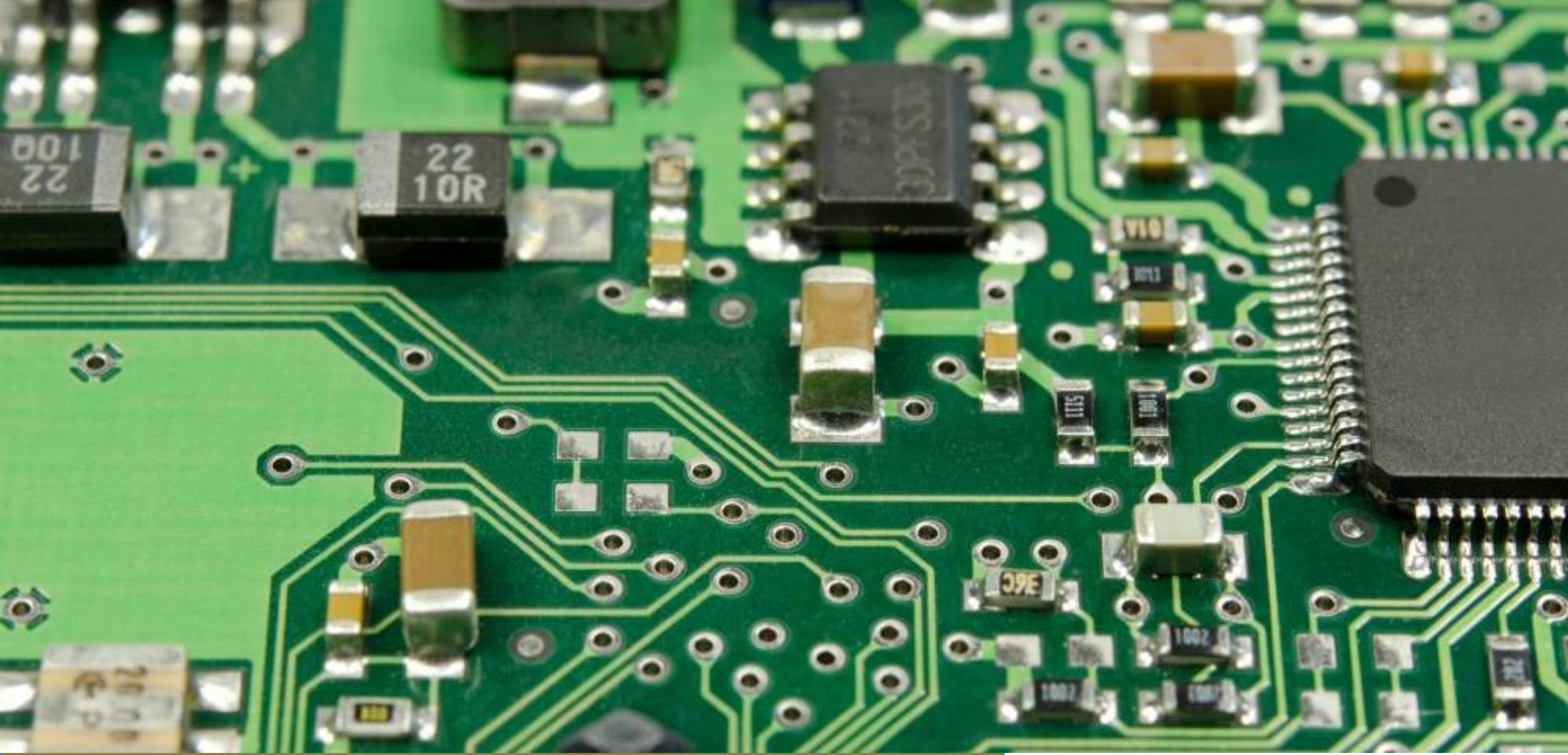

HARDWARE DESIGN TECHNIQUES

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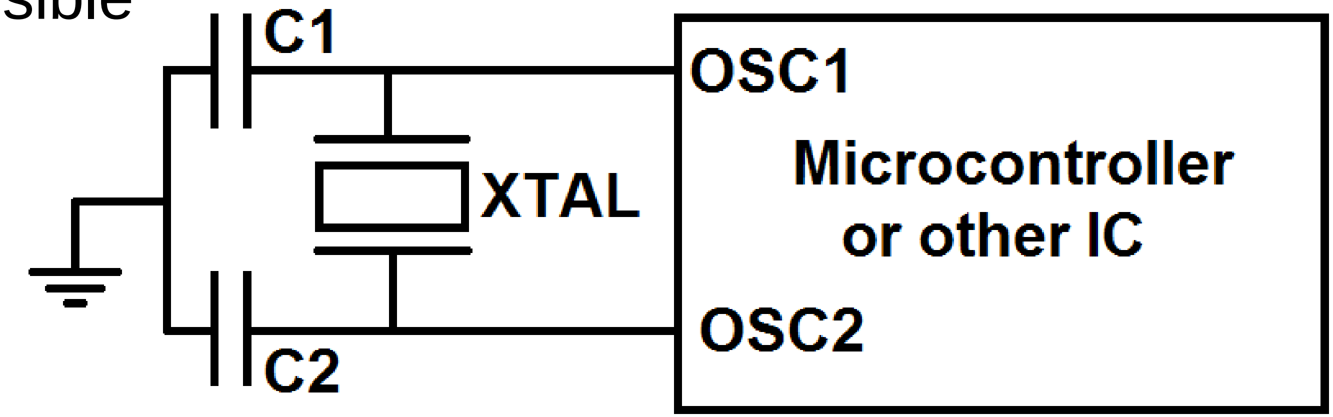
OUTLINE

- IC Support Techniques (Clocks, Reset, Decoupling Caps)
- Mechanical Considerations
- Electromagnetic Interference (EMI)
- Debugging and Verification Techniques
- Other hardware techniques

IC SUPPORT TECHNIQUES

Oscillator Circuits

- Oscillators provide the clocking signal to digital ICs which allow them to function (i.e. VERY IMPORTANT)
- Leave the area beneath and immediately around clock circuits free of graces and components (reduces EMI)
- Clocks should be placed as close to ICs as possible
- Clock traces should be as close to equal length as possible



IC SUPPORT TECHNIQUES

Support Capacitors Capacitors

- Digital logic necessitates the switching of a circuit between high (energized) and low states quickly. To energize quickly, transistors in digital circuits require access to a small amount of on-demand current
- Decoupling Capacitors: Small capacitors placed physically near digital ICs to provide internal transistors with a temporary source of current during switching (serve as "low pass filter" against high-frequency transient power events)
- Bulk Capacitors: Larger capacitors placed on a circuit board to reliably supply power to decoupling capacitors in the face of power fluctuations

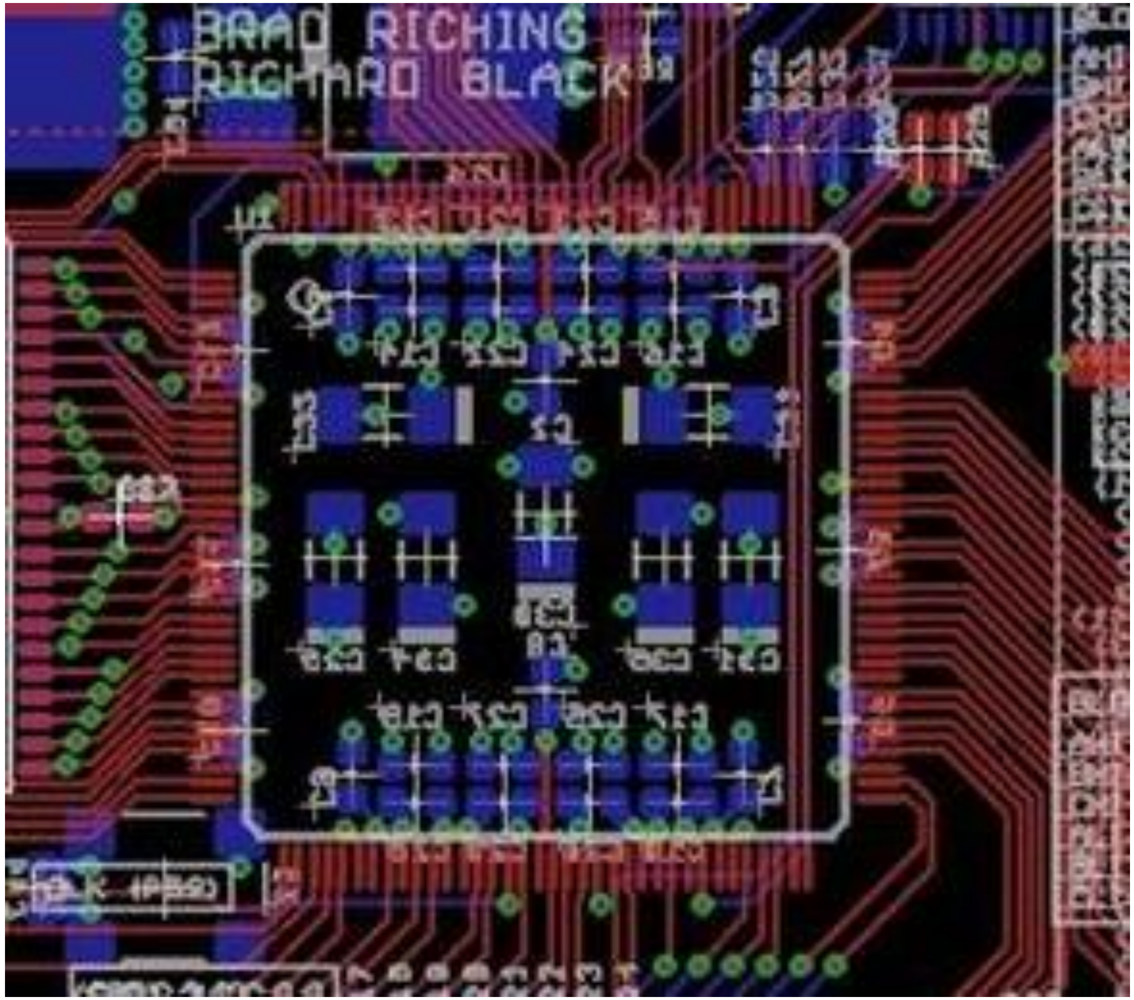
IC SUPPORT TECHNIQUES

Support Capacitor Guidelines

- Capacitance value:
  - Decoupling capacitors: 100nF – 1μF typical (large enough to store charge but small enough to react quickly)
  - Bulk capacitors: Size not critical, 10uF – 100uF common
- Physical placement:
  - Decoupling capacitors: Place as physically close to IC as possible. Common to place underneath (opposite side of board) from the IC
  - Bulk capacitor: Placement generally not critical

IC SUPPORT TECHNIQUES

Support Capacitor Placement



IC SUPPORT TECHNIQUES

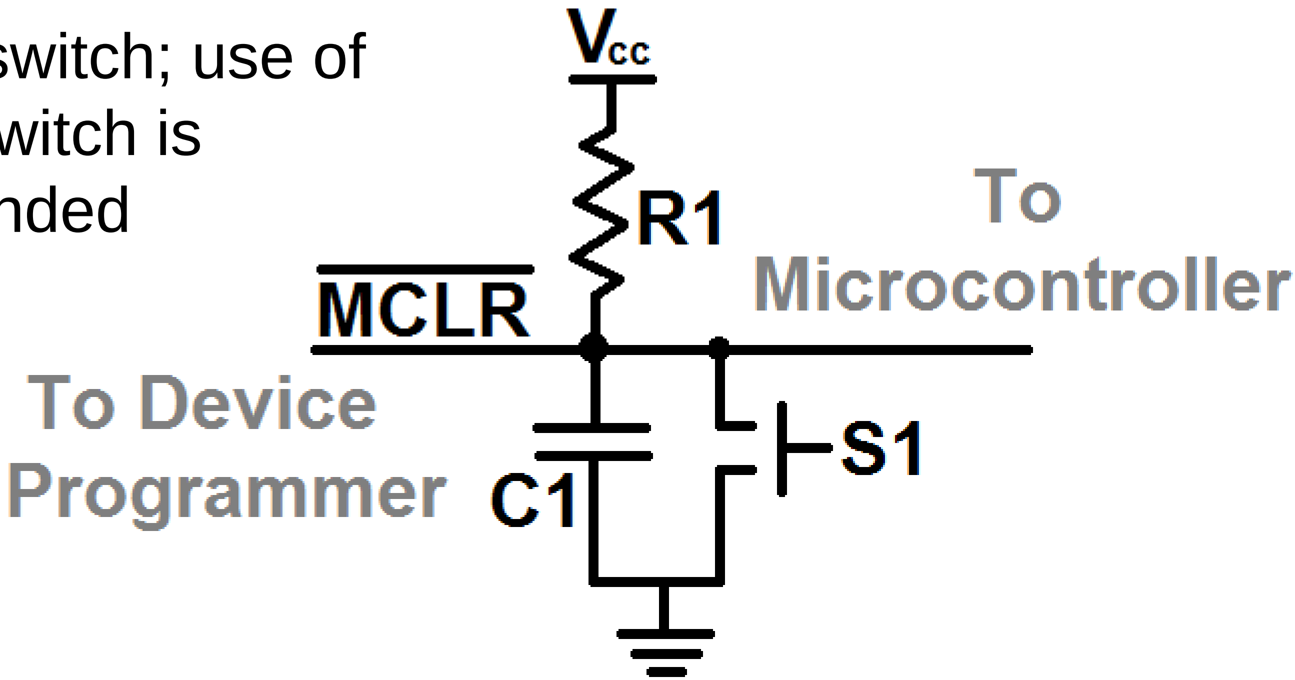
Reset Circuits

- Microcontrollers and other ICs generally must be reset to a known state prior to actions such as programming, and inclusion of a reset switch is a useful inclusion in nearly all digital circuits
- Failure to properly handle device reset logic may result in spurious resets, failure to program the device, and unpredictable device behavior
- Reset lines are generally active low, and pulled high during normal device operation

IC SUPPORT TECHNIQUES

Reset Circuit Example

- Example Microchip PIC Reset Circuit
- R1 should be chosen to pull reset line high (10kΩ typical)
- C1 decouples reset line from high-frequency transient events
- S1 reset switch; use of a tactile switch is recommended



MECHANICAL CONSIDERATIONS

Space Conflicts and Accessibility

- 2D layout packages (such as Eagle) can sometimes miss important considerations in the Z-axis
- Consider:
  - If 2+ boards are stacked, what will you be able to access in the covered area? (Answer: nothing)
  - How will your board fit into your packaging when you consider the height of "tall" components such as connectors and capacitors?

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MECHANICAL CONSIDERATIONS

Space Conflicts and Accessibility Solutions

- A few techniques to deal with space conflicts and accessibility:
  - When performing board layouts, ask yourself "How will this component work in 3 dimensional space? What could it run into?"
  - In 2D layout packages, include the X/Y dimensions of every component in the documentation (or other) layer. (For example, include the dimensions of a breakout board rather than a simple pin header to access it)
  - Use a 3D tool such as Eagle3D to generate a three dimensional model of your board to spot check for issues

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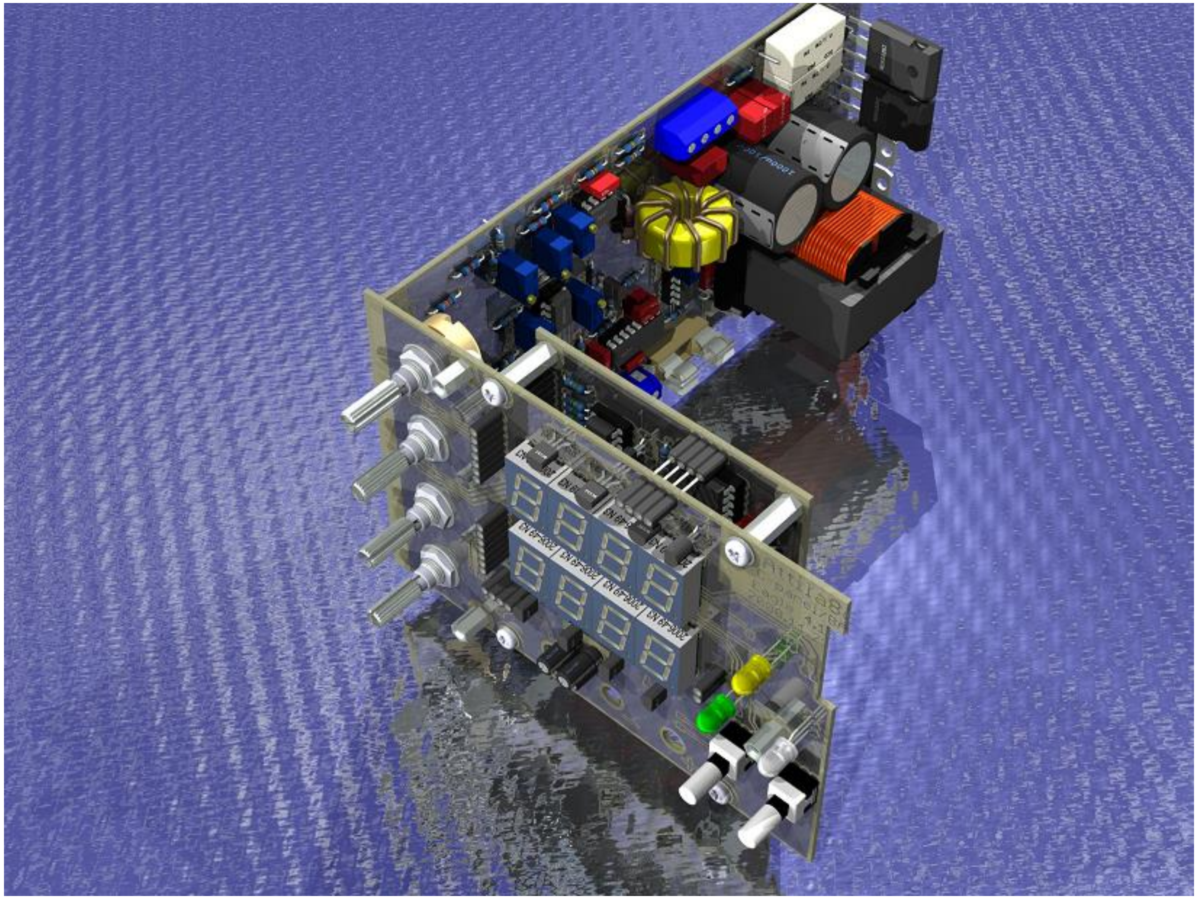
MECHANICAL CONSIDERATIONS

Space Conflicts and Accessibility Solutions

- Example Eagle3D Output:



MECHANICAL CONSIDERATIONS

Connectors and Standoffs

- Standoffs: Most circuit boards should include 3+ mounting holes to allow the board to be securely fastened to its project packaging
- Connectors: Place connectors and other user I/O (such as SD card slots or buttons/switches) on the edges of the board to enable easy access

ELECTROMAGNETIC INTERFERENCE

Motivating Question

- Circuit boards often involve traces in close proximity to each other and switching digital waveforms

- Q1: If noise is present on a conductor, what will the current/voltage characteristics be of any connected conductors?
- Q2: What does the frequency response of a pulse function look like?
- Q3: If two wires are placed close together and current flows through one of them, what will happen to the current/voltage of the second wire?

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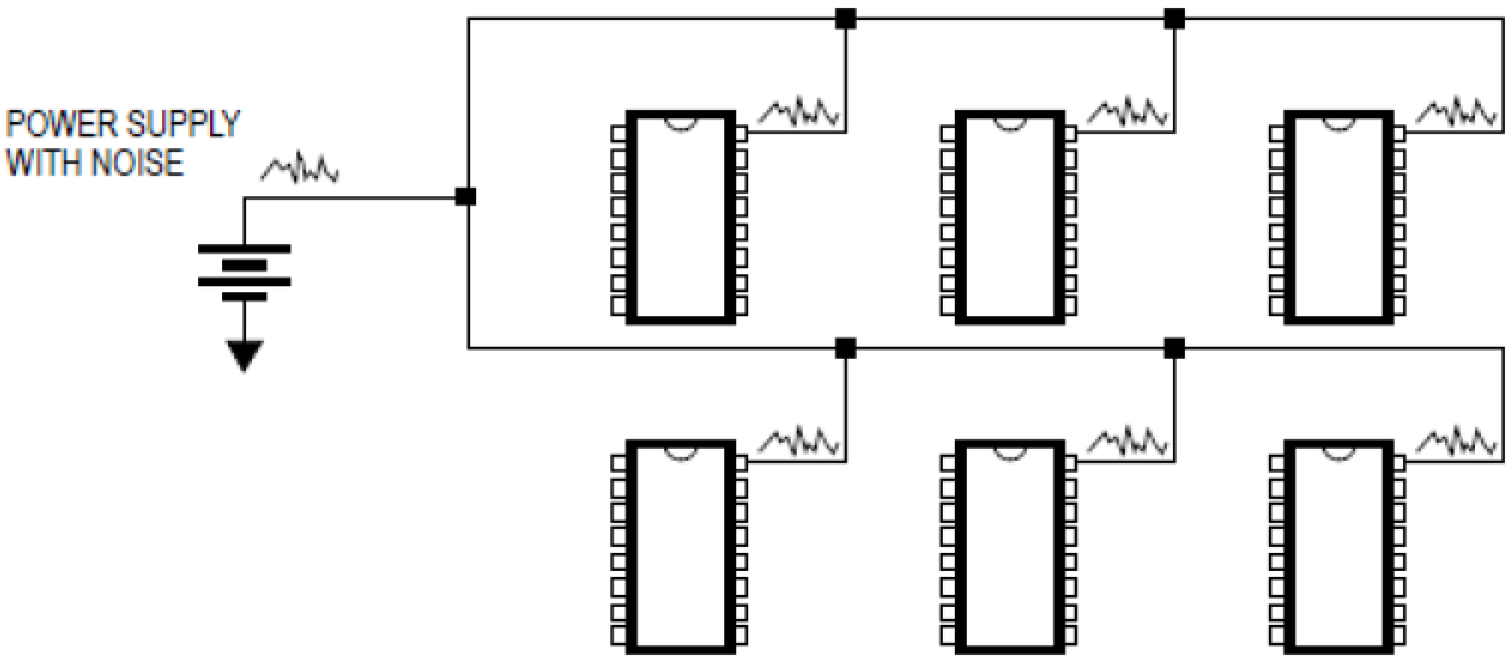
ELECTROMAGNETIC INTERFERENCE

Electromagnetic Interference

- A1: Noise on a conductor will propagate to any shared conductors



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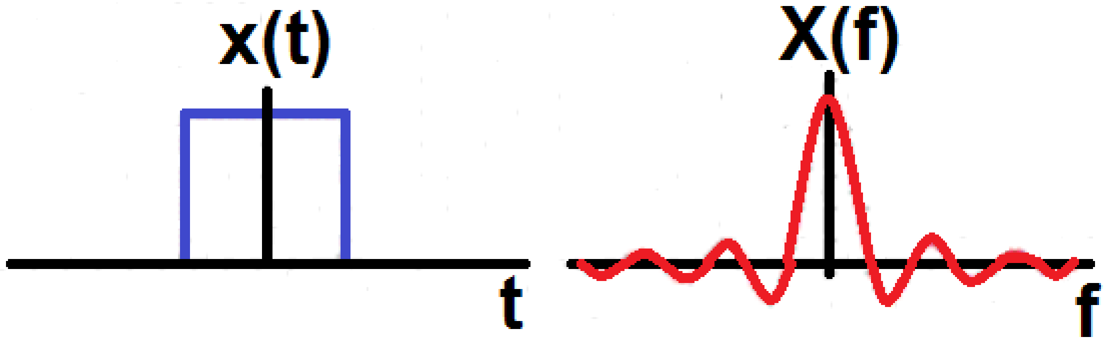
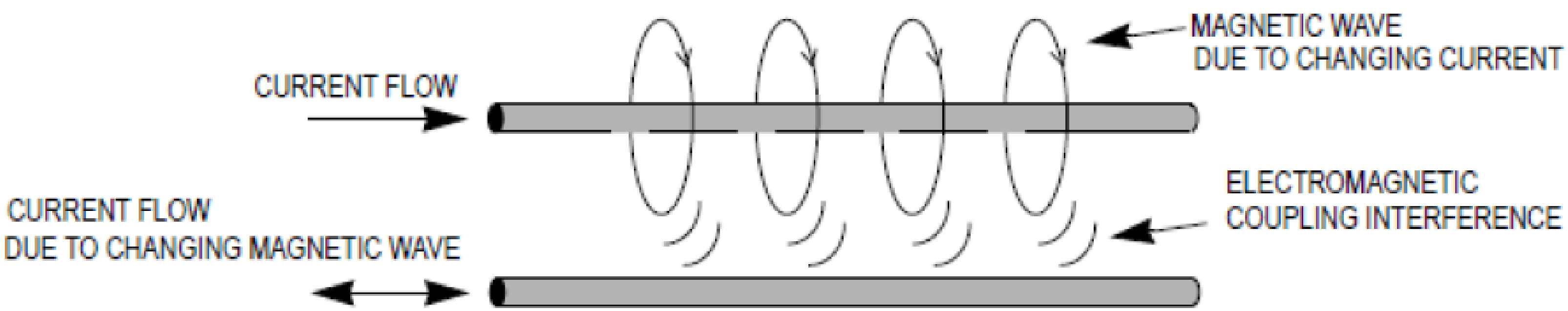
ELECTROMAGNETIC INTERFERENCE

Electromagnetic Interference

- A2: Frequency content of a pulse function = wideband noise



- A3: When wires are placed close together, electromagnetic coupling can occur



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ELECTROMAGNETIC INTERFERENCE

Design for Electromagnetic Compatibility (EMC)

- A circuit is electrically compatible if it does not affect or become affected by its environment
- Remedies:
  - Decrease emissions – can be suppressed at the source through proper system design
  - Shielding – protect sensitive areas of the circuit from emissions
  - Increase noise immunity – susceptibility to noise can be decreased by “hardening” the circuit’s design

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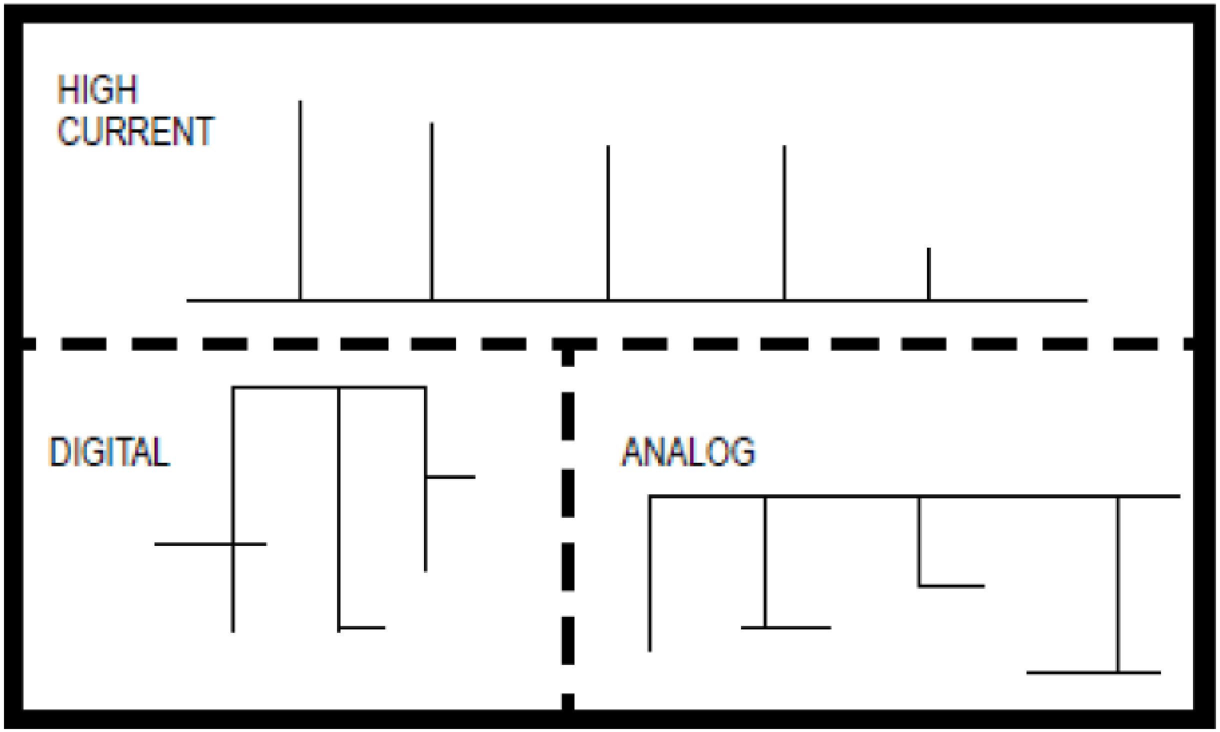
ELECTROMAGNETIC INTERFERENCE

Design for Electromagnetic Compatibility (EMC)

- Separation of circuits on a PCB
  - Where possible, separate out circuits by function or type, and minimize interactions between subsystems:



ELECTROMAGNETIC INTERFERENCE

Design for Electromagnetic Compatibility (EMC)

- Perpendicular Routing:
  - In spots where analog and digital lines must be routed through the same area of the board, routing them perpendicular to one another will help to minimize cross coupling
- Ground plane shielding
  - Surrounding sensitive traces with a ground plane can help minimize noise introduction into the trace through other noise sources

ELECTROMAGNETIC INTERFERENCE

Design for Electromagnetic Compatibility (EMC)

- Analog and Digital Grounding:
  - Generally, analog and digital circuits should be given separate analog ground (AGND) and digital grounds (GND). These circuits can then be joined together at a finite number of points.
  - Access to the analog ground can be controlled through the use of jumpers or solder bridges (0Ω surface mount resistors which are soldered together when the board is assembled)

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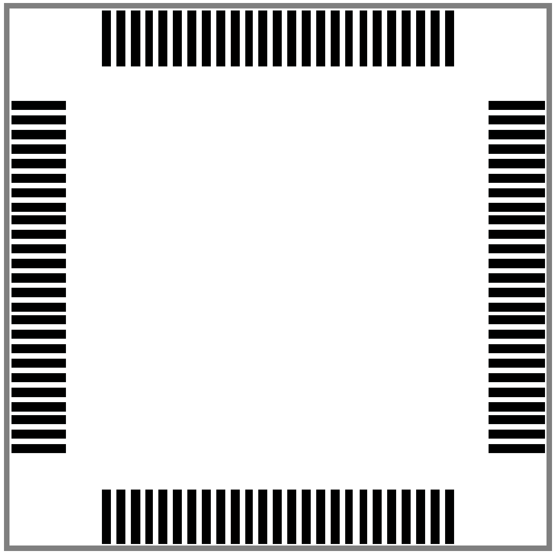
DEBUGGING AND VERIFICATION

Chip Polarity

- IC packages usually involve some degree of rotational symmetry. In the footprint to the right, which pin is pin 1?



- For every device that involves a specific polarity (diodes, LEDs, ICs, connectors, etc.) pin 1 should be clearly marked in a way that is easy to determine
- Markings for device polarity should be visible even after components are soldered, for ease of debugging and verification (if pin marking is under an IC, then the IC will cover it up and slow down debugging later)

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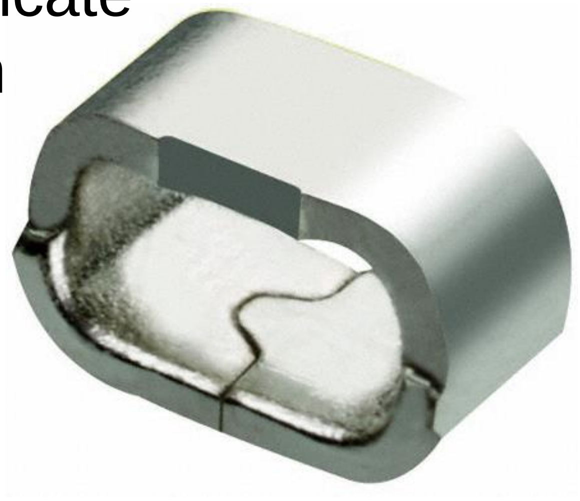
DEBUGGING AND VERIFICATION

Breakout Pins, Test Points, and LEDs

- Hardware can be incorporated into designs to greatly improve the ease with which a project can be debugged
- Breakout pins: Provide access to signals, debugging interfaces, and future functionality not yet in design
- Test Points: Vias, pads, or other parts to provide access to signals with measurement tools
- Debugging LEDs: Can be used to indicate code execution has reached a certain state in the code, indicate power is applied to the board (power led) and indicate the device is alive and executing (heartbeat LED)



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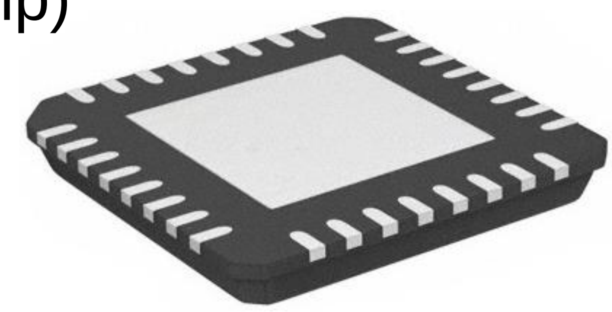
OTHER HARDWARE TECHNIQUES

Under Chip Pads

- Some ICs feature exposed (under chip) pads on the bottom of the package for thermal, mechanical, or electrical reasons



- Accessing these pads for soldering purposes generally requires the use of reflow soldering techniques

- A workaround for hand soldering is to place vias with large diameter holes into the exposed chip pads. The holes must be large enough to allow the tip of a soldering iron to pass through, enabling the part to be soldered.