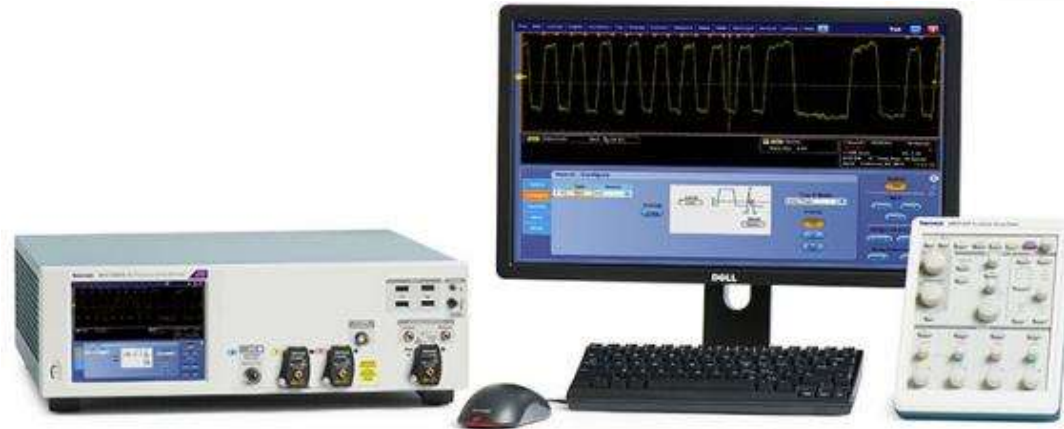


**Tektronix**



# Choosing the Best Test setup for the Thunderbolt™ Testing

25 MARCH 2021



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Systems Expert  
Tektronix

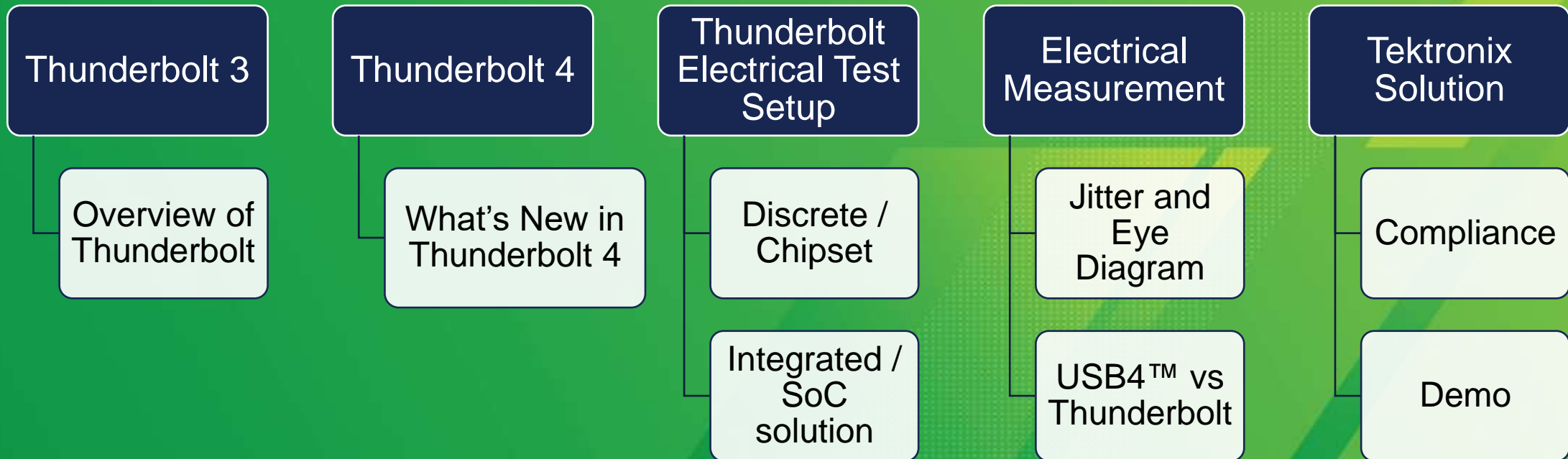


# Disclaimer



- Thunderbolt™ is a trademark of Intel Corporation.
- USB4™, USB Type-C® and USB-C® are trademarks of the Universal Serial Bus Implementers Forum (USB-IF).
- All product names are trademarks, registered trademarks, or service marks of their respective owners.
- Refer to the Appendix E of USB4 Electrical CTS for the TBT3 compliance/certification testing.

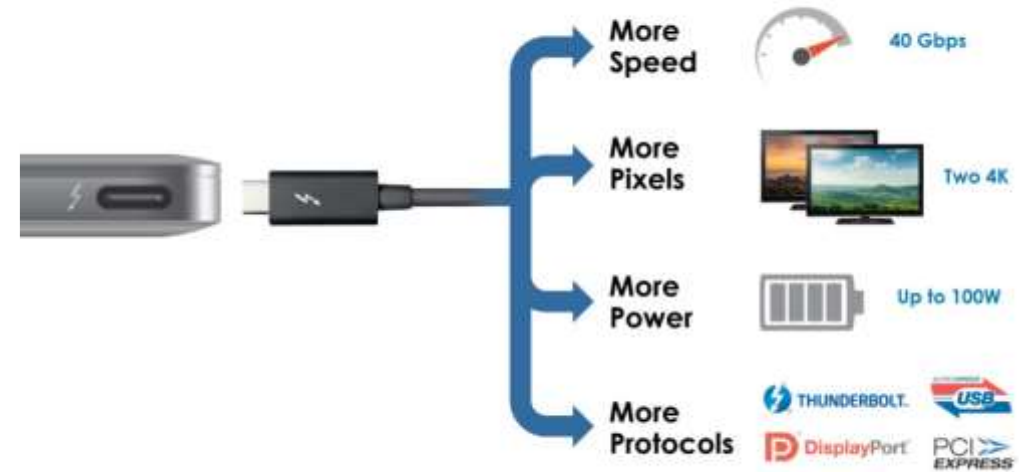
# Agenda



# Thunderbolt 3

## OVERVIEW

- What is Thunderbolt?
  - One connector for everything; power, data and display
  - Thunderbolt 1 and Thunderbolt 2 builds on Mini-DP connector
- Thunderbolt 3 builds on USB-C® connector
  - Double the speed of TBT2
  - Compatible with USB 3.1 and DP 1.2
  - Small and reversible USB-C connector and cables
  - Daisy chain up to 6 devices
  - ALT Mode



# Thunderbolt 4

## WHAT'S NEW

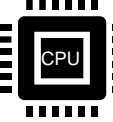
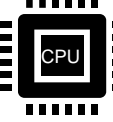
- Thunderbolt 4 and USB4 will use the same underlying protocol specification
  - Thunderbolt 4 offers the most complete version of USB-C
    - Supports all the optional capabilities in the USB4 specification
- How it's affecting the Electrical Verification?
  - TBT4 electrical verification is same as TBT3
    - TBT4 will be USB4 specification compliant
- What it means to end-user?
  - TBT4 port will support USB4, TBT3, and DisplayPort
  - Single TBT4 cable that does all
    - USB-C cable in the market: USB 3.2 Gen1, USB 3.2 Gen2, USB3.2 Gen2x2, USB4 20 and USB4 40

# Thunderbolt Electrical Test Setups

- Test setups
- Common setup issues

# Thunderbolt Electrical Verification

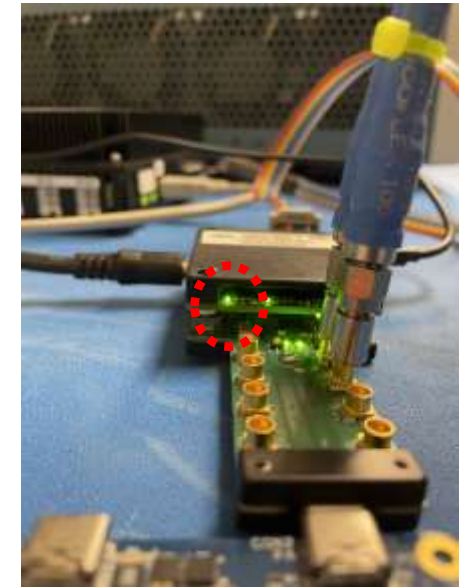
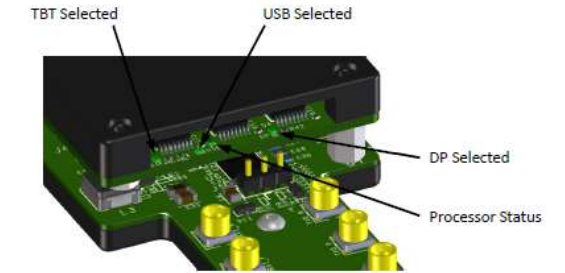
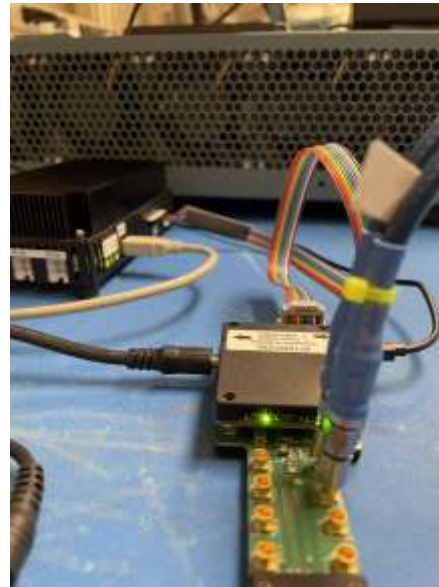
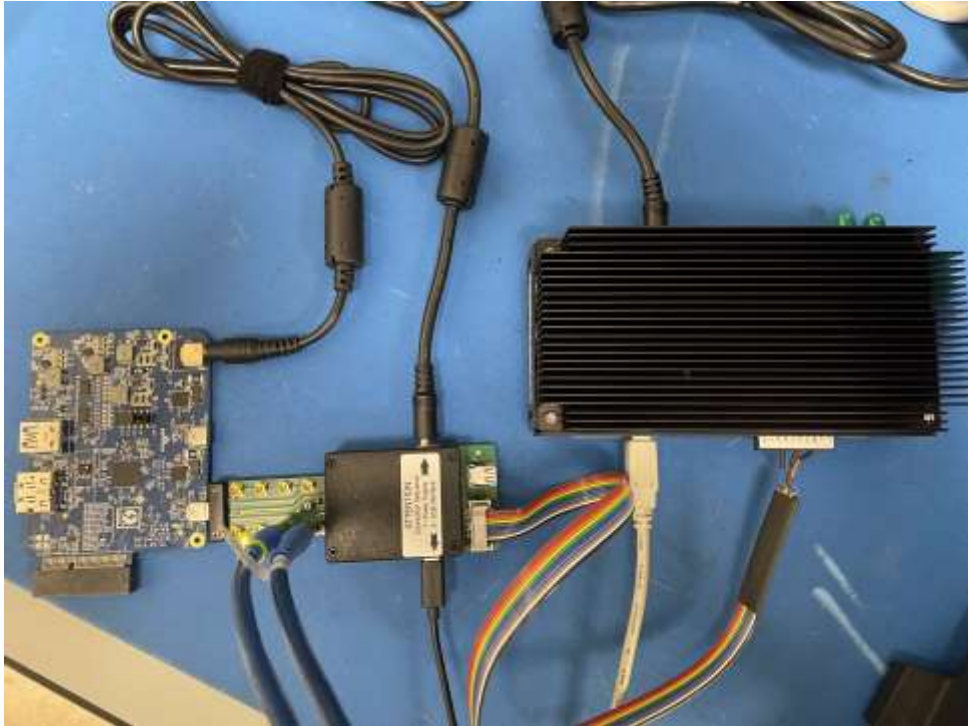
## TEST SETUPS

	Product Type	μController	Fixture	Tool / Script
	TBT3- Discrete ex. Intel's 7000 or 6000 series controller	TBT-TPA-UHG2	TBTCAM-TPA-PR	Intel's TenLira/ TDT and Discrete Electrical scripts
	TBT3 – Integrated ex. Intel's 10 <sup>th</sup> Gen CPU	USB4-TPA-UC-K	USB4-TPA-HS-K	Intel's TenLira/ TDT and Integrated Electrical scripts
	TBT4 – Discrete ex. Intel's 8000 series controller	USB4-TPA-UC-K	USB4-TPA-HS-K	USB4 ETT, and Wilder Controller GUI
	TBT4 – Integrated ex. Intel's 11 <sup>th</sup> Gen CPU	USB4-TPA-UC-K	USB4-TPA-HS-K	USB4 ETT, and Wilder Controller GUI

- The electrical test setup varies based on the type of Thunderbolt controller used in the product.
  - But the electrical verification is the same for all test setups

# Thunderbolt Electrical Verification

## TEST SETUP : TBT3 DISCRETE

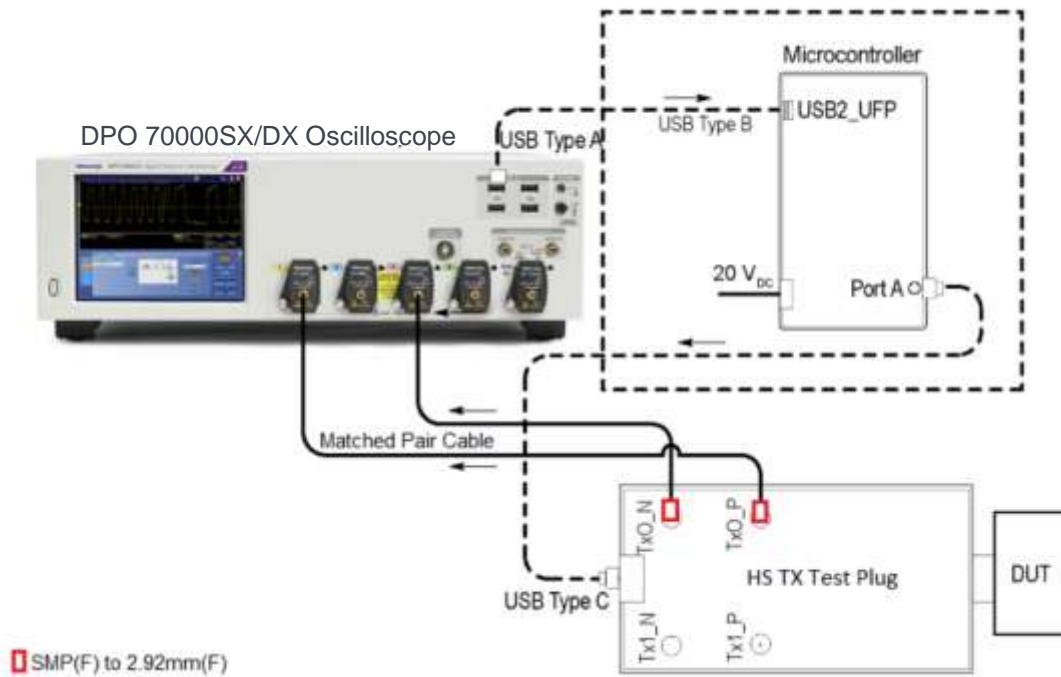


- First enter the TBT mode using Wilder fixture interface or API
- On the Scope, use the discrete electrical scripts to get the desired pattern and data rate.



# Thunderbolt Electrical Verification

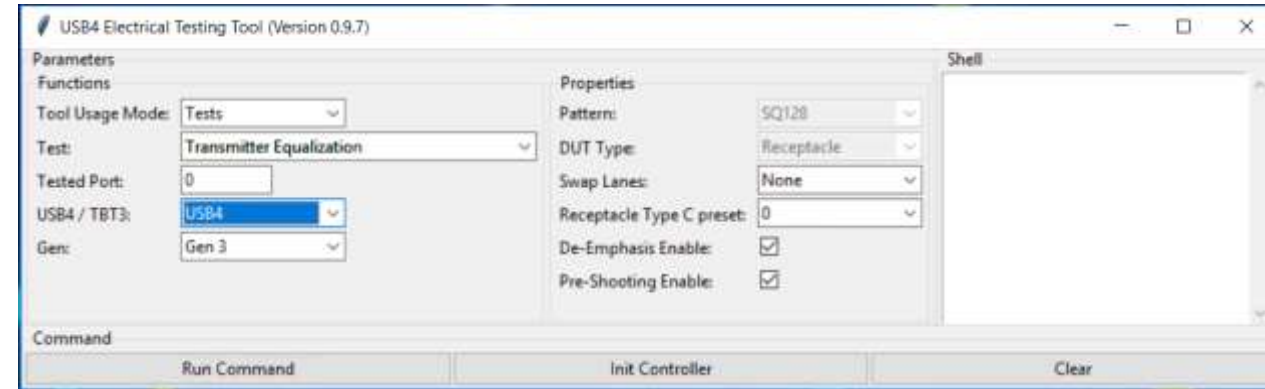
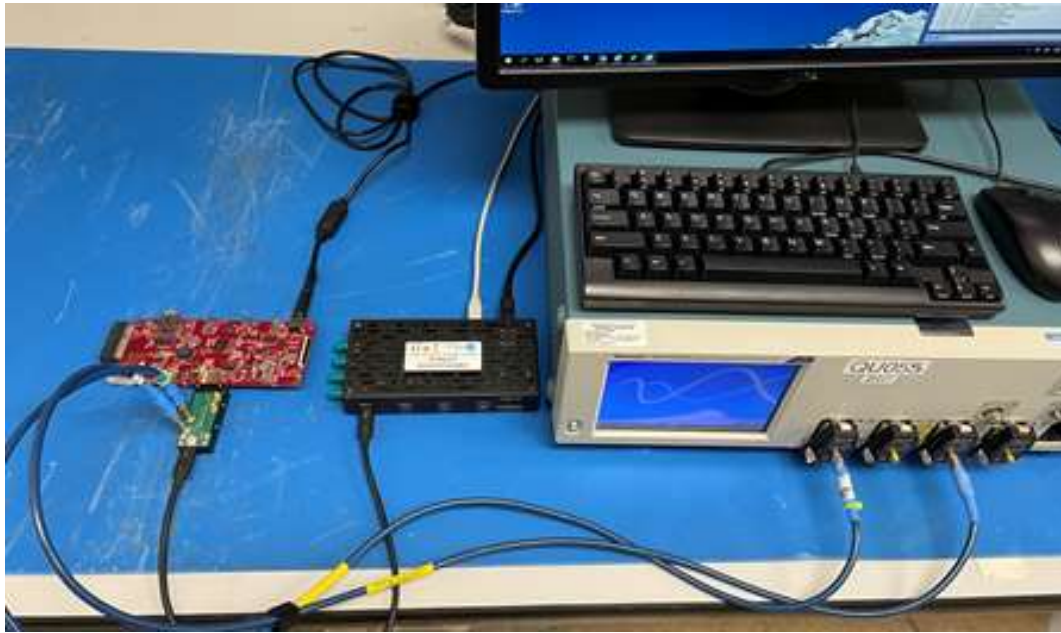
## TEST SETUP : TBT3 INTEGRATED



- On the Host /DUT, use the integrated electrical scripts to enter into the TBT3 compliance mode
  - Disable the power saving options (Device Manager → Power Management)
- On the Scope, use the integrated electrical scripts to get the desired pattern and data rate.

# Thunderbolt Electrical Verification

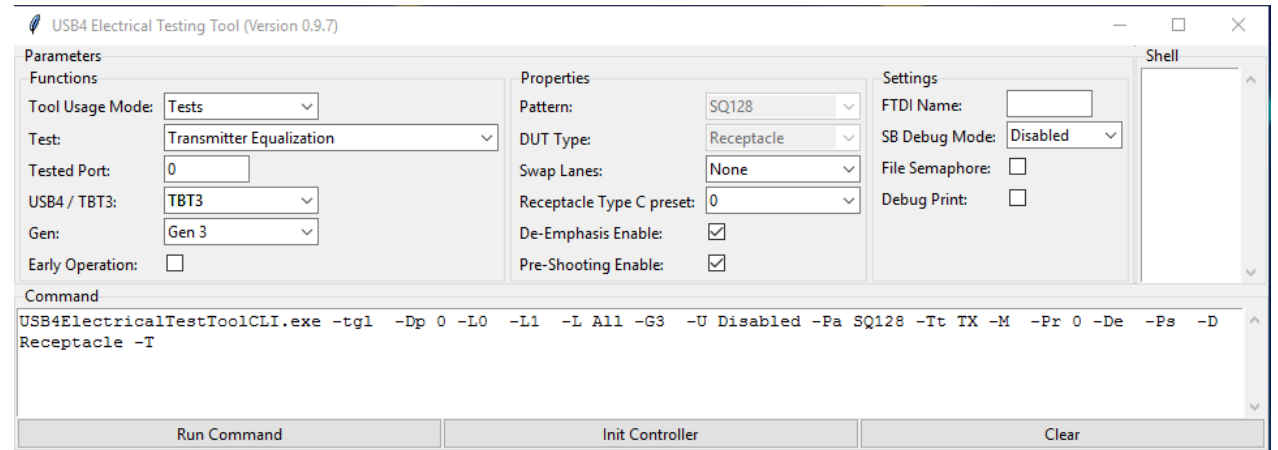
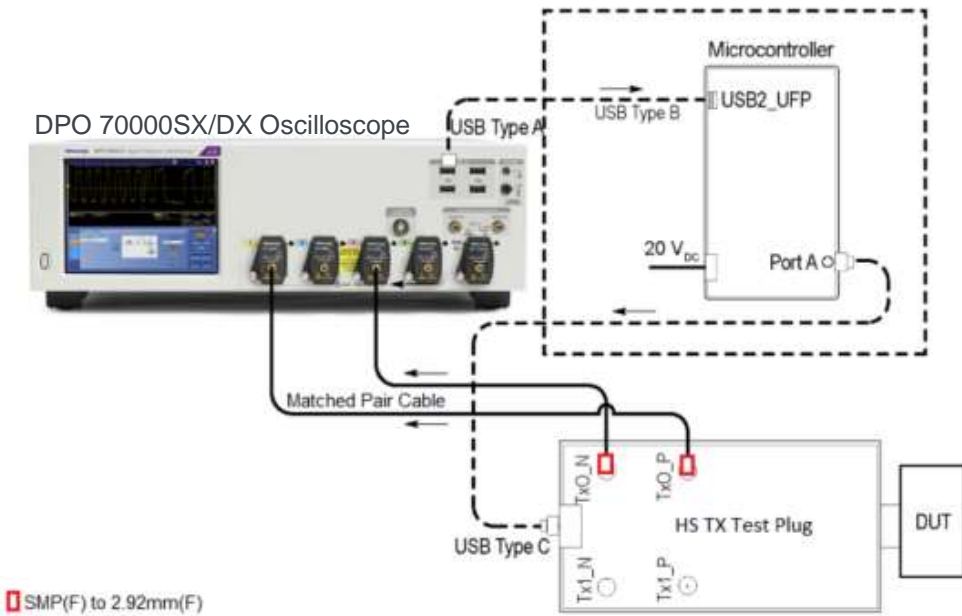
## TEST SETUP : TBT4 DISCRETE



- Same connection but different DUT controlling scripts
  - USB4 ETT to get the desired compliance patterns

# Thunderbolt Electrical Verification

## TEST SETUP : TBT4 INTEGRATED



- Requires a special mode in USB4 ETT
- Disable the power saving options (Device Manager → Power Management)

# Thunderbolt Electrical Verification

## COMMON SETUP ISSUES

### Secure Memory

- Error running the TenLira electrical scripts or USB4 ETT commands

### DUT does not respond to pattern change requests

- DUT must be in TBT3 compliance mode

### Getting only 10G (or 10.3G) patterns

- Use the certified TBT3 40Gbps (0.8m or 0.5m) Type-C cable

### Wrong fixture orientation

- Use the right fixture (Plug or Receptacle) based on DUT type. And check the direction.

### uController driver missing or corrupted

- The scripts will throw exceptions like no RS232/FTDI device or operation timeout

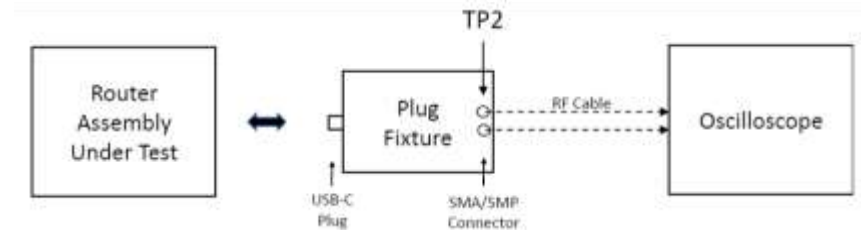
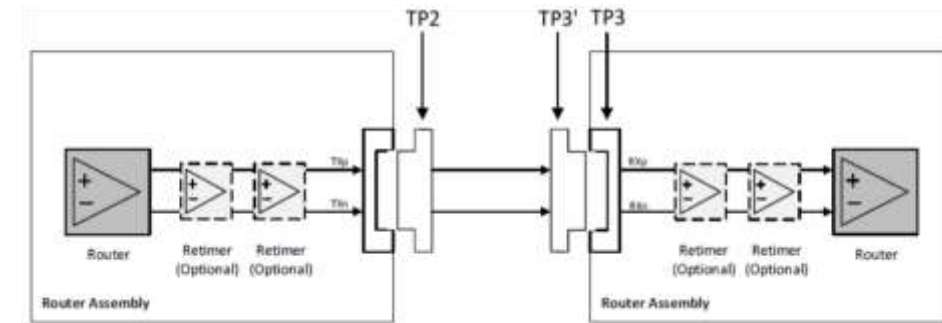
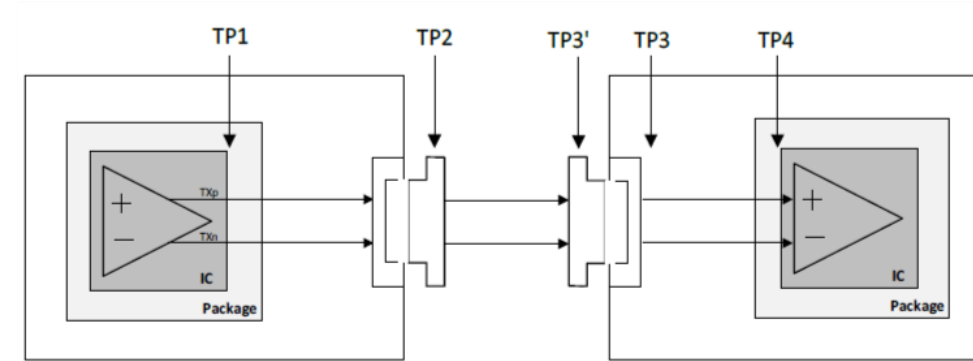
# Thunderbolt Electrical Testing

- Test Points
- Measurements

# Thunderbolt Electrical Test

## TEST POINTS

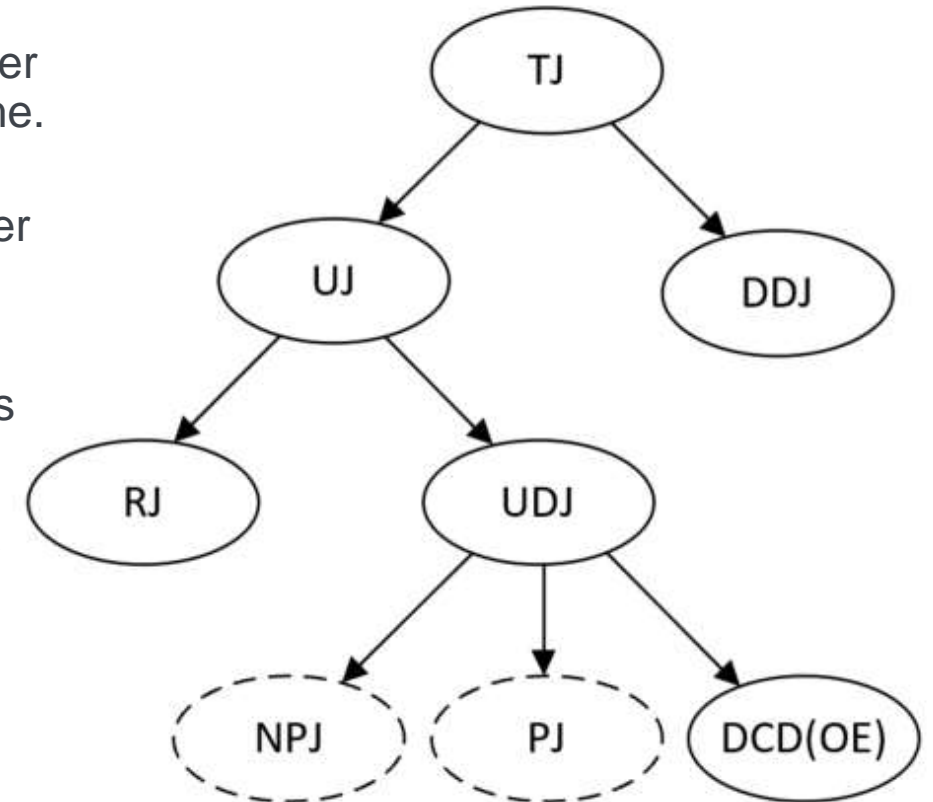
- TP2: Transmitter Port connector output
  - The test fixture insertion-loss from the connector pad to compliance point is  $0.5\text{dB}_{\pm 0.25\text{dB}}$  @5GHz and  $1\text{dB}_{\pm 0.25\text{dB}}$  @10GHz
- TP3: Receiver Port connector output
  - The USB4 Tx waveform are captured at TP2, and the passive cable model will be embedded to make it TP3.
  - All measurements at TP3 will be done by applying reference equalization



# Thunderbolt Electrical Test

## NEW JITTER DECOMPOSITION HIERARCHY

- The jitter measurements in Thunderbolt 3 (and USB4) organize the jitter hierarchy differently than the traditional jitter model used by other serial standards, although the fundamental components are the same.
  - USB4 Jitter Decomposition: The Total Jitter (TJ) first breaks out correlated Data Deterministic Jitter (DDJ) and Uncorrelated Jitter (UJ)
    - Note: DCD in USB4 is Even-Odd Jitter or F/2.
  - Traditional Jitter Decomposition: The Total Jitter (TJ) first breaks out bounded Deterministic Jitter (DJ) and unbounded Random Jitter (RJ)
- Tektronix DPOJET (Jitter and Eye analysis) Tool supports the TBT3/USB4 jitter decomposition method



# Thunderbolt Electrical Test

## JITTER MEASUREMENTS

Test	Test Points		Objective & Definition
	TP2	TP3	
Total Jitter (TJ)	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Confirm the Total Jitter referenced to 1E-13 statistics falls within the specification limits. TJ is sum of all “Deterministic” and Random jitter. $TJ = DJ_{dd} + 14.7 \times RJ$
Uncorrelated Jitter (UJ)	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Confirm the non-equalizable jitter falls within the specification limits. $UJ = TJ - DDJ$
Uncorrelated Deterministic Jitter (UDJ)	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Confirm the uncorrelated deterministic jitter falls within the specification limits. “Deterministic” jitter exclusive of DDJ
Data Dependent Jitter (DDJ)	<input checked="" type="checkbox"/>		Confirm the (equalizable) data dependent jitter falls within the specification limits.
Low Frequency UDJ (LF UDJ)	<input checked="" type="checkbox"/>		New test. Same as UDJ but adding the 2 <sup>nd</sup> order low-pass-filter (LPF) w/ 3dB cut-off at 0.5 MHz
DCD (Even-Odd Jitter)	<input checked="" type="checkbox"/>		Confirm the Even-Odd jitter associated with duty cycle distortion falls within specification limits.



# Thunderbolt Electrical Test

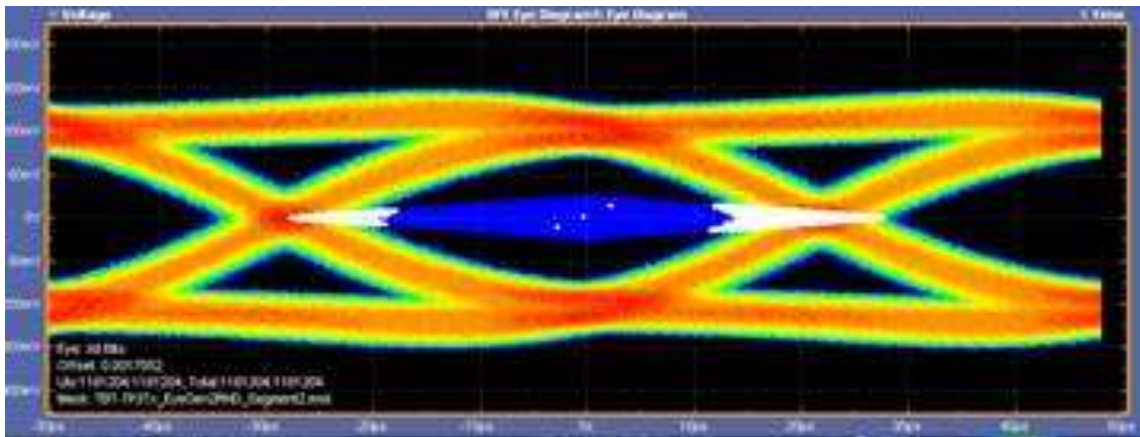
## EXAMPLE OF JITTER VALUES AT TP2 & TP3

Data Rate	Test	at TP2 (mUI)	at TP3 (mUI)
20 Gbps	TJ	152.82	388.86
	DJ	77.41	236.05
	UJ	90.41	189.86
	UDJ	28.92	60.65
	DDJ	62.40	199
	LFUDJ	13.71	
	DCD	2.70	

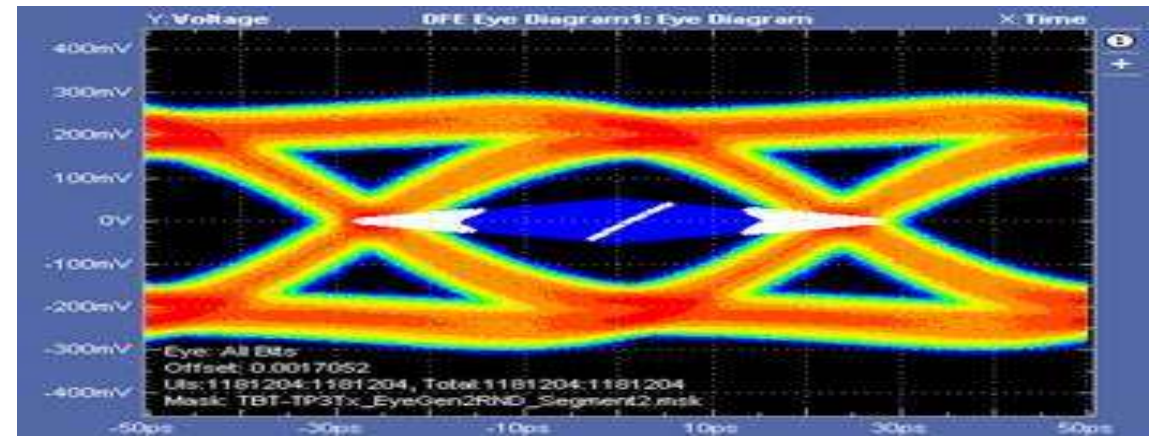
# Thunderbolt Electrical Test

## EYE DIAGRAMS AT TP2 AND TP3

- Transmitter eye diagram confirm that the differential signal has an eye opening that exceeds the specification limits.
- The eye diagram requires interpolation for obtaining effective sample rate of 1280GS/s



X4 (400G)



X12.8 (1280G)

# USB4 vs TBT3/4

- Similarities and Differences
- Hardware Configuration

# USB4 vs TBT3

## ELECTRICAL TEST LIMIT DIFFERENCES – APPENDIX E OF USB4 CTS

Test	USB4	TBT3
SSC Down-Spread Rate	30 kHz – 33 kHz	35 kHz – 37 kHz
SSC Phase Deviation (p-p)	2.2 ns – 22 ns	2.5 ns – 18.5 ns
Minimum Unit Interval Measurement (Gen 2)	99.97 ps – 100.03 ps	96.9406ps – 96.9988 ps
Minimum Unit Interval Measurement (Gen 3)	49.985 ps – 50.015 ps	48.4703 ps – 48.4994 ps
Average Unit Interval Measurement (Gen 2)	NA	97.1348 ps – 97.2420 ps

- All the other TP2 and TP3 tests are the same between USB4 and TBT3

# USB4 vs TBT3/4

## HW CONFIGURATION

- Controller
  - ✓ USB4-TPA-UC-K



- Fixture
  - ✓ USB4-TPA-HS-K



- Scope
  - $\geq 21\text{GHz BW}$



# USB4



- Controller
  - ✓ USB4-TPA-UC-K
  - ✓ TBT-TPA-UHG2



- Fixture
  - ✓ USB4-TPA-HS-K
  - ✓ TBTCAM-TPA-PR



- Scope
  - $\geq 21\text{GHz BW}$



# TBT3/4



# Tektronix Thunderbolt Solution

- Automation Software
- Debugging Tools

# Tektronix TBT3 and TBT4 SOLUTION OFFERING

## Tektronix TekExpress TBT3 & 4

- Fully automated single-button compliance solution
- Support all 4 data rates
- Comprehensive reporting with easy sharable and post analysis formats. (PDF, .MHT & CSV)



## Debug Solutions

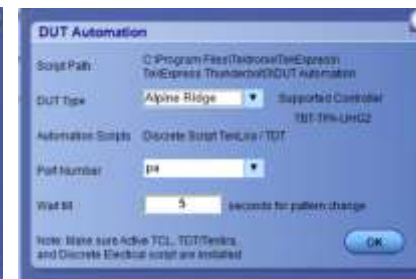
Tektronix comprehensive DPOJET and SDLA tools help to identify critical design issues.

- CDR, Filter Option
- Side by side analysis w/ multiple test points
- Embedding/De-embedding
- IBIS-AMI model simulation



## DUT Automation

- Support both USB4 Controller and TBT3 Controller
- Supports both TenLira/TDT (Intel Scripts) and USB4 ETT (USB-IF scripts)



The screenshot shows the 'TekExpress Thunderbolt4 Compliance Test Report'. It contains several tables of test results. The first table has columns for 'Test ID', 'Test Name', 'Test Result', and 'Test Status'. The second table has columns for 'Test ID', 'Test Name', 'Test Result', 'Test Status', 'Test Date', and 'Test Time'. The third table has columns for 'Test ID', 'Test Name', 'Test Result', 'Test Status', 'Test Date', and 'Test Time'. The report shows various test results for different parameters.

## Signal Validation

Automatically Validate the signal is correct or not

## Pre Recorded

Offline Mode

Cross Geo collaboration

**Telxtronix<sup>®</sup>**