“Sampling” and “Real-Time” Oscilloscopes

“Advanced Measurements …not only Signal Integrity ” ***- July2009***

LeCroy

Agenda

- **What are the differences ?**
  - in the front-end architecture
  - in the applications
- **How much Bandwidth do I need ?**
  - Serial Data Frequency Content
- **RTO Frequency Response Optimization**
  - Pulse Response
  - Eye Diagram
  - Flatness
- **Innovative Acquisition Technologies**
  - DBI for the “Real-Time” oscilloscope
  - CIS for the “Sampling” oscilloscope
- **“Sampling” and “Real-Time” good companion**

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Real-Time vs. Sampling Oscilloscopes

Banner Specs (@20 GHz BW)

Sampling

Wave Expert 100H + ST-20

BW = 20 GHz

(up to 100 GHz with ST-100 plug-in)

Repetitive Signals and TDR

Sampling Rate (max.) = 10 M/s

Noise @50mV/div = 500 uV typ.

Jitter noise floor (HCIS-typ.) = 230 fs

Price around 35 KEuro

Real Time

Wave-Master 820Zi

BW = 20 GHz

(up to 30 GHz with BW upgrade)

Single Shot Signals

Sampling Rate (max.) = 80 GS/s

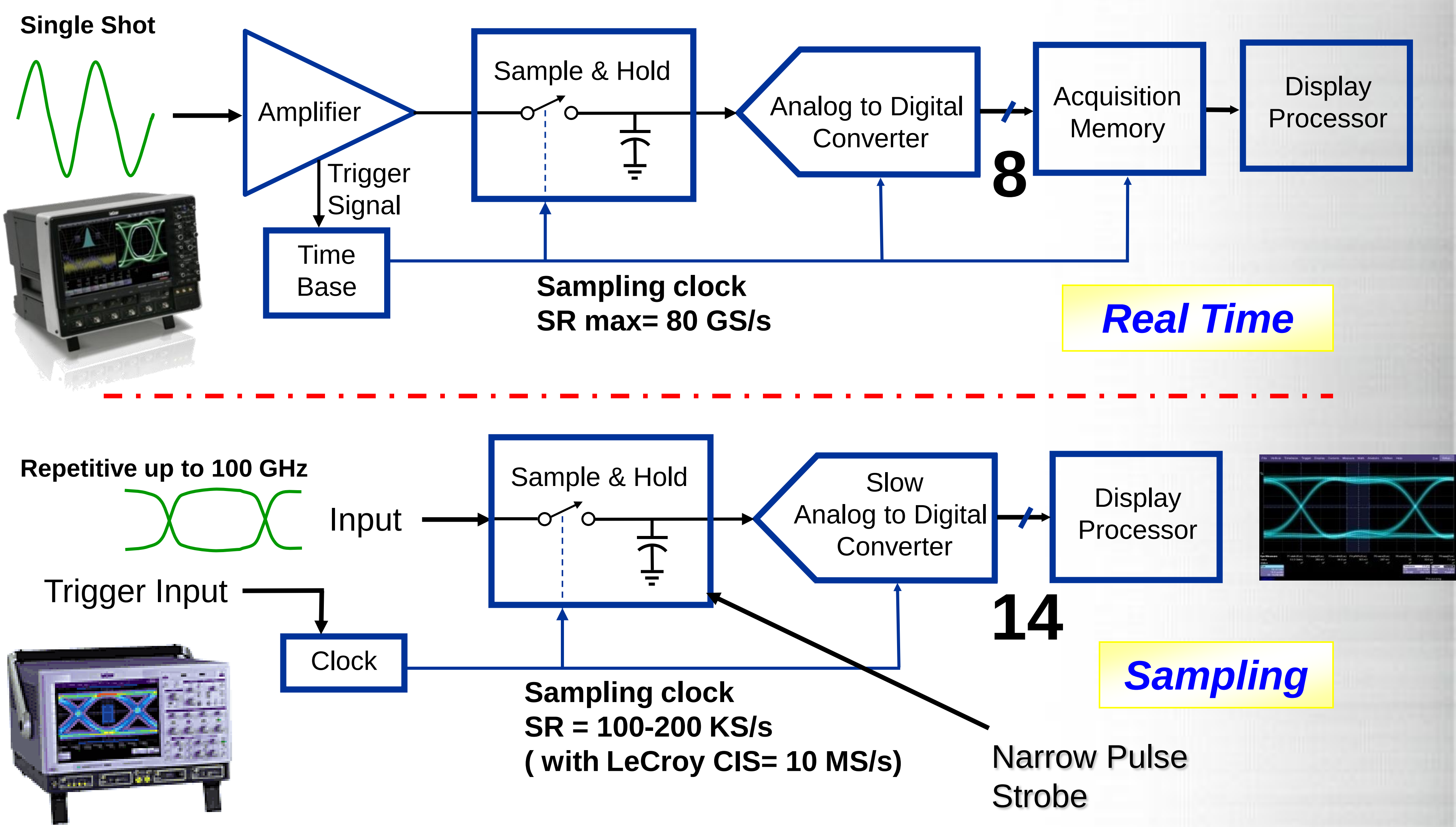
Noise @50mV/div = 2.5 mV typ.

Jitter noise floor = 300 fs typ.

Price around 140 KEuro

Real-Time vs. Sampling Oscilloscopes

Front-end architecture



Real-Time vs. Sampling Oscilloscopes Applications

Real time

I. "Single-Shot" signals
II. Up to 30 GHz BW

- Bit Rate below 12 Gb/s
- Compliance testing:
  USB , ENET, SAS-SATA , PCIe , UWB, HDMI …..

✓ *Pros*
- *Fast SR (up to 80 GS/s)*

✓ *Cons*
- *Inaccurate (A/D typ. 8 bits)*
- *Bandwidth limited up to 30 GHz*
- *Expensive*

Sampling

I. "Repetitive" signals
II. Up to 100GHz BW

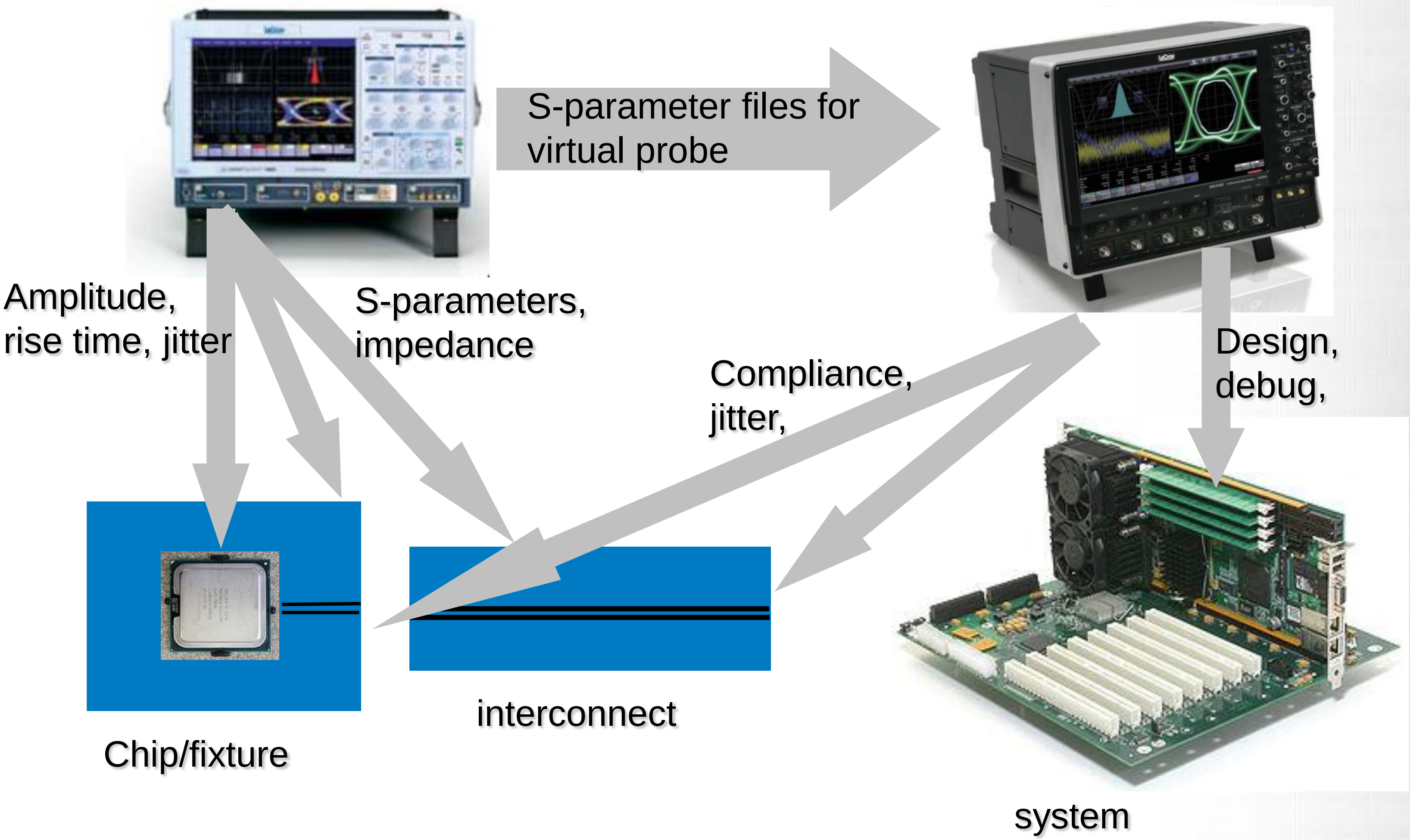
- Higher Bit Rate on Serial Data
- TDR – Reflectometry / Signal Integrity
- Serial Data Design and Cross-Talk

✓ *Pros*
- *Accurate (A/D typ. 14 bits)*
- *Modular: Optical & Electrical Plug-ins*
- *Bandwidth (SE-100: 100 GHz @ 1 mm.)*

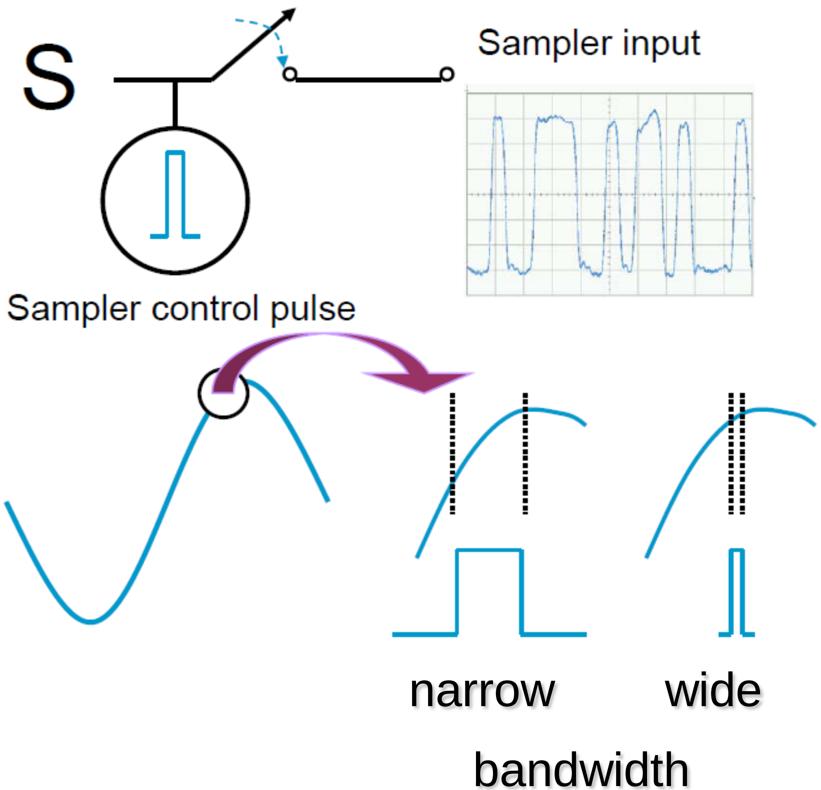
✓ *Cons*
- *No compliance testing for lower bit rate*

LeCroy Real-Time and Sampling have the same user interface

Sampling and Real-Time good companion
for Signal Integrity Measurements



100 GHz BW for “sampling” ?
Bandwidth is independent from sample rate



- **Sampling scope bandwidth is set by the width of the strobe (aperture)**
  - BW ~ 1/aperture
  - Aperture can be as small as 1 ps
- **Slow sampling rate allows for narrow A/D bandwidth**
  - Low noise
  - 14 bit A/D
- **NLTL technology used**

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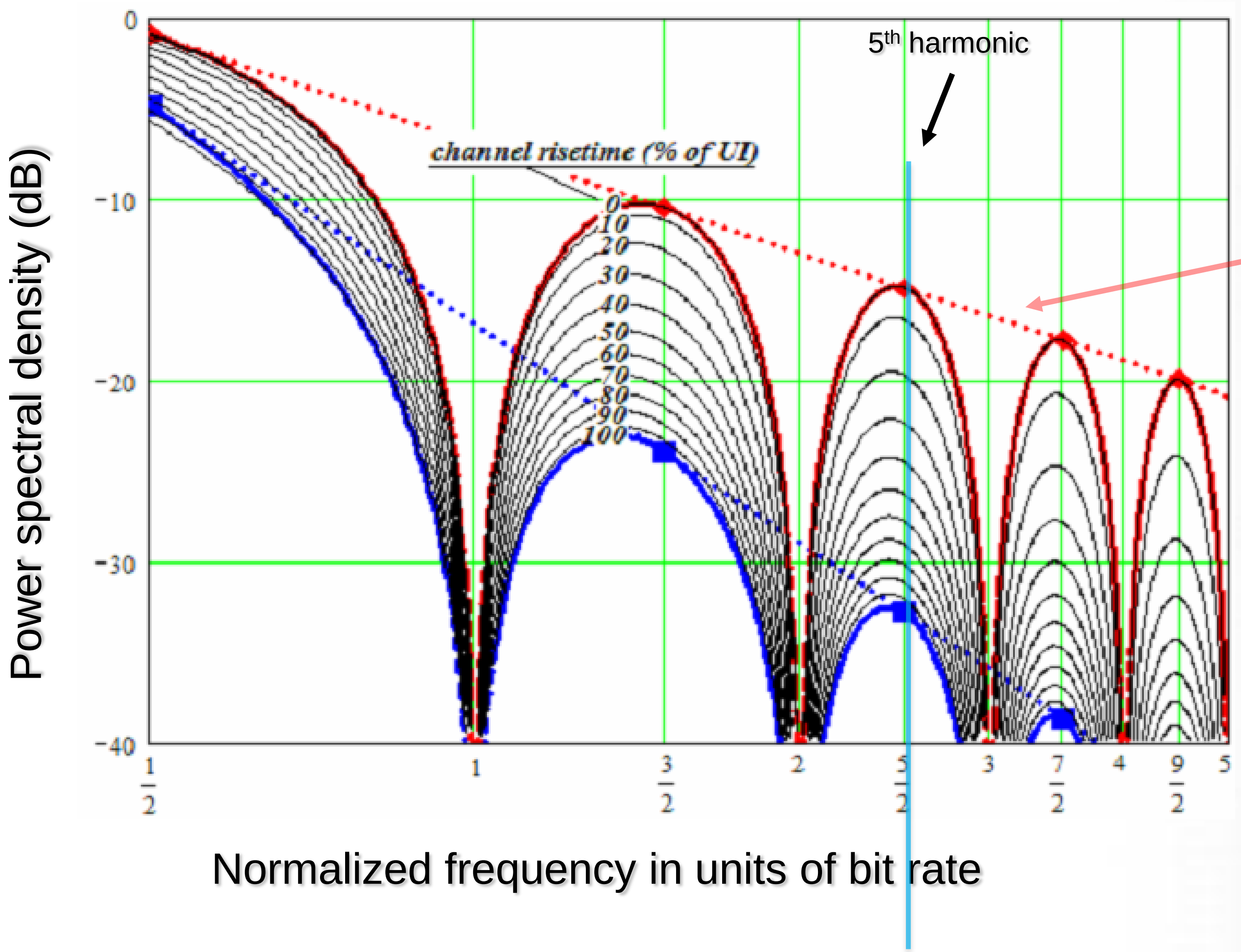
Serial Data Signal Frequency Content
depends on bit rate and rise time



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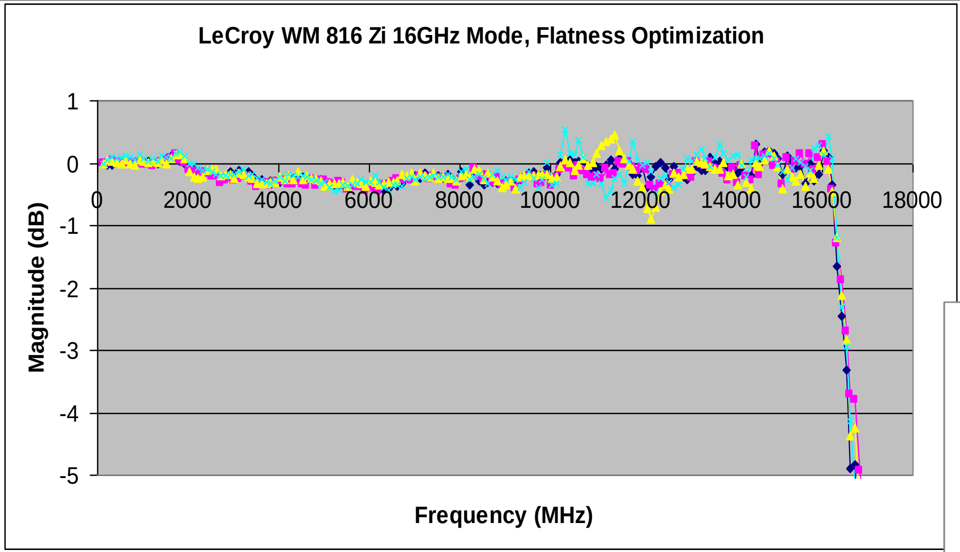
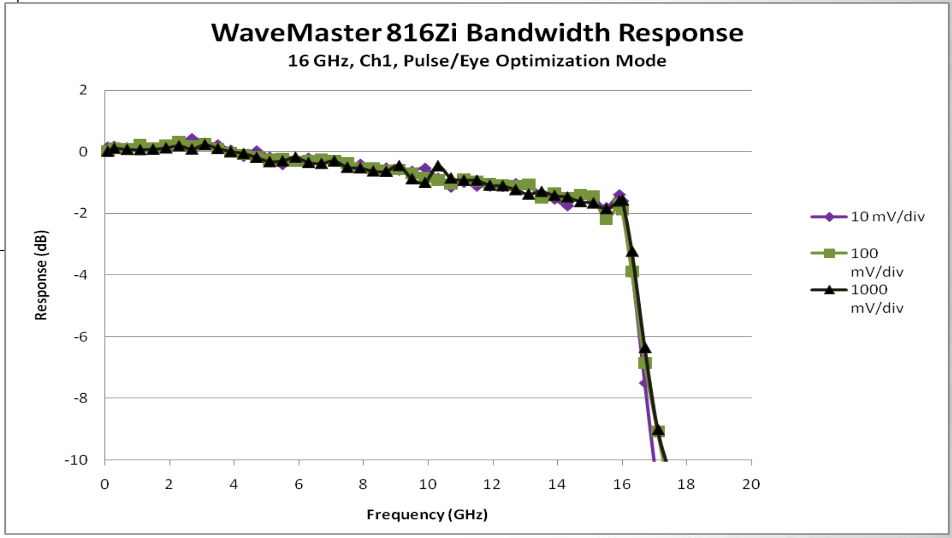
Frequency Response Optimization
LeCroy Real-Time 7 Zi and 8 Zi platforms



Flatness Optimization Mode



Pulse/Eye Optimization Mode

Frequency Response (i.e. Magnitude Response roll-off and Phase Response) influences rise time and the overshoot of the step response in time domain.

A “brick wall” rolloff produces higher overshoot and shorter rise time.
A “slow” rolloff produces less overshoot but longer rise time.

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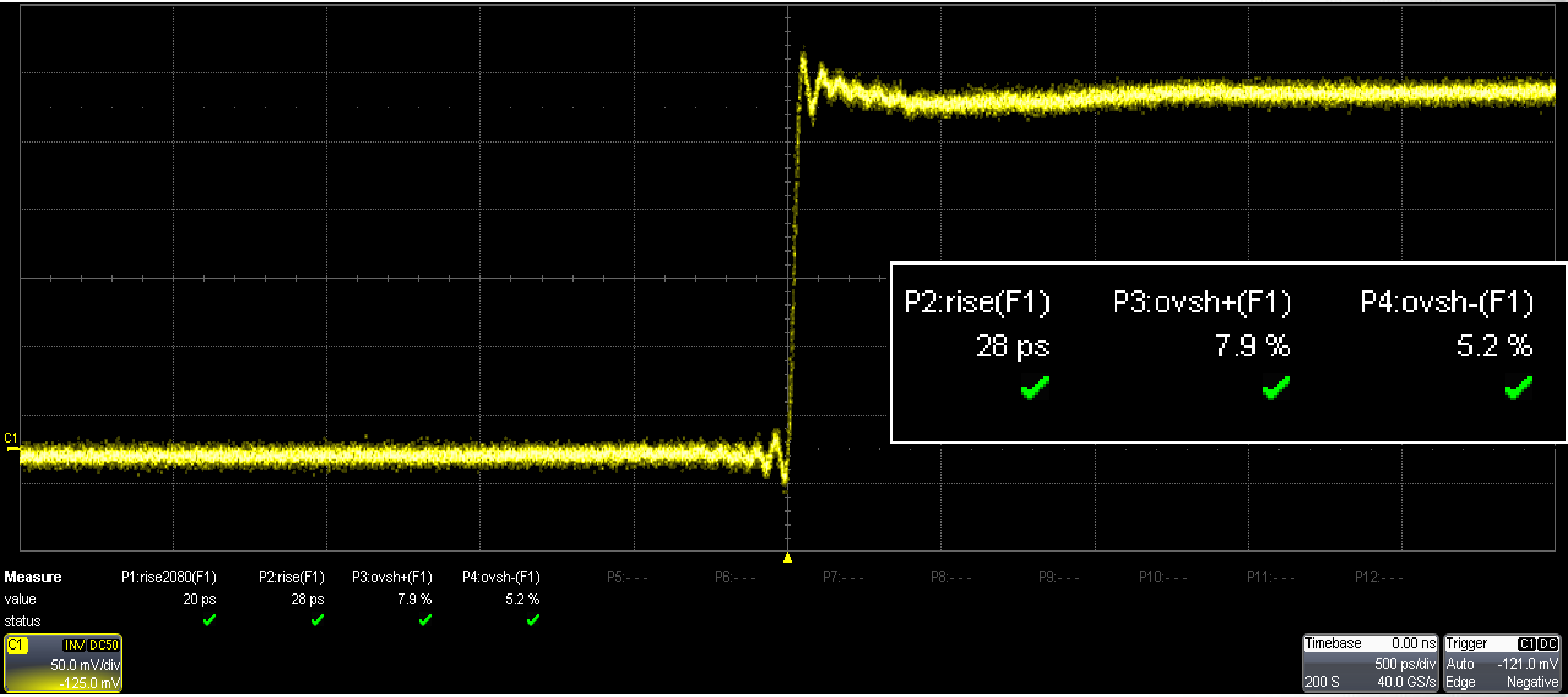
User can optimize frequency response to his application

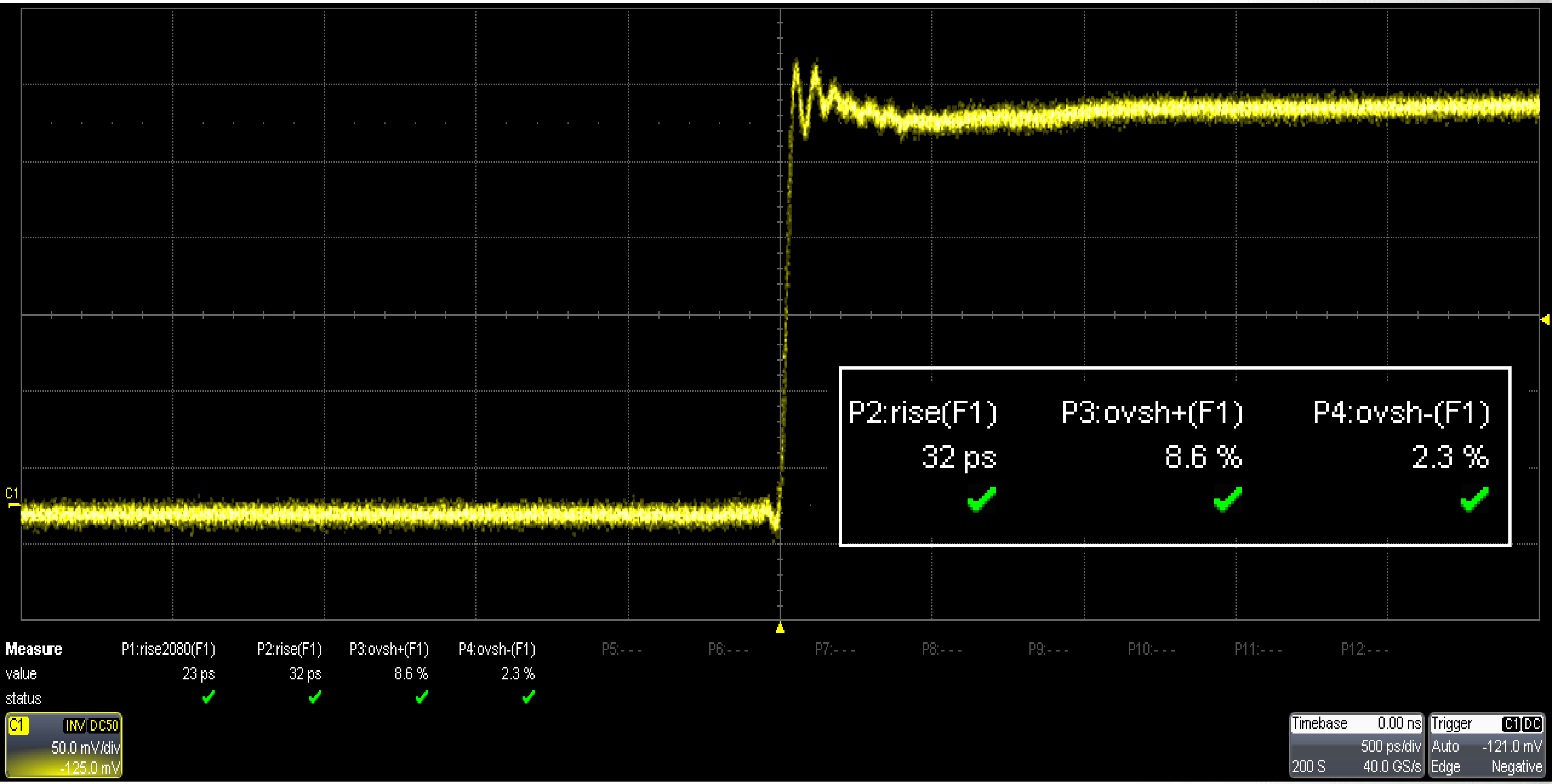
Optimization Mode	Magnitude Response	Phase Response "Group Delay"	Benefits	Tradeoff	Typical Application
Pulse Response	4th order Bessel-Thompson	Minimum Phase	Closely mimics an analog scope.	Slower edge speed	**General purpose**
Eye Diagram	4th order Bessel-Thompson	Linear Phase	Linear Phase Response reduces overshoot and improves edge speed.	Increased preshoot since preshoot and overshoot are equalized (Doesn't matter for serial data)	**Serial Data Testing**
Flatness	Brickwall	Linear Phase	Maximum flatness in the pass band.	Increased Overshoot (Doesn't matter for sine waves or modulation)	**Spectral Analysis**

“Flatness Mode” Optimization

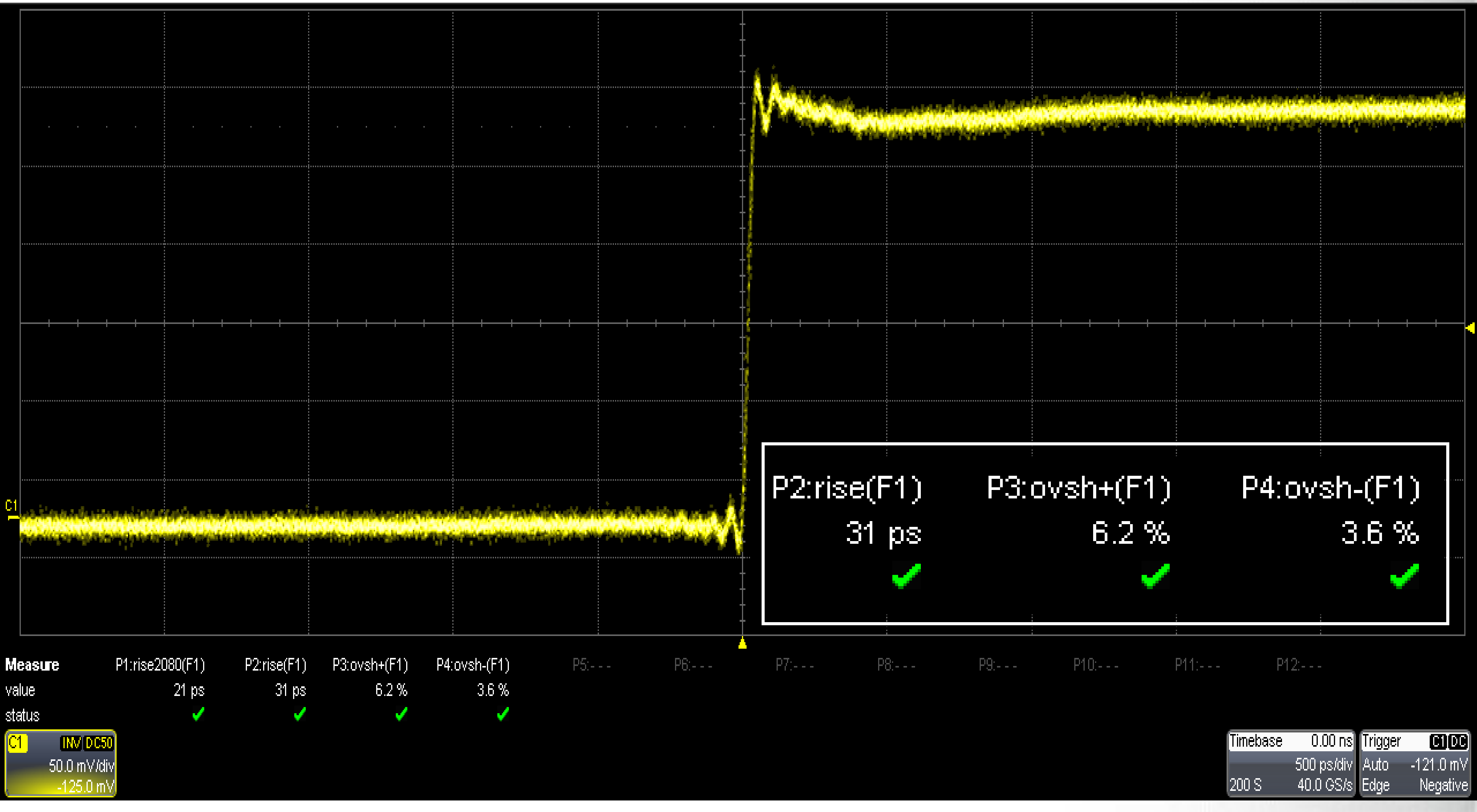


$$\text{Scope Only Risetime} = \sqrt{\text{Measured Risetime}^2 - \text{Input Risetime}^2}$$

"Pulse Response Mode" Optimization



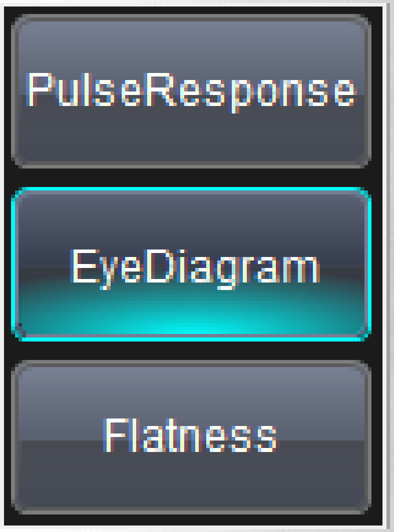
“Eye Diagram Mode” Optimization



Frequency Response Optimization

Example : Real-Time 16GHz Oscilloscope

	Pulse Response	Eye Diagram	Flatness
Measured Risetime (10%-90%)	29ps	27ps	25ps
Preshoot	2%	6%	8%
Overshoot	13%	6%	8%
Magnitude Response Bandwidth Shape	Bessel	Bessel	Flat
Phase Response	Minimum	Linear	Linear



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Digital Bandwidth Interleaving

US007058548B2

(12) **United States Patent**
Pupalaikis et al.

(10) **Patent No.: US 7,058,548 B2**
(45) **Date of Patent: Jun. 6, 2006**

(54) **HIGH BANDWIDTH REAL-TIME OSCILLOSCOPE**

(75) Inventors: **Peter J. Pupalaikis**, Ramsey, NJ (US); **David C. Graef**, Campbell Hall, NY (US)

(73) Assignee: **LeCroy Corporation**, Chestnut Ridge, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/693,188**

(22) Filed: **Oct. 24, 2003**

(65) **Prior Publication Data**

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Related U.S. Application Data

(60) Provisional application No. 60/420,937, filed on Oct. 24, 2002.

(51) **Int. Cl.**
G01R 23/00 (2006.01)

(52) **U.S. Cl.** **702/189**; 702/75; 702/76; 341/155; 341/126

(58) **Field of Classification Search** 702/189, 702/66, 67, 69–71, 73–76, 106, 112, 124, 702/126, 110, 190, 191, 195, 197, 198; 324/76.19, 324/76.22, 76.23, 76.24, 76.28, 76.29, 76.31, 324/76.38, 76.41–76.47; 327/91, 94, 100, 327/107, 129; 341/122, 123, 126, 155; 375/224, 375/225, 316; 708/300, 309, 311; 331/42, 331/43, 30–32, 64, 135; 382/260
See application file for complete search history.

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(Continued)

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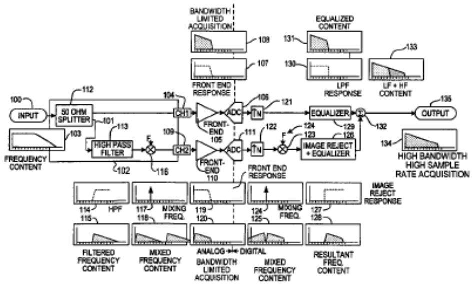
(74) *Attorney, Agent, or Firm*—Frommer Lawrence & Haug LLP; William S. Frommer

(57) **ABSTRACT**

A method and apparatus for digitizing a data signal. An input analog data signal, is received and split into a plurality of split signals. At least one of the split signals is mixed with a predetermined periodic function with a predetermined frequency. The split signals are then digitized and combined mathematically to form a single output data stream that is a substantially correct representation of the original input signal.

28 Claims, 23 Drawing Sheets



"DBI is a technology which combines the resources of multiple channels resulting in a channel with the sum of the individual source channels resources".

- ✓ **Memory**
- ✓ **Sample Rate**
- ✓ **Bandwidth**

DBI Explained

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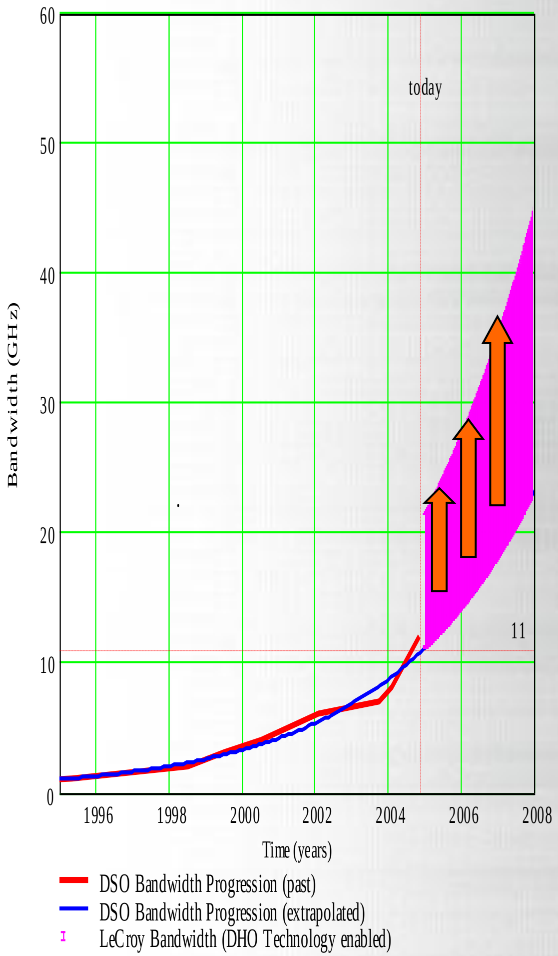
DBI – A Whole New Ballgame

- **Moore's Law:**
  - *Transistors density continues to double every 18 months; the speed of circuit is doubling every three years*.
- **Test Equipment manufacturers use the same technology employed by state of the art devices under test**

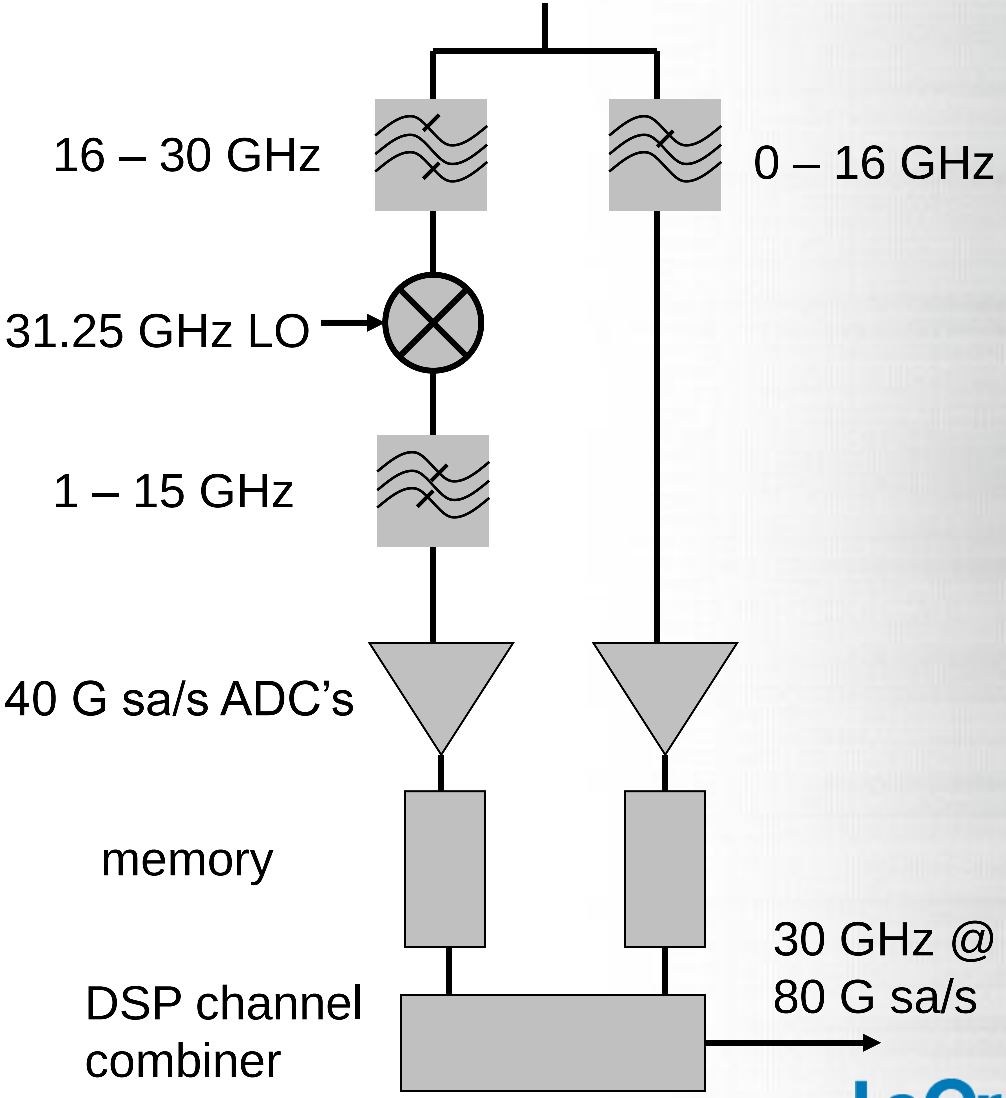


- **DBI is a new way to extend the bandwidth and the sample rate of a silicon platform**
- **i.e. …. a step function to the Moore's Law**

Bandwidth Interleaving

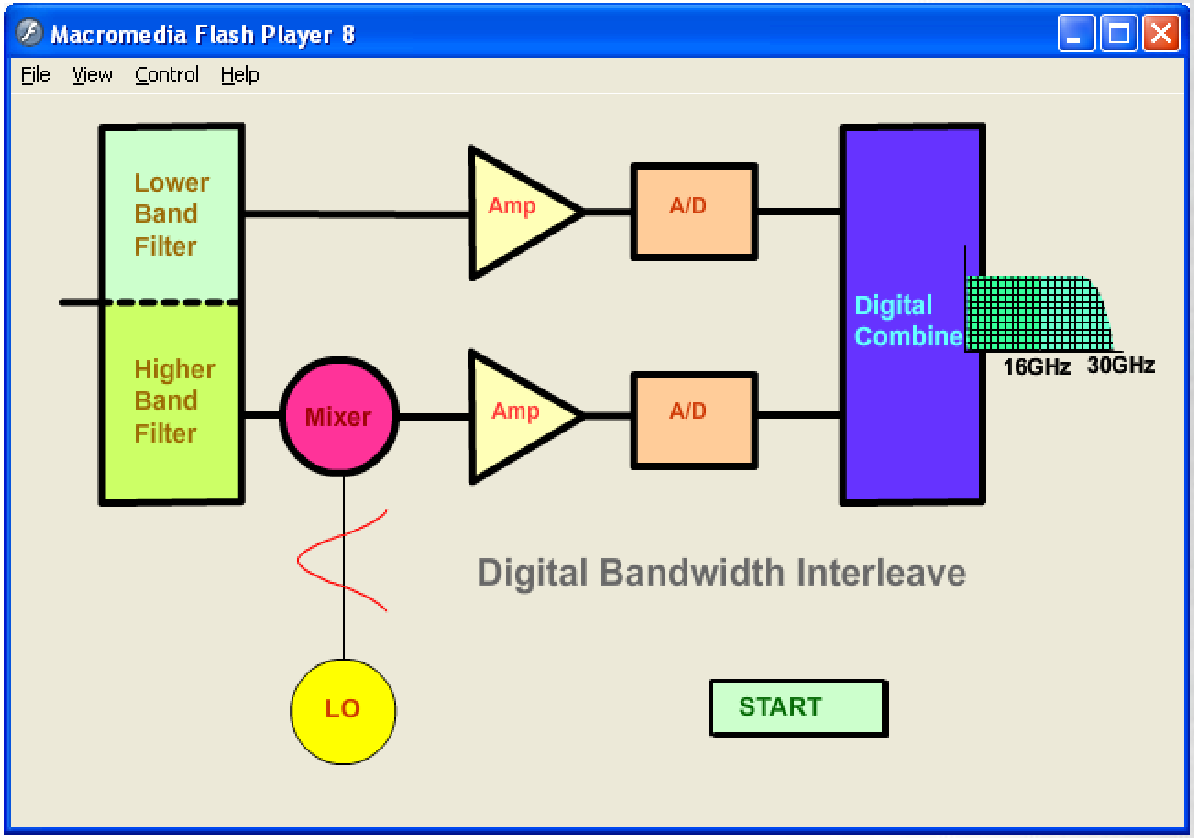
An innovative method to stay ahead of the BW curve

- Separate signal into frequency bands
- Down-convert high band to low frequency
- Digitize down-converted and low-band simultaneously
- Use DSP to compensate delay, phase and amplitude and combine bands



Bandwidth Interleaving – Animation

DBI Animation - Click Here



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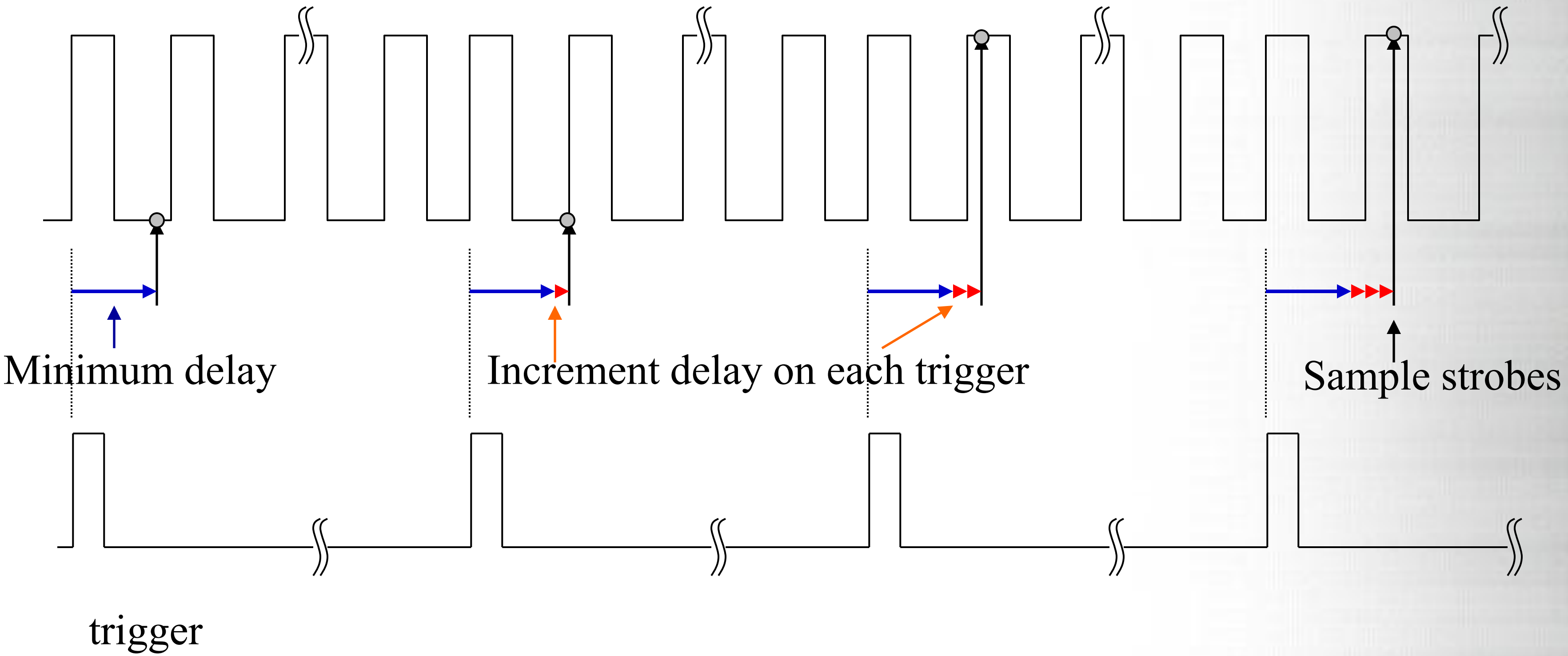
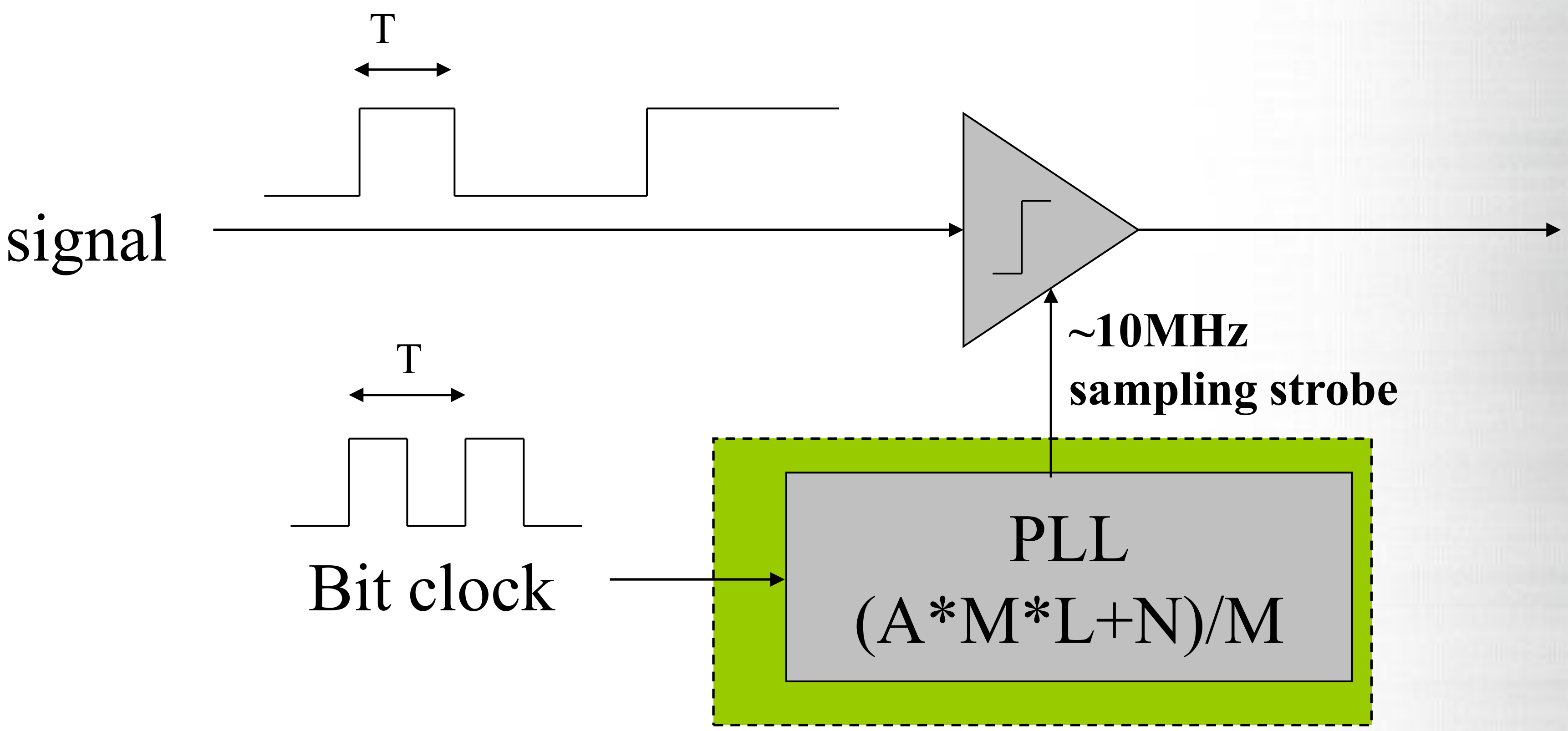
Sequential Time Base
"traditional" Sampling Oscilloscope



- Trigger signal controls sample acquisition
- Sample position controlled by delay generator in timebase
- Delay calibrations are applied to achieve ~1ps time accuracy
- Observed jitter is the sum of clock, signal and intrinsic jitter

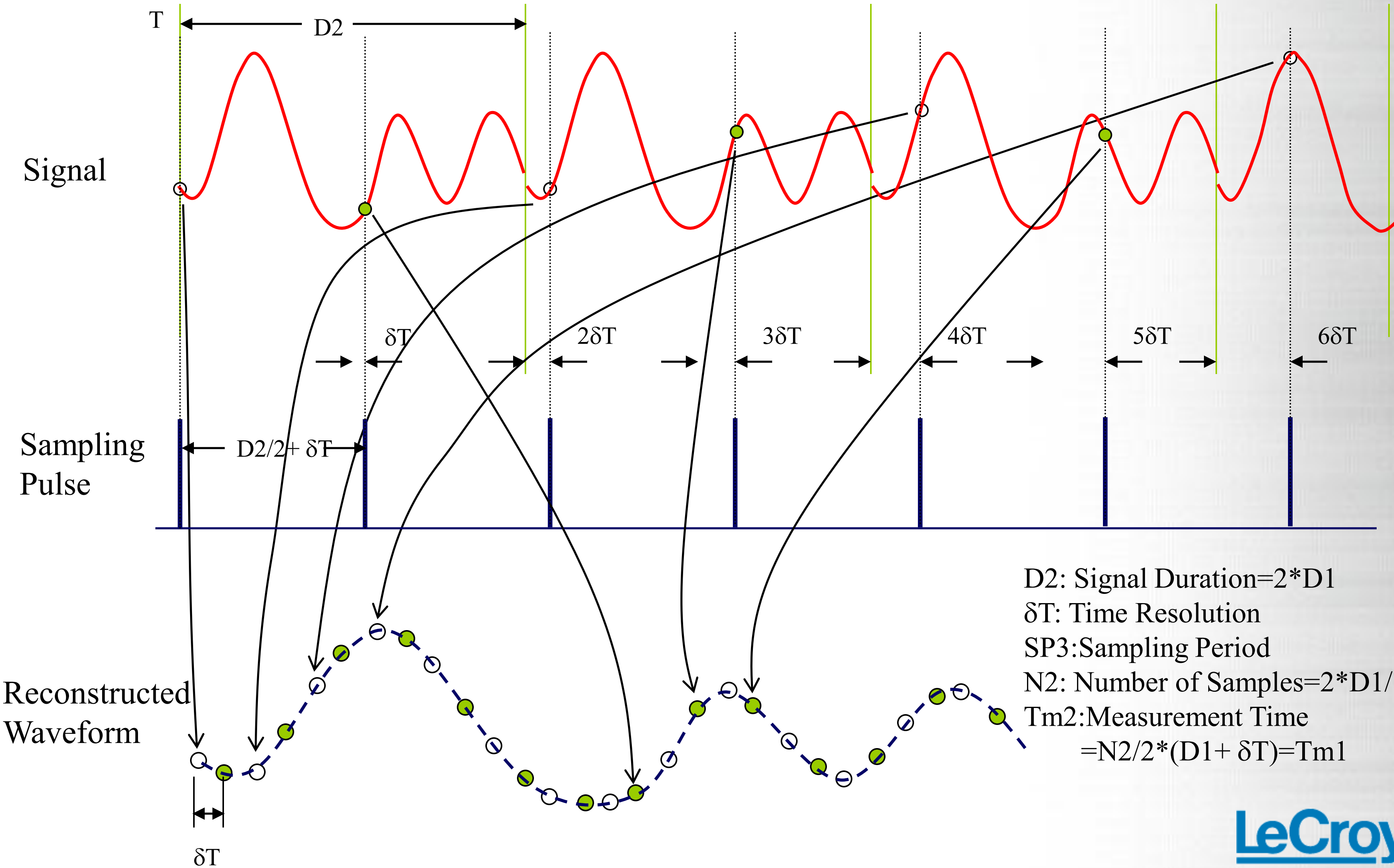
Coherent Interleaved Sampling

Time Base “Sampling” oscilloscope



Coherent Interleaved Sampling

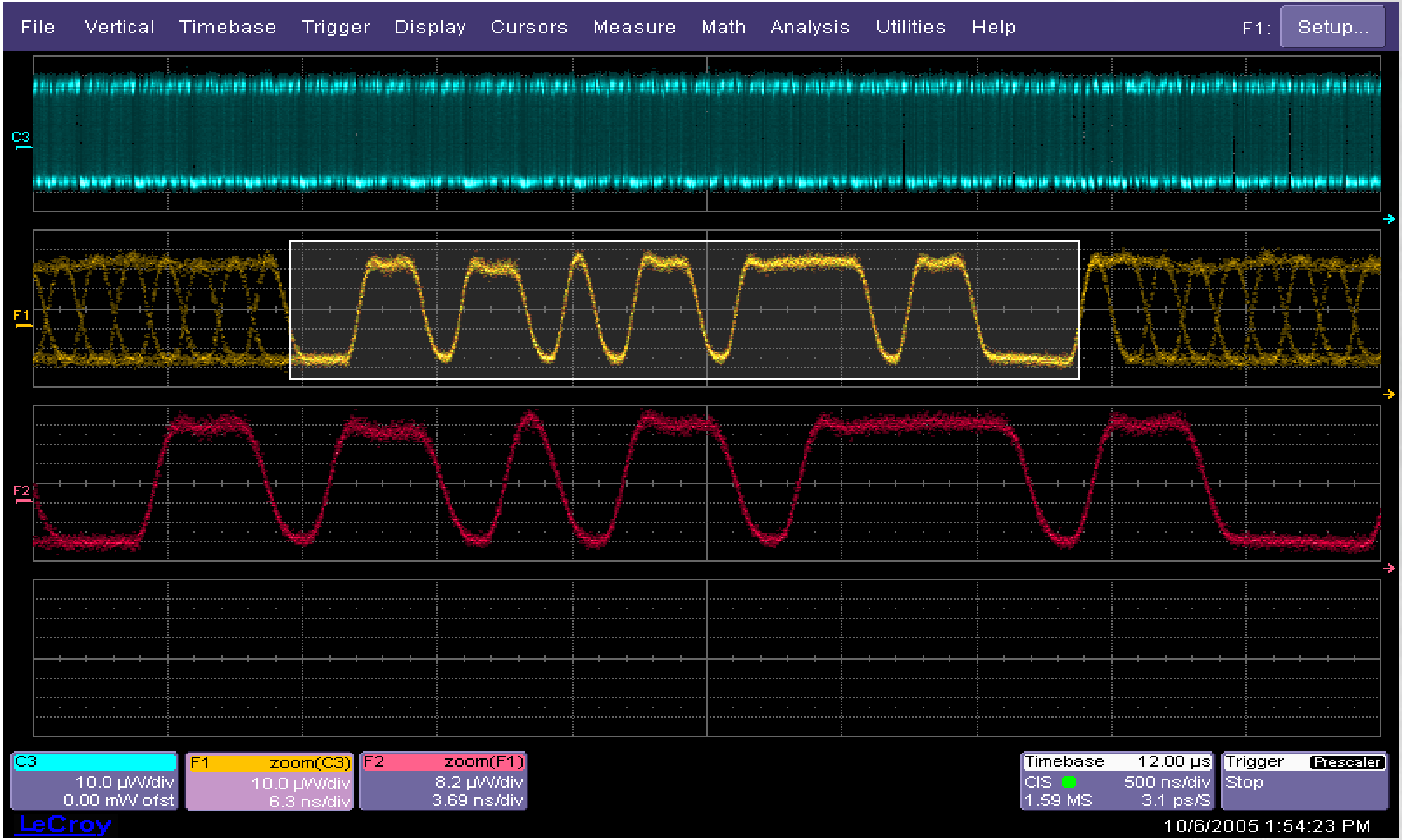
Innovative "Sampling" oscilloscope



D2: Signal Duration=2*D1
δT: Time Resolution
SP3:Sampling Period
N2: Number of Samples=2*D1/δT
Tm2:Measurement Time
=N2/2*(D1+ δT)=Tm1

Voltage vs. Time without a pattern sync

CIS Timebase



Benefits of CIS Time base
on "Sampling" Oscilloscope

- **Very High Throughput – Speed**
  - Enables 10 Ms/s Sample Rate on "Sampling"
- **Voltage vs. Time without a pattern sync. signal**
  - Provides pattern locked trace without a pattern sync.
  - Enables very long waveform memory (up to 512M)
  - Math functions available including the FFT
- **Trigger free Operation**
  - Achieves very low intrinsic jitter

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Sampling and Real-Time good companion
for Signal Integrity Measurements