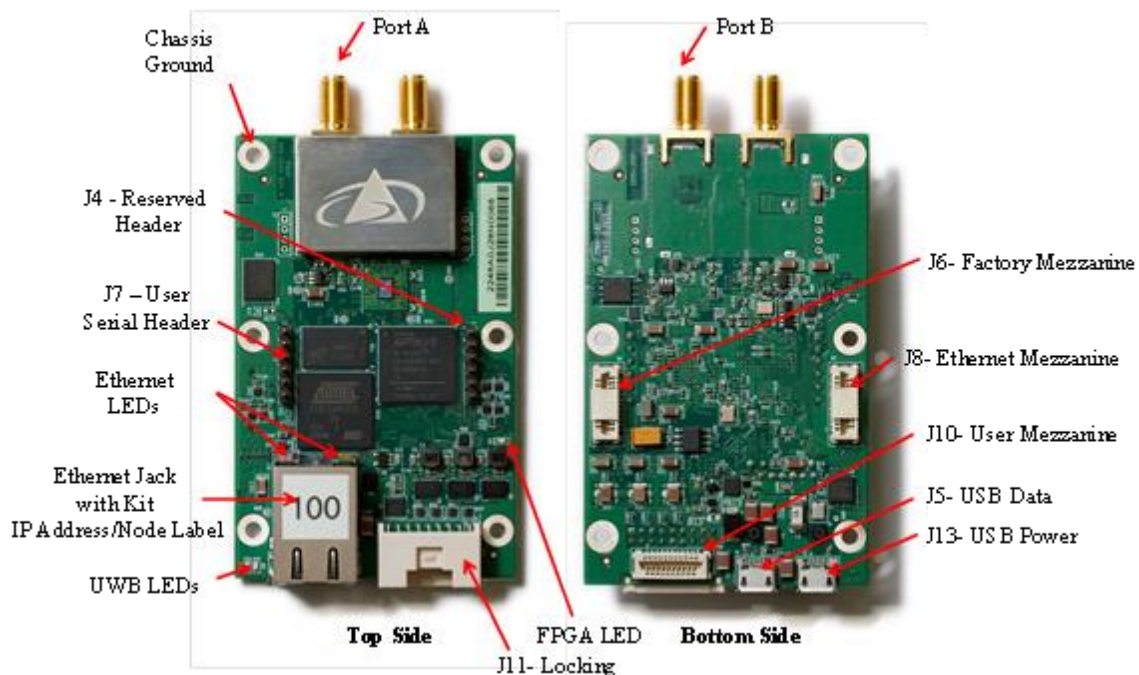

Fig. 2: P440 with Broadspec antenna

This section provides and discusses at a high level the P440 functional hardware block diagram, as shown in **Figure 3**.
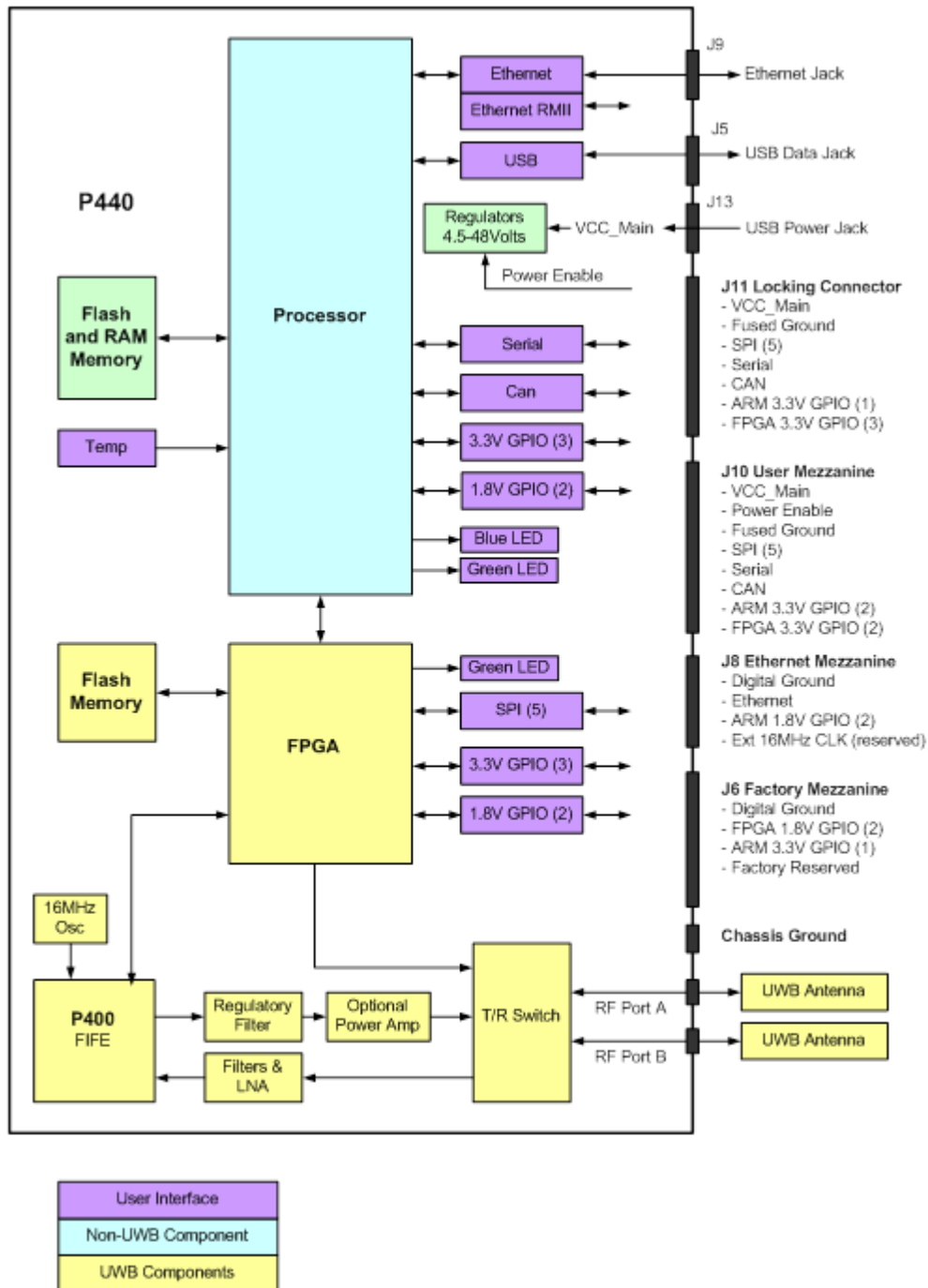
Fig. 3: P440 hardware functional block diagram

To power the board, the user must supply a maximum of 2.0 Watts at any voltage between 4.7 and 48V. This can be accomplished either with the provided power supply or from a battery. Indicating lights provide operating status information.

The user can interface to the P440 through Ethernet, USB (standard USB Micro B connector), Serial connection, SPI or CAN. In addition, the user can request the P440to report the board temperature..

The processor controls the UWB front end through a Digital Baseband FPGA interface. More specifically, the FPGA configures the Time Doman P440 UWB transceiver chip (FIFE), provides timing signals and out-going data, receives incoming data and controls the position of the transmit/receive (T/R) switch.

There are three RF sections:
- A variable transmit power amplifier is provided in the Pulser chip.   This allows the user to adjust the transmit power over approximately a 19 dB range. At its maximum setting (and when using the standard P200 antenna) these transmissions are compliant with FCC Part 15 levels
- Receive chain consists of gain stages and band pass filter; and
- T/R switch supports two configurations: Transmit/Receive on Port A and Transmit on A, Receive on B.

3 Broadspec Antenna

The P440 is designed to operate with the Broadspec P200 antennas shown in **Figure 4**. Use with *ANY* other antenna invalidates the FCC certification. 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.

The P440 can be operated with a single antenna (used for transmit and receive) or with two antennas (where one is dedicated for transmit and the second for receive).

The Broadspec Ultra Wideband Antenna (~3dBi) provides an omni-directional transmit/receive pattern supporting a frequency range of 3.1-5.3 GHz. It has a standard SMA female connector and measures 1"x 2.5" x 0.125". Specifications available on the web at:

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

Figure 4: Broadspec Antenna with right angle connector

4 Transmission Specifics Relevant to FCC Certification

The following questions pertain specifically to the intentional and unintentional transmissions. To aid in the discussion of a more detailed block diagram and schematics are provided in Appendix A. This block diagram calls out specifics of power supply voltages and key frequency sources.

Modulations supported:

> The P440 supports "Flip" modulation also known as 180 degree phase modulation. Flip modulation means the radio transmits either a UWB pulse or a mirror image (inverse) of the pulse.

Transmit Frequency Range:

> The UWB pulse transmitted by the P440 has a bandwidth that is contained within the handheld UWB portion of the FCC mask. See the SGS test report for further details.

Maximum power rating:

> This UWB device transmits a pulse train that has a maximum EIRP power density that is below the FCC limit for UWB handheld devices.. The maximum PSD specified by the FCC is -41.3 dBm/MHz.

Range of operating power or specific operating power levels, and description of any means provided for variation of the operating power:

> The maximum transmit power is set to such that the P440 is below the FCC limit of -41.3 dBm/MHz. A variable attenuator is provided for those users interested in operating at lower power levels. This attenuator is controlled by a Digital to Analog Converter (DAC) the output of which is set by user through commands issued to DAC by the processor through the FPGA.

Ground system and antenna, if any, used with the device.

> The P440 does not have a ground system and antenna.

Additional descriptions for understanding the block diagram provided in Appendix A.

> The key items contained on the Appendix A block diagram relate to the location of the key oscillators. The main system oscillators are a 16 MHz device and 1 GHz VCO. The 16MHz oscillator is a standalone discrete part, while the 1 GHz VCO is incorporated within the FIFE ASIS. The Oscillator and VCO are used in conjunction with a phase lock circuit on the FIFE custom ASIC to generate a stable 256 MHz clock. This clock is used not only in the FIFE but also as the main clock to drive the FPGA.

Description of all circuitry and devices:

> **for determining and stabilizing frequency,**
>
> > This is accomplished by phase locking a 1.024 GHz oscillator in the FIFE custom ASIC to an external 16 MHz oscillator.
>
> **for suppression of spurious radiation,**
>
> > The P440 transmits a UWB pulse that is not based on a carrier and the UWB signal contains all of the frequencies and the UWB pulse does not have any spurious radiation. The shape of the pulse is defined by Time Domain's custom FIFE ASIC, a

filter for the RF transmit circuitry, and the Broadspec antenna. The pulse generation circuitry and the DACs are located inside Time Domain's custom FIFE ASIC and are digitally defined and set using a Digital to Analog Converter (DAC). The settings for the DACs were set at the emissions testing lab and are not accessible by users.

for limiting modulation,

The only modulation provided by the P440 is Flip (180 degree) modulation. There is no other modulation provided. No digital filtering is provided.

and for limiting power.

The UWB pulse is generated by Time Domain's custom FIFE ASIC. This device has been designed to transmit a pulse which, at the fastest pulse repetition rate provided, cannot and does not exceed the FCC maximum power density.

The DC voltages applied to and DC current into the several elements of the final radio frequency amplifying device for normal operation over the power range.

The final radio frequency amplifying device in the P440 is the FIFE ASIC. This device operates on three separate supply voltages all of which are derived from 3.7 Volt regulator. The three supplies and their DC currents are as follows: 3.3Volts @ 23mA, 2.5Volts @ 50mA and 1.5 Volts @ 33mA.

Finally, the device does not use digital modulation techniques and does not utilize frequency hopping to spread the signal across the spectrum.