EMI Debugging Solution using *Mixed Domain Oscilloscope*
Agenda

- What is EMC?
- What is Mixed Domain Oscilloscope?
- Troubleshooting EMI using MDO4000
- Conclusion for MDO
What is EMC?
EMI, EMS, EMC

EMI: Electromagnetic Interference
EMS: Electromagnetic Susceptibility
EMC: Electromagnetic Compatibility

EMI : Electromagnetic Interference
EMS: Electromagnetic Susceptibility
EMC: Electromagnetic Compatibility
What is EMC?

Conducted & Radiated Measurements

Conducted measurements

Freq. Range : <30MHz

Conducted Emissions with Line Impedance Stabilization Network (LISN)

Radiated measurements

Freq. Range : <1GHz (Commercial)
10, 18, 26.5GHz and Higher (Military)

TEM Cell  Open-Air Test Site (OATS)  Anechoic Chamber
What is EMC?

EMC Measurements Stage

Compliance Measurements
- LISN, OATS or TEM cell
- Compliant receiver and certified site required

Pre-compliance measurements
- LISN for conducted measurements
- Techniques vary for radiated (uncertified OATS, cell, anechoic chamber)
- Measurement tool yields ‘good enough’ results
- Limits in dynamic range, accuracy

Diagnostics measurements
- Development lab & Screen room or screen box
- Close-field probes for evaluation of ‘fixes’
- Relative ‘before and after’ measurement

Time & Cost Problem
What is EMC?

What’s the New Problem?

- Multiple noise sources
- Intentional Radiators & Multiple receivers
- Transient noise → Interference
What is EMC?

EMC Standards

- Comparable results require agreed-upon tools
- Standards Bodies define receivers in terms of
  - Frequency range
  - Resolution bandwidth
  - Detectors and averaging
  - Accuracy, sensitivity and dynamic range
- Requirements vary by geography and application
  - CISPR, ANSI, TELEC and MIL
What is EMC?

Basic Measurement Settings for EMI

- Frequency ranges are defined
- Resolution bandwidths and shapes are defined

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>Bandwidth (6 dB)</th>
<th>Reference BW</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 kHz to 150 kHz (Band A)</td>
<td>100 Hz to 300 Hz</td>
<td>200 Hz</td>
</tr>
<tr>
<td>0.15 MHz to 30 MHz (Band B)</td>
<td>8 kHz to 10 kHz</td>
<td>9 kHz</td>
</tr>
<tr>
<td>30 MHz to 1000 MHz (Bands C and D)</td>
<td>100 kHz to 500 kHz</td>
<td>120 kHz</td>
</tr>
<tr>
<td>1 GHz to 18 GHz (Band E)</td>
<td>300 kHz to 2 MHz</td>
<td>1 MHz</td>
</tr>
</tbody>
</table>

**Table 1.** Measurement Bandwidth versus Frequency specified by CISPR 16-1-1.

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>Bandwidth (6 dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 Hz to 1 kHz</td>
<td>10 Hz</td>
</tr>
<tr>
<td>1 kHz to 10 kHz</td>
<td>100 Hz</td>
</tr>
<tr>
<td>10 kHz to 150 kHz</td>
<td>1 kHz</td>
</tr>
<tr>
<td>150 kHz to 30 MHz</td>
<td>10 kHz</td>
</tr>
<tr>
<td>30 MHz to 1 GHz</td>
<td>100 kHz</td>
</tr>
<tr>
<td>Above 1 GHz</td>
<td>1 MHz</td>
</tr>
</tbody>
</table>

**Table 2.** Bandwidths versus frequency specified for peak, average and RMS detectors by ANSI C63.2.

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>Bandwidth (6 dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 Hz to 20 kHz</td>
<td>10, 100, and 1000 Hz</td>
</tr>
<tr>
<td>10 kHz to 150 kHz</td>
<td>1 and 10 kHz</td>
</tr>
<tr>
<td>150 kHz to 30 MHz</td>
<td>1 and 10 kHz</td>
</tr>
<tr>
<td>30 MHz to 1 GHz</td>
<td>10 and 100 kHz</td>
</tr>
<tr>
<td>1 GHz to 40 GHz</td>
<td>0.1, 1.0 and 10 MHz</td>
</tr>
</tbody>
</table>

**Table 3.** Bandwidths versus Frequency specified by Mil-STD-461E.
What is EMC?

Measurement Settings: Bandwidth Effects

Analyzer with selectable -3 dB (RBW) and -6 dB filter definitions, 1 dB/division

Random noise measured with 100 kHz filters.
-3 dB, 100 kHz response in yellow,
-6 dB, 100 kHz response in blue.
The power difference is 1.54 dB, in close agreement with the theoretical value.

$$10 \log_{10}(BW1/BW2), \text{ or } 10 \log(71/100) = -1.5 \text{ dB difference from using wrong BW}$$
What is EMC?

Measurement Settings: Detector and Meter Response

The Quasi-Peak Detector and Associated Voltmeter

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>9 kHz to 150 kHz (Band A)</th>
<th>0.15 MHz to 30 MHz (Band B)</th>
<th>30 MHz to 1000 MHz (Bands C and D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth (6 dB)</td>
<td>0.2 kHz</td>
<td>9 kHz</td>
<td>120 kHz</td>
</tr>
<tr>
<td>Detector Charge Time</td>
<td>45 ms</td>
<td>1 ms</td>
<td>1 ms</td>
</tr>
<tr>
<td>Detector Discharge Time</td>
<td>500 ms</td>
<td>160 ms</td>
<td>550 ms</td>
</tr>
<tr>
<td>Time Constant of Critically Damped Meter</td>
<td>160 ms</td>
<td>160 ms</td>
<td>100 ms</td>
</tr>
</tbody>
</table>

Characteristic of Quasi-peak Detector versus Frequency Specified in CISPR 16-1-1 and ANSI C63.2
What is EMC?

Measurement Settings: Peak, Average and QP Detectors

- Average or QP+ Meter ≤ Peak measurement
- Measured CW power are equal for Average, QP and Peak detectors
What is EMC?
Measurement Settings: Video Filter

- Video filtering: original trace smoothing technique
- Specified ‘off’ or ‘not used’ for all but TELEC

<table>
<thead>
<tr>
<th>Standards</th>
<th>VBW Requirements</th>
<th>Analyzer VBW Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>CISPR</td>
<td>VBW not used</td>
<td>Maximum value or disabled</td>
</tr>
<tr>
<td>TELEC</td>
<td>VBW = RBW or VBW ≥ 3*RBW</td>
<td>VBW = RBW or disabled</td>
</tr>
<tr>
<td>MIL</td>
<td>Greatest value or not used</td>
<td>Maximum value or disabled</td>
</tr>
</tbody>
</table>

Video Bandwidth Requirements Specified for EMI Measurements
**What is EMC?**

**KCC EMI Requirements**

### Conducted Emission

<table>
<thead>
<tr>
<th></th>
<th>Spec.(dBuV)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freq. Range(MHz)</td>
<td>Quasi-Peak</td>
<td>Average</td>
</tr>
<tr>
<td>A</td>
<td>0.15~0.5</td>
<td>79</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>0.5~30</td>
<td>73</td>
<td>60</td>
</tr>
<tr>
<td>B</td>
<td>0.15~0.5</td>
<td>66-56</td>
<td>56-46</td>
</tr>
<tr>
<td></td>
<td>0.5~5</td>
<td>56</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>5~30</td>
<td>60</td>
<td>50</td>
</tr>
</tbody>
</table>

Conducted Emission Requirement for Power Line

### Radiated Emission

<table>
<thead>
<tr>
<th></th>
<th>Quasi-Peak (dBuV/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freq. Range(MHz)</td>
</tr>
<tr>
<td></td>
<td>30~230</td>
</tr>
<tr>
<td></td>
<td>230~1000</td>
</tr>
</tbody>
</table>

Conducted Emission Requirement for Communication terminals

* A급 (업무용 기기), B급(가정용기기)
Troubleshooting EMI using MDO
38% of embedded designs are wireless.

$2.50 cost of complete Zigbee radio.

1 Billion wireless devices will ship in 2011.

Evolution of Design Challenges

Design Engineers: Many Signals, Multiple Domains, Little Time

Analog, Digital, Buses and RF
The Tektronix MDO4000 Series
Tektronix MDO4000 Series of Mixed Domain Oscilloscopes

See time-correlated analog, digital, and RF in a single instrument

Traditional Time Domain Display

New Frequency Domain Display

Built-in spectrum analyzer

Mixed Signal Oscilloscope Controls

Dedicated Spectral Analysis Controls

RF Input w/ N-Type Connector
Architecture of the MDO4000 Series

- Dedicated hardware optimized for RF acquisition
  - N-connector
  - Hardware downconversion
  - Integrated preamplifier
  - RF step attenuation

- Not just a typical scope FFT
  - Independent, but time correlated acquisition systems allow for optimal views in both domains

- 60dB dynamic range (typical) and up to 6 GHz RF
Capture time - correlated analog, digital and RF signals

Complete System Visualization
Troubleshooting EMI using MDO4000(1)

1. Discovering the location of the peaks of the offending signal using a Near-field probe.
Troubleshooting EMI using MDO4000(2)

2. Captured peak RF spectrum on Frequency Domain.

- Captured in Max-hold with peak detection at 137MHz
- Signal increases by ~12dB at times.
Troubleshooting EMI using MDO4000(3)

3. **RF Amplitude vs. Time Trace** Turn On with RF Spectrum

- The spectrum time indicator is moved in-between the RF bursts.
- The level of the 137MHz signal at this location in time is ~12dB lower.
4. **Analog Ch1 Turn on** With RF Amplitude vs. Time Trace & RF Spectrum

It is clear that the high speed data bursts on this header coincide with the bursts of energy at 137MHz!!
The MDO4000 Series

- Up to 21 channels provide complete system visibility
- Built-in spectral analysis
- Time-correlated analog, digital, and RF in a single instrument

<table>
<thead>
<tr>
<th>Model</th>
<th>Analog Channels</th>
<th>Analog Bandwidth</th>
<th>Digital Channels</th>
<th>RF Channels</th>
<th>RF Freq. Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDO4054-3</td>
<td>4</td>
<td>500 MHz</td>
<td>16</td>
<td>1</td>
<td>50 kHz – 3 GHz</td>
</tr>
<tr>
<td>MDO4054-6</td>
<td>4</td>
<td>500 MHz</td>
<td>16</td>
<td>1</td>
<td>50 kHz – 6 GHz</td>
</tr>
<tr>
<td>MDO4104-3</td>
<td>4</td>
<td>1 GHz</td>
<td>16</td>
<td>1</td>
<td>50 kHz – 3 GHz</td>
</tr>
<tr>
<td>MDO4104-6</td>
<td>4</td>
<td>1 GHz</td>
<td>16</td>
<td>1</td>
<td>50 kHz – 6 GHz</td>
</tr>
</tbody>
</table>
The World’s First Mixed Domain Oscilloscope

The **only** solution for seeing **time-correlated** analog, digital, and RF for complete system visualization

The **Tektronix** MDO4000 Series
Thank You!

**MDO**-The only *Oscilloscope* with a built-in *Spectrum Analyzer*