PCB精確阻抗量測及不同方法之相關驗證

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Agenda

- **TDR Basic**
- Challenges to Obtain Measurement Accuracy and Correlation
- E5063A ENA Series PCB Analyzer Introduction
- Summary

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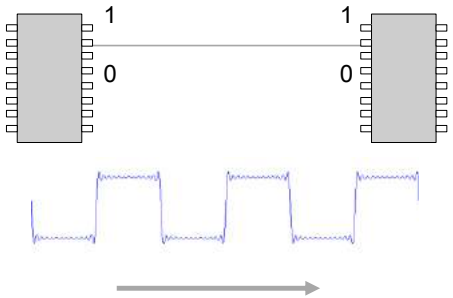
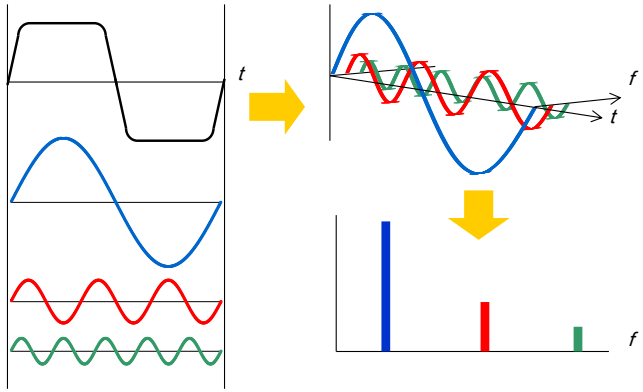
» Will digital signals operate by merely being connected?

Signal Propagation



Looking at a Signal's Wave Form Through Its Frequency Axis

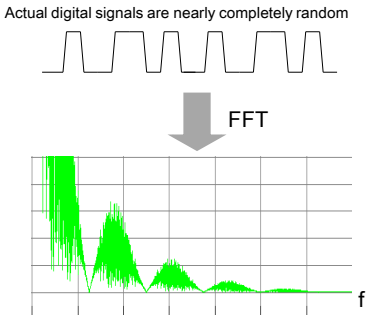
» A pulse is a combination of sine waves

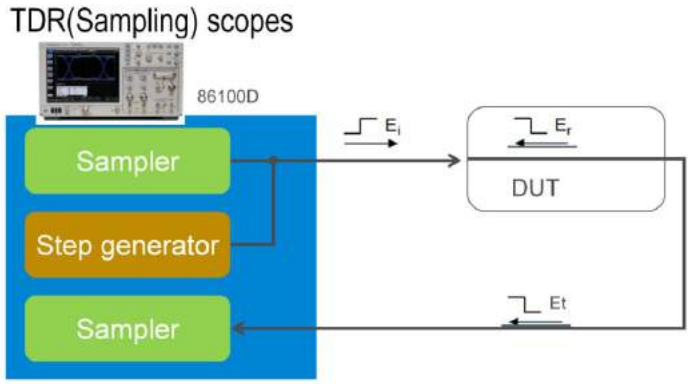


- The Relationship Between Tr, Tf, and Signal Bandwidth
  - Knee Frequency

Signal Rise Time and Bandwidth

$$Bw_{[Hz]} = \frac{0.5}{Tr_{[s]}}$$





Block diagram (TDR Scopes)

Input step signal, and derive impedance/loss from reflection/transmission measurements

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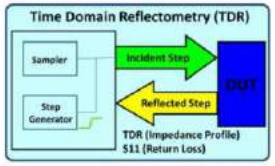
Quick Review – TDR



Time Domain Reflectometry (TDR)

- Impedance measurements
- Locate the position and nature of each discontinuity
- Propagation/Time delay
- Excess Reactance (Capacitance or Inductance)
- Effective dielectric constant

What TDR edge speed should I use?

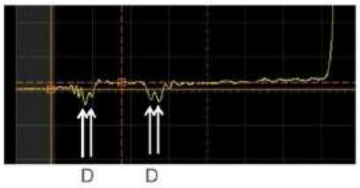
Edge speed determines two important parameters:

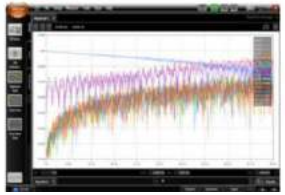
1. **TDR Resolution:** The faster the edge, the closer two impedance discontinuities can be identified as separate events on the TDR trace.

$$D_{min} = \frac{c \bullet t_{rise}}{2\sqrt{\varepsilon}}$$

- $t_{r_{system}} = \sqrt{t_{r_{step}}^2 + t_{r_{scope}}^2}$
- ε = dielectric constant of the transmission system
- c = speed of light in a vacuum.

For ε = 4 and system rise time of 8 ps, D_{min} < 1mm.



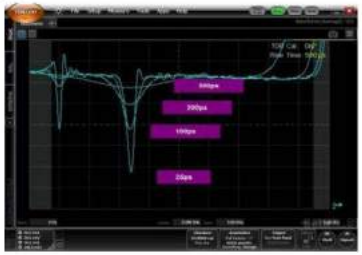


2. **Max S-parameter frequency**
   A step with a fast edge has higher frequency content and enables S-parameter testing to a higher frequency.

What TDR edge speed should I use?

Select a solution based on your application:

- **Too fast:** you'll see impedance discontinuities that will not affect the real signals in your design (you'll waste time fixing things that do not matter)
- **Too slow:** discontinuities are masked



Choose your TDR edge speed:

1. Full Characterization "Rule of Thumb": use TDR edge speeds that are minimum 2x faster than the rise times of your design
2. Compliance Test: use 20%-80% TDR edge speed specified by Standard

TDR Two-Event Resolution (Spatial-Resolution)

– To increase the two-event resolution of the TDR system, three items are considered:

1. Increase the speed of the step generator
2. Increase the bandwidth of the oscilloscope
3. Minimize the bandwidth-limiting effects of the test system
   - minimize use of adapters, cabling
   - use good quality fixturing
   - compensate for losses using TDR calibration (de-embedding)

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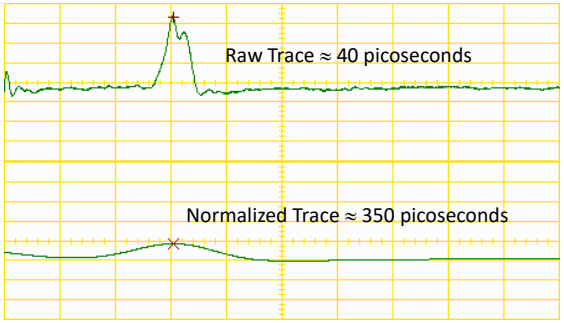
Rise Time and Distance Resolution

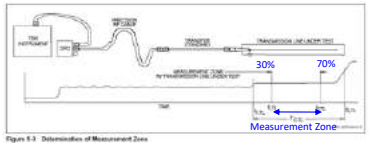


Target Market, Applications, and Customers

[Demo] PCB Characteristic Impedance Measurement

Measurement:

•Characteristic Impedance of single-ended transmission line, within measurement zone defined below



[Reference] IPC-TM-650 Test Methods Manual Characteristic Impedance Lines on Printed Boards by TDR
http://www.ipc.org/4.0_Knowledge/4.1_Standards/test/2-5-5-7a.pdf

Procedure Overview:

1.Set measurement conditions
2.Define measurement zone
3.Set the measurement zone and measure characteristic impedance

Setup:

VNA-TDR-DEMO-01
(For Demo Purpose Only, Not for Sale)

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IPC-TM-650
TEST METHODS MANUAL

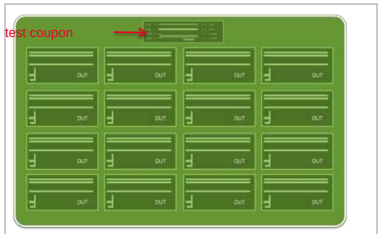
For a given length of transmission line to be measured, the resolution should not exceed one fourth (0.25) of the available length, L_{TL}, of the transmission line. Table 4-I provides examples of required resolution for typical surface microstrips in air, and on FR4 circuit board ($v_p \approx 2x10^8$ m/s), for a given TDR system risetime.

Table 4-I Resolution of TDR Systems

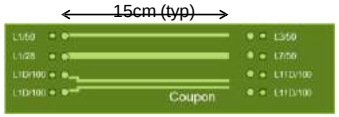
TDR System Risetime	Resolution	4X Resolution
10 ps	5 ps / 1 mm [0.04 in]	4 mm [0.16 in]
20 ps	10 ps / 2 mm [0.08 in]	8 mm [0.31 in]
30 ps	15 ps / 3 mm [0.12 in]	12 mm [0.47 in]
100 ps	50 ps/ 10 mm [0.39 in]	40 mm [1.57 in]
200 ps	100 ps / 20 mm [0.79 in]	80 mm [3.15 in]
500 ps	250 ps / 50 mm [1.97in]	200 mm [7.87 in]

5.1.3 Establishing the Measurement Zone The value of the measurement zone is critical to the accuracy and repeatability of the TDR measurement process. Measurement zone differences are a large factor in correlation problems between measurements. The measurement zone should be set repeatability for each transmission line independent of the type of dielectric material surrounding the transmission line or its structure (surface microstrip, embedded microstrip, stripline, differential pair, etc.). The following process can be incorpo-

Traditional PCB Measurements

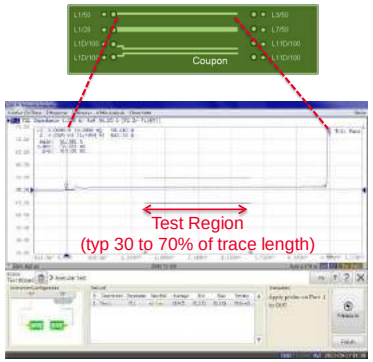


•Test Coupon Example:



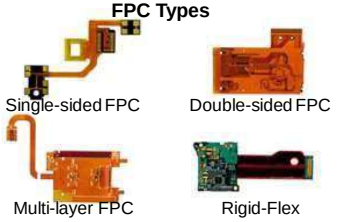
•Parameters = Impedance (SE & DIFF)
•Required Tolerance = ±10%

•L1/50 trace measurement example



FPC Types and Applications

FPC Types



FPC Applications

- Camera module
- LCD module
- Touch sensor panel
- Antenna

Measurement Requirements:

- FPC trace is measured, rather than coupon. Since trace length is short, higher response resolution is required.
- Due to increase in data rates, tighter impedance control requirements are increasing. (± 10% => ± 5 ~ 8%).
- S-parameter required for FPC antenna. VSWR (S11) measured in production. In addition, impedance and isolation (S21) are typically measured in QA.

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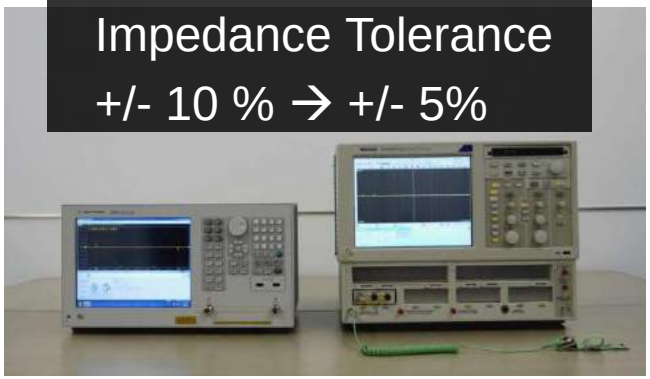
Problems with TDR Oscilloscopes

1. Inadequate measurement accuracy
2. Measurement results can differ between channels or instruments

Measurement Accuracy Verification

Impedance Tolerance
+/- 10 % → +/- 5%



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Measurement Setup

TDR Oscilloscope

Measurement Cables

Blue

Purple

NIST Traceable Standards

50Ω Airline

Reference for error compensation

25Ω Airline

Device for measurement result comparison

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Measurement Accuracy with TDR Oscilloscopes

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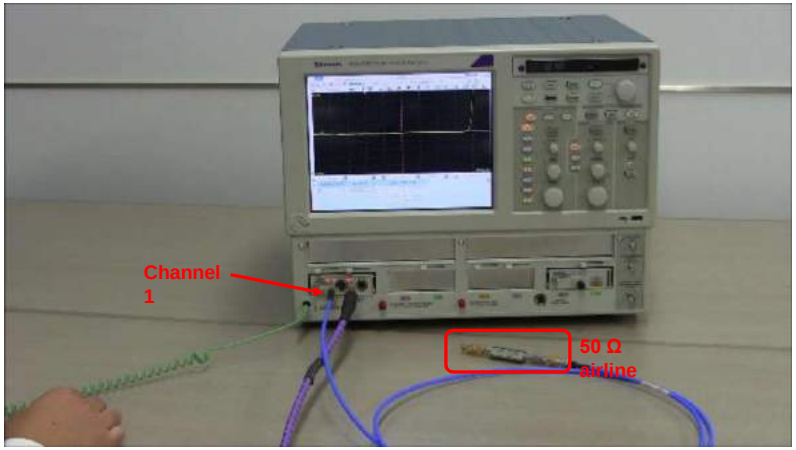
Measurement Setup

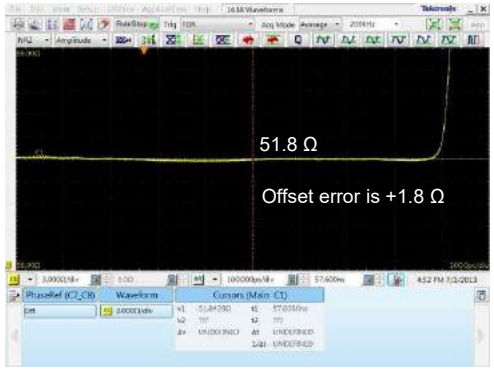


Offset Error Measurement at Channel 1

60 Ω

50 Ω
(airline)

40Ω



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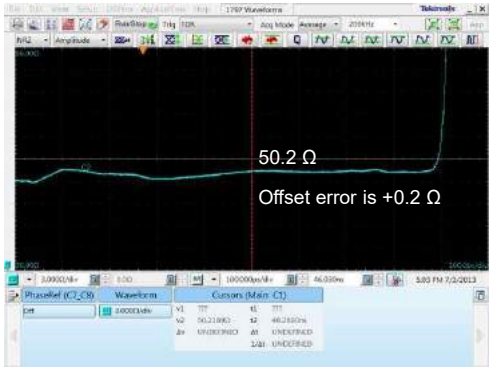
Offset Error Measurement at Channel 2

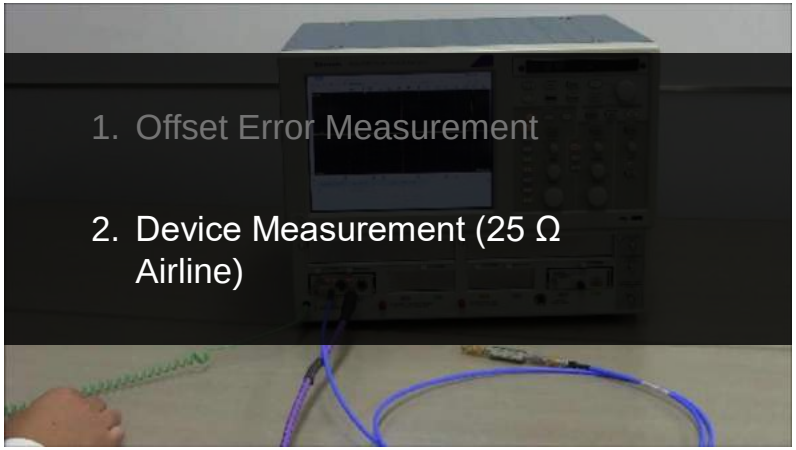
60 Ω

50 Ω
(airline)

40Ω



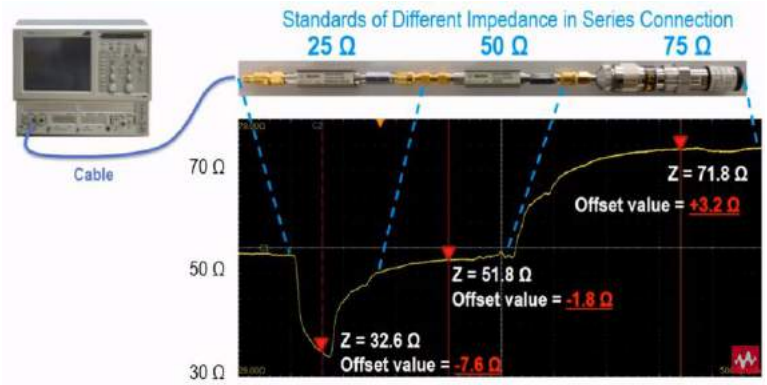
Measurement Accuracy with TDR Oscilloscopes



Measurement Results Comparison

Measurement Accuracy with TDR Oscilloscopes

Considerations for Offset Compensation



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What is E5063A ENA Series PCB Analyzer?

E5063A ENA Series PCB Analyzer
The Best Solution for PCB Manufacturing Test

- More Accuracy and R&R*
- More Languages Supported
- More ESD Robustness

… also the lowest cost solution in the industry.

* Repeatability & Reproducibility

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Dedicated GUI for PCB Manufacturing Test

Similar look-and-feel to traditional solutions

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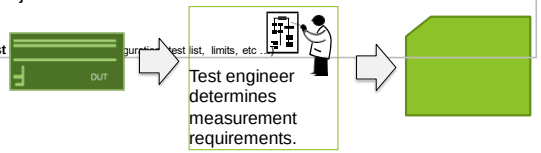
Modes of Operation

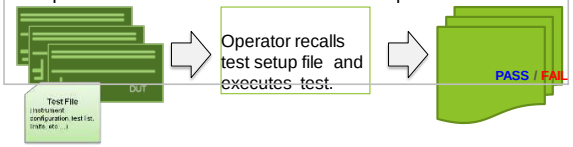
Edit Test Mode

•Integrated test file editor allows test engineers to create files with just a few mouse clicks



Execute Test Mode

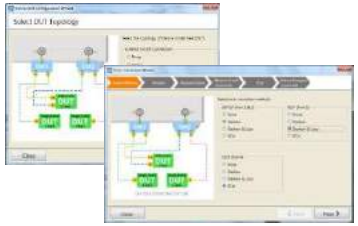
•Simple and intuitive GUI for non-technical operators



Edit Test Mode

Setup and Error Correction Wizards

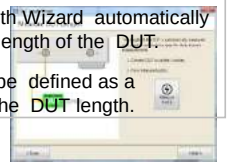
Intuitive and error free setup, error correction, and measurements.

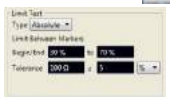


Dedicated controls for common adjustments

The DUT Length Wizard automatically measures the length of the DUT.

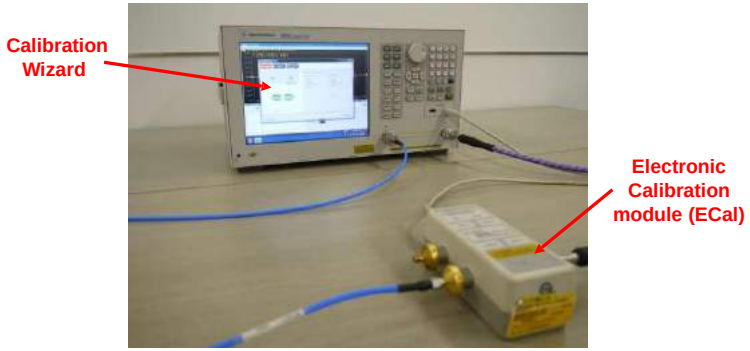
Test limits can be defined as a percentage of the DUT length.





Accuracy Verification (Measurement Setup)

Accuracy Verification (Performing Full Calibration)



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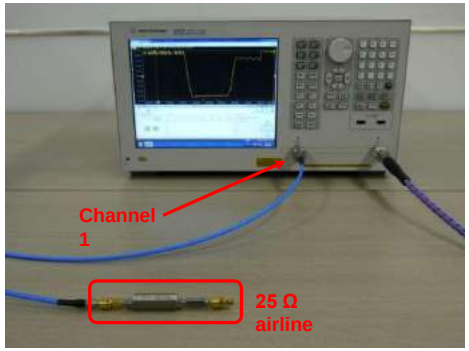
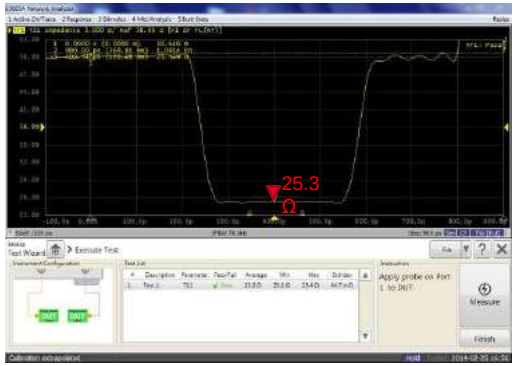
Accuracy Verification (Performing Measurements)



25 Ω Airline after Full Calibration (Channel 1)



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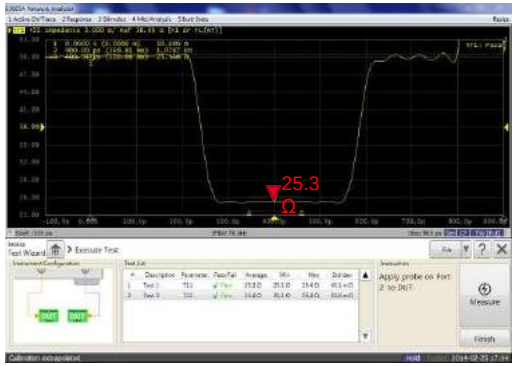
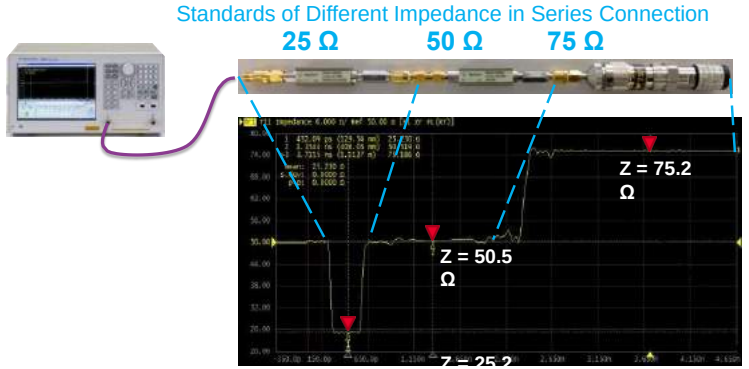
25 Ω Airline after Full Calibration (Channel 2)



Measurement Accuracy after Full Calibration



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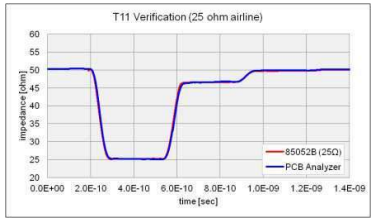
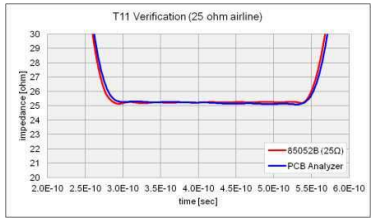
Accuracy Verification using a NIST Traceable Standard

Measurement results are within 0.1 ohm of 25 ohm airline standard.

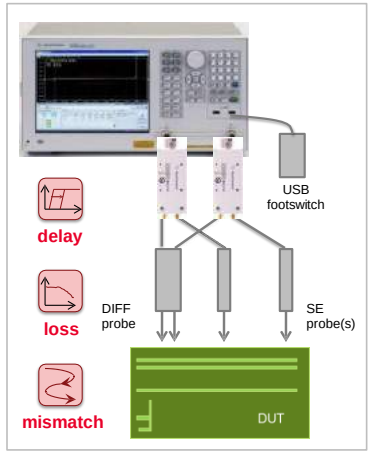
DUT: 25 ohm airline (85052B Verification Kit)

The verification kit includes measurement data and uncertainties which are traceable to National Institute of Standards and Technology (NIST).





Why Error Correction?



Measure your device, not your measurement system.

Cables, probes, switches, and fixtures are no longer ideal at today's data rates.

To get the most accurate information about the device under test, you must account for errors introduced by your measurement system, such as **delay**, **loss**, and **mismatch**.

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Error Correction Method Comparison

Two common types of error correction methods:

Deskew

- Commonly used in time domain instruments
- Simple to perform
- Only corrects for delay

Full calibration (ECal)

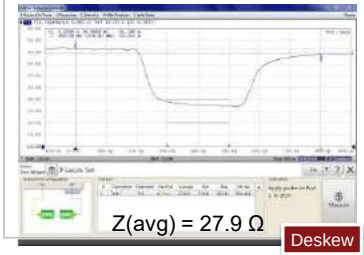
- Commonly used in frequency domain instruments
- Requires more standards
- Accounts for all major sources of error

Accuracy Considerations

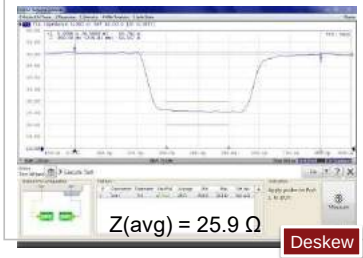
Same DUT with different test cable lengths, results in very different impedance values.

85053B NIST Traceable 25Ω Airline

150 cm test cable



30 cm test cable



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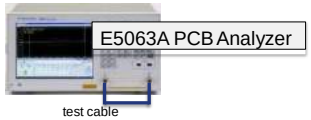
Accuracy Considerations

Cable loss affects measurement results.



Rise Time = 35 ps

150 cm test cable

Rise Time **Insertion Loss**

・Actual rise time：**58.5 ps**
・Insertion Loss：**4.4 dB**

30 cm test cable

Rise Time **Insertion Loss**

・Actual rise time：**40.6 ps**
・Insertion Loss：**1.9 dB**

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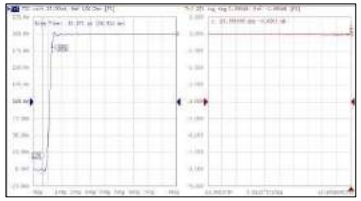
Accuracy Considerations

Cable loss is removed by calibration.

Rise Time = 35 ps

150 cm test cable

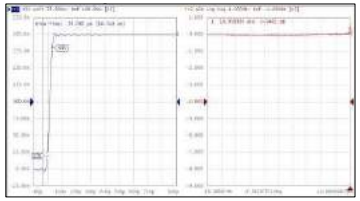
Rise Time **Insertion Loss**



・Actual rise time：**35.1 ps**
・Insertion Loss：**0 dB**

30 cm test cable

Rise Time **Insertion Loss**



・Actual rise time：**35.1 ps**
・Insertion Loss：**0 dB**

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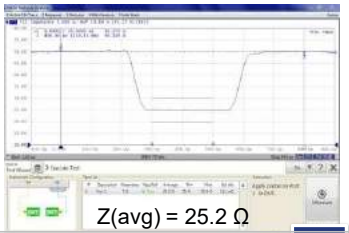
Accuracy Considerations

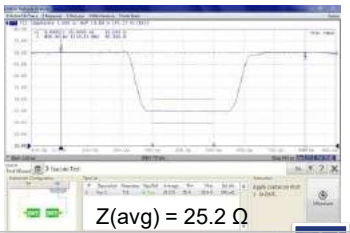
Error correction is essential to measure the true performance of the device.

85053B NIST Traceable 25Ω Airline

150 cm test cable

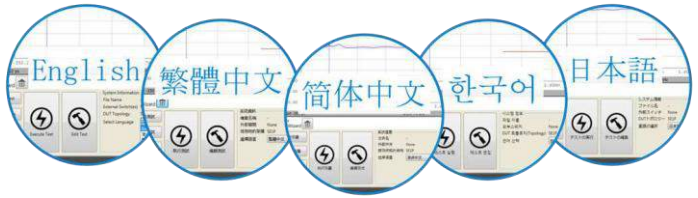


30 cm test cable



More Languages Supported

An analyzer that speaks your language



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More ESD Robustness

TDR Scopes

Difficult to implement protection circuits inside the instrument without sacrificing performance.

"In addition, **protection diodes cannot be placed in front of the sampling bridge as this would limit the bandwidth.** This reduces the safe input voltage for a sampling oscilloscope to about **3 V**, as compared to 500 V available on other oscilloscopes. "

Tektronix ApNote "XYZ of Oscilloscopes", p17 (02/09, 03W-8605-3)

External ESD protection module (80A02) available, but rise time is degraded.
- Rise time degradation from **28ps** to **37ps** with 80E04 TDR module.
- Single-channel protection, but only four slots are available.
- Additional cost of $4K/module.

More ESD Robustness

E5063A PCB Analyzer

Higher robustness against ESD, because protection circuits are implemented inside the instrument for all ports, while maintaining excellent RF performance.

ESD protection circuits inside the instrument

Proprietary ESD protection chip significantly increase ESD robustness, while at the same time maintaining excellent RF performance (24.8 ps rise time for 18 GHz models).

To ensure high robustness against ESD, E5063A PCB Analyzer is tested for ESD survival according to IEC801-2 Human Body Model (150 pF, 330Ω). RF Output Center pins tested to **3000 V**, 10 cycles.

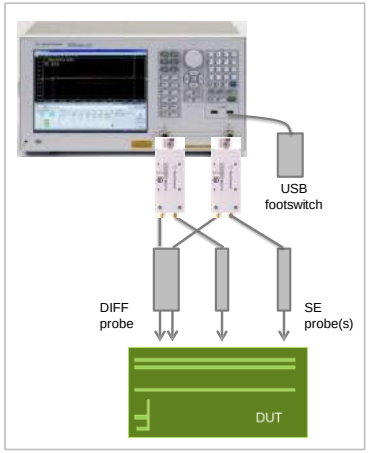
Configuration

E5063A PCB Analyzer = E5063A + Option 011
•E5063A => frequency domain
•Option 011 => time domain and PCB GUI

Model/Option	Description
E5063A	**ENA Series Network Analyzer**
Test set options (choose one):	
E5063A-245	2-port test set, 100 kHz to 4.5 GHz
E5063A-285	2-port test set, 100 kHz to 8.5 GHz
E5063A-2H5	2-port test set, 100 kHz to 18 GHz
Software option (mandatory):	
E5063A-011	Time Domain Analysis / Test Wizard

Note: Option 011 is a superset of Option 010. Option 010 is not available separately.

Typical Configuration



•ENA Mainframe
  •E5063A-245: 100 kHz to 4.5 GHz, 2P
  •E5063A-285: 100 kHz to 8.5 GHz, 2P
  •E5063A-2H5: 100 kHz to 18 GHz, 2P
•Time Domain / Test Wizard Option (E5063A-011)

•U1810B USB Coaxial Switch, DC to 18 GHz, SPDT

•ECal Module
  •N4431B for E5063A-245/285
  •N4433A for E5063A-2H5

•Third Party Solutions
  •TDR Passive Probes (*1)
  •USB Footswitch
  •USB Barcode Reader

(*1) Any TDR passive probe can be used with the PCB Analyzer.

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Agenda

- PCB Market Overview
- Challenges to Obtain Measurement Accuracy and Correlation
- E5063A ENA Series PCB Analyzer Introduction
- **Summary**

What is E5063A ENA Series PCB Analyzer?

E5063A ENA Series PCB Analyzer
The Best Solution for PCB Manufacturing Test

- More Accuracy and R&R*
- More Languages Supported
- More ESD Robustness

… also the lowest cost solution in the industry.

* Repeatability & Reproducibility

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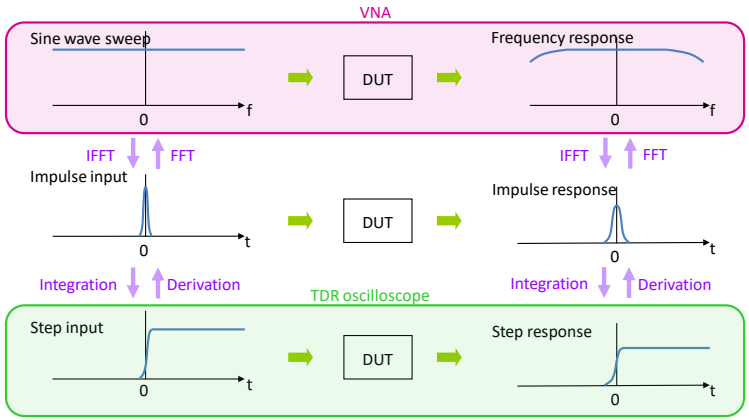
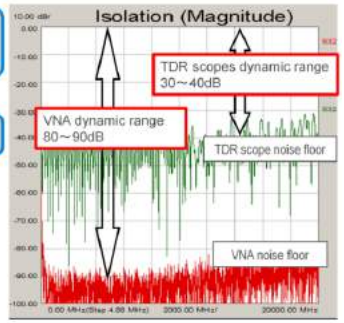
VNA-TDR Theory and Correlation

In VNA based time domain analysis, a frequency response is converted into a time response by inverse Fourier transform.



VNA vs. TDR scopes – Advantage of VNA

- Low Noise
  High dynamic range
- Fast measurement speed
- State of the art calibrations
- ESD Robustness
- Support both time and frequency domain measurements with various format



VNA offers more accurate measurements

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Summary

TDR Oscilloscopes with Offset Compensation Method

- Users need to make sure measurement devices and measurement standards for compensation have the same impedance value
- If the above condition is not satisfied,…
  1. measurement errors cannot be properly compensated resulting measurement inaccuracy
  2. measurement results between channels or TDR instruments can differ from each other

Keysight E5063A PCB Analyzer

- Measurement errors can be completely removed with full calibration for…
  1. accurate measurements
  2. measurement correlation between different channels and instruments

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