Course Introduction

Purpose
• This course discusses techniques for analyzing and eliminating noise in microcontroller (MCU) and microprocessor (MPU) based embedded systems.

Objectives
• Learn about how packaging affects efforts to reduce EMI.
• Understand the necessity for carefully designed decoupling capacitors, such as three-pin teed-through types.
• Find out how to evaluate EMI countermeasures.
• Discover the best way to implement EMI reduction techniques.

Content
• 15 pages

Learning Time
30 minutes
Reducing EMI

EMI reduction is a goal shared by both the semiconductor experts who design MPUs and other LSI devices and by the engineers who apply those chips in embedded systems.

### Explanation of Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anechoic chamber</td>
<td>A room designed to block radiation from the outside and to minimize reflections off the room’s walls, ceiling, and floor</td>
</tr>
<tr>
<td>Balun</td>
<td>A passive electronic device that converts between balanced and unbalanced electrical signals</td>
</tr>
<tr>
<td>Core</td>
<td>A microcontroller chip is composed of a core, I/O ports, and power supply circuitry. The core consists of the CPU, ROM, RAM, and blocks implementing timers, communication, and analog functions.</td>
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<tr>
<td>ECU</td>
<td>Electronic Control Unit</td>
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<tr>
<td>EMI</td>
<td>Electromagnetic Interference</td>
</tr>
<tr>
<td>Harness</td>
<td>Cables (wires) connecting a board and power supply or connecting one unit in a system to another</td>
</tr>
<tr>
<td>LISN</td>
<td>Line Impedance Stabilization Network</td>
</tr>
<tr>
<td>Power supply</td>
<td>Two power supplies are applied to the LSI: Vcc and Vss. The core power supply internal to the LSI is VCL (internal step-down). The Vss-based power supply routed through the LSI is VSL.</td>
</tr>
<tr>
<td>TEM Cell</td>
<td>Transverse Electromagnetic Cell</td>
</tr>
<tr>
<td>WBFC</td>
<td>Workbench Faraday Cage</td>
</tr>
</tbody>
</table>
Design goal for EMI reduction: Increase current supply from decoupling capacitor (Cdc, loop B) and decrease current from main power supply (loop A) as much as possible.

- Current ratio A/B is determined by the impedance ratio: \[ \frac{\text{Loop B}}{\text{Loop A}} \]
  - If possible, this ratio should be <1/100 (-40dB)

Two methods for reducing EMI:

- Increase loop-A impedance by inserting ferrite bead in loop
- Decrease impedance of loop by decreasing its inductance
  - Make the loop area as small as possible to minimize its inductance
  - Use feed-through capacitors because they have intrinsic impedances less than 1/10th those of conventional SMD ceramic capacitors
BGAs and CSPs Save Board Space

Smaller chip packages allow products to become more compact and convenient, but complicate design efforts to place decoupling capacitors where they will be most effective for reducing EMI.
Decoupling Capacitors for BGAs

Finding sufficient mounting space can be a problem!
Low-ESL Bypass Capacitors

Three-pin SMD feed-through capacitors provide very good connections:
- No extra paths, so 100% of supply current is fed through

Design alternative:
IDC-type capacitor achieves low supply impedance

<table>
<thead>
<tr>
<th>Capacitance</th>
<th>1.0µF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Tolerance</td>
<td>-20%</td>
</tr>
<tr>
<td>Upper Tolerance</td>
<td>30%</td>
</tr>
<tr>
<td>Rated Current</td>
<td>2A</td>
</tr>
<tr>
<td>Rated Voltage</td>
<td>16Vdc</td>
</tr>
<tr>
<td>Insulation Resistance</td>
<td>500M ohm min.</td>
</tr>
<tr>
<td>Withstand Voltage</td>
<td></td>
</tr>
<tr>
<td>Max. of DC resistance</td>
<td>0.03ohm</td>
</tr>
<tr>
<td>Min. of Operating Temp.</td>
<td>-40°C</td>
</tr>
<tr>
<td>Max. of Operating Temp.</td>
<td>85°C</td>
</tr>
<tr>
<td>Length</td>
<td>2.0mm</td>
</tr>
<tr>
<td>Width</td>
<td>1.25mm</td>
</tr>
<tr>
<td>Thickness</td>
<td>0.85mm</td>
</tr>
</tbody>
</table>

*Source: Murata Manufacturing
Evaluation of Supply Decoupling

Area under device showing pads for decoupling capacitors

Current measurement points (Vcc, PVcc, Vss)

Power supply connections

Pads for inductors (ferrite beads)

Top of evaluation board

Bottom of evaluation board

Page 7
Slide Changed
(Text moved to left, away from top photo.)

Typical decoupling capacitor
Near-field tests* using the evaluation board allow comparisons of levels of RF current in the power supply lines.

* MPU: SH7055R  
Frequency: 80MHz
Capacitor Tests with 256-pin QFP

Near-field Tests

Twelve 3-pin capacitors (0.1µF each)

One 3-pin capacitor (NFM21: 1µF)

VDE Measurements

MPU: SH7055R (40MHz)
Macro (sensitive) probe @80MHz
Capacitor Tests with 256-pin BGA

Near-field Tests

Eight 2-pin capacitors (0.1µF each)

One 3-pin capacitor (NFM21: 1µF)

VDE Measurements

MPU: SH7055R (40MHz)
Macro (sensitive) probe @80MHz
Near-field tests reveal EMI problem distant from MPU
- Magnitude of noise near output connector of ECU-B is 20dB higher than that of ECU-A

Scan for EMI at All Locations

ECU-A: Good EMI performance

ECU-B: Excess Leakage

Problem with slide — Dotted lines in scans have been replaced with solid lines and moved. Please correct.
Data Shows Progress — and Problem

Noise reduction efforts were successful for both ECUs, yet insufficient for ECU-B

- Target level was exceeded by ECU-B’s design

![Graph showing noise current vs. frequency for ECUs A and B with and without decoupling components](image)

Test data showing decoupling effects on basic boards
Test data showing degradation on ECU-B
Effects of Adding Components

Using a ferrite bead and multiple decoupling capacitors is an effective way to reduce EMI.

Page 13
Problem with slide — Block diagram (bottom right) is broken up and moved down.
Countermeasure Implementation

It’s best to follow a step-by-step EMI reduction procedure:

1. Find the most important noise contributor and eliminate/reduce that problem; then repeat the process until design goal is met.

Reducing noise from unimportant element has no effect.

Reducing noise from important element drops overall level by 3dB.

Before countermeasure | After countermeasure
--- | ---
Effect: 0dB

-10dB

Before countermeasure | After countermeasure
--- | ---
Effect: -3dB

-10dB

Problem with slide — Vertical arrows should be dotted, not solid.

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Course Summary

• How packaging affects EMI reduction
• Three-pin SMD feed-through capacitors
• Evaluating EMI countermeasures
• Iterative method for countermeasure implementation

For more information on specific devices and related support products and material, please visit our Web site:
http://america.renesas.com