Standardisation of Automated Industrial Test Equipment for Mass Production of Control Systems

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Industrial Test Equipment Project

Power converters and their controls electronics are key elements for the operation of the CERN accelerator complex, having a direct impact on its availability. They must be designed to achieve a high Mean Time Between Failure (MTBF) and hardware reliability must be ensured by board-level testing before hardware is assembled and installed. A key element to achieve this, is the development of the industrial testers used in the board production phases. The roles of these testers are: to validate mass production during the manufacturing phase and to provide a means to repair failed modules brought back from operation during exploitation. Recently, the National Instrument PCI Extension for Instrumentation (PXI) was chosen by the TE-EPC-CCE section at CERN as standard platform for the development of testers. PXI is a modular platform for measurement and automation systems offering a low cost and flexible solution providing the benefits of an open industry standard.

The PXI Platform Solution

Before moving to the PXI solution, a Generic Test Chassis (GTC) was developed to validate the first version of the Function Generator Controller (FGC). The GTC hardware was complex, difficult to maintain and expensive. Every card to be tested required a test card to adapt its interfaces, to correctly control and observe the various resources, specific to that card. Every test card consisted of a microcontroller, a FPGA and a flash memory, all these have complicated the GTC's hardware and software. This is the reason why the TE-EPC-CCE section has chosen moving to the PXI Platform.

GTC Platform

PXI is a rugged PC-based platform for measurement and automation systems. PXI combines PCI electrical-bus features with the modular, Eurocard packaging of CompactPCI and then adds specialized synchronization buses and key software features. National Instruments provides many standard modules to choose from, each providing a different function. Third party vendors can also produce boards for the NI PXI system making the system extremely adaptable to any tester setup. This allows the testers to share the same hardware and software structure resulting in significant resources sharing, a quick turnaround time, and a lower per-unit cost than a complete in-house design.

Table 2. Parts of GTC System

Module Types	Description
Embedded PC	Windows based Embedded Controller
MCU M32C/87	Renesas Microprocessor
Spartan 3AN-700	Xilinx FPGA
Spansion FLASH	FLASH Memory
FAT16 USB	USB Device

Table 1. Parts of our PXI System

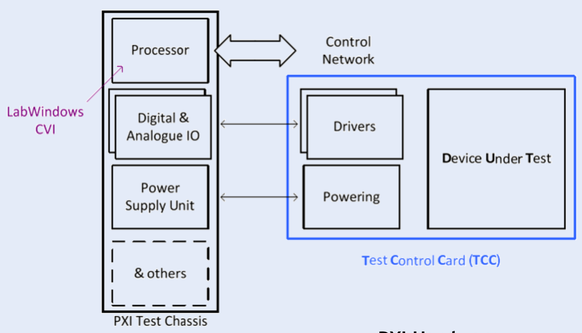
Module Types	Description
NI PXI-1042Q	8-slot 3U PXI Chassis with Universal AC
NI PXI-8108	2.53 GHz Dual-Core PXI Embedded Controller
NI PXI-4110	Triple-Output Programmable DC Power Supply
NI PXI-6221	16 Analog Inputs, 2 Analog Output, 24 Digital I/O
NI PXI-6509	Low-Cost, High-Current, 96 Ch, 5 V TTL/CMOS Digital I/O
INCAA DIO8	TTL Digital I/O (Timing Module)
Exoligent WorldFIP	FIP designer

PXI Platform

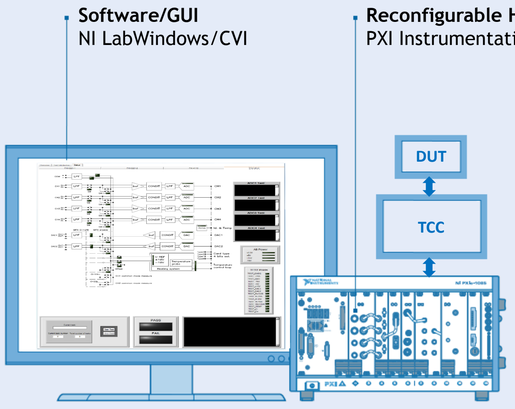
Hardware Architecture

The PXI Chassis consists of a processor running windows, using LabWindows CVI to give access to the PXI bus and execute test programs. In addition to the PXI crate, the generic test setup consists of a specific Test Control Card (TCC) designed to interface the PXI Chassis with the Device Under Test (DUT). The TCC is by definition the hardware part dedicated to each card or module that must be tested. This TCC is mainly used to realise the interface in terms of voltage level or signal translation, between the specific board to test and the PXI. Sometimes this TCC can have some programmable logic embedded inside.

PXI Setup
- All PXIs have an identical setup:
  - Hardware
  - Software
- Barcode reader.
- Dallas ID reader.
- FPGA Programmer.



PXI Hardware



PXI Chassis
- PXI Embedded Controllers.
- Programmable PSU.
- DAQ Modules.
- INCAA FPGA Module.
- Exoligent WorldFIP designer Module.

PXI TCC
- Simple interface between PXI and DUT.
- No FPGAs or microcontrollers required.
- Low cost.

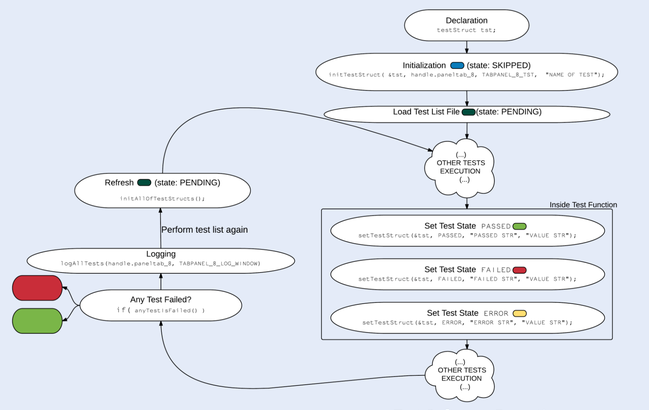
GUI
- Virtual LEDs.
- Displays relevant information.
- Allow control of the test.

Software Architecture

Each tester is implemented by developing a control sequence written in LabWindows/CVI, a C-based language, providing an easily maintainable structure.

PXI Software
- Windows based system.
- Running LabWindowsCVI:
  - C-based Language
  - Easy to maintain and understand
  - Structured Template developed
  - Reusable functions
  - Excel support

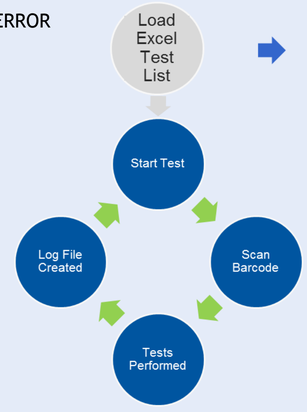
Log File
- Detailed Log is created at the end of each test.
- A unique file created for each board.
- Information included:
  - Date/Time
  - Test list performed
  - Dallas ID
  - Barcode ID
  - Temperature
  - Test performed: PASS/FAIL/PENDING/SKIP/ERROR
  - Measured parameters (if required)



Test Software Execution

```
************************************************************
03-09-2015 (mm-dd-yyyy)
15:50:55
Version :v2.0
Test List : Ver.2 AB Temp Test.xls
************************************************************
------------------------------
Dallas ID :
Temp[00]:0x0F000000F2091A28 SPad0x0000000000000000
Temp[00]:0x0F000000F2091A28 SPad0x0000000000000000

Barcode ID :
HCRAKST002-CR000010
------------------------------

POWER +3.3V Test                :PASS   : 3.30085V
POWER 5V Test                   :PASS   : 5.01191V
POWER +15V Test                 :PASS   : 14.9876V
POWER -15V Test                 :PASS   : -14.9775V

ADC1 Test                       :PASS
ADC1 Passed at : 0.0v           (Measured -0.00173283V)
ADC1 Passed at : 1.0v           (Measured 1.00513V)
ADC1 Passed at : 5.0v           (Measured 5.03226V)
ADC1 Passed at : 10.0v          (Measured 10.0669V)

DAC1 Test                       :PASS
DAC1 Test (10V)                 :PASS   : 9.95342V
DAC1 Test (6V)                  :PASS   : 5.97195V
DAC1 Test (2V)                  :PASS   : 1.99049V
DAC1 Test (0V)                  :PASS   : 8.12469e-05V
DAC1 Test (-4V)                 :PASS   : -3.98073V
DAC1 Test (-8V)                 :PASS   : -7.96285V
DAC1 Test (-10V)                :PASS   : -9.95326V
+10V Ref Test                   :PASS   : 9.99829V
-10V Ref Test                   :PASS   : -10.0009V
GNDSense Test                   :PASS   : 0.00101409V
DAC1 to ADC1 Test               :PASS

************************************************************
END OF TEST
************************************************************
```

Log File



Running the Test

Description	Test bench test list template		
Date	16/08/2011		
Function name	Short Description	Parameters	
Set To Default State	Set To Default State		
Psu Set Voltage	Set output value	0.5	
Psu Set Voltage	Set output value	1.15	
Psu Set Voltage	Set output value	2.15	
Psu Compliance	Test compliance	0	
Psu Compliance	Test compliance	1	
Psu Compliance	Test compliance	2	
Test AB Power	Test AB Power		
Test +/-10V Reference	Test +/-10V Reference		
Test +/-10 Ref Through ADCs	Test +/-10 Ref Through ADCs		
Test All ADCs	Test All ADCs		
Sweep Test DAC	Test DAC from -10V to 10V		
Test DAC to COMMON	Test DAC to COMMON		
Sweep Test DAC to ADCs	Sweep Test DAC to ADCs		
Test Temperature Control	Test AB Temperature Control		
Test Offset	Test Offset		
Test Power Control	Test Power Control		
Psu Set Voltage	Set output value	1.0	
Psu Set Voltage	Set output value	2.0	
Psu Set Voltage	Set output value	0.0	
Psu Measure	Measure voltage & current	1	
Psu Measure	Measure voltage & current	2	
Psu Measure	Measure voltage & current	0	

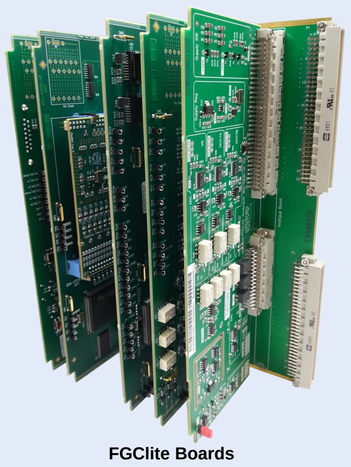
Excel Test List

Excel Test List

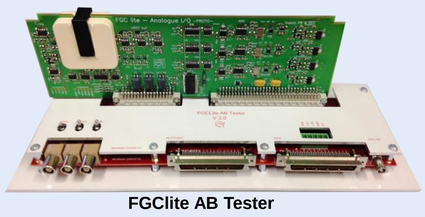
In order to be able to execute functions "from" Excel spreadsheet, a special library that associates strings in Excel Spreadsheet file cells with function names has been implemented in the CVI software .

Example Project - FGClite Testers

The LHC has several thousand magnets, both warm and super-conducting, which are supplied with current by power converters. Each converter is controlled by a purpose-built electronic module called a Function Generator Controller (FGC). The new converter controls for the LHC are based on the radiation tolerant version of the Function-Generator Controller (FGClite) to be used in the radiation areas of the LHC. For each board of the FGClite crate, the PXI based tester has been developed to verify the electrical continuity of the boards.

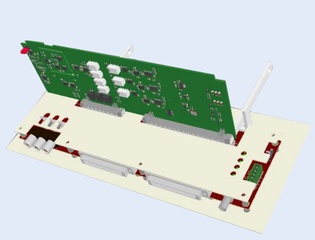


FGClite Boards

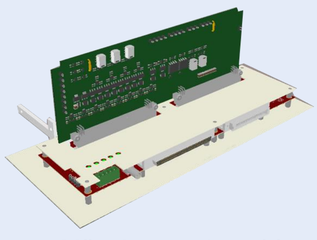


FGClite AB Tester

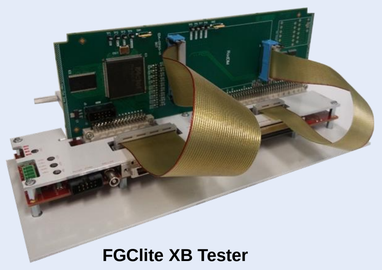
FGClite RadDIM Tester



FGClite AB Tester 3D Model



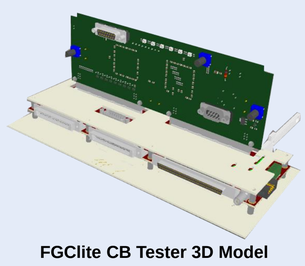
FGClite IOB Tester 3D Model



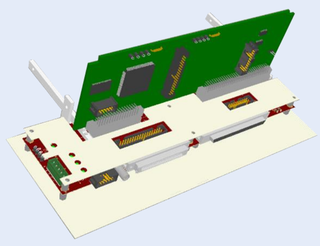
FGClite XB Tester

Table 3. Parts of FGClite

FGClite Board	Description
FGClite MB	Main Board
FGClite AB	Analogue Board
FGClite CB	Communication Board
FGClite XB	Auxiliary Board
FGClite PB	Power Board
FGClite IOB	Input/Output Board
FGClite RadDIM	Diagnostic Interface Module

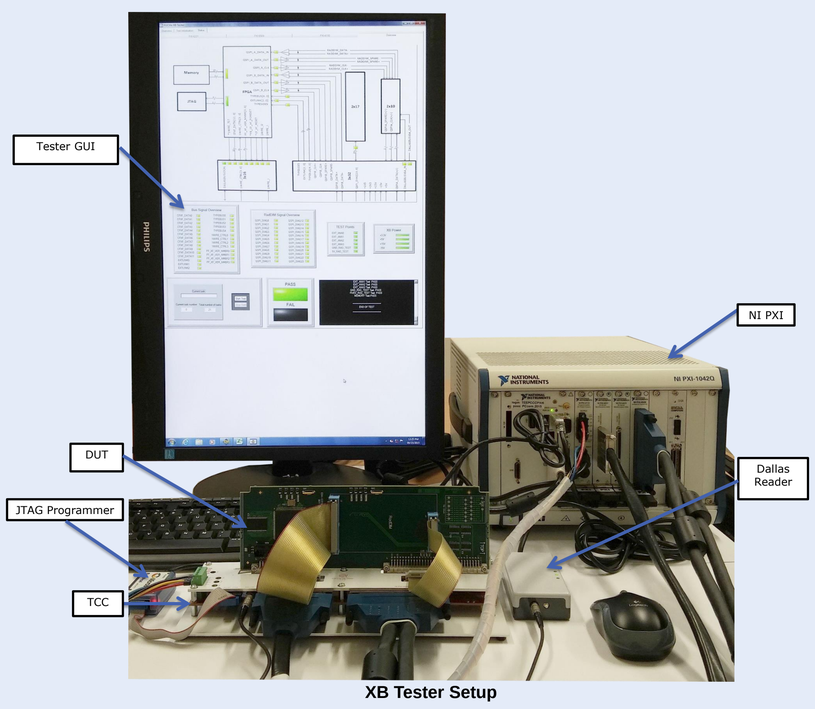


FGClite CB Tester 3D Model



FGClite XB Tester 3D Model

FGClite PB Tester



XB Tester Setup

Conclusions

Over the past years we evaluated different platforms for the development of testers. Several versions of a Generic Test Chassis (GTC) were developed. It has turned out that the complexity of the hardware, the software and the excessive cost became too problematic. Therefore, recently, the National Instrument PCI Extension for Instrumentation (PXI) was chosen by the TE-EPC-CCE section at CERN as standard platform for the development of testers. The outcome of the aforementioned actions was achieving the flexibility and increase in the test platform's performance while decreasing the costs.

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