Automated Controlled Impedance Test Equipment
Cost Justification Analysis

May 3, 2006

Table of Contents

General Information

This document is a detailed description of the commercial and technical justification for the acquisition of an automated controlled impedance tester to provide production testing of PWB for the high frequency properties.

Corporate Need

This section summarizes the technical and financial reasoning in the equipment acquisition.

Roadmap Requirements

Hold +/-5% (manual test methods and some manual testers lack of precision to measure to this tolerance)
Propagation Delay Data
Interconnect Loss Data
Smaller line widths will be more affected by variability in measurement

Capacity Requirements
High percentage of product is controlled impedance
Demand for more high frequency data leading to longer test times

Labor Requirements
Rising labor cost
Shortage of skilled manual operators
Reduce Repetitive Motion Disorder
Reduce operator turnover and training costs

Customer Requirements
Customer demand for not only hitting the window but also hitting the target (variance reduction)
Customer coupons or in-circuit test points (image area traces)
OEM customers stating TDR test risetimes as threshold for Tier level approval
OEM customers requesting Prop Delay and Interconnect Loss measurements

Process Requirements
Full compliance with IPC TM-650 Test Standards
Higher measurement bandwidth to better simulate and characterize actual product attributes
Simplify high frequency characterstics failure analysis
Control process more accurately (fewer false failures)
Improvement in test precision to tolerance ratio (P/T)
Keeping current with technology

Solution Definition

CI1000 Automated Controlled Impedance System

Capabilities
Single-ended TDR Measurements
True Differential TDR Measurements
High Frequency Data Collected

- Impedance
- Propagation Delay
- Propagation Velocity
- Effective Er (Dielectric Constant)
- Interconnect Bandwidth
- TDR Waveform capture

IPC TM-650 2.5.5.7 Test Standard Compliant
Simplified Data Entry Screens for Test Program Generation
Automatic Test Program Generation and CAM Download
Data storage compatibility with Accu-Prober System
Extensive Test Report Generation (including Histograms and Out-of-Center reports)

Reporting of Impedance, Delay and Bandwidth for both sides of Differential pair
Programmable Threshold for Prop Delay Measurements
Selective CI Test Results Verification
Automated system calibration procedure
Automated system verification procedure for impedance and prop delay
Operational Event Logging
Interface to Tektronixs TDS8200
Rotation of probe assembly to probe all test pad orientations
Handles boards as small as 5.25" x 0.5" and panels upto 36" x 28.5"

Hardware

Robot Assembly
Four (4) axis robotic system, X,Y,Z,θ
Working envelope: 1000mm (39.3") x 750mm (29.5") with
360 degree rotation and extend/retract capability of 225mm (8.9")
Robot Speed: 65 inches/sec

Operators Station
Flat panel monitor (Black)
Keyboard (Black)
Mouse (Black)
Ergonomic swing arm
PC computer has a minimum of a Pentium processor, 1GB ram, 80 GB hard disc,
10/100/1000BaseT ethernet port, One GPIB card

Panel Holder Fixture
Movable Tooling Pins for multiple panel sizes
Board Support Pin Hole Grid System and movable spring pins

Calibration/Verification Station
Precision Calibration Airline: 50Ω
Robotic Landing Area
Airline Mounting assembly

Tool Changer System
Probe Tool Stand-Holds upto 4 probes
"Probe Available" sensors
Probe Tool Changer-Robot side include Probe ID system

Guarding and Operator Access Area
Robotic guarding
Operator front access light curtain
Probe access door
Door interlocks

TDR Instrumentation Interface
Two (2) Meter Sampling Head Extension Cable
Sampling Head Mounting Bracket
Two (2) Meter GPIB Cable

Base Table
Wheels: Four(4)
Electronic cabinet with three (3) doors
Leveling legs: Four (4)

Probes
IBC Single-ended TDR Probe (Pitch: 100mil)
IBC Differential TDR Probe (Pitch: 100mil Square)

TDR Meter
Tektronix TDS8200 Digital Sampling Oscilloscope
Mainframe-Certificate of Traceable Calibration Standard
Tektronix TDR Electrical Sampling Head
Model #80E04 Sampling Module, 20GHZ w/TDR
Certificate of Traceable Calibration Standard

Software
CI1000 System (one license)
- Full TDR test capabilities as listed above

CI Report Writer (unlimited site license)
- Data filtering (date, operator, customer, PN#, Order#, Pass/Fail, etc)
- Sort and Display by Layer number or Serial Number
- Export to MSExcel, Adobe Acrobat, etc.
- Display full statistics, histograms, and Out-of-Center reports

TDR Waveform Viewer (unlimited license)
- Off-line viewing of captured TDR Waveforms
- Allows easy selection of impedance measurement zone.
- Displays end and midpoint VIA affects.
- Dynamic cursor provides readout of impedance along entire trace.
- Creates printouts for documentation purposes.

CI CAM Importer (unlimited site license)
- Automatic generation of Test Program thru importation of IPC data
- Eliminates loss test time due to utilization of test equipment to generate test programs

Support
Site Installation and full site inspection
Operations and Maintenance Training (at installation)
Operations and Maintenance Manuals
Application Engineering Assistance (throughout warranty period)
Preventative Maintenance Site Visit (twice within warranty period)

New Process Capabilities

Improve etch process (Put 5% back into the precision of the etch process through the addition of repeatable test result equipment)

Achieve Impedance tolerance +/5% by eliminating test equipment measurement error (Precision-to-Tolerance Ratio (P/T) < 5%) and providing accurate measurement feedback loop to achieve specification. (Note: Standard manual probe stations achieve no better than P/T=120%- 6Sigma value =6ohms with USL-LSL=5ohms.)

Measure other higher frequency material and finish board properties:

-Prop Delay (Characteristic of laminate only)
Quality check on laminate supply (Dk)

-Loss (Characteristic of laminate and copper)
Quality check on laminate supply (Dk, Df, foil-to-core interface) and etch process

Enhanced process analysis capability – Precision measurement tool to monitor out-of-center process and data to enable faster failure analysis (differentiate laminate vs. etch problems)

Eliminate test bottlenecks. "TDR room" no longer source of shipment delay.

State of the art capability

Ability to achieve or surpass customer roadmap goals

Test at higher TDR signal frequencies (Older capability: 1.5 GHz, New capability: 14 GHz) (Newer customer requirement for TDR testing)

Total Cost of Acquisition

Table 1 Total Cost of Acquisition

Cost Item	**Budgetary Cost**
Equipment	$335,000
Transportation	$ 1,800
Consumables (1 Year)	$ 3,500
Installation	Included
Training	Included
CAM software support[1]	$ 40,000
Facility Support[2]	$ 5,000
Budgetary Total	**$385,300**

Note[1]: In order to maximum the capability of the automated test equipment it is necessary to automated the software generation of the test program which may require software programming from the CAM department.

Note[2]: Equipment requires minimum facility utilities and minimum support for installation.

Cost Savings and Revenue Gain

Cost Savings

Direct Labor – Experienced personnel can be re-assigned to other critical work areas.

Operating Expenses (Floor space, consumables) - Floor space reduction over equivalent manual stations. Consumables will decrease. Overhead support will decrease.

Training cost – Reduction in direct labor requirements will reduce the manpower training costs. The skill level needs of the operator will decrease.

Throughput savings due to test time reduction – The ability to test quickly reduces the amount of time product is in the TDR work area and the ability to eliminate bottlenecks within the department will increase throughput. An improvement of one (1) day of turn time will increase revenue (Plant Revenue $100Mil / 365 days/year =) $260,000 or reduce costs by $200,000.

Savings from impedance failure due to better test equipment accuracy. With a 1% failure rate through TDR testing and a false failure rate of 5% due to inaccurate test equipment, the cost of false failures is $50,000.

Ability to more accurately control etched line widths and material variations (increase yields). The accuracy and repeatability of the test equipment allows the tighter control of etched line widths. Defer the need for more expensive etch equipment. (Savings: $500,000)

Cost of Failure analysis: Ability to more quickly determine failure or out-of-center conditions. Reduce the time for root-cause analysis and reducing scrap. Reducing engineering time (Savings: $100,000)

Eliminate repetitive motion injuries due to hand probing. (Insurance and legal costs: $75,000)

Revenue Gain

New Customer - Qualify for board builds previous unable due to limited process control or test equipment specification requirements. (Revenue Gain: $500,000- $2Mil)

Higher Tier Supplier – Qualify as a higher tier supplier with existing customers. (Revenue Gain: $500,000- $2Mil)

Quick turn price opportunities – Better ability to consummate quick turn opportunities with increased throughput and failure analysis capability. (Revenue Gain: $300,000)

Achieve full compliance with IPC TM-650 2.5.5.7 TDR Test Requirements. Prevent loss of customer or dispute over test results. (Revenue Gain: $100,000)

Satisfy customer requirements including:
Measure image area traces
Measure Dielectrics(Er) and trace Propagation Delay
Measure Trace Signal Integrity (Bandwidth)
Accurate test data
State of the art equipment
(Revenue Gain: $300,000)

Table 2 Costing Savings and Revenue Gain

	Benefit Description	**$ Current**	**$ Saving**
Cost Savings			
1	Direct Labor	584,00	318,000
2	Operating Expense	10,000	4,000
3	Training	25,000	20,000
4	Throughput Improvements (1 day savings)	200,000	200,000
5	Not failing good boards	50,000	50,000
6	Reduction in failure analysis	150,000	50,000
7	Reduction in repetitive motion injuries	75,000	75,000
8	Better process control – etch process	500,000	500,000
	Cost Savings Sub-total		$1,217,000
Revenue Gain			
1	New Customers		2,000,000
2	Improve Tier level supply with existing customers		2,000,000
3	Improve Quick Turn revenue opportunities		300,000
4	Achieve Customer test requirements (IPC Test Standards)		100,000
5	Ability to accept jobs with customer coupons or image area traces with less cost		300,000
6	Ability to accept +/-5% impedance jobs		500,000
	Revenue Gain Sub-total		$5,200,000

Comparison to Current Technology

The existing common equipment used today for TDR test comprises the following attributes:

Manual Test Station – Hand probing of all test traces
Repeatability: 1.0 ohms
Precision-to-Tolerance Ratio: 60% (50ohm impedance level +/-10%)
Accuracy: +/-0.5 ohms
Reproducibility (Operator-to-operator): 2 ohms
No automated method for collecting prop delay or bandwidth
Image Area (or customer coupons) testing very difficult
Differential testing is not in compliance with IPC TM-650 test standards
Tremendous amount of repetitive motion required of operators

What are the Future Requirements?

The following elements are typical of technology roadmaps:

+/-5% impedance
Propagation Delay Data
Interconnect Loss Data
Smaller line widths (while holding or improving impedance tolerance)
Customer demand for not only hitting the window but also hitting the target (variance reduction)
Customer coupons or in-circuit test points (image area traces)
Full compliance with IPC TM-650 Test Standards
Test at higher TDR frequencies (e.g., 5 GHz)

Quality Considerations

The following quality issues should be considered:

Final test equipment must be as accurate as possible to ensure bad product is not being shipped to the customer

Tighter control over the process through an accurate feedback method will ensure that yields are improved and quality focus is placed where it is needed (e.g., inspection of raw laminate).

More accurate test equipment will lead to less test result correlation problems with the customer and raise the customer understanding of the quality of the produced product.

More accurate and better repeatability of the test equipment and the availability of more test data will lead to faster and more accurate failure analysis and will reduce scrap rates.

Alternatives

Fixture based test solutions.

Technology Risks

The CI1000 Automated Controlled Impedance Tester is 5 years old and there has been multiple installations with many years of 24/7 operations. Others have worked out problems and minimized the risk.

How is ROI going to be verified

The following tools/system will be utilized to track the anticipated return on investment (cost saving and revenue gain).

Impedance test point tracking
Impedance to non-impedance job mix
Customer tier improvements
# of customers
Safety improvement metrics
Average turn metric
Cost of Labor for TDR test work center

Conclusion

There is substantial justification for the investment in an Introbotics Corporation CI1000 Automated Controlled Impedance Tester. The technology is sound and proven, there is broad industry acceptance (including customer base) of the technology, and the cost benefits and revenue gain are sufficient to provide a substantial and early return on investment. Major benefits include:

1) Increase TDR test throughput .
2) Eliminate TDR test bottleneck.
3) Reduce operating cost of TDR test.
4) Eliminate repetitive motion injuries due to hand probing.
5) Satisfy customer requirements including:
    a) Measure image area traces
    b) Measure Dielectrics(Er) and trace Propagation Delay
    c) Measure Trace Signal Integrity (Bandwidth)
    d) Accurate test data
    e) State of the art equipment
6) Achieve full compliance with IPC TM-650 2.5.5.7 TDR Test Requirements.
7) Ability to more accurately control etched line widths and material variations (increase yields).
8) Ability to provide +/-8% or +/-5% impedance tolerance at a lower cost.
9) Eliminate shipping failed boards or scrapping good boards.
10) Ability to more quickly determine failure or out-of-center conditions.