POLITECNICO DI TORINO

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in Mechatronic Engineering

Master Thesis
General-purpose testing machine design and related-test design for the operation panels and control unit modules of washing machine

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ABSTRACT

The aim of this thesis was to design a new system interface to exploit the new automatic test equipment “T100” designed by Spea Spa, to program and test the washing machine control panel and its board into as a whole and verify its performance. It can also be seen as improved design of flying probe tester, by adjusting the test head, fixture, and other important parts to broaden its field of application.
This thesis was offered by SPEA Spa, through the coordination of Fabrizio Carnisio and Piergiuseppe Ranieri, respectively customer manager and test engineer in Spea company. The project was commissioned by a European leader company in this field. In this spring (2019), this company, involved in the full range of small and large domestic appliances, decided to find a new way, combining efficiency and accuracy, to detect its washing machine panel with the electronic board.
The machine could be considered as a new type of tester designed by Spea, it included the technology of flying probe system, but the main technology used to detect the electrical function of the board under the panel and get the feedback of the signal from the system was quite near to the bed of nails tester, and this was also the part of my main involvement.
It was a very complete project, through the efforts of professionals in all aspects of mechanics, electronics and programming in SPEA to meet customer requirements. The core task was to use a new test head instead of flying probes, simulating human fingers, touch the options on the panel and verify the board performance under the panel. It was also required to use the camera to check the panel status at any time. In terms of electrical, a suitable adapter of BON system should be designed to receive the signal from the system and using VB.net as a bridge to accomplish the data compilation and data transfer between the systems and the boards, then analyzed the feedback signals with a computer to confirm whether the test results of washing machine panel were passing or failing.
The project was mainly divided into three parts: hardware design, BON adapter design, and software design. All the requests were discussed by both the staff members of Spea spa and customer, after the design consensus (which performance can be achieved, and which cannot) was reached, the machine was started to design and rebuild.
The result of the thesis is to design a new tester interface for testing washing machine control unit module with board performance test and panel vision test.

Keywords washing machine control unit module, bed-of-nails system, adapter, test programming and debugging.

Contents

Chapter 1

Introduction

Nowadays, with the continuous improvement of automation technology, more and more companies start to find a way with higher efficiency to verify product performance and guarantee its reliability, which is not only mandatory but also essential.

The aim of this project was to design a new system interface, with minimal and simplest manual operation, to test the operation panel of washing machine and its board into as a whole and affirm its performance. Furthermore, it could also be considered as a challenge to design a new type of the tester which could use for more difference situation , based on the experience of designing the flying probe tester and bed of nails tester, finally, a new test machine was completed.

Spea spa, as a R&D company, is mainly dedicated to design and manufacture the best automatic test equipment. In this project, Spea used a flying probe tester as a testing prototype, which is mostly used to detect any possible defect in electronic products, through the adjustment of its hardware and system compilation, to achieve the requirement of the customer, detecting washing machine panel with electronic board to ensure it won't fail while working.

According to requirement of the customer, Spea created a temporary team to find out an optimal design to meet test needs with lower cost. The design concept can be mainly divided into the following section:

In terms of mechanical part, to make the fixture and pallet perfectly match the fixing requirement of the panel, enable the test head to accurately find the position of the panel touch screen switch, enable the conveyer to transport the test panel into the fixed position of the tester more efficiently and precisely, enable the scan gun to quickly find the location of the barcode and scan it and to make camera detect the surface of panel rapidly at any time.

In terms of electrical and software part which were my main responsibility, I needed to design a suitable adapter of bed of nail tester, design the programming logic structure to satisfy the customer demands (the detailed programming is done by the staff of Spea who specialize in building the system) , debug the functional test and process the feedback signal, through the signal, the user/operator could figure out whether the panel (with board) is working properly.

In order to best meet the needs of customer, throughout the project, Spea and the customer always kept in touch, once in a while, the stuff of the customer would come to Spea to confirm the process and discuss improvements. The project is a long-term cooperation between the Spea and the customer, since after finishing the reform of tester, Spea still need to keep designing the new fixture, pallet and related-programming for the new panels and the boards, and this thesis would focus on the duration of reforming the tester only. The design process of the test machine body took a total of 27 weeks. During this time, the customer gave Spea five different shapes of panels with the two different kinds of electronic boards,

When the project was in progress, many tasks were carried out simultaneously, for example, the fixtures of the panel and the circuit of the board were designed by the different employees in different departments, and at same time, the test head design and production, the code compilation between the board and tester system were being promoted too. Every afternoon, the staffs involved in this project would assemble and check the work progress, and finally, a new system interface was completed to the new automatic test equipment - "T100".

Chapter 2

Background to the project

This thesis project was carried out in spring 2019 at Spea spa in Turin. The panels and boards of the washing machine used in the project were provided by the customer (To avoid copyright disputes, the brand name of the customer would not be shown in the thesis) and the project was commissioned by a European leader company in this field.
The main objective of the thesis was to design a new system interface to exploit the new automatic test equipment. Materials used in component machines were divided into two types: self-produced and purchased. The models and specifications of these component would be indicated in the paper.

2.1 SPEA Spa

In 1976, with the development of computer technology, electronics was widening to computer science, a new company was found in this key moment, aiming to create the standard equipment to test electronic devices, called SPEA.
After more than forty years of hard work, the company is among the undisputed testing leaders of the world, both in the semiconductor industry and in the field of electronic boards.
The headquarters of the company is located in Turin, Piedmont, Italy. At the same time, to become a successful company in test field, the company has also established partnership with the most important electronic manufacturers worldwide and stacked on a network of branch offices placed in most of area in the world where electronic manufacturing is located, from Europe to the Americas and Asia.
SPEA automatic Test equipment can be used to semiconductors ICs, MEMS, electronic boards and modules, all of these are utilized from vehicles to smartphones, from tablets to the most complex aerospace, medical, military devices, etc.
As we know, we are living in a world surrounding by electronics equipment, and the main purpose of SPEA is to ensures that all electronic devices work defect-free for their entire life and SPEA systems are built to detect any possible defect in electronic-related products, so that they won't fail on the field. It can be mainly divided into three parts:

(1) Semi and MEMES Test business unit focuses on analog mixed signal test for

- Identification
- Automotive
- Medical
- SoCs
- MEMS test
- Calibration
- Products line includes H3000 test handlers, Comptest MX and DOT testers.

(2) Electronics Test business unit is an automatic test equipment for

- Assembled electronic boards (PCBAs)
- Modules
- Main products are flying probe test, ICT testers and functional testers.

(3) Special Products business unit is specialized in developing custom equipment to answer specific test requirements, where time-to-market is essential. It's here that the most innovative solutions to

the test the latest technologies are born.
For this project, it can be defined as this part.

2.2 Introduction of flying probe tester

SPEA Flying Probe Series is designed to include the widest range of test requirements for electronic boards with high mechanical testing speed and extreme accuracy automatic board loading, using single or dual-sided probing, overall configurability and fast set-up changes technologies to test the board.
With extreme mechanical accuracy, the flying probes can contact the smallest pins of micro-SMD packages directly. Then, the mechanical performance, supported by on-axis, high-resolution measurement electronics, can reach ultra-precise measurements, while reducing sampling time of measurement to a few microseconds.
All of these are executed by a multi-process platform managements to optimize the test program, combining with in-circuit test (powered-up or not), short circuit test, optical inspection, boundary scan test, functional test, etc.
Usually, the flying probe system control is more like a robotic arm which can touch the pins of board directly. Users can change the coordination of the probe by operating the computer (or programming) without any changes to the hardware part of the system.

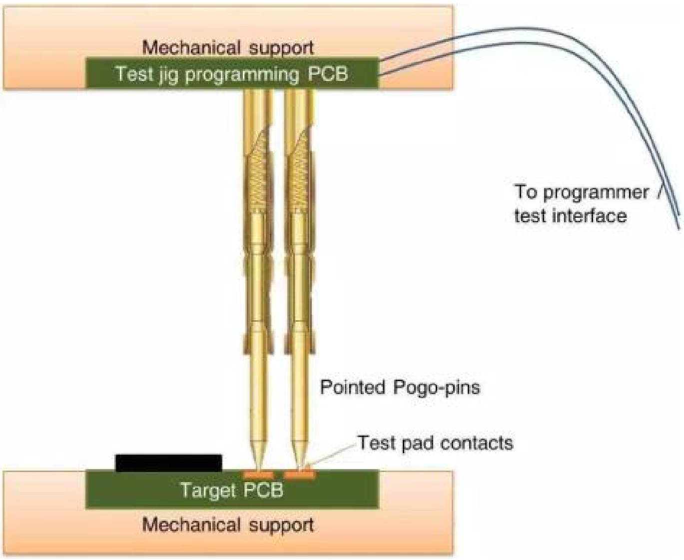


Figure 2.1 Test method of flying probe tester

To meet the test requirements asked by the customer for testing the washing machine panels and boards, SPEA used part of function which can be realized by the flying probe tester, especially the core technology with the test probe control.

2.2.1 Flying probe tester

Since the technology of the new tester inherited part of technologies of common flying probe tester designed by Spea is combined the 4 high-speed top flying heads with additional tools to contact the bottom side of the board to complete in-circuit test, power-on test, sink/source analog, digital D/S, on-board programming and others, with increasing throughput and test capabilities.
While using the 4 top probes to perform flying probe test on the top side of the board, a bottom lifted platform can be used for bed-of-nail fixture, multiple high-current power supplies, high-speed signals, digital I/O, fixed probes and planarity supports.

Figure 2.2 Example of Flying Probe Tester & internal testing environment

2.2.2 Features and capabilities

Most of the flying probe tester designed by Spea is built with top-performance linear optical encoders on XYZ axis and can contact to the Micro-SMD pad accurately. Here show the key features of the test machine:

- High throughput
- Best measurement accuracy
- Accurate Micro-SMD probing
- No cost of fixture
- Intuitive programming
- Field returns are practically eliminated

The flying probe Tester is also can be used widely in many fields of testing. Operators just need to provide appropriate codes for the software system of the tester, it can performance different tests to meet different requirements.
The test capabilities include but is not limited as follows:

- In-circuit test
- 100% short circuit test
- Nodal impedance test
- Power on test
- Functional test
- Colour optical test
- LED light test
- 3D laser test
- Boundary scan test
- Built-In-Self test

According to the customer requirements, for the project, the main test should be executed was In-circuit test.
In-circuit test which can be referred to as ICT, is used to test the electrical performance and electrical connections of online components to check for manufacturing defects and component defects. It also can be regarded as a white box testing, by testing a populated printed circuit board (PCB) through electrical probes to check for opens, shorts, resistance and other quantities to verify the function of the board or whether the assembly was correctly fabricated.

The main technology on the flying probe tester which was also used on the new test machine and its reason would be introduced in detail in Chapter 4.4.

2.2.3 Operating system

Spea uses an operating system developed to control the both flying probe testers and bed of nails tester, and the software used here is also created by the SPEA itself with following advantages:

- This user-friendly software design allows non-professionals to quickly generate a test program, even if the tested board has thousands of nets.
- The import data of the tested board can be performed with a variety type of sources: CAD, Bill of materials, netlist, etc.
- The automatic test program generator analyses the circuit description and generate the test pattern for all components on the board.
- Debug of the in-circuit tests is generated automatically which can boost the speed of the generated test program development.
- Using this operating system as a self-programming software to control the flying probe tester is easy and fast. The automatic test program can be generated with or without CAD files in minutes, the debug and tuning of the system which can be seen on the monitor (with analyse and optimize the production process) are faster and fully automatic.
- It is also very easy to control the performance of the machine by manual programming and compiling the system (just need to put the code file into the specified folder of the software). The language we used here to control the performance of the tester is VB.net.

2.3 Bed-of-nails Tester

To design the new tester, Spea also needed to use the technique based on bed-of-nails fixture testing to detect the board function of washing machine control unit.
A bed of nails tester is a traditional electronic test fixture, combing with numerous pins inserted into holes in an epoxy phenolic glass cloth laminated sheet (G-10) which are aligned using tooling pins to make connect with test points on PCB and are also connected to a measuring unit by wires, here, the connection of another side is the control system of flying probe tester.
Bed-of-nails fixtures contain an array of small, spring-loaded pogo pins and each pins makes contact with one node in the circuitry of the device under test (DUT), by pressing the DUT down against the bed of nails, reliable contact can be quickly and simultaneously made more than hundreds of individual test points within the circuitry of the DUT and afford the testing result (including defects) to the user.

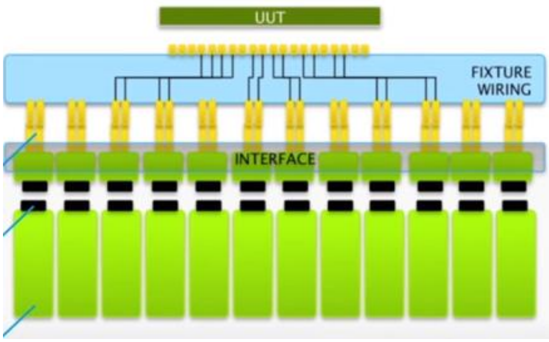


Figure 2.3 Structure of Bed-of-nails fixture

Bed of nails fixture needs a mechanical assembly to fix the PCB in place. Using it to product in-circuit test also has a lot of advantages for electronic board production like no error at final functional test, minimized effort to repair and elimination of field return.
Spea, as a company which is mainly involved in developing testing machine, its business also involves the development of bed-of-nails fixture, the following figures showed the most common type of ICT Testers Spea designed.

Figure 2.4 Eample of BONTester

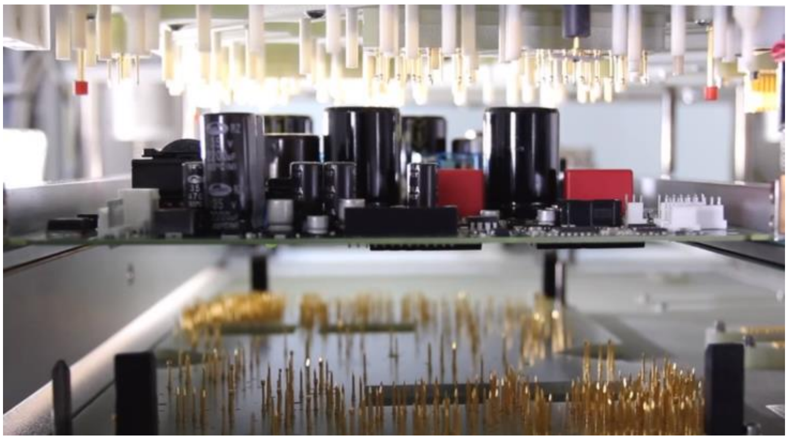


Figure 2.5 Internal environment of BON tester

Normally, Bed of nails systems are combined with instrumentation, a receiver which can perform board contacting and a controlling system. The controlling system of Spea which can control the receiver sensors and actuators is composed by a general-purpose computer (PC) and a various of PLCs with drivers.
To product a specific UUT of tester, it needs the so-called adapter. A bed of nails adapter also can be regarded as a “system interface” with the electrical board. So, different boards need different adapters and they should be developed accordingly to the UUT since they contact with each other directly. Through this way, the adapter can be contacted to the test points of UUT with board deformations and minimal signal interference.
Since this fixture is main related to the circuit design to connect the system and the board, it is mainly based on the test points and the functions of programmed chips on the board.
The fixture and circuit design will be introduced in detail in the Chapter 5.

2.3.1 System configuration of BON

Bed of nails tester is developed by Spea and widely used in various test fields. Usually, it can be equipped with up to 4 independent Core where each core with independent CPU, instrumentation and local memory and has ability to test in parallel up to 4 boards.

Different from the standard ICT tester of other company, The productivity of Spea BON tester is up to 400% higher, thus minimizing the cost of testing.

Besides of the main power supply, mother board, analog & digital bus, BON tester can also has one or two (the quantity is depended on the testing needs) racks where instruments are placed.

A BON system has a “Multi-Core” architecture. The table shown below that it has a high customization to match a wide range of test demands. The 4 independent Core with the instruments means the setup can be changed at any time, by modifying and expanding to answer the changes as the test needs.

In the table shown below, the engine corresponds to the core as an equivalent notation.

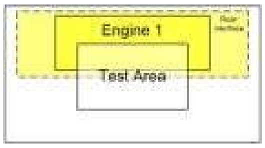
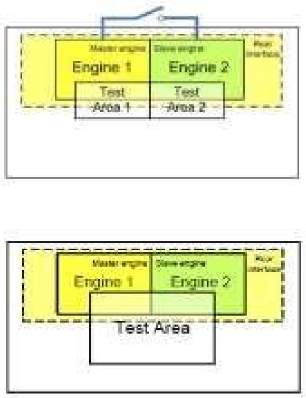
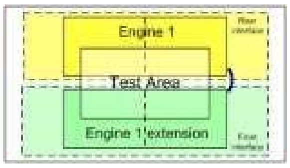
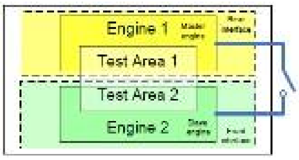
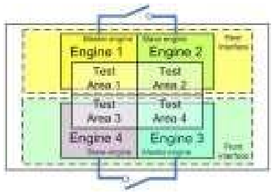
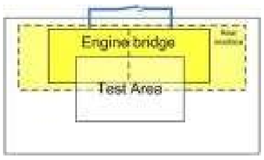
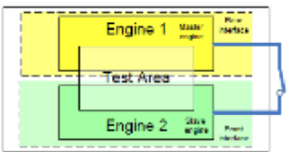
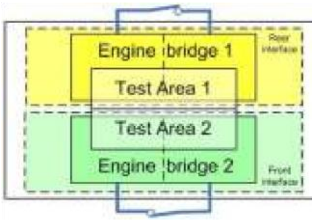
Active Bay Link	Rack Number	Single Core (real/virtually)	Dual Core (real/virtually)	Quad Core
No	1			NA
	2			
Yes	1		NA	NA
	2			NA

Figure 2.6 Spea BON Tester system configuration

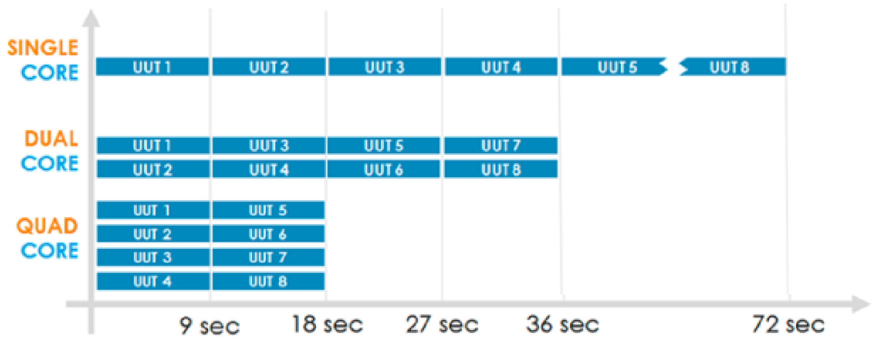


Figure 2.7 Time of unit under test with different numbers of core

The minimal configurations which allow the system to be initialized is:

- Mother Board (ABUS, MBUS):
  It also includes the sharing bus. They are Analog bus and Mod bus (internal) they manage the instrument interfacing and system communication.
- Power supply board (YAPSU):
  Power supply unit provides power to the rack instruments, but it is not used to the PC and automation actuators.
- Matrix Relay Board (YASCA #1):
  The board allows to connect any test points to any ABUS lines.
- CPU board (YACPU):
  The bay has the same number of the core must has a corresponding YACPU. This allows the system to parallelize the test sequence and reduce testing time.

  - Drivers: A general generator (+/-10V, +/-100mA) with high precision and low voltage. The HOT and COLD (system earth) terminals of the drivers can be linked to any ABUS/MBUS lines, or it also can be wired to the fixture directly.
  - Guard: It is a module used to limit some functional part of board when needed during the component measurement. Through using a voltage follower or direct connecting to change the circuit behaviour and isolate the component needed from the rest of the board.
  - Digital Voltmeter (DVM): It can be used to customize low pass filters among other typical functions. Same to the driver, the HOT and COLD terminals of the drivers can be linked to any ABUS/MBUS lines, or it also can be wired to the fixture directly.

The function of these configurations which should be used on the reformed tester would be introduced in detail in Chapter 5. Figure Below also shows the main structure of the common BON tester Spea designed.

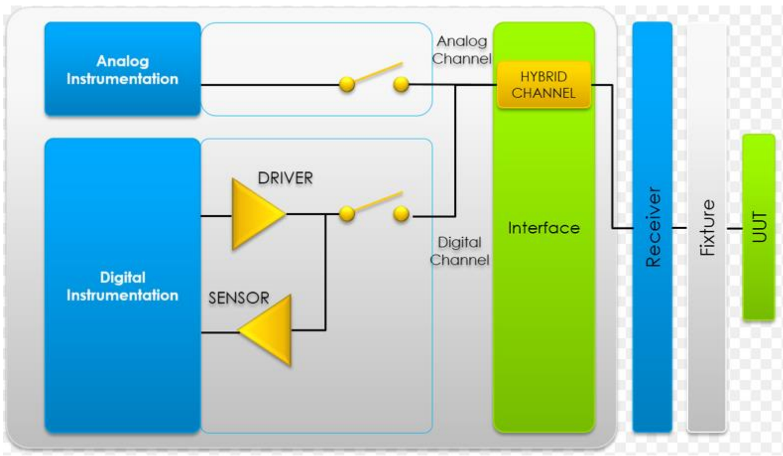


Figure2.8 internal and external structure of BON Tester

2.3.2 External movement

As the following figure shows, from the external side, the most important compositions on the tester are conveyer, receiver and control PC. In the In-line system, the modules of conveyors and receiver is done automatically, without any human intervention.

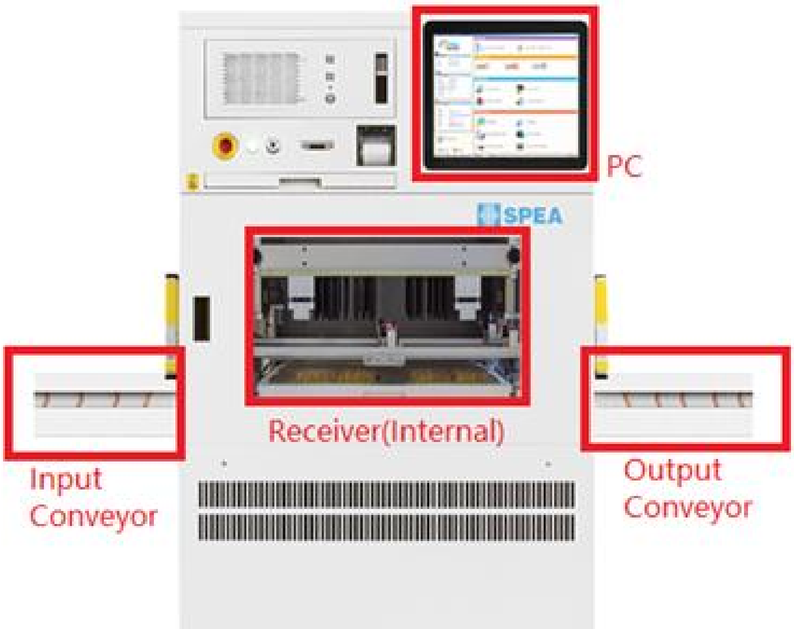


Figure 2.9 Example of external structure of BON Tester

The operation sequence of using common BON tester can be divided into 5 steps:

1. Move the board into the Receiver:
   (1) Confirm the board presence on the input conveyer (slideway)
   (2) Start movement (operate the PC)
   (3) Confirm the transition (in this moment, the board is not on the input slideway.
   (4) Confirm the board is now in the receiver (test area)
2. Move down the receiver
   (1) Confirm the optical barriers are not interrupted
   (2) Confirm the system door has closed
   (3) Confirm the board is well loaded, the UUT is correct
   (4) Start movement
   (5) Stop and Abort if any prior requirement is not reached
3. Perform ICT test
4. Move up the receiver
5. Move out the board
   (1) Confirm the output conveyer is free
   (2) Start movement

Fail boards will be conveyed mechanically with a handler and the fail information will be written into the board database.

2.3.3 Sensor of conveyer

As described above, the system of tester will recognize the position of the board by itself, there are 3 different purpose sensors equipped on the different position of the input/output slideways to verify the board position.

- Presence sensor:
  Verify whether a fixture with board(s) has arrived and the front edge of the fixture is placed correctly.
- Volumetric sensor:
  Verify the boar length to confirm whether the UUT is correct.
- Anti-rotation Sensor:
  Verify whether a fixture with board(s) is in the correct orientation since a board have 8 possible rotated direction

Different applications have different effects on managing the whole test time, but usually it needs near 3 seconds.
Also, in the duration of installation, debug and board production, the different adapters need to be extracted and adopted into the system receiver. This task is completed by the receiver which must ensure the locking of the adapter has been performed suitably and the interface strips have connected to the system correctly.
Besides, since the receiver includes a heavy-duty autonomous mechanism, it is necessary to protect the operator and UUT from a failure or a wrong function. To ensure the safety and correct function of UUT, sensors need to be equipped in the receiver to realize a abortion of movement when any anomalous behaviour is detected.

The sensors used in a BON Tester include:

- Front door sensor (Input Sensor)
- Back door sensor (Output Sensor)
- Laser array sensor: prevent

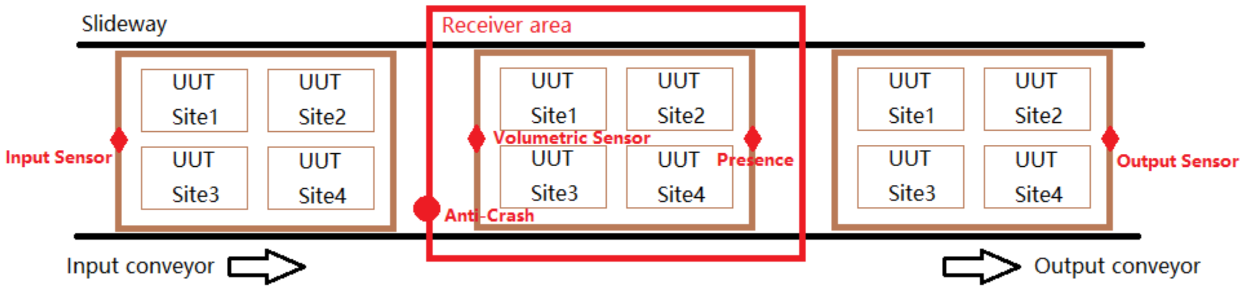


Figure 2.10 System Conveyor

In this case, no one/other things can enter the test area (receiver) without interrupting the safety chain which protect the operator from bad performance to the system.
Another important thing should be noticed is its motion mechanism was also applied to newly designed tester “T100”.

2.3.4 Adapter

The adapter is a device which can adapt a system to a specific board. The system can manage instruments and test point interconnection with a relay matrix which is used to manage a four rows analog bus. They all connect to the test point of the UUT through the adapter.

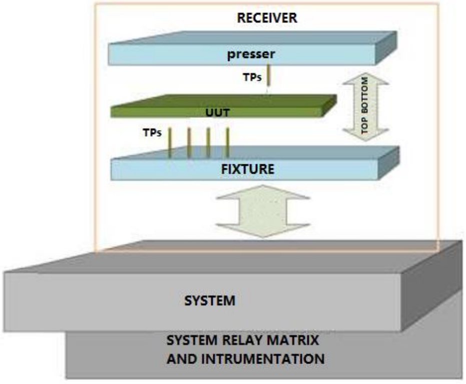


Figure 2.11 Structure of Adapter

As the figure above shows, the wiring goes from needles which contact with the board test point through the adapter to the end up of interface strip which connect the test point to the correspondent channel of the system relay matrix.

Once the test points have been placed on the top of UUT, the wire routing can pass through a top-bottom interface to the interface strip in the fixture.

A traditional adapter in BON tester is consisted with 2 parts:

- Presser: A structure contains auxiliary hardware, sensors and nails. It is placed on the top of the receiver. The presser realizes the pushing movement during the test, driving the nails of Fixture and Presser in contact with the UUT
- Fixture: A structure contains auxiliary hardware, sensors and contacting nails. It is placed on the internal of the receiver and keep locked when during the test.

2.3.4 Nails

There are many different nails which are used to ICT Tester to deal with the different topologies of test point pads, for the BON Tester, the probes usually used were introduced below:

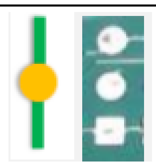
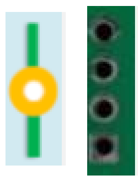
TP TYPE	Sample	Probe Type	Probe Sketch
Pad		Sword	
Through hole		Nine Points	
Through hole (not mounted)		Pyramid	

Figure 2.12 Type of probe

The designer needs to according to the situation of the test points to choose the most suitable nails when design the adapter.

2.4 Comparison of BON system and Flying probe system

Although, both technologies can be used by contacting and touching the board on at least 2 test points at the same time to realize many kinds of functional tests for the assembling chips. The difference is that a flying probe tester can utilize a highly accurate of coordinate-controlled test head, while a bed-of-nails tester is like an acupressure chair a fakir would use, where even hundreds of pins contacts can be performed on the board in a time.

	Flying probe	**Bed-of nails fixture**
Advantages	1. Lower setup cost with software-contrlloed coordinates	1. Suitable for all levels of electronic engineering
	2. Fast to start the first test since short development time	2. Easy to implement and testequip -ment setup or operation
	3. High-density PCBs do not need specific test pads	3. Fast test/programming for mass-production boards
	4. Capable of testing off-angled legs and pads of different chip package	4. On-Board programming (OBP), ICT, Functional Circuit Testing on one fixture
Disadvantages	1. limited lifespan test head (needle) needs periodic replacement	1. Necessary test-pad areas on the PCB will take up real-estate space
	2. High capital investment of equip-ment, unsuitable for hobbyists with low throughtput	2. Where time, to test a new board needs to design a new suitable adapter

Figure2.13 Comparison of BON and Flying probe system

BON tester and flying probe tester are both the most common board testers used in many different occasions. For the purpose of this thesis, to design a tester which can not only control the test head to touch the washing machine panel but also needs to detect the board electrical function, both the flying probe and bed of nails technology should to be applied to the new machine.

Since this was a real big project and many people involved in it, my main responsibility was to design the adapter of the board (This part would be introduced in detail in Chapter 5). Meanwhile, I also participated in the designing the structure of programming and debugging of the board with other colleagues. (This part will be introduced in detail in chapter 6)

The basic structure and features of the flying probe and BON tester introduced above would not be repeated in detail in the later chapters except the necessary parts deep related to the new test machine - “T100”.

The purpose of this thesis was not introducing the inside structure and mode of operation for the completed tester machines, so in the later chapter, my main aim was to focus on the different parts of the common flying probe tester (most related to the mechanical design) and a completely new design of BON adapter for the customer-supplied board.

Chapter 3

Washing machines control unit module

This section gave detailed introduction and explanation about the whole project. The shape and feature of the washing machine panel and its electric functions would be also shown in this section. All design concepts of tester (in chapter 4) were derived from actual situation and test requirements of the washing machine panels.

3.1 Composition of washing machine panels

Today, with the continuous advancement of technology, the demands of consumers for home appliances are gradually becoming more convenient and intelligent. How to maintain a higher security and stability of home appliance operation in this state has become one of the top concerns of manufacturers.

This project was commissioned by the customer who is a European domestic appliance company, their main request was to design a multifunction tester of washing machine digital control panel which can not only detect the situation of panel but also can confirm the operation of the board under by operating the panel.

They gave Spea a total of five different shapes of panels with the two different kinds of electronic borads. Inside, four different shape of panels were paired with the same board, and rest one panel which its display was LCD, loaded with two different functions of electronic boards.

According to the privacy rules of Spea, in the thesis, I called these board: Board A and Board B, they were used as a specific case to introduce the whole process of tester reforming and panel test-related parts design to achieve the purpose for testing this washing machine panel.

The main function of Board A was displaying the interface and control the unit module of the washing machine which was operated by the LCD screen.

On the other hand, the main function of Board B was to make the washing machine display the sound through buzzer after receiving the command.

As one of the designers who participated in design of the test sequence, my main responsibility was to build the test plan, design the related components for the testing and program and debug the boards functions of this panel (with LCD display).

Here, to protect the privacy of customers, the brand and real panels would not be shown in the thesis, here are the samples with very similar shape and performance of the panels provided by the customer.

Figure 3.1 Example of normal washing machine panel (1)

Figure 3.2 Example of washing machine panel with LCD display (2)

All the digital operation panels provided by the customer were mainly composed of a display, a main switch, and some control buttons. In some products, the display and buttons were integrated, in the others, they were separated.
According to the customer requirements, in this project, the objects of testing and verification were the display screen and buttons on the panel.
Since most of the traditional buttons were controlled by capacitive sensing (whether or not integrated with the screen), the buttons had no obvious bumps and the function of washing machine could be activated when the buttons were touched without strong force.
Although, the shapes of the panel were different, their overall size and the function of buttons were basically similar, which means except of the different fixtures used to fix these different shapes of panels, some rest parts of the tester used to perform the test can be versatile.

3.2 Design Concept

Before asking Spea Spa to design the tester, the customer company performed the testing by themselves which each panel with different shapes was detected by different machines. It also means, to test one kind of panel required one special tester and it can be only used to test this panel. Although the test liked a belt line testing, but the cost of time and money on designing machine decreased the whole benefit.
Finally, to further improve work efficiency and reduce the manufacturing cost, the company asked Spea to design an universal machine to solve this problem.
The main purpose of tester was to let the operator can use only one machine to detect different types of washing machine unit in high speed and high quality guarantee.
So, Spea discussed with the customers and built a detailed design content which the tester need to meet.

3.2.1 Test contents

According to the test requirement, Spea established a development cycle of several months, the core part was to decide the specific implementation of the required test contents. After the discussion and analyzing the actual feasibility of the tester, Spea built a series of implementation plan for different shapes and types of washing machine panel.
Since every panel had separate test contents, in this thesis, I would use the panel with LCD display which loaded with the Board A and Board B.
The following specific test contents were for the panel with Board A and Board B which put forward by the customer.

- Camera checking
  Using camera to check confirm that the surface state of panel. It also can be used to check the situation of the LCD screen (for example, color)

- Power on test
  After press the main switch on the panel, the electronic boards shall be applied voltage on both Board A and Board B. On the system level, operator can get the result that whether the power supply can provide voltage steady.
- LCD color check
  After power on, command should be sent for color palette like following image, the LCD screen should be like Figure 3.3 (to keep the privacy of the customer, the figure displayed here has difference with actual one) and operator could use camera to do the color check and get the test result.

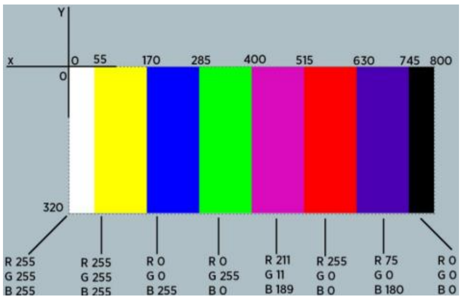


Figure3.3 Color check

- LCD alignment check
  Command should be sent for alignment test display like following image, the LCD screen has to be like Figure 3.4 (to keep the privacy of the customer, the figure displayed here has difference with actual one) and operator could use camera to do the alignment check and get the test result.

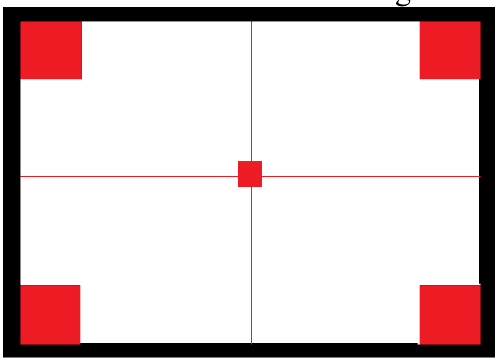


Figure 3.4 Alignment check

- LCD touch check
  Command should be sent to the system to control the test head of tester to execute the touch display test and check voltages.
  If the all the dots showed on figure 3.5 (to keep the privacy of the customer, the figure displayed here has difference with actual one) had been pressed by test head, on the operating system, the operator could get a command like "PASS". On the opposite if after few seconds all the dots had not been present, the operator would receive a command like "NOT PASS" from the interface of operating software.

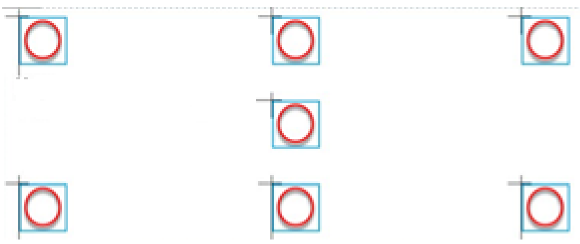


Figure 3.5 Touch test

- LED lighting check
  LED check shall be executed when power on and power off, camera should be used to check the lighting situation of the LED on the panel.
- Read system data of Board A
  Using the computer to receive the data (feedback from the system) of Board A after the test head touched the screen.
- Sound check test
  The test should be done in two situations: when the Board B was power on and when the Board B was power off. When it was power on, the buzzer should make sound and the voltage should equal to the set value (provided by the customer). When power off, the buzzer should be quite and be deactivation.
- Read system data of Board B
  Using the computer to receive the data (feedback from the system) of Board B after the test head touched the screen.
- Test complete
  Once all the test contents above are complete with success, the board must be powered OFF and marked as PASSED OK.
  If one of the tests fails, the board should repeat procedure at least one, then if failure continues to happen it should be marked, for each board, the failing step and kept for further examination.

The testing steps should be performed on the "T100" tester as following sequences:

Step1: Power on test (test for Board A)

Step2: LCD color check (test for Board A)

Step3: LCD Alignment check (test for Board A)

Step4: LCD Touch check (test for Board A)

Step5: Board A data check (test for Board A)

Step6: Sound check (test for Board B)

Step7: Board B data check (test for Board B)

3.2.2 Mechanical design concept

According to the test contents, after a series of discussion with customer, Spea decided to design a new test machine which combined the relevant technologies of both flying probe tester and bed of nails tester.
After information sorting and summarizing, the main design of mechanical purpose was to ensure the safety and increase the testing efficiency and it could be divided into two parts.
Since component must be installed on the line complete with an engraved plaque attached to the frame, following technology could be almost relied on the performance of flying probe tester itself:

- The motion control must be carried out downstream of the transmission/cylinder to filter breakage upstream, or, it also can be installed on the cylinder sensor with LED connector to displays its status.
- To maintain the facilitation, motorized roller line must be provided on the shaft of the belt parts.
- The speed of movement on the rollers is to be considered the maximum acceptable in consideration of the product to be transported.
- Hot surfaces can be protected from contact.
- All motors shall be placed in open spaces and easily accessible, to ensure both ventilation and maintenance.
- Drip pans are provided under hydraulic units and lifting tables.

- Air compressed and energy must enter only in 1 unique point for all line, with a main electro valve connected with PLC, on which will be inserted working daily calendar in order to switch off energy and close main valve when the line is not working.

On the other hands, based on the structure and performance of the original machine, in order to make the whole test process can be much easier and faster, the following design elements also needed to be considered:

- Suitable Fixture of washing machine panel.
- Two-way transmission conveyer allows the test panel can be entered the tester in both sides.
- Suitable touch test head.
- The possibility of automatic reading the bar-code on the product.
- Using camera to detect the surface situation of washing machine panel.

Since the core component, test head of the machine mainly used similar technology of the flying probe tester, its details of the mechanical part would not be highlighted in this thesis.
On the other hands, the additional mechanical properties of module control unit of the tester listed above would be described in detail in the chapter 4.

3.2.3 Electrical design concept

As a test machine, the most important part was the system to drive the machine assembled by the required mechanical parts. As the customer required, the electrical design also could be divided into 2 parts: one is related to the real wire connect condition, and the other was to design the circuit to connect with system.
For the first part, all the terminals, cables, etc., must be labeled easily found on the wiring diagram (the numbering follows the same rule as seen by the PLC), so:

- The power for inputs and outputs must be separated: they must be installed 2 power supplies.
- All solenoids shall have a protective RC with LED display.
- All sensors must have a connector that can see the status via LEDs.
- For pneumatic equipment, shall be subject to the same labeling rules

For the second parts, since some part of the chips on the electronic board had been programmed, and during the test, by calling the function, it should work. The programming concepts were provided by the customer and Spea had to check the function and confirm that these functions could work successfully, so, the only problem was, how to use them to activate the function and make the machine system itself to recognize these commands and execute them.
To solve this problem, the first thing to do was to connect the board with the system and then establish a “hub” to make the chip controlled by the customer codes and the system programmed by Spea could recognize each other.
The connection between the board and the system could be called adapter, as the introduction in Chapter 2, the core technique Spea used was based on bed of nails tester and for the design part, the most important thing was to design a suitable adapter for the electrical board. The whole project combined with mechanical design and electrical design would be introduced in detail in chapter 5.

Chapter 4

Mechanical design for control unit module

To achieve the suitable testing purpose for the washing machine panel with its boards, the things Spea had to do mainly could be divided into two parts: designing and developing of test machine body and designing the panel-related electrical part to connect the tester with the electrical boards of the panel. And both could be subdivided into mechanical transformation and electrical transformation.
In terms of mechanical design, the goal of the reform was to make the test machine body can produce all the test contents as customer requirement in a convenient, efficient and safe operating way, minimizing the difficulty of the operator himself/herself and emphasizing the performance of the tester itself.
My work was to be concentrated on the electrical design of its fixture, so the mechanical part would not be described superficially.
The following contents would emphasize on the mechanical components changing which was modified or newly built on the original basis of the flying probe tester.

4.1 Adapter

There was only one thing which could not to be universal inside the test components were the adapter, which was consisted by two components: fixture and the pallet.
As the part of adapter, the fixture was fixed on centre of the button in the receiver area, since there were two centring spines on the bottom of the fixture, it could be coupled perfectly with the system. Also, the receiver could lock the mechanism to prevent the fixture moving in the tester.
Once the pallet loaded with two panels entered the tester and arrived the same x, y axis position as the fixture, the fixture fixed on the receiver would arise to connect to the pallet and the nails on the fixture would touch the boards under the panel to be a whole test composition. Once the fixture went above to make its nails contact on the board to let the fixture, panel with the board(s) and the pallet become a whole, it could be called “adapter”.
For the different shapes of washing machine panels, the different adapter should be designed based on the shape of the panels, the position of the test points of the boards and the related electronic components to make the boards connect with the system.
This was also the reason I mentioned before that the project was a long-term cooperation, since the adapter would keep updating as long as the customer provides new panels or new boards.
Considering the internal space of the flying probe tester and the size of the panels provided by the customer, the pallets should be designed to mount two panels at one time which also means the fixture should be designed to test at least two boards (if one panel loads one board).
In testing aspect, the fixture fixed in the receiver should be ensured to contact with the UUT and all the probes mounted on it must touch the corresponding test points of the tested board precisely and stably.

4.1.1 Fixture

The fixture design was based on the positions of the test points on the board and it also meant if operator wanted to test another panel with different type of board, both pallet and the fixture inside the machine should be changed too.

Normally, even the shapes of panels were different, as long as the board(s) loaded under the panels was the same and set in the same position, the fixture did not need to change, but if the same board loaded in the panel with different position or orientation (for example, rotating 180 degree), the fixture inside the machine had to be changed.
The design concept of the fixture here was almost the same as the design of the normal bed-of-nails test system and it also included the design of the internal electrical design of the adapter, all of these would be introduced in detail in chapter 5.
Here was an example of the fixture I designed directly of the Board A and Board B washing machine panel with LCD display provided by the customer.

Note: the customer information had been covered to protect the customer privacy. So, the real fixture of the panel could not be shown in this thesis.

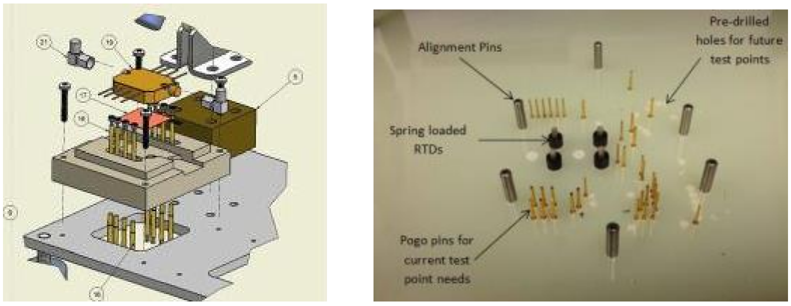


Figure 4.1 Example of the fixture structure

For now, the customer provided 5 different shapes of panels with three different kind of boards, so, Spea had designed three different fixtures and five different pallets for the testing.
Although, the shape of the fixture had the rate to be change, the main compositions of the fixture were still the same, which including:

- Nails
  This part was used to touch with the test points of the board directly, and the position of the nails should be designed based on the position of the test points.
- Connector 1
  The female part of the connector was to connect the wire under the nails and the male part was used to connect with the system of test machine.
- Connector 2
  Power supply relay. This part would be introduced in detail in chapter 5.
- Pallet connector
  It was used to connect with the pallet of the board.

The following figure showed the internal wire structure of the fixture used to connect the nails and the connector connected with the system.

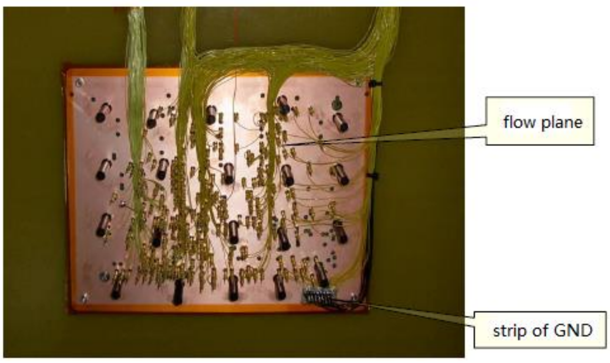


Figure 4.2 Example of the wire structure under the fixture

4.2 Pallet

To fix the panels well, Spea needed to design the pallets which conformed the shape of the panel suitably.
The shape of pallet was mainly followed by the shape of panel and the machinery staff of Spea decided the fix position of the panel.
Another thing had to be considered was its electrical function showing on the pellet. As the customer requirements, in order to allow the operator to understand the test results ("PASSED OK" or "FAILED") more intuitively while the test was complete, Spea needed to install 4 LEDs on the pallet which were used to show the direction of the pallet entering the tester.
For example, if the pallet entered the machine from the left side conveyer, the result of the test would show by two LEDs on the left sides of the panel after testing, while if the pallet entered the machine form the right-side conveyer, the test result would show by two LEDs on the right side of the panel.
Although, the operator could also know the test result on the computer, through this way, the operator could know the test result more quickly.
The electrical circuit of controlling these LED would be introduced in Appendix.16 of pallet circuit part. And the real pallet designed would be shown as follow figure:
Here was an example of the pallet we designed for one type of washing machine panel provided by the customer:

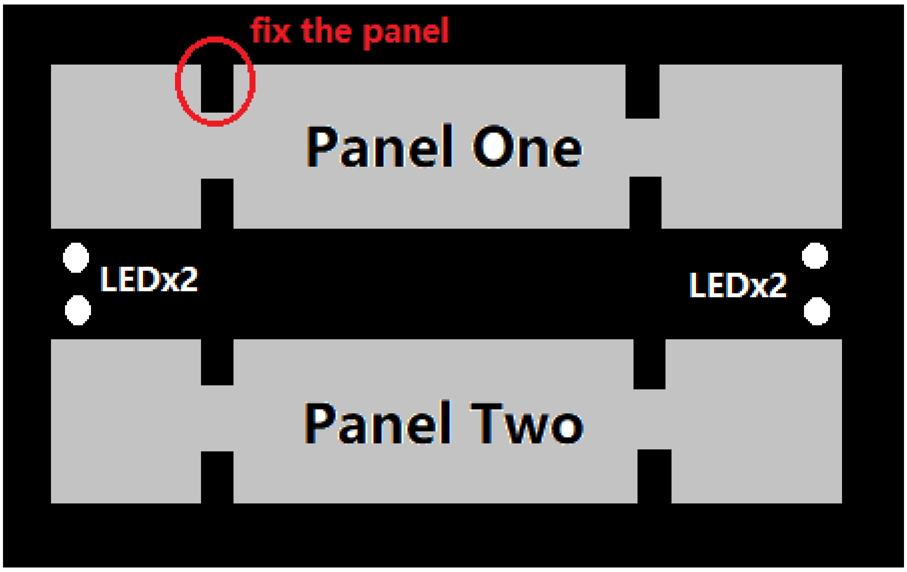


Figure 4.3 Pallet part of adapter

The figure showed all the position of fixture and LED, though it was only a layer of the whole fixture.
The control method of LEDs was programmed by Spea, it would be introduced in detail in Chapter 6.
Beneath the pellet, there was the adapter with bed of nails, so we also needed to design the layout of all the electrical component like FXSEZ200, FXSEZ150 and the connector of the adapter based on the shape of pallet.
The dimension of the adapter would be decided by the department of mechanical of Spea, and my responsibility was to decide the approximate location for those components which could make operator be more easily to connect wire with the system and the bed of nails.

4.3 Two-way transmission conveyer

No matter the flying probe tester or bed of nails tester designed by Spea before, the traditional conveyer of the tester made by Spea is single side with short distance transmission slideway. However, to test the washing machine panel, the length of the slideway must be increased to make enough room for putting fixture which should be loaded out of the tester.

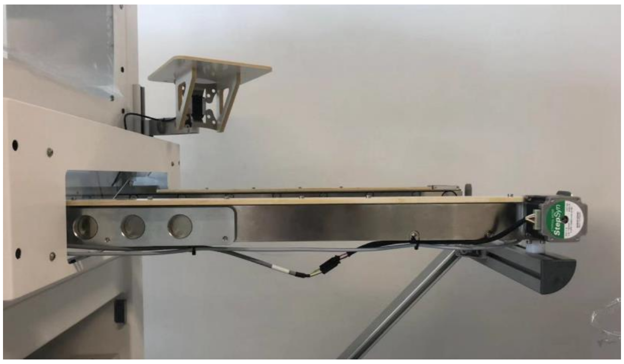
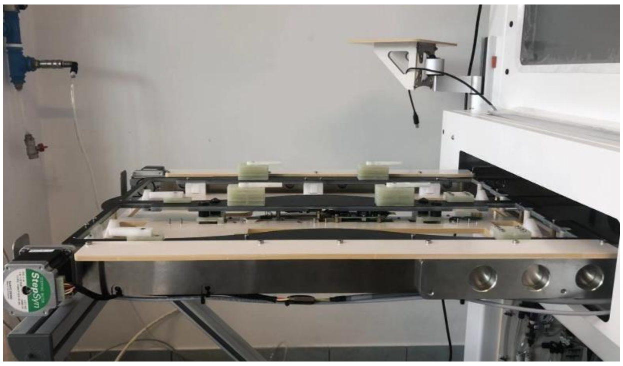



Figure 4.4 one side of conveyer (right side)
& Conveyer loaded with washing machine panel (left side)

Note: The length of the slideway should be almost equal to the length of the pallet, however, since the dimension of the panel would be changed sometime, the slideway also needed to be changeable by operators.

At the same time, since one fixture could only load one pallet with two panels, in order to improve the test efficiency, customer asked to install two-way transmission conveyer so that in the process of testing, when a panel entering from one side and is started testing in the machine, the operator could load another two pending panels on another pallet and put them on the opposite side of conveyer. Once, the test of panel inside the receiver had been completed and moved out from the tester, the pallet with another two panels could enter the tester directly without excessive operation and waiting and started a new round of testing. In this way, the efficiency of the test can be maximized.
Based on the above consideration, Spea decided to reform the machine from one-side slideway to two-side so that the fixture could be entered the machine from both right side and left side.
The concept of the conveyer transmission had been described in Chapter 2.2.3, the only difference was to add a new side of slideway in the opposite position of the tester which means the number of the sensors had doubled and the length of conveyer could be adjusted by changing the different length of slideway by operators.

4.4 Test head

Before introducing the test head which we designed for this project, I wanted to introduce the test head used on its original flying probe tester in brief.
The normal machine flying probe tester is usually combined with 4 high-speed top flying heads with additional tools to contact the bottom side of the board.
The flying probe system with those 4 or more robotic arms which can contact the tested board component even if the testable design has not been done since it can contact directly on the components pin (usually are the test points or the test pads).
In fact, it not only adapts the UUT directly (does not need any adapter), but also make the flying probe system be more flexible in the board testing.
The coordinates of the probes can be actively modified, so the system can perform different test for the different electronic board without stopping the system or changing anything.

The operator can use camera which would be also introduce in this chapter to find the test pin, and the test head loaded with flying probe would following the coordinate set from the camera to find the right position and the system would control the angle of flying probe to touch the test pin in a suitable way and get the test result immediately.
Through the combination of the camera and the test head, the flying probe system can test variety of different boards without adding any other auxiliary tools.

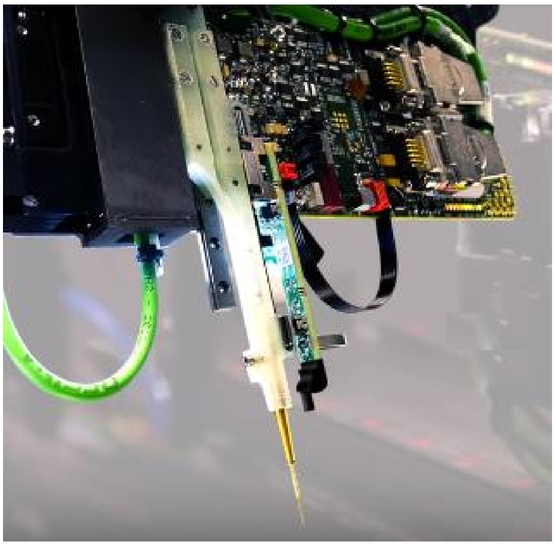


Figure 4.5 Common test head (with flying probe) of flying probe tester

Now I started to introduce the design concept of the test head for testing the washing machine panel.
In this case, the test head was not used to test the circuit function since this part would almost be completed by the bed of nails system below the panel, the only thing the test head needed to do here was to simulate a real human finger to touch the screen to activate and gave the command to control the board below the panel.
In fact, before the customer company asked Spea to make the tester, they had to make the test machine to verify the panel and board performance by themselves. The problem was every time when they would like to change the type of the panel, they had to make another machine with a specific program and test head to find the suitable test position on this panel. So, this kind of machines could only test one specific kind of panel and could not be applied to other panels.
The biggest difference between the testers designed by Spea and the customer was that the test head (including the control system) designed by Spea can be moved according to the set position through the camera positioning and computer control. So, once the programming setup was complete, the test head could quickly find the right positions for different panels and test them.
The reason why Spea needed to use the technology based on the flying probe tester was also for solving this problem, through using the combination of camera and the test head, the operator could find the touch points (maybe it was a physical button and maybe it was a touch screen button which was depend on the type of panels) before executing the test by him/herself. Even the panel and the position of the button were change, the operator only needed to find the new touch position by the camera and set them as the new touch position in the system just like the flying probe system.
However, since the test head needed to simulate the human finger here, Spea had to change the type of the test head from the probe needles to a bigger, flat, has a certain frication head.
Another changing of the coordinate moving system was the angle of the test head, the original tester with flying probes needed to adjust the probes angle to touch the different pins, while here, the touch behaviour only needed to be produced in vertical degree, so the angle of the test head could be fixed.
The test steps of executing the touch behaviour showed below:

Step1: Open the software operating system made by Spea.

Step2: Find touch position by camera.
Using the operating system to control the position of camera and find the positions of touch buttons on the panel one and panel two respectively, set those positions into the Leonardo system. Then the test head would go back to its start position.

Step3: Coordinating the test head system.
Since the coordinate of the touch points is calculated by the coordinate of the camera, the system must calculate the distance between the centre of camera and the centre of the test then get the button position with test head as its coordinate system.

Step4: Execute the test.

Step5: Test head finds the first touch point.

Step6: Test head moves downward automatically.

Step7: Determine if the test head touch the panel.
Once the test head touch the panel and the force between the test head and panel has been created, this stress causes the voltage in the test head to suddenly increase and give the machine hit that the test in this position has been completed, the test head move backup to the 0 position of the Z axis automatically.

Step8: Test head moves to the next position

Step9: Repeat the operation from Step6 to Step8.
(Until all touch points of two panels have been completed.)

Step9: Test head moves back to its start position.

Step10: Test complete

By executing the test steps above, operator could get the test information of all the button control for the board beneath the panel, since the ICT test would execute together when the buttons were touched.
To ensure the friction of the touch surface, Spea chose the material with frosted surface as test head. The following figure showed the mechanical structure of test head designed by Spea to execute the real touch test on the washing machine panel. However, according to the privacy principle of the company, the terminal of the test head which touch the panel directly could not be displayed in this thesis.

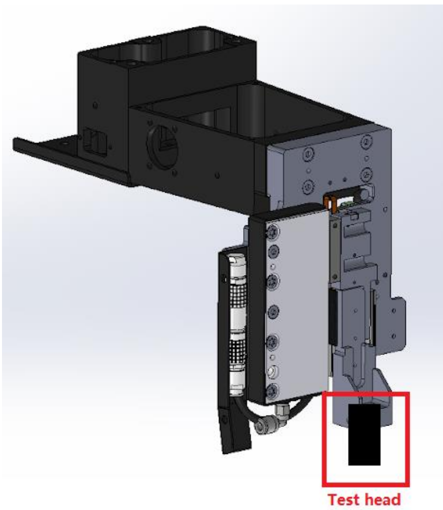


Figure 4.6 Test head of tester

4.5 Camera

The role of the camera in the whole test was not only used to find and locate the position of the touch points, but also used to detect the surface of the panel which included the plastic material parts, the switch, the display and the LEDs working status, to ensure the entire panel surface, including all components mentioned above on the panel, were intact.
As I introduced in Chapter 4.4, the normal flying probe tester had already equipped with a camera to allow the operator to accurately locate the centre position of the test points on the board by eyes and set these points/pads as test points by the operating system manually.
The distance between the camera and the test head was a constant value, and usually they were regarded as a whole. It also meant the camera was also a part of test head.
The camera was recruited by a circle of LEDs, these LEDs were used to illuminate the board when the operator was using the camera to locate the position of the pins, it made operator can see the pins more clearly and make positioning more precise.
On these basis concepts, in order to display the test points on the different size of the boards more clearly, especially for those small size boards with very small pins the magnification of the camera should be very high.
However, in this project, the customer required that the camera should be able to scan the two panels loaded on the pallet in the receiver and take the a series of photo in a very short time, in this case, due to the large positional deviation allowed by the touch test, excessive camera magnification become a disadvantage.
So, to meet the requirement of the customer and maximize the scan speed, Spea changed the type of camera and chose an another lower magnification one which was not only sufficient to clearly observe the surface of the panel but also did not affect the positioning accuracy of the touch test.

4.6 Barcode gun and printer

In order to allow different types of washing machine panels to be randomly sorted for testing, the tester should be able to read product model information (using barcode) and according to this information, the tester system can automatically find the correct test programs to execute the testing.
When all tests are over, printer would print out the test results which can be pasted on the panel.
Since the slideway of the tester is bidirectional, in order to distinguish the fixture (with panels) entered the machine, there were two corresponding printers near the slideway on both sides of the tester.

Figure 4.7 Printer

4.7 Execute switch

Through the improvement of the above mechanical related components, the experimental requirements required by the customer had been basically realized.
However, the customer still wanted to further minimize the manual content and process of operator and Spea decided to increase two switches on both right and left side near to the conveyer on the external of the tester.
Since all the tests could be started by computer control after few steps' operations, these buttons were more like a shortcut to make the test operation activate more quickly.
Once the switch on one side was pressed, the pallet loaded on that side of conveyer would be transferred into the testing receiver, performed the test and moved out of machine from the same side.
For example, the operator pressed the switch near the right side slideway, the pallet equipped with two panels on the right side slideway would be transferred into machine and fixed on the fixture. After testing, it would move out and back to the initial position of the slideway. In the same time, another operator stood near to the left slideway could press the left side switch and the same operation would be happened on the pallet loaded on the left slideway. In this way, the testing efficiency and speed could be maximized.
These switches were connected to the system directly, and the operation activated by them could also be stopped by control the system on computer. These gave the operator more operation choices when testing.

Figure 4.8 Position of the "Execute" switch

Chapter 5

Electrical design for control unit module

After careful mechanical parts selection and reform for the test machine, now I started to focus on the design of electrical parts. The brief introduction had been written in chapter 3.2.3.
The step of the electrical-related design could be mainly divided into two parts:

- Bed-of-nails fixture circuit design for creating the connection to transfer the signal and data between the board and test machine.
- Design programming logic structure (This part would be introduced in detail in Chapter 6)

5.1 Bed-of-nails fixture design

Different from flying probe tester which can be used to test different type of boards, ICT test needs to design the suitable bed-of-nails fixture for every different kind of boards since the internal circuit and external shape of fixture are fixed.
The customer gave Spea totally 5 different kinds boards with different internal electrical circuit, every board (with panel) needed a specific adapter to fixed and detect. At the beginning of the project, I worked as an intern to study the design concept and be an assistant to help other engineers, later, I started to design the adapter by my own with a panel with two boards: Board A and Board B.
These two boards were loaded on one panel and must be verified the function dividedly, so, I needed to design an adapter of BON fixture which could detect the features of both boards in the limited test channels.

5.1.1 Data check

To design the bed-of-nails fixture, the first thing I needed to be done was to check the electrical data of the Board A and Board B sent from the customer. Among them, the contents of files included were as follows:

- Board Specification
  Mainly including purpose, system block diagram, board connectors list, functional verification test contents, board step sequence description, etc.
- Board schematic prints
  Detailed circuit structure inside the board
- Board serial protocol
  The basic concepts about serial communication, covering physical and application levels of the protocol. The system is composed by an electronic board, where a serial communication port is present and can be plugged to a PC or any device with 5V logic UART port.
- Programming requirement
  Information about which chip on the board need to be programmed and debugged.
- Board Gerber
  The data which can be opened with operating system and display the detailed structure of each layer of the board in 2D mode. It also should be allowed to add new contents (such as test points) on the original basis.

With the above data, the bed-of-nails fixture could be started to design.

5.1.2 Select test points

Since the customer asked to prove the board functional performance during the test and provided the part of programming code of the chips, Spea needed to create the corresponding electrical circuit to apply the power supply, ground and interact with necessary pins on the board to activate the board.
However this time, the adapter should be used not for one board inside the panel but two boards, I needed to design an adapter which could be used for both.
According to the data offered by the customer, I summarized two list of necessary test points to perform the test, one showed all the functional test points of universal asynchronous receiver-transmitter, programming of wireless receive module and micro module of Board A and Board B, and the other showed all the power supply points to make board function activated.
After checking all the relationship between the connectors or test points and chips of the Board A and Board B, the next step was to set these points on the digital schematic diagrams.
With the Gerber of the boards provided by the customer, I used operating system of Spea to open the files, extract the board circuit configuration and set the test points on the Gerber file.
This step was necessary for the fixture design to let the operators who real made the adapter wire connection can understand the position of the test points more clearly to avoid the mistakes may happen in production and connection relationship between the system and the electrical boards.
The figure 5.4 showed an example Gerber of the board, since the real board of Board A and Board B could not be shown in this thesis.

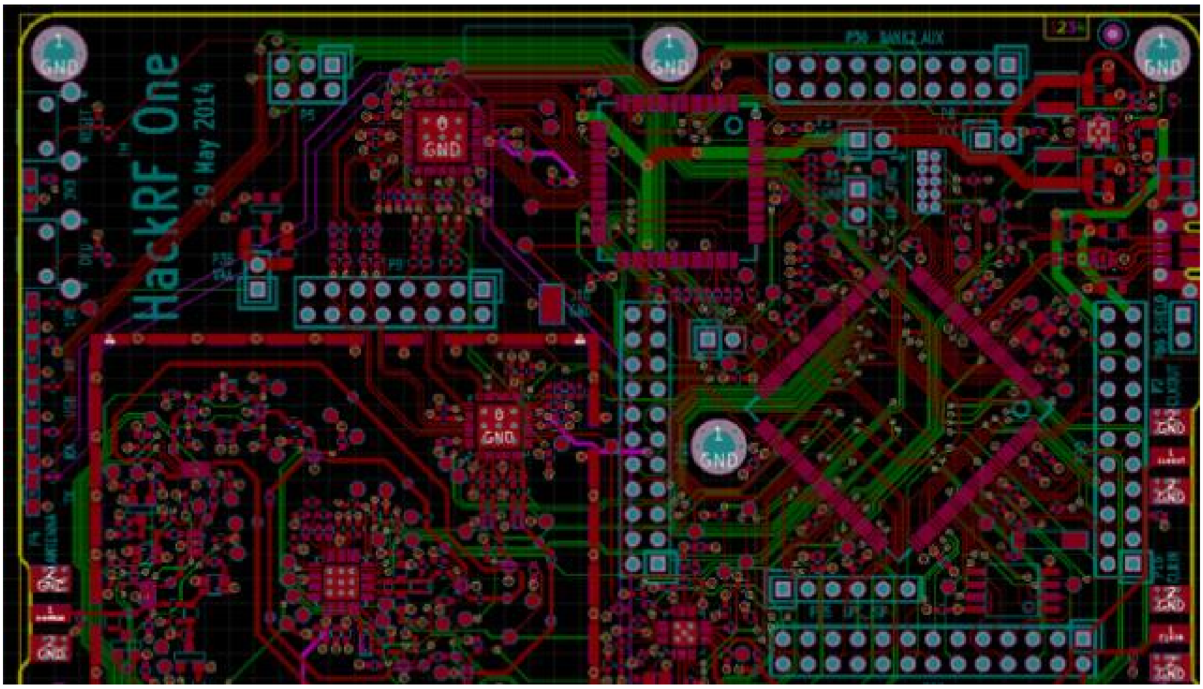


Figure 5.1 Example of Gerber on operating system

According to the test requirements, the points related to program, debug and power on/off should be set as test points, then also set the probe type.
The way to make sure these pads/points were the test parts Spea needed to make nails, was to use multimeter and compare with the board circuit to find whether these pads/points were connecting with other component as the circuit diagram showed and set the correct pads/points on the digital Gerber of the boards.
Note:

(1) Sometimes, the customer only asked to test for example 10 test points/pads and there were 4 power supply related inputs, but, to ensure the chip control can be more comprehensive, we still added another two-power supply which also may be related to these test points, ensuring all the board can be activated no matter some of functions we did not need in the whole testing process.

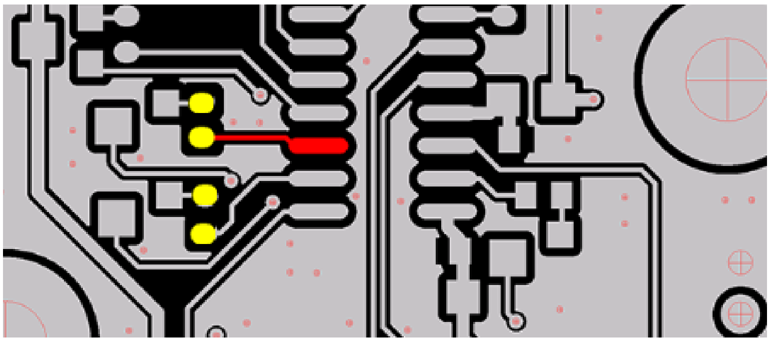


Figure 5.2 Example of setting the pins as test points

Since the positions of the electrical board: Board A and Board B loaded under the panel were fixed (based on the shape of the panel itself) and these two were quite near with each other.
For the mechanism side, the test nails for these two electrical boards on the fixture could also be considered together.

5.2 Circuit design for the fixture

As I introduced in Chapter 4.1, the most important component used to connect the board(s) and the system was called "Adapter", and the adapter was consisted by the fixed part – fixture and the moving part – pallet. Considering the internal configuration of the bed of nails tester and the flying tester made by Spea were very similar, here, I could consider the fixture part as the only electrical control unit used to connect the system and the board.
Following figure was the internal structure of the tester system, and the circuit design of fixture used to connect the board and the system was also based on this.

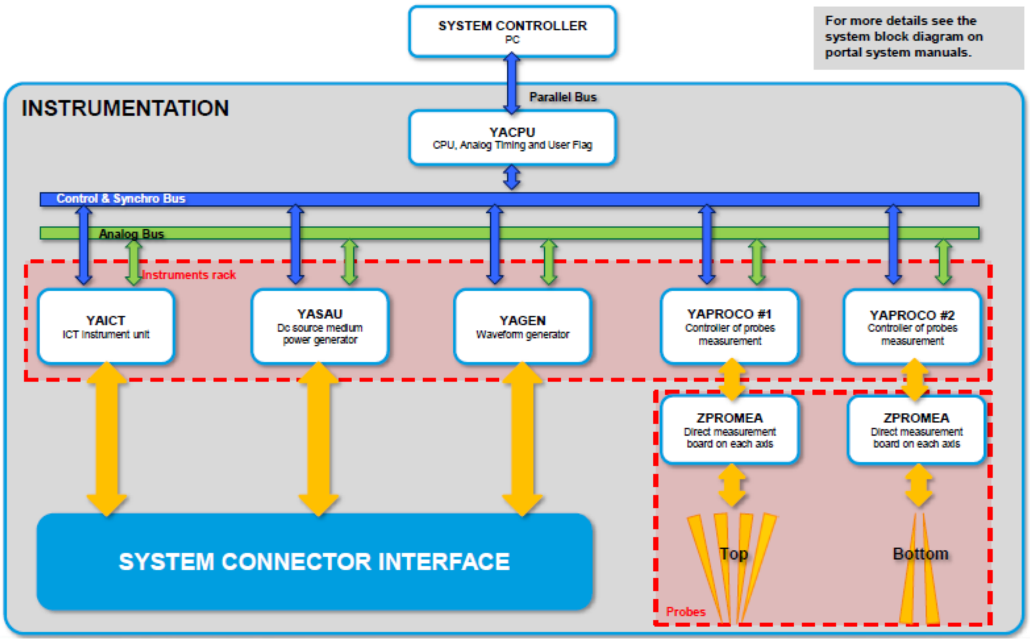


Figure 5.3 Internal structure of tester

As introduced in Chapter 2.3.1, these internal structures had already included the minimal configurations of the system, and through this electrical based diagram, the way of designing the fixture of board could be mainly divided into 5 steps:

Step1: Choose power supply

Step2: Design Relay control

Step3: Choose Analog channels

Step4: Choose Digital channels

Step5: Decide suitable positions for all electrical parts

These 5 steps process of design concept was suitable for all different kind of electrical boards since in the whole process of the test (with different panels), once the tester had finished reforming, the internal system including the number of channels and the power supply structure would not be changed any more.
On the real test machine "T100", these internal electrical control systems were loaded inside the machine under the receiver, it was consisted with lot of different kind of large electrical boards made and programmed by the stuffs of Spea (for example, YACIT, YASAU, YAGEN, etc).
These electrical boards could be installed and removed by hands since there was a cover in front of the machine could be took off and changed the internal structure of these boards.

Figure 5.4 control system inside the "T100"

5.2.1 Power supply

Same with the system of flying probe tester, the test machine "T100" had three different kind of voltage generators, as the figure 5.5 shown, they were YAICT, YASAU and YARAC, of which YAICT and YASAU could be used as power supplies to the boards.
YAICT is usually used as a driver, it is a high precision low voltage generator which can generate low sine wave forms voltage. It can be used to generate the stimulus of the test in many situations.

While YASAU is used as a booster which can generate a medium voltage.
Both of YAICT and YASAU are programmable, the value of the input can be set by operating system, and the user also can use external programming editor (here we use VB.net) to set the ideal voltage.

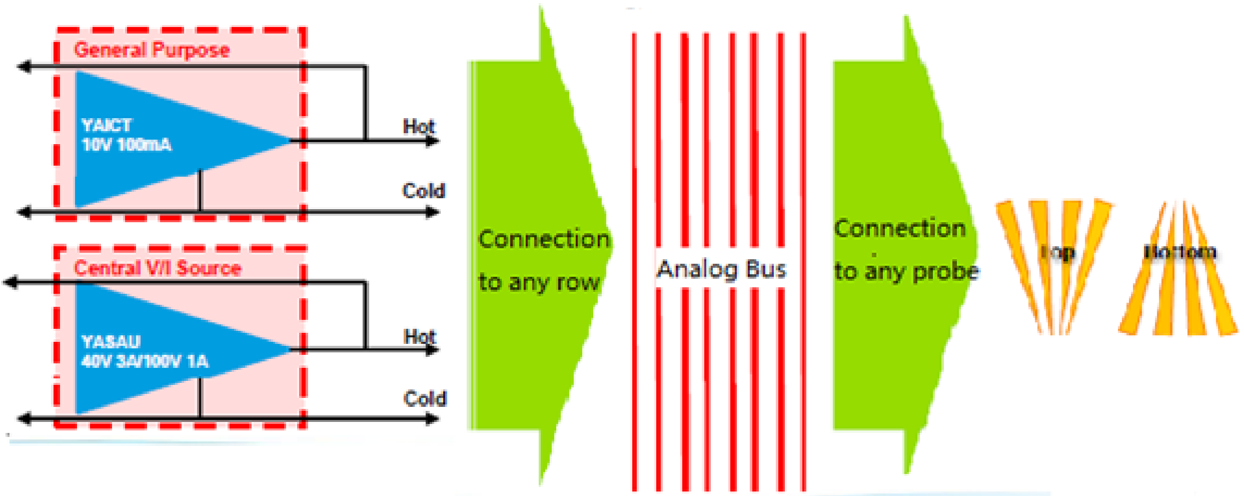


Figure 5.5 Internal Structure and control sequence of YAICT and YASAU

The detail information of the Power supply can be found in Appendix.4 and Appendix.10.
For this project tester, we only needed two power supply: one YAICT (driver) and one YASAU (booster).
The driver was used to afford 5V output to activate the boards, after board activation, operator could press the "On" button to activate the display of the LCD, meantime, 5 voltages could also activate the function of the UART which stood for universal asynchronous receiver/transmitter, it was a physical circuit in the microcontroller to transmit and receive data.
While the booster was used to afford 3.3V to activate the microchip and other important chip.

5.2.1.1 Choose power supply for Microcontroller

The chip used as core to control the main function of Board A was in a family list of STM32xxxxxxxx.
The series of STM32 is based on the high-performance ARM Cortex-M7 32-bit RISC core operating at up to 216 MHz frequency. And it also combines with high-speed embedded memories with a Flash memory protection unit which increases the application security. It can be used in many different situations such as motor drive, industrial applications (PLC, inverters), printers and scanners, alarm system, home audio appliances, etc.
Inside, the ARM Cortex-M7 with FPU processor is the latest generation of ARM processors for embedded system which can offer a low-cost platform to meet the needs of MCU implementation.
The serial port relies on RS-232 standard (UART/USART peripheral for microcontrollers) at 6V logic. "This standard does not define such elements as the character encoding such as ASCII, EBCDIC or others. The frame of characters, transmission order of bits or error detection protocols. The character format and transmission bit rate are set by the serial port hardware, typically a UART, which may also contain circuit to convert the internal logic levels to RS-232 compatible signal levels".
According to the datasheet of the STM32, there are three related power supply which can be used for STM32:

- V_{BAT} = 1.65 to 3.6V
  This power supply is used for RTC, external clock 32kHz oscillator and backup registers (through power switch) when V_{DD} is not present.

➢ $V_{DD} = 1.7$ to $3.6V$
This power supply is used as external for I/Os and the internal regulator (when enable), provided externally through V_{DD} pins.

➢ $V_{SSA}, V_{DDA} = 1.7$ to $3.6V$
This power supply is used as external analog power supplies for ADC, DAC, reset blocks RCs and PLL. V_{SSA} and V_{DDA} must be connected to V_{DD} and V_{SS}, respectively, and it was also the main input of power supply in the test.

Following figure showed the relationship between the voltage and its operating mode.

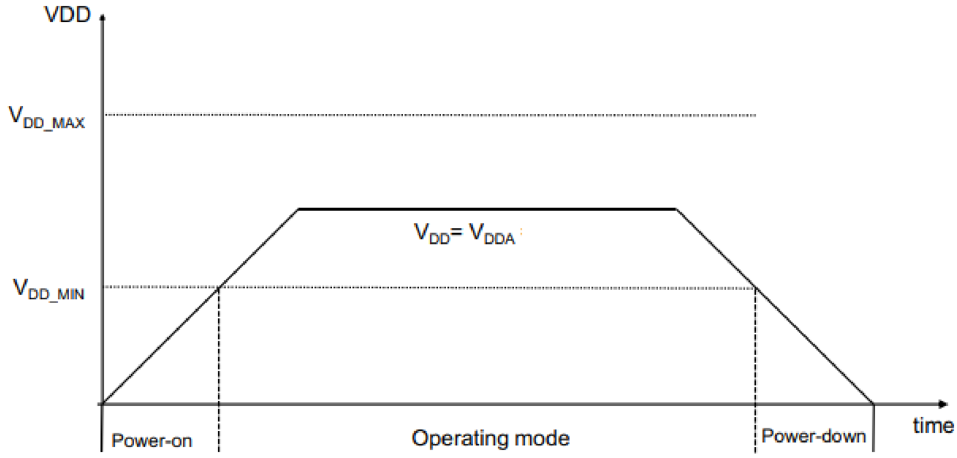


Figure 5.6 Operating power supply

Since the customer required to use 3.3V as the power supply to provide the voltage on microchip as MCU. Considering the inrush current made by activate voltage could be high and to ensure the chip could get the enough input of voltage and current to activate, Spea chose to use booster to provide this suitable voltage to activate the function of the chip.

And for another kind of important chip which the activated voltage is 3.3V, due to the privacy principle I could not mention the type of it, but since it was more sensitive, for this chip, Spea chose to use booster to provide this suitable voltage to activate the function of this chip.
Although, the activated voltages of two chips on the two boards (Board A and Board B) were 3.3V, in the Board B board situation, only 5V could be generated and the 3.3V used to STM32 and other chips would be generated automatically by partial voltage of 5V.
In order to distinguish the use of the 5V voltage on the Board B board, we used driver to control the board itself and the chips needed 5V to activate and we used booster with 5V output through dividing voltage circuit to control those chips activated in 3.3V. Since both driver and booster were programmable, to detect the Board A and Board B fixed on the adapter, the control way of the output of driver and booster was described as following:

Step1: Tester power on

Step2: Default the driver and booster connect with the Board A

Step3: Set the output of driver and booster as 5V and 3.3V

Step4: Verify the functions of the Board A

Step5: Power off the driver and booster

Step6: Switch the connection to the driver and booster from the Board A to the Board B

Step7: Power on and set the driver and booster both with 5V

Step8: Verify the functions of the Board B

Step9: Power off the driver and booster

To realize the connection change between the Board A and the Board B, here we used four user flag relays to control the circuit pass or not.
The user flag relays were controlled by the third power YARAC which had been mentioned above. YARAC is a fixed power supply which can only connect with the control and Synchro bus while YAICT and YASAU can also connect with analog bus and all of three are controlled by the system connector interface.
Different with the driver and booster of the board, YARAC is a fixed setting for the power supply with a low fixed voltage and fixed current. One the YARAC is set, the output is always the same without any inrush current and high inrush voltage while the initial current and voltage of YAICT and YASAU may be significantly higher than the current and voltage after stabilization.
So, YARAC was the best choice to control user flag relay on and off for controlling the connection from the driver and booster to the tested boards.

5.2.2 Relay control

Relay control design was a very important part in the aspect of designing adapter. There were two things needed to use relays to control the signal on and off.
The first part was using user flag relays to control the power supply as we mentioned above.
In the real test situation, we had two panels: panel-1 and panel-2, in the receiver. Each panel loaded with two electrical boards: Board A and Board B.
Since each board needed to be verified completely, four user flag relays (in the tester system, the board loaded with 16/32 user flag relays is YA16/32UFLR) called UFL1-1, UFL1-2, UFL1-3, UFL1-4 were used here to control the corresponding relay type FXSEZ200.
The main idea was: One panel shares two user flag relays and one FXSEZ200 relay.
For example, UFL1-1 related to FXSEZ200-J2-1 which was used for the Board A, the switch parts of FXSEZ200-J2-1 were not connected both with the driver (5V Output) and booster (3.3V) but only used to provide the voltage for the Board A on panel-1.
Once the coil of UFL1-1 had been on, the connection between the driver-Board A and booster-Board A on panel-1 would be turn on.
With the same principle, UFL1-2 was used to control the continuity between the driver – Board B and booster- Board B on the panel-1.
UFL1-3 was used to control the continuity between the driver-Board A and booster-Board A on the panel-2 and UFL1-4 was used to control the continuity between the driver – Board B and booster-Board B on the panel-2.

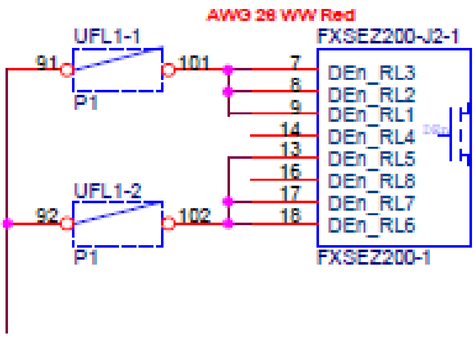


Figure 5.7 UFL control structure for the FXSEZ200

As the figure 5.7 shown, the relation between UFL and FXSEZ00 with 8 DEn relays, among them, RL1 and RL2 were related to driver and Board A on panel-1 while RL3 was related to booster and Board A on panel-1. The same way for RL5,6,7 to control the driver and booster with the Board A on panel-2. The whole relay-related power supply control circuit of Board A and Board B could be found in Appendix.4 and Appendix.10 too.

The second part was using relays to change the digital channel connection of system to two boards. As the OBP test points list shown above, for the Board A, it had 11 different test points which meant it needed 11 digital channels to test all these signals generated from the test points after power on while for the Board B, it had 10 test points and needed 10 digital channel connections. It also meant, for one panel with two boards, it totally needed 21 digital channels to test all the test points and for two panels, the sum become 42.
However, in the internal system of the test machine "T100", the system Spea would like to use had only 32 digital channels which could be used at same time and for each panel, there were only 16 usable digital channels.
The problem was how to save five digital channels from 21 to 16 for each panel.
The way we used was to create 5 public digital channels which could be not only used for the test points of Board A but also could be used for the Board B.
Since the Board A would be tested before testing the Board B, at the beginning these 5 public digital channels with other 6 Board A - private digital channels were used to get the signal from Board A.
Then, when the testing of Board A had been completed, the system would change to test the Board B, this time, these 5 public digital channels with rest 5 Board B - private digital channels would receive the signal from Board B. In this way, the system only needed

$$5 + 6 + 5 = 16$$

digital channels to get all the signal feedback from one panel with 2 boards.
So, I used relays to build these shared channels.
For each panel with 2 boards, I chose 5 relays type FXSEZ150, with one coil, one normally open switch and one normally close switch to connect with the test points of both boards. Meantime, I set a new user flag relay UFL1-5 to control the all these relays.
The coils of FXSEZ150s were also controlled with UFL1-5 (UFL relay can be controlled by programming) and the switch parts were set between the digital channels and test points. Since the digital channels were public for both boards, it was set on the common side, the normally close switch side connected with 5 test points of Board A and the normally open switch side connected with 5 test points of Board B.
By setting in this way, when testing, at first, the relay coils of FXSEZ150 were in the power-off states, and the switch of relays the kept normally open. Board A would be tested first and all 5 public digital channels were connecting with the test points of Board A, since the system provided power supply to the Board A, all the chips would be activated, and operator could get the signal feedback of Board A from those 5 public digital channels and 6 Board A - private digital channels.
Then, the tester would begin to test Board B related functions. At this time, YARAC would provide suitable voltage to power-on the coils of UFL1-5 and through closing the normally open switch UFL1-5, all the FXSEZ150 would be power-on.
By powering up the coil, the switch of FXSE150 would change to normally open side, the connection between digital channels and Board A would be cut off, and a new connection between digital channels and test points of Board B would be created and operator could get the signal feedback from the public digital channels and the rest 5 Board B-private digital channels to verify the feature of Board B.
The same mode of operation was applied for both panel-1 and panel-2, which means we all need ten FXSEZ150 relays, two user flag UFL1-5 and UFL1-6 to adjust the channel connection from digital channels to the test points of Board A or to the test points of Board B.
Through this way, we could save 5 digital channels successfully to get the all signal feedback from the boards.
The whole relay control circuit mentioned above could be found in Appendix.5.

5.2.3 Analog channel and digital channel

To test the feature of the boards and process OBP testing, the necessary test points needed to be wired directly or indirectly to the system channels.
These parts of channels are usually used to detect the output voltage and compare with the set value are managed by the system through the analog bus.
The most common use of analog channels is to act as a sensor and for the system of the test machine "T100", there are 20 usable analog channels set on the system board YASCA.
To be a precise sense and detect the accuracy voltage of electronica parts of UUT, these analog bus are always set near to the tested components. The reason is the output voltage from the driver, or the booster should be used to afford voltage to activate the chips, however, sometimes, between the power supply and the chips, the length of wire or other internal resistance of component would affect the final voltage applied on the chips. The output voltages which must to be ensured are not the voltage of the driver or the booster, but the voltage on the chip voltage input section, it also means, the voltage of the driver and the booster cannot be set just as the demand voltage. So, the best way to ensure the voltage set on the chip is to connect a wire (analog bus) to the power input or ground pin of chip as close as possible and to check whether its actual voltage is enough or not. We called this function of analog bus as "Sense".

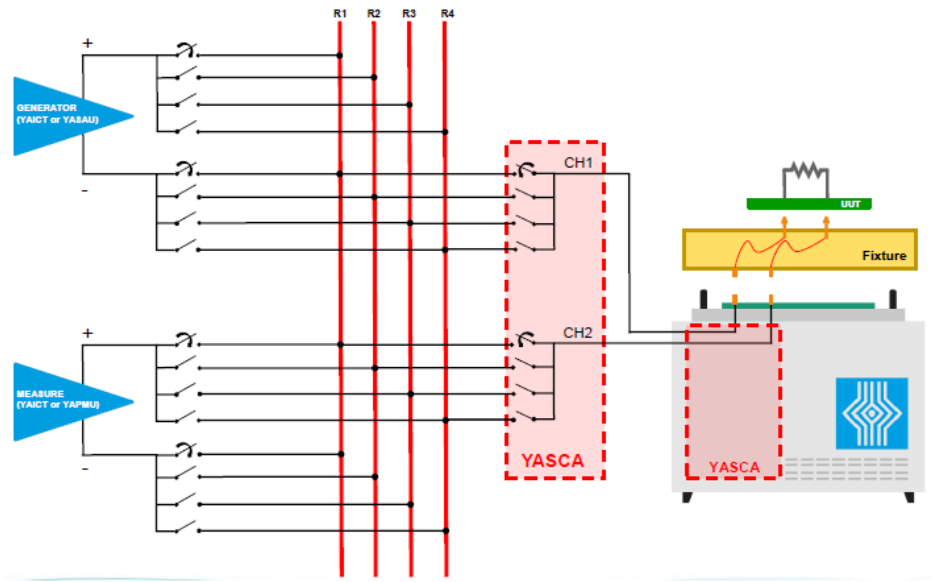


Figure 5.8 Analog bus detail of system

All the analog channel related bus would be named "ACHxx" and the detailed information would be shown in Appendix.6-8 and Appendix.10-12.
Then, I started to discuss about digital channels for the reformed tester. The board used to set these digital channels into the common flying probe is called DBDIO and the main aim of DBDIO with digital channels (here there are 32 channels on the DBDIO) is to realize the on-board programming and get feedback signal during the test.
On-board programming refers to the programming of target memory on a board through boundary scan compliant devices on the board or in-circuit-emulation JTAG port. The target/eeprom memory to be programmed itself does not have to be IEEE1149.1 compliant.
Since the programming concept and way of chips had been provided by the customer, the thing we need to do was to program the chip as required and make an interface to the system recognise these chips information. The effect of digital channels here was to connect these test points (almost used to program and control the chips on the board) to the system and the operator can use them as an interface and control their feature through computer.

Chapter 6

Software Design

This chapter would describe the programming structure about serial communication with the chips provided by customer, covering physical and application levels of the protocol.
Since the internal structure of Board A was mainly composed by an electronic board, where a serial communication port was present and could be plugged to a PC or any device with a 5V logic UART port. The external node acted as a MASTER of the communication, sending READ and WRITE commands, while the electronic board would act as a SLAVE serving requests from MASTER node.
The whole testing method of Board A with its electronica structure here could also be called "FVT" and my main responsibility was to find the way to establish the serial communication protocol with the aim of performing product/board testing (FVT) according to the customer requirement.
As I introduced in Chapter 5.2.111 and Chapter 5.2.1.2, micro control chip and other important chip were used as MCU, flash, and other important function in this case, there was no control signal used, only with simple RX/TX full duplex implementation.
Here was the following information of connection parameters provided by the customer:

- Full duplex RX-TX
- No RTS/CTS control signals
- Frame setting: 1 start bit, no parity, 1 stop bit

6.1 chip protocol description

In this control system, the PC/external tool would act as a MASTER, while the board would act SLAVE, the definition of the addresses setting in the communication was shown below:

- Master: node 0
- Slave: node 1

It was not foreseen that SLAVE sent itself packet on the bus, so basically the arbitration by MASER and SLAVE node sent data only to answer to MASTER requests.
Operators could use MASTER to send different types of packets:

- SET:
  It could set s specific value in microcontroller firmware, by addressing it using a unique ID, followed by the value to be set.
  SLAVE would answer with command acknowledged (ACK) or command NOT acknowledged (NACK) simple packets.
- GET:
  It requested to read a specific value in microcontroller firmware, by addressing it using a unique ID. In this case, SLAVE would answer replying the same ID, and the latest value in memory for that parameter.
- COMMAND:
  These packets contained specific data to perform specific operations. This content was may vary depended on the operation requested. SLAVE would answer with ACK (command as acknowledged) or NACK (command NOT acknowledged) simple packet.

6.2 Packet structure

The following table described the fields composing all the packets created by MASTER and SLAVE. Each packet was starting with a pre-defined 4 bytes' header that permitted the operator to recognize a "start of packet" sequence which was organized by the information provided by the customer. This could enable a more robust communication in case of noisy environment or fragmentation events of data sent.
Inside the field of packet, the byte 4, Address and command was the first byte of the packet and contained two information structured as a bit field which could be used in programming.

Address and Command bitfield							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Sender Address	Command						

Figure 6.1 Structure of Address and Command bitfield

Here, the address field was set basing on the sender of the packet. It contained the sender node address and there was no need to indicate receiver since this protocol was point-to-point.
Below were the valid values for this field:

- 0: sender of message was MASTER node
- 1: sender of message was SLAVE node

Command field contained the specific opcode related to the operation requested by MASTER node. The SLAVE node would just replicate the command value that was satisfied, and the real commands descriptions and sequence diagrams would be introduced later.

6.2.1 Data length and Payload

Data length is a byte value that indicates the number of bytes contained in the Payload field of packet. If this value was 0, then the Payload segment would not be present and so there would be placed directly the CRC1 and CRC2 bytes.
Meantime, Payload is also an array of byte of dimension defined by the Data length field. If Data length is 0, then Payload field is not present. Else, Data length indicates the number of bytes before expecting the CrC1 and CRC2 fields.
The data stored in Payload field may be of different sizes (char, unsigned short, etc.). In case of values bigger of a bite, their content would always packet in big endian format to maintain common data parsing for the whole communication process.
Moreover, in case of native floating values, they are passed in protocol using Qx notation: it simply consists in a multiplication by 2^x when data is sent, and division by 2^x when message is received and interpreted.

6.2.2 CRC1 and CRC2

The full name of CRC is cyclic redundancy check and the CRC calculation unit is used to get a CRC code using a configurable generator polynomial value and size. Usually, the CRC- based techniques are used to verify the data transmission or storage integrity, and in the scope of the EN/IEC 60335-1 standard they also offer a mean of verifying the Flash memory integrity which would be used here.
This is an unsigned 16-bit value sent always in little endian, that represents the CRC16 calculation of the packet content including all bytes from Address until last of Payload (if present).
The algorithm used for calculation was:

CCITT CIR-16 polynomial 0x1021 (x^{16}+x^{12}+x^5+1)

This particular algorithm has a “self-checking” property: if same CRC is calculated over same bytes’ stream including the CRC1 bytes but avoiding performing bitwise negation operator (~) on it, the result called CRC2 would be always 0xF0B8.
The packet would also contain in CRC1 position the CRC of the packet, and in CRC2 position the self-check value would be 0xF0B8.
If a packet is received and CRC2 differs from 0xF0B8, the packet would be discarded due to self-check failure.
By using this calculation, it would help the operator to compute a signature of the system during the test and comparing with its reference signature generated at link-time and stored at a given memory location.

6.3 Testing command description

For the FVT control on the Board A, each command should be sent from MASTER and must be served from SLAVE as the following sequences shown in the table below which had contained all the test commands.
By using these commands to finish programming on the computer by the system staffs, operator could test the all functions of the Board A required by the customer on the interface of the operating system easily.

6.3.1 Check external memories of the chips

This command was used to verify if all memories connected to the microcontroller were working well or not. Operator could activate the function of board and test these memories as a self-check to know whether the board was activated successfully and prepared to start receiving the next commands.
In this case, The SLAVE would always ACK a read request, unless the parameter requested by MASTER was not valid.

6.3.2 Write parameter into the chips

This command was used to activate the buzzer (sound) and LED on the LCD and check whether they would be acted by inputting the suitable value of parameter.
A retrial mechanism was performed by MASTER in case of NACK or unexpected behavior from SLAVE.

6.3.3 Check digital and icons of UI element

This command was used to set the status of the UI elements on the LCD screen. After setting the UI elements, the LCD could launch officially check the color by entering the parameter provided by the customer to finish the test contents of “LCD color check”, “LCD alignment check” and “LCD touch check” described in Chapter 3.2.1.
Since the setting of the chip had been completed by the customer and the value used to control the LCD display the information (color) was also provided by customer, these parameters should be input into the program and the detailed programming was finished by the staffs of system programming department in Spea.
On the other hand, before giving this information to the staffs of system programming department, I had tested these functions by connecting the board and computer directly with real wires and input these values one by one on the professional simulator to check the all tests about LCD display could be executed successfully.

When using the reformed tester "T100" to execute this command, the system would have offered these values step by step automatically to realize the automatic detection of test contents in short time.

6.3.4 Read button

This test command was used to retrieve last button pressed, then the internal electrical circuit could execute the button command.
To test the different situations of the button control, operator also needed to use different values to set the different operations for the chip.

6.3.5 Read switch version

This command was used to read the SW version label in 4 ASCII digits format. Since there were many different functions of washing machine and LCD display would show the option button which users could press to execute (for example, choosing the using language, laundry function, setting the timer, etc.), the system needed four SW parameter to differentiate these functions and allow the board to identify the task which needed to be performed by the button being pressed.

6.3 On-board programming

The test contents mentioned above were chip-specific FTV test, since this part of command was related to the customer privacy, it could not be expanded in detail and it was quite simply because Spea just needed to input the value provided by the customer and execute the chip to check whether it could activate as command or not.
Except of the test related to the LCD display and switch action, another important thing Spea needed to do was "On board programming".
On Board Programming (OBP) is a technique to program on-board assembled electronic devices. OBP can program devices based on different technologies or programming systems by using different protocols and interfaces.
The OBP modules are available on SPEA bed of nails and flying probes testers and they can program and read the contents of components directly on the board to be tested. Through special commands, the test system supplies voltages, control signals, addresses and data in order to reset and program the device.
Programming can involve both a single component and several components in parallel and it can be performed by using specific connectors (JTAG, for example) or by using the traditional spring contacts (of bed of nails testers) or flying probes (of flying probe testers).
Some examples of devices that may be programmed with OBP are:

- Flash Memory
- E^2PROM
- Programmable logic (e.g.: Altera, Xilinx, etc.)
- Microcontroller
- Functional

The OBP module is programmable by a dedicated test plan. This test plan contains instructions written by using the syntax of the most common programming languages.

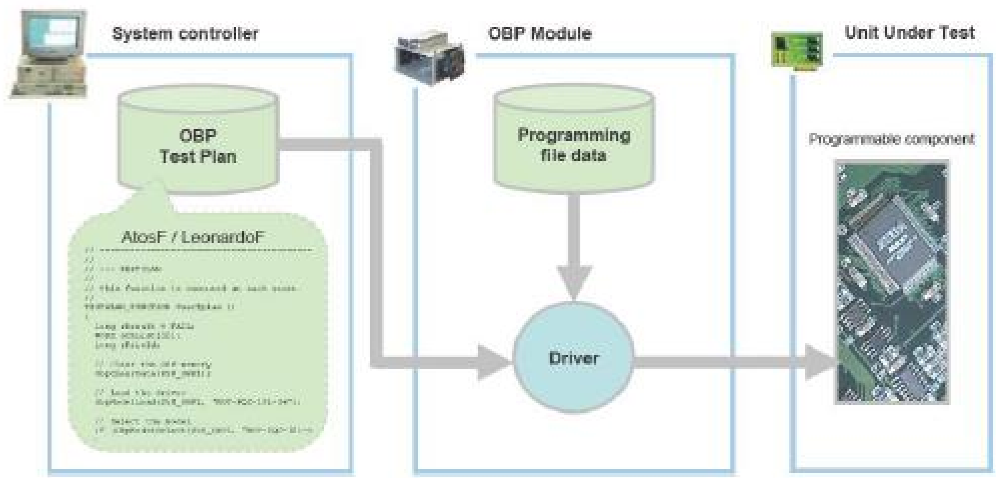


Figure 6.2 Structure of On-Board Programming

In chapter 5.2.3, I introduced that there were total 32 analog channels and 32 digital channels could use in the system of test machine, and one important purpose of these digital channels were used to connect the test points and system to produce the on-board programming test.
Following figure showed an example of the relationship between the probes and system interface made by Spea:

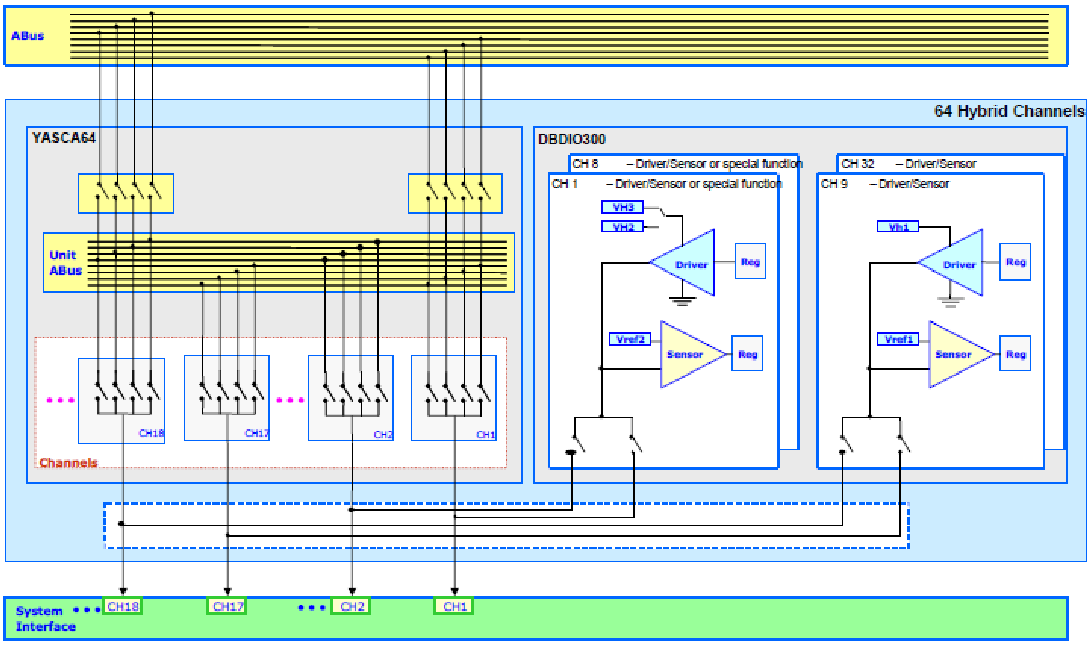


Figure 6.3 System structure for On-Board Programming

6.4.1 Driver of the chips

To produce the On-Board programming for each chip on the test machine “T100”, Spea needed to use their specific driver to execute the function of the chip.
Each chip had its own drive code, and on the test level which I had to do was when testing the function of the Board A and Board B, input the code of driver to confirm that whether the chip on the board could activate properly.
Here was an example step of on-board programming for microcontroller (based on the privacy principle, the code of driver c for real microcontroller could not be shown in this thesis):

Step1: Select programming, site and programming options

Step2: Setting and connection of used channels

Step3: Board Power On

Step4: Erase, program and verify

Step5: Disconnect used channels

Step6: Board Power Off

Step7: Get site programming result

Step8: Set result

6.4.2 Programming instruction

The following OBP instructions are commonly used to program and to verify the devices of microcontroller using the driver:

ObpBlankCheck	Check if the component is clear	ObpId, DataType
ObpChipErase	Execute the memory erasure of the programmable component	ObpId, DataType
ObpWriteData	Write a specific value in a defined address in the device's memory	ObpId, DataType, Address, Value
ObpVerifyData	Verify the presence of an specific value in an defined address of the device	ObpId, DataType, Address, Value
ObpWriteVerifyData	Write a specific value in a defined address in the device's memory and then verify it	ObpId, DataType, Address, Value
ObpWriteFile	Executs the component programming using the information stored in a file previously loaded	ObpId, DataType, FileId, StartAddress, StartPosFile, Len, SkipValue
ObpVerifyFile	Execute the verification of the component using the information stored in a file previously loaded	ObpId, DataType, FileId, StartAddress, StartPosFile, Len
ObpWriteVerifyFile	Execute the component programming using the information stored in a file previously loaded	ObpId, DataType, FileId, StartAddress, StartPosFile, Len, SkipValue
ObpReadData	Read the data from the component	ObpId, DataType, StartAddress, Len, Value

Figure 6.4 common instruction of driver for microcontroller

Like the drivers, each type of chip had its own programming instruction, the detailed instruction could be found in the list made by Spea and followed the guide book to find the suitable programming code to execute the on-board programming.

6.4.3 Test plan and flow chart

Using the operating system designed by Spea, the operator could insert the test plan of on-board programming and input the required code to make the system run.
Following figure showed an example of on-board programming test plan:

Task			Enabled	Fail bin	Pass bin	Datalog	Type	Refresh Site	Location	Description
- FixtureSetup			Yes	1 - Fail	0 - Pass	Yes	Analog	Ignore Yes	Testplan	Fixture Setup
Test id	Test	Enabled	Functions	Fail bin	Pass bin	Remark	Nominal	Th low	Th high	Factor
1	Test 1	Yes	fVRADInitStrInfo	1 - Fail	0 - Pass	InitRecord	CPASS			
1	Test 1	Yes	fVRADInitStrInfo	1 - Fail	0 - Pass	InitRecord	CPASS			
2	Test 2	Yes	fVRADInitPrintFileIni	1 - Fail	0 - Pass	InitPrintIni	CPASS			
2	Test 2	Yes	fVRADInitPrintFileIni	1 - Fail	0 - Pass	InitPrintIni	CPASS			
3	Test 3	Yes	fVRADPower	1 - Fail	0 - Pass	FpsOn	CPASS			
3	Test 3	Yes	fVRADPower	1 - Fail	0 - Pass	FpsOn	CPASS			
4	Test 4	Yes	fVRADSetLED	1 - Fail	0 - Pass	SetLED	CPASS			
4	Test 4	Yes	fVRADSetLED	1 - Fail	0 - Pass	SetLED	CPASS			
5	Test 5	Yes	fVRADNoSnReadSt	1 - Fail	0 - Pass	CheckSn	CPASS			
5	Test 5	Yes	fVRADNoSnReadSt	1 - Fail	0 - Pass	CheckSn	CPASS			
+ OBP_ chip 1 (microcontroller)			Yes	1 - Fail	0 - Pass	Yes	Analog	Yes	Testplan	OBP STM8
+ OBP_ chip 2			Yes	1 - Fail	0 - Pass	Yes	Analog	Yes	Testplan	OBP ESP32
+ OBP_ chip 3			Yes	1 - Fail	0 - Pass	Yes	Analog	Yes	Testplan	OBP PIC
+ FCT_I2C			No	1 - Fail	0 - Pass	Yes	Analog	Yes	Testplan	Functional Tes
+ FixtureReset			Yes	1 - Fail	0 - Pass	Yes	Analog	Ignore Yes	Testplan	Fixture Reset

Figure 6.5 Test plan interface on the operating system

Now I could start to think about the whole program process on the operating system. The following figure showed the flow chart of whole process of testing on the operating system.

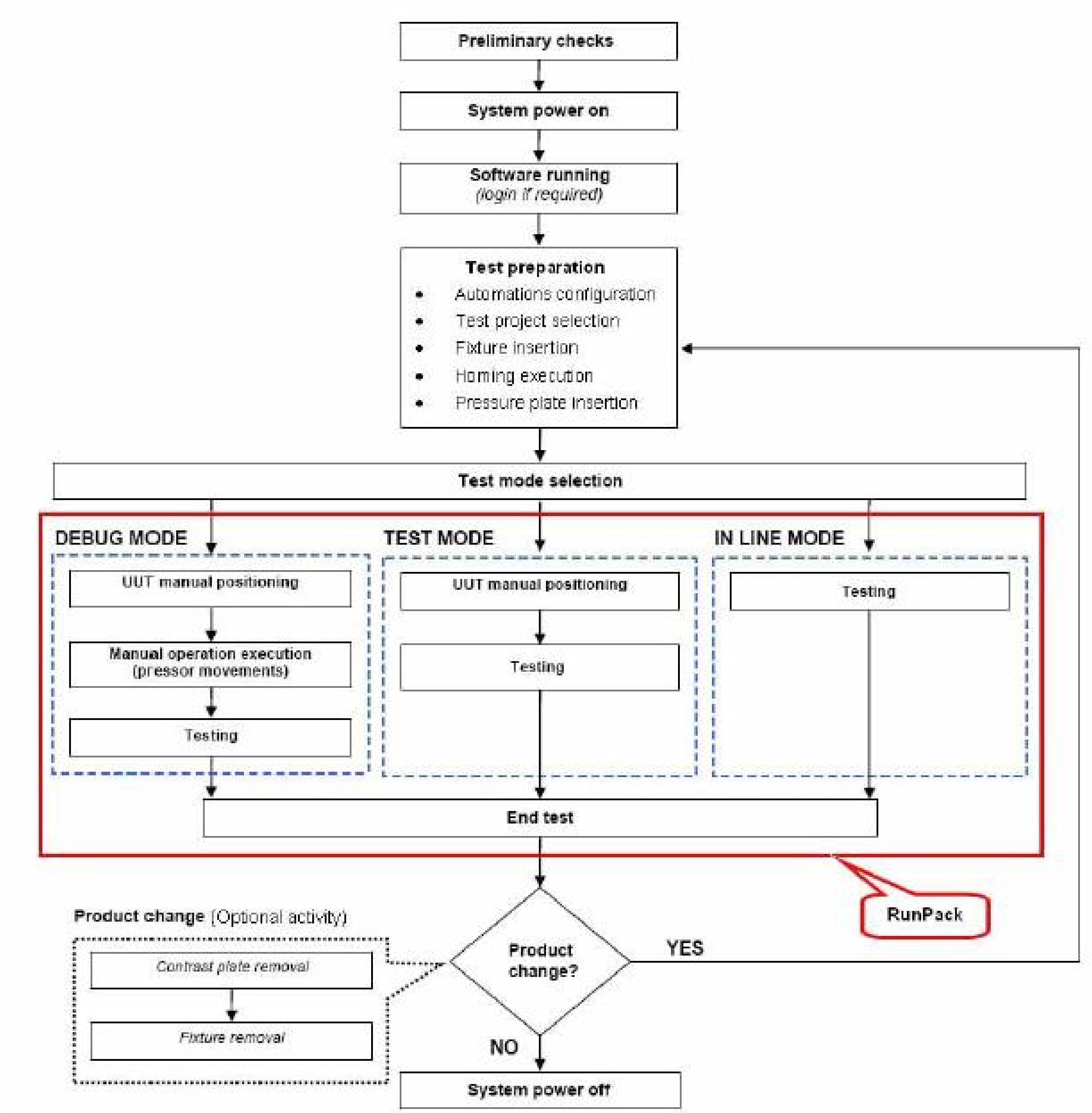


Figure 6.6 Test flow chart of execution the test

6.4.4 Debugging on operating system

After finishing the on-board programming for each chip and input these codes into the system based on the sequence of test plan, the operator could run the on-board programming code in the interface of VB.net which Spea used to program and debug these codes.

In the bottom of the interface of the operating system, operator saw the process of debugging by the system.

The sequence of debugging the chips and the "continue" and "stop" condition were based on the following flow chart.

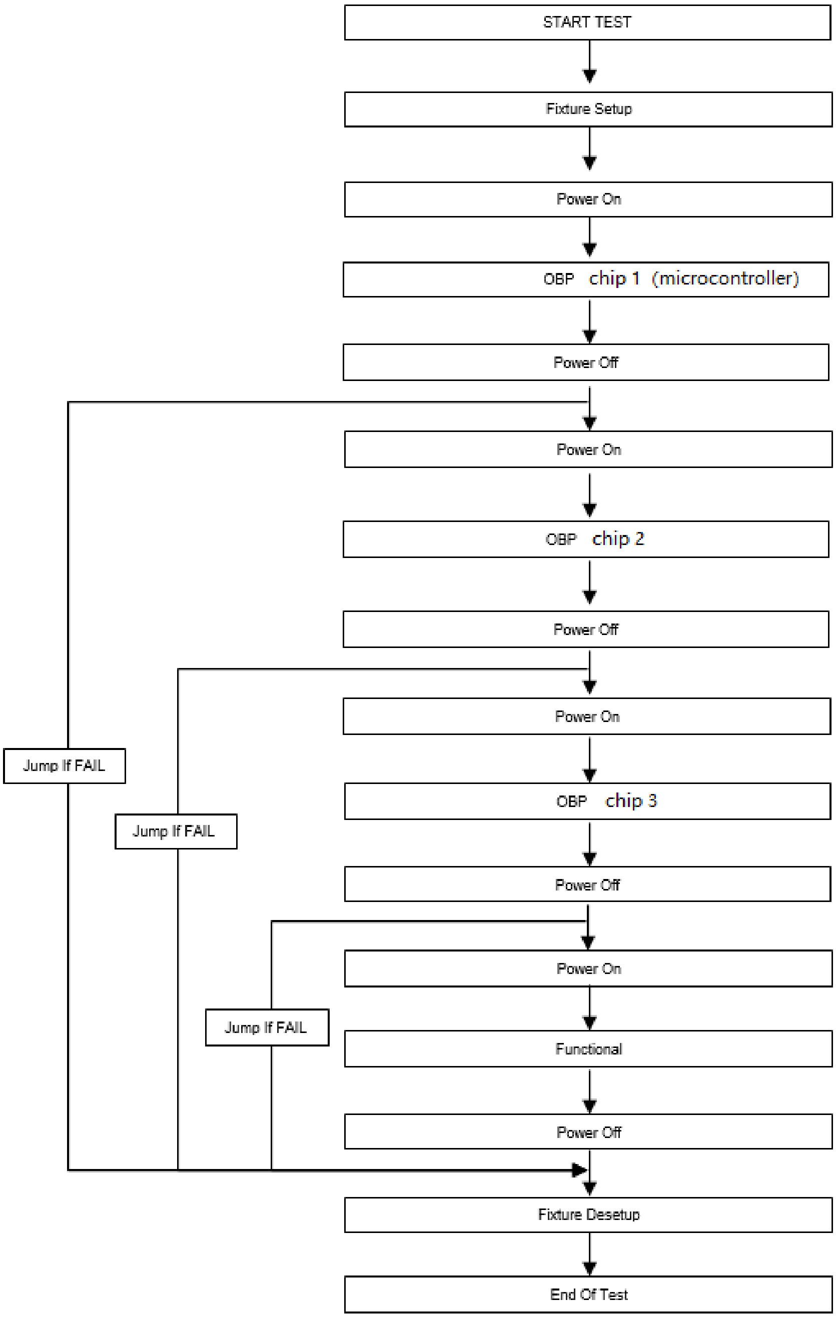


Figure 6.7 Example process of debugging chips of the Board A

If all the test function had been passed, then after some seconds, operator could see the whole sequence of debugging contents and get the results from the system.

Following figure showed a part of content got from the system, it also showed the test result displayed by the test machine "T100".

```
DEBUG 2019.05.28;10:44:28.105; ObpGetSiteResult site: 1 -  result: 0
ObpGetSiteResult site: 1 -  result: PASS
DEBUG 2019.05.28;10:44:28.109; ObpGetSiteResult site: 2 -  result: 0
ObpGetSiteResult site: 2 -  result: PASS
SetObp OBP_PIC
DEBUG 2019.05.28;10:44:28.117;ObpProgrammingSelect result: 0
DEBUG 2019.05.28;10:44:28.159;ObpSiteSet result: 0
DEBUG 2019.05.28;10:44:28.163;ObpModelOptionsSet result: 0
DEBUG 2019.05.28;10:44:28.165;ObpChLevelSet result: 0
DEBUG 2019.05.28;10:44:28.169;ObpChSensorSet result: 0
ObpChVppLevelSet
ObpChVppLevelSet -  result: PASS
DEBUG 2019.05.28;10:44:28.229;ObpChConnect result: 0
SetObp -  result: PASS
ObpInterfaceEnable
DEBUG 2019.05.28;10:44:28.265;ObpInterfaceEnable result: 0
ObpInterfaceEnable -  result: PASS
PowerOn
PowerOn -  result: PASS
ObpChStuckSet
DEBUG 2019.05.28;10:44:29.081;ObpChStuckSet result: 0
ObpChStuckSet -  result: PASS
ObpChipErase
DEBUG 2019.05.28;10:44:29.103;ObpChipErase result: 0
ObpChipErase -  result: PASS
ObpBlankCheck
DEBUG 2019.05.28;10:44:29.717;ObpBlankCheck result: 0
ObpBlankCheck -  result: PASS
ObpWriteFile
DEBUG 2019.05.28;10:44:29.721;Obp File Name: EDUTM000_001B_0_Z01.hex
DEBUG 2019.05.28;10:44:30.493;ObpWriteFile result: 0
ObpWriteFile -  result: PASS
ObpVerifyFile
DEBUG 2019.05.28;10:44:30.497;Obp File Name: EDUTM000_001B_0_Z01.hex
DEBUG 2019.05.28;10:44:30.835;ObpVerifyFile result: 0
ObpVerifyFile -  result: PASS
PowerOff
PowerOff -  result: PASS
ResetObp
DEBUG 2019.05.28;10:44:30.855;ObpChDisconnect result: 0
ResetObp -  result: PASS
GetResultV2
DEBUG 2019.05.28;10:44:30.863; ObpGetSiteResult site: 1 -  result: 0
ObpGetSiteResult site: 1 -  result: PASS
DEBUG 2019.05.28;10:44:30.867; ObpGetSiteResult site: 2 -  result: 0
ObpGetSiteResult site: 2 -  result: PASS
```

Panel 1: Pass
Panel2: Pass

Figure6.8 Interface of debugging the on-board programming

6.5 Summary

By proceeding all the software testing mentioned above, including the chip specific tests (for example, LCD color display, touch test, etc.) and the common on-board programming test for each important chip on the board, from the digital channels connected with the test points of the board, operator could get all information requested by the customer and confirm its electrical functions quickly and precisely.

Chapter 7

Testing for the panels and control unit modules

The best way to verify the test machine functions whether it could meet the needs of customer after mechanical and electrical reforming and designing and realize the ability to test the different panels with different shapes and boards, was to test these panels with the boards directly on the machine. In this chapter, I would like to introduce the whole test sequences and results in detail and represent the conclusion and some personal ideals of this project.

7.1 Preparation of testing

After receiving a machine with basic function of flying probe tester from the warehouse of the Spea to the lab, the stuffs of Spea began to work. The preparation of the test and machine design could be roughly divided in the following steps:

Step1: Change the conveyer

Step2: Change the test head

Step3: Change the camera

Step4: Install the barcode gun and printer

Step5: Install the "Execute" switch

Step6: Insert the necessary system control unit boards into the "T100"

Step7: Install the fixture of the electrical board on the bottom of the receiver

Step8: Connect the mechanical components described above to the control unit of system

Step9: Press the "on" button to activate the test machine and control computer

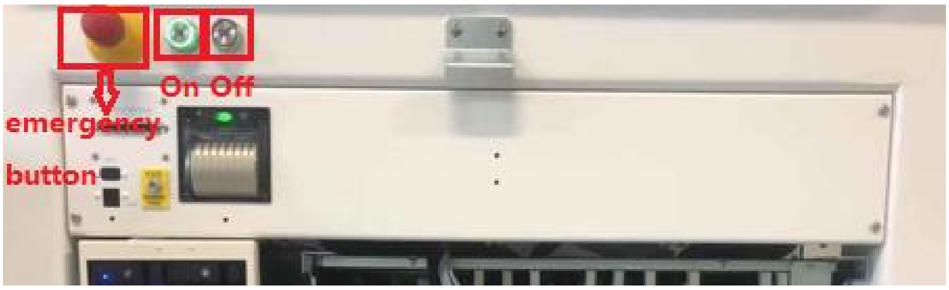


Figure7.1 the position of the control buttons

Step10: Enter the operating system made by Spea and program the system control unit to activate the functions of these mechanical components

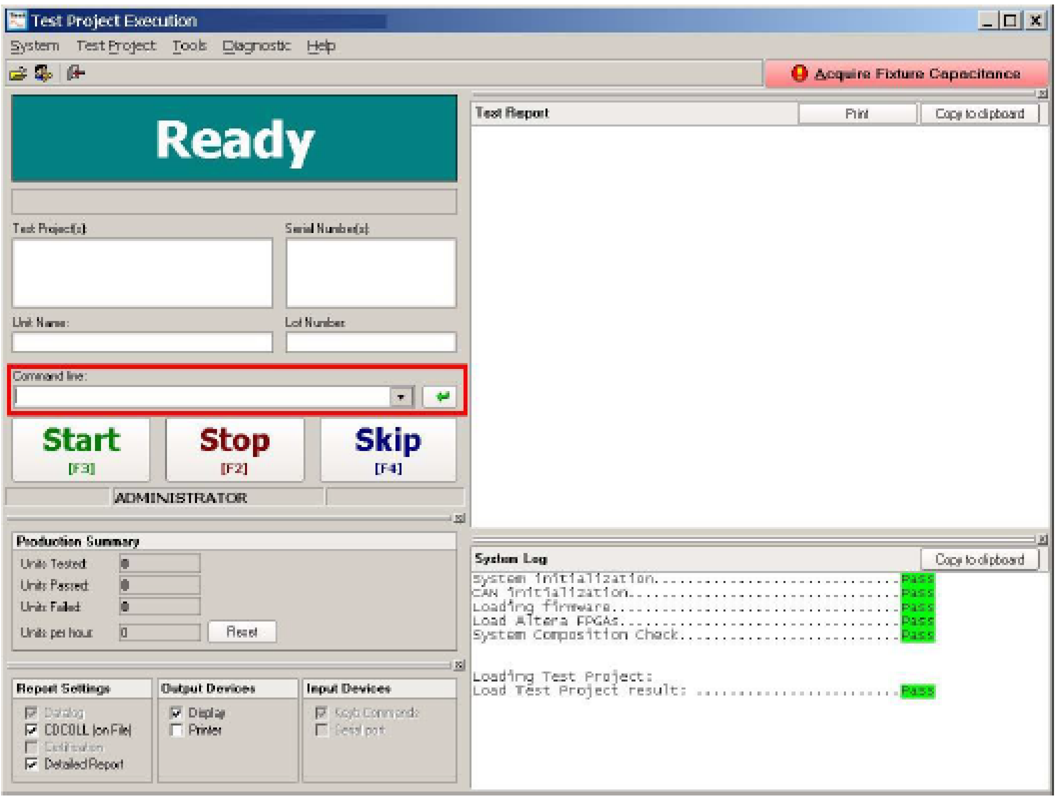


Figure 7.2 Interface of Leonardo OS2

Step11: Debug the code on VB.net

Step12: Finish the preparation of the testing and wait to execute the tests.

The following Figure showed the entire test machine of “T100” which could use to test the panel with Board A and Board B.

Figure 7.3 Test machine - “T100”

7.2 Testing sequence

When the preparation was completed, the real test could be executed. As I mentioned before, the whole test could be processed automatically, and the only thing operator needed to do was to press the "Execute" button on the side of conveyer where he/she would like to start first. The whole test sequence can be divided into the following steps:

Step1: Operator pressed the "Execute" switch (for example, the button on the right side of "T100" near the slideway). In the same time, the operating system would start execution and run as following flow chart.

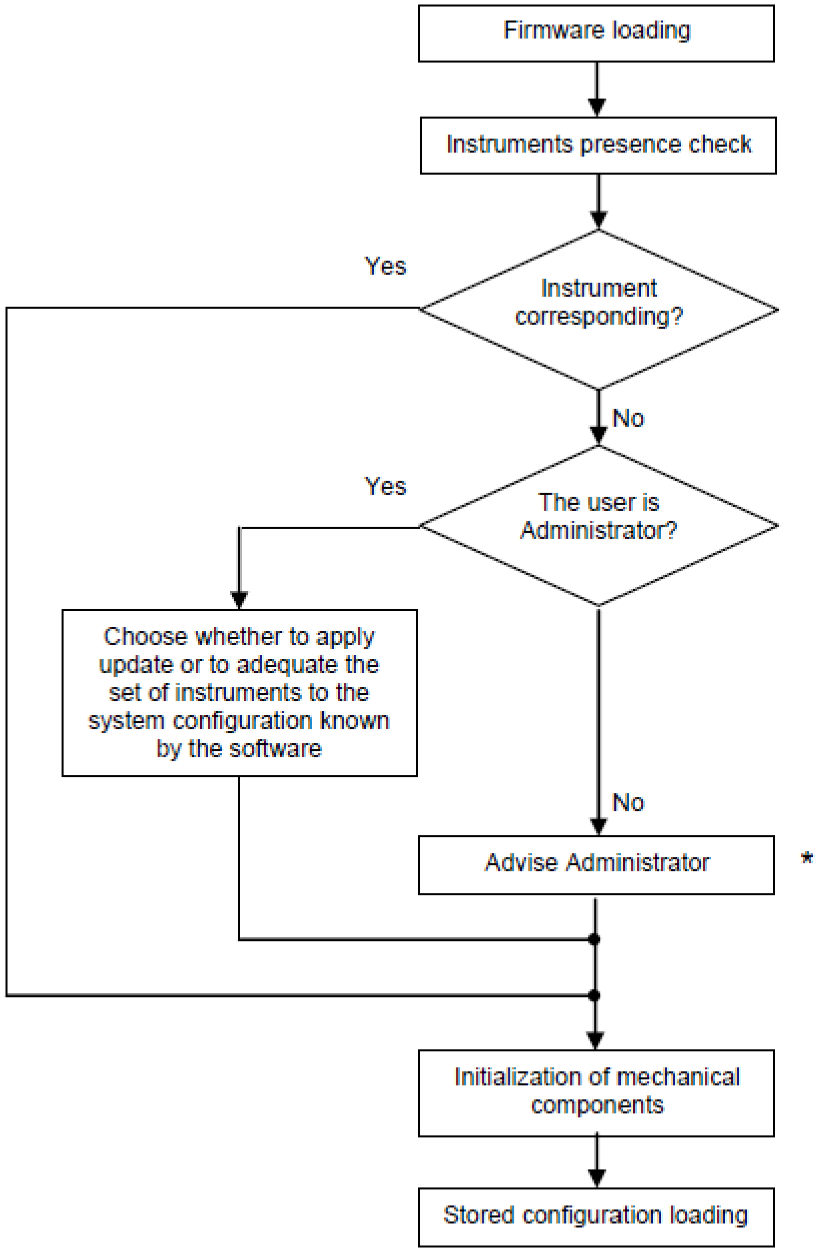


Figure 7.4 Flow chart of initial run of operating system

Step2: The pallet equipped with two panels which load with Board A and Board B underneath the panels respectively, entered the machine through the right side slideway into the receiver and stopped at the upper of the fixture.

Step3: The test head part activated, moved the camera to scan the whole panel rapidly to check the surface situation of the panel, then went to the position where the barcode gun could scan the barcode.

Step4: By reading the barcode pasted on the left part of the panel to make the system recognize the type of panel and confirm the fixture equipped in the receiver whether it was suitable for this panel. At the same time, the system would decide to which programs should be used for this panel.

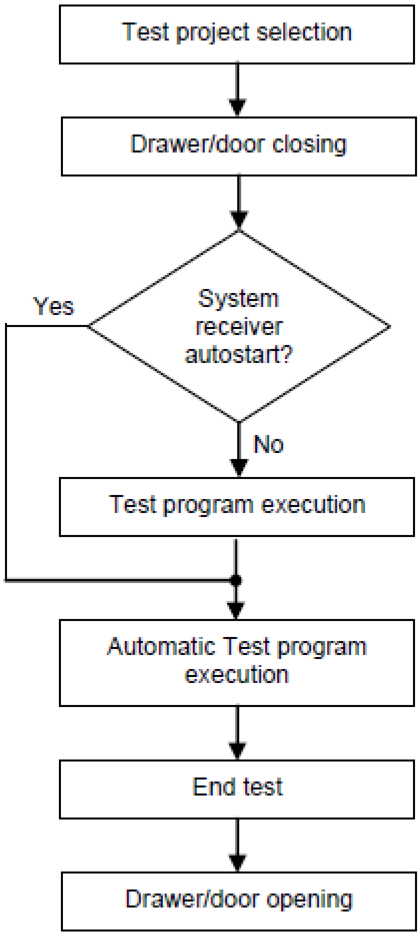


Figure 7.5 Flow chart of choosing and execute test plan

Step5: After confirming the fixture and the electrical boards could match each other, the air valve inside the fixture would activate to make fixture arise and the nails equipped on the fixture would touch the test points of the electrical boards stably and precisely.

Step6: The programs were divided into two parts, one was used to activate the electrical boards under the panel and the other one was to make test head find the touch position set for the panels.

Step7: The system started to read the test programming code, since the reading and execution of the codes inside the system needed some time, during this time, the machine would not do anything which operator could see directly on the panels.

Step8: The test head moved to the position of the "Power On/Off" switch of the panel one (it was also the only physical button on this panel), moved downward to press the button. After that, the test head would go to the position of the same switch on panel two and do the same action to check the function of "On" button on two panels respectively.

Step9: Once the "On" button had been pressed, the system started to afford the power supplies to both Board As under two panels. (In this case, the Board B was still power off) And he Board As entered the self-check mode, by executing the program code used on the chips to check the functions of the color and Alignment situations of the Board A.

Step10: Test head worked again, moved down to touch the LCD screen followed the positions on panel one set by the operator before the testing and checked its touch functions and execute the on-board programming test. Then moved to panel two and did the same touch test on its set positions.

Step11: After finishing the all touch check on both Board As, powered off Board As and powered on both Board Bs on two panels.

Step12: The Board Bs entered the self-check mode and checked the sound functions of the boards one by one.

Step13: The process of test contents from step7 to step11 was based on the sequence of testing panel1 – Board A, to testing panel2 – Board A, to testing panel1 – Board B, to testing panel2 – Board B, once a fault was detected on any step, the subsequent tests related to this board would stop and continued to carry out the next sequence.

Step14: After finishing all function checks of the panels and the electrical boards, if both the panels and two boards under it had passed all the test contents, the LEDs equipped on the pallet on the right side (since the pallet was enter from the right side of the conveyer) would show green. If one panel had passed all tests and another had not, one LED would show green and another would show read. If both panels had not passed all the test, both LEDs would show red.

Step15: Printer activated and printed out the result of the tests including the related information of the panel.

Step16: The air valve inside the fixture closed and make fixture move downward to disconnect it with the electrical boards, then the pallet would move out the machine and go back to the original position on the right side of conveyer.

Step17: When the machine was testing the panels as above steps, the operator could prepare the next tested panels and put them on another pallet, then put this pallet on the slideway on the left side. Once the panels which had finished the test moved out from the machine and stopped on the right side slideway the operator could press the button near the left side conveyer and start a new round of test.

7.3 Fault simulation

Since the panels and the electrical boards offered by the customer were all in good condition without any performance failure. To verify the detection effect of test machine “T100” was effective, Spea had to simulate some faults to confirm the machine could find the fault precisely. The way of simulation was to create some failure to make the test head cannot touch the switch or screen options successfully and checked the feedback signal whether it was passed or not.
For example, the test staff could stick a piece of soft thick cotton on the power switch which could give the test head feedback force without pressing the switch exactly to check whether the electrical boards under the panel powered on or kept off.
Another way to verify the circuit function of adapter was to take off the nails on the fixture to make the connection between the boards and the fixture become incompletely to check whether the function of electrical board would be influenced (failure) or not.
Every panel loaded with electrical board(s) had to process the fault simulation to confirm the test value of the test machine can satisfy the testing needs of customer.

7.4 Conclusion of the project

After more than 5 months studying and working in this project provided by Spea, I had learned many things like how to use the Leonardo system, how to design the circuit of adapter and adjust the position of electronic components on the fixture, and I also learned the basic skill of using VB.net to create the test function for the different kind of electrical boards.

Since my main responsibility was to test the function of the Board A, Board B and its panel configuration which was just one kind of testing panel in the whole project.

In the real situation, Spea had designed 5 different kinds of fixture and corresponding programming to test 5 different panels. After carefully designing and analyzing for different panels and their electrical boards, the test machine “T100” designed by Spea can successfully complete all the relevant tests required by the customer.

However, since I mentioned above, this was a long period cooperation and the customer would send new shape of panel with different type of electrical boards, the designing of the fixture and pellet for these new panel which could be used on the machine “T100” would still last for a long time.

I was so glad that Spea gave me this good change to involve in the entire design plan which let me get a very valuable experience and have a deep learning of the testing field.

APPENDIX: Electrical schema

The electrical diagram of the fixture for the Board A and Board B was divided into the following parts:

1. Title cover page of fixture
2. Layout of the fixture (including Board A and Board B)
3. Layout of Board A Top View (for the privacy principle, the detailed structure could not be shown in the thesis)
4. Power supply and Service circuit of Board A
5. FASEZ150 relay power supply
6. Digital channels connection of Board A
7. Fixture connection with test points of Board A (for panel 1)
8. Fixture connection with test points of Board A (for panel 2)
9. Layout of Board B Top View (for the privacy principle, the detailed structure could not be shown in the thesis)
10. Power supply and Service circuit of Board B
11. Digital channels connection of Board B
12. Fixture connection with test points of Board B (for panel 1)
13. Fixture connection with test points of Board B (for panel 2)
14. Title cover page of pallet
15. Layout of pallet (with 2 panels)
16. LED control circuit used on pallet
17. BON interface pin out of T100

BOARD ELECTRICAL LEVEL	EL. LEV.	A

DRAWING RELEASE	REL.	01.00

COVER	REV.	A
	PAGE	01

LAYOUT	REV.	A	A	A
	PAGE	02	03	09

[redacted]

Sheet revision tables

ELECTRICAL DIAGRAM (BOARD)	REV.	A	A	A	A	A	A	A	A	A												
	PAGE	04	05	06	07	08	10	11	12	13												
	REV.																					
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TABLES	REV.																					
	PAGE																					

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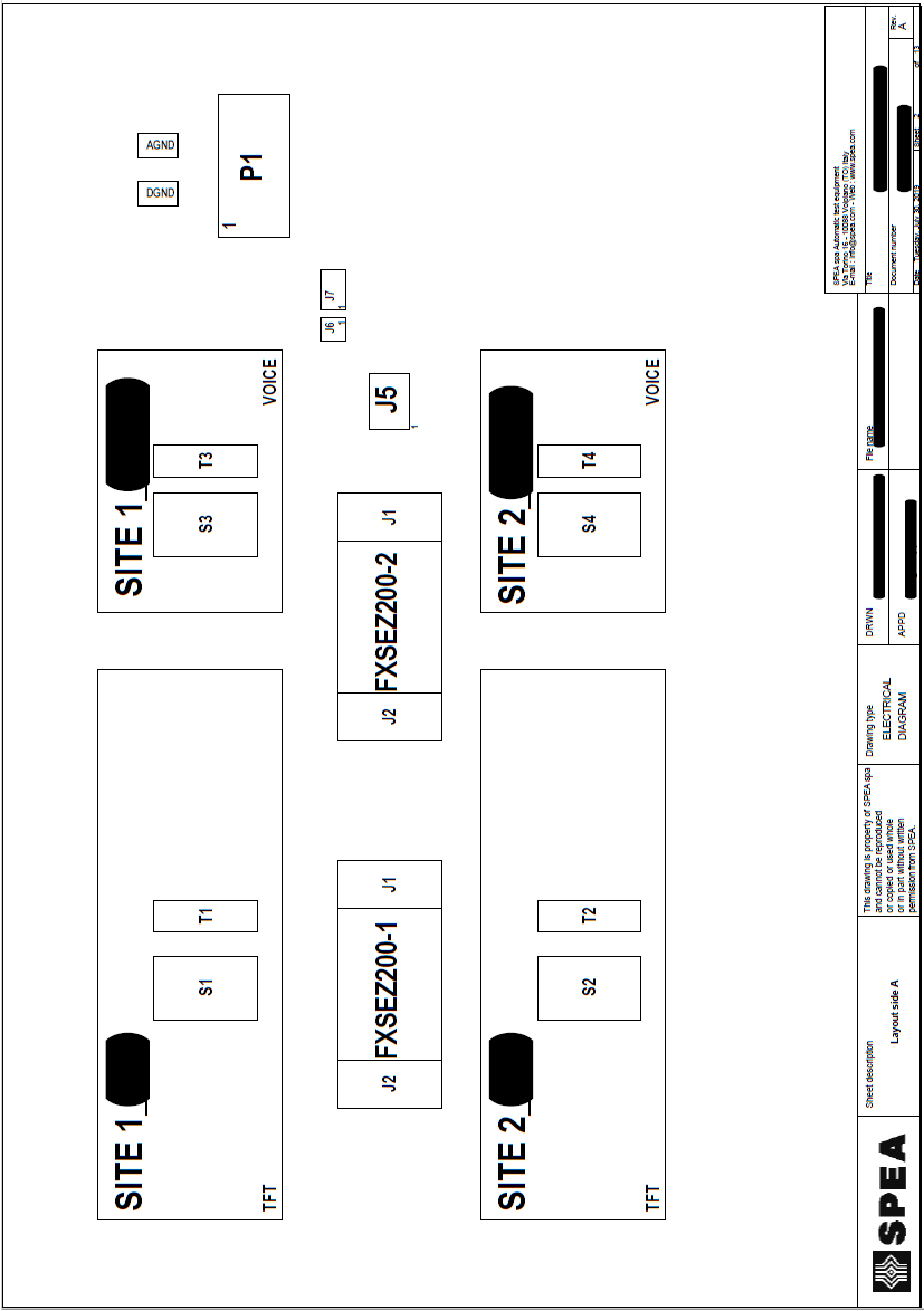
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DGND
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J7
J6
SITE 1 [redacted]
VOICE
T3
S3
J5
SITE 2 [redacted]
VOICE
T4
S4
J1
FXSEZ200-2
J2
SITE 1 [redacted]
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T1
S1
J1
FXSEZ200-1
J2
SITE 2 [redacted]
TFT
T2
S2
SPEA spa Automatic test equipment
Via Torino 16 - 10088 Volpiano (TO) Italy
E-mail : info@spea.com - Web : www.spea.com
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Document number [redacted]
Rev. A
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Layout side A
SPEA

[redacted]BOARD (TOP VIEW)

Board A

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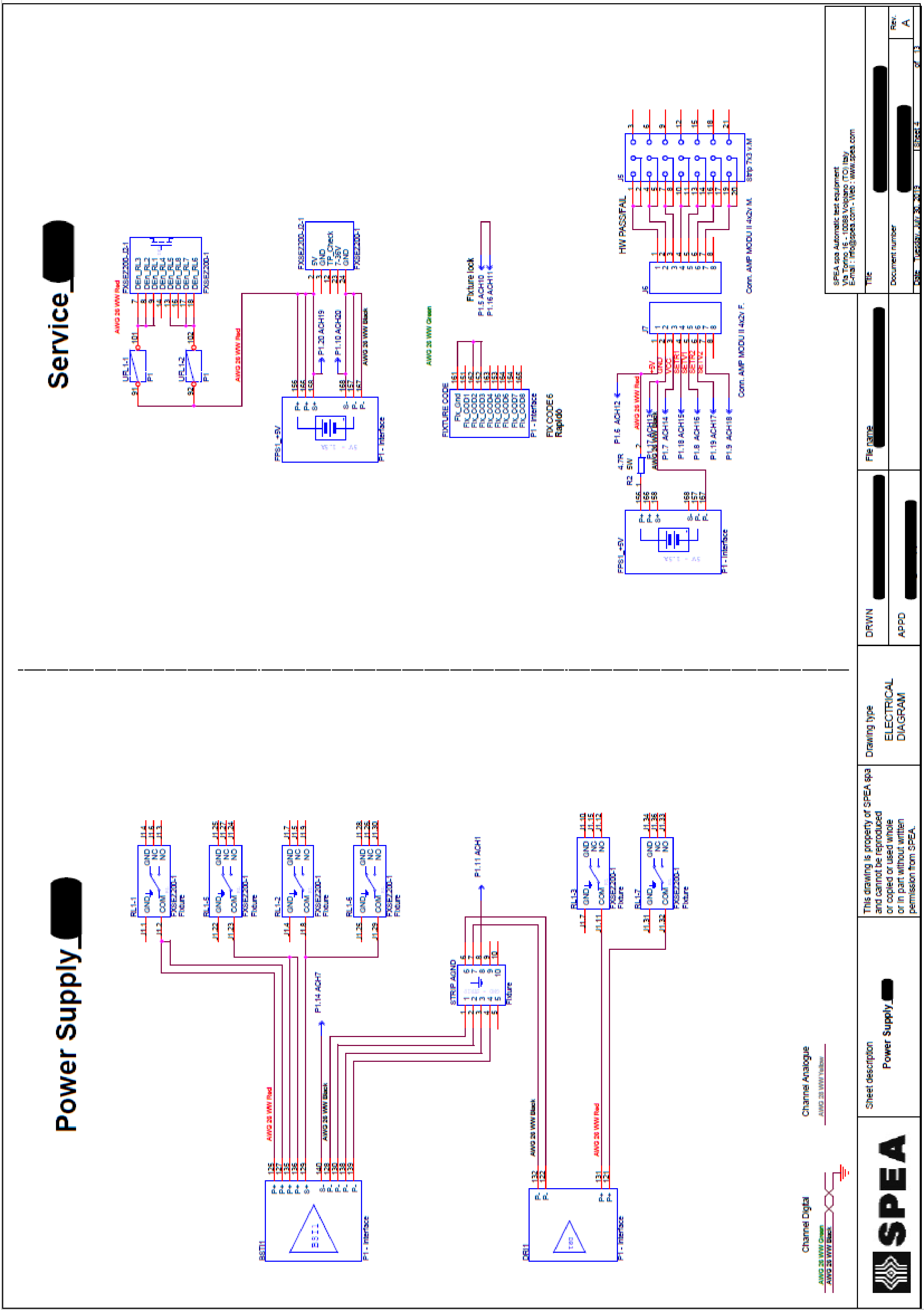

Power Supply_[redacted]
Service_[redacted]
Channel Digital
Channel Analogue
Fixture lock
HW PASS/FAIL
FIX CODE 6
Rapido
SPEA spa Automatic test equipment
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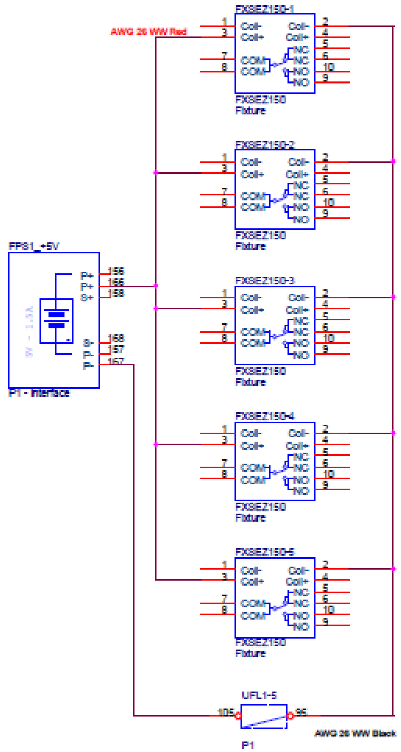
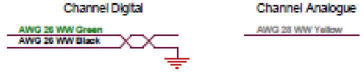
FASEZ150 POWER SUPPLY (SITE 1)





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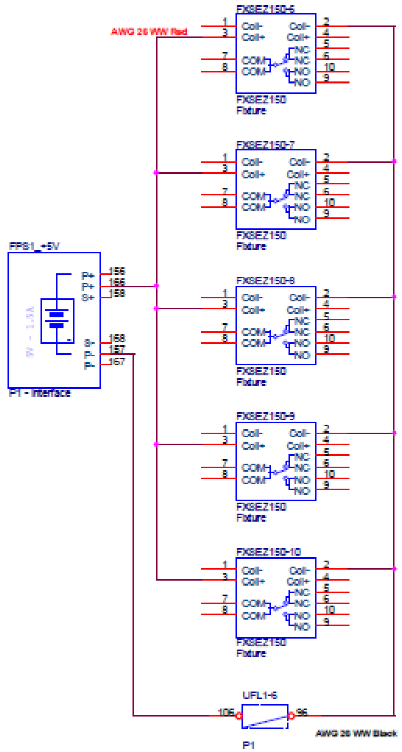

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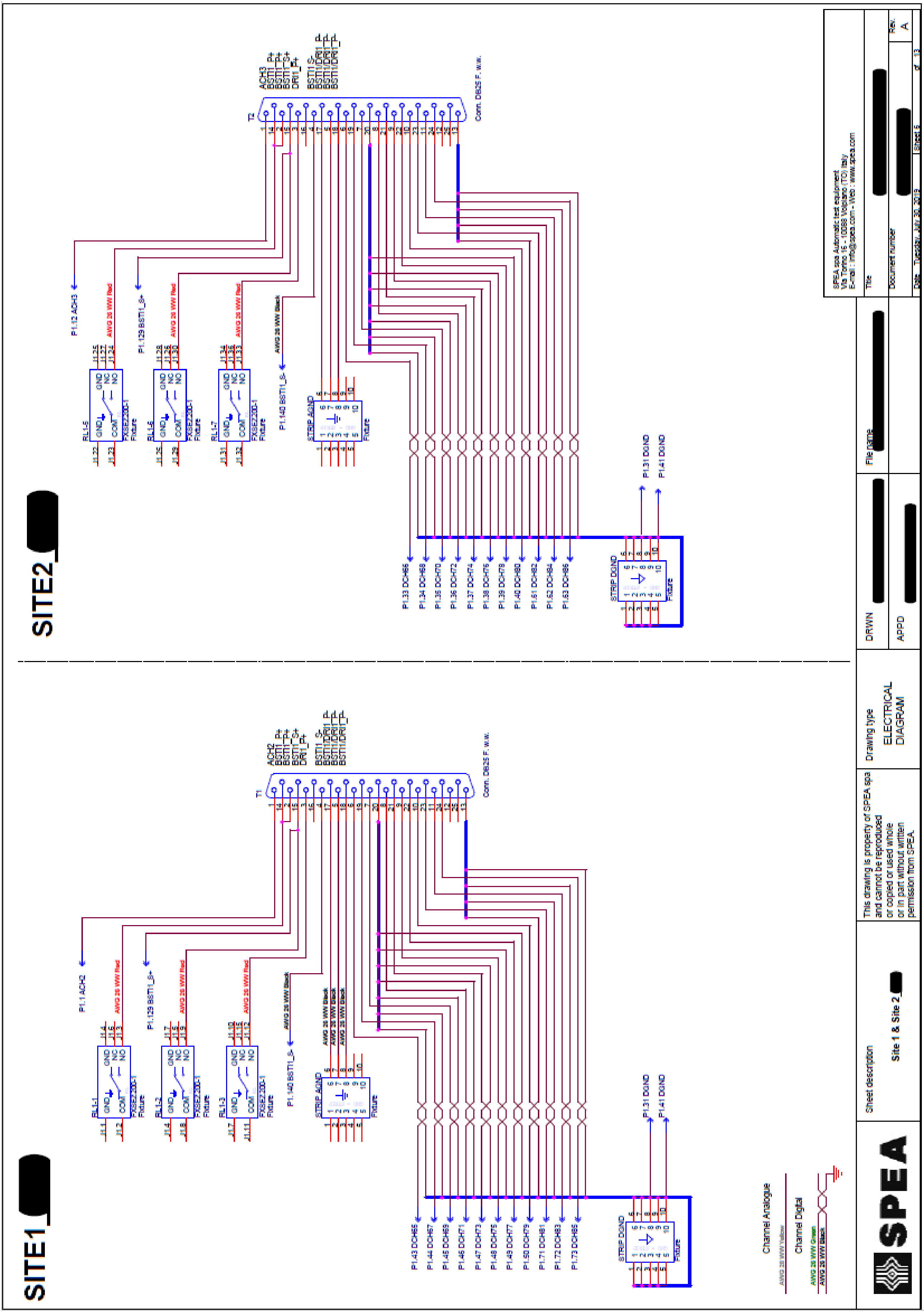

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SITE2_[redacted]
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STRIP DGND
Fixture
P1.31 DGND
P1.41 DGND
Channel Analogue
Channel Digital
SPEA
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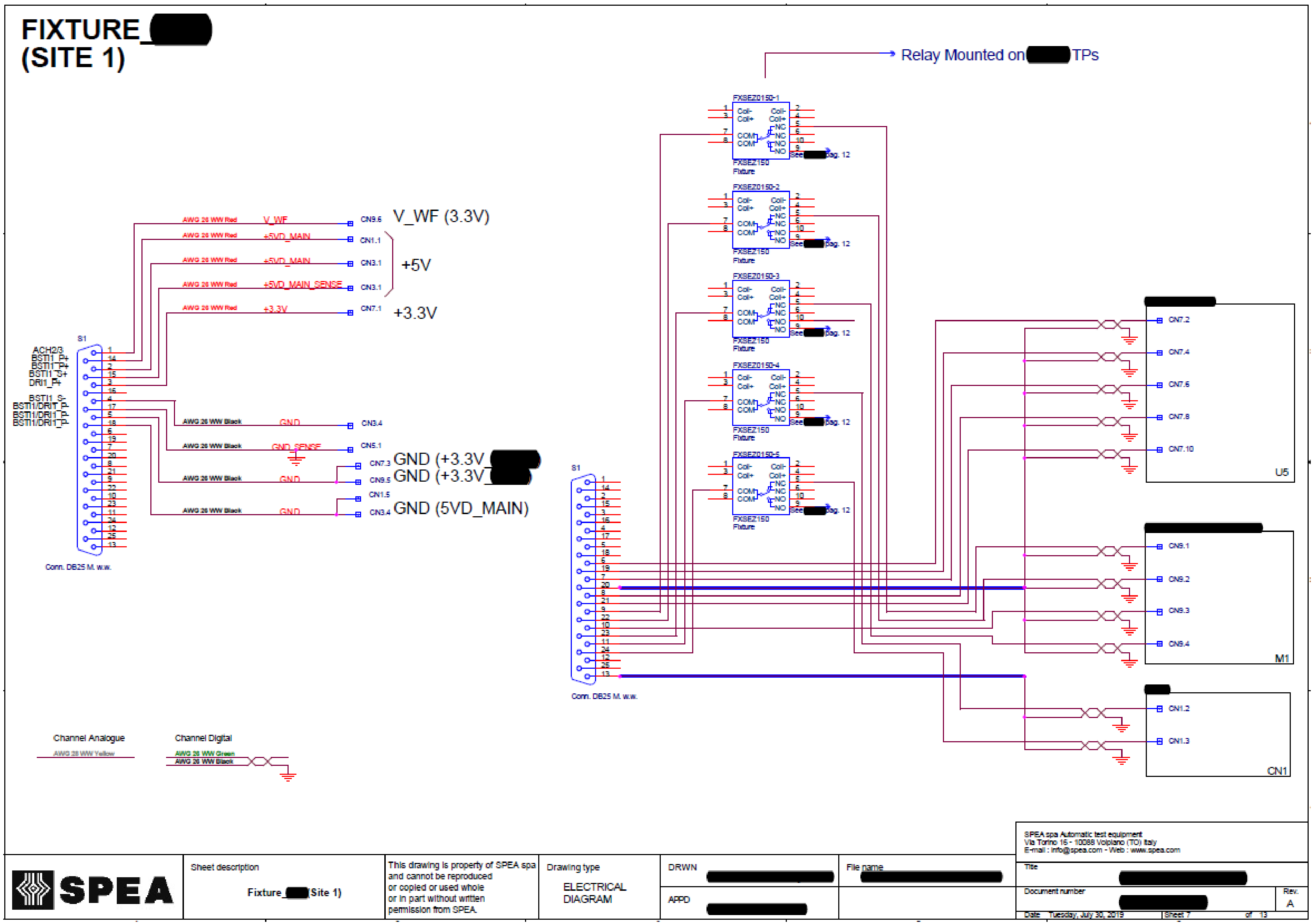
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+5V
+3.3V
GND (+3.3V_[redacted]
GND (+3.3V_[redacted]
GND (5VD_MAIN)
V_WF
+5VD_MAIN
+5VD_MAIN_SENSE
+3.3V
GND
GND_SENSE
AWG 26 WW Red
AWG 26 WW Black
CN9.6
CN1.1
CN3.1
CN7.1
CN3.4
CN5.1
CN7.3
CN9.5
CN1.5
ACH2/3
BSTI1_P+
BSTI1_T+
BSTI1_S+
DRI1_P+
BSTI1_S-
BSTI1/DRI1_P-
Conn. DB25 M. w.w.
S1
FXSEZ0150-1
FXSEZ0150-2
FXSEZ0150-3
FXSEZ0150-4
FXSEZ0150-5
FXSEZ150
Fixture
Coil-
Coil+
COM
NC
NO
See [redacted] pag. 12
U5
CN7.2
CN7.4
CN7.6
CN7.8
CN7.10
M1
CN9.1
CN9.2
CN9.3
CN9.4
CN1
CN1.2
CN1.3
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Channel Digital
AWG 26 WW Green
AWG 26 WW Black
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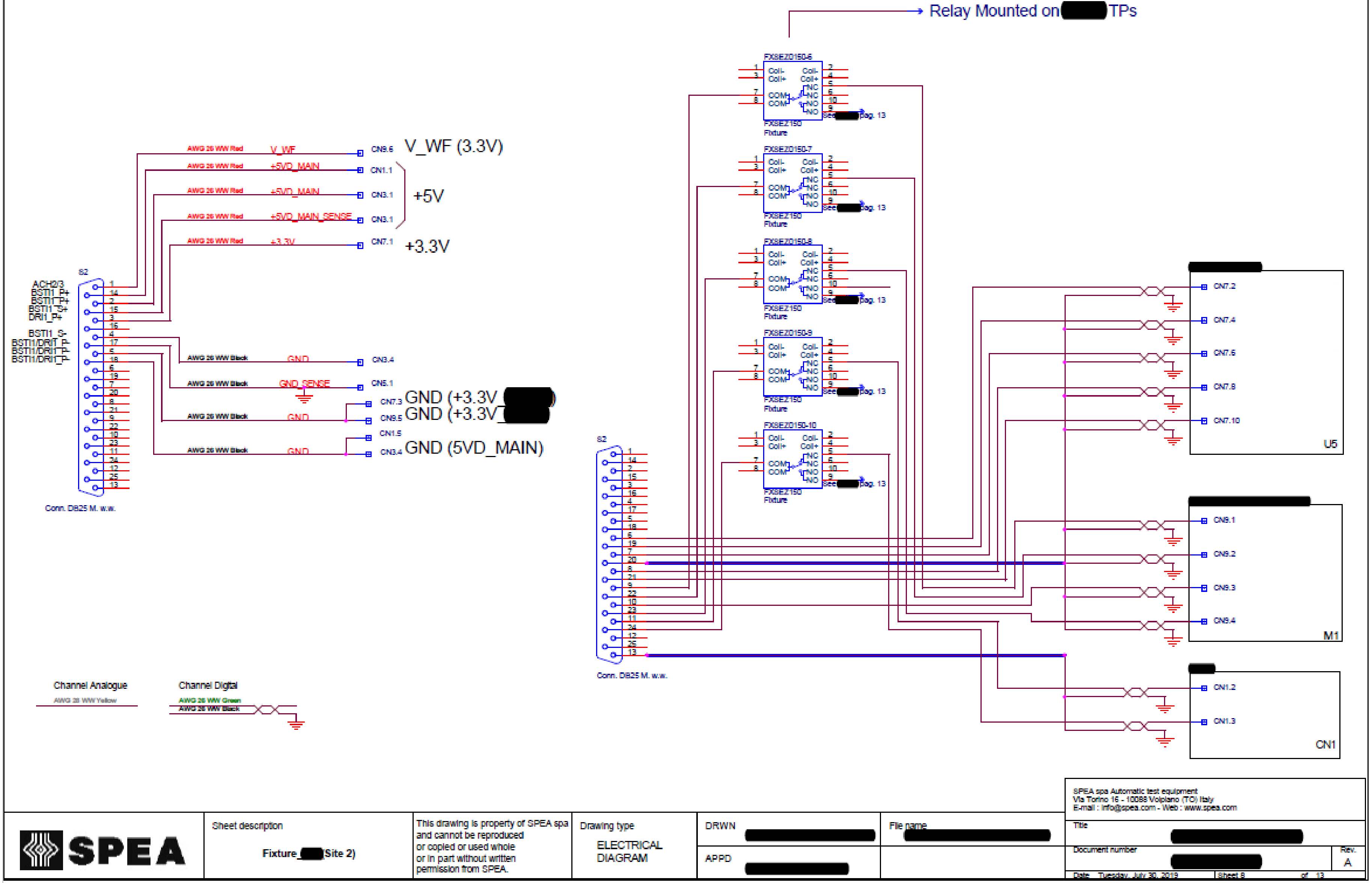
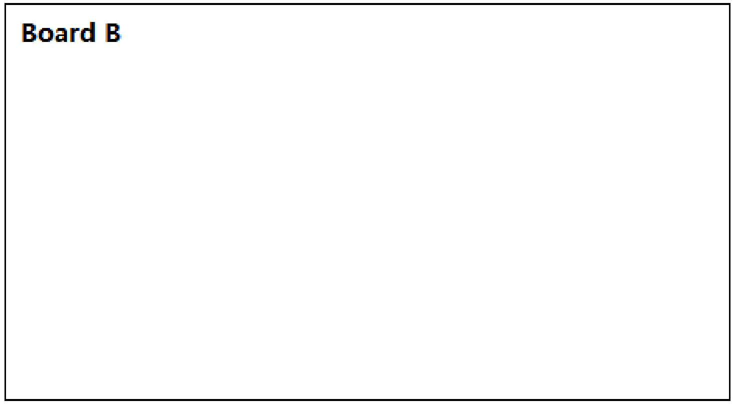
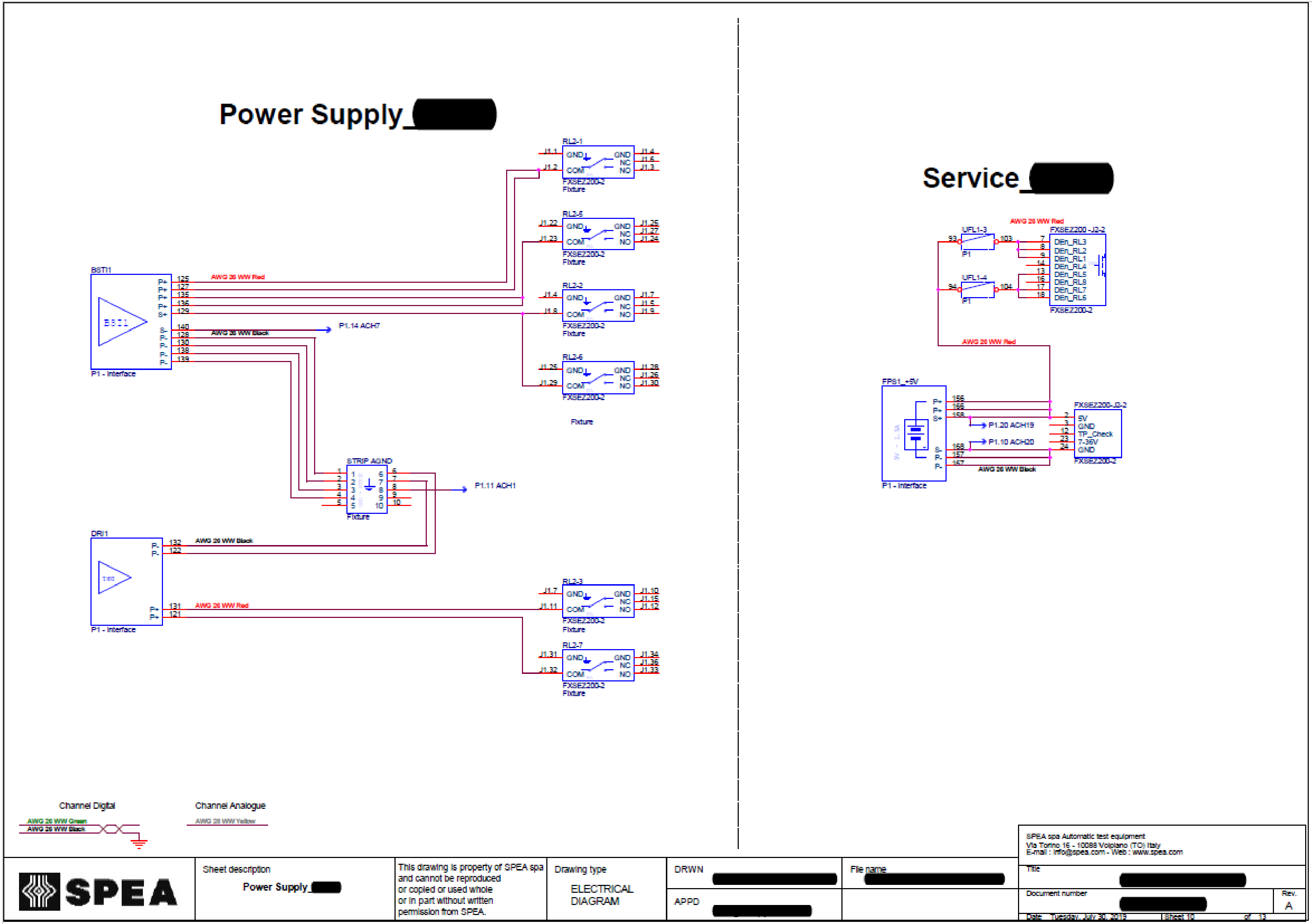


[redacted] BOARD (TOP VIEW)



SPEA	Sheet description Layout side C_[redacted] Board	This drawing is property of SPEA spa and cannot be reproduced or copied or used whole or in part without written permission from SPEA.	Drawing type ELECTRICAL DIAGRAM	DRWN [redacted] APPD [redacted]	File name [redacted]	SPEA spa Automatic test equipment Via Torino 16 - 10088 Volpiano (TO) Italy E-mail : info@spea.com - Web : www.spea.com Title [redacted] Document number [redacted] Rev. A Date Tuesday, July 30, 2019 Sheet 9 of 13


Power Supply_[redacted]
Service_[redacted]
BSTI1
P1 - Interface
DRI1
P1 - Interface
AWG 26 WW Red
AWG 26 WW Black
P1.14 ACH7
P1.11 ACH1
STRIP AGND
Fixture
RL2-1
RL2-5
RL2-2
RL2-6
RL2-3
RL2-7
FXSEZ200-2
GND
NC
NO
COM
UFL1-3
UFL1-4
FXSEZ200 -J2-2
FXSEZ200-J2-2
FP81_+5V
P1.20 ACH19
P1.10 ACH20
5V
GND
TP_Check
7-36V
Channel Digital
AWG 26 WW Green
AWG 26 WW Black
Channel Analogue
AWG 28 WW Yellow
SPEA
Sheet description
Power Supply_[redacted]
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Drawing type
ELECTRICAL DIAGRAM
DRWN [redacted]
APPD [redacted]
File name [redacted]
SPEA spa Automatic test equipment
Via Torino 16 - 10088 Volpiano (TO) Italy
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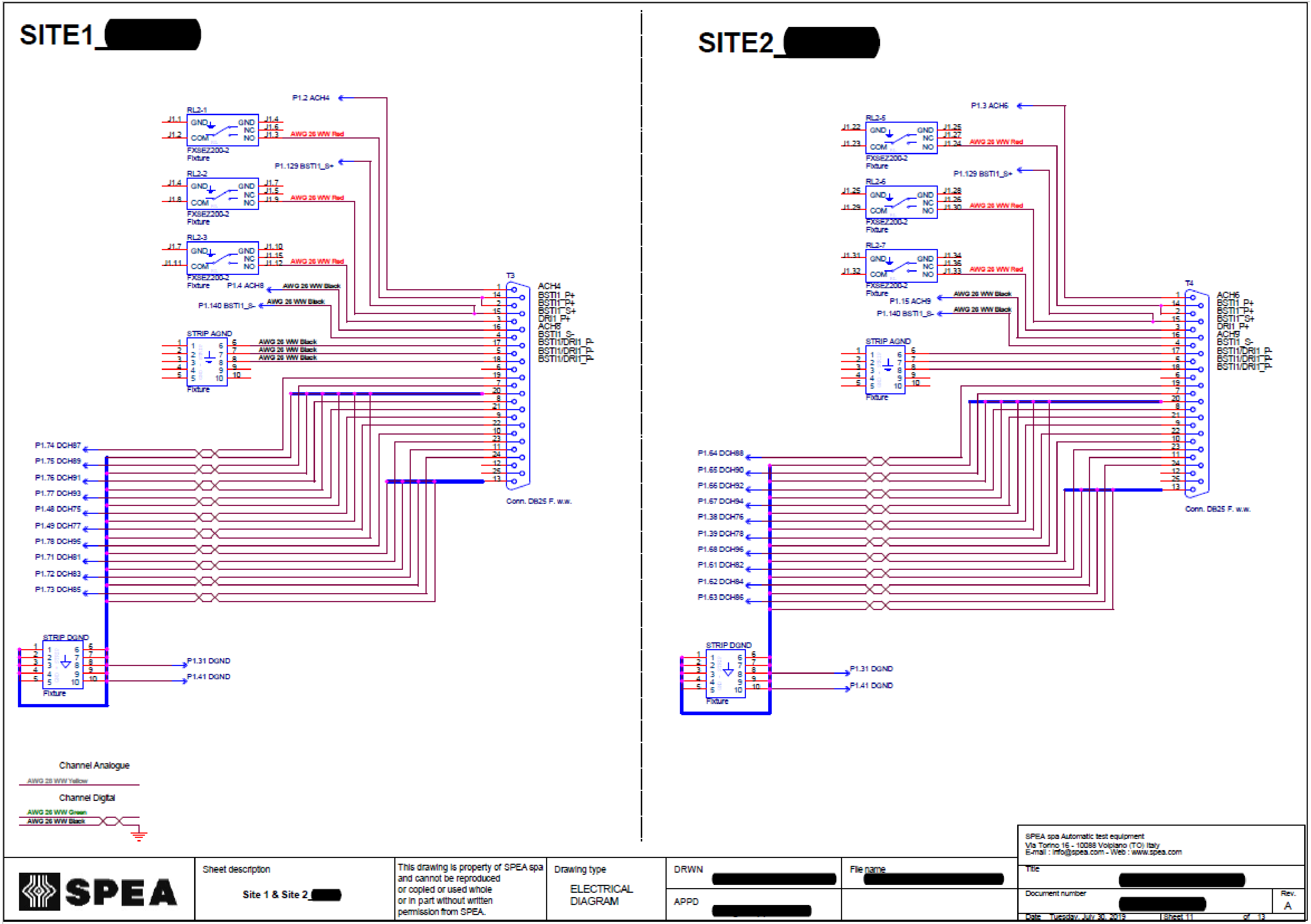
Title [redacted]
Document number [redacted]
Rev.
A
Date Tuesday, July 30, 2019
Sheet 10 of 13


SITE1_[redacted]
SITE2_[redacted]
RL2-1
RL2-2
RL2-3
RL2-5
RL2-6
RL2-7
FXSEZ200-2
Fixture
P1.2 ACH4
P1.129 BSTI1_S+
P1.4 ACH8
P1.140 BSTI1_S-
P1.3 ACH6
P1.15 ACH9
AWG 26 WW Red
AWG 26 WW Black
STRIP AGND
STRIP DGND
T3
T4
ACH4
BSTI1_P+
BSTI1_S+
DRI1_P+
ACH8
BSTI1_S-
BSTI1/DRI1_P-
ACH6
ACH9
Conn. DB25 F. w.w.
P1.74 DCH87
P1.75 DCH89
P1.76 DCH91
P1.77 DCH93
P1.48 DCH75
P1.49 DCH77
P1.78 DCH95
P1.71 DCH81
P1.72 DCH83
P1.73 DCH85
P1.64 DCH88
P1.65 DCH90
P1.66 DCH92
P1.67 DCH94
P1.38 DCH76
P1.39 DCH78
P1.68 DCH96
P1.61 DCH82
P1.62 DCH84
P1.63 DCH86
P1.31 DGND
P1.41 DGND
Channel Analogue
AWG 28 WW Yellow
Channel Digital
AWG 26 WW Green
AWG 26 WW Black
SPEA
Sheet description
Site 1 & Site 2_[redacted]
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Drawing type
ELECTRICAL DIAGRAM
DRWN [redacted]
APPD [redacted]
File name [redacted]
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Document number [redacted]
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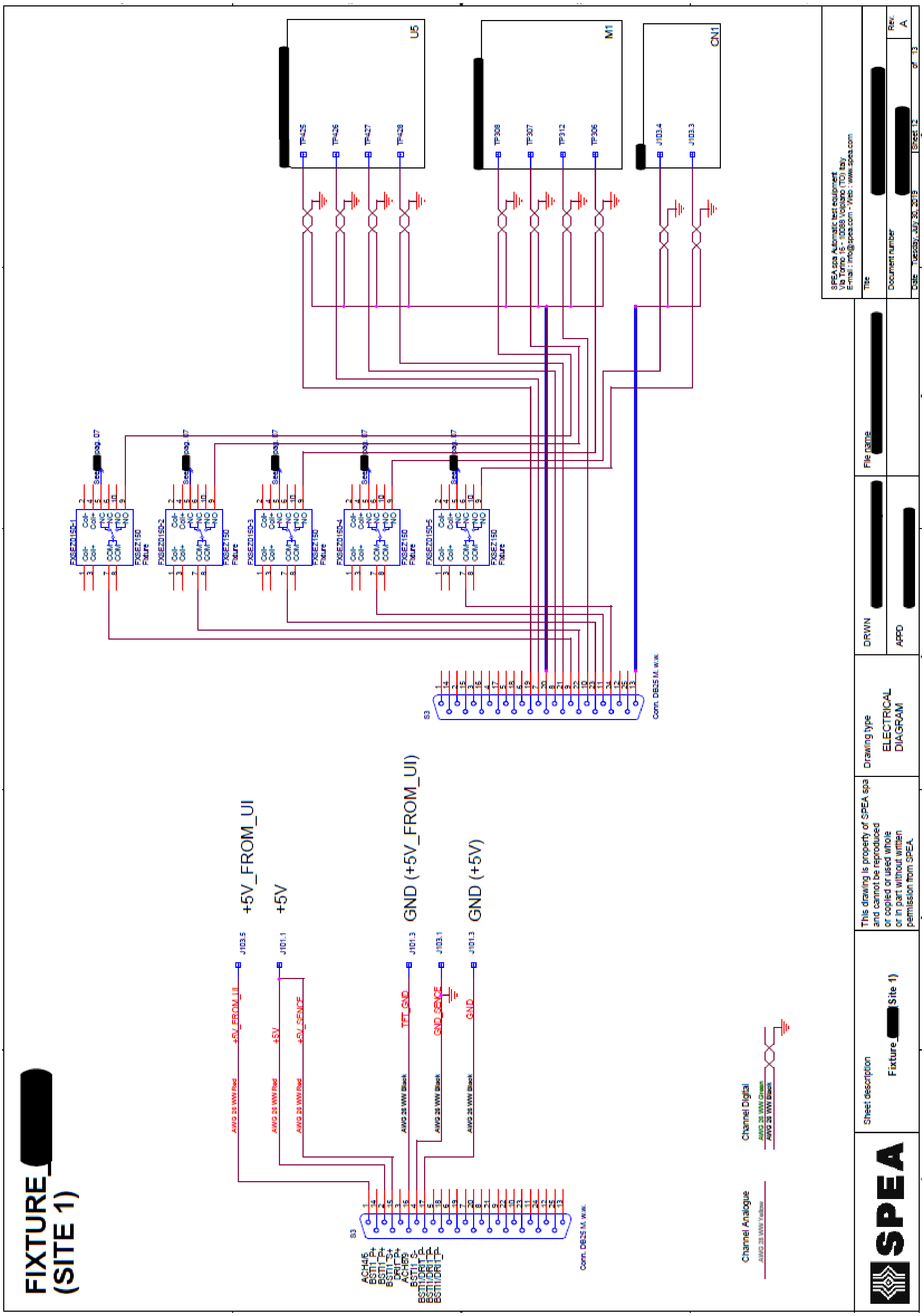
Sheet 11 of 13



FIXTURE_[redacted]
(SITE 1)
+5V_FROM_UI
+5V
GND (+5V_FROM_UI)
GND (+5V)
J103.5
J101.1
J101.3
J103.1
+5V_FROM_UI
+5V_SENCE
TFT_GND
GND_SENCE
GND
AWG 26 WW Red
AWG 26 WW Black
Channel Digital
Channel Analogue
Conn. DB25 M. w.w.
U5
M1
CN1
TP425
TP426
TP427
TP428
TP308
TP307
TP312
TP306
J103.4
J103.3
FXSEZ150
Fixture
ELECTRICAL DIAGRAM
Drawing type
Sheet description
DRWN
APPD
File name
Title
Document number
Rev.
A
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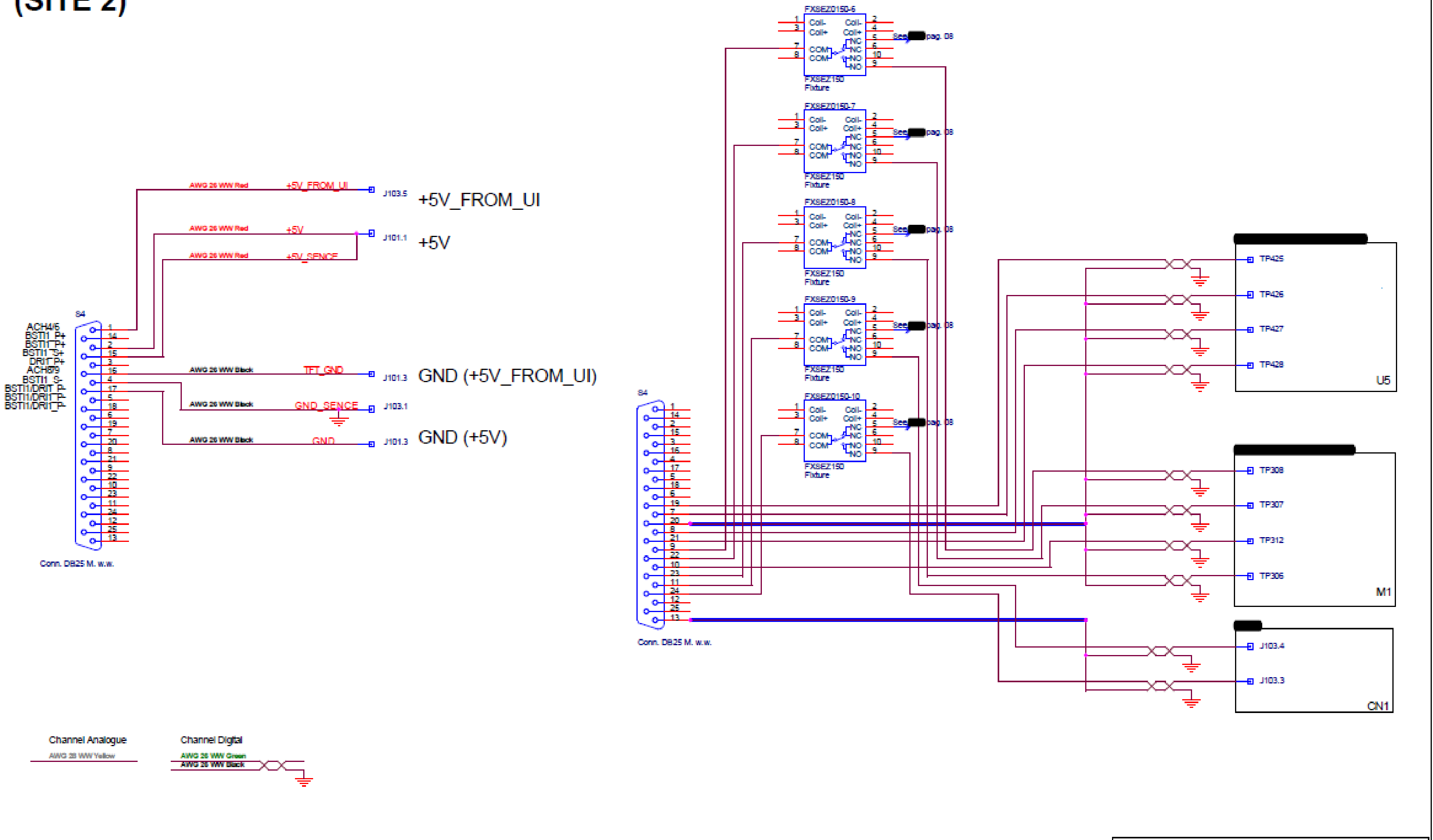
FIXTURE_[redacted] (SITE 2)



SPEA	Sheet description Fixture_[redacted](Site 2)	This drawing is property of SPEA spa and cannot be reproduced or copied or used whole or in part without written permission from SPEA.	Drawing type ELECTRICAL DIAGRAM	DRWN [redacted] APPD [redacted]	File name [redacted]	SPEA spa Automatic test equipment Via Torino 16 - 10088 Volpiano (TO) Italy E-mail : info@spea.com - Web : www.spea.com Title [redacted] Document number [redacted] Rev. A Date Tuesday, July 30, 2019 Sheet 13 of 13

BOARD ELECTRICAL LEVEL	EL. LEV.	A	
DRAWING RELEASE	REL	01.00	
COVER	REV.	A	
	PAGE	01	
LAYOUT	REV.	A	A
	PAGE	02	03

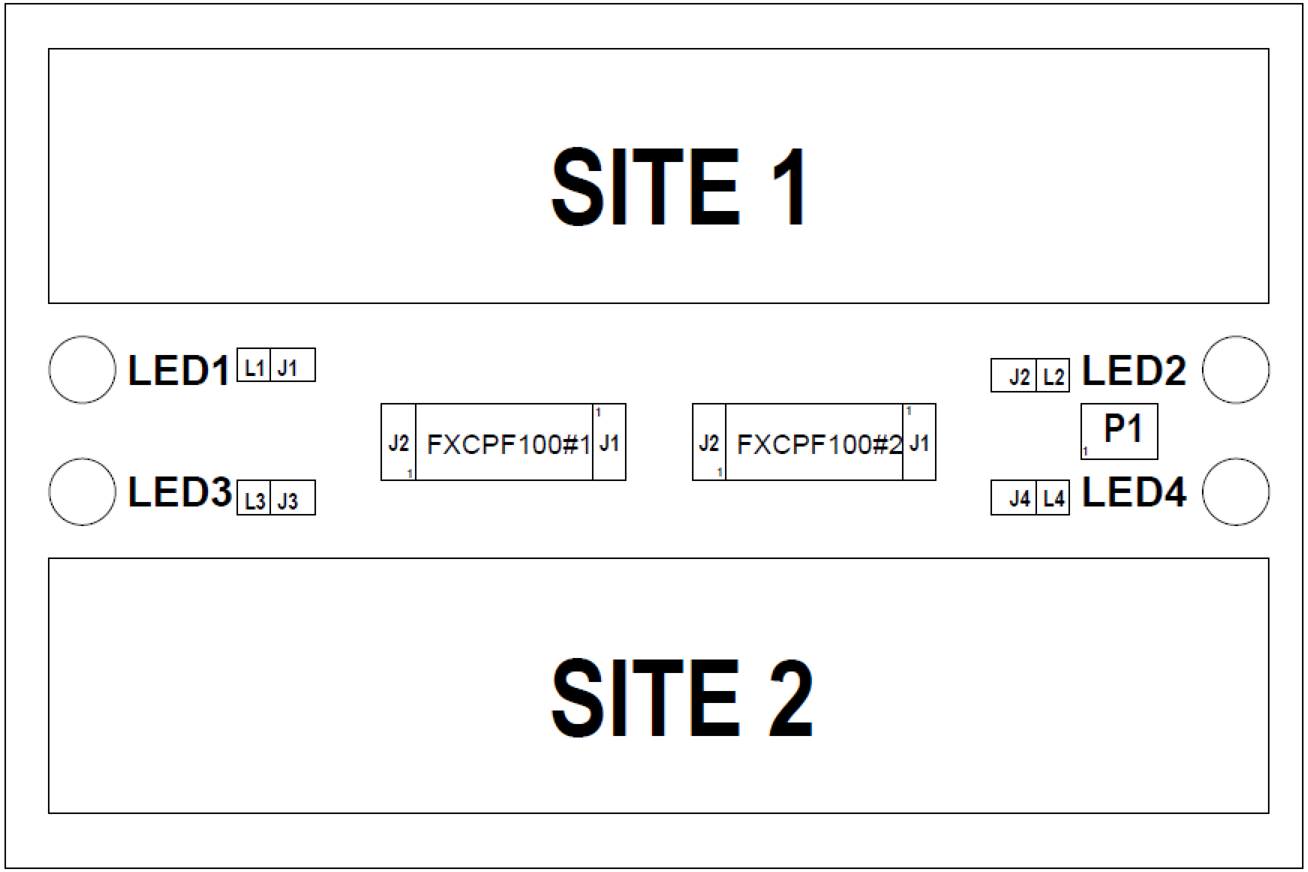
[redacted] - Pallet

Sheet revision tables

ELECTRICAL DIAGRAM (BOARD)	REV.	A
	PAGE	04
	REV.	
	PAGE	
	REV.	
	PAGE	
TABLES	REV.	
	PAGE	

SPEA

Sheet description Cover	This drawing is property of SPEA spa and cannot be reproduced or copied or used whole or in part without written permission from SPEA.	Drawing type ELECTRICAL DIAGRAM	DRWN [redacted] APPD [redacted]	File name [redacted]	SPEA spa Automatic test equipment Via Torino 16 - 10088 Volpiano (TO) Italy E-mail : info@spea.com - Web : www.spea.com Title [redacted] - Pallet Document number [redacted] Rev. A Date Thursday, June 13, 2019 Sheet 1 of 4



SPEA

Sheet description: Layout side A

Drawing type: ELECTRICAL DIAGRAM

DRWN [redacted]

APPD [redacted]

File name [redacted]

SPEA spa Automatic test equipment
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Document number: [redacted]

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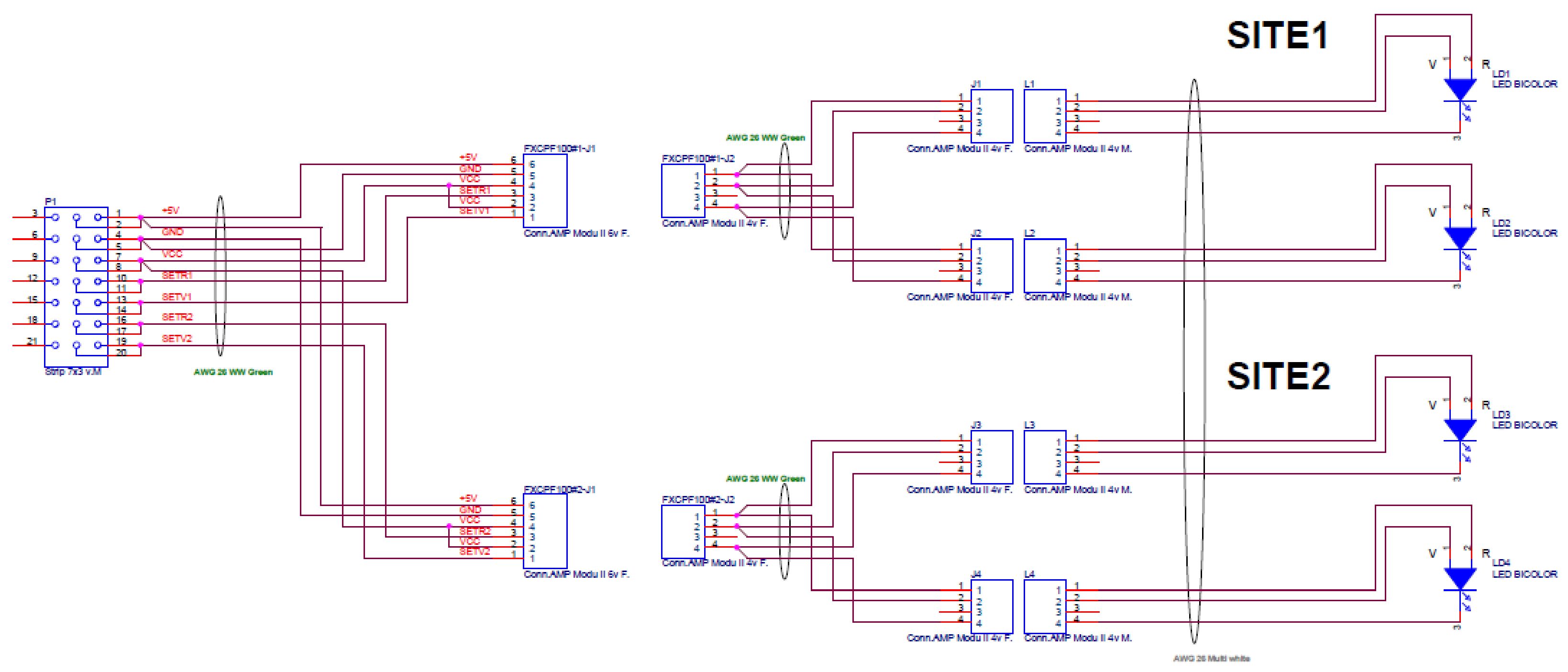
Date: Thursday, June 13, 2019 Sheet 2 of 4



SPEA	Sheet description Electrical sheet	This drawing is property of SPEA spa and cannot be reproduced or copied or used whole or in part without written permission from SPEA.	Drawing type ELECTRICAL DIAGRAM	DRWN [redacted] APPD [redacted]	File name [redacted]	SPEA spa Automatic test equipment Via Torino 16 - 10088 Volpiano (TO) Italy E-mail : info@spea.com - Web : www.spea.com Title [redacted] Pallet Document number [redacted] Rev. A Date Thursday, June 13, 2019 Sheet 4 of 4