11069 DSO

DSO Debug Techniques for Embedded Systems

Class Objective

When you finish this class you will:

- Learn (presentations, hands on and Q&A) about capabilities and features on modern DSO equipment for testing the mixture of digital and analog signals in embedded systems
- Understand system debug techniques for embedded systems using digital scopes
- Know how to choose the right tools for your embedded system needs

Class Objective

Abstract

- In this hands-on workshop, you will use the capabilities and features of the modern Digital Storage Oscilloscope (DSO) to investigate and debug system level issues. Focus will be on practical examples of how to acquire, view, measure and analyze the mixture of digital and analog signals present in modern embedded systems. Examples include CANbus, LIN, I^2C™, RS-232, SPI, generic UART's, Flexray and other types of data buses.

Prerequisites

- Basic knowledge of electronic measurements

Agenda

Review Typical Embedded Controller Environment
- Types of signals
- Issues on timing
- Digital parallel data transfers and serial communications

Techniques to make debugging easier

Test equipment tools to validate designs and looking for signal anomalies

Utilizing oscilloscopes for both Physical Layer and Data Link Layer information

Graphical tools to make debug easier and faster

Knowing more about your embedded system design than you expected…

We will blend Lecture & Labs together…seamlessly

Embedded System Testing

What is the Basic Need?

- Engineers want to use a high quality 4 channel scope to view key signals with high sampling rate, long memory, good triggering and easy to use measurements. But they also need to view many lines of digital addresses/data.
- Probe the Electrical Signals without changing their shape (PRB 11068)
- Analog and Digital start up sequencing and data messaging are difficult to analyze and are important in validating a embedded design
- It can be cumbersome (and expensive) to use an oscilloscope and a logic analyzer

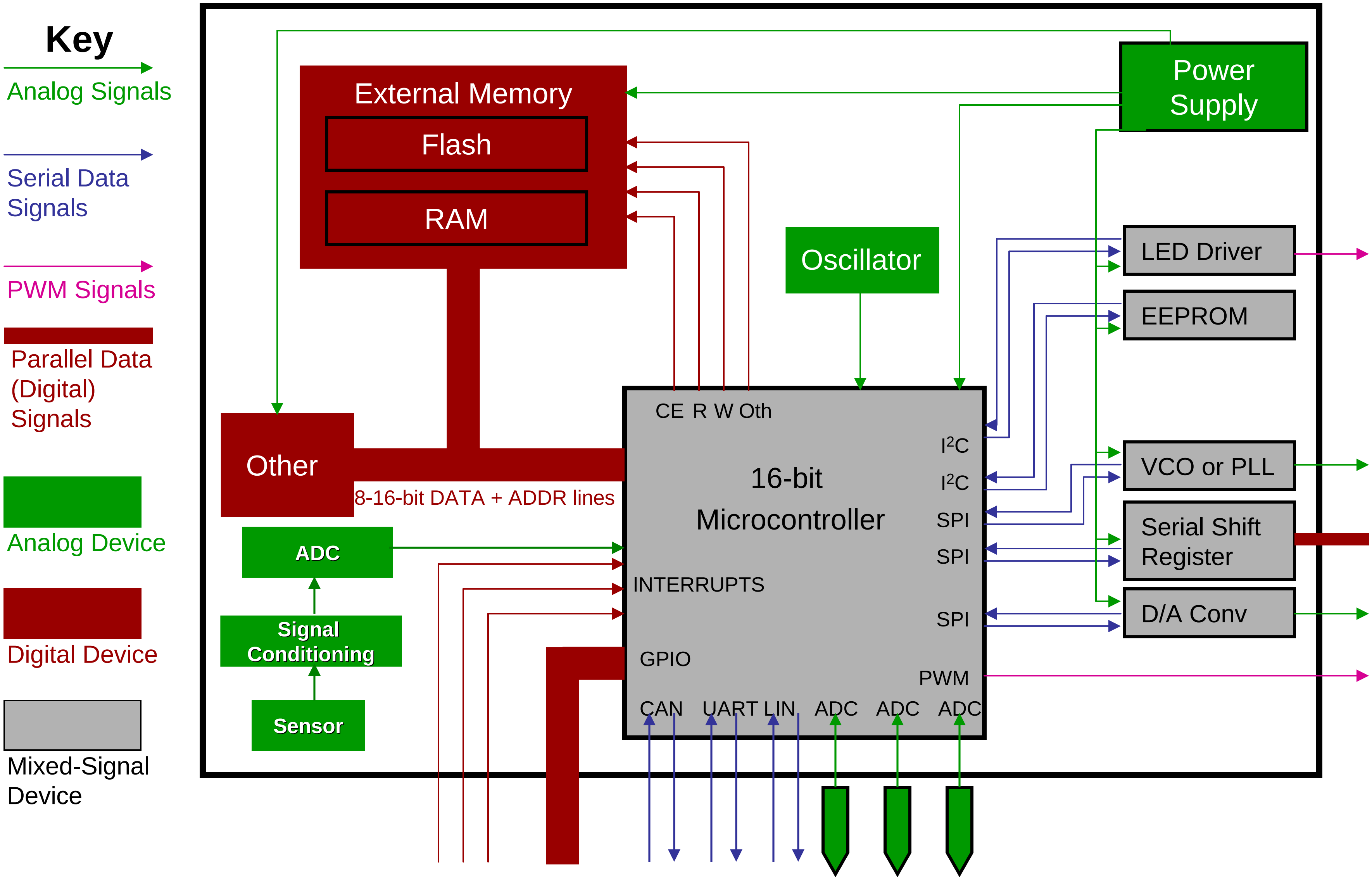
Embedded System Testing

What is the Basic Need?

- As digital signals become faster they take on more properties that previously were attributed only to analog signals
- Digital engineers are starting to worry about signal rise time, overshoot, ringing, pulse widths and other types of "analog" properties
- They also need to capture and view the timing of many digital lines, find errors and troubleshoot system performance
- Let's take a look at a typical embedded system

A Typical Embedded Controller

(Your System may have some/all of these elements)



What Engineers Say – What do you say? *Discussion*

The Need for Performance

- "My signals are often faster than 125 MHz, even up above 250 MHz"
- "We need longer memory, 1 Meg is not always enough, we like to capture a lot of digital messages in a single trigger"

The Need for Channels

- "Provide me with enough channels for address lines, data lines, control lines and serial data lines; sometimes we use 20 or 32"

The Need for Simplicity

- "External MSOs are great because I can get closer to my board but it must be easy to set up"
- "Make the MSO simple so I can use it just like my scope"

The Need for Serial Data Analysis

- "Give me an easy way to understand data bus traffic and trigger or search for specific data messages"
- "Make the decoded information easy to read quickly"
- "Let me capture and decode data busses on the MSO inputs and leave the scope channels open for other signals"

Breaking Down the Measurement

Capture

- Use the right trigger (combination of digital and analog conditions)
- Use long memory at high sample rate for most accurate capture of both the digital and analog signals
- Triggering on a certain data value or ID can be useful

View

- A large display with room for all the signals is very useful
- View digital lines individually or as bus values

Measure

- Use scope cursor and parameter measurements on digital lines in the same fashion as on analog signals

Lab - Analog Triggering

- Introduction to the lab signal (WaveSource 100)
  - Signal On Screen
    - Edge, Slope

Lab – Needle In the Haystack

- **Today's Oscilloscopes**
  - **Sample rate & memory**

- **Navigating Through Memory to Identify Design Problems**

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Overview

One Method for Capture and View of Mixed Signals

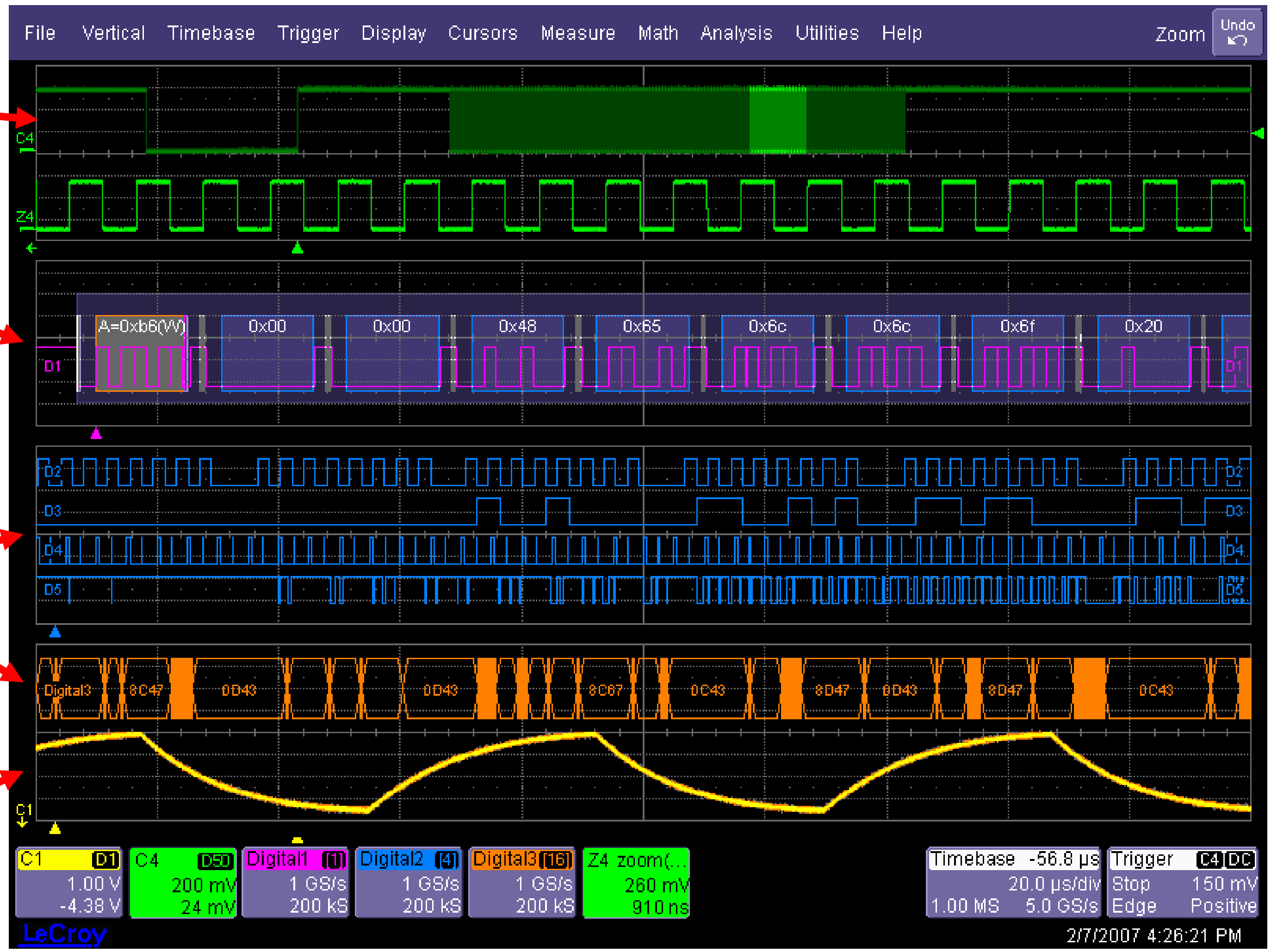
Capture signals on analog inputs with bandwidths up to 2 GHz and sampling rate up to 10 GS/s

Trigger on and decode serial data signals such as I²C™, SPI, UART, RS-232, CAN and LIN

Long captures of digital signals up to 500MHz with up to 50 Mpts/ch memory

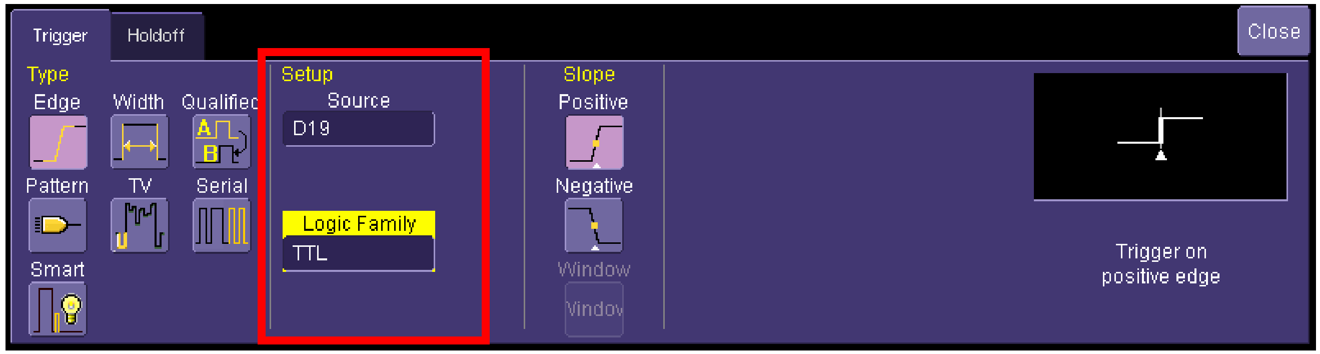
View digital signals as individual lines or as a bus

Capture long records of analog signals with up to 12.5 Mpts/ch

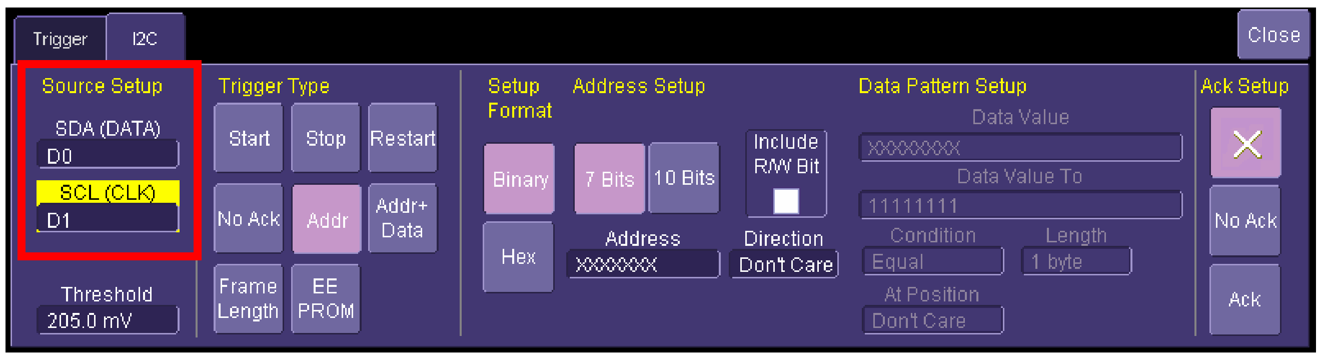


Triggering on a Mixture of Analog and Digital Conditions

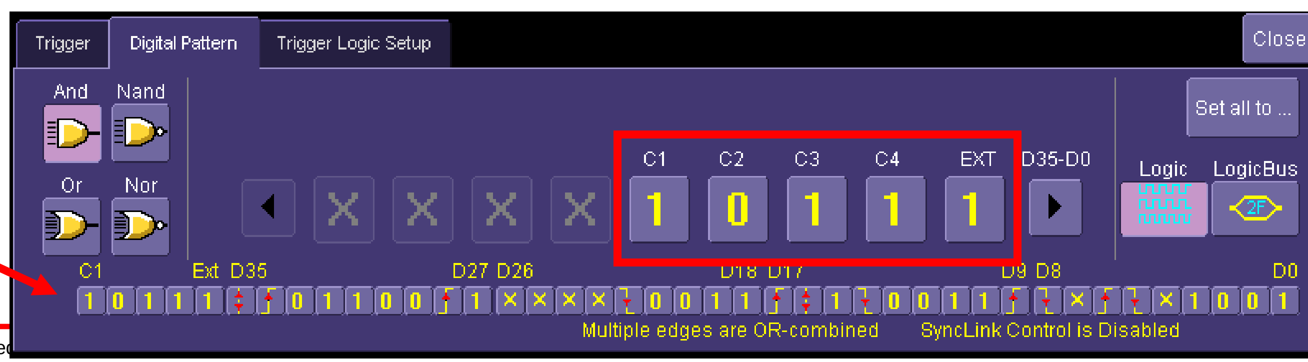
Digital channel as a source for oscilloscope trigger



Digital channel as a source for serial data trigger

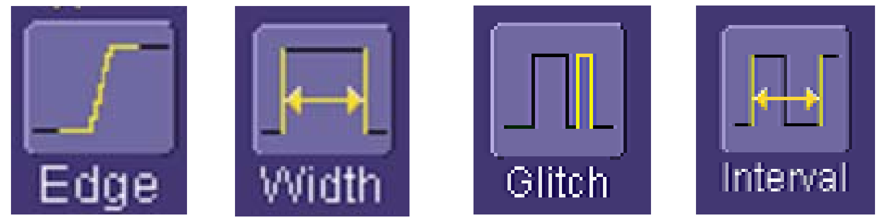


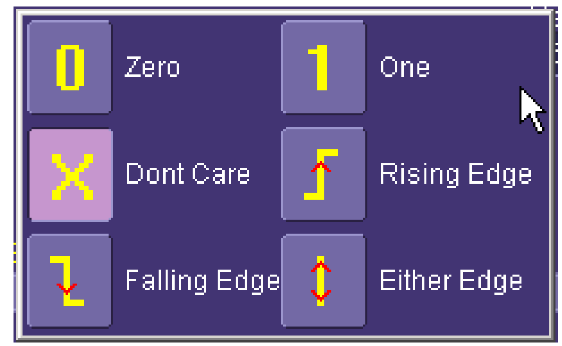
Analog/Digital Cross Pattern Trigger

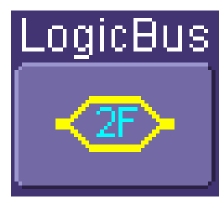


Analog, Digital and Cross Triggering Capabilities

- **Use basic or complex triggers on any of the analog or digital lines**
  - Edge, Width, Glitch, Interval, Dropout
- **Pattern trigger can be used to set a simple or complex pattern using any combination of analog and digital channels**
  - Choose between 1, 0, rising edge, falling edge, either edge or don’t care trigger conditions
- **Bus Trigger - Create a digital trigger that corresponds to a hexadecimal bus value for up to 36 digital bits**
- **Qualified Event Trigger – Arm the trigger on an analog signal and trigger on a pattern or use one pattern to arm the trigger for a second pattern**



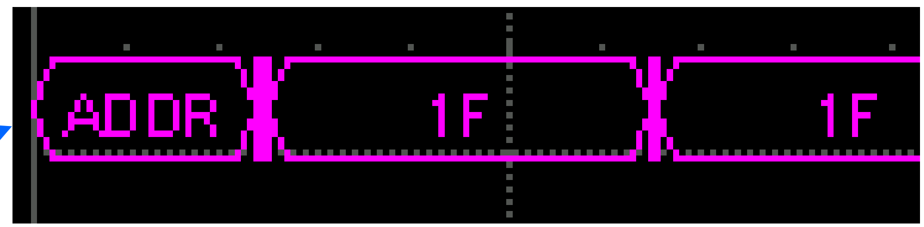


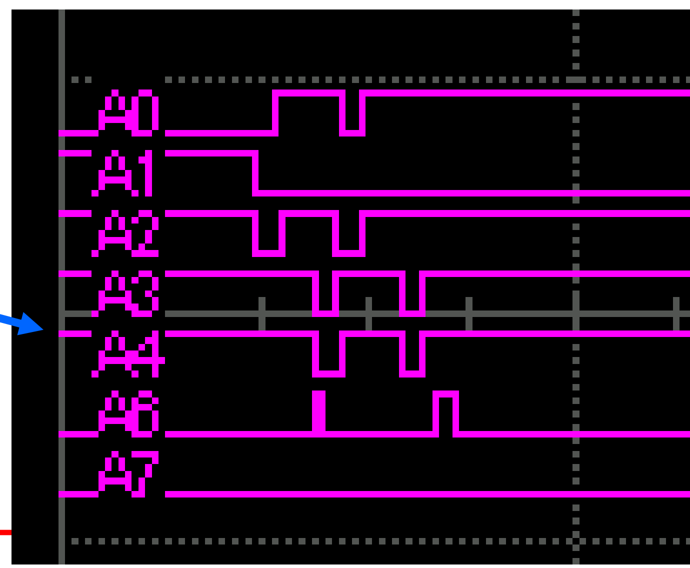


Viewing Digital Waveforms

Digital logic lines can be grouped into “buses” and displayed as a bus view

- *Saves display area*
- *Makes interpretation easier*
- *Can make trigger setup easier*



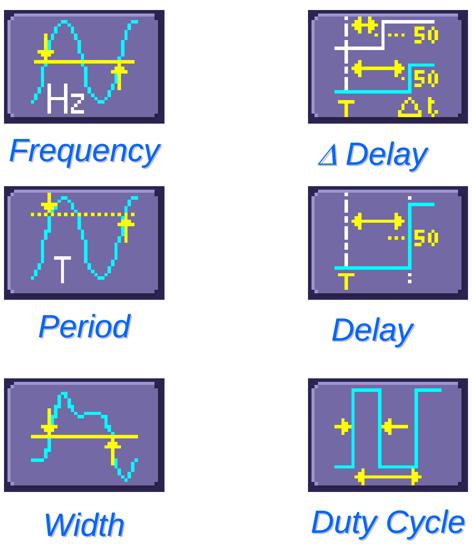


User can control size and position of digital lines and digital buses

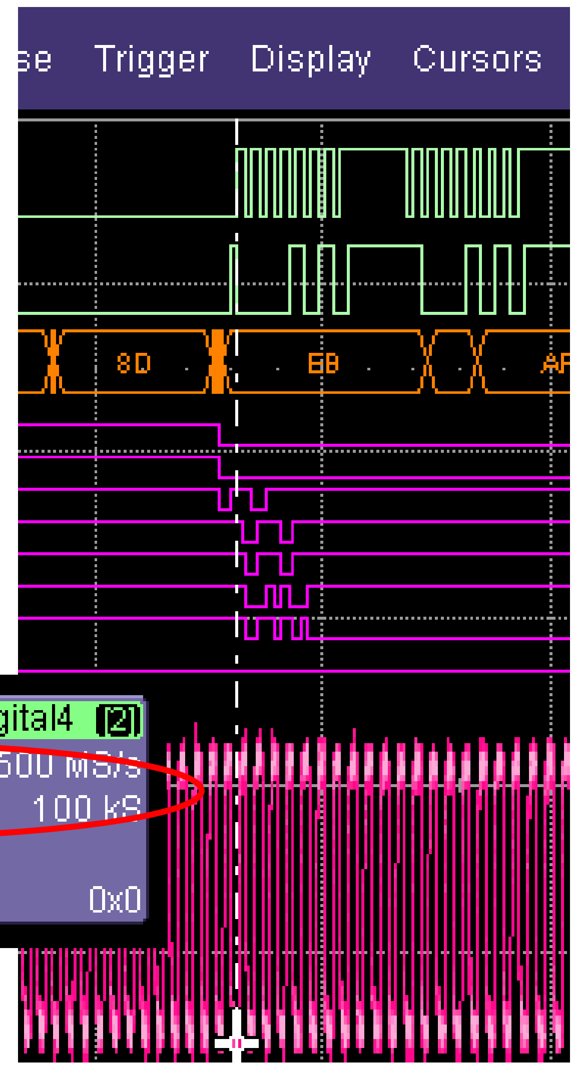
Cursors and Measurements

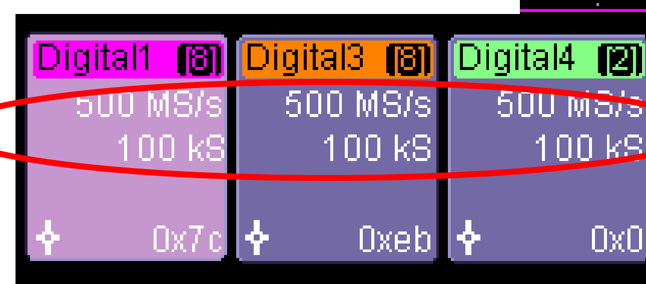
Use common oscilloscope tools to measure digital signals

Measurements may be used with Digital Channels



Cursor Values are Calculated for each Digital Group and displayed in Hexadecimal Format





CAN Bus Message Decoding

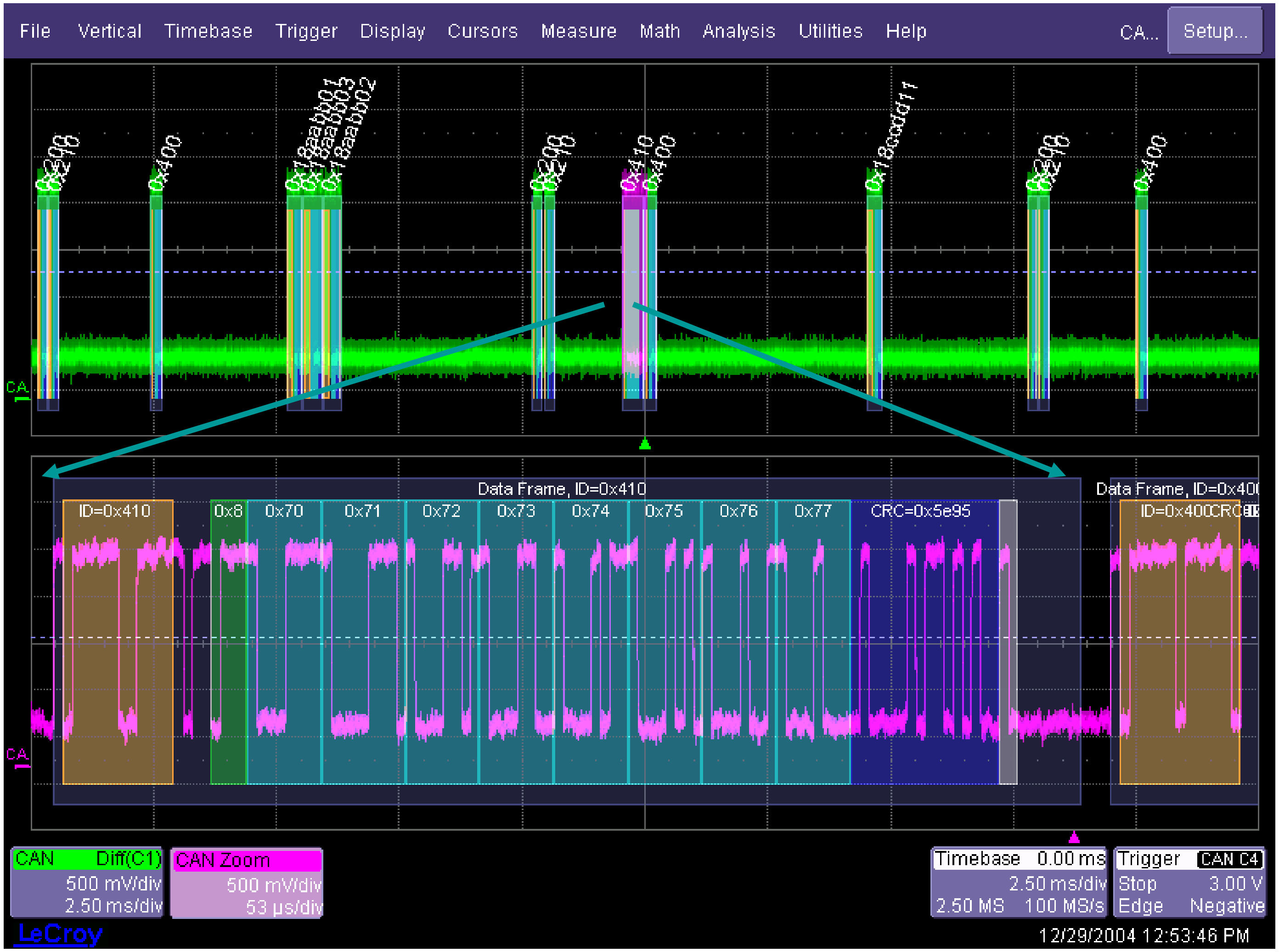
(note the use of long memory and zoom)

Capture Seconds Worth of CAN Traffic

Message Decoding Provides Quick and Easy View of Frame Information

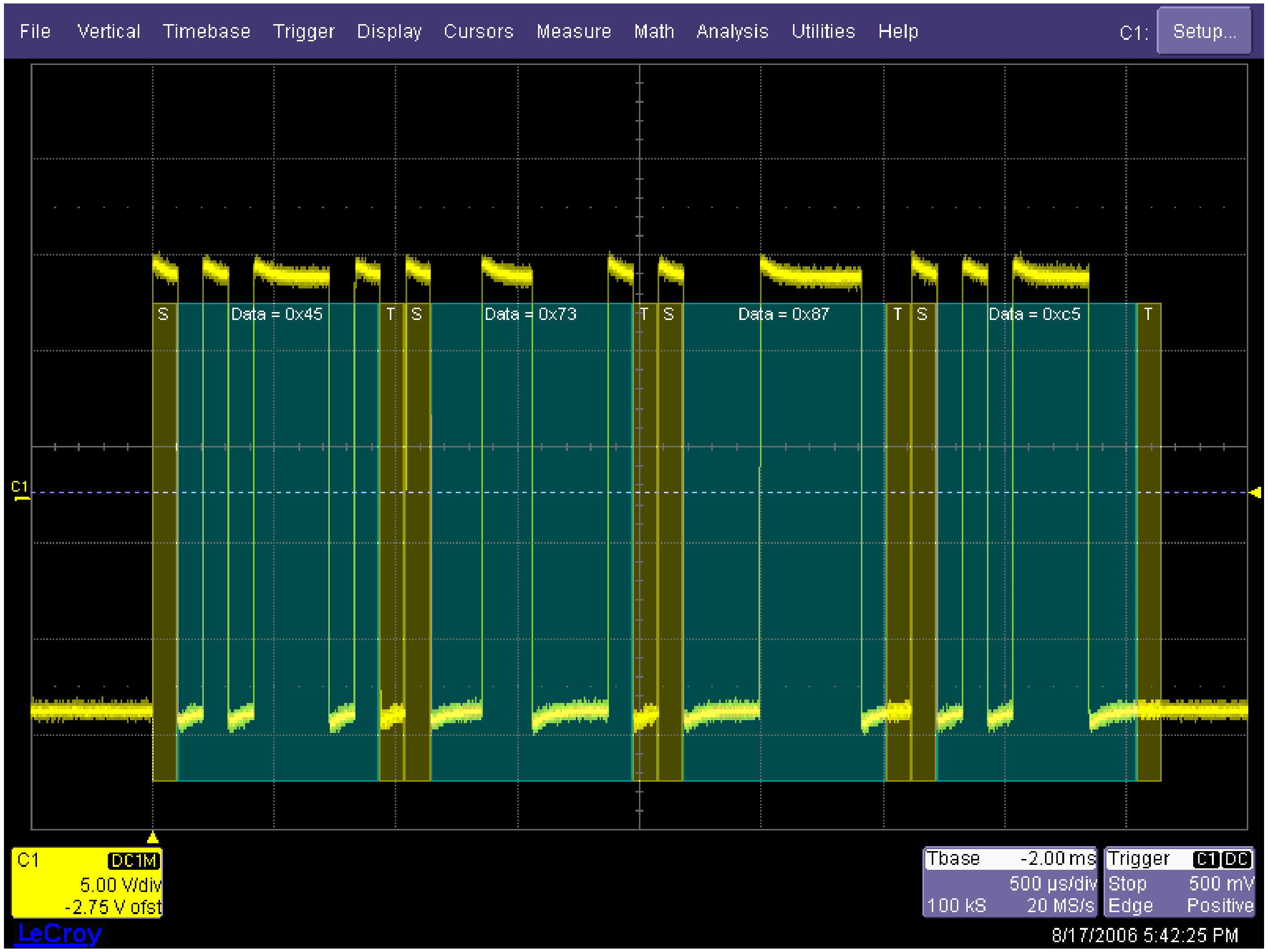
Both Standard and Extended CAN ID's Supported

CAN Zoom Provides Details of Each Frame's Physical Layer Characteristics



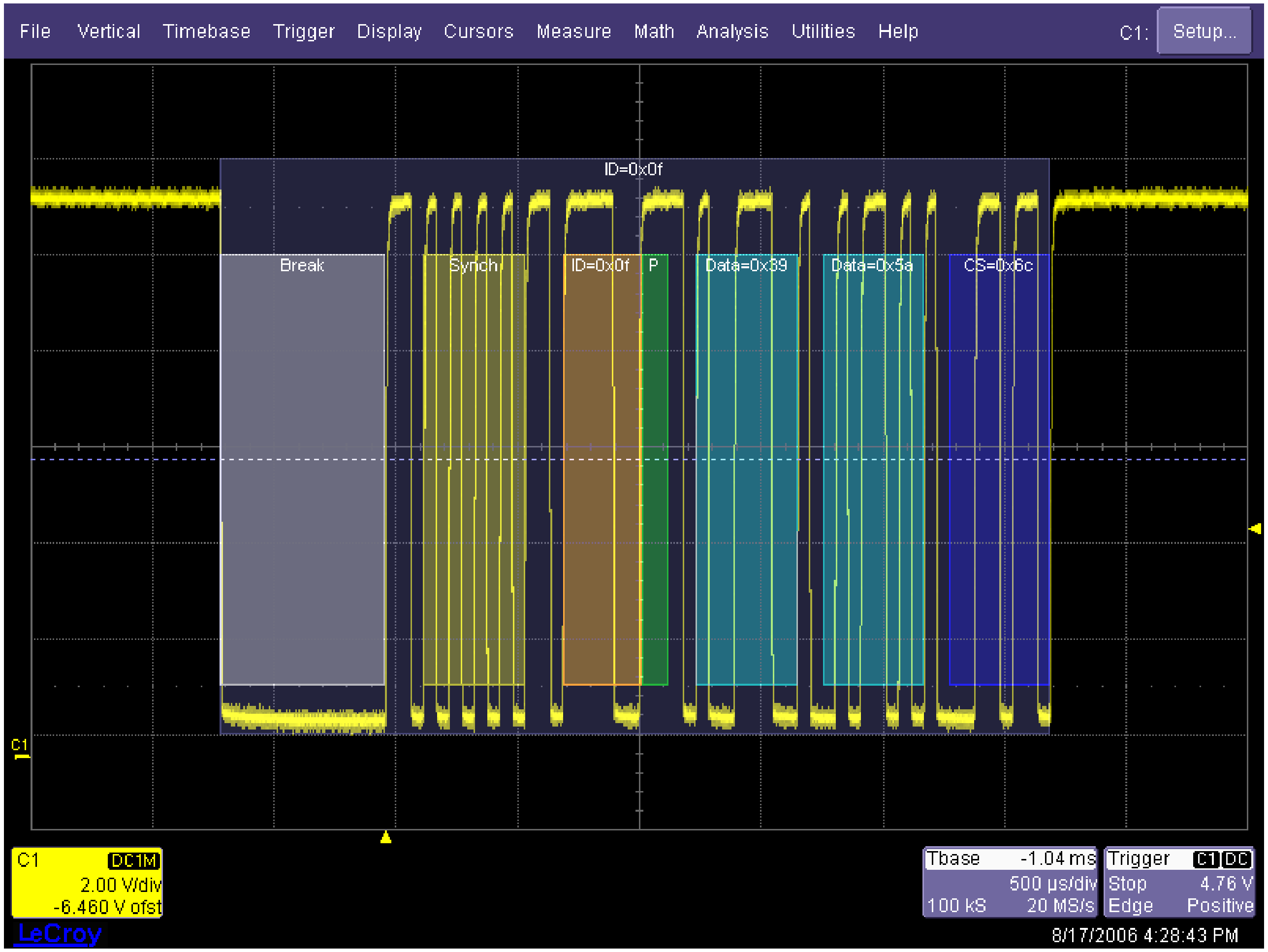
UART and RS-232 Trigger and Decode

- Trigger and decode on RS-232 or generic UART busses
- Customizable UART settings allow for the trigger and decode of proprietary busses using a UART backbone
- Built in support of 9 bit UART
- Conditional triggering for UART messages which are less than, greater than or in or outside a specified range



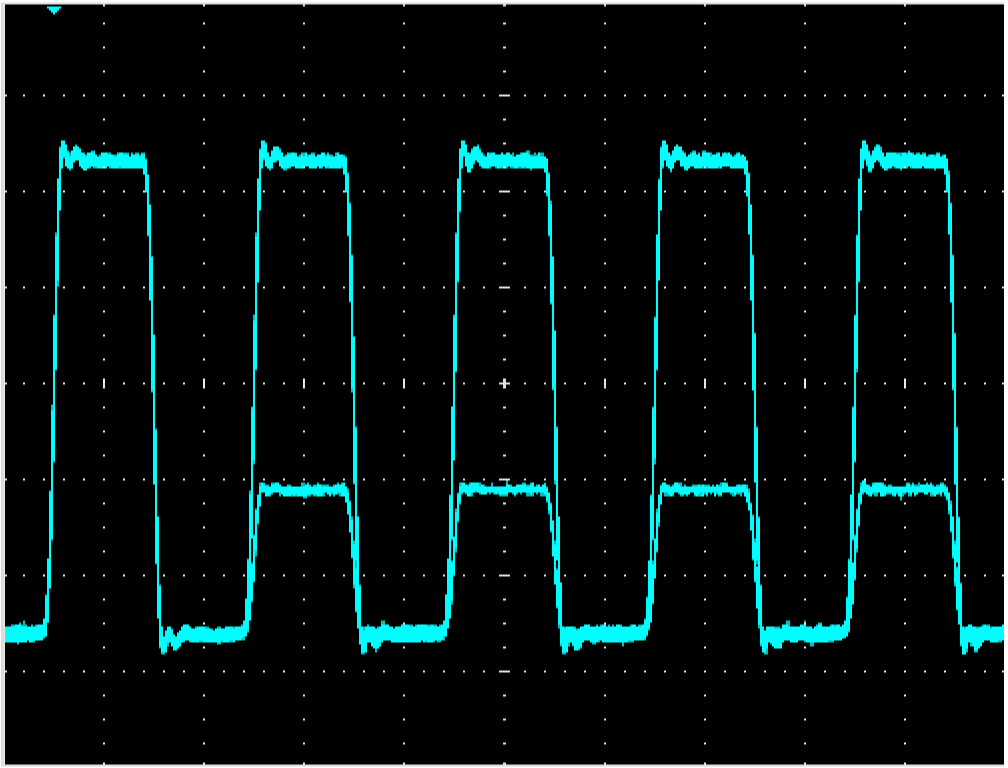
LIN Trigger and Decode

- Full support of LIN 1.3, 2.0 and J2602
- Trigger on Break (Start of Frame), Message ID, Message ID + Data and Error Frames
- Multiple Error triggers available for checksum, header parity and sync byte errors
- Conditional triggering for LIN messages which are less than, greater than or in or outside a specified range



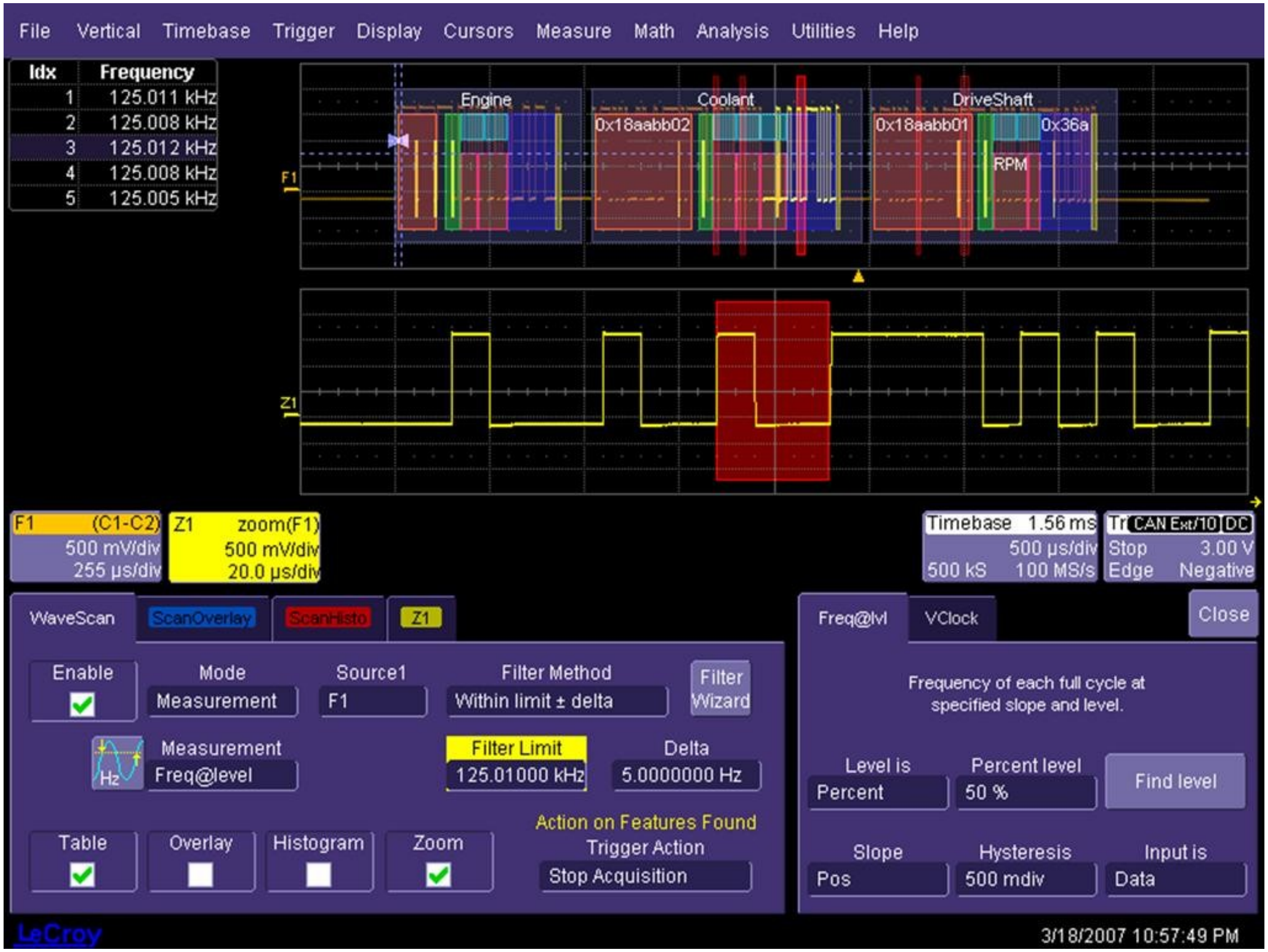
Debug Tool for Intermittent Signal Faults

- The Replay Mode feature is a unique feature in the WaveJet class of scopes (100-500 MHz)
- In Normal or Auto trigger mode WaveJet captures runts, glitches, etc
- When the trigger is stopped and Replay Mode is activated a history of the waveform is displayed
- The history of all acquisitions can be seen in page mode and rotating the knob flips through the acquisitions



The Replay mode can be very useful for debugging intermittent faults in either analog or digital lines. It lets you see the individual signal acquisitions that built up the persistence display on the screen of the scope.

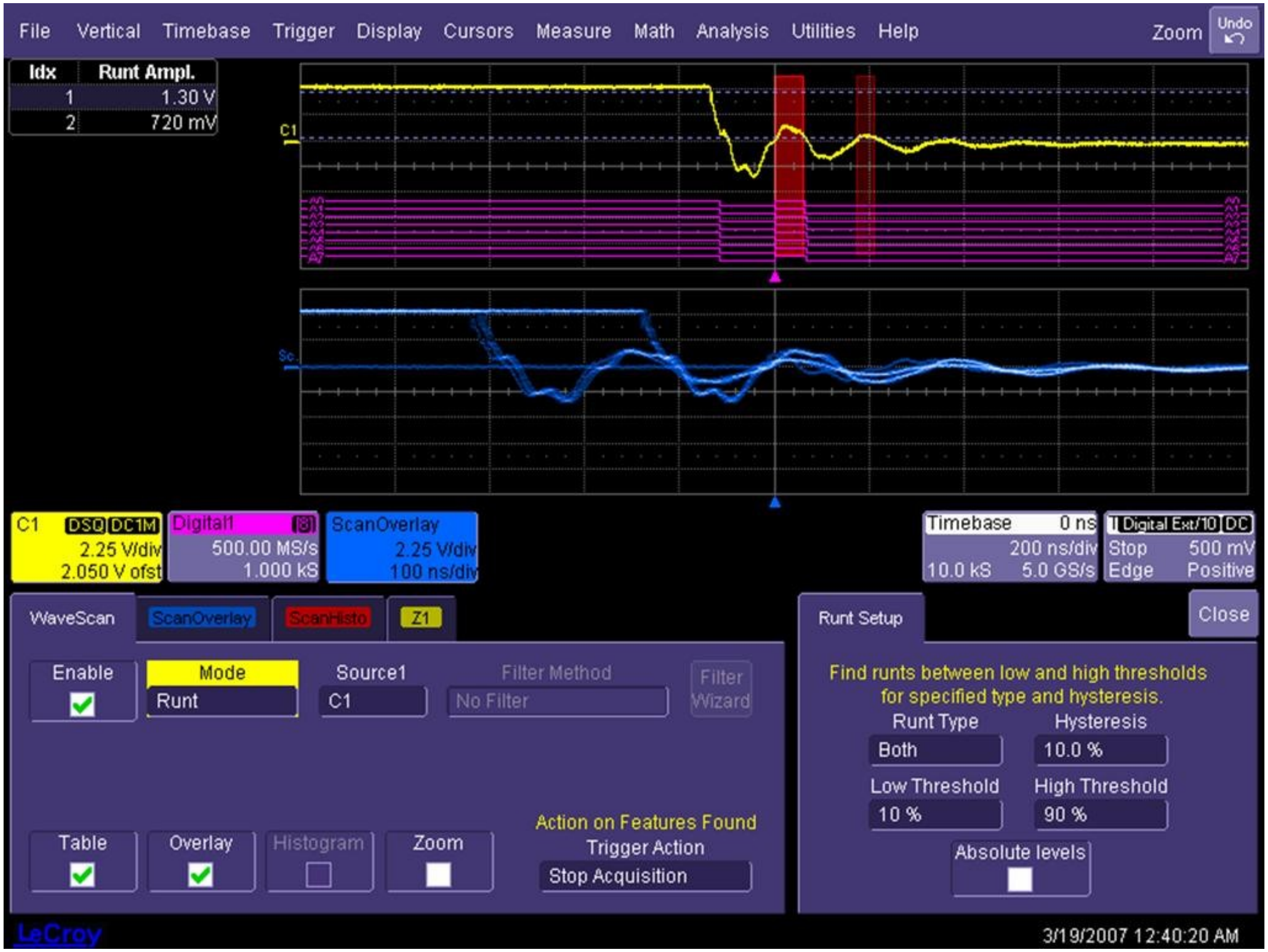
Debug/Analysis Tools



In this example the scope scans the data in a digital line to look for improper frequency of data transitions.

This can be done on a long record of captured data or as a "soft trigger" monitoring the live data coming into the scope.

Debug/Analysis Tools

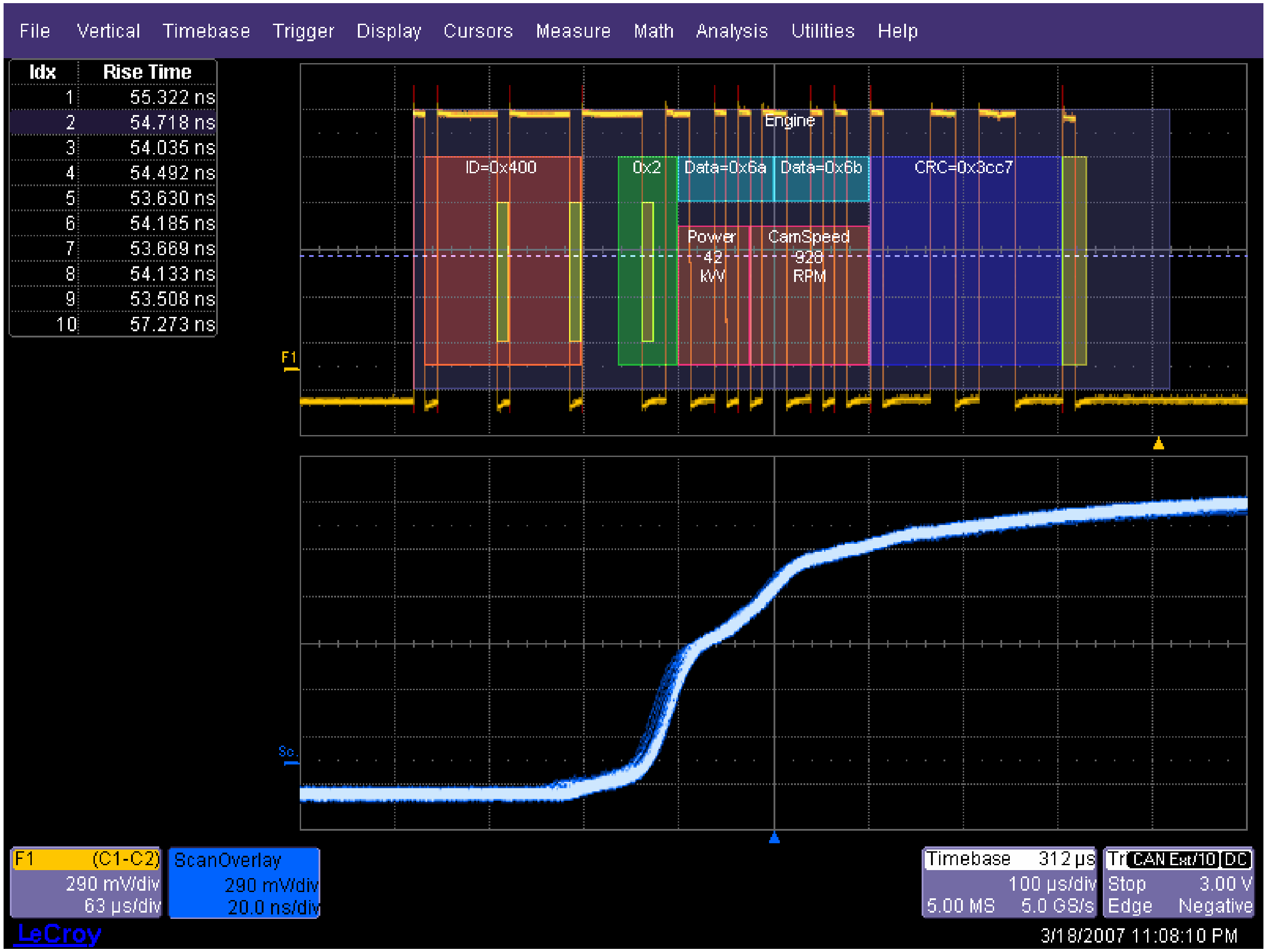


This example shows detection of a "runt" pulse.

The signal goes to logic low, then passes through the 10% level without attaining the 90% level.

The user can set the voltage levels which define "runt".

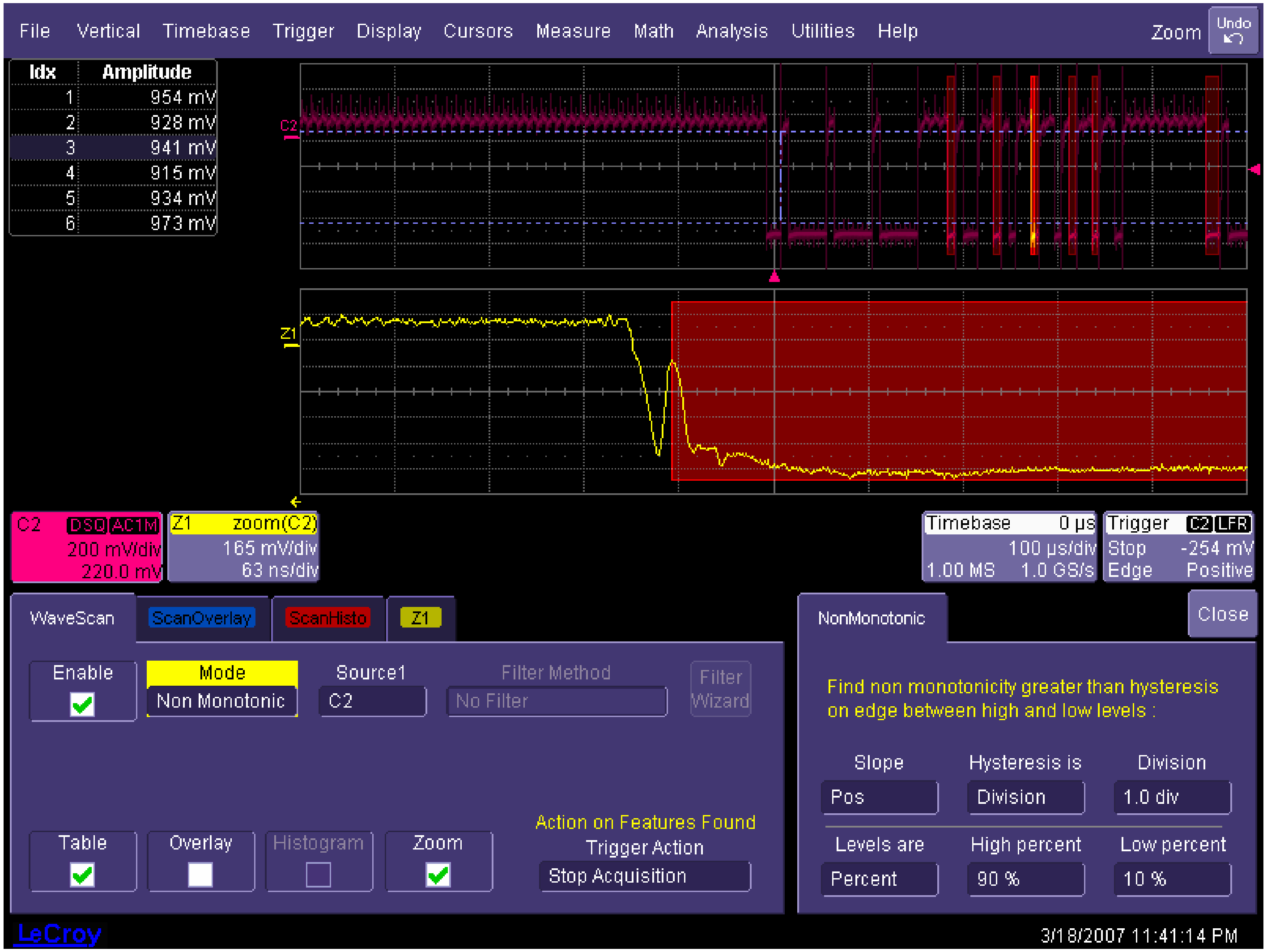
Debug/Analysis Tools



This example shows detection of an improper rise time.

The example is a CANbus signal. Note the decoding of the ID, data values and CRC of the CAN packet.

Debug/Analysis Tools



In this example the scope scans the waveform for non-monotonic edges.

Reflections, glitches, metastable states and other types of circuit faults can be spotted using this technique.

Lab

- **Debug & Analysis**
  - **WaveScan**

Debug/Analysis Tools

(the next several slides will show an example of using histograms to troubleshoot a timing problem between an analog line and a digital line)

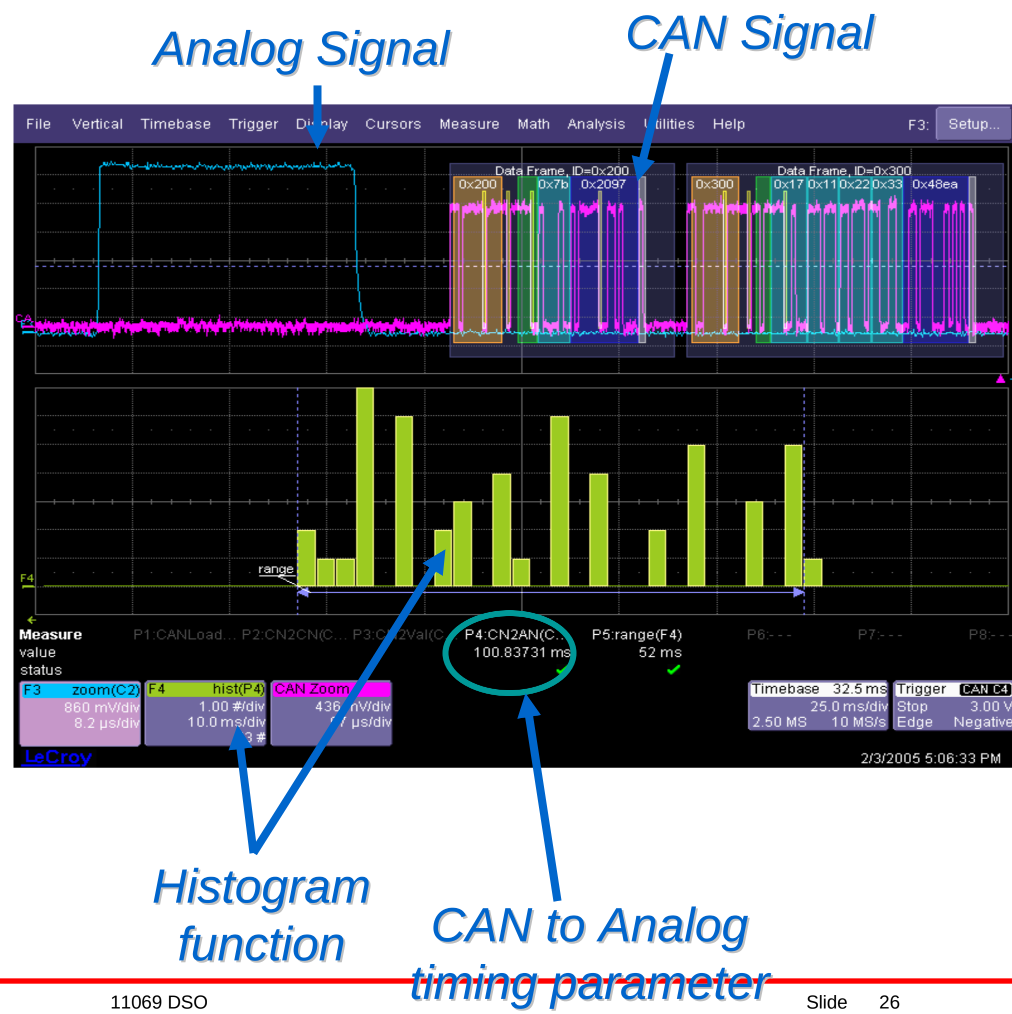
The Evolution of Debug/Analysis Tools

Automated Timing Measurements replaced cursors

Capture thousands or millions of events

Graph and understand statistical significance of data

Ensure that worst case events are understood and designed out



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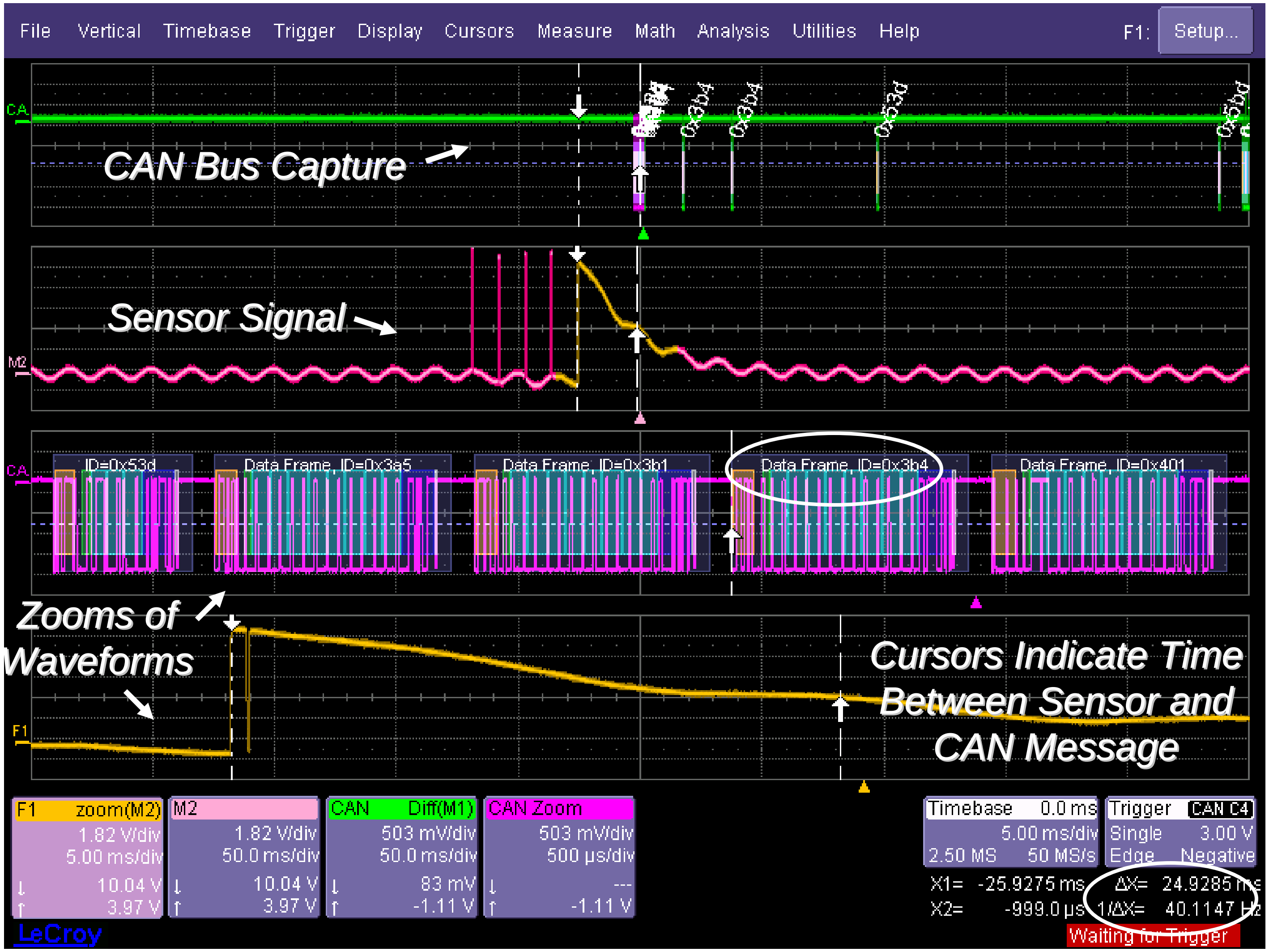
Debug/Analysis Tools
(using Histograms)

Goal:
Measure Time from Sensor to Specific CAN Frame

Procedure:
CAN Trigger Captures Data Frame of Interest (ID=0x3b4)

Scope Captures Analog Signal from Sensor

Timing from Sensor's 5th Edge to CAN Data Frame's SOF is Measured with Cursors



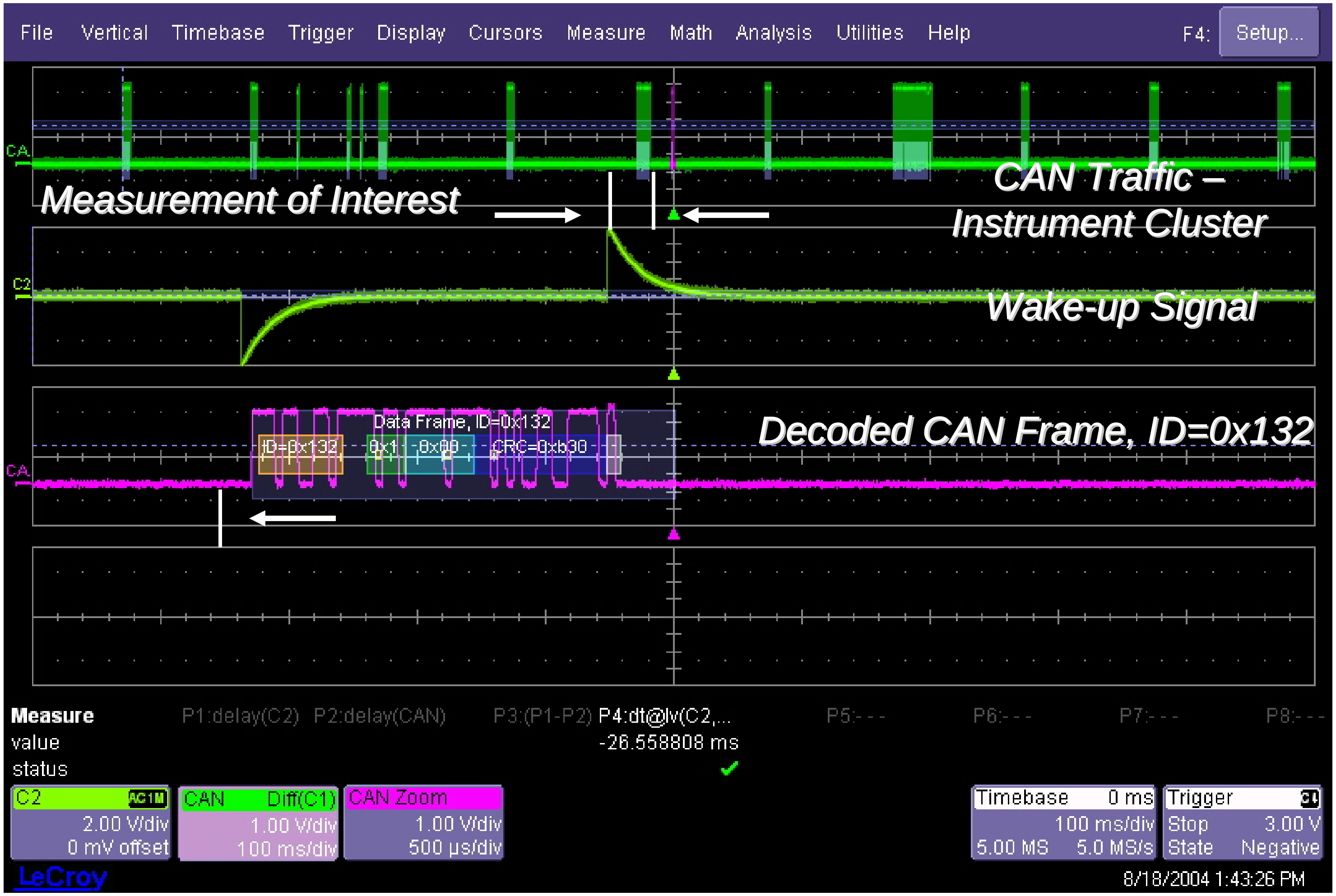
Debug/Analysis Tools
(using Histograms)

Goals:

Determine Time from Wake-up Signal to Specific CAN Frame

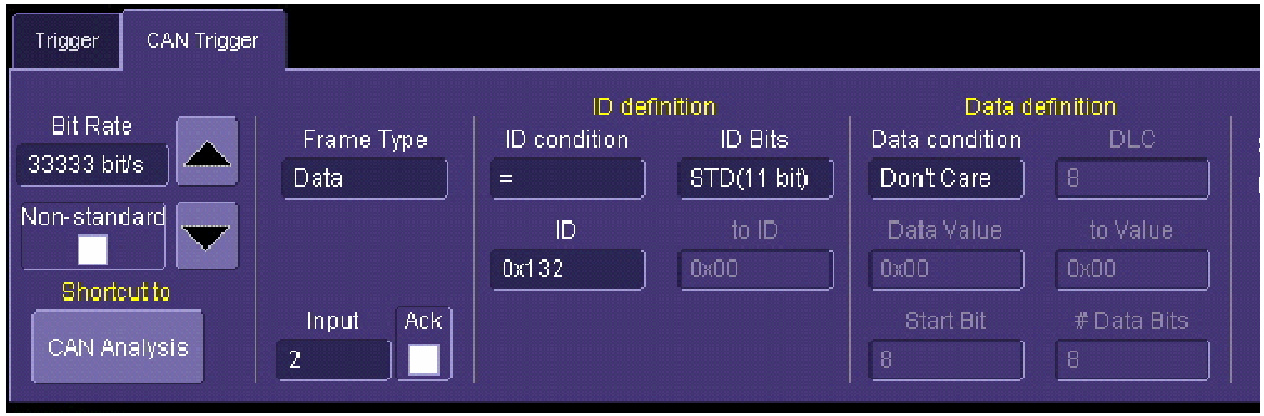
Accurately Determine Message Latency

Gain Insight to Variance in These Latency Values

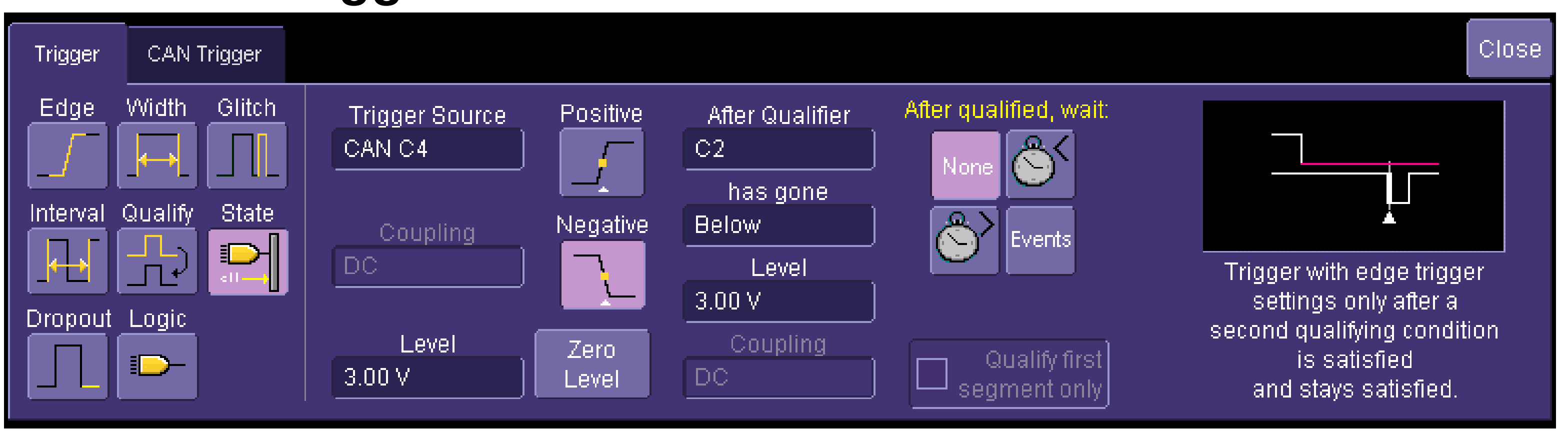


Debug/Analysis Tools
(using Histograms)

First Step: Define CAN Trigger Condition – Trigger on Data Frame with ID = 0x132



Second Step: Setup State Trigger to Find Wake-up Signal as Pre-Qualifier for CAN Trigger



Debug/Analysis Tools
(using Histograms)

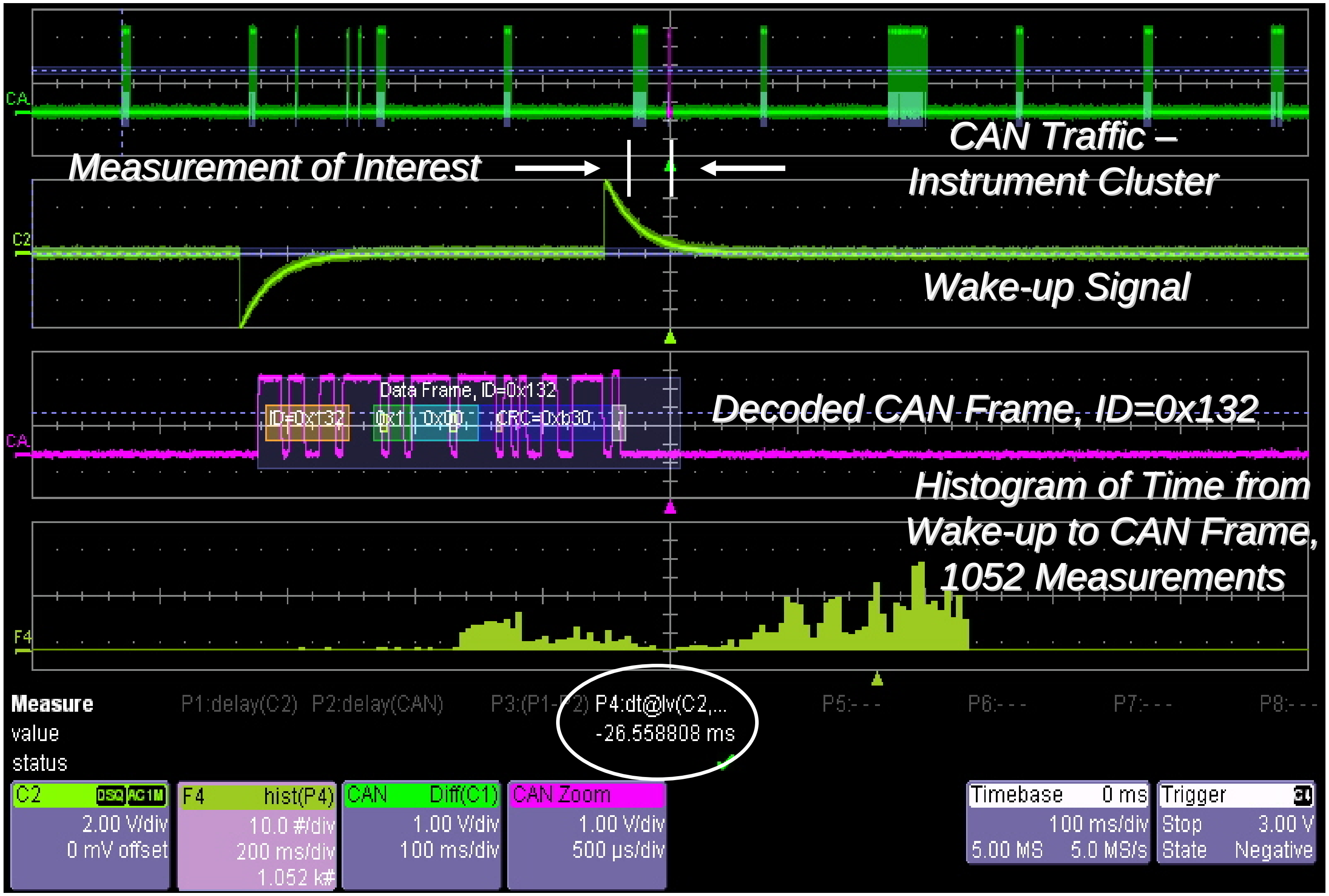
Results:

State Triggering Coupled with CANbus TD Captures Signals of Interest

CAN Decoding Provides CAN Message Details

Measurement Parameters Provide Timing of Message Latency

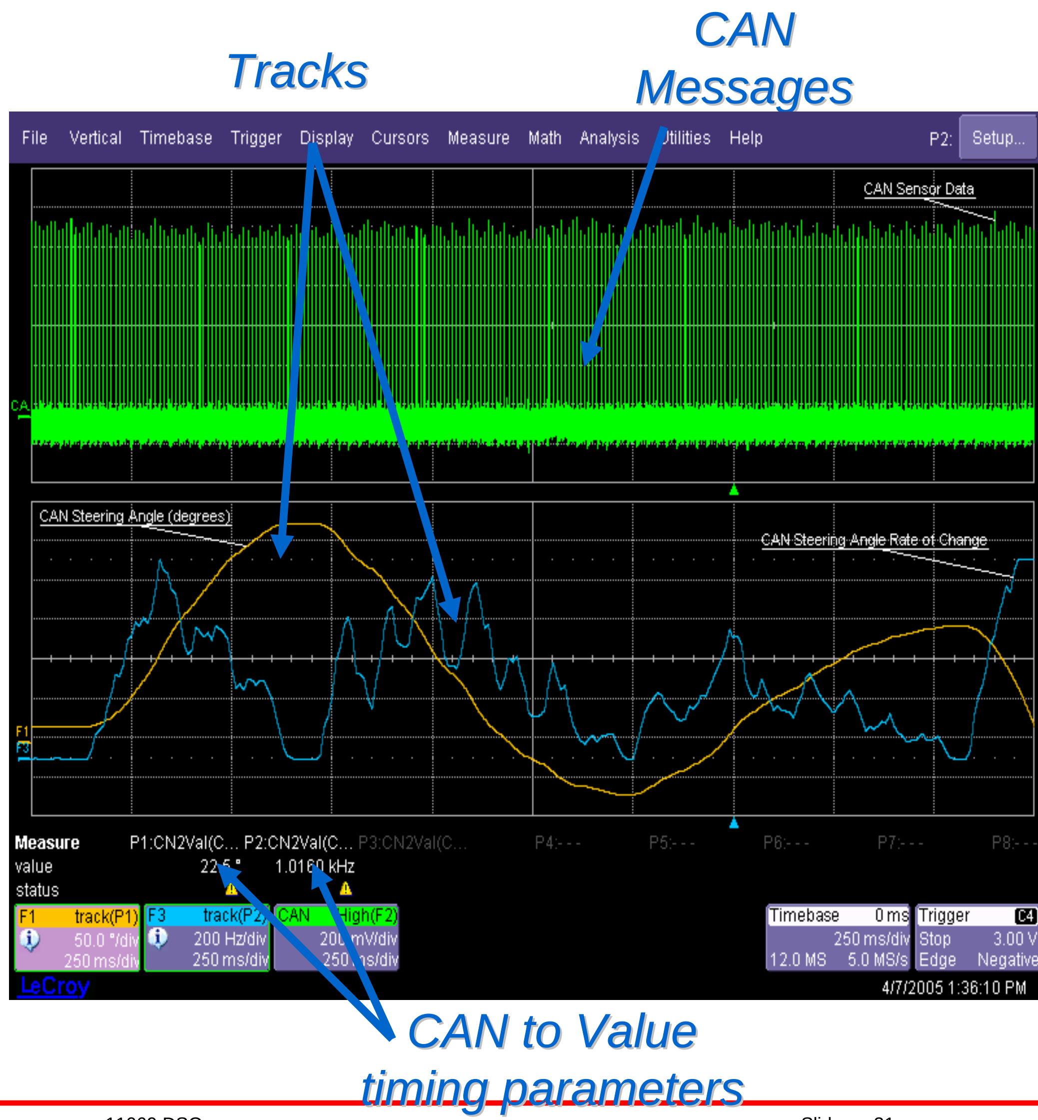
Histograms Provides Insight to Variance of Latency Values



Debug/Analysis Tools
(tracks of parameter values)

In this example the scope:

- Extracts decimal data from a specific CAN Messages
- Rescale to user-defined units
- Plots data
- Understand correlation with analog signal information



Lab- MSO Applications

Use the WaveSource 100 Digital Pattern Pins
- Connect digital leads to pins D0 – D3, connect passive probes from C1 and C2 on the scope to D4 and D5 respectively
- Connect one of the grey ground leads with a gripper to the WaveSource 100 ground plane

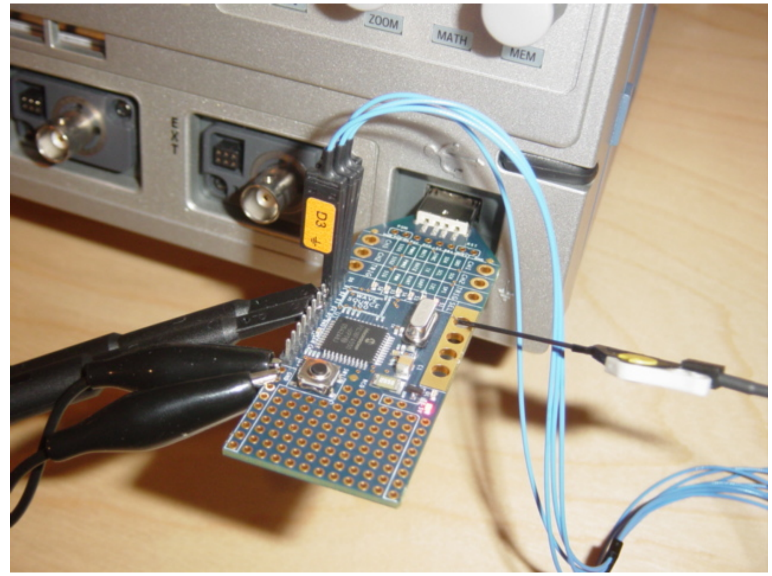
Set Digital Group 1 to display D0 – D3 and set an edge trigger on D3
- This shows how digital channels are completely integrated into the oscilloscope, all digital channels can be used as sources for scope triggers, edge, width, interval, etc

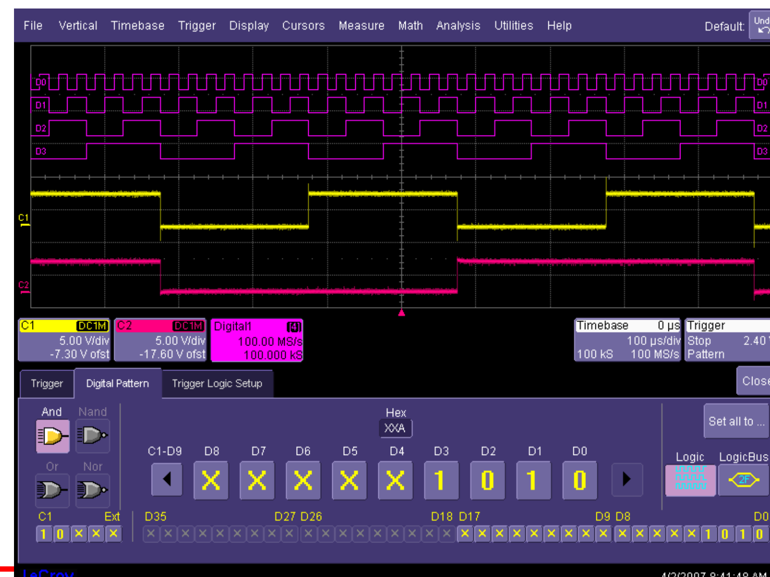
Turn on C1 and C2 and set up a pattern trigger with these values
- C1 – 1, C2 – 0, D3 – 1, D2 – 0, D1 – 1, D0 – 0 and note the trigger position
- In 100 us/div you can see that the proper trigger condition is met, see screenshot on this slide
- This shows our new cross pattern triggering, the user can create simple or complex trigger patterns consisting of up to 4 analog and 36 digital channels

Turn on Horizontal Absolute cursors and show how cursors read out timing measurements and digital bus values below the waveform grid

Turn on measurement parameters and show how they work on both analog and digital channels
- Try Period, Frequency, Width, Duty Cycle, Delay, Delta Delay

Turn on long memory by going to the timebase menu and turn it up to 50 Mpts, turn back the T/div and show how much data can be captured – Use the zoom along with the touch screen





Lab- Serial Data Trigger and Decode

The MS-500 and MS-250 are capable of serial data trigger and decode

The TD packages for I^2C™, SPI, UART and LIN all work with digital inputs

Setup

- Use any digital lines and set them up in Digital Group 1
- Then from the touch screen select the proper sources for data and/or clock just as you would an analog scope channel
- Trigger and Decode using the digital lines. Save the scope channels for important analog signals

Lab- UART/RS-232

Use Ch2 of test device WS 100 and press the switch twice until the S3 LED is blinking

Connect a passive probe from C1 of the scope to Ch2 and ground the probe

Set an edge trigger on C1 and select 50 us/div

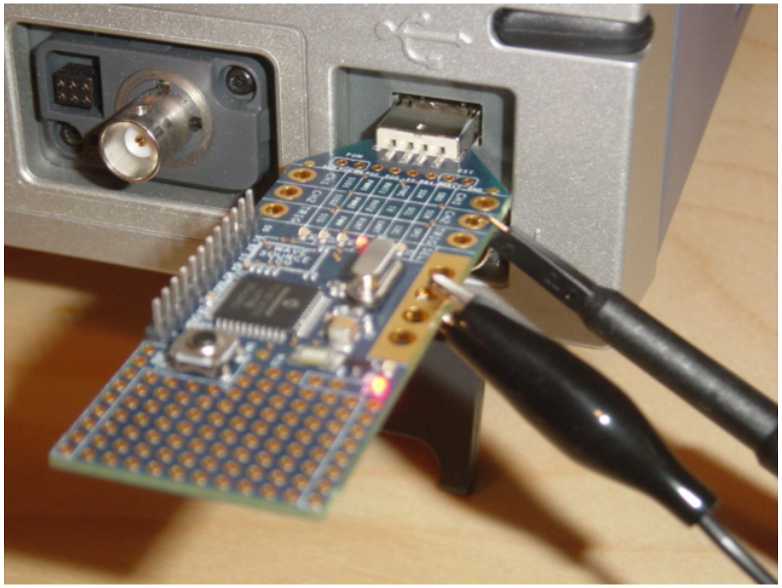
Enter Decode Menu, select UART and the source as C1

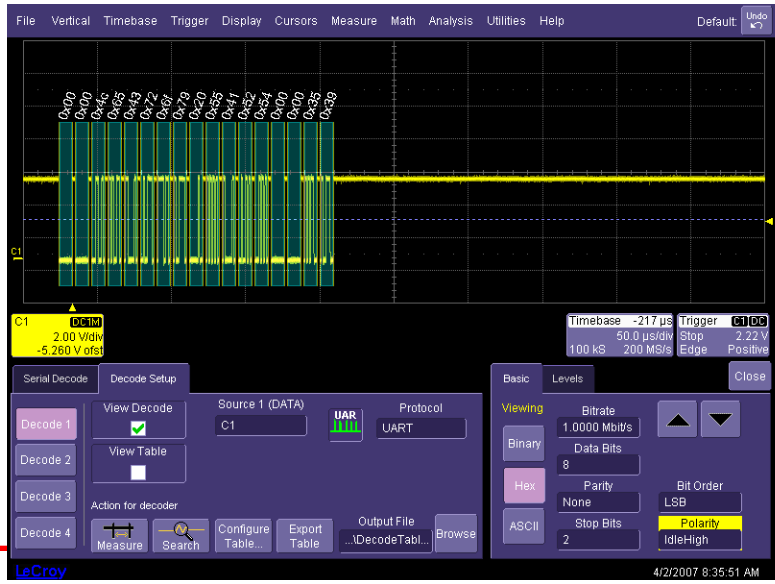
Set the following parameters and turn the decode on

- **Bitrate – 1 Mbps, Data bits – 8, Parity – None, Stop Bits – 2, Bit Order – LSB, Polarity – Idle High**
  - Your display should match the screenshot on the bottom of this slide
- **The color coded decode overlay lets the user quickly scan through captured data for the bytes they are looking for**
- **Switch between Hex, Binary and ASCII to show that decoded data can be displayed in several different ways**
- **Increase the memory to 5 Mpts and change the timebase to 20 ms/div**
- **Turn on the table and show how easy it is to locate message in long captures**
- **Select an entry in the table and click on it, a zoom takes you right to the data of interest**

Enter the trigger menu, confirm the proper settings and set the trigger as desired

- **Set the trigger on any of the following data bytes to show how the trigger works - 4C, 65, 6F, 20**
- **Try a conditional trigger by selecting one of the trigger conditions and any data byte you see decoded on the screen**





Choosing the Lab Tools for Your Embedded System Needs

Equipment Considerations

There are three basic types of scope architectures for capture of signals from embedded systems.

1. Use an oscilloscope and a separate logic analyzer (expensive and complicated- but has the performance needed for data rates 1 GHz and faster)
2. Use an oscilloscope with a built in attachment for capturing digital lines (typically limited to 16 digital lines with short memory and 250 MHz data rate)
3. Use an optional external module that captures digital signals which are then transferred into the scope (easier to share, easier to get short lines from DUT to module, up to 36 digital lines with long memory, up to 500 MHz digital signals, up to 2 GHz analog signals)

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Elements of an MSO Option

High Performance

- Max Input Frequency for digital signals
- Measured as Max Sampling Rate

Long Memory

-Length of digital signal

-Should relate well with scope memory

Display

- How to see and overlay analog and digital

More Channels

- 8, 16, 32 or more on 2 or 4 ch scope

Easy Setup

-Simple Connection to Oscilloscope

- Quality of Integration

Easy to Operate

- Intuitive User Interface

- Compare analog with digital inputs and then measure

Price/Performance

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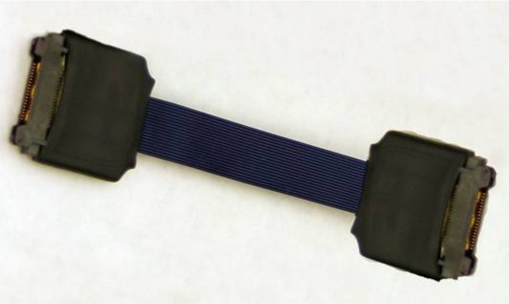
These Qualities appear in all spec sheet

	MS-500	MS-500-36	MS-250
Maximum Input Frequency	**500 MHz**	**250 MHz**	**250 MHz**
Max Sample Rate	**2 GS/s**	**1 GS/s**	**1 GS/s**
Acquisition Memory	**50 Mpts/ch**	**25 Mpts/ch**	**10 Mpts/ch**
Number of Channels	**18**	**36**	**18**
Threshold Groupings	**D0-D8, D9-D17**	**D0-D8, D9-D17, D18-D26, D27-D35**	**D0-D8, D9-D17**
Threshold Levels	**TTL, ECL,PECL, CMOS (2.5V, 3.3V, 5V), LVDS or User Defined**		
Trigger Types	**Edge, Width, Glitch, Pattern, Qualified, Interval, Dropout**		
Serial Data Triggers (Optional)	**I2C, SPI, UART, RS-232, LIN**		
Trigger Sources	**C1-C4, D0-D17**	**C1-C4, D0-D35**	**C1-C4, D0-D17**

Courtesy LeCroy Corporation

Accessories – Mictor Cables

Mictor connection cable, 3" (7.62 cm) long, 38-pin (32 digital channels).



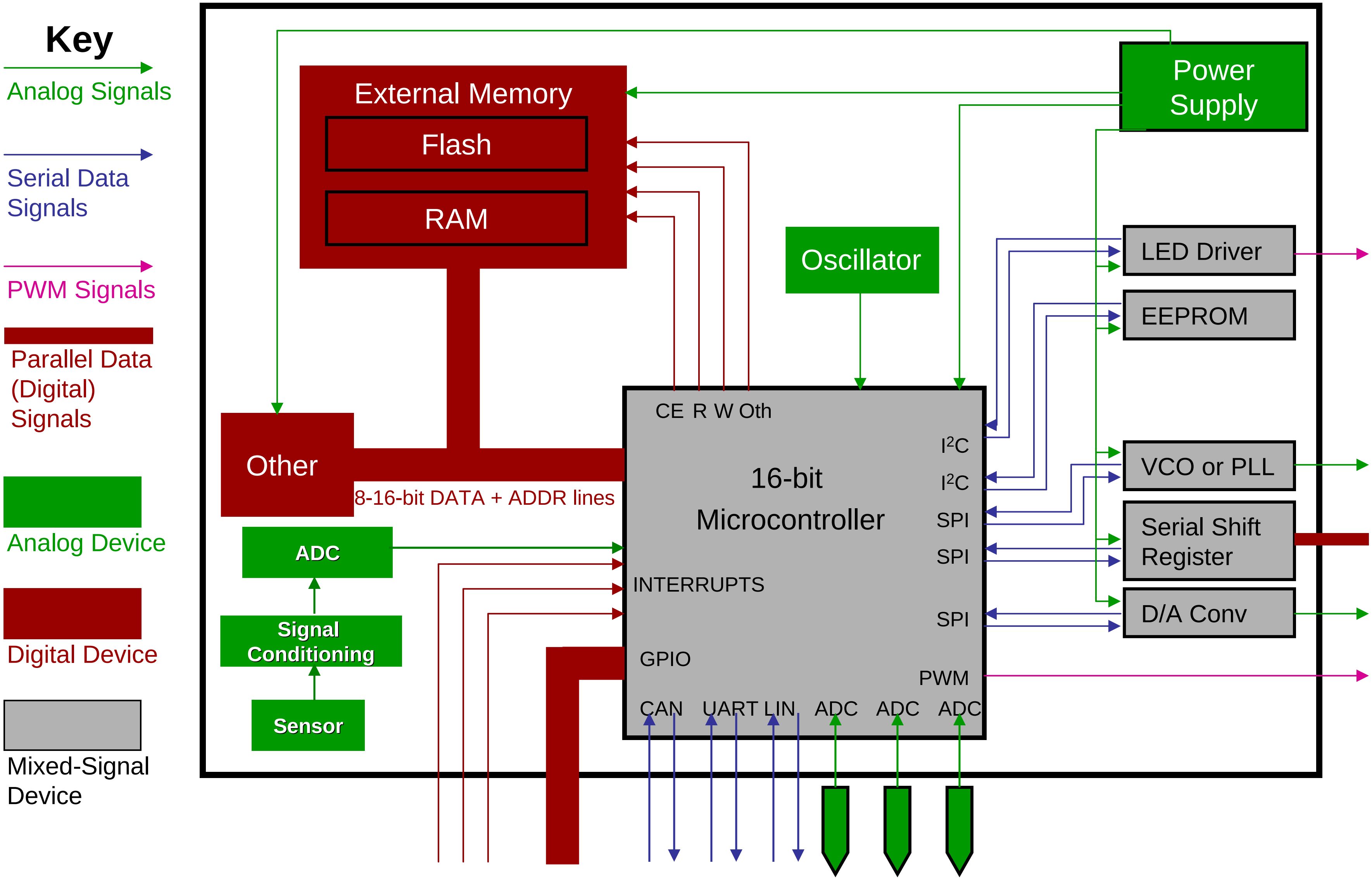
Mictor connection cable, 14" (35.56 cm) long, 38-pin (32 digital channels). Maximum digital clock frequency with this lead set is 125 MHz.

s

Note: Mictor cable connections do not allow precise time alignment of analog and digital signals on the oscilloscope. Use the blue cables for precise timing measurements.

A Typical Embedded Controller

(Your System may have some/all of these elements)



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Summary

Capture

- Use the right trigger (combination of digital and analog conditions)
- Use long memory at high sample rate for most accurate capture of both the digital and analog signals
- Triggering on a certain data value or ID can be useful

View

- A large display with room for all the signals is very useful
- View digital lines individually or as bus values

Measure

- Use scope cursor and parameter measurements on digital lines in the same fashion as on analog signals

Summary

Analysis

- Some scope option packages will allow you to decode and analyze bus traffic
- Graph (track) the values of key signal characteristics
- Histogram the timing between events
- Find the source of errors

References

Literature

- Application Notes
- Tech Briefs
- Text Books

References

Websites

- Microchip Technology Inc.
  - www.microchip.com
- LeCroy
  - www.lecroy.com

References

Web Seminars

References

Demo Boards

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