Course Introduction

- **Purpose:**
  - This course discusses techniques that can be applied to reduce problems in embedded control systems caused by electromagnetic noise

- **Objectives:**
  - Gain a basic knowledge of the types of noise that affect embedded control systems
  - Learn approaches and design methods for protecting systems against problems caused by external sources of noise
  - Get basic insights for handling noise problems during the system design and development cycle

- **Content:**
  - 18 pages
  - 3 questions

- **Learning Time:**
  - 25 minutes
Noise Can Cause Big Problems

Noise = “Unwanted electrical signals that produce undesirable effects in the circuits of control systems in which they occur.”

Two types of noise:
- Radiation Noise
- Reception Noise

Electromagnetic Compatibility (EMC) issues encompass both types

Noise reduction approaches:
- Techniques for reducing EMI (Electromagnetic Interference) — Cutting the noise emitted by a specific system, circuit or device that causes other devices/circuits to operate incorrectly
- Techniques for decreasing EMS (Electromagnetic Susceptibility) — minimizing the effect that external noise has on the operation of a system, circuit or device

Noise reduction: a goal common to both microcontroller (MCU) designers and the system engineers who apply those devices
EMS Protection Is Essential

- External sources of noise could cause a microcontroller to run out of control
- Results can range from inconvenient momentary disruptions of embedded functionality to failures of microcontroller based equipment that cause injuries or fatalities

Whether a system runs from the power line or a battery, it is essential that the MCU include EMS measures that protect it against external noise.
EMS Protection Measures - 1

- **Reduce the length of the system wiring**
- **Shorten all interconnect wires as much as possible**

- **Select a smaller package type to achieve shorter interconnect wiring**
  - The length of the connection between the Vcc & GND terminals of the package and the Vcc & GND terminals of the chip is much shorter in a small outline package such as a QFP or SOP than it is in a DIP package — and that shorter length makes bypass capacitors more effective in shunting external noise to ground.

Connection inside the QFP is about 90% shorter than connection in the DIP.
EMS Protection Measures - 2

- Mount and connect bypass capacitors in the best possible locations
  - Put bypass capacitors close to the device and at positions where the Vcc and GND (Vss) wiring traces are isometric and as short as possible

(Devices with multiple Vcc & GND terminals facilitate noise reduction measures that are exceptionally effective)

- Use multiple bypass capacitors of different types and make Vcc and GND lines run parallel to each other
  - A combination of a ceramic capacitor and a tantalum type provides good filtering; series inductances further improve EMS protection
Is the following statement true or false? Click Submit when you are finished.

"To protect devices and circuits against external noise, reduce the length of interconnect wires, which act as antennas."

- True
- False
EMS Protection Measures - 3

- **Adopt a serial bus connection**
  - Reduce the wiring length, which is proportional to the number of data lines, by replacing a parallel bus with a serial bus.

- **Use a single-chip microcontroller**
  - MCUs with on-chip memory can eliminate external RAM and ROM and associated wiring.
EMS Protection Measures - 4

- Mount current-limiting resistors close to the MCU
  - Reduce noise problems by placing the resistors within 2cm or less from the microcontroller

- Use serial damping resistors
  - When signal lines are long, mount serial damping resistors close to the MCU
  - Their value should be about 100 Ohms to match the characteristic impedance of the wiring on the printed circuit board
EMS Protection Measures - 5

- **Put a low-pass filter on RESET line**
  - Adding an R-C filter to the signal line to the device or circuit that resets the MCU will shunt to ground external noise that might otherwise result in partial initializations that cause the microcontroller to run out of control.

- **Make wiring pattern of clock oscillator compact and close to MCU**
  - Especially, locate the ground connection for the oscillator circuit very near to the MCU’s GND (Vss) terminal and make a direct connection to it.
EMS Protection Measures - 6

- Use a serial resistor to reduce noise picked up by wiring to external analog sensor
- Insert a resistor (100Ω to 1kΩ) in series with the MCU’s A/D input pin, close to the MCU, and if possible, connect a capacitor to ground to form a low-pass filter

[Diagram showing noise reduction circuit with resistor and capacitor]

- Reduce vulnerability of EPROM programming pin (Vpp)
- When you mount a previously written EPROM on a circuit board, connect one end of a series resistor to Vpp and the other end of it to either 5V or GND

[Diagram showing EPROM programming with resistor and current]
Which statements of the following about EMS protection measures are correct? Select all that apply and then click Submit.

- Current-limiting and serial matching resistors should be located close to the external devices to which they are connected.
- A low-pass filter or even just a series resistor will help protect against noise picked up by the wires connected to an external sensor.
- Using a microcontroller with on-chip memory eliminates the need for external RAM and ROM, so there is less wiring to pick up noise.
- The wiring pattern for the clock oscillator circuit should be short and close to the MCU.
EMS Protection Measures - 7

- Be particularly careful when laying out the oscillator circuit and the area near it.

- Here are some key printed circuit board layout suggestions regarding the MCU clock circuit(s):

  - Do not intersect signal lines and clock lines.
  - Keep lines that carry large currents, and those that switch at high frequencies, away from clock lines.
  - Develop wider ground area to separate dual clock signals and prevent signal interference between them.
  - If possible, do not use the terminals near the clock pins; connect them to GND.

- Recommended layout configurations.
EMS Protection Measures - 8

- Use the best methods for implementing power and ground wiring
  - Develop a solid GND pattern on one side of a 2-layer circuit board

- Develop solid GND and Vcc patterns on the inner layers of a 4-layer PCB

- Beneficial results of these approaches include the following:
  - Wiring impedance from chip through bypass capacitors is minimized
  - Noise from each signal line through ground or Vcc dissipates readily
  - Even if strong noise enters power line, the electric potential is maintained with hardly any fluctuation; by contrast, a narrow GND line causes a voltage change
EMS Protection Measures - 9

- Apply PCB layout methods for power and ground patterns that reduce system susceptibility to noise

- If you can’t use a multi-layer PCB and solid Vcc and GND patterns, use loop or net-like patterns to make connections.

- If loop or net-like patterns aren’t feasible, arrange the Vcc and GND wiring in parallel and make wiring lengths isometric.
Choose a microcontroller that offers good noise immunity

To provide good protection against noise, the MCUs in the M16C family have suitable internal noise filters in all the necessary places:

- a pin layout that minimizes noise problems by various measures,
- placing a GND pin between the oscillator pins,
- easing the design of Vcc and GND wiring on the PCB, and aiding the optimum placement of bypass capacitors.
Basic Design Insights on Noise

**It is very important to implement noise measures at initial stage of design work**

If a problem is discovered in the later stages of the system development process, the noise measures required to solve the problem will end up being far more costly than expected.

**Investigations of noise problems take time and are costly**

Because it's difficult to simulate a noise-oriented malfunction, a lot of work will be necessary to identify the root cause of the problem.

**Noise problems sometimes require a fundamental solution, such as a re-design**

Unless noise measures are taken at the initial design stage, a malfunction that occurs later might be extremely difficult to eliminate using superficial correction methods; a re-design may be necessary to correct the problem.

**Attempts to eliminate all possible EMI/EMS problems typically lead to unnecessarily high costs**

The optimum design approach is to take pinpoint measures in key areas that require solutions.
Match each item to its description by dragging the boxes on the right to their appropriate locations on the left. Click Submit when you are finished.

Clock lines: Can have internal filters and pinouts that help promote noise immunity
Solid GND and Vcc patterns: Minimize impedance and are highly recommended for EMS protection
Loop or net-like patterns: Reduce system susceptibility to noise
Microcontrollers: Must be kept short and should not be intersected by signal lines
Course Summary

- Need for EMS protection
- EMS protection measures
- Design insights