Design and Validation of USB 3.0 Inserter for Use in Automated Test Equipment

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INTRODUCTION

This report shows the development process that was taken for a consumable USB 3.0 extension (*referred to as a USB inserter) that was designed for use inside automated Raspberry Pi test equipment within Sony UK Technology Centre.

AIMS AND OBJECTIVES

DESIGN BRIEF

The aim of this project is to design a consumable USB 3.0 inserter board that is compatible with the automated test jigs for Raspberry Pi4 and Raspberry Pi5. The consumable part must be capable of connecting to both ports of a USB stack connector at the same time. It must also be easy to align within the automated test equipment.

FUNCTION

The most critical part of the design is that it functions as a USB extension. The project would be a complete failure if the part does not function correctly. This was the first thing to be tested. It must also be able to connect to both ports of the USB stack connector. This can easily be confirmed by connecting the USB 3.0 device used at test with the new inserter into a computer.

DAMAGE

The inserter must not damage the connector on the product it mates with during the test. This is critical as if it does damage the product, then every unit that is tested will have a damaged USB connector, which is not an acceptable result. To validate if any damage is caused to the product, the new inserter will be inserted into a Raspberry Pi in a controlled way and the connector will be closely inspected for damage. The quality control department within Sony will also be given tested products to inspect for damage after insertions and make a judgement to deem it acceptable or not.

ROBUSTNESS

The inserter must be able to last a significant time in the production environment before it needs to be replaced. Any inserters that are installed into production jigs will be monitored to see how long they last. A judgment will be made to determine if their robustness is acceptable.

RELIABILITY

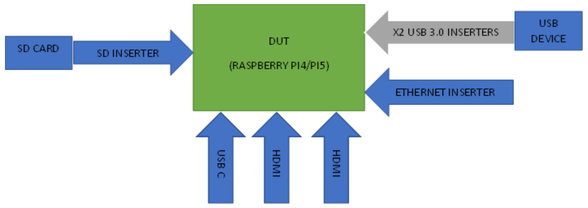
A study will need to be done to evaluate if the 4% NFF has been reduced with a redesigned inserter. To evaluate if there is a reliability improvement. A data study was conducted to review the USB failure test data.

MAINTAINABILITY

The design must allow the inserter to be aligned quickly to reduce downtime on production equipment. To check this, a timed alignment of both the old and new design was be undertaken and then compared.

PRODUCTION TEST SETUP

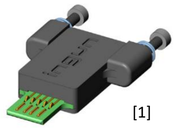
The Raspberry Pi test jig automatically connect 7 things to the DUT as part of the automated test. These can be seen in the diagram below. The USB inserter relevant to this project has been highlighted in grey.



Connected to each of the USB inserters is a USB device. This contains both a USB 2.0 device and a USB 3.0 device and is used to verify that the USB functionality on the DUT is working correctly. The pass condition at test requires 4 devices to be detected when the USB inserters are connected.

RESEARCH

The research conducted was an evaluation of established designs for USB inserters that are available on the market. The characteristics of each were compared with the aim of identifying features that will help improve the design for this report. Example products show below.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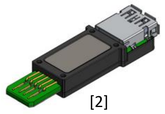
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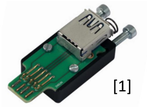
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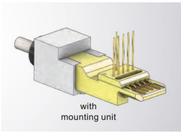
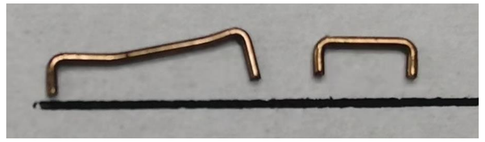


[3]

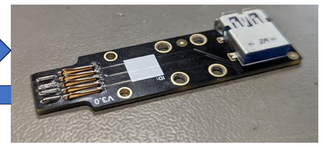
CUSTOMS SPRING PARTS

The literature review identified that all inserter products had springs that were used to connect to the USB 3.0 connections on the mating connector. This feature was a desirable feature to add to the new inserter. This was one of the most challenging parts of the project, however eventually, a method to manufacture very small custom springs was identified.



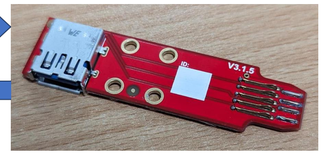
DESIGN AND TESTING

5 different versions of the inserter were designed and tested in various ways during the project; improvements were made after testing. The results have been summarised below:



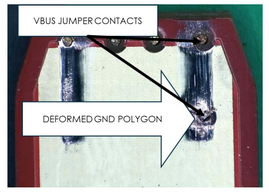
V3.0 INSERTER

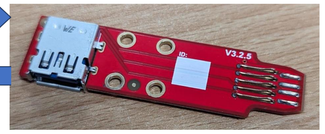
- Critical design issue identified that will cause VBUS to ground short circuit when a connected to a USB connector.
- Mounting holes are incorrect in size.
- If wired correctly, the inserter can function for a significant number of insertions.
- They are robust enough to not become damaged after a significant number of insertions.
- Fresh connectors do show some marking and minor damage after 1 insertion with a 1.6mm thickness inserter. Reducing the thickness of the PCB may reduce damage further. The Quality Check department must make a judgement to determine if the marking is deemed acceptable or not.
- Not suitable for production



V3.1.5 INSERTER

- Damage testing confirmed the inserters will not cause concerning damage to the product and deemed acceptable by the quality department.
- Continued usage of V3.1.5 inserters in production jigs may cause a short between VBUS and GND nets. Shown in image below.

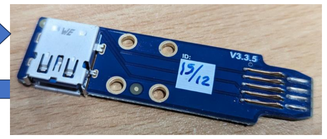




V3.2.5 INSERTER

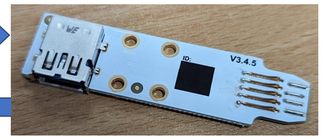
- Error in design meant that there was no improvement during production testing.

Further adjustments required.



V3.3.5 INSERTER

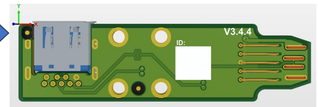
- Shorting issue was resolved on this revision
- No major issues identified during production testing.



V3.4.5 INSERTER

- The V3.4.5 was installed into production equipment with no issues.

This is the final version of the inserter to be used on Raspberry Pi 5 test hardware.



V3.4.4 INSERTER

The V3.4.4 inserter was designed to be used for Raspberry Pi4 test equipment. The USB 3.0 connectors location is in a different location on the Pi4 and therefore requires a design with the connector on the opposite side of the board.

This design will inherit all improved features of previous revisions. It has not been manufactured yet.

EVALUATION

FUNCTION

The inserter successfully worked as a consumable USB extension, and it can successfully connect to both ports of a USB 3.0 connector. The design was fully functional from V3.3.5 onwards and this was shown in the design review section. The function was proven both by inserting into an individual Raspberry Pis and confirming devices could be detected, and through repeated cycle USB tests. The successful implementation into production equipment further showed how the devices functioned correctly.

DAMAGE

The testing of the inserter showed that very minor marking can be made on the inside of a connector that is mated with a USB inserter, on early revisions of the inserter. Later tests showed reduced cosmetic damage and it was deemed acceptable by the quality department within Sony. The products shown were also inserted into 10 times, which is far more than any that would normally go through the process. The PCBs were manufactured to be 1.4mm thick to reduce the risk of damage even further.

The build of the USB inserters is a critical part of the build, and it is of paramount importance to build them correctly. A detailed operational standard on how to build the devices was also produced as part of the handover to the production engineering team.

Most products going through the process will only be inserted into 1 time and from the tests, 1 insertion on the later revision boards left no visible markings.

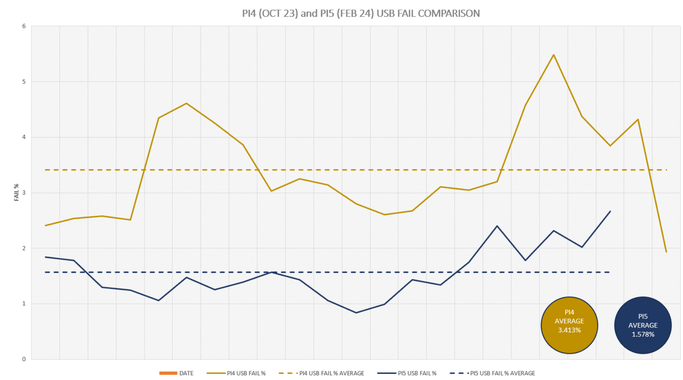
ROBUSTNESS

The inserter was proven to be able to survive many insertions. Initial testing showed that it could survive 10,000 insertions without any damage in the offline test jig.

There were some initial issues with the robustness of the inserters, however they were eventually designed out of the PCB. V3.3.5 was deemed robust enough for production use.

RELIABILITY

From the data gathered during the data study of the project, there was a reduction in USB failures by 1.835%. This was further quantified to show an estimated cost saving of £9,666.80 per year, based on the time that would be saved retesting 1.835% of boards.

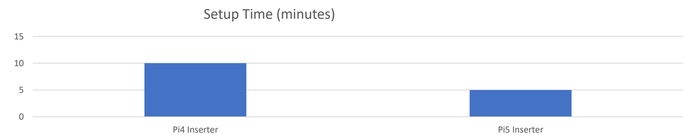


MAINTAINABILITY

To evaluate the maintainability of the new inserter, the setup time was measured for the old and new design (V3.4.5) and compared, the results are shown below.

The main reason for the increased setup time for the Pi4 inserter is that there was far more adjustment in the setup, which required some time to get aligned correctly, whereas the new style inserter was much closer fit into the connector and did not have this issue.

The reduced setup time shows that the new style of inserter is more maintainable.



REFERENCES

[1] Ingun, "Tillbehor-ZUB_USB3.0-kontakter_EN_2.2.pdf," [Online]. Available: https://www.promoco.se/wp-content/uploads/2018/08/Tillbehor-ZUB_USB3.0-kontakter_EN_2.2.pdf. [Accessed 19 10 2023].
[2] FEINMETALL CONTACT TECHNOLOGIES, "2112159_TC-P_198_009_USB3A_EN.pdf," [Online]. Available: https://www.heynen.com/application/files/9016/1727/0172/2112159_TC-P_198_009_USB3A_EN.pdf. [Accessed 19 10 2023].
[3] ENGMATIC, Product catalogue, Test plugs, for functional tests and EOL tests.