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STATIC MEASUREMENTS OF 16-BIT DIGITAL TO ANALOG CONVERTERS IN AUTOMATIC SYSTEM BASED ON HP-81200 SYSTEM[1]

Summary. This article presents an application of HP 81200 platform for automatic testing of digital to analog converters. The HP 81200 platform and a HP-VEE application for static testing of 16-bits digital to analog converters are described. Data achieved by HP-VEE application is used to calculate INL and DNL errors and to estimate SFDR metric.

STATYCZNE POMIARY 16-BITOWYCH PRZETWORNIKÓW CYFROWO-ANALOGOWYCH Z WYKORZYSTANIEM SYSTEMU HP-81200

Streszczenie. W artykule opisano zastosowanie platformy HP-81200 do automatycznego testowania 16-bitowych przetworników cyfrowo-analogowych (CA). Platforma HP-81200, kontrolowana przez aplikację HP-VEE, pozwala na przeprowadzenie serii pomiarów służących do wyznaczenia charakterystyki testowanego przetwornika CA. Dane zgromadzone podczas testów służą do wyznaczenia błędów INL, DNL oraz oszacowania wartości SFDR.

1. Introduction

Static parameters of analog to digital converters, like DNL (Differential Nonlinearity) and INL (Integral Nonlinearity) errors can only be obtained using automatic test equipment. The calculation of these errors is based on output values for the full conversion scope of a

[1] Presented results were achieved at WISD diviosion of Motorla, Tempe, USA

converter. For example, to calculate DNL for 16-bits digital to analog converter, 65536 points should be measured.

Various types of automatic systems can be used for testing data converters, although each of them have to include multimeter, data generator, clock generator, power supply and usually PC as a controller. In many cases the automatic test systems are based on HP-IB interface (Hewlett Packard – Interface Bus), which is a medium connecting all elements of the system and providing communication between them. Controlling the HP-IB based systems is very complicated due to the number of elements connected together and has to be done using a PC. Another solution of automatic systems is an integrated system such a HP 81200 Data Generator/Analyzer VXI test platform. The HP 81200 system has modular construction, a built-in PC controller and a HP-IB interface. The HP 81200 system includes modules, which can generate and receive digital data in a way needed for testing elements placed on DUT (Device Under Test) boards. The HP 81200 system has no provision to use analog signals, therefore cannot be used for testing analog-to-digital converters. To build a system for testing data converters additional devices such as multimeters have to be added.

The HP 81200 system can be controlled by a HP-VEE (Hewlett-Packard Visual Engineering Environment) application. The HP-VEE environment uses SCPI (Standard Commands for Programmable Instruments) command set to communicate with modules comprising the system and other devices connected to the system through HP-IB interface. The most important element of the HP 81200 system is the synchronization between the HP 81200 system and instruments working on the HP-IB interface.

This article provides description of the HP 81200 platform and architecture of the system used to obtain data necessary to calculate two static metrics, INL and DNL, and one dynamic metric, SFDR. The HP 81200 platform and other equipment were a part of Motorola laboratory at Wireless Infrastructure Systems Division in Tempe, USA.

2. HP-81200 Data Generator/Analyzer Platform

The HP 81200 Data Generator/Analyzer Platform is a digital stimulus/response system that consists of a VXI mainframe and modules built into the mainframe. The HP 81200 platform comprises of Clock modules and Data Generator/Analyzer modules. The Clock module generates the system clock and synchronizes all others modules in the mainframe. The Clock module provides the sequencing capability of a system and can use its internal clock source. A Data Generator/Analyzer module has front-ends for generating signals for the DUT board and front-ends for analyzing signals from the DUT. The structure of the HP 81200 system is presented in figure 1.

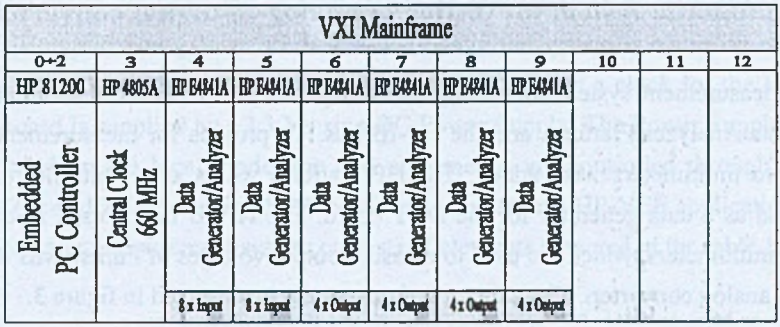

Fig. 1. Structure of the HP 81200 Data Generator/Analyzer Platform
Rys. 1. Struktura platformy HP 81200

The main module of the VXI mainframe is an embedded PC controller, which allows the entire system to be treated as a PC based equipment with HP-IB interface. The HP 81200 system can be operated from the graphical user interface or controlled via LAN or HP-IB interface. These features are useful while working with the HP-VEE environment or with C/C++ programming interface.

The present hardware resources form the base of the so-called virtual instruments. A virtual instrument is an instrument, which is defined as a set of modules comprising the HP 81200 system. For one hardware configuration many virtual instruments can be created and used.

The HP 81200 system is a base for building automated systems useful for testing various types of devices. This means that the HP 81200 system provides the ability to generate testing data and acquire data generated by the tested device. Generated and received data are defined by a data pattern. The structure of a data pattern is shown in Fig. 2.

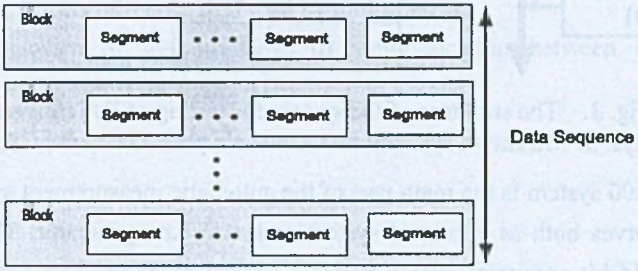

Fig. 2. Data pattern structure
Rys. 2. Struktura szablonu danych

A data pattern consists of data blocks, which include data segments directly connected with defined input and output pins. The ability of using loops allows data to be generated sequentially.

3. Automatic system for testing of analog-to-digital converters

The measurement system for testing of analog-to-digital converters is based on the HP 81200 Data/Analyzer Platform and the HP-IB bus. To provide for measurements of analog signals two multimeters were added. The HP platform works as a controller of the whole system and as a data generator for the DUT board. The HP-IB bus is used to communicate with two multimeters, which are used to measure output voltages of Fujitsu MB 86060 16-bit digital-to-analog converter. The structure of the system is presented in figure 3.

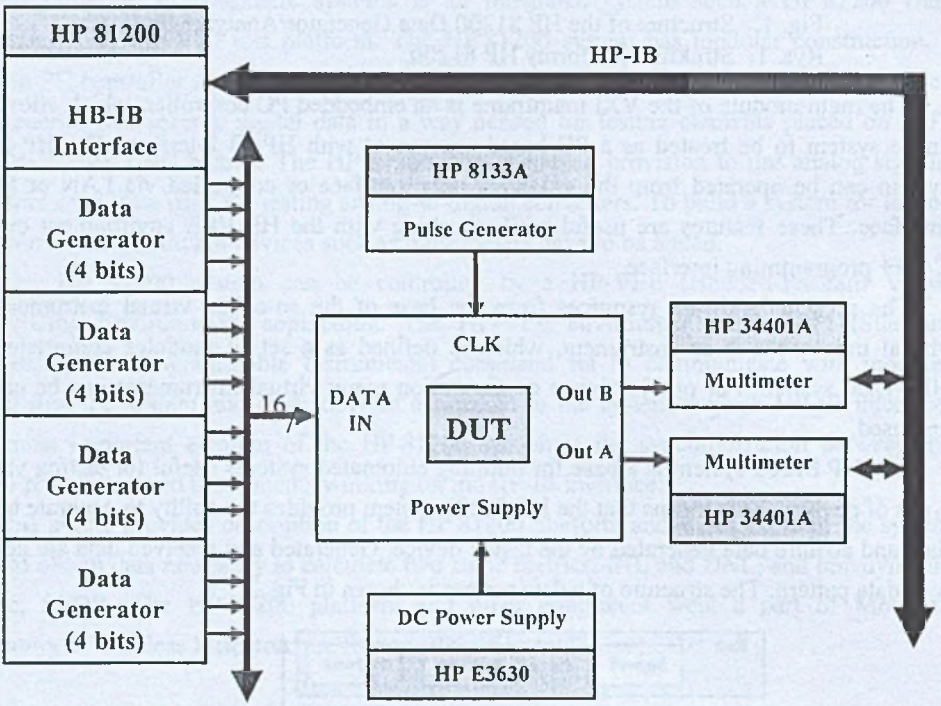

Fig. 3. The structure of the system for testing of DA converters
Rys. 3. Struktura systemu do testowania przetworników CA

The HP 81200 system is the main part of the automatic measurement system presented in figure 3 and serves both as a control system and as a data generator. The MB 86060 DA converter is a 16-bit converter, which imposes the length of the data vector that has to be generated by the HP system. Four Data Generator modules constitute the input vector for the DA converter. Data vector generation is controlled by HP 81200 system. Each data vector is prepared by the HP-VEE application and then sent to the HP 81200 system. Results of conversion are read by two multimeters (the DA converter has two complementary outputs), which are connected to the DUT board and to the HP-IB interface. The HP-IB interface is

used to synchronise readings and to send results of conversion to the HP-VEE application. The HP-VEE application gathers all data. Additionally the system is equipped with a Pulse Generator and a Power Supply. The Pulse Generator is used as a clock for the DUT board. The DUT board is supplied by +3.3 V using DC Power Supply. The Power Supply and Pulse Generator work in the local mode; the two multimeters are controlled through the HP-IB (addresses 722 and 730) bus using SCPI commands sent from a HP-VEE application.

The automatic measurement system consists of elements gathered in the table 1.

Table 1

Elements of the measurement system

Instrument	Description	Mode	Function
HP 81200	VXI Mainframe	Control, local	Main system module
HP 4805A	Central Clock 660 MHz	Control, local	Clock source for HP 81200
HP E4841A	660 MHz Data Generator	Control Data Output	Data source for DUT (16 bits)
HP 34401A	Multimeter	Control, Remote HP-IB 722, 730	Reading DAC outputs
HP 8133A	Pulse Generator	Control, Local	Clock source for DAC (50 MHz)
HP E3630	Triple Output DC Power Supply	Local	Power supply for DUT board (3.3 V)

4. Control of the measurement system

The main part of the control of the measurement system is a DAC test application working under the HP-VEE environment. The DAC test application has access to both, the HP-IB bus and to the HP 81200 resources. The main objective of the DAC test application is to maintain synchronization between all elements of the system, generate consecutive data vectors and gather results of conversion read by multimeters.

The block diagram of the structure of communication between elements of the measurement system is shown in figure 4.

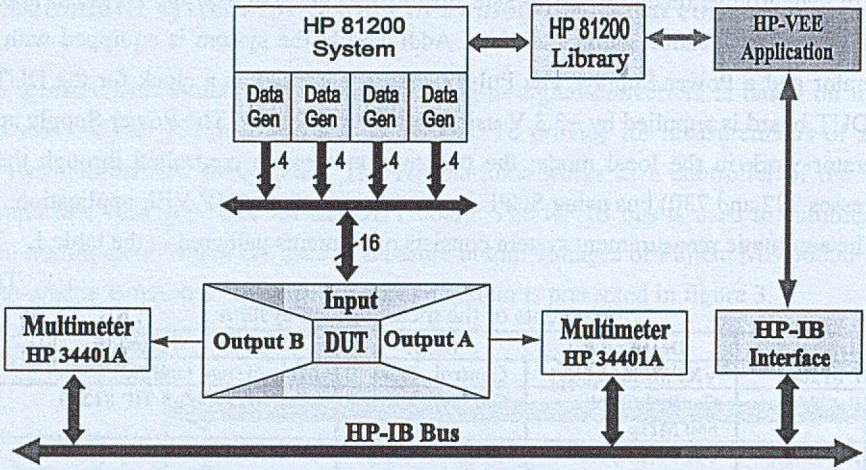

Fig. 4. Communication between HP-VEE application and DAC testing system
Rys. 4. Komunikacja pomiędzy aplikacją HP-VEE i systemem testującym

Each device working on the HP-IB bus has its own address and is accessible by SCPI commands from the HP-VEE environment through the HP-IB interface.

The HP-VEE based application works on the PC embedded into the HP 81200 VXI mainframe. The access to the instruments working on the HP-IB bus is available directly from the environment. Consequently no additional device is required to send or receive data using HP-IB interface. To get access to the modules of the HP 81200 an interface library is needed. The interface library allows passing from a HP-VEE application to the HP-IB interface any valid SCPI commands.

5. The DAC test application

The HP-VEE based application for testing of digital-to-analog converters comprises of three main parts: initialization, main loop and measurement procedure. The initialization part has to establish the connection with the HP 81200 system, check the settings of the multimeters and prepare system for measuring. The main loop is used for communication with user, and allows for setting and checking the parameters of the whole system. The measurement procedure performs the measurements and stores results in an output file.

5.1. Initialization

During initialization, the HP 81200 system connects to the HP-VEE application using Connect_HP81200 function. The interface library has to be loaded before any communication

with the HP system can be realized. The HP 81200 system is then configured. In this step a configuration file is loaded to the HP 81200 system. The configuration file consists of information about the settings of the HP 81200 modules and connections defined for the DUT board. The data pattern is also loaded during initialization, and defines the sequence structure used later for output data generation. Initialization also contains setting up two HP 34401A multimeters working on the HP-IB bus (HP-IB addresses 722 and 730). Initially they are configured by sending SCPI commands for voltage measure with accuracy 6.5 digit. For each trigger signal, five measurements are taken. Results are kept in the multimeters internal buffers until the 'FETC?' command is sent to read them.

5.2. Main loop

After initialization of the HP 81200 system and devices working on the HP-IB bus, the application is ready to perform tests or to change parameters of the test. In the main loop of the HP-VEE application, the user can generate events by pressing buttons and in order to make a decision on what action should be taken. Using appropriates buttons, the parameters of the HP 81200 system can be changed and the test results can also be displayed.

5.3. Measurements

The measurement is based on settings, which was prepared during initialization or changed by the user after initialization. The measurement process consist of eight main steps:

1. Sending SCPI setting commands to the multimeters
2. Preparing first data pattern for the data generators
3. Sending data pattern to the HP 81200 system
4. Connecting the data generator output pins to the DUT board
5. Sending SCPI command to trigger the multimeters
6. Reading measurement results and saving them to the output file
7. Preparing next data point to be sent to the HP 81200 system
8. Checking if the current data point is not bigger then the last one, if not go to point 3

Main disadvantage of this measurement structure is that each data pattern has to be created by the HP-VEE application and sent to the HP 81200 system. The HP 81200 system has ability to use data patterns kept in a file, which is useful when generation of a data pattern is complicated. However, this feature cannot be used in case of communication with very slow devices, such as multimeters. The HP 34401A multimeters are too slow to perform measurements in response to an external trigger, which is available in the HP 81200 system.

Each measurement lasts about 0.4 second. Hence, the maximal trigger frequency cannot be bigger than 2.5 Hz. In the HP 81200 system the minimum clock frequency is about 10 kHz.

Synchronization between the HP 81200 system and the HP-IB bus is maintained by the HP-VEE application, in which one measurement cycle comprises of four steps shown in figure 5.

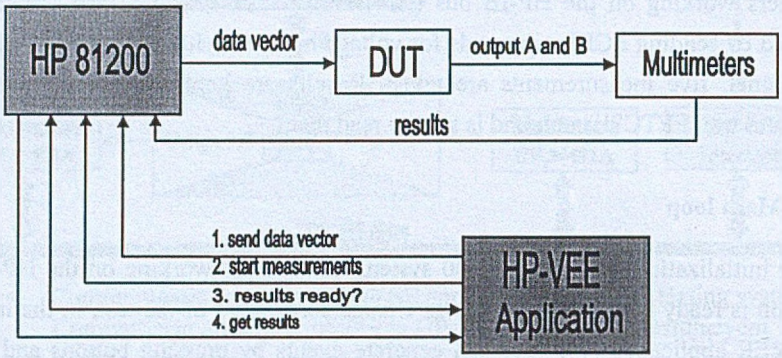

Fig. 5. Synchronization between HP-VEE application and DAC testing system
Rys. 5. Synchronizacja pomiędzy aplikacją HP-VEE i systemem testującym

5.4. User Interface

The HP-VEE application allows an interactive changing of parameters of the HP 81200 system and the HP 34401 multimeters. Additionally there is a possibility to set the start and stop point of measurement, and show the results on the display.

User interface was divided into five groups:

- VXI system configuration
- HP-IB system configuration
- Measurements control
- Control buttons

VXI and HP-IB monitor

The screen shot of the main view of the HP-VEE application is shown in Fig. 7.

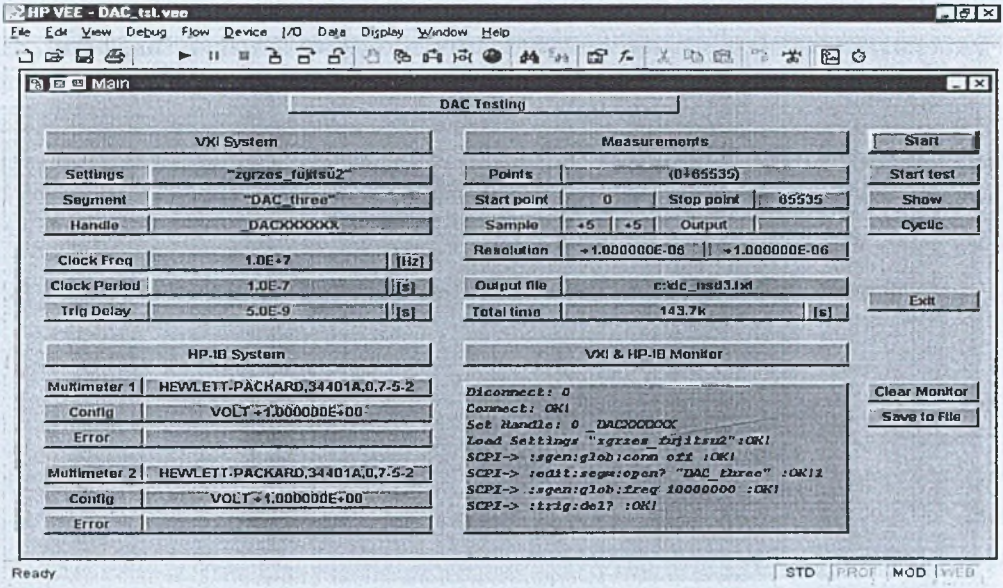

Fig. 6. User interface of the DAC testing application
Rys. 6. Interfejs użytkownika aplikacji testującej przetworniki CA

5.5. VXI and HP-IB system functions

The VXI system functions enable changing the parameters of the virtual instrument: Settings, Segment and Handle. In addition it is also possible to set parameters of the clock module: frequency, period and external trigger delay.

The configuration of the two HP multimeters can be read using the HP-IB system functions. When an error occurs during communication with the multimeters, the error string can be read from the multimeter.

5.6. Measurement and control functions

The measurement functions allow setting up parameters that are directly connected with measurement. The first and the last point of generated data can be set. Number of samples taken during one measurement and resolution of the measurement can be established. Data collected during measurements is placed into a file whose location and name sets the 'File name' button. On collection of all output values, the time used for measurement is presented in the display 'Total time'.

The control functions of the DAC test application can be used to start measurement, show results and exit the application.

Results of measurements can be presented in a graphical form, which is shown in Fig. 7.

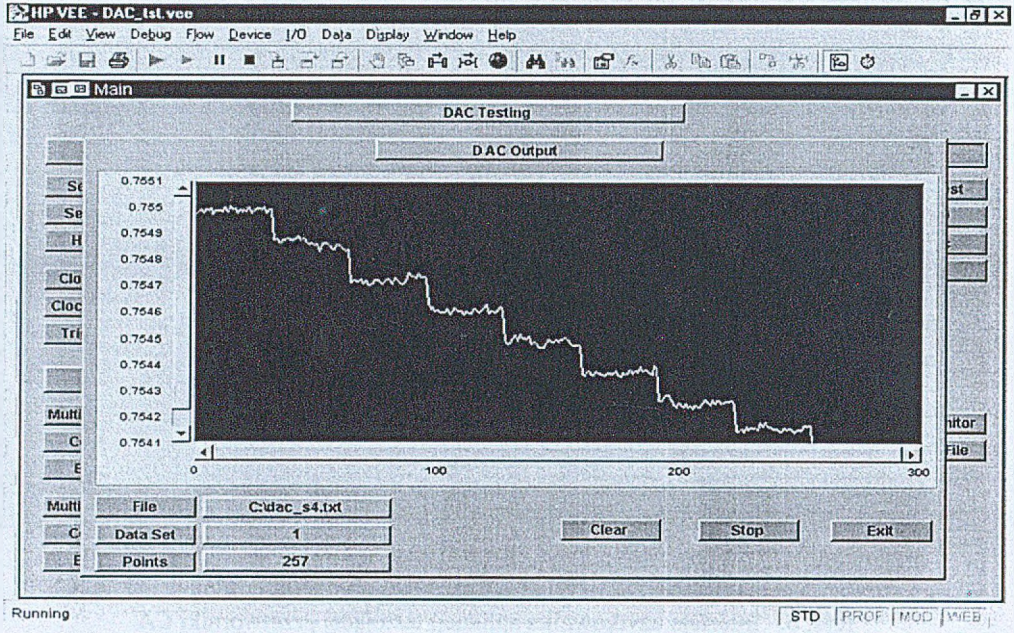

Fig. 7. Presentation of the results
Rys. 7. Prezentacja wyników

Results of measurements are saved to the text file. Each line of the output file consists of 10 measurements (five for each output of the DAC). The output text file is used for calculation of the INL and DNL errors, which is realized using Matlab software.

6. Conclusions

The HP 81200 system has the ability to cooperate with the HP-VEE environment and C/C++ applications. The HP-VEE environment is very useful for creating graphical applications with the capability to exchange data through a serial interface, HP-IB interfaces and sockets. As an alternative solution, the interface to the C/C++ application can be used. In this case the C/C++ application has to maintain communication on the level of the SCPI commands. The SCPI commands have to be sent directly through the hardware interface (HP-IB or RS-232). The main advantage of the C/C++ application is the ability to create a tool, which not only gathers data from HP-IB bus but also calculates DNL and INL errors. It also prevents from moving data from one operating system platform to another.

Usage of the HP 81200 system is simplified by utilization of a HP-VEE application as a control application. Communication with modules comprising the HP 81200 system and

devices connected to the HP-IB interface is uniform and thus very easy in use. However the HP 81200 system is not prepared to perform synchronization with very slow measurement instruments, such as multimeters.

Presented HP-VEE application for static testing of digital-to-analog converters was used for testing of 16-bit interpolating digital-to-analog converter. The MB 86060 DA converter has built in interpolating filtering and programmable high-pass filtered dither. The DA converter is designated for cellular base station, direct IF synthesis and for wide band communication systems.

7. Acknowledgments

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Streszczenie

Artykuł prezentuje automatyczny system przeznaczony do testowania 16-bitowych przetworników cyfrowo-analogowych (CA). Opisany system bazuje na platformie HP 81200 i jest sterowany przez aplikację napisaną w środowisku HP-VEE. Platforma HP 81200 jest

cyfrową platformą Generatora/Analizatora pozwalającą na komunikację z urządzeniami wyposażonymi w interfejs HP-IB. System służący do testowania przetworników CA, oprócz platformy HP 81200, zawiera dwa multimetry, generator oraz moduł zasilacza. Tak skonfigurowany system pozwala na pomiar napięcia dwóch komplementarnych wyjść przetwornika CA. Wyniki pomiarów są wykorzystane do określenia błędów nieliniowości całkowej INL (Integral nonlinearity), nieliniowości różniczkowej DNL (Differential nonlinearity) oraz określenia warotści SFDR (Spurious Free Dynamic Range).

Proces testowania przetwornika CA obejmuje generację 65536 punktów pomiarowych (od 0 do 65535), które odpowiadającą 16 bitom rozdzielczości przetwornika CA oraz składowanie wyników przetwarzania w pliku tekstowym. Aplikacja HP-VEE generuje kolejne punkty pomiarowe (postać cyfrowa), które wysyłane są do przetwornika za pośrednictwem platformy HP 81200. Wyniki konwersji CA odczytywane są za pomocą multimetrów kontrolowanych przez aplikację HP-VEE. Seria wyników pomiarów, składająca sie z 65536 punktów, stanowi podstawę do późniejszego wyznaczenia parametrów konwersji przetwornika CA. Aplikacja HP-VEE udostępnia również szereg dodatkowych funkcji służących do konfigurowania i monitorowania pracy całego systemu. Parametry testowanego przetwornika są wyznaczane przez aplikację pracującą w środowisku MATLAB.