Design of a Test System for Analog and Mixed-Signal Electronic Devices

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ABSTRACT

This paper presents test and diagnostic system for analog and mixed-signal electronic devices. System is based on single-board instrumentation platform and includes custom designed programmable power supplies. Test system software enables rapid creation of automated workstations for various electronic devices. Development of test system software is described. Examples of automated workstations based on this system for existing analog devices are given.

Categories and Subject Descriptors

B.8.1 [**Hardware**]: Performance and Reliability—*reliability, testing, and fault-tolerance*; J.2 [**Computer Applications**]: Physical Sciences and Engineering—*electronics*

Keywords

Automated test system, analog and mixed-signal devices, automated workstation, Red Pitaya

1. INTRODUCTION

Nowadays, production of analog and mixed-signal electronic modules for severe climatic and radiological conditions is increasing. Because of strict requirements for their reliability and huge number of laser-trimmed and adjusted components, those devices undergo numerous iterations of functional testing and parametric measurement [2]. At that, given procedures are often performed by hand with a great number of standalone instruments, which demands high qualification of operating personnel. For that reason, test automation of those electronic devices is of immediate interest.

Electronic enterprises produce vast variety of such devices, each of them in quantities of several thousand a year. That is why, it is more feasible to develop automated test systems of modest cost (within \$10,000). It is desirable that these systems are mobile and do not demand highly qualified operating personnel. The most effective way is to develop several automated test system based on a universal instrumentation platform.

We developed a test and diagnostic system which contains all necessary measuring instruments and control software for rapid development of automated test systems for analog and mixed-signal devices. This system is intended for testing various electronic devices and can be operated by low-qualified staff. We have made two KDK-MT hardware units (revision 2 unit is shown in Fig. 1). We also developed several automated workstations based on KDK-MT platform and evaluated our test system hardware and software by performing functional test of various analog electronic devices.

The rest of this paper is organized as follows. Section 2 reviews existing test systems for analog and mixed-signal devices and also presents universal single-board instrumentation platform Red Pitaya. Section 3 describes hardware of test system. In section 4 we present development of our system software. Finally, section 5 proposes our future ways to deal in this area and makes a conclusion.

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2. REVIEW

There are a lot of systems for automated test of analog and mixed-signal electronic devices. Test systems of a common type consist of standalone measuring instruments, which have a PC-interface for automatic control. Those systems often use LabView software. More advanced approach is to use instruments based on modular instrumentation platforms PXI, VXI and LXI [6]. These platforms enable creating test systems for almost any electronic device. The main disadvantage of those systems is their high cost, often connected with excessive for test problems accuracy. Another drawback is low mobility. Besides that, setup of such systems demands highly qualified personnel.

A new approach to build up test systems is to use single-board instrumentation and control platforms. Such devices contain analog front-end (oscilloscopes, arbitrary waveform generators) and a computer to perform instruments control, result processing and communication with user. One of such devices is Red Pitaya board [4]. It appeared on the marked in 2014.

Red Pitaya has two fast ADC and DAC channels with maximum sampling rate of 125 MSPS, 16 GPIO, additional ADC and DAC with lower sampling rate. The board is equipped with a Xilinx Zynq-7010 SoC. It contains dual core ARM processor and FPGA with 28k logic cells. The operating system is an embedded version of Debian 8 Jessie. A

Table 1: Comparison of test systems

Features	NI VirtualBench	KDK-MT
Oscilloscope, sampling rate	2 ch. 1 GSPS	4 ch. 125 MSPS
Generator sampling rate	1 ch. 1 GSPS	4 ch. 125 MSPS
DC voltmeter	multimeter 5 1/2 digits	12-bit auxiliary ADC
Digital I/O	8	16
Power supplies	1x 0..6 V 1x 0..25 V 1x -25..0 V	4x isolated 3..20 V 14x fixed voltage 3.3 V to 24 V
Price of hardware unit	$4000	est. $2000

user's computer can be connected via Ethernet. The main feature of Red Pitaya architecture is that all measuring instruments control logic is implemented in FPGA. This enables board customization for specific application [1].

In Table 1 our test system is compared to another single-unit instrument - National Instruments VirtualBench [3]. This is a universal single-unit test and measurement system which combines oscilloscope, signal generator, multimeter, digital I/O and power supplies.

The main disadvantage of NI VirtualBench as a universal platform for test systems (automated workstations) is low number of generator and oscilloscope channels; however, this system has higher sampling rate of analog front-end which may be useful for testing some devices. In addition, KDK-MT has more power supplies and four of them are isolated. A large number of measurement channels and power supplies are essential for development of automated test systems for vast variety of analog electronic devices.

3. DESIGN OF TEST SYSTEM

Fig.1 presents KDK-MT test system. It contains four oscilloscope channels and four arbitrary waveform generators with 50 MHz bandwidth. Digital interface consists of 14 GPIO. Besides that, there are four programmable power supplies with a useful current measurement function and 14 fixed voltage supplies. This system is designed to test devices with supply voltage up to 20 V and operating frequency up to 50 MHz.

The KDK-MT system is based on two universal instrumentation boards Red Pitaya. Boards and user PC are connected in network using Ethernet switch. One of the boards also acts as a primary controller of the test system.

Fig. 2 presents a custom developed programmable isolated power supply for KDK-MT, which can measure current consumption within the accuracy of 0.1 mA. This function is crucial for the diagnostic method of analog devices basing on current consumption, which was proposed by our research group. Power supply is based on STM8L 8-bit microcontroller which features 1 MSPS 12-bit ADC. Programmable power supplies are connected to master Red Pitaya board via UART interface.

Testing of analog devices often includes measuring of pulse response, which requires advanced signal acquisition synchronization. Usually, in this case signal generator and oscilloscope must be triggered simultaneously. KDK-MT in-

Figure 1: Test and diagnostic system KDK-MT.

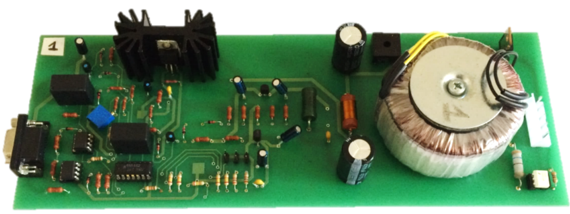

Figure 2: Programmable power supply for KDK-MT.

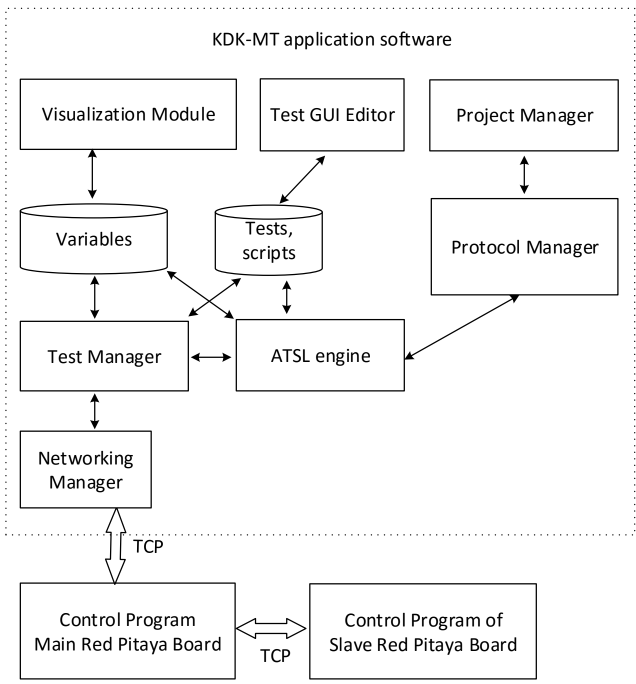

Figure 3: Architecture of test system software.

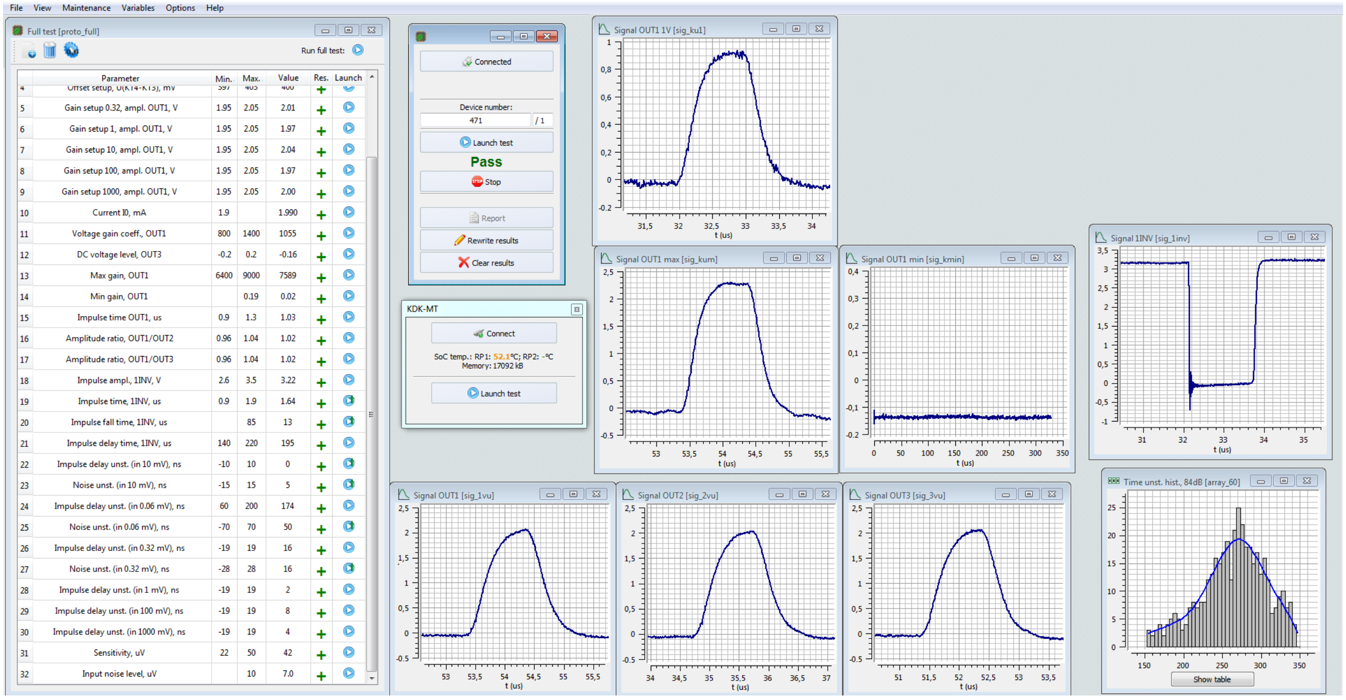

Figure 4: User interface of automated workstation for impulse amplifier testing.

ternal synchronization system allows oscilloscopes of both Red Pitaya boards to be triggered by synchronization signal from any generator channel. This signal is emitted in the beginning of every generator waveform period. To implement this function we modified the default configuration of FPGA. Trigger signal from generator control logic in FPGA is routed to the special pin on Red Pitaya expansion connector. These pins of both boards are connected to external trigger inputs of master and slave Red Pitaya by synchronization bus.

4. TEST SYSTEM SOFTWARE

Software of test system consists of control program of master and slave Red Pitaya boards and a client application. Control program is designed to interchange data between measurement equipment and digital interfaces of Red Pitaya boards and to interact with client program on user's PC.

4.1 Control program

Control program is running on the master Red Pitaya board. The slave board is controlled by a modified version of this program. It comprises only modules of oscilloscopes, generators and digital outputs management and a networking module which enables interaction with master board. Architecture of system software is shown in Fig. 3. Most of the test data, including KDK-MT generated and acquired signals, as well as measurement processing results, is stored in generalized container objects called variables. Test system scripting engine can read and modify these variables, enabling flexible control of testing process.

The control logic of board oscilloscopes and generators is implemented in FPGA. Data buffers and configuration registers are mapped into RAM with specific physical addresses. Control program communicates with instruments through reading and writing these registers in memory [5]. Digital outputs are also controlled that way.

4.2 Client program

User is working with KDK-MT test system using client application. This software is an integrated environment for test creation, tuning and launching. After completion of test its results are displayed as tables and charts. Program uses multiple document interface to allow customization of client application GUI for particular device test.

KDK-MT is used as a platform for development of automated workstation for particular analog and mixed-signal devices. An automated workstation consists of KDK-MT test system, an electronic coupling device for signal multiplexing between test system and device under test, and a client application which runs on user's PC.

Client application operates in two modes:

- *Test program setup mode.* In this mode user creates sequential description of test, which is named test protocol, and designs graphical interface of automated workstation. GUI includes protocol as a table with test stages, launch buttons and result marks; plots and information panels. This mode can also be used for analysis of device under test functioning. In setup mode a highly qualified operator is required.

- *Automated test mode.* A low-skilled user can operate in this mode. Operator would be responsible for connecting device to automated workstation coupling device, launching given test program and analyzing test results from the final protocol. Sample user interface of automated workstation is shown in Fig. 4.

System software (control and client programs) is written in C++ language using Qt library. Key features of Qt are signal and slot mechanism which enables convenient handling of asynchronous events; TCP sockets (using signals and slots), XML parser (this format is used to store test results); container classes and etc. Client application uses Qt as graphical framework. The Qwt library is used for displaying plots.

Test programs are written in scripting language ATSL. This language has simple syntax, close to numerical computing systems Matlab or Octave. It contains basic set of arithmetic and logic operators, cycles and conditional statements, as well as special purpose directives to control testing. A key feature of complex software is capability to upload a part of the script for execution in control program. At that, constant intensive network communication between KDK-MT and client application during test is eliminated. This results in a significant increase of test performance. Script uploading is important when a repetitive measurement of single parameter is required.

After completion of test final protocol is automatically filled up and can be printed or exported into PDF format. User can customize format of this document. We employ free HTML editor CKEditor for this purpose. It runs on Web engine QWebKit, which is part of Qt framework.

4.3 Automated workstations

We developed several automated workstations based on KDK-MT test system for existing analog electronic devices. First one is performing parametric measurement of special-purpose impulse amplifier with high sensitivity. The second workstation is designed for automated measurement of DC current gain of bipolar transistors and grouping them into pairs. The last one performs functional test of Manchester code transceiver.

For each automated workstation we created a coupling device in which the device under test is plugged in. These coupling devices usually contain multiplexing switches, amplifiers and other circuits required for a particular test object. A single KDK-MT unit can be used in several automated workstation; in this case switching between them requires only connecting cables and opening a test project in client application.

5. CONCLUSION

In this paper we presented the KDK-MT test system for analog and mixed-signal electronic devices. We described design of software, which enables rapid development of new automated workstations for vast variety of electronic devices. This system is cheaper than others presented on the market. Besides, automated workstation based on KDK-MT can be operated by low-qualified personnel.

Future work includes design of programmable power supply with improved characteristics, essential for current consumption diagnostic methods. Also we are planning to use JavaScript as a test scripting language instead of ATSL because of its higher performance and bigger capabilities, which are required for complicated processing of test results.

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