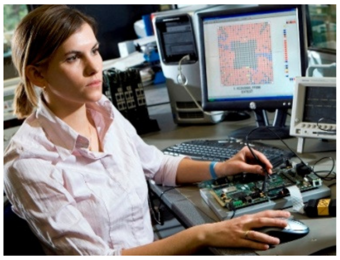

Optimizing the Cost of Production Test Equipment

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Introduction

Testing of new designs is best thought out at the very beginning. Managers must decide what to do about testing the new product in the early and later versions of a Product's Life Cycle.

This article describes the tradeoffs for creating electronic test equipment for the Final Test of a PCB Assembly or System. It describes the economics of testing at all product development phases, from Engineering Design to Manufacturing Final Test, QA Returns, and others. The least expensive place to consider testing is at the Early Design Phase. The costliest phases start at the beginning of the Final Manufacturing Test, especially after a series of field failures.

The considerations for each NPD phase are as follows:

1. During Pre-Design Phases

   During this phase, a decision should be made on the choice of the test system architecture. This choice significantly impacts the overall cost of tester development and production test costs. The architecture depends on several factors. These include:

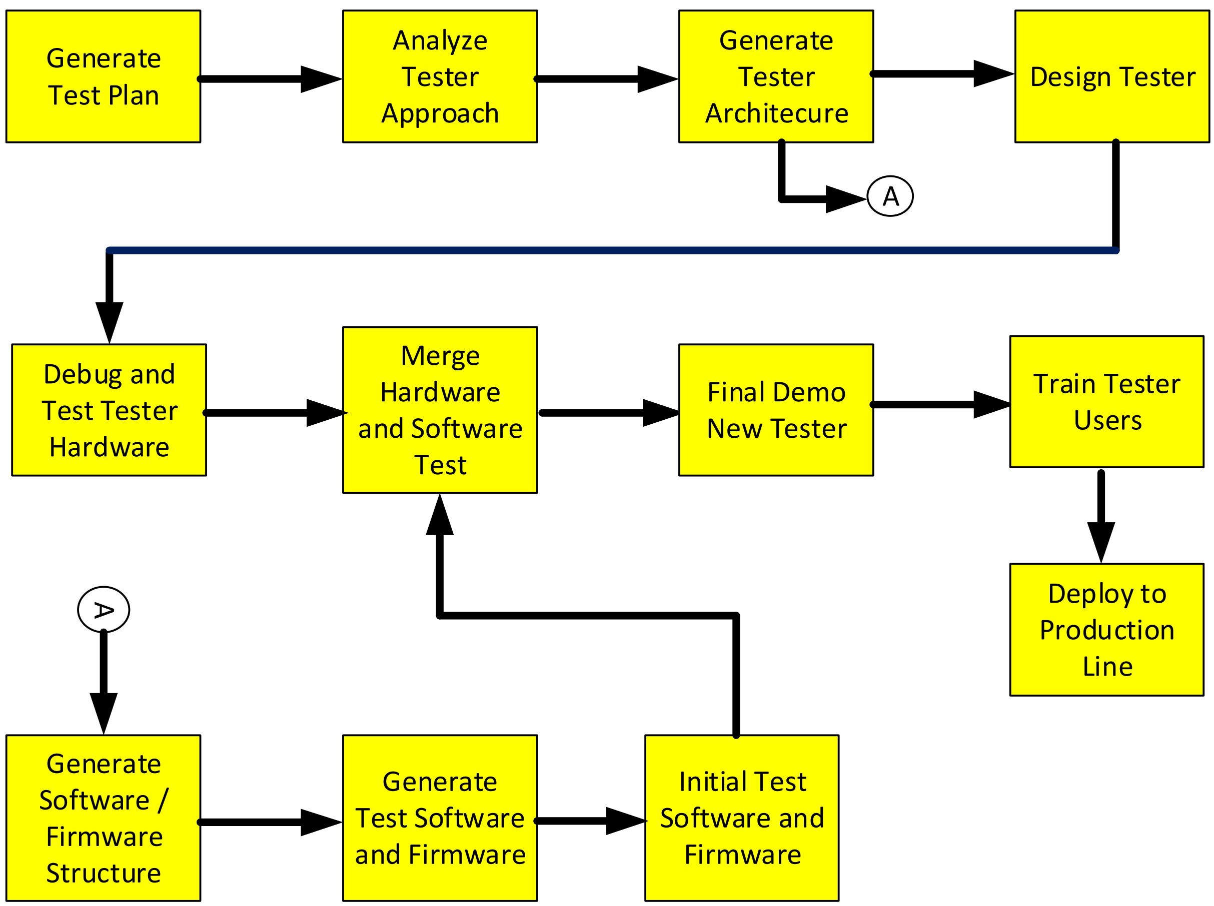
   - Experience with Building Such Testers
   - Final Cost of Device to be Tested
   - Volume Level of Nominal Build
   - Volume Level of the Estimated Life Cycle Build Total
   - Funds Available for Test System and Software or Test Procedures
   - Cost to Build the Tester and Write the Software and Test Procedures
   - Skill Level of Test Operator
   - Risk of Field Failures for Cost and Reputation Considerations
   - Cost of Field Failure Detection, Return, and Replacement

   To assist in the design process, Angotti Product Development has created a spreadsheet. It covers the tradeoffs between the above factors to make manual, semi-automatic, or automatic testers in practice. It is available in **Appendix 1** of this document.

2. During Engineering Product Development
   At this point, a good test plan can significantly increase test fault coverage and lower the overall cost for the final functional test (Design for Testability or DFT). This plan can include design-in of good test points and access to them, and the Built-in Initial System Test performed at power-up (BIST or Power-On Self-Test (POST), or Continuous Built-In Test (CBIT).

   Of considerable advantage is the plan for using high-level commands in the embedded code to perform System Test. These System-level tests can be used during the Development Debug and utilized in the final Manufacturing Functional Test. For board-level testing, the test designer makes use of the unique board-level JTAG port or ports. These tests can be used for lower-level debug or to expand some of the system-level tests available outside the firmware.

3. Tester Development Process
   Much like a typical New Product Development (NPD) process, a tester development process follows a plan with milestones that track the Tester Development process. This process would look something like this:



4. Pre- Production Functional Testing

   Pre-production testing is testing at the PCB Fab and Assembly level. Such testing would include testing the fabricated PCB for trace opens and shorts. Fab testing allows for the assessment of PCB manufacturing quality to catch problems before the PCB assembly.

   After the Assembly process is completed, PCBs can be visually inspected to a high degree using sophisticated optical comparison methods and electrical flying probe testing to potentially pick up problems such as bad parts and solder joints, faulty parts installation, among others.

   Testing at this level can achieve test coverage accuracy from 90 to 95%. Such testing today can be performed at a relatively low cost per PCB assembly.

5. During Low Volume Production, including batches of 10 to 100 builds

   This testing is performed on PCBs and Systems at the final Functional Test level. The intention is to catch about 99% or more of the electronic and potential mechanical functional failures. These tests can reduce returns significantly and impact the reputation of the fabrication house and the product design system company.

   a. There have been several approaches to produce Final Testing in the past. These include:
      For larger systems or multi-card assemblies – use a "gold standard" reference system and then substituted for a previously tested reference PCBs with the new UUT.

   b. This approach still requires generating the written final test procedures for final tests but can be one of the least expensive methods for producing hardware test facilities. This approach often has the requirement to have testing done by more highly skilled technicians or even the design engineers and can be very costly on a per-unit test cost basis.

   c. This testing also does not provide any automated capturing of test results data. It also doesn't allow for any margin testing of signal Input/Outputs.

   d. For Low production volumes of 10 to 100 units per month

   e. For this production level, custom manual or semi-automated testers for the Device under test (DUT) can be designed. This approach can work for a PCB Sub-Assembly or the testing of small systems or single PCB systems.

6. Manual Testing

   This level of testing involves the use of more highly skilled persons to perform the testing. The test person performs tests according to a written procedure and manually sets up inputs and assesses outputs. Test technicians or engineers often do this level of testing. If done intelligently, it can capture data reports for the DUTs tested and provide for margin testing, but it is usually costly and slow on a per unit UUT.

During high volume of production, much more expensive approaches are used to test to take advantage of high volume fully automated testers.

7. Semi-Automated Testing

   In this approach, Manual Testing is extended by having manual inputs and outputs manually selected. Then, if required, system-level test commands are sent to the DUT. In this case, the operator still assesses the PASS/FAIL of the test results. Often these tests can be performed by trained, lower-level test persons. Using this approach can reduce production test costs and lower the system input errors by sending repetitive commands to the DUT. The method is still prone to errors in input and output switching and interpretation of test results.

8. Automated Testers

   High Production Volume testing is where automated testers are genuinely needed, whether the DUT cost is low or high. At very high test volumes, sample testing instead of 100% screening is utilized. Such testers can often be quite expensive for both hardware and especially software.

   A clear case can be made for automatic testers in the complete system test except for lower production volumes. In this case, subassemblies usually use automated testing for sub-system DUTs. In such cases, a full-fledged test plan is a must.

   For System tests, high-level commands are often sent to the entire system, and responses are measured. These can be done using a semi-automatic or automatic testing approach, and measurements are done either automatically or by the operator.
   In automated testing, all system inputs and outputs are automatically switched, commands are sent to the DUT and measurements are made with automatic test equipment via a control program. The test results are then usually read by the test program and compared with the test program limits.

   Testing proceeds in an automated manner one after another until testing is complete. The measurements are often stored in an output file generated to keep track of the test results for later reference.

   Even during automated testing, occasionally, the operator utilizes hand probe testing. The program stops execution, the probe is placed appropriately, and then a command is issued to continue the program.

9. Testing a Very Expensive DUT

For an expensive or very expensive PCB DUT, test probe mechanical fixtures are generated that insert test probe pins at various internal points in the circuitry to permit signals' measurement. These test probes can be created semi-automatically from the formal fabrication drawings and can add significant additional expense to the Tester. They allow isolation of failures to a much smaller section of the board circuitry than just utilizing system Inputs and Outputs for measurements.

For this approach to be practical preplanned test points must be placed throughout the PCB layout design.

Of course, this approach must be coupled with the Fully Automated Test approach to be effective.

10. Future Newsletters

Future newsletters will discuss in more detail each of the testers described in this newsletter. Get on our mailing list by sending an email to carl@angotti.com and requesting to be included. You can learn much more about the test engineering services we provide by going to http://www.angotti.com/Test%20Engineering%20Menu.html .

Appendix 1 - Example Decision Spreadsheet

This section outlines a simplified method for using a business decision analysis tool to determine if a manual, semi-automatic, or fully automatic tester is suitable for a particular tester design. In such an analysis, each factor involved in a decision is listed in a spreadsheet for ease of analysis. This approach is then used by creating a checklist. If a factor is critical, that factor is given a one. If it isn't, then it is given a zero.

Then the sum of these factors is generated in the spreadsheet. In this example, the result of this sum ranges from 0 to 27. A range of these results is then assigned to determine a requirement of need for a manual, semi-automatic or automatic tester.

The decision-maker usually uses such an approach to improve over a simple "top-of-the-head guess," just using a single top-level gut feeling to choose which of these solutions is best. For such an analysis, the significant factors are taken into account one at a time instead of all at once. An approach like this often produces better results. The approach still involves mainly using a gut feeling judgment on each factor in turn. In the end, a final gut feeling check is used to see if the outcome makes sense.

For this improved approach, a value is given to each factor from say 1 to 3 or even 1 to 10. Finer resolution can add complexity to choosing the value so often. Just 1 to 3 is used. Assignments this would look like:

- 3 = High
- 2 = Med
- 1 = Low

Sometimes, the situation is reversed when the weighting is as follows:

- 1 = High
- 2 = Med
- 3 = Low

For example, for Factor #1, "Experience with Building this type of Tester," this might look like:

- High = Lots of experience with making such testers, say five years at it.
- Med = Some experience with building such testers, say having constructed at least one of them.
- Low = No experience at all with building such a tester

Or, for another example the Factor #7 needs inverted weighting, "Skill level of the Operator" might look like:

- Low = Using a much less skilled person to perform the testing rapidly with a minimum of intervention. (requires a more complex and automatic tester, especially for higher test volumes). Weight = 3

- Med = Using a lower skill level technician, or a person with considerable knowledge of the system (needs some automatic assistance, even if to improve speed and accuracy), weight = 2

- High = Using an Engineer or Advanced Technician to perform the tests (lessens the need for automatic testing). Weight = 1

This type of approach allows general "guesstimates" to be made in a more refined way. One should always see if the overall result makes sense. If not, perhaps some critical factors have been left out.

In the appendix example below, each word Hi, Med, and Low is automatically converted to its weighted number, and then the results are tallied. A high score means that an Automatic Tester should be used in this situation. A low score means that manual testing may be utilized. Manual testing is usually lower cost to design and write test procedures for, and Automatic testers leave judgment out of the situation. It is placed in the test software.

A detailed explanation for using and an Excel Spreadsheet for Calculations are available from APD. Email: carl@angotti.com and request one.

Example Evaluation Checklist for a Test Equipment Build Decision

Factors	Decision Factors	Value = Hi, Med, Lo	Factor Calculated Value
Factor 1	Experience with Building Similar Testers	Hi	3
Factor 2	Est. Final Cost of UUT	Med	2
Factor 3	Volume Level of Nominal Build	Med	2
Factor 4	Volume Level of Est Life Cycle Build Total	Med	2
Factor 5	Funds Available for Tester Project	Lo	1
Factor 6	Est. Cost to Build Tester and Write software or Test Procedures	Hi	1
Factor 7	Skill Level of Test Operator	Lo	3
Factor 8	Likelihood of Field Failure	Lo	1
Factor 9	Cost of Field Failure	Hi	3
	Computed Value of All Factors		**18**

Computed Value Ranges:		
Max Value	27	**Definitely Auto Tester is needed**
Mid Value	18	**Likely a Semi-Automatic Tester would work.**
Min Value	9	**Definitely, a Manual Tester is needed**