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DEPARTMENT OF APPLIED ELECTRONICS AND TELECOMMUNICATIONS

MASTER'S THESIS

Optimization of the existing test system

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Copy of assignment

Abstract

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This master's thesis is concern with testing of the printed circuit board. Special printed circuit board is designed for this test. This board connects the tested unit and peripheral devices. The program is developed for the test system. This program communicates with the peripheral devices.

Key words

ICT testing, LabVIEW, climatic chamber, state machine, serial communication

Anotace

Lukáš Strnad. Optimalizace stávajícího testovacího systému. Katedra aplikované elektroniky a telekomunikací, Západočeská univerzita v Plzni – Fakulta elektrotechnická, 2015, vedoucí: Doc. Dr. Ing. Vjačeslav Georgiev

Tato diplomová práce se zabývá testováním desky plošného spoje. Pro tento test je vytvořena speciální deska plošného spoje, která spojuje danou testovanou jednotku a periferní zařízení. Pro testovací systém je vyvinut program, který komunikuje s periferními zařízeními.

Klíčová slova

ICT testování, LabVIEW, klimatická komora, stavový automat, sériová komunikace

Statement

I hereby submit for review and defence my master‘s thesis. I declare that I prepared this thesis independently using professional literature and resources listed in the list, which is part of this thesis. I also declare that software used to prepare this thesis was obtained legally.

In Pilsen on May 11, 2015 ....

Acknowledgment

I would like to thank Zollner Elektronik AG for the provision of the project and the financial support.

I am glad to express hearty appreciation to my thesis supervisors Michael Breu and Vjačeslav Georgiev for their time, patience, support, thoughts and motivation.

I am thankful to Arnold Frankl for support by writing the program.

Contents

List of Abbreviations

ABS	- Anti-lock Braking System
ADC	- Analog-to-digital converter
DMM	- Digital multimeter
DUT	- Device under test
EBS	- Electronic Braking System
ECU	- Electronic Control Unit
ELC	- Electrical Level Control
EPROM	- Erasable programmable read only memory
FAT	- Function Analyse test
ICT	- In-Circuit Test
NI	- National Instruments
PCB	- Printed circuit board
PLC	- Programmable Logic Controller
RFID	- Radio-frequency identification
TCS	- Traction Control System
VI	- Virtual Instrument

1 Introduction

In the beginning there is the existing test system which runs unstably. This is the reason why the test system has to be reworked. The principle of the testing is completely changed.

This project deals with the ICT testing. In the company Zollner Elektronik AG there is a production line which executes the function test of the electronic component called ELC4. The object is to optimize this production line, i.e. designing a new stable test system. A board is necessary to design. This board will connect the tested unit ELC4 with peripheral devices and it will control the measurement. A program for the test system has to be also designed. This program has to communicate with the peripheral devices and control the connecting board. All devices has to be connected with the test computer.

The company Knorr-Bremse AG designed the electronic component ELC4. This component is produced and tested by the company Zollner Elektronik AG. The Knorr-Bremse AG deals with the development of the braking system for tractor vehicles and trains. That's why the component ELC4 is tested in the climatic chamber by the operational temperature. The Zollner Elektronik AG deals with electronic manufacturing services. Its headquarters is in Zandt in Germany where this project is realized.

2 Climatic test

In the beginning of the project there is the existing climatic chamber called screening oven. The climatic chamber is a device used to test the effects of specified operational conditions on electronic components. This process called climatic test is mostly used to accelerate the effects of exposure to the environment. The electronic components are under effect of extreme temperatures in climatic cycles, it means that the low and high temperatures change in turns. This way is possible during several hours in the climatic chamber to reach the state of the component after two years using in operational environment. This highly accelerated stress test exposes errors on the beginning of component life. The screening oven executes only two cycles, first by temperature -30°C and second by 80°C. The electronic component is tested at the end of each cycle. This way is verified that the component works faultless by limit operational temperatures.

2.1 Screening oven

The screening oven under internal designation PTM made by the company Hatec Vertrieb is in actual fact a production line where two kinds of electronic components (EBS7 and ELC4) are tested. The PTM line can’t produce two different components, just one test adapter can be installed.

2.1.1 Electronic component EBS7

The Electronic Braking System (EBS) integrates the basic function of braking control (ABS and TCS) into one electronic system. EBS7 is designation for the electronic component with pressure sensor, this component is put into a tractor vehicle to electronic control of braking power. [4] The test of the EBS7 is run by the program MCON.exe on the testing computer. For testing of the components EBS7 there is available a specific adapter and five boxes with specific arrangement for these components. One box contains 15 components EBS7.

2.1.2 Electronic component ELC4

The Electrical Level Control (ELC) checks and adjusts the level of the tractor vehicle. This function is used to lower the level of the bus to enable the handicapped get in and out more easily. [4] Electronic component ELC4 contains the pressure sensor too, a source regulator and a system of flyback diodes. The task of this project is screening of the source regulator function and the flyback diodes. An adapter with the specific bed of nails and five boxes are prepared for testing of electronic component ELC4. Each of boxes can accommodate up to three components ELC4.

2.2 PTM line

The screening oven consists of four modules and two computers. Each module executes some operation with the box. The computers control these operations. The first is an operator computer which controls the motion of the boxes in the production line and displays information about tested units to the operator. The operator sets up parameters for the production line using the operator computer. The second is a test computer which controls the screening of the tested units and displays information about the test system to the technician. The technician can manually control the screening using the test computer.

Before the production of the electronic components from the Knorr-Bremse the technician has to insert the right adapter to the switched off PTM line. Then he has to gradually switch on all modules using a red button. After a system of the PTM line is launched the technician sets up the right process of the screening and puts all five boxes into the PTM line through a load module. When the operator loads the electronic components into the current box in the load module and presses the green button, the production can start.

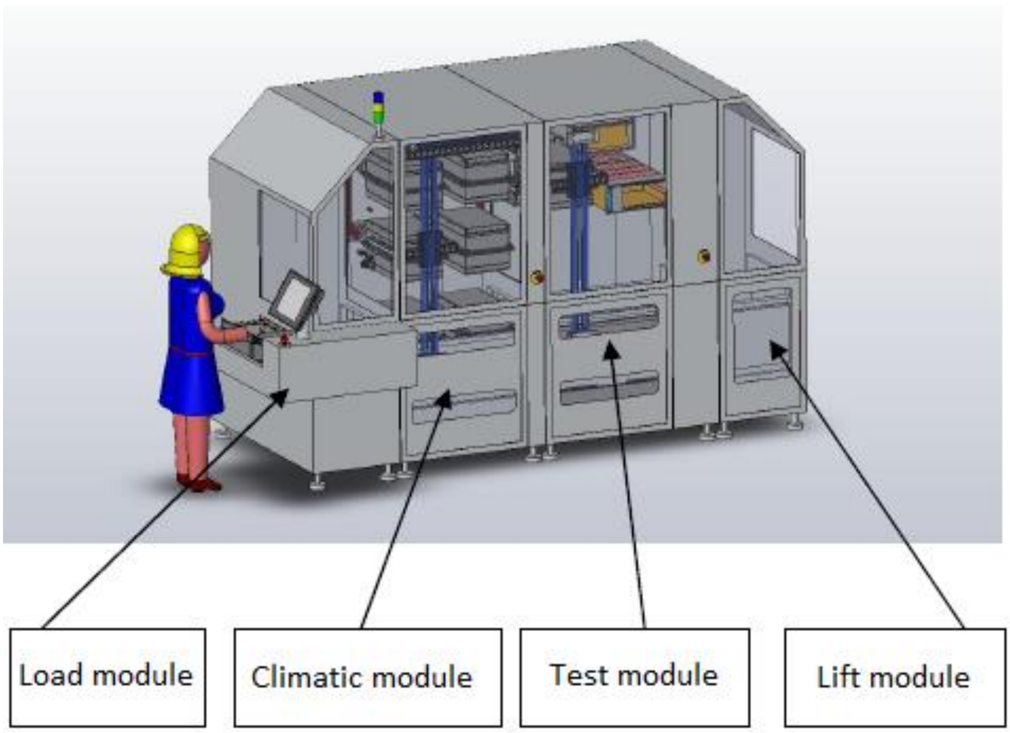


Figure 1 PTM line [5]

Five boxes called also as thermoboxes travel through all four modules. Each box contains memory chip EPROM and RFID tag. The PLC reads box-ID in every its step. The operator computer and the test computer get this information and therefore they know what they has to exactly do with the mentioned box.

2.2.1 Load module

The load module is used to putting the boxes into the PTM line. The operator puts untried electronic components into the nest in the box which is currently ready to load. The operator has available touch screen of the operator computer which displays the passed components and the failed components to sorting on two groups, on the wasters and on the components to deliver to the customer.

After the operator loads up the box and presses the green button as acknowledgement of the loading, the box enters inside of the load module where the scan device reads the barcode on the tested components. After reading the cover of the box is closed and the box continues to the climatic module.

2.2.2 Climatic module

The climatic module includes four station where the boxes are cooled up to -30°C or heated up to 80°C. When all four station are occupied by thermoboxes, the fifth box waits in the load module until one station releases. Every box is lifted up to the following free station. Every box has to visit all four station in fixed order, the last station has the biggest pressure power. Every box has within a temperature sensor which gives the information about reached temperature through the connection with the climatic station to the PLC. If the sensor measures the defined temperature the box leaves climatic module and shifts to the test module.

2.2.3 Test module

The test module ensures the screening of the electronic components. This module contains the adapter with bed of nails, the test industrial computer and facilities to the testing such as power supply, digital multimeter (DMM) and I/O device. The PLC hand the information, such as the box-ID, the number of installed adapter etc., over to the test system which processes these data and executes the inspection process according to them. After the test finishes the test system sends a command to the PLC to leave the box from the test position.

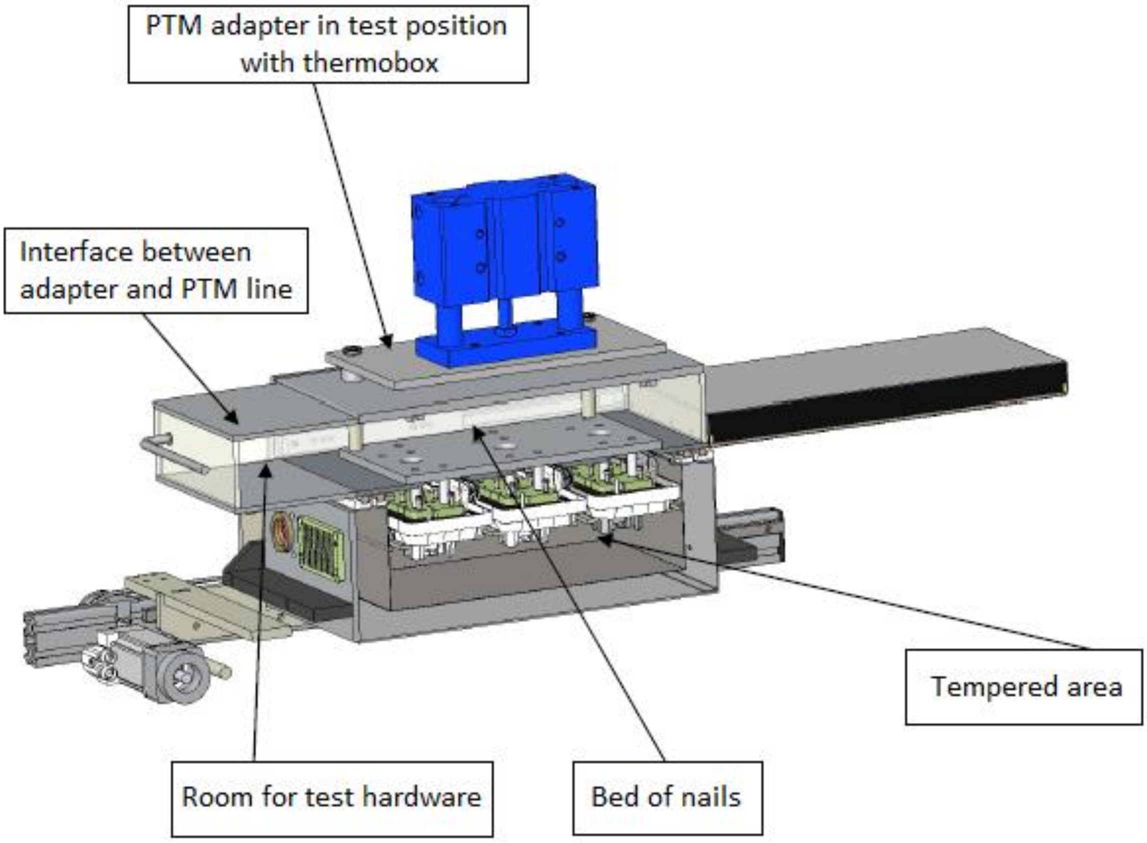


Figure 2 Adapter with thermobox [5]

2.2.4 Lift module

The lift module returns thermoboxes back to the load module. The thermobox is shifted to the lower level by the lift at first then is moved to the load module and lifted up.

If the thermobox is tested by the low and high temperature then goes to the operator else the thermobox continues to the climatic module to heating up.

2.3 ICT testing

In test adapter there are the test probes which connect the tested unit with the test hardware. Each test probe contacts the test point of the DUT, on the other side of the test probe there is a wire led to the connector connected to the test hardware. The test probes are pressed on the predefined point on the DUT. This process concerns with the Function Analyse Test (FAT) in circuit. The strategic, safety and protective elements such as flyback diodes are measured to find out their correct function. This measurement finds out whether the element is mounted or whether a polarity of the element is correct. The test using test probes to measure is called In-Circuit Test (ICT).

3 Project specification

The Knorr-Bremse company designed a test specification for electronic control unit ELC4. This document determines parameters of the inspection process for the particular temperature. This specification defines the tolerance and accuracy of the measurement, required values for low and high temperature in °C, conditions for the particular tests and specific test circuit for the inspection process.

3.1 Test conditions

For the measurement the following conditions are valid. [6]

- A tuning isn't necessary.
- The supply voltages are set up with an accuracy of ±0,02V.
- The measured accuracy has to be smaller than 1%.
- The signal ground for the supply voltages and measured reference point for the voltage measurement is PS_GND (X1-4) when nothing else is stated.
- The evaluation is default executed 200 ms after the putting the supply voltage.
- The tolerance area for low temperature on the DUT: $-32°C < \vartheta < -24°C$
- The tolerance area for high temperature on the DUT: $+75°C < \vartheta < +87°C$
- The production process of the PCB ELC4 has to be executed at least one time by the low and high temperature according to the test table (see below).
- The production process can be executed either with the mounted PCB or with the finished assembled electronic control unit (ECU).
- The production process of the finished assembled ECU has to be executed at least one time by any temperature.

The production process by the room temperature isn't necessary ordered but it could serve as the end production process for the finished assembled ECU.

On the following page there is test table for the inspection process by the room temperature. The inspection process for the ELC4 by the low and high temperature has the table with the same parameters like the inspection process by the room temperature, this is the reason why only one table is stated.

3.2 Test table for the inspection process

The test table defines the parameters of the screening.

Table 1 Test table [6]

Pos.	Test	Test conditions	Measured point/line	Unit	Value	Reference point / comment
1	Voltage loss by U-PS_SPL min	U-PS_SPL = 4,65V	MP22 (VCC)	U [mV]	3 - 12	U-SP_SPL (X1-6)
2	Voltage loss by U-PS_SPL max	U- PS_SPL = 5,35V	MP22 (VCC)	U [mV]	3,5 - 14	U-SP_SPL (X1-6)
3	Sensor signal voltage by U-PS_SPL max	U- PS_SPL = 5,35V	X1-5 (U-PS_SIG)	U [V]	0,57 – 0,72	
4	Current draw by U-PS_SPL max	U-PS_SPL = 5,35V	X1-6 (I-PS_SPL)	I [mA]	2 - 8	
5	Supply of sensor (VCC) by overvoltage U-PS_SPL	U-PS_SPL = 6V	MP22 (VCC)	U [mV]	< 200	
6	Current draw by overvoltage U-PS_SPL	U-PS_SPL = 6V	X1-6 (I-PS_SPL)	I [mA]	2,5 - 4	
10	Function of valve control over X100 - X106	U1 = 28V S1 in position 2	I1	I [A]	2,25 – 2,5	GND (X1-1 or X1-2)
11	Function of flyback diodes D120 - D126	U2 = -28V S1 in position 1	I2	I [A]	2,25 – 2,5	GND (X1-1 or X1-2)

3.3 Circuit diagram

In the following picture there is a circuit diagram for the inspection process. The circuit diagram contains the component ELC4 displayed as a box with outputs and surrounding elements determined to execute the inspection process.

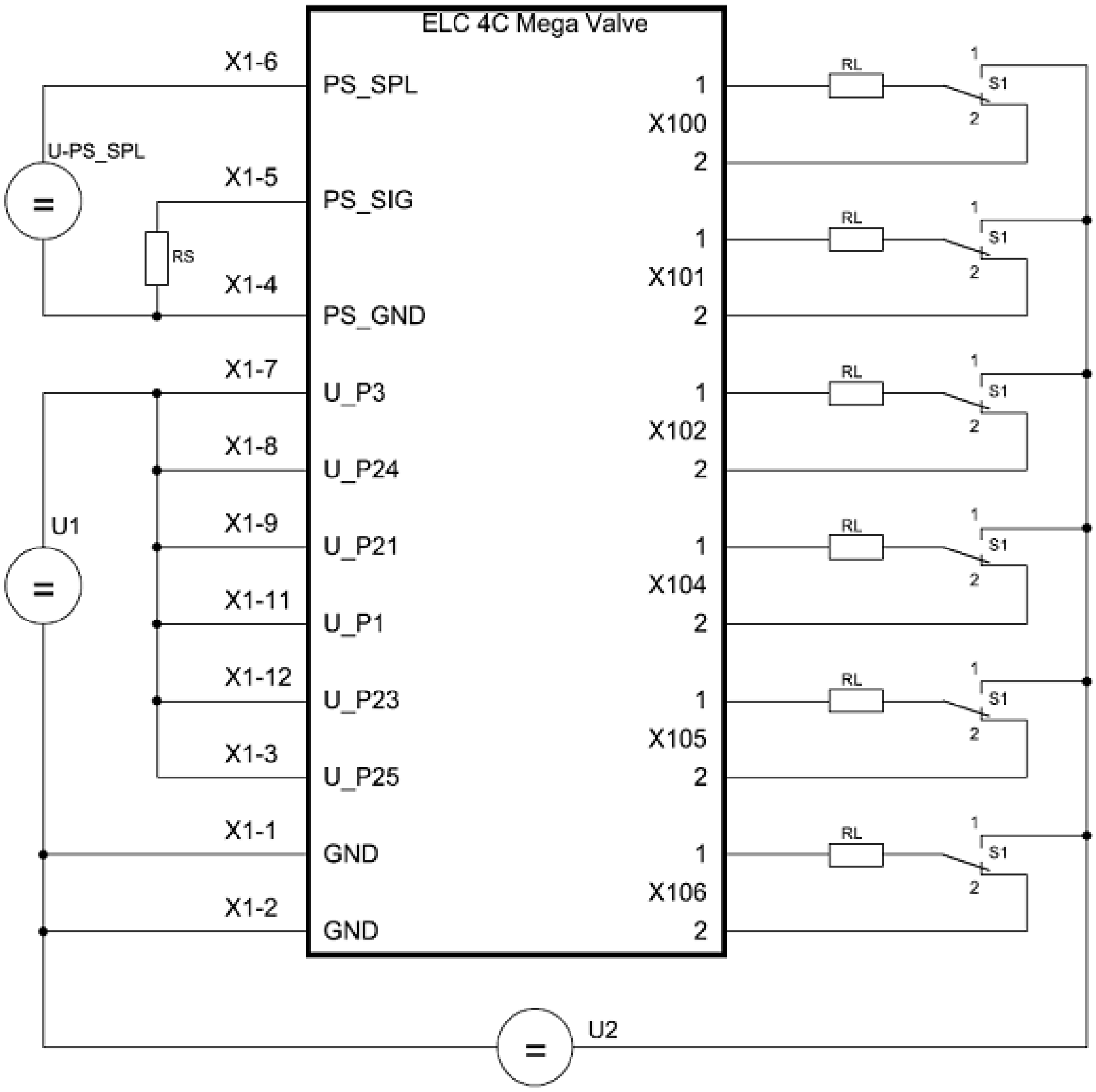


Figure 3 Circuit diagram [6]

RL = 68Ω, 1%, 10W

RS = 220Ω, 1%

4 Project solution

4.1 Previous solution

The screening oven ran on the solution from a company with specialization on the ICT testing but only briefly, their system was unstable. The previous solution uses two PCBs, one as control and the other as connecting. Control board contains 8-bit Atmel microcontroller to execute of operations, calculation and processing incoming data. Furthermore it includes also ADC to convert analogue signal of measured data to the digital signal for the processing by the microcontroller, RS-232 driver for communication with a computer and an amplifier of a received signal. The connecting board contains D-Sub connectors for a connecting with the DUT and relays for choice of the required signal. The same D-Sub connectors are also used in the new solution. This 37 pin D-Sub has occupied 24 pins (see below).

Table 2 D-Sub pinout

D-Sub	ELC4
1	X1-6
2	X1-5
3	X1-4
4	X1-7
5	X1-8
6	X1-9
7	X1-11
8	X1-12
9	X1-3
10	X1-1
11	X1-2
12	MP22
20	X100-1
21	X100-2
22	X101-1
23	X101-2
24	X102-1
25	X102-2
26	X104-1
27	X104-2
28	X105-1
29	X105-2
30	X106-1
31	X106-2

4.2 Principle of measurement

All measurements are executed by the multimeter. This multimeter has only one measured channel, this is the reason why relays are used to branch the channel of the multimeter. Only one couple of the relay contacts is always closed i.e. that just one measured point is connected with the multimeter. The relays are placed on the printed circuit board called connecting board located in the room for test hardware in the adapter. This solution enables automatically to measure any number of points by the one channel multimeter. The principle is illustrated in the picture below.

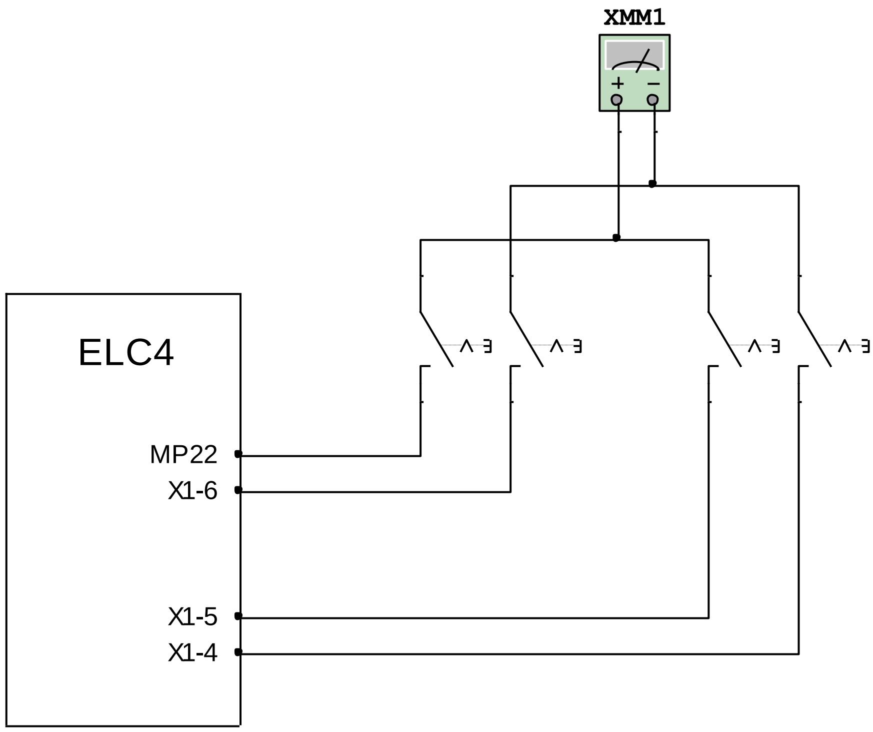


Figure 4 Principle of measurement

4.3 Digital multimeter

The digital multimeter Keithley 2000 is chosen as the measurement device. The model 2000 has 0.002% DC voltage accuracy i.e. that meets the test conditions. Its broad measurement range for DC voltage is from 1µV to 1000V. [7] The input connection on the rear panel of the multimeter is used to measurement. The input HI is used as plus and the input LO as minus. For the communication with the Keithley the RS-232 standard is used. The straight-through DB-9 cable connects the DMM and the test computer. By this connection there is one problem, the test computer has only four COM ports. The table below shows devices which communicate with the test computer using COM port.

Table 3 COM ports

Indication	Port	Device	Description
A	COM 1	MCON	Control board for EBS7
B	COM 2	PLC	Control computer of PTM line
C	COM 3	HAMEG	Power supply for DUT
D	COM 4	UPC	Power supply for PTM line

The communication with the PLC of PTM line and both power supply is absolutely necessary. The control board for EBS7 is placed in the room for test hardware in the adapter for EBS7 and is connected with the test computer through a Harting connector. It means that it isn’t used during screening of ELC4. And so there are 3 options to solve this problem.

1) Using of USB to serial RS-232 converter.
2) Connection of the definite DB-9 cable to the computer (either MCON or DMM).
3) Using the Harting connector and taking the wires of the serial communication through the Harting connector to the digital multimeter.

The first option is refused because of the instability of the converter. The second option is also refused, the technician would have to change the connection of the port COM 1 by the change of the adapter, i.e. disconnect the cable from MCON and connect the cable from DMM and the other way around. Therefore the third option is used. Three wires leads from COM 1 of the test computer to the MCON through the 40 pin Harting connector. The adapter for ELC4 has the same connector but test board for ELC4 doesn’t need the serial communication. Therefore these three wires (in the adapter) are returned back to the Harting connector and from the connector to the DMM. The following picture illustrated the connection of the test computer and the DMM through the Harting connector.

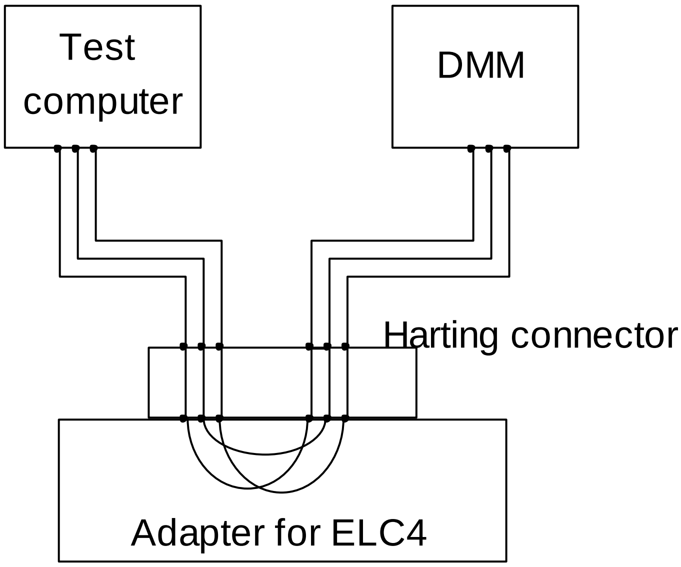


Figure 5 Connection DMM and test computer

The table below shows all three wires used to the DMM communication.

Table 4 D-Sub connector for the DMM communication

Signal Name	Abbreviation	Pin	Colour
Receive Data	RxD	2	red
Transmitted Data	TxD	3	orange
Signal Ground	GND	5	green

The digital multimeter Keithley 2000 is placed in 19-inch rack in the test module.

4.4 Digital I/O device

The portable digital I/O device NI USB 6509 has 96 bidirectional I/O channels compatible with TTL, CMOS and 5V digital logic levels. A USB-6509 is ideal for industrial control and automated manufacturing test. [8] This device is used to drive the relays. The ports of the USB-6509 are configured for output. The compatible software (e.g. LabVIEW) sets up a voltage 5V on the particular output. This voltage closes the contact of the particular relay. The USB-6509 is connected with the test computer using USB connector. To the connection with the connecting board the shielded I/O connector block (SCB-100) is used. This block contains headers (screw terminals) from which wires leads to the connecting board. The block is connected with the USB-6509 using shielded 100-conductor cable (SH100-100-F).

4.5 Power supply

The HAMEG HMP4030 is a programmable 3 channel high-performance power supply. This voltage source supplies the tested unit ELC4. In a circuit diagram there are three different voltage source (U-PS_SPL, U1 and U2). All three channels of the HAMEG are used together with sense. All 12 wires leads from the outputs on the rear panel to the connecting board through Harting connector. This power supply communicates with the test computer using RS-232 standard.

4.6 Harting connector

The Harting connector is 40 pin industrial connector which contains a male insert and a female insert. The both adapter (ELC4 and EBS7) has own female insert. The male insert is common for both adapter. In the following table there is use of the particular pins in the Harting connector from the inside. Where the characters Px_y mark headers on the connecting board, x indicates number of header and y indicates position in the header.

Table 5 Harting connector from side of connecting board

10	9	8	7	6	5	4	3	2	1	
P3_2	P4_1	P4_3		P6_5	P6_6	P6_3	P6_4	P6_1	P6_2	**A**
P3_1	P3_3	P4_2	P4_4	P2_1	P2_2	P13_1	P13_2	P13_3	P13_4	**B**
P8_2	P8_4	P8_6	P8_8	RxD	TxD	GND	RxD	GND	TxD	**C**
P8_1	P8_3	P8_5	P8_7	P6_5	P6_6	P6_3	P6_4	P6_1	P6_2	**D**

The table below shows the pin arrangement of the Harting connector from the outside. Where the charekters Px.y marks position in the headers on the connector block (SCB-100).

Table 6 Harting connector from the outside

10	9	8	7	6	5	4	3	2	1	
P1.1	P1.3	P1.5		U3 -	U3 +	U2 -	U2 +	U1 -	U1 +	**A**
P1.0	P1.2	P1.4	P1.6	DMM +	DMM -	5V	P0.0	P0.1	P0.2	**B**
P2.1	P2.3	P2.5	P2.7	Tx Data	Rx Data	GND	RxD	GND	TxD	**C**
P2.0	P2.2	P2.4	P2.6	U3 - Sense	U3 + Sense	U2 - Sense	U2 + Sense	U1 - Sense	U1 + Sense	**D**

4.7 Block diagram

The following picture shows connecting of the particular devices.

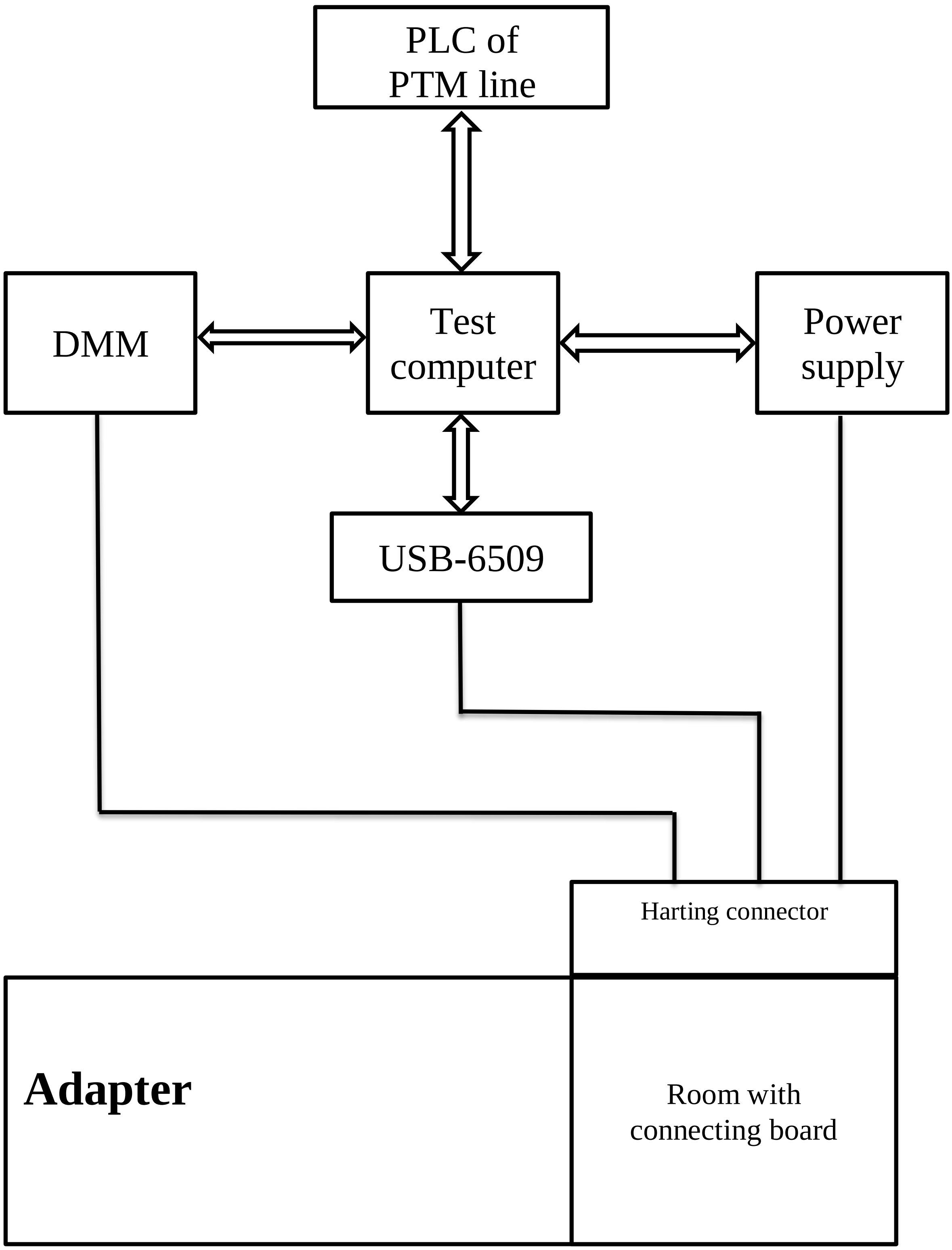


Figure 6 Block diagram

5 Test hardware

This chapter deals with a design of the connecting board placed in the room of the adapter. This board connects the tested unit ELC4 and peripheral devices such as multimeter, power supply and I/O device.

5.1 Principle

The object of the connecting board is getting of the voltage source to the DUT and measuring a voltage between two points. All channels of the power supply are connected to the header P6 (6 conductors). If the one section of the DUT is powered, the other sections have to be disconnected from the power source. It means that each section has to connect to the power source by own relays. The principle of this solution shows the following picture.

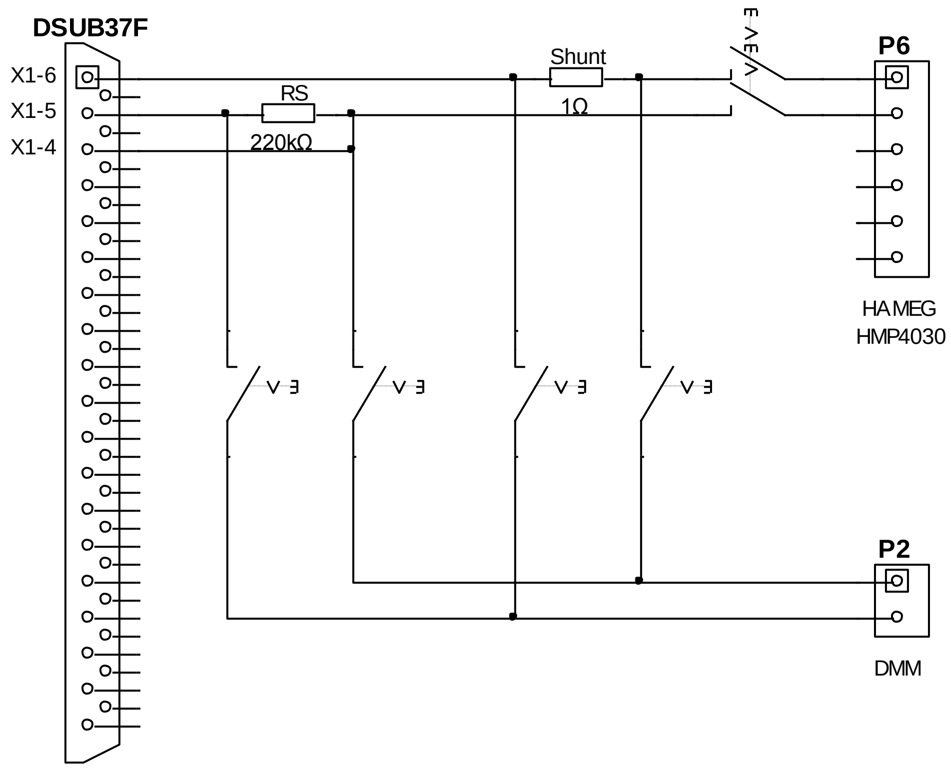


Figure 7 Circuit with power source and DMM

The figure above shows also the header for the power supply P6, the header for the multimeter P2, D-Sub 37 pin female for the connection with the tested unit, resistor RS defined by the customer specification, shunt resistor for the current measurement and the relays for switching among the measured points.

5.2 Kinds of measurement

5.2.1 Voltage measurement

The voltage is ordinarily measured between two points defined in the test table. For example the sensor signal voltage (test no. 3 in the test table) between points X1-5 and X1-4. Similarly the tests no. 1, 2 and 5 according to the test table.

5.2.2 Current measurement

To the current measurement it's necessary to put the multimeter to the power line, however this option isn't possible to do. That's why the shunt resistor is used for the current measurement. The shunt is a resistor of the small value (e.g. 1Ω, 0.1Ω) which is put to the power line where we want to measure the current. The multimeter measures the voltage on the shunt. The final current is calculated from the measured voltage and the value of the shunt by the Ohm's law. This solution is used by the tests no. 4, 6, 10 and 11 in the test table. The tests no. 10 and 11 have the value of the shunt 0.1Ω because of the big flowing current (up to 2.5A).

5.3 Relays

The Relays Finder 30.22.7 are chosen to switching conductors to the measured point. Finder 30.22.7 is relay DPDT (*Double Pole Double Throw*), it has two common terminal and each of them connects to either of two others. This relay enables to connect two lines to measured point together.

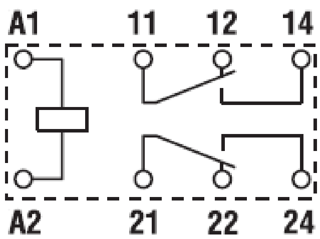


Figure 8 DPDT relay [9]

The Darlington transistor array ULN2803 is used to control the relays. The relays are supplied by the external 24V power source of the PLC. The control voltage 5V is connected to the Darlington pairs through the line driver SN74HCT244 which activates control signals for the particular DUT. On the inputs of the control signals there are pull-down resistors. The activation of the SN74HCT244 by the /OE has to be executed by the negative power supply voltage. That's why the Hex inverter 74HCT05 is also used. The pull-up resistors on the inputs of the line driver ensure positive power supply voltage if the control signal isn't available. Over the relay coil there is placed flyback diode to elimination the voltage spike created across an inductive load when the supply voltage is suddenly reduced or removed.

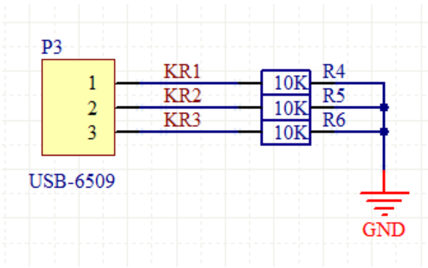


Figure 9 Control signals and pull-down resistors

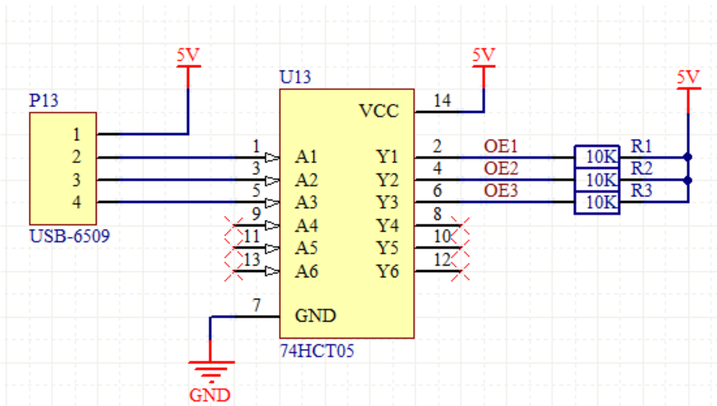


Figure 10 Hex invertor and output enable signals

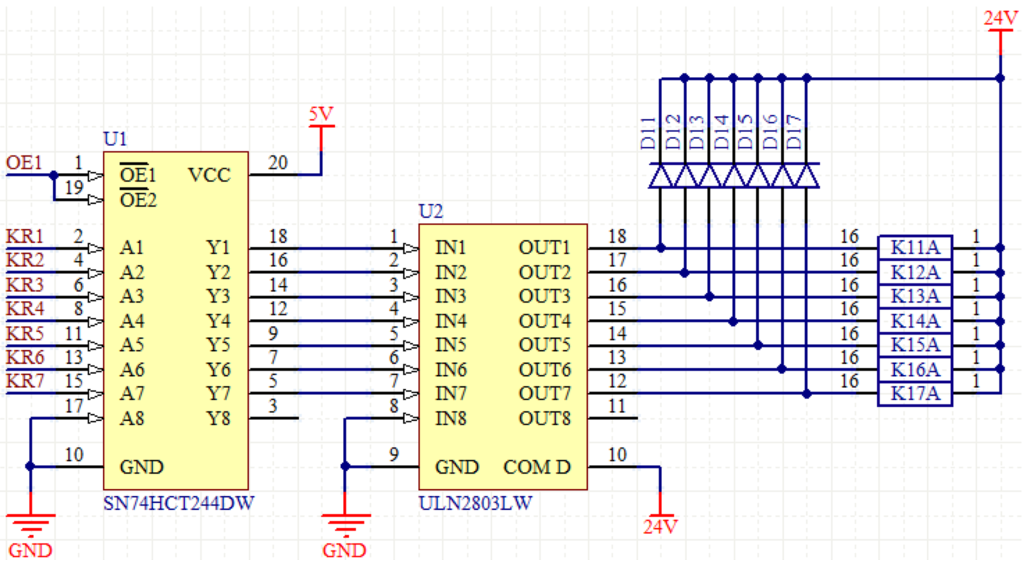


Figure 11 Line driver, relay driver, relay coils and flyback diodes

5.4 Circuit diagram for test of one DUT

The figure below illustrates complete diagram for the test of one tested unit.

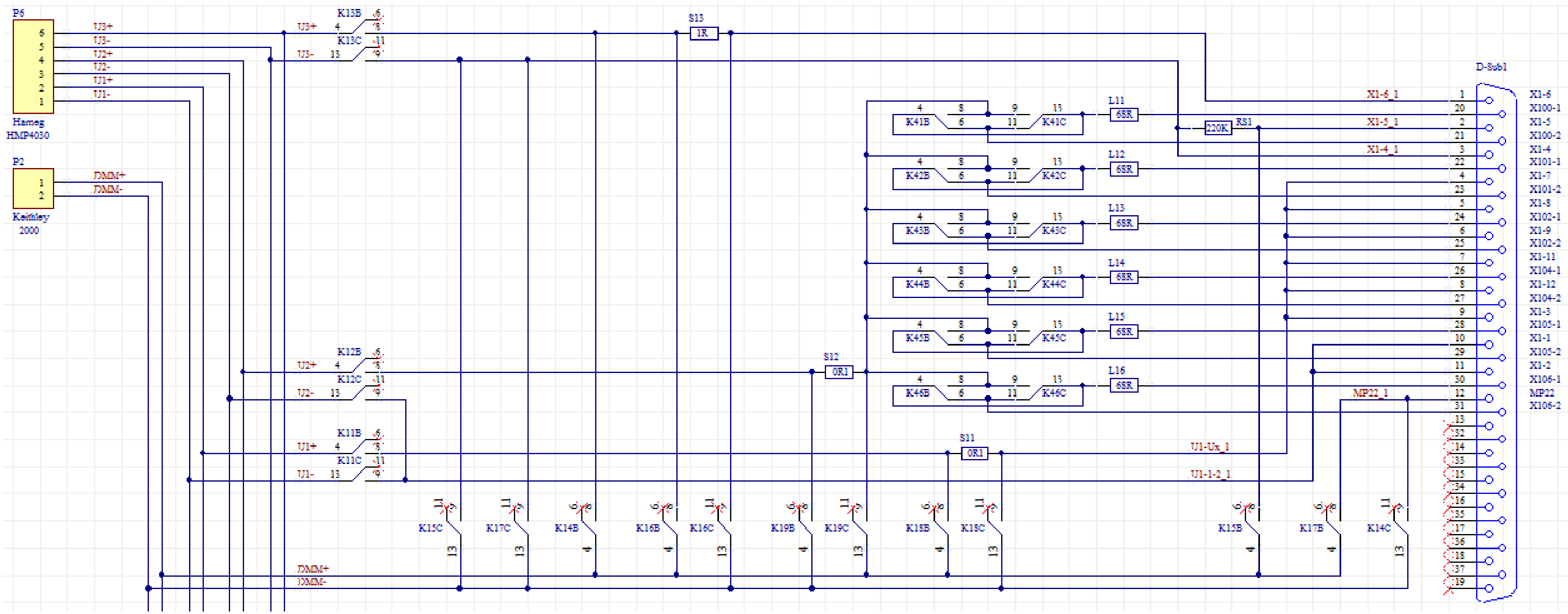


Figure 12 Circuit diagram for test of one DUT

6 Test software

For the inspection process of the tested unit ELC4 is designed the software program to communicate with the peripheral devices such as digital multimeter, power supply, digital I/O device and PLC. The task of the program is the controlled communication with the test machine, the execution of inspection of the DUT and design of the test report. The whole solution is designed using NI LabVIEW.

6.1 LabVIEW

The system-design platform and development environment LabVIEW (*Laboratory Virtual Instruments Engineering Workbench*) from the National Instruments Corporation (NI) is visual programming language. The NI is a pioneer and the biggest producer in the virtual instrumentation industry. LabVIEW is used to programming of systems for measurement and analysis signals, control and visualization technological process. LabVIEW replaces finance-consuming use of the technical devices by the virtual and graphical tools which arrange the highest illustration to a user. This solution enables fast design of a new application and executing of a modification in the configuration. LabVIEW program is called virtual instrument (VI). Every VI includes two parts: a block diagram and a front panel. The block diagram contains the graphical source code. The front panel is built controls and indicators. Using controls a user can supply information to the VI. Indicators puts to a user information from VI, they display results of the executed VI. All objects placed in the front panel are displayed in the block diagram as terminals. Each VI is represented by the connector panel which can be used within the other VI in the block diagram. Data flow goes from left to right. LabVIEW is concurrent language, all tasks and functions are executed parallel, for sequential behaviour is necessary to use some programming structure such as while loop, for loop, case structure. LabVIEW supports work with the devices from measurement and instrument manufacturers. NI prepares for communication with these devices drivers. These prepared VIs write or read data from the device, set parameters of the device or transmit commands to the device. All these benefits are reason why is LabVIEW used as software solution for the inspection process.

6.2 Hierarchy

The program is designed hierarchically. This means that in the main program there are several subprograms (subVI) which include next subVI inside. This system makes the program well-arrange and programming systematic. The virtual instrument ELC4 is the main application. This application is automatically run with the start of operating system Windows. Running of the production process is not so dependent on the operators. The errors of the operator are also eliminates this way. The ELC4 VI includes five different subVI, four of them represent the inspection process for zero, room, low and high temperature stress, the fifth subVI ensures the communication with the screening climatic chamber. Every subVI for the inspection process includes other five subVI. Three of them ensure the communication with the voltage source Hameg for three different channel. The fourth subVI executes setting of the digital I/O device. The fifth subVI executes particular test step and includes the last subVI ensuring the communication with digital multimeter Keithley.

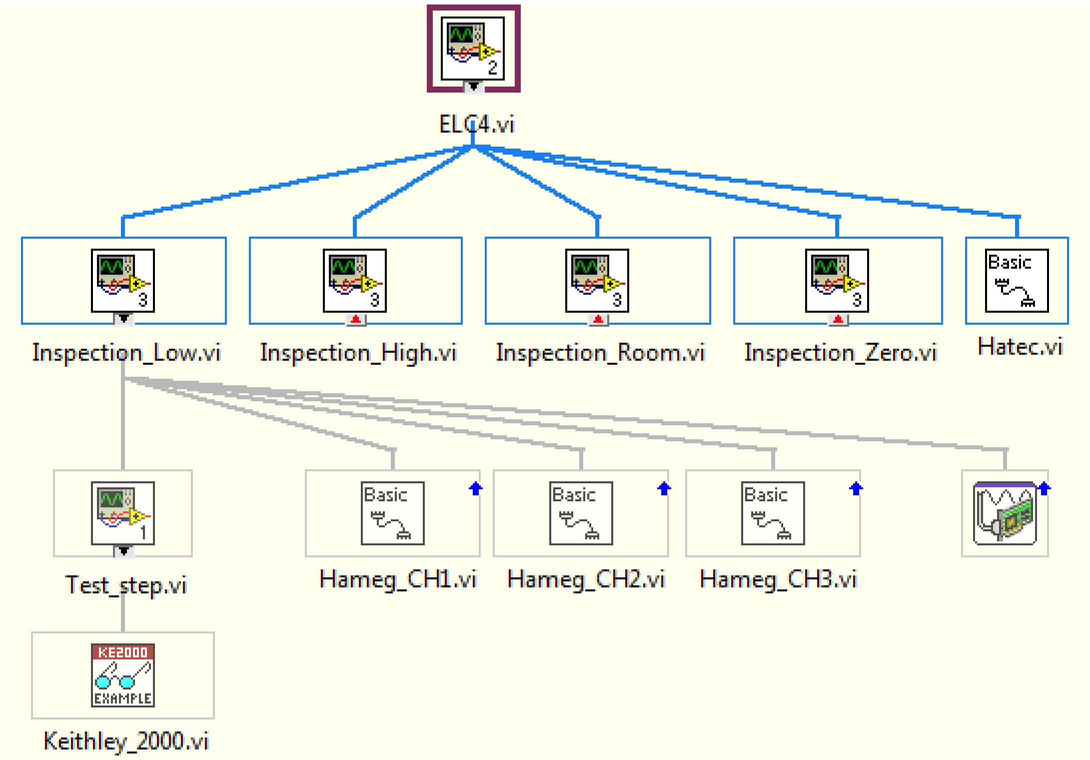


Figure 13 VI hierarchy

6.3 PC – PLC communication

According to a technical specification of the Hatec Company the particular virtual instrument is designed to communicate with the test station. In the technical specification there are defined hardware connection, parameters of interface, communications protocol, a list of commands, a list of error reports and a flow diagram.

6.3.1 Hardware connection

The test station owns an interface RS-232 to the communication with a test system. The connection is realized by the 9-pin D-sub connector.

Table 7 Signals and pin assignment [3]

Signal Name	Abbreviation	Pin
Receive Data	RxD	2
Transmitted Data	TxD	3
Signal Ground	GND	5

The test system is connected using RS-232 serial cable by the communication method null modem.

6.3.2 Interface parameters

- **Baud rate** – number of symbol changes made to transmission medium per second.
- **Data bits** – number of bits in the incoming data.
- **Stop bits** – number of stop bits used to indicate the end of frame.
- **Parity** – specification of parity used for every frame to be transmitted or received.
- **Handshake** – sets the type of control used by the transfer mechanism.

Table 8 Interface parameters [3]

Parameter	Value
Baud rate	9600 Bd
Data bits	8 bits
Stop bits	1 bit
Parity	none
Handshake	none

6.3.3 Communications protocol

The test station behaves concern about the communication with the test system passive (Slave), i.e. the PLC of the test station doesn't send any commands itself.

The current status is reported back by the request for status from the test system. A command as acknowledgement of the receiving from PLC is reported back by the command from the test system.

Every telegram has to be concluded with CR/LF (Carriage Return / Line Feed). [3]

6.3.4 List of commands

The test system communicates with the PLC of the test station using commands defined by the Hatec Company. Example below shows a command for login of the test system.

Table 9 List of commands [3]

PC/Tester	←→	PLC	Description
Tson	→		The test system logs in with this command on the test cell.
	←	*tson*	Acknowledgement to the receiving of the command *tson*.

6.3.5 List of error reports

Error reports can be fundamentally reported by the test station after every command or request for status from the test system.

Table 10 List of error reports [3]

PC/Tester	←→	PLC	Description
	←	*f001*	device failure, not ready
	←	*f002*	device stands
	←	*f003*	no DUT in the test station
	←	*f004*	incorrect or missing coding
	←	*f005*	error RS-232: sign length
	←	*f006*	error RS-232: checksum
	←	*f007*	unknown command
	←	*f008*	---
	←	*f009*	command can't be executed
	←	*f010*	device not in automatic mode

6.3.6 Flow diagram

This diagram doesn’t contain all commands and introduces only principal course.

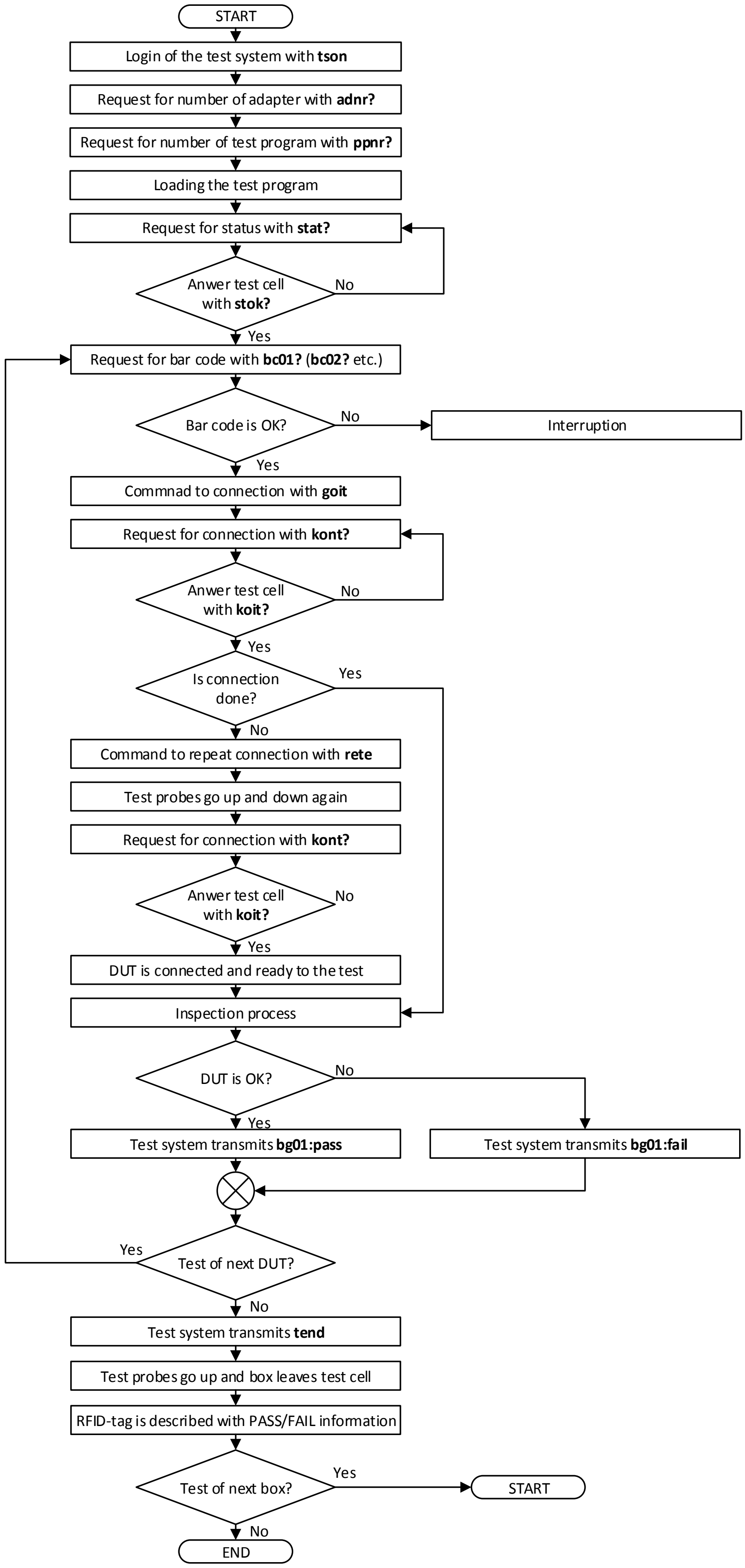


Figure 14 Flow diagram [3]

6.4 Hatec VI

This virtual instrument ensures the communication with the PLC of the test station. On the front panel there are string control (write buffer) as input and string indicator (read buffer) as output of the Hatec VI. In the beginning of the block diagram there are defined interface parameters using VISA Configure Serial Port where VISA resource name (COM2), baud rate, data bits, parity, stop bits and flow control (handshake) have to be specified according to interface parameter (Table 2). The resource name specifies the resource to be opened. The output resource name out is wired to the VISA Write function. This function writes data from write buffer to the device specified by resource name. The string control filled in the ELC4 VI is wired to this function. Behind VISA Write there is Stacked Sequence structure with a Wait function within. This function ensures necessary time to device on response. Before reading the response, a property node finds out the number of bytes at serial port, this value is wired to byte count of VISA Read function and determines the number of bytes to be read. VISA Read returns the data to read buffer. This string indicator puts information to the main application ELC4 VI where is processed in the state machine. After the response is read, the VISA Close function closes a device session. The resource name is also wired to the input of this function. All error in/out of the function are connected and terminated in the Simple Error Hadler VI to indicate whether an error occurred.

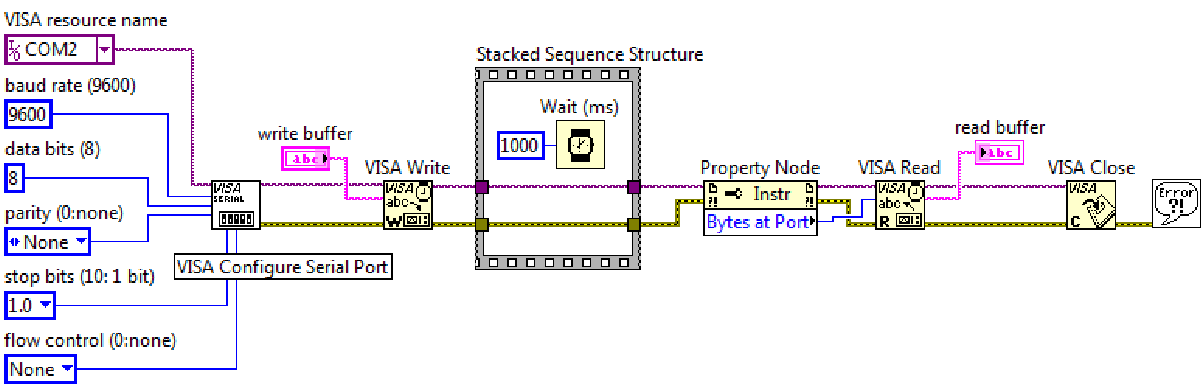


Figure 15 Hatec VI

6.5 ELC4 VI

The main program called ELC4 VI controls communication with the PLC of the test station and ensures inspection process. A stand-alone application (EXE) is built from this VI. This way is made easier the launching of the program. The operator needn't open the VI and look for run button. This stand-alone application is added to the Startup application to automatic open after start the operating system. It means that the whole inspection process isn't dependent on any operator.

6.5.1 Main panel

On the main panel there are displayed many string and LED's indicators as information for an operator what is just going on at the test module. The operator has prepared string indicator Status which informs about actual event in the test system. When some error occurs, the string indicator Error reports what happened and the LED's indicator Error changes colour on the red. A text indicator Record displays current test step of the measurement. The operator can see running measured values, margin of error, number of current test and its result. For this running overview the reference to the string indicator Record has to be created. Each nest of the box has own LED's indicator which has white colour in the beginning. After the inspection process ends, colour of the tested nest changes according to the result of the test. If the test passed, the indicator is green else red. The operator can also see which nest is just tested using string indicator Nest. The last three characters of the box-ID are displayed in the indicator Box, these characters are also written on the chassis of the box. The operator has information about number of repeating, test program, serial number of the DUT, path to the test report, initial and end time of the inspection process. The technicians caring about the climatic chamber can control the test system manually using a toggle switch AxM (Automatic x Manual) and a button Contact. If the toggle switch is up then the manual mode is active and the technician can decide when will the connection be done or whether the connection will be repeated. At the time when the connection should be executed, the text: "*Push the button Contact.*" is displayed in the Status window. The button Contact gets the test probes down. The operator can stop the program pressing the button STOP on the front panel.

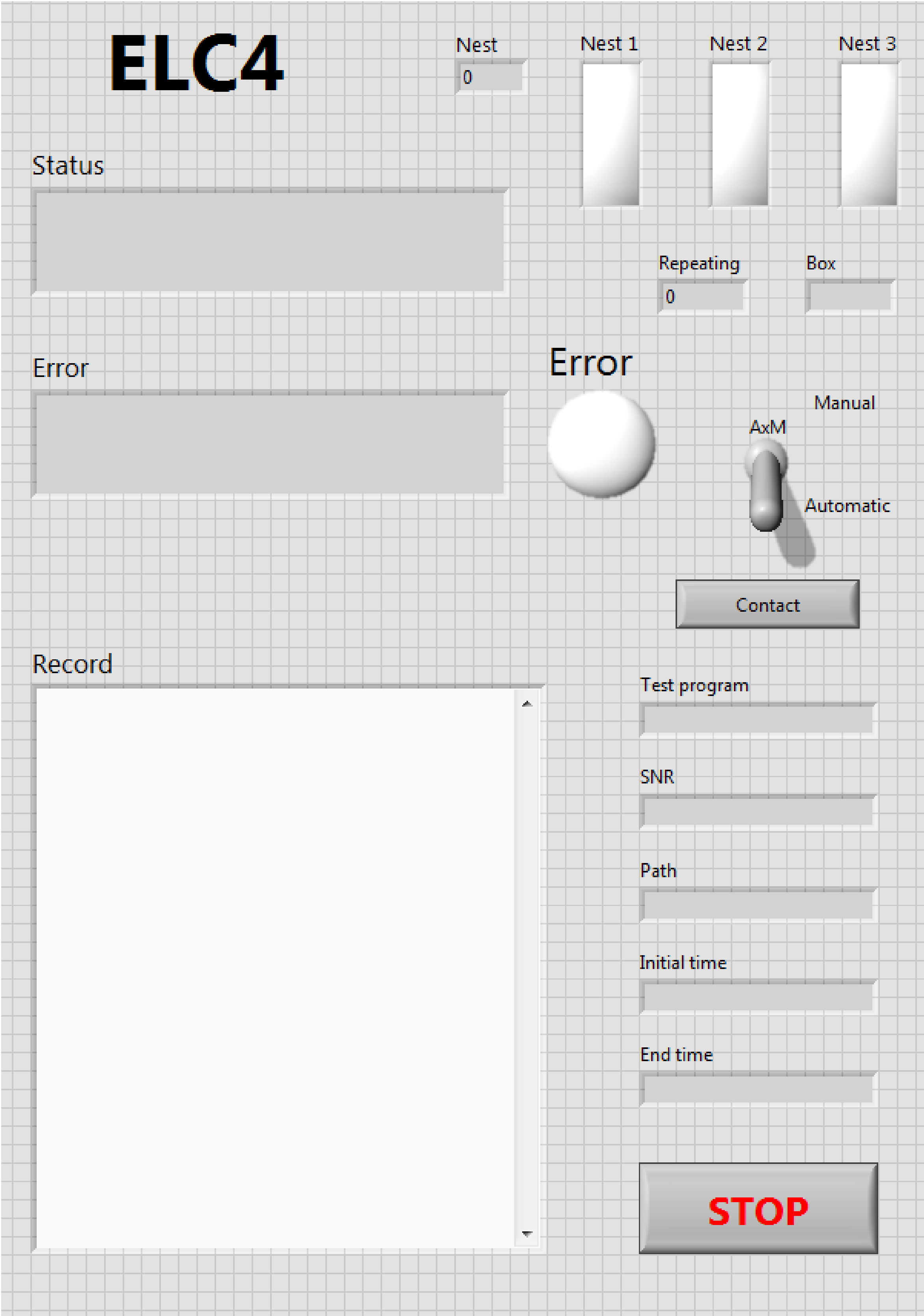


Figure 16 Main panel

6.5.2 State machine

A state machine is chosen as a solution for the task to design standard test program. The state machine provides quick and well-arranged solution where the individual steps of the communication are solved separately. Using the state machine, any state can go to any state. Any state can also end the program. The while loop is the heart of state machine because transfers the values from one state to other state. It works like a local variable, which hands over value received as output to the input of the next cycle. This transfer ensures the shift register created on the border of while loop. The shift register is connected to the case selector of the main case structure. This structure executes the state, which is on the input of case selector. Within the main case structure there is an Enum constant. This enumerated constant creates a list of string labels with corresponding integer values which can be selected on the block diagram. The Enum constant is wired through the tunnel on the border of the case structure to the shift register and determines the following states. Another Enum constant is outside of the while loop wired to the shift register too and determines the initial state. This is the base of the state machine, however another case structure within the main case structure is required for the communication with the PLC of the test station. The output of virtual instrument Hatec is wired to the case selector of the second case structure where the mentioned Enum constant is occurred. A string constant with the command for the PLC is wired to the Hatec VI. The second case structure expects except acknowledgement of the receiving of the command also receiving of the error code. In such case the state machine shifts to the state Login and an error status (according to the list of error reports) is displayed on the front panel. An example of the one state is in the figure below. In the next figure is displayed the state diagram.

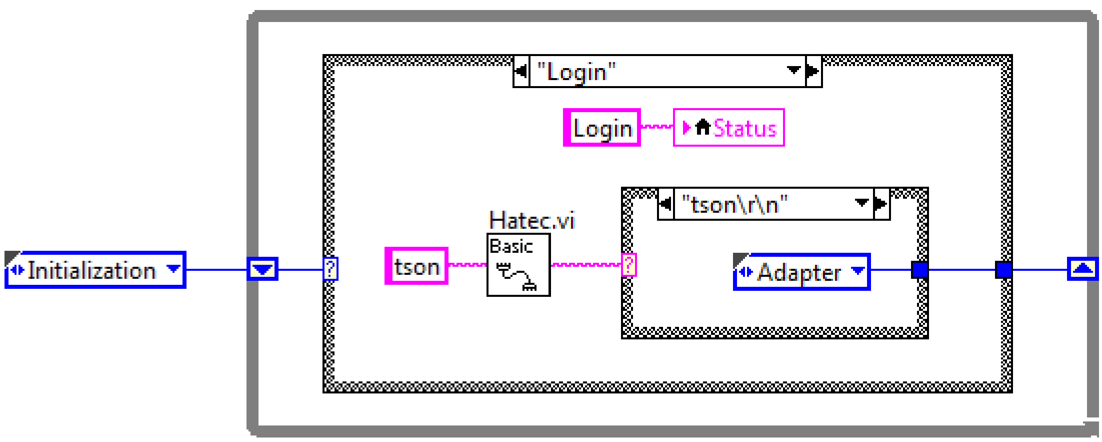


Figure 17 State machine

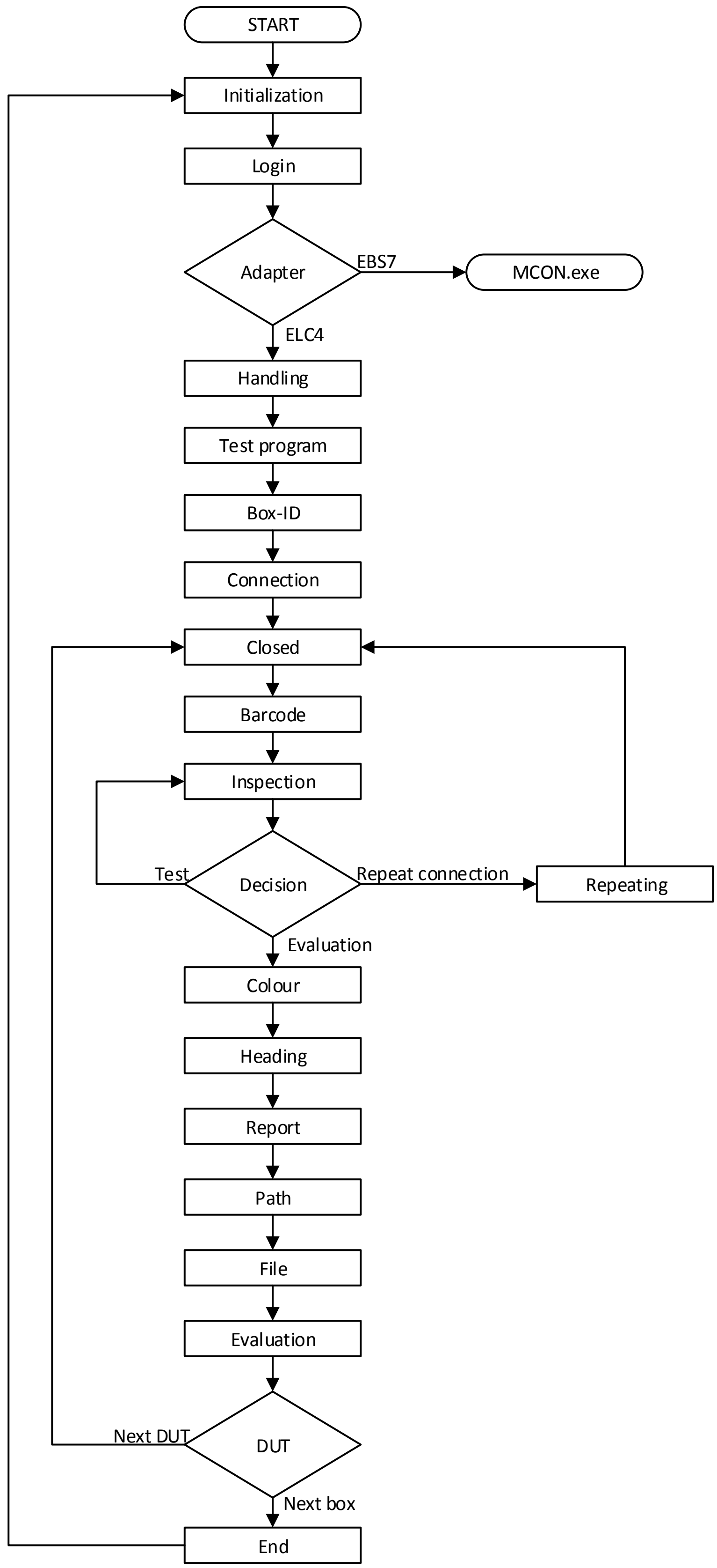


Figure 18 State diagram

If the PLC transmits something else than the test system expects then the state machine repeats the same state once again.

Below there are described all 20 states. To the description of more complicated states the figure with the part of the block diagram is added. Each state contains the string indicator Status which describes what the particular state is doing.

Initialization

In the state Initialization there are all indicators and controls set up into the default value. All string indicators are wired to string constant filled zero, the old values from the previous states are overwritten this way. To all LEDs (Boolean indicators) white colour is set up in RGB hex code. #FFFFFF (255, 255 and 255) represents white colour. In this state there is also Wait function which is set up on 10 seconds. The state machine is automatically shifted to the state Login after 10 seconds.

Login

The test system transmits a command "*tson*" (test system on). This command logs the test system in the test cell. The automatic mode of the test cell can run only when the test system is logged. The test system waits until the PLC acknowledges the receiving of the command "*tson*" by the same string, then the state machine shifts into the next state.

Adapter

The test system transmits a request for a number of the adapter with a command "*adnr?*" (Adapternummer). The number of an installed replaceable cartridge is communicated by the PLC to the test system. If answer of the PLC is "*adnr:00*", in the climatic chamber there is the adapter for testing EBS7. In this case the test system launches external file MCON.exe placed on the desktop using a System Exec VI which executes other Windows-based applications from within virtual instrument. To an input command line of the System Exec VI a string constant is wired. This string constant contains a command "*cmd/c start*" and full path to file MCON.exe. This file tests the other PCB called EBS7. The current instance of LabVIEW is ended using Quit LabVIEW Function in this case. If answer of the PLC is "*adnr:01*", the state machine continues in testing PCB called ELC4.

Handling

The test system finds out with a command "*stat?*" (status) the position of the tested unit. The PLC transmits on this request one of the four strings according to the position of the DUT.

- "*stli*" (status in) – The contact station wait for a new tested unit. Alternatively, a new tested unit is just pushing into the station.
- "*stlo*" (status out) – A tested unit is just leaving the test module.
- "*stok*" (status ok) – A tested unit is in the test cell and is ready to contact.
- "*busy*" – The device is at the moment installed.

If the tested unit is in the test cell, the PLC transmits the string "*stok*". Then the test system makes a request for number of a test program.

Test program

In this state the PLC informs the test system about a test program which is necessary to execute with current box. There are four kinds of the test program.

- "*ppnr:00*" – determines a test specification for an inspection process without temperature stress.
- "*ppnr:01*" – determines a test specification for an inspection process by the room temperature.
- "*ppnr:02*" – determines a test specification for an inspection process by the low temperature.
- "*ppnr:03*" – determines a test specification for an inspection process by the high temperature.

The test system requests for the number of the test program transmitting of a command "*ppnr?*" (Prüfprogrammnummer). The PLC informs which from four test program must be executed. The number of the test program is saved to a local variable of a string indicator Test program which is displayed for the operator on the front panel. The value of this variable is used for the choice of the inspection process in one of the following states.

Box-ID

The test system makes a request for a box-ID with a command "*bxid?*". The PLC acknowledges this command transmitting 64bit code in ASCII Format, for example "*bxid:1E4F8D23594A7CE2*". On the output of the virtual instrument Hatec.vi there are two String Subset function. This function returns the substring of the input string starting at offset and containing the length number of character. The offset of the first String Subset function is set up on 18. It means that the first 5 characters "*bxid:*" and the first 13 characters of the 64bit code of the box are ignored. Three left characters are saved into a local variable of the string indicator Box. These three characters represent designation of the box and are displayed for an operator on the front panel. By the second String Subset function, the length is set up on 4. It takes the first 4 characters which are compared with a value in a selector label of the case structure.

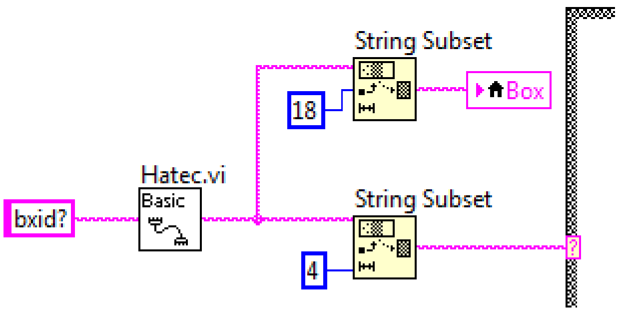


Figure 19 Box-ID

Connection

An operator can choose manual or automatic mode. This option is chosen using a toggle switch on the front panel. A local variable of this toggle switch AxM (Automatic x Manual) is wired to a case selector of a case structure. If this toggle switch is up (condition is TRUE), then manual mode is active and an operator controls the contacting pushing the button Contact. For the operator is prepared Status: "Push the button Contact". In the case structure there is a flat sequence structure with two windows. The first window has a while loop, within this while loop there are a local variable of the button Contact and Wait function with a constant 200 ms. The variable Contact is wired to a loop condition of the while loop. When the button Contact is pushed, the condition is TRUE, then the while loop is stopped. The Wait function reduces load of the processor and operating system in this case. The transmitting of a command "*goit*" is executed in the second window after the while loop is finished.

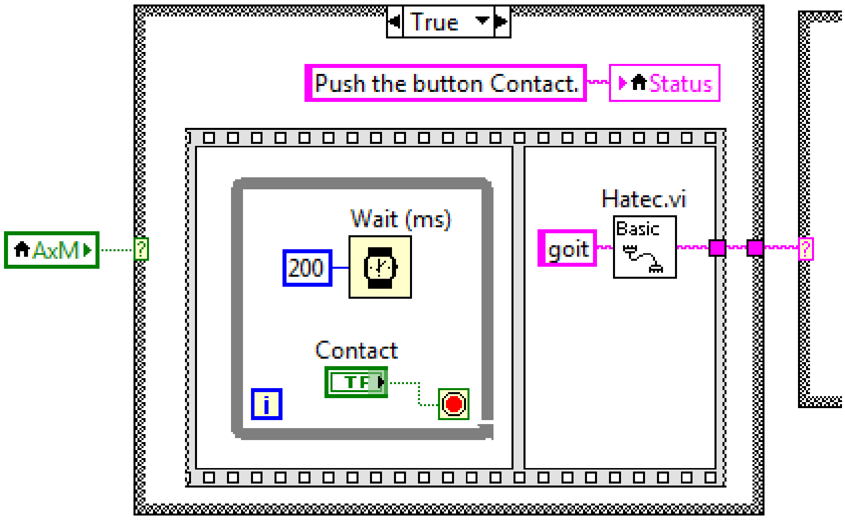


Figure 20 Manual connection

If the toggle switch AxM is down, a value of the variable AxM is false, then automatic mode is active and the command "*goit*" is automatically transmitted to the PLC. In this section there is a status with a text: "The connection has to be fully done." After the test system receives the acknowledgement from the PLC by the same string "*goit*", the state machine goes to the state Closed.

Closed

In this state the test system requests for a status of the connection with a command "*kont?*". The contacting can be in one of five following states.

- The DUT is disconnected. This state is acknowledged with a command "*koop*". The test system transmits the request again after this string.
- The test probes are going down. At this moment the PLC transmits a command "*kodn*" and the state Closed repeats.
- The test probes are going up. At this moment the PLC transmits a command "*koup*" and the state Closed repeats.
- The connection is done. This state is acknowledged with a command "*koit*". The state machine shifts in to the state Barcode after this acknowledgement.
- The test probes are in intermediate position, in this state the PLC transmits a command "*koft*" and the DUT can be tested.

Barcode

The test system requests a bar code of the tested unit placed in the box. The tester transmits a command "*bcxx?*" where characters *xx* mean number of a nest in the box. Numbers 01 to 30 are available for every box. A string indicator Nest is created for this command. A local variable of the indicator Nest is used to numbering of the tested units in the box. In the state Initialization there is the variable Nest filled zero. In the state Barcode the value of the Nest is increased by an increment one. This value is converted from number to decimal string. To creating the command "*bcxx?*", the decimal string have to be put together in a Concatenate Strings function with string constant "*bc0*" (from the left of the decimal string) and string constant "*?*" (from the right of the decimal string). The output of this function is wired to the virtual instrument Hatec.vi. The output of the Hatec.vi is wired to three String Subset functions. The first String Subset function takes only first four characters and this string constant compared with a selector label in a case structure. This case structure expects these three following string constants: "*bc01*", "*bc002*", and "*bc03*". If one of these string constants is matched, the state machine shifts into the inspection process. The second String Subset function takes 29-digit number which represents serial number of the tested unit. This number is saved in a local variable of a string indicator SNR. In this function, an offset is set up for 5. This means that the first five characters "*bcxx:*" are ignored. The third String Subset function takes 6 characters after the first five characters "*bcxx:*". These six characters are compared with a string constant "*NOREAD*".

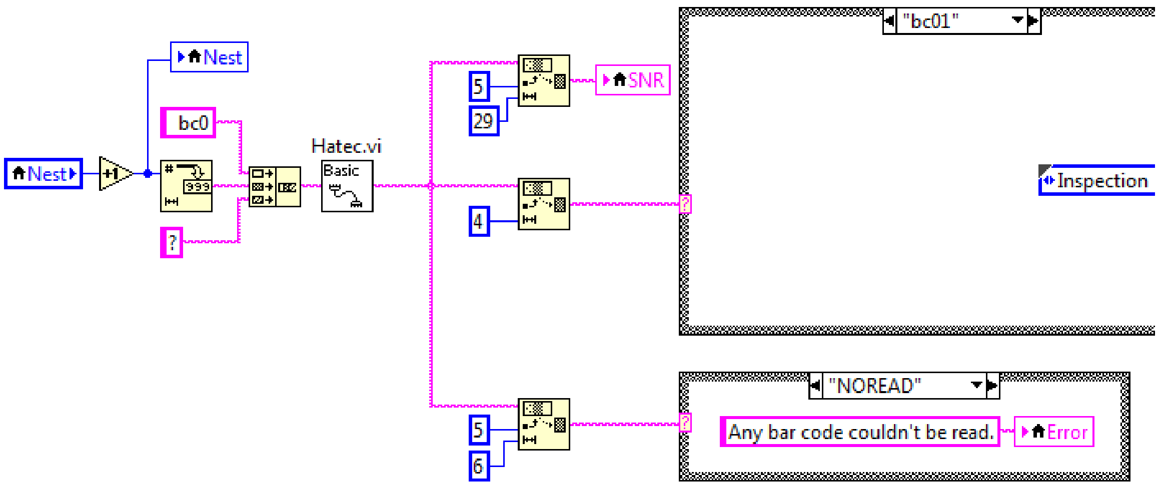


Figure 21 Barcode

The PLC puts the string NOREAD to the string “*bcxx:*”, when it couldn’t read any bar code. When this case comes, a string “*Any bar code couldn’t be read.*” is displayed in a string indicator Error.

In this state there is also the record of the initial time of the test created using a Time String function. This function displays a numeric value as time in the format which is specified using time format code.

Table 11 Time format code [1]

Format code	Value
%Y	year, including the century
%m	month number (01 - 12)
%d	day of month (01 - 31)
%H	hour (24-hour clock) (00- 23)
%M	minute (00 - 59)
%S	second (00 - 59)

The string constant “*%Y-%m-%dT%H:%M:%S*” is wired to an input time format string of the time string function. Where the character “*T*” (according to German *der Tag*) separates date from time. This format is created on the basis of Zollner test report protocol which determines the following time format: YYYY-MM-DDThh:mm:ss. This information is used in the test report.

The status “A *DUT’s bar code is announced*” is displayed for an operator in this state.

Inspection

In the state Inspection there is the test itself. The variable Test program is used to selection of the correct test program here. This variable is wired to a case selector. In this case structure there is a virtual instrument Inspection representing the test. One of the four tests (Zero, Room, Low and High temperature) is chosen according to the value in the case selector. The test Zero temperature is set up as default. A unique virtual instrument (subprogram) is designed for every test. Every test program has other parameters according to the test specification. This virtual instrument has two inputs (Pointer and Nest) and two outputs (Record and Result). The variable Nest, wired to input Nest, determines which

DUT will be tested. The output Record is wired to a local variable of the string indicator Record which contains the record of measurement. A reference (pointer) is created from this indicator. A control is created from this reference and moved to the subVI Inspection. The reference from Record is wired directly to the input Pointer sending a reference (pointer) to the control in the subVI Inspection. This allows the subVI to perform operations on this control. Within the subVI, property nodes take control reference and allow an access to the control's attributes (e.g. value). The output Result informs about result of inspection process and is wired to a local variable Result. It is concerned Boolean variable. This variable is also used for a calculation of repeating of the inspection process.

Within the state Inspection, there is also a local variable Repeating representing the number of repeating of the inspection process. This number is compared with number one (greater or equal one). This variable is displayed in a string indicator on the front panel and has to be filled zero before the next DUT will be tested. The output from the comparison is computed with the result of the inspection process in the logical OR. The output of OR is wired to a variable Not repeat. If the test is passed or ran twice then the program continues and the inspection process doesn't already repeat. After the inspection process and the comparison are finished, the state machine goes into the state Decision. In the status for this state there is a string constant "The *inspection process is running (35 seconds)*". 35 seconds is measured time for the inspection process.

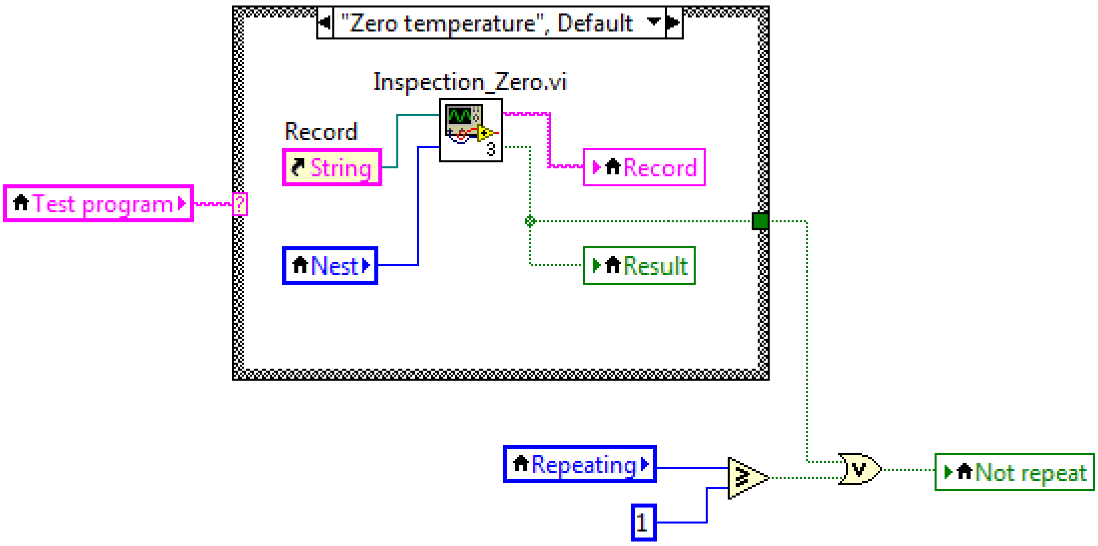


Figure 22 Inspection

Decision

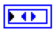
When manual mode is active, the operator can determine what will happen with the tested unit in this state. A dialog box is displayed to the operator on the screen during the process. The dialog box contains a message and three buttons. The following parameters are set up:

- **Windows Title** ("*Decision*") is displayed in the title bar of the dialog box.
- **Message**: "*Decide, whether the program has to execute inspection process again or repeat the connection or evaluate the test.*"
- **Left Button** ("*Test*") executes inspection process again.
- **Centre Button** ("*Repeat the connection*") shifts the state machine into the state Repeating.
- **Right Button** ("Evaluation") executes evaluation of the test.
- **Keyboard Shortcuts** specifies keyboard shortcuts for each button in the dialog box.
  - **Left** (Centre, Right) **Button Key Shortcut** has two Boolean constant (Control and Shift) and one string constant (Key)
    - **Control** – If this constant is TRUE, the keyboard shortcut includes the <Ctrl> key.
    - **Shift** – If this constant is TRUE, the keyboard shortcut includes the <Shift> key.
    - **Key** – This constant representing the name of the shortcut key.

Shortcut key by the left button is <F1> key, by the centre button <F2> key and by the right button <F3> key. All Boolean constants are FALSE in this case.

- **Permission of user to close the window** – If this Boolean constant is TRUE (default), the operating system window close button appears in the dialog box and the user can close the dialog box without clicking the left, centre or right button. In the most operating systems, the window close button appears in the upper right corner of the window. [1] The value of this Boolean constant is FALSE, any user doesn't have the permission to use window close button. He has the choice only from three standard buttons

(Left, Centre and Right). This way is ensured that an unexpected situation will not happen.

 **Selected button** – determines the button that the user selected**.** This output is wired to the case structure.

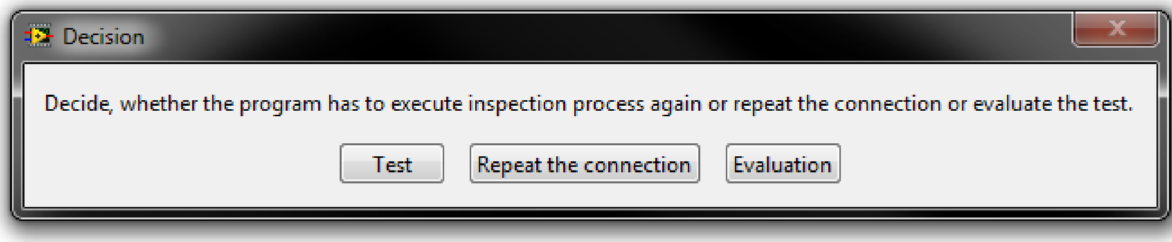


Figure 23 Decision

When automatic mode is active, a value of the variable Not repeat determines here whether the test will be repeated. If the value is TRUE, the state machine shifts into the state Colour else shifts into the state Repeating.

Repeating

This state is executed only when the first test of a DUT is failed or when the operator orders the repeating of the connection in the manual mode.

The test system transmits a request "*rete*" to the disconnecting of the DUT and to the connecting by the test probes again. The PLC acknowledges the receiving with the same string "*rete*". Afterwards the state machine goes to the state Closed to satisfy that the connection is already done and the inspection process is executed again.

The local variable Nest has to be decremented in this state to ensure that the same DUT will be tested. In the state Barcode, the value of nest is incremented again.

The local variable Repeating is incremented in this state. This way is ensured that the state Repeating is executed only one time in the automatic mode, because of the comparison in the state Inspection.

For the operator a status "*The repeating of connection*" is displayed.

Colour

On the front panel there is LED's indicator for every nest, which indicates result of the inspection process of the particular tested unit. Within the state Colour there is a case structure where the colour of LED's indicators is changed according to the result. The local variable Nest is wired to the case selector of the case structure and determines which nest has to be coloured. The local variable Result is wired to an input tunnel on the border of the case structure. One wire leads from input tunnel to the local variable Nest because of the evaluation of the tested unit. Another wire leads to the **S** input of the Select function. The Select function returns the value wired to the **T** input or **F** input, depending on the value of **S** input. If the value of **S** input is TRUE, then the Select function returns the value wired to **T** input. If the value of **S** input is FALSE, then the Select function returns the value wired to **F** input. A property node Colours is created from LED's indicator Nest, changed to write and wired to the output of the Select function. Two constants Colours are created from property node Colours of the indicator Nest and their display format type is set up on hexadecimal. One constant is wired to the **T** input of Select function and has hex value for green colour (#00FF00). Another constant is wired to the **F** input of Select function and has hex value for red colour (#FF0000).

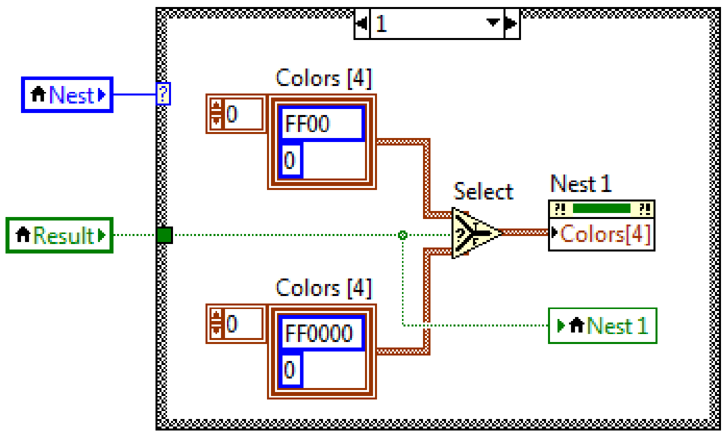


Figure 24 Colour

In this state there is also the record of the end time created by the same way like the initial time in the state Barcode. This record is used as official time when the test ended.

After the colouring is finished, the state machine automatically goes to the state Heading.

Heading

The state Heading designs the report head according to the table of keywords which is located in the document Design and handover of Zollner test report. This document contains principle of the report, keywords, handover to Zollner system, possible test types, table of units and an example of test report.

Table 12 Keywords [2]

Key	Meaning
/*B	Begin of report
BDT:	Zollner SAP material number
OPT:	Test person (personal number)
SNR:	Serial number of DUT (Zollner trace-SNR)
dtS:	Initial time of test (in format YYYY-MM-DDThh:mm:ss)
dtE:	End time of test (in format YYYY-MM-DDThh:mm:ss)
TAR:	Test type
TMA:	Test machine

Example of the report head:

```
/*B
BDT: 159076000
OPT: 33707
SNR: 012011042901345900000001981182
dtS: 2014-05-28T09:37:04
dtE: 2014-05-28T09:37:42
TAR: RIN
TMA: Hatec
```

The SAP material number represents the Zollner or customer article number. As the test person OPT is stated a personal number of author in this place, 33707. The entries as the serial number, initial time and end time are taken over from the local variables filled in the previous states. As the test type is chosen RunIn test (RIN). The manufacturer of the test machine the company Hatec Vertrieb OHG is stated by entry TMA. All entries are separated by a constant End of Line. The heading of report is designed separately to reduce number of string constants and variables in the state Report. This is the reason why the heading isn’t designed together with the rest entries of report. After the report head is designed the state machine automatically goes to the state Report.

Report

This state designs the report of the inspection process. The test report is an ASCII file which is built up line by line. This report contains all tests / test steps which the test system executes with the DUT. The additional entries (like e.g. serial number or article number of DUT) together with test results are necessary to ensure unambiguous categorization / evaluation of the test. The next processing of the test report is handed over from test system to special software to save in a database, where according to file name and additional entries all information about tested unit such as manufacturer, when was it tested, who tested it, how was it tested, measured values, evaluation etc. can be find out.

A local variable Report is completely designed in this state. The component entries are put together using a Concatenate Strings function. First input of this function is the variable Report head from the previous state. The next input is string variable Record including all measured tests for current DUT. The next entry DESC informs about number of Nest where the current DUT is located. The next string input depends on the result of inspection process. In the case that the result passed, then the string constant "*PASSED*" is inserted otherwise the empty string constant is used. For this choice the Select function is used. The last entry of the report is the string constant "*##*".

Table 13 Keywords [2]

Key	Meaning
DESC**x**:	Free defined description / information
PASSED	Total result of inspection process
##	End of report

Example, when the inspection process passed:

```
DESC0: Nest 1
PASSED
##
```

Example, when the inspection process failed:

```
DESC0: Nest 1
##
```

After the test report is designed the state machine automatically goes to the state Path.

Path

This state designs the file name and the path to this file according to following standard of Zollner. [2]

P_ComputerName_ArticleNo_SerialNo_TimeStamp.dat

- P – Sign for test report protocol
- ComputerName – Release name of test system computer in Zollner LAN
- ArticleNo – Zollner article number or customer article number
- SerialNo – Serial number of DUT
- TimeStamp – YYYYMMDDHH24MiSS
- .dat – end of file

For example:
P_WZZ054076XP_159076000_012013013000944300000002476484_20140528093746.dat

Concatenate Strings function concatenates a path where the test reports are located ("*c:\Dokumente und Einstellungen\s01217\Desktop\Protokoll*"). Next input strings are computer name (WZZ054076XP) and article number (159076000). Serial number of the DUT is taken from the variable SNR which is filled in the state Barcode. The time stamp is created by Time String function and last input string constant is end of file ("*.dat*"). The output string is wired to the local variable Path. Then the state machine is automatically moved to the state File.

File

This state designs the file with the inspection process report. The Create File function is used to the design of a new file. This function has the following inputs / outputs:

- **File path** is absolute path to the file.
- **Operation** is the operation to perform.
- **Access** determines how you plan to access file.
- **Refnum out** is the reference number of the open file.
- **Error out** contains error information.

The string variable Path is wired through the String to Path function to the input File path of the Create File function. The option "*Create*" is selected by the operation. The option "*Write-only*" is selected as an access to the file. The outputs Refnum out and Error out are wired to the Write to File function. This function writes a string as lines to a file. The string variable Report is wired to the input Text in this place. Afterwards the file is closed using Close File function. This function closes an open file specified by reference number of the file. The last link of this chain is Simple Error Handler VI. This virtual instrument indicates whether an error occurred. If an error occurred, this VI returns a description of the error. [1]

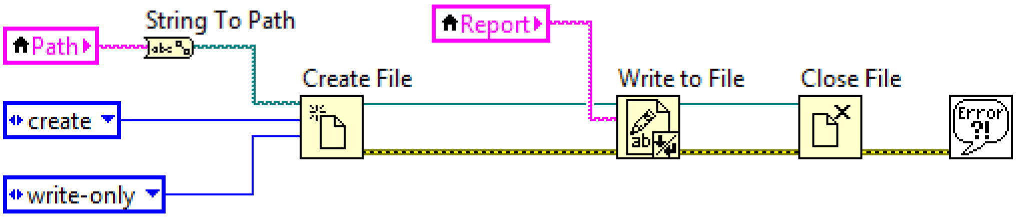


Figure 25 Path

When the file is designed the state machine automatically goes to the state Evaluation.

Evaluation

The state Evaluation transmits the result of the inspection process to the PLC. The task of this state is to send the command "*bgxx:pass*" if the DUT passed or the command "*bgxx:fail*" if the DUT failed. The characters "*xx*" represent number of the nest. This command is designed using a separate case structure to hand over the result to the Select function. The case structure is controlled by the local variable Nest which determines number of currently tested nest. Within the case structure there is the Boolean variable Nest *x* with saved value of the result. This value is wired through the tunnel on the border of case structure to the Select function. The **T** input of the Select function is wired to

the string constant "*:pass*" and the **F** input is wired to the string constant "*:fail*". The next part of the chain is the Concatenate Strings Function to concatenate the string constant "*bg0*", the number of the current tested nest converting by the Number to Decimal String function and output of the Select function. The final string is wired to the virtual instrument Hatec. The output of this virtual instrument is wired to the case structure to compare with the same string as the created command. If the comparison matches the state machine is shifted to the state DUT.

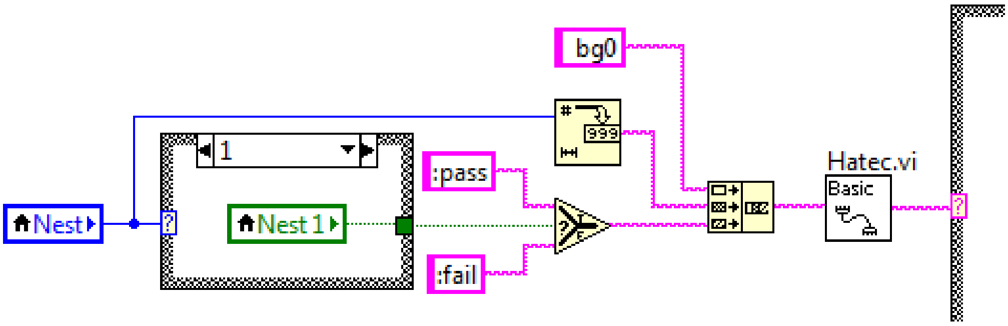


Figure 26 Evaluation

DUT

The state DUT finds out whether all nests were already tested. The value of the local variable Nest is compared with number three. If number of the nest is equal three then the state machine automatically goes to the state End, else the state machine is shifted to the state Closed again. This State also overwrites value of the variable Repeating on the value zero to ensure potential repeating of the next DUT. Furthermore this state sets up value FALSE for the variables Result and Not repeat. This way is ensured that the inspection process will not unnecessarily repeat.

End

The last state End terminates the operations with the current box and sends it from the test station.

The test system transmits a command "*tend*" (test end). This command sends the test probes up and the box can leave the test position. The test system waits until the PLC acknowledges the receiving of the command "*tend*" by the same string, then the state machine shifts into the state Initialization again and waits until the next box comes.

6.6 Inspection VI

The object of this virtual instrument is the execution of the inspection process and setting of the USB-6509's outputs. The whole program is written in the sequence structure.

The first task is the transmitting value of the voltage for the current test. The second task is the setting of the DAQ – Assistant (USB-6509) according to the following table. And the third task is the filling Test step VI by the test values. In every window of the sequence structure there is Wait function which provides time for execution of the process in the current window. For the Test step VI there are set an upper limit (e.g. 12), a lower limit (e.g. 3), a unit (e.g. mV), a constant for multiplication (e.g. from V on mV), the previous records (tests), the previous result (pass or fail) and the name of the test (e.g. "*Test 1: Voltage loss by U-SP_SPL min*"). The Test step VI has two outputs, the test record and the test result which are wired to the next Test step VI.

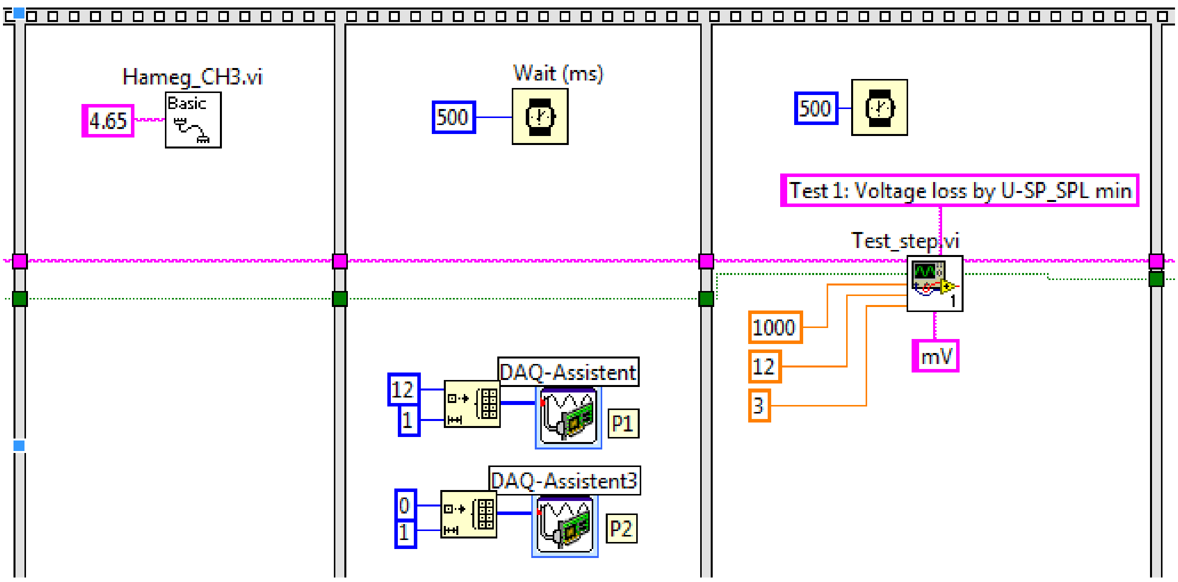


Figure 27 Inspection VI

Table 14 Setting of DAQ - Assistant (USB-6509)

Test no.	Relays for test	Relays for power	Port for test	Port for power	Port for test binary	Port for power binary	Port for test decimal	Port for power decimal	SUM P1	SUM P2
1	K4	K3	P1.3	P1.2	0000 1000 (P1)	0000 0100 (P1)	8 (P1)	4 (P1)	12	0
2	K4	K3	P1.3	P1.2	0000 1000 (P1)	0000 0100 (P1)	8 (P1)	4 (P1)	12	0
3	K5	K3	P1.4	P1.2	0001 0000 (P1)	0000 0100 (P1)	16 (P1)	4 (P1)	20	0
4	K6	K3	P1.5	P1.2	0010 0000 (P1)	0000 0100 (P1)	32 (P1)	4 (P1)	36	0
5	K7	K3	P1.6	P1.2	0100 0000 (P1)	0000 0100 (P1)	64 (P1)	4 (P1)	68	0
6	K6	K3	P1.7	P1.2	0010 0000 (P1)	0000 0100 (P1)	32 (P1)	4 (P1)	36	0
10	K8	K1	P2.0	P1.0	0000 0001 (P2)	0000 0001	1 (P2)	1 (P1)	1	1
	K9		P2.1		0000 0010 (P2)		2 (P2)			
	K41		P2.2		0000 0100 (P2)		4 (P2)			
	K42		P2.3		0000 1000 (P2)		8 (P2)			
11	K43	K2	P2.4	P1.1	0001 0000 (P2)	0000 0010 (P1)	16 (P2)	2 (P1)	2	254
	K44		P2.5		0010 0000 (P2)		32 (P2)			
	K45		P2.6		0100 0000 (P2)		64 (P2)			
	K46		P2.7		1000 0000 (P2)		128 (P2)			

6.7 Hameg VI

The object of this virtual instrument is the communication with power supply HAMEG HMP4030. In the beginning there are set the parameters of the serial communication (similarly like by the Hatec VI). The next step executes reset of the device, after that the output channel is set up. The following step sets up voltage and current limitation. The last write switches on the particular output and the last step closes VISA.

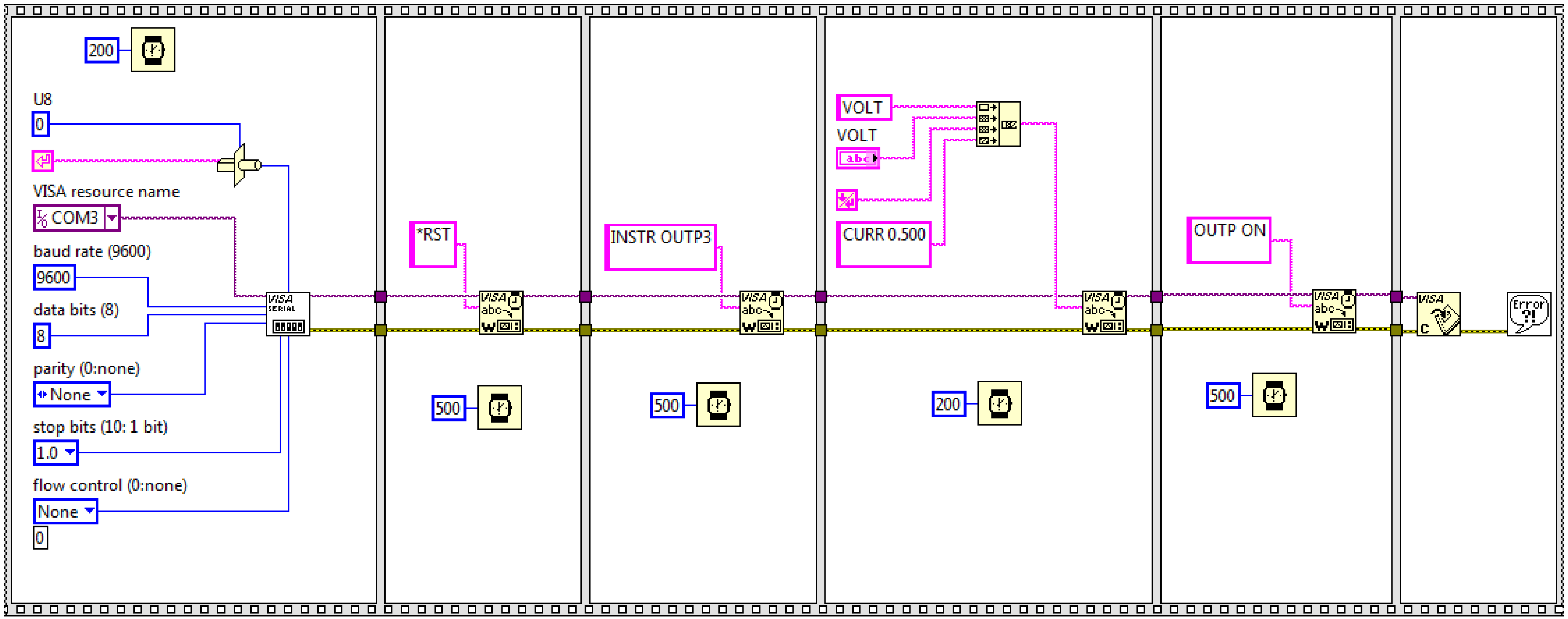


Figure 28 Hameg VI

6.8 Test step VI

The virtual instrument Test step ensures the measurement and creates the record of the measurement. The table below shows parameters according the Zollner standard for the particular test step.

Table 15 Keys for test step

Key	Meaning	Example
/*M	Begin of test step	
MRM:	Name of test step	Test 1: Voltage loss by U-SP_SPL min
MBE:	Name of DUT	ELC4
MVA:	Measured value	6,305744
MVU:	Unit	mV
MOL:	Upper limit	12
MUL:	Lower limit	3
MRS:	Result of test step	PASS
/*M	End of test step	

The measurement is executed by the Keithley_2000.vi which is downloaded from NI library. The measured values is compared with the upper and lower limit, the result (pass or fail) is saved to the record and alongside is compared with the previous test, after that the result of this comparison is sent to the next test step to next comparison. One failed test step ensures failed DUT.

7 Conclusions

The object of the project was met. A new test system was designed. Over some imperfections a connecting board and a test program were created. Two contacting boards were designed in a PCB design tool Altium Desiner. The first board hasn't any block capacitors, wide of the conductors on the board wasn't kept, the conductors were not dimensioned on the high current and this board was routed using the auto-router. The second board eliminates these errors expect one, the tolerance of the power resistors wasn't kept. Instead of using power resistors with 1% tolerance the resistors with 5% tolerance was implemented. The resistors with 1% tolerance was found by the Mouser Electronics late. The test program was designed in LabVIEW using the state machine which enables well-arrange solution for the design. Some elements of the program were consulted with the technicians which had some requirements for the main panel of the program. The technicians wanted to control the process manually and see the current results of the particular test steps immediately on the main panel. These requirements were satisfied. During the debugging of the test system the production of the electronic component EBS7 ran also, this production has priority before a debugging that's why the debugging had to be stopped. This project is very specific and it would be difficult to use this test system for different tested unit. Over some failures and delay the functional test system was designed. This master's thesis can be used as specification to this project. This project was also supported by the grant SGS-2015-002.

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