Apertuisane System Architecture

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Abstract

Overall high-level system design.

Contents

1 Purpose of this Document

This document describes the Apertuisane flying probe tester (FPT) at the system level.

It is also meant to gather system requirements and justify design decisions.

1.1 Design Drivers

Apertuisane aims to be a low-cost, DIY solution. As such it should be built exclusively from off-the-shelf components or parts that can be easily produced in makerspaces. Also, assembly should not require unusual tools.

2 System Architecture

Project Apertuisane refers to a system for efficiently testing bare or populated circuit boards. At the highest level, it is therefore a process and the tools to support that process.

FPT's defining feature is flexibility, so the Apertuisane process must support that flexibility by making it as simple as possible to:

- Setup the testing of a new board design, ideally straight from board CAD files.
- Create validation sequences, ideally using Excel for input and reporting.
- Integrate Apertuisane into a product's production process.

  (This list is not limitative)

Setting up testing would ideally be done entirely automatically, by recovering copper geometry from a board's CAD files. Key information is the netlist, along with pad locations and geometry, which will be used to compute where to send the probes, and which pads should be connected together. More advanced tests may be developed in the future.

Creating validation sequences will allow for tests to be grouped. This is a future-proofing requirement, looking down the line where Apertuisane will support more than just continuity testing. Initially, a validation sequence Excel file would list each net along with a pass/fail criterion and result, all generated automatically from CAD data, but editable by hand.

Integration into a production process involves, for instance, making Apertuisane testers easy to operate by minimally-trained personnel. It also involves design provisions for inserting Apertuisane testers into an automated production line, for example before a solder printer and/or after a reflow oven.

2.1 Apertuisane Setup Application *(Name TBD)*

For any given board design to be tested, Apertuisane must let the users generate, review and edit a test program. Since such a program would be a list of measurements to perform, a spreadsheet makes the most sense. Due to its ubiquity, Excel shall be used as the starting point.

The setup application will start by creating an Excel representation of a board that includes pad locations and connectedness. The application will also set each pair of pads on a net to be tested for continuity.

Testing for shorts is more complex. Except for the simplest boards, it is not efficient to test every combination of nets for short circuits. It makes more sense to test nets that are physically close together. Automating the generation of such test will require the application to analyze the geometry of the copper tracks. Even then, the resulting test program may not be fully adequate, hence the need to enable operators to edit the test programs via Excel.

The same Excel file may also be used to store test results for each board in a batch, for later analysis.

The setup application does not need to run on the tester: it may be run by anyone on their own computer, as part of their board design process. The resulting test programs, in the form of Excel files, are the only data that needs to be loaded into the actual tester.

2.2 Apertuisane Tester Application *(Name TBD)*

This front-end application will run on the computer integrated into the flying probe tester. Its input is a board reference and the associated test program, an Excel file generated by the setup application. Test programs may be loaded automatically from a version control repository, allowing program updates to be performed by board designers for each board known to the tester.

The front-end shall have a simple user interface intended to guide an operator through the testing of boards. It will essentially prompt the operator at each phase of a test cycle to:

- Select the board type (which may later be read directly from a barcode or QR code etched into the copper, or by RFID tag)
- Enter the number of boards to test.
- Insert a board into the tester and clamp it down.
- Remove the board.
- Bin the board depending on test outcome.

The idea behind the front-end application is to be as efficient as possible and accessible to personnel with minimal training.

Behind the scenes, the front-end application may also store and transmit test results to board designers and facility managers, allowing production problems to be analyzed before a batch of boards has been completely tested.

2.3 Apertuisane Tester

This is the actual flying probe tester. It is intended to be modular, stand-alone and self-contained.

Modularity is required for ease of design, customization and maintenance.

Stand-alone means it can be installed in a factory as easily as a reflow oven, and requires only mains power and a network connection.

Self-contained means it does not require setting up a work station.

3 Mechanical Architecture

The Apertuisane tester is a CNC machine tool.

To simplify development, construction, operation and maintenance, the tester will be designed as a stack of functional elements, called "stages". From top to bottom:

- Supervisory electronics, including the tester's integrated computer and operator interface.
- Top side test package, including probe interfaces and data acquisition systems.
- Top side prober, a Cartesian robot capable of placing probes on the board under test.
- Board handling system, responsible for feeding, clamping and ejecting the boards under test.
- Bottom side prober, identical to the top side prober.
- Bottom side test package, identical to the top side test package.
- Ancillaries, such as power supplies, pumps, etc...

This stacking design allows for a clear division of design efforts. It also allows for quick customization of the tester.

Interconnection between the stages is TBD, and may not be limited to electrical power and data connections. See subsection 3.6 below.

3.1 Supervisory Stage

- An operator interface TBD.
- Machine vision interfaces for board and pad registration.
- Motion controllers for the electromechanical stages.
- A network interface allowing for remote setup and operation of the tester.
- Physical controls, notably an emergency stop button.

3.2 Test Package Stages

The prober stages are only intended to physically connect probes with the board under test. The probes will be wired to the test packages, which will hold the instruments that actually test the board: DAQ, ADC, GPIB instruments, etc...

Test packages may also feature probe multiplexers, allowing the probes to be routed to different instruments for different tests, without operator handling.

3.3 Prober Stages

A tester may have one or two prober stages (one on each side of the board under test). This stage is essentially a Cartesian positioning stage using two independent gantries running along the X axis (left-right).

Each gantry may carry one or two probe assemblies on independent Y axes (front-rear).

Each probe assembly combines a Z axis (vertical) and an electrical test probe. In addition, an angular actuator (around the Z axis) may be used to allow multiple probes to be brought closer together.

Any and all probe assemblies may also be equipped with a low-cost, high-resolution miniature camera for machine vision.

3.4 Board Handling Stage

The boards to be tested need to be inserted and clamped reliably into the tester.

The initial prototype of this stage will be fully manual, based on a removable tray design. The operator will be able to clamp a board onto one of several spare trays, and then insert that tray into the Board Handling Stage, where it will be locked in place during testing.

Various sensors will detect the presence of a tray and the status of the tray locks, preventing the tester to operate unless a board is correctly secured in.

The board handling stage will feature tray slots on two opposing sides, to allow pass-through operation. The slots should be on the left and right sides of the tester.

The front side of this stage should be transparent, to allow visual inspection during board testing.

3.5 Ancillaries Stage

This stage will contain the bulky and heavy subsystems of the tester, such as electric power supplies, air compressor, pumps, etc... as required by the design. It may serve as a base for the tester and therefore may be equipped with feet and/or wheels.

One of the reasons for placing all the heavy subsystems at the bottom of the tester is stability during operation: the tester's probers may move at high acceleration and be heavy enough that their inertia needs to be accounted for.

3.6 Stage Interconnect

All the stages are interconnected. To avoid cable clutter, the rear side of the tester will be reserved for wiring and divided width-wise into several channels, so that cables do not cross. To simplify maintenance, the number of cables will be kept to a strict minimum by concentrating signals into high-density connections.

Moreover, to reduce costs and simplify spare part procurement, off-the-shelf cables should be used, such as computer cables.

Due to the electromechanical nature of the machine, all connectors are required to feature a mechanical locking device. Examples of desirable connectors are modular jacks (RJ45) and PATA ribbon connectors associated with locking sockets. Examples of undesirable connectors are USB and HDMI, unless a custom locking solution is designed for them, such as: `https://www.apertus.org/cablearmour`

References