

Drone Radio Performance Primer

How to Use the Proteus Software Defines Radio to
Evaluate Drones in Congested and
Contested Electromagnetic Environments

Enabling the Breakthroughs of Tomorrow

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Validating Drone Performance in Congested and Contested Electromagnetic Environments

Introduction

One of a drone's largest vulnerabilities is its radio signal, which forms a significant part of its mission. Critical information is transmitted and received that includes control, telemetry, pictures, and video.

A remote-control device forms the Ground Control Station (GCS), sending signals to the drone's aerial receiver, which then processes the commands to control the motors and other functions. The control link transmits information, such as altitude, speed, and remaining battery life, as well as feedback from the drone's mission, such as a live video feed from the drone's camera.



Drones can use different frequency bands to optimize performance. The ISM (Industrial Scientific Medical) band is widely used, especially for commercial drones, as it is unlicensed spectrum; however, other frequencies and stealth techniques are used, such as hopping and spread spectrum, to hide the signal from adversaries. A drone can also be autonomous, using only GPS or optical waypoints to complete its mission.

The principles of frequency, range, and bandwidth apply, with bandwidth decreasing as the distance from the GCS increases. However, there tends to be more transmitter congestion at lower frequencies.

For example, an ISM 2.4GHz signal can be used for longer-range control signals, but as discussed, this band is often crowded with other devices like Wi-Fi, Bluetooth, and even microwave ovens, which can cause interference. The 5GHz ISM band can be used for higher-speed video transmission due to its higher bandwidth and lower latency, providing a clearer video feed. This band has more channels and is less congested, but it does not travel as far as 2.4GHz signals and is more easily blocked by objects. Many advanced drones use a dual or multi-band system, dedicating 2.4GHz for control and 5GHz for video to get the best of both worlds.

Some drones can automatically switch between bands or allow the user to manually select the best one for their environment. For example, in a busy urban area, the drone might switch to 5GHz to avoid interference with other signals.

Using Software-Defined Radio (SDR)

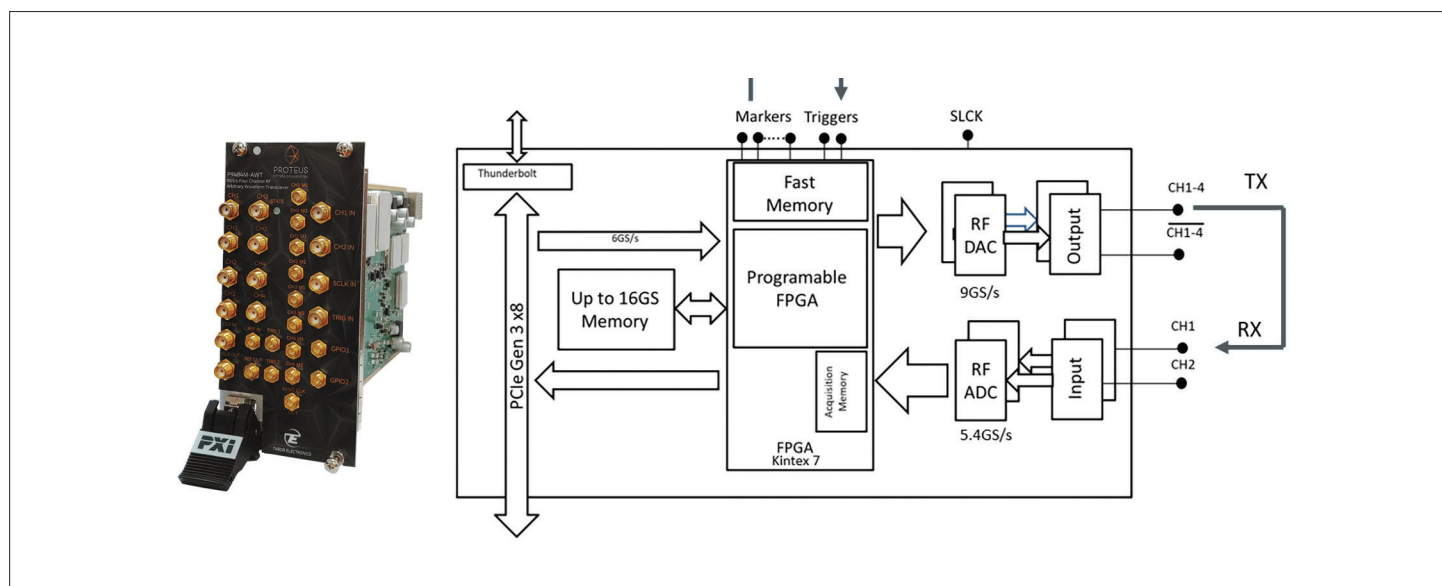
Software-Defined Radios (SDRs) provide powerful and flexible capabilities for drone testing, enabling adaptability, advanced security, and comprehensive analysis through software-driven functions like frequency hopping, jamming, and signal analysis. They allow for testing communication links under various conditions, stress-testing security mechanisms, detecting unauthorized drones, and developing solutions for secure operations.

The Tabor Electronics Proteus series of Software Designed Radios offers unparalleled capabilities, ensuring accurate and efficient test and evaluation processes utilizing its advanced commercial off-the-shelf (COTS) transceivers technology.

Key Features of the Proteus SDR:

- **Direct Digital Architecture:** Utilizes wide bandwidth RF DACs and ADCs for precise signal generation up to 10GHz.
- **High Performance:** Up to 4.5GHz of instantaneous transmission bandwidth, deep memory, and dynamic upload capability for continuous waveform memory.
- **Real-Time Adaptability:** 2.7GHz of instantaneous receiver bandwidth and a programmable FPGA for real-time threat behavior adaptation.
- **Scalability and Flexibility:** Configurable as a benchtop instrument, desktop instrument, or PXI module, offering full-phase coherent operation across all channels.

The Tabor Arbitrary Waveform Transceiver is a type of software define radio that is based on the concept of a system in a module. The core elements of the module are RF Digital to Analog and Analog to Digital Converters, user programmable FPGA, large memory, and high speed data bus technology.



RF Tranceiver System in a Module

The Proteus System is a modular platform, consisting of 4 Channel direct to RF modules, that are phase coherent and have deterministic timing behavior. Transmitters can be scaled to hundreds of channels if required. The architecture provides wide bandwidth high resolutions waveforms, and an easy to program Test & Measurement style language (SCPI), allowing for fast creation of sequenced waveforms enabling fast and easy creation of complex emerging threat scenarios.



4 Direct to RF Synchronous
Outputs, 2 RF Digitizers



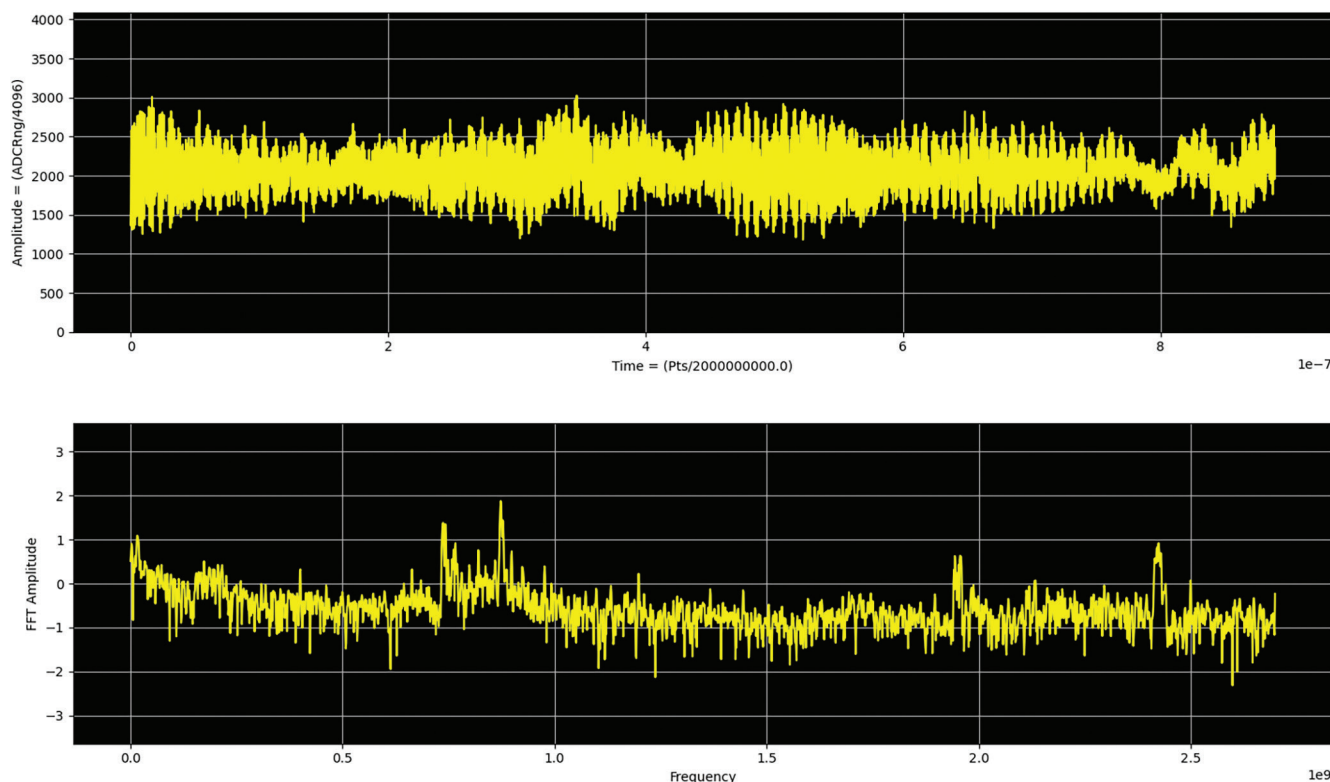
Scalable to 1000's of Synchronous Channels



Test Scenarios

Congestion, Interference, and Susceptibility

Verify the drone's susceptibility to interference or jamming in congested or contested spectrum. The Tabor Proteus SDR is excellent at both wideband EME (Electromagnetic Emission) generation and analysis. Our wideband DAC technology will generate a spectrum as wide as 4GHz in its direct mode of operation or give you access to up to two IQ modulators per channel to generate RF modulated signals digitally, with one or two GHz of bandwidth, depending on how you configure the unit.



The Tabor Acquisition system can capture 2.7GHz of Instantaneous Bandwidth

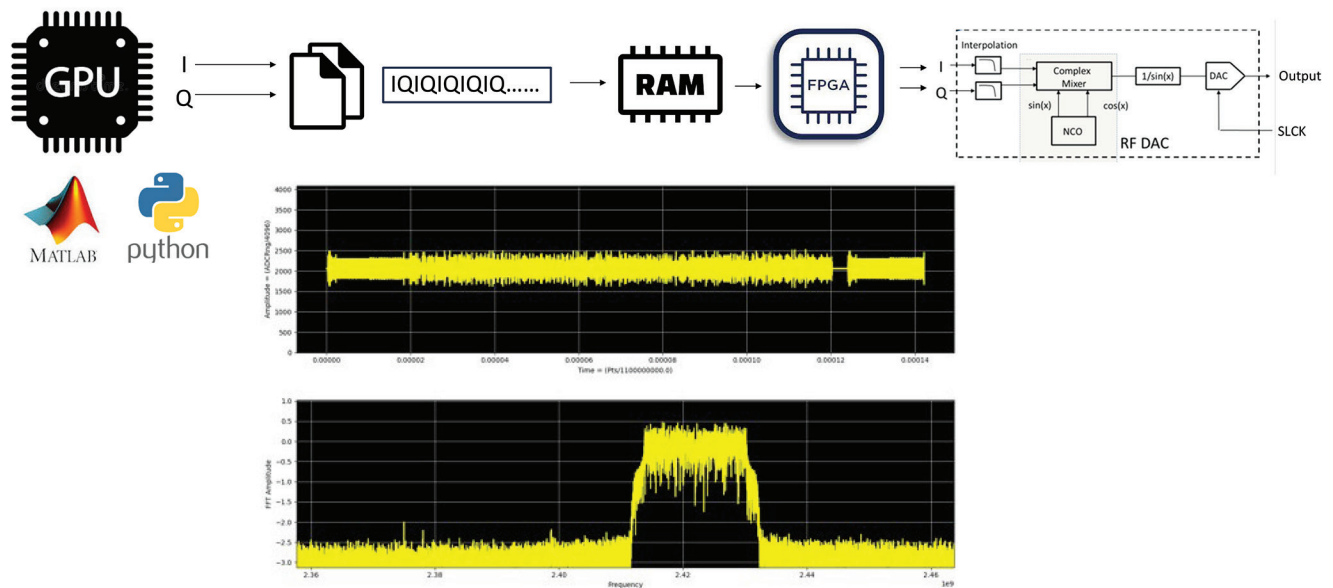
Jamming and Deception

The Tabor Proteus SDR has advanced capability for both drone signal jamming and deception.

Wideband noise jamming: The Proteus SDR can easily generate wideband noise up to 4 GHz of bandwidth for simple jamming scenarios.

Directional jamming: with four coherent outputs per module, the Proteus SDR can also beamform, creating scenarios that can test the drone's susceptibility to directional jammers.

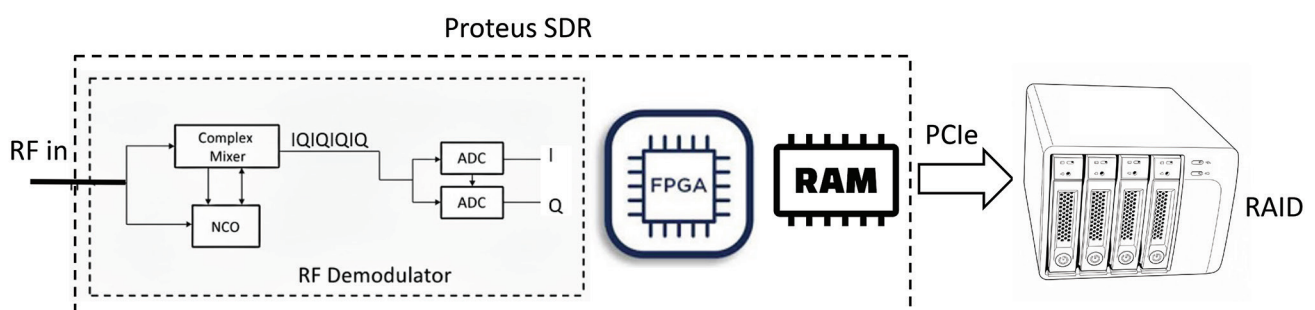
Deception: The ability to stream IQ data directly from a baseband unit, GPU, or RAID to modulate the RF output means that you can verify the drone's susceptibility to signals that counter your control signal.



IQ data can be continuously streamed across the PCIe interface and modulated onto an RF Carrier

Validating a real-life scenario back in the laboratory

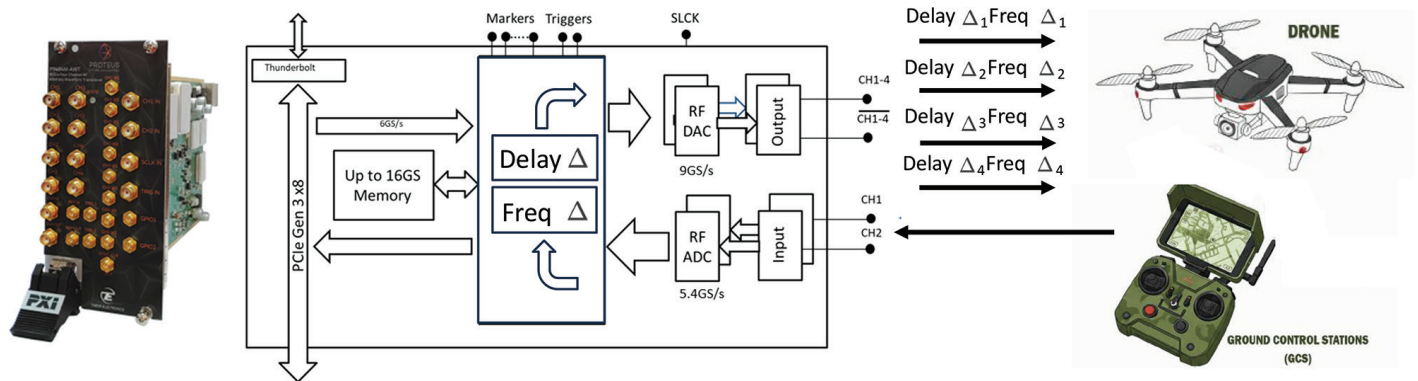
The Proteus SDR is also an RF recorder, hook up the digitizer to a large memory device such as a RAID many hours of environmental and RF signal behavior and protocols can be recorded for analysis to get to the root cause of any issue.



Demodulated RF data can be continuously streamed as IQ pairs to a recording device.

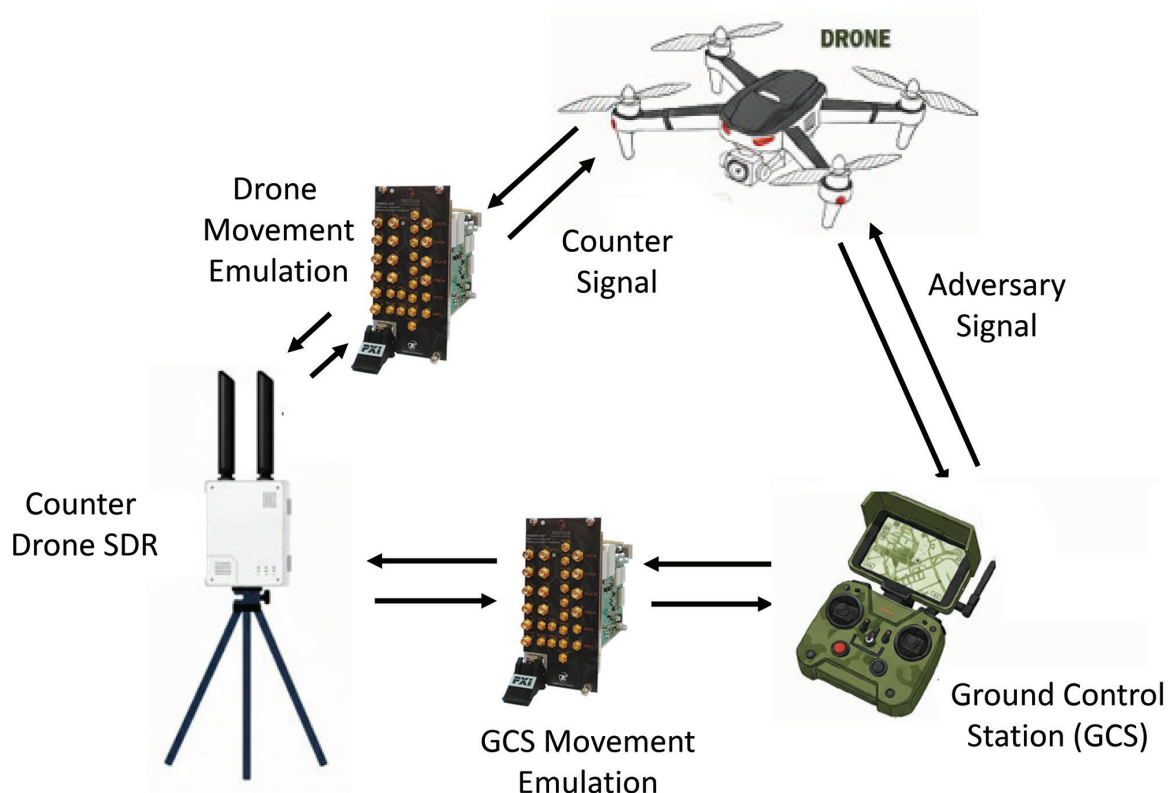
Emulating a dynamic environment with movement

The Proteus SDR has a real-time Doppler and Distance function built into its FPGA. Time delay and frequency shifts can be added to the signal received and re-transmitted, creating movement.



Velocity and Distance can be changed in real-time, emulating flight.

Movement emulation is a crucial application of Software-Defined Radio (SDR) testing, providing a robust and repeatable method for validating the performance of Counter-Drone Systems in a controlled laboratory environment. This technique involves dynamically simulating the real-world movement and resulting radio frequency (RF) signal characteristics changes.



Counter Drone SDR's performance can be validated on the bench

Putting it all together

Using the Proteus Modular SDR's a complete radio environment, mission simulations, and adversary attacks can be created, ensuring the drones' mission success in any type of theater location, from urban to rural.



The Proteus SDR modular architecture allows for the creation of complex radio environments

Conclusion

The Tabor Proteus Software-Defined Radio (SDR) stands out as an excellent tool for drone radio signal analysis due to its high-performance, wideband transmit and receive architecture using high-performance RF Digital to Analog, and Analog to Digital converters. It provides robust signal generation capabilities, including broadband environment generation, noise jamming, and IQ data streaming to RF. Furthermore, the Proteus SDR functions as a critical RF recorder, capable of streaming IQ data over its high-speed PCIe interface to deep memory storage (like a RAID system). Using transmit and receive together, delay and Doppler can be adjusted to emulate movement.

Its coherent modular architecture allows test and evaluation teams to create complex real-world, real-time scenarios, validating drone and counter-drone mission performance and effectiveness.

Software Defined Radios

Proteus Series

Proteus provides both state of the art Arbitrary Waveform Generation and optional Arbitrary Waveform Transceiver capability. The system integrates the ability to transmit, receive and perform user-programmable FPGA based digital signal processing and decision making all in a single instrument. Proteus provides key capability for closed loop transceiver applications in aerospace, defense, telecommunications, automotive and physics applications.

Module Platform

Utilizing state of the art RF DAC and ADC technology, phase coherent channel density (up to 32 channels per 19" 3U 19" chassis) and high- speed data transfer, the Proteus RF PXIe Series can be used to create complex RF environments in real-time..



MODEL	P1282M P1284M	P2582M P2584M	P9082M
Channels	2 4	2 4	2
Modes	Standard, Arbitrary, Task		
Max. Sample Clock Rate	1.25GS/s	2.5GS/s	9GS/s
Memory Size	1G/2G/4G	2G/4G/8G	2G/4G/8G
Vertical Resolution	16 bits	16 bits	Up to 16 bits
Output Type	DC	DC Direct (AC)	
bandwidth	625MHz	1.25GHz 2.5GHz	4.5GHz 9GHz
Max Amplitude (into 50Ω)	1.2Vp-p	1.2Vp-p 600mVp-p	
Transition Time (20/80 typ.)	<150ps	<100ps <40ps	
Run Modes	Continuous, Trigger, Gate		
Remote Programming	Full IVI (C++, CVI, LabView), Python & MATLAB drivers and Wave Design Studio		
Connectivity	PXIe Gen3 x8 Lanes		

Desktop Platform

The Desktop Platform provides up to 12 channels of capability, but without a touch screen, saving both space and cost. This compact platform has both an internal computer and remote control via an external PC. Connectivity to the instrument is provided by 3 x USB HOST and 1 x 10Gbit LAN as standard. Thunderbolt 3, GPIB, or 2 x 10Gbit Optical are available as options.



MODEL	P1282D P1284D P1288D P12812D	P2582D P2584D P2588D P25812D	P9082D P9084D P9086D
Channels	2 4 8 12	2 4 8 12	2 4 6
Modes	Standard, Arbitrary, Task		
Max. Sample Clock Rate	1.25GS/s	2.5GS/s	9GS/s
Memory Size	1G/2G/4G	2G/4G/8G	2G/4G/8G
Vertical Resolution	16 bits	16 bits	Up to 16 bits
Output Type	DC	DC Direct (AC)	DC Direct (AC)
Bandwidth	625MHz	1.25GHz 2.5GHz	4.5GHz 7GHz
Max Amplitude (into 50Ω)	1.2Vp-p	1.2Vp-p 600mVp-p	1.2Vp-p 600mVp-p
Transition Time (20/80 typ.)	<150ps	<100ps <40ps	<100ps <40ps
Run Modes	Continuous, Trigger, Gate	Continuous, Trigger, Gate	Continuous, Trigger, Gate
Storage	Removable SSD		
Remote Programming	Full IVI (C++, CVI, LabView), Python & MATLAB drivers and Wave Design Studio		
Connectivity	3 x USB HOST, 1 x 10Gbit LAN Std., Thunderbolt 3, GPIB, 2 x 10Gbit Optical Options		

Benchtop Platform

The benchtop platform has all the same capability as the modular system, i.e., transmit, receive and user programmable FPGA, but adds a 9" touch screen and an on-board PC creating a fully standalone system. With a maximum channel count of 12 AWT's it is a compact, self-contained unit, providing waveform creation and sequence programming on the bench.



MODEL	P1282B P1284B P1288B P12812B	P2582B P2584B P2588B P25812B	P9082B P9084B P9086B
Channels	2 4 8 12	2 4 8 12	2 4 6
Modes	Standard, Arbitrary, Task		
Max. Sample Clock Rate	1.25GS/s	2.5GS/s	9GS/s
Memory Size	1G/2G/4G	2G/4G/8G	2G/4G/8G
Vertical Resolution	16 bits	16 bits	Up to 16 bits
Output Type	DC	DC Direct (AC)	DC Direct (AC)
Bandwidth	625MHz	1.25GHz 2.5GHz	4.5GHz 7GHz
Max Amplitude (into 50Ω)	1.2Vp-p	1.2Vp-p 600mVp-p	1.2Vp-p 600mVp-p
Transition Time (20/80 typ.)	<150ps	<100ps <40ps	<100ps <40ps
Run Modes	Continuous, Trigger, Gate	Continuous, Trigger, Gate	Continuous, Trigger, Gate
Display	9" Touch Color LCD Display		
Storage	Removable SSD		
Remote Programming	Full IVI (C++, CVI, LabView), Python & MATLAB drivers and Wave Design Studio		
Connectivity	3 x USB HOST, 1 x 10Gbit LAN Std., Thunderbolt 3, GIPB, 2 x 10Gbit Optical Options		

Waveform Creation Software

Wave Design Studio

Wave Design Studio is the latest in instrument control and signal creation software. The intuitive graphical interface facilitates a quick and efficient working process. In addition to the standard waveform creation capability, WDS has a number of optional add-ons for RF, microwave, radar and general purpose applications.



WAVE DESIGN STUDIO

Key features

- PC based software for instrument control and signal creation
- Dedicated add-ons for radar applications, signal correction, digital modulation
- Easy to use waveform creation tools for generating chirps, pulses and modulation
- Powerful and intuitive graphical user interface, including preview of the generated

scenario and simultaneous multi-channel and marker view.

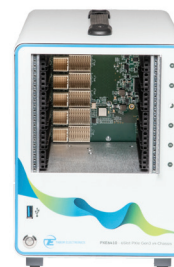
- Automatic detection of all connected instruments
- Offline mode for creating waveform, scenarios and setups without a connected

instrument.

- Log file and SCPI command editor for code debugging.

PXIe Chassis with Embedded Controllers

The PXIe Chassis allows you to purchase any Proteus PXIe module or amplifier and later add more channels or upgrade to higher sample rates. The system includes an embedded PC with an internal SSD drive, HDMI connection, and USB interfaces for a mouse and keyboard, as well as control using USB-C and 1000BASE-T LAN.



MODEL	PXE6410	PXE21100
Slots	6 slots	21 slots
Bus Configuration	Gen 3, x4 Lanes	Gen 4, x8 Lanes
Embedded Controller		
CPU	Intel D1508 2 Cores Std. / D1548 8 Cores Opt.	Intel i5-13500E Std. / Intel i9-13900E Opt.
Memory	16G Std. / 64G Opt.	16G Std. / 128G Opt.
Storage	120GB Std. / 1T Opt.	
Ports	3xUSB A (Host), 1xUSB C (Device), LAN	4xUSB A (Host), LAN
Build-in Graphics	HDMI	Display Port
Operating System	Windows 10 IoT Std.	

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