Distributed Sensor Network with Synchronization via IEEE 1588 Precision Time Protocol

IEEE 1588

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Outline

• DTS background
• Brief overview IEEE 1588 (PTP)
• Problem: High speed DAQ for vehicle blast testing
• Solution: Ultra-miniature PTP design embedded at sensor level
• Flight test applications
Overview of DTS

• Designer/manufacturer of high sample rate, high shock rated sensors and data recorders.
• Privately owned since 1990, founded by 3 test engineers.
• ~85 Staff members, based in Seal Beach CA
Crash Test 1989 – 33 Total Channels: Current Crash Test can be 500+ channels!

Advanced DAS: Bell & Howell 14 Channel FM Tape Recorder - ~80 lbs
DTS PHILOSOPHY

FAILURE IS NOT AN OPTION

HIGH SPEED, RUGGED DATA ACQUISITION SYSTEMS

VEHICLE CRASH TESTING
INJURY BIOMECHANICS
BLAST TESTING
FLIGHT TESTING
TYPICAL APPLICATIONS & SHOCK LEVELS

- **NVH (5k sps)**: 20 g
- **VEHICLE SAFETY (20k sps)**: 100 g
- **MOTORSPORTS (20k sps)**: 500 g
- **RESEARCH, ACOUSTICS (20k to 100k sps)**: 500 to 5,000 g
- **BLAST PROTECTION TESTING (100k to 1M sps)**: 5,000 to 25,000 g
- **ORDNANCE & BALLISTICS (500k to 1M sps)**: Up to 100,000 g
SLICE NANO PRODUCT LINE

BATT
- 26 x 31 mm footprint
- Up to 500K sps/channel
- 16 Gbyte flash Memory
- Signal conditioning for accelerometers, pressure sensors, load cells, strain gauges, etc.

BASE+

BRIDGE
- Up TO 24ch

IEPE
SLICE NANO PRODUCT LINE

ATD APPLICATIONS – HYBRID III M50 & F5

- 96 Channels
- Head – 9 Ch
- Tibia – 12 Ch
25+ kg SHOCK SURVIVABILITY
PICATINNY ARSENAL – ACCEL/ARS data from 155mm projectile

Approximately 15,000 g’s for 14 msec – A lot of Energy!
CHINA LAKE – Daisy chain multiple 3-channel SLICE HG systems
NOTHING COMES CLOSE

ONLY DAS ON THE MARKET CAPABLE OF

1 MILLION SAMPLES PER SECOND
>25,000 g SHOCK SURVIVABILITY
18ch SLICE MICRO
Limited size/weight
Long duration testing
AEROSPACE

Crew Capsule Stresses & Parachute Loading

30-Channel Flight Test
2.5 Hours @ 20k sps

SLICE MICRO System

S-C-MSC
USB Cable

S-C-SDC
CHAIN CABLE

S-C-EOC
End Of Chain Terminal
**Brief Overview of IEEE 1588 (PTP)**

  - Defines a Precision Time Protocol (PTP) designed to synchronize real-time clocks in a distributed system.

- **PTP vs NTP (Network Time Protocol) vs IRIG (Inter-Range Instrumentation Group)**

<table>
<thead>
<tr>
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<th>NTP</th>
<th>IRIG</th>
<th>PTP</th>
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<tbody>
<tr>
<td><strong>Description</strong></td>
<td>Relatively easy to implement using existing LAN architecture</td>
<td>Improves time transfer accuracy with dedicated cabling and hardware clocks at both ends</td>
<td>Existing LAN architecture with addition of Master and Slave clocks</td>
</tr>
<tr>
<td><strong>Potential Sync Precision</strong></td>
<td>0.5 to 2 msec</td>
<td>1 to 10 µsec</td>
<td>10 to 100 nsec</td>
</tr>
<tr>
<td><strong>Cabling</strong></td>
<td>Standard LAN hubs &amp; switches, CAT5</td>
<td>Dedicated, usually coax</td>
<td>Standard LAN hubs &amp; switches, CAT5</td>
</tr>
</tbody>
</table>

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Brief Overview of IEEE 1588 (PTP)

• Why is IEEE 1588 so accurate? Hardware timestamping.
Brief Overview of IEEE 1588 (PTP)

- A simplified diagram of how this might work is shown below.

Grand Master Clock (usually synced to GPS)

- Ethernet Switch
- Slave Clock
- MCU

- Ethernet Switch
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- Ethernet Switch
- Slave Clock
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The Problem

Army WIAMan (Warrior Injury Assessment Manikin)

- DTS is Prime Contractor for development.
- Designed for underbody blast.
- Fully integrated dummy with 200+ channels or in-dummy DAS.
- Up to 12 manikins in a test.
- Also on-vehicle and off-vehicle DAS and high speed cameras.
- Total channels can be > 3,000.
- Requirement to sync all data sampling to within < 5 µsec at sampling rates of 400K to 1M samples/sec/channel.
Example Exterior Blast Environment
Example Interior Blast Environment
System Configuration at Blast Range

Supports up to 12 ATD Umbilical Cables (only one connection shown for clarity)

- Bomb Proof
  - All OK
- Master Clock
  - Available
    - Start
    - Status
    - On/off
- TRIGGER
  - BNC (isolated)
  - 0 – 5 volts
- Earth
- Exit
- Umbilical L ≤ 100m

- 110/220V 1000W
- 10-36 VDC

All ADCs in every dummy to be synched (clocked) within < 5 µsec

12 x 200 = 2400 manikin channels
WIAMan
WIAMan with Embedded DAS

- ~200 Channels
- 6 channel load cells
- 6 Degree-of-Freedom sensors
- All channels networked via Ethernet
- One exit umbilical for manikin
The Solution?

200 channels using National Instruments PXI with IEEE 1588

Need to fit all this inside the manikin (plus batteries)
A New Solution

- 6 channel DAS (24 x 30 x 10 mm) plugs on to each sensor.
- All data digitized at the sensor, synchronized using miniaturized IEEE 1588 hardware built in to each 6 channel DAS.
- Data stored to local 16 GB flash memory and DAS/sensors chained via Ethernet to create a large, distributed sensor network.

6 Channel DAS

- Excitation for sensors
- Prog. gain, offset, AA filters
- 400 Ksps/chan, 16 bit ADC
- 16 GB flash Memory
SLICE6 IEEE Synchronized Clock

- **Master Clock (MC):** Provide reference clock to synchronize all slave devices on network.
- **3-Port Ethernet Switch.**
  - Port 1: Upstream to MC
  - Port 2: SLICE6 MCU
  - Port 3: Downstream
- **Transparent Clock (TC):** Synchronize with MC & reference clock ADC.
- **Slave Clock (SC):** Synchronize with MC via PTP stack.
- If MC lost, internal oscillator takes over clocking ADC until MC returns.
SLICE6 – Signal Conditioning

Sensor Side ⟷ → Internal to SLIC6 (x6 channels)
SLICE6 Specs

- 6 differential input channels - can plug directly on to sensor or used with sensor harness
- Sig. Cond. for accels, pressure sensors, load cells, strain gauges, etc.
- Size: 24 x 30 x 10 mm
- 16 bit, 400 Ksps/chan ADC (one per chan) - FPGA for managing ADC
- 16 GB flash memory
- 3 port Ethernet switch – Clocks and FW for IEEE 1588 PTP
- Shock rated to 5,000 g – Rated from -40 to +85 C
WIAMan with Embedded DAS

- Femoral LC – 3 axis (Fx, Fy, Fz)
- Femur 6DX
- Mid Femur LC – 6 axis
- Knee Pot – 1 axis (Y)
- Tibia 6DX
- Mid Tibia LC – 6 axis
- Foot 6DX
- Calcaneus LC – 3 axis (Fx, Fy, Fz)
- Temp sensor connected to HUB
  - DAS
  - SLICE6 x 7
  - HUB x 2
Sensors with embedded, chainable IEEE 1588 PTP

Talking with one customer about making SLICE6 lower profile, maybe < 5mm thick

IEEE 1588 for Flight Test

Eth to PCM to Telemetry

SLICE6

www.dtsweb.com
Integrated into Existing Flight Test

Sensors with embedded PTP can be linked into existing flight test systems.
QUESTIONS?
THANK YOU