Experimenting with Red Pitaya STEMlab Gen 2

Practical Projects and Programs

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Red Pitaya: Open-Source Instrumentation for Research, Education and Industry

- Red Pitaya provides open-source, high-performance instrumentation platforms widely used in research, education, and industrial applications with more than 1,500 universities, 700 research institutes, and over 5,000 industrial labsworldwide employing its technology. Its platforms are trusted by institutions such as MIT, Stanford, CERN, and organizations including NASA and Apple, and have been used by more than 150,000 engineers, students, and researchers to accelerate experiments, prototype novel systems, and bridge laboratory precision with scalable applications.
- Red Pitaya has been recognized internationally for its impact on science and education. Most recently, in 2025, it received the Learning Technologies Award (Gold Winner), multiple distinctions at the Engineering Matters Awards— Gold Champion for Environment and Silver Champion for Innovation and Diversity & Inclusion — and was named a Design Team of the Year finalist at the Elektra Awards, receiving Highly Commended recognition for Educational Support.
- These recognitions reflect Red Pitaya's commitment to democratizing access to advanced instrumentation and supporting the global research and education community.

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Preface

Test and measurement form the foundation of every scientific and engineering discipline. The ability to observe, quantify, and analyze signals is essential for both education and research. Traditionally, these tasks have been carried out with specialized laboratory instruments, each optimized for a narrow function. While indispensable, such instruments are often costly, inflexible, and beyond the reach of students, small laboratories, and individual innovators.

Red Pitaya is a credit card-sized, open-source test and measurement board that can be used to replace most measurement instruments used in electronics laboratories. With a single click the board can be transformed into a web-based oscilloscope, spectrum analyzer, signal generator, LCR meter, Bode plotter, and microcontroller. The Red Pitaya can replace the many pieces of expensive measurement instruments found at professional research organizations and teaching laboratories. Red Pitaya is a network attached device based on Linux. The device includes an FPGA, digital signal processing (DSP), dual core ARM Cortex processor, signal acquisition and generation circuitry, micro USB socket, microSD card slot, RJ45 socket for Ethernet connection, and USB socket.

By combining a powerful system-on-chip architecture with an open-source software environment, Red Pitaya offers a reconfigurable, compact, and cost-effective platform capable of emulating a wide range of measurement instruments. More importantly, it provides opportunities for experimentation and customization that conventional equipment cannot match.

Red Pitaya can be controlled using Matlab, LabView, Python, Scilib, and Visual Programming Language. Even the newcomers to the field of electronics and computing can start writing applications and programs using the visual programming language and they can create basic to intermediate level projects. Red Pitaya offers two analog inputs and two analog outputs, as well as digital I/O ports, making it suitable to interface to the external world of sensors, actuators, and displays.

This book is written for educators, researchers, and students seeking both a practical introduction and a detailed technical reference to Red Pitaya in the context of test and measurement. It provides an overview of the hardware and software architecture, explores measurement principles, and demonstrates how the platform can be adapted for various laboratory and research applications. Students can use the Red Pitaya to learn the practical applications of various electronic components, including resistors, capacitors, inductors, diodes, transistors, operational amplifiers, and so on.

The book utilizes the **Red Pitaya Gen 2,** which is the latest hardware version of Red Pitaya family. The Red Pitaya Gen 2 builds on the foundation of earlier Red Pitaya models while introducing significant enhancements in both hardware and performance. Compared to the first generation, Gen 2 offers a more powerful Xilinx Zynq Ultrascale+ MPSoC platform, increased memory, and improved data throughput, enabling faster signal processing and greater computational flexibility. The improved FPGA in Gen 2 transforms Red Pitaya from a primarily educational/prototyping platform into a professional-grade system capable of industrial control, advanced RF analysis, and real-time high-speed signal processing**.**

The upgraded analog front end of Red Pitaya Gen 2 provides higher sampling rates and improved ADC/DAC resolution, resulting in greater bandwidth and dynamic range for precision measurement and control. These improvements allow Gen 2 to move beyond the educational and prototyping space, positioning it as a high-performance platform suitable for advanced research, signal processing, and industrial deployment. Gen 2 provides higher bandwidth and dynamic range, making it suitable for more demanding measurement and control applications. While the earlier models established Red Pitaya as a versatile, affordable alternative to traditional lab instruments, Gen 2 elevates the platform to a professional-grade tool capable of addressing advanced research, industrial, and educational needs. Red Pitaya Gen 2 adopts USB-C connectivity, which marks a clear step forward compared to the micro-USB or standard USB ports on earlier models.

Large section of the book is devoted to the very important topic of using and programming the Red Pitaya FPGA. Example projects are given on using the FPGA with the help of the latest programming tools such as the **Vivado and Verilog.**

I hope that you will find the book useful and enjoyable and that it will help you while carrying out electronic experiments.

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