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Evaluating Multi-Line EMI Filters for CM & DM

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FR-AM-5 Workshop
“EMC Issues in Hybrid & Electric-Propulsion Vehicles”
What is being Measured?

Identify the following:

- EMI Filter
  - How many elements comprise filter?
  - Where are they located?
    - Centralized
    - Different locations
    - Exit Point of shield, housing, PCB edge, connector, IC etc.
  - What are the values, tolerances & parasitic values
    - What does the component manufacturer supply
    - How does the manufacturer test components
    - Does the manufacturer data relate to your circuit.
  - How are they integrated
    - On a trace?
    - With vias to inner layers?
    - Combination?
What is being Measured?

- Circuit loop and layout
  - How many layers in PCB?
  - Is there a Ground Plane?
  - PCB Stack-up of layers?
  - Is there a Chassis Ground?

- Test points
  - Are there test point locations
  - What are possible test points
  - How are test cables going to be attached
    - Connector (SMA, BNC etc.)
    - Probes
Classify the type of measurement

- **System** – shows the net result of adding an EMI filter to a circuit’s loop that measures the total impedance of the filter plus physical geometries.

- **Filter-in-System** – same as “System” except that it measures only the impedance of the filter and the filter’s loop on the PCB.

- **Filter-only** – requires a specifically designed test coupon to measure the EMI filter outside the full circuit. This measurement hopes to eliminate parasitics and other circuit elements.
“System” Example

Note: this is a 2-port passive example not a 4-port active
What is being Measured?

- “Filter-in-System” Example
What is being Measured?

“Filter-only” Example

- T.P. 1
- T.P. 2
- T.P. 3
- T.P. 4

EMI Filter
Understanding the Test Equipment

- Network Analyzer Set-up
  - Number of points
  - Start/Stop Frequency
  - Measurement Bandwidth
  - Channel and Trace Setup
  - Type of Measurement

- Cables

- Calibration

- Fixture Extension
Understanding the Test Equipment

- 2-port vs. 4-port vs. ##-port
- S-parameters
- Balanced Pair Measurement (Mix-Mode)
  - Common Mode (CM)
  - Differential Mode (DM)
  - Common-to-Differential Conversion (CD)
  - Differential-to-Common Conversion (DC)
- Network Analyzer Measurement Operation
  - “Virtual” vs “True”
  - Why it matters
Understanding the Test Equipment

- “True” vs. “Virtual” Measurement
- R&S ZVA8
  - Start/Stop 300kHz – 3GHz
  - BW 1kHz
  - Points 1601
  - Fixture Correction added
Defining a Test Fixture

- No Standard Fixture
- Considerations
  - Frequency Range
  - Type of measurement classification
- Parameters to Define
  - Dielectric material of Fixture
  - Size (length, width & height)
  - Shape
  - Trace/wire geometry
  - Test Point location
  - Construction (mechanical stress)
Defining a Test Fixture

- Fixture Correction Example with “Open” & “Short”
- VNA = Agilent E507C
  - Start/Stop 100kHz-3GHz
  - BW 100Hz
  - Points 1601
  - Type “Virtual”
CANBus Application Criteria

- Communication speeds 250-1000kbps
- Capacitance per node 56-100pF (typical)
- Concerns
  - Total capacitive loading
  - Line-to-Line capacitive balance
  - Line-to-ground capacitive balance
- Typical automotive PCB is 2-4 layers, FR-4 Material, 62 mil thick.
- Typical minimum filter is CMC.
CMC manufacturers typically give an impedance for a given frequency.

Typically do not provide impedance vs. frequency curve.

Do not detail how test is performed.

Questions to answer:
- Do CMC exhibit significant amount of parasitic capacitance?
- If so, in what made does it register CM or DM?
- How balanced are the CM, DM, CD, DC modes?
Automotive Low Power Filter Example

CC "True" - Sample #1

CD "True" - Sample #1

DC "True" - Sample #1

DM "True" - Sample #1
Automotive Low Power Filter Example
Conclusions

- Both sample exhibited a significant parasitic capacitance in the DM measurement. The table below shows calculated values from the data.
- Conversion modes ideally would be 0dB. Since this was not the case it is interesting to note the balance of the forward and reverse measurement as well as the balance between CD & DC.

<table>
<thead>
<tr>
<th>Sample #1 – DM (Calculated Values)</th>
<th>Sample #2 – DM (Calculated Values)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacitance</td>
<td>506 nF</td>
</tr>
<tr>
<td>SRF</td>
<td>228 MHz</td>
</tr>
<tr>
<td>ESR</td>
<td>10.8 mΩ</td>
</tr>
<tr>
<td>ESL</td>
<td>695 pF @ 500 MHz</td>
</tr>
</tbody>
</table>
Voltage & Current requirements

- **Typical Conventional Automotive System**
  - 12-24V operating
  - Transient ±150V (or less)
  - Current
  - -40° to 105° C Operating Temperature

- **Hybrid Automotive System**
  - 300-600V operating
  - Transients ≤ 1000V (or less)
  - 100-300 Amps current
  - -40° to 105° C Operating Temperature
Challenges with Hybrid Vehicles

- Specifying Filter Components
  - DC Loss
  - CM filtering
  - DM filtering
  - Parasitics
  - Packaging
  - DC Bias & Loss

- Minimizing Parasitics in the design
  - Layout
  - Mounting
  - Physical size
Questions???

For more information and technical papers go to:
http://www.Jastech-emc.com