

Impact of Quality on Cost Economics for In-Circuit and Functional Test

Each step in the production process for a printed circuit board assembly (PCBA) or final product requires a sustained minimum standard to be of financial value. Too much test costs money, while not enough test can be a disaster later if the product ships with existing or non-identified problems. The accounting is clear, assuming equivalent product quality, every dollar eliminated from test costs goes directly to the bottom line.

Careful analysis of supplier alternatives to In-circuit and Functional test represents the difference between choosing a strategy that will last the product's life-cycle, or a solution that places burden on test costs. In cases, it can be more beneficial to invest additional resources at a specific step in the production process in order to avoid costs later, especially field-service and warranty-repair.

Corporate managers and procurement personnel often demand concrete accounting of cost-savings and benefits from test engineers and test managers when adopting a new solution. The purpose of this guide is to provide an overview of test costs so test engineering and management can more efficiently assemble a total cost-of-test. With a complete view of test costs, procurement is better able to justify superior solutions which may not be of the lowest initial investment.

Costs that result from attempting to sustain a low-quality test system or test fixture which demonstrates inconsistent device-under-test (DUT) interface mechanics or less than adequate measurements, adds extra burden through the entire total cost.

A key to any test purchasing decision is the final "best" strategy may not perform any one test step in the least-expensive way. Rather, it may minimize overall test costs.

Comparing Supplier Fixturing Assemblies and Test Solutions

An efficient method to comparing strategies for test involves calculating test capacity at full production. The below examples make the assumption that a production facility is operating fully in an attempt to help simplify understanding.

In-Circuit Test (ICT) Fixtures

Re-test or a repair loop absorbs manufacturing time that can be utilized on other products. For example, if the yield is 90 percent, for every 1000 boards tested, 100 require at least one retest.

How much does testing actually cost, and what do those costs include?

Below is a listing and definition of common economic costs required in most production environments. If already familiar, skip this section. In later sections, it will be shown which components have a large effect on total cost-of-test, and how often they are overlooked by management and procurement.

- **Startup costs**
- **Test equipment evaluation costs**
- **Equipment-acquisition costs**
- **Test-program development costs**
- **Training costs**
- **Labor costs**
- **Board or product repair costs**
- **Scrap costs**
- **Maintenance costs**
- **Spares cost**
- **Downtime costs**

The PCBA fixturing for an in-circuit tester has a large effect on yield. A good board that fails, enters the bad-board process loop, consuming precious test and diagnosis resources with no ultimate benefit. The variables of Labor and Repair costs, in addition to Maintenance costs, can quickly accumulate. In the end, the economic advantage to selecting the lowest price ICT fixture supplier disappears and can go negative.

Why select Circuit Check In-circuit test fixtures:

The investment to build a quality ICT test fixture that will last the product's life-cycle requires high performance components. Producing quality fixturing mechanics and accurate probe alignment requires state-of-the-art machinery and technical staff knowledge. The Return-on-Investment (ROI) for a CCI high-performance ICT fixture can easily pay for itself. Low cost fixtures often incur pre-mature failures or repeated maintenance. Low performance fixtures with poor quality probe pins, bushings, or fixture alignment adds to diagnostic work-in-progress (WIP) and rework.

The Cost of Test

Startup costs are non-ROI investments. Money must be spent, even if the test strategy is abandoned.

Test equipment evaluation costs accrue while considering the merits of various proposals or bids.

Equipment acquisition costs includes equipment, and may include the procurement overhead cost.

Test-program development costs depend upon the complexity of the PCBA or product tested.

Training costs often cover time and labor included in the solution investment, as well as cost of space for in-house training and supplier travel.

Facilities costs represent space for test and repair areas, including office space. The total fixed cost of a manufacturing and test facility does not change with production. As production levels fall costs increase.

Labor costs cover salaries and benefits for persons in the test activities. It is not unusual for full burden rates to be many times actual salaries.

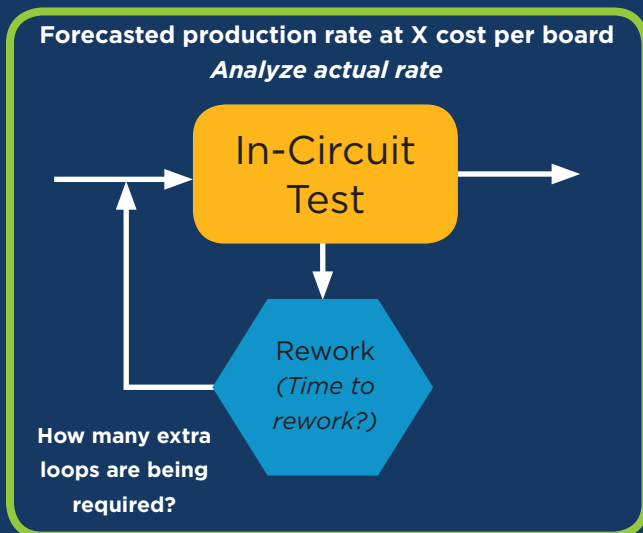
Board or product repair costs account for equipment: oscilloscopes, RF instruments, DMMs, and spare testers at a repair station. Labor cost for technicians is generally higher than for operators.

Scrap costs account for the value, including labor and materials that a scrapped product represents if it's decided not to repair the faulty product. This ignores that scrapping units requires raising production levels to ship the same products volumes.

Maintenance costs covers estimated costs for preventive maintenance. These costs can range from as little as .5% per month to as much as 15% percent per year of the equipment purchase price.

Spares cost is often allocated to inventory or maintenance costs.

Downtime costs for scheduled or unscheduled maintenance is a cost of lost production volume.



- False failures divert technician focus away from real failures.
- False failures often lead to unnecessary rework and retest.
- Unnecessary rework leads to extra labor and component costs that is not budgeted.
- Excess WIP due to repairs impact inventory levels.

✓ Functional Test Fixtures

To maximize throughput, functional test fixtures often perform go/no-go tests, for which bad-board and good-board test times are relatively close. Verses earlier test stages, test costs often increase more quickly in functional test due to longer repair diagnosis time and higher labor costs. It may be of lower cost to scrap a product verses the bench-time costs for a technician to diagnosis and repair. Good boards could be scraped, when perfectly operational.

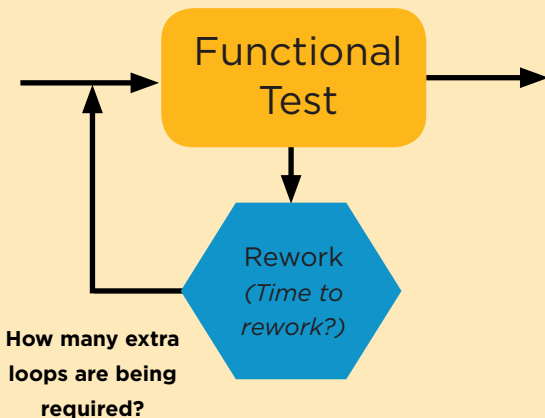
Failures in functional test affect the cost variables for rework Labor, Training, Test Equipment, Spares, among others. Similarly, false failures affect the cost for rework labor due to the level of workmanship required. All of these variables increase per unit build costs. For many suppliers, products with an unknown failure during functional or system test often end up as a Scrap cost.

- **Any issue resulting from a faulty test (i.e. downtime, false failures, etc.) in functional test often requires staff involvement from a more costly labor center to resolve.**
- **Intermittent test results often require attention from the engineering staff, and may leave the capital asset in a “down” condition until the issue is resolved.**

Why select Circuit Check functional test fixtures:

The investment to build a quality functional test fixture that will last the production life-cycle requires components of the highest performance. Tenured design expertise in fixture engineering is required to architect functional fixtures for RF, probe-based or through-connector. The ROI for a Circuit Check high-performance functional test fixture can easily pay for itself after one pre-mature failure from a low-quality fixture in a production line. Low quality functional fixtures have an exponential negative affect on manufacturing test costs.

Forecasted production rate at X cost per board
Analyze actual rate



Turn-key Testing Stations for PCBA and Product-level Functional Test

The challenge associated with quickly evolving products is that it complicates the test system development process; including electrical and mechanical design, software development, fabrication, system integration and deployment. Selection of test fixturing and the system enclosure is critical to the architectural design of a functional test station that meets today's complex test requirements. Additionally, quickly evolving products require staff that can quickly adapt to change. Complex technologies require personnel to have a broad knowledge in testing methods.

It is difficult for in-house test engineering teams to stay abreast of the latest test methods. For example, understanding the latest advancements that enable the same test system to be quickly reconfigured with new tooling for different products. Understanding that configurable drop-in fixturing can help achieve maximum value from fixture mechanics to test multiple products in the same family. Both, when architected properly, maximize equipment re-use while minimizing the cost for each new test.

Secondly, properly estimating the documentation requirements as part of an end solution, such as user manuals, tutorials and maintenance guides, is a common challenge in test engineering. These seemingly simple tasks are often overlooked by internal teams which in-turn absorbs expensive labor costs later, taking away from more important duties.

Lastly, a challenge often overlooked is forecasting employee attrition. When a core test engineer leaves a company, the knowledge goes with it. As many are aware, departed employees typically do not host a support contract to ensure the test station continues to operate in the future.

All of these challenges can lead to inadequate test architectures that cannot scale as product technology evolves, or to test systems that do not offer enough fault-coverage test capability. Failures and false failure costs in functional test will affect a multitude of the cost variables outlines, such as Test-program Development, Labor, Repair, Training, Test Equipment, Spares, Maintenance and Downtime.

- Staff often spend more time than budgeted installing a test system that is viewed as unstable.
- Lack of knowledge in designing-for-test (DFT) within a team, nor leveraging DFT through the organization, often results in higher product failure rates.
- Pressure on teams with limited resources often leads to a lack of proper acceptance testing and Gage R&R during the deployment of a test system.

Why select Circuit Check functional test fixtures:

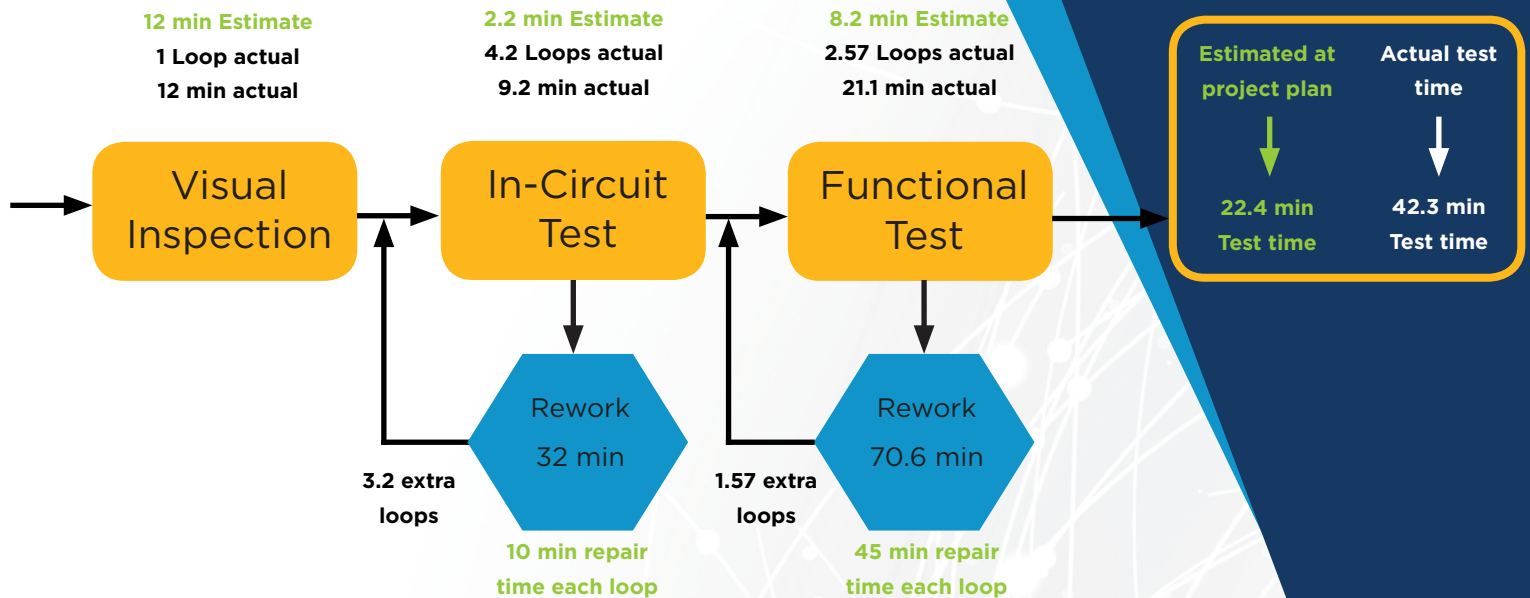
The investment to build a quality functional test station is large. The pressure to drive cost-of-goods downward is high. Test systems that are based upon modular technologies accelerate deployment and enable capital equipment reuse. Understanding best practice on how test architectures can lower costs, while at the same time, preserve measurement correlation to design and validation is paramount. Circuit Check high-performance functional test solutions achieve short return-on-investments. Circuit Check is an industry leader with over 40 years' experience building test solutions each day. Circuit Check customer configurable test stations can be designed with manual, pneumatic, automated, rotary or in-line fixturing to satisfy any production capacity requirements.



Example Cost Analysis

The following example is a flow diagram of a typical production line, and demonstrates the importance of selecting high quality ICT and Functional test solutions. This simple financial example shows that it does not require high volume production for poor quality fixturing or test solutions to have a negative effect on test cost economics. The following is example data that can be replaced with the reader's actual internal data.

Units and Yield:	Build quantity of 1000 boards, a first pass yield of 75%
Rework loops:	The 'average' number of times the unit passed through each rework loop is listed. This is the average number of loops across the population of units tested. Data shows the total test time the average unit was handled when the product went through each process (# loops multiplied by test time).
Labor Rate:	In-circuit/Functional Test: \$15.00/hour Operator rate \$30.00/hour Rework station Technician rate \$60.00/hour Test Engineer rate Factory Productivity Cost: \$70.00/hour Factory full burden rate



Costs of re-test and rework at In-circuit test:

- On average, 250 units of the 1000 did not pass first test at in-circuit test
- $9.2\text{min actual} - 2.2\text{min estimated} = 7\text{min}$ of retesting per unit
- Cost at Operator labor rate = \$1.75 per unit ($\$15/\text{hr} = \$0.25/\text{min}$)
- Cost or labor to review failure and diagnose if false-fail or rework (ave 3.2 loops per board) = \$16.00 per unit ($\$30/\text{hr} = \$0.5/\text{min}$, 10min repair time per unit)
- Total cost per unit in labor = $\$1.75 + \$16.00 = \$17.75$ per unit
- **Underestimated cost of 250 units on 1000 unit lot = \$4437.50**

Costs of re-test and rework at Functional test:

- On average, 250 units of the 1000 did not pass first test at Functional test
- $21.1\text{min actual} - 8.2\text{min estimated} = 12.9\text{min}$ of retesting per unit
- Cost at Operator labor rate = \$3.22 per unit ($\$15/\text{hr} = \$0.25/\text{min}$)
- Cost or labor to review failure and diagnose if false-fail or rework (ave 1.57 loops per board) = \$35.30 per unit ($\$30/\text{hr} = \$0.5/\text{min}$, 45min repair time per unit)
- Total cost per unit in labor = $\$3.22 + \$35.30 = \$38.52$ per unit
- **Underestimated cost of 250 units on 1000 unit lot = \$9,630.00**

Costs of lost productivity due to Quality:

- Production run at project plan = 1000 units
- Time estimated at project plan = 22.4min per unit
- Time actual = 42.3min per unit
- Factory productivity cost = \$70.00/hr
- Total costs in lost productivity due to poor quality = $(42.3\text{min} - 22.4\text{min}) \times 250 \text{ units} / 60\text{min} = 82.91$ Hours
- **Lost productivity caused by the 250 units on the 1000 unit lot = \$5803.7 ($82.91 \times \$70/\text{hr}$)**

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The Leaders in Automated Test Solutions & Interfacing Technology

For over 40 years Circuit Check has been a leading edge provider of custom engineered test solutions to the electronics industry. The company began as a bare board testing service in 1979. As our clients' needs for test equipment grew more sophisticated, we evolved to meet those requirements with innovative new products and processes.

Circuit Check continued to invest in our engineering staff, creating one of the largest and most experienced engineering groups within the industry.

Circuit Check's global footprint and technology-enabled services facilitate our electronics manufacturing customers to take advantage a smooth transition from low-volume to high volume production. Our test solutions;functional test systems, analysis software and test engineering services, can be deployed to any region on the globe.

Summary

Accurately comparing testing alternatives requires understanding benefits, actual savings and cost avoidance compared to no test or another strategy. The best strategy is not necessarily the lowest-cost alternative, but the one providing the best payback for money spent. Questions to think ask the next time management challenges budgeting for newer more advanced test technologies.

- What is the cost of late shipments, expedited shipping?
- What is the cost for field failures, RMA's?
- What is the cost of a lost customer?

With a test solution from Circuit Check, accelerate deployment of products at a reduced cost of test. Innovation and the ability to get products to market fast are driving a call to action for more robust and repeatable processes that can minimize the risk of product failure and protect brand owners from product launch failures and damaged customer satisfaction. Circuit Check solutions integrate information and action to increase overall product quality and drastically reduce product return rates.



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