EMC PCB Design Study

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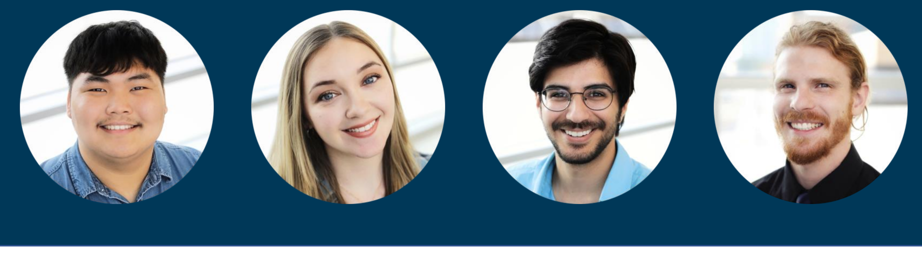


E3 Compliance

Background

Electromagnetic compatibility (EMC) describes the ability of an electronic device to function in its operating environment with respect to ambient electromagnetic energy. Compliant devices are designed to limit the intensity of undesired electromagnetic energy which they may generate (emissions), or which they may receive from other nearby electronic equipment (immunity).

The presence of printed circuit boards (PCBs) in electronics is nearly ubiquitous. It is not uncommon for multiple PCBs to operate in close proximity to each other within the confines of a single device or system. As devices grow in complexity, so does the necessity for good EMC design.

E3 Compliance is an engineering consulting firm which specializes in EMC design, analysis, pre-compliance, and diagnostic testing. Clients work with E3 to identify and strategically address EMC concerns in the development of products for industries including automotive, aerospace, consumer, medical, office, and industrial.

Purpose

Sometimes PCBs are developed to the point of a production-ready state without consideration for EMC. This practice results in devices with unacceptable performance, and higher overall project costs. When these late-stage devices exhibit poor EMC performance, it is often too late to make the necessary design changes to reduce electromagnetic interference at the source.

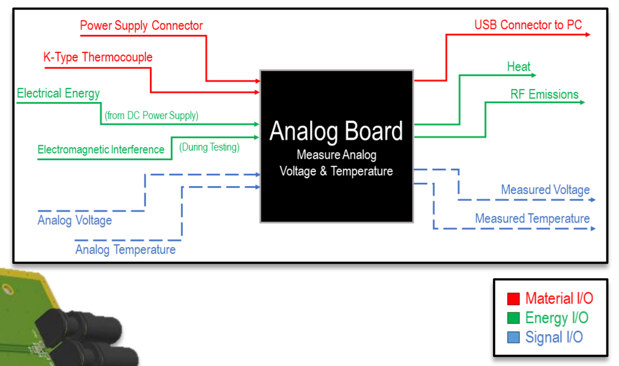
To prevent this, it is crucial to make intelligent decisions during the early stages of board development. The EMC PCB Design Study aims to demonstrate how thoughtful layout strategies, such as ground plane usage and the inclusion of decoupling or filtering components, can prevent poor EMC performance. When a PCB performs well by design, it may not be necessary to remedy performance by means of grounding or shielding.

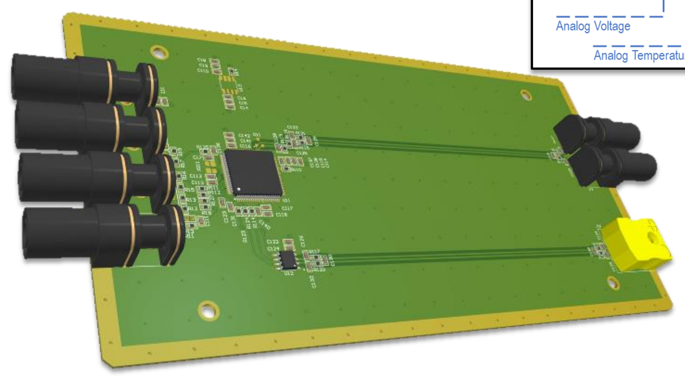
Key Specifications

Two device classes included in the study were chosen to represent common device applications that are relevant to the EMC industry. The first device uses analog measurement instruments to accurately determine temperature and voltage. The second device is a USB Type-C power delivery board, similar to devices used for charging laptops, smartphones, and other consumer electronics. Each device will have a number of variants, where each variant has the same functionality, but its own unique board layout. Key design specifications are as follows:

- 7 variants of Analog Measurement Board
  - Use of thermocouple to measure temperatures between 15°C to 100°C with ±3°C accuracy
  - Measures DC voltage between 9V to 16V with ±0.5V accuracy
  - Sends measurement data to PC terminal at least every 200ms
- 3 variants of Power Delivery Board
  - Use of USB-C power delivery architecture
  - Capable of delivering 15W of power
- Custom conductive enclosure for each device
  - Option for grounding to enclosure using conductive hex standoffs
  - Option for isolation from enclosure using non-conductive hex standoffs
  - Option for grounding to enclosure using exposed ground trace at board edges
- Custom non-conductive enclosure for each device
  - Ability to swap variants without the use of tools or hardware

Measurement PCB

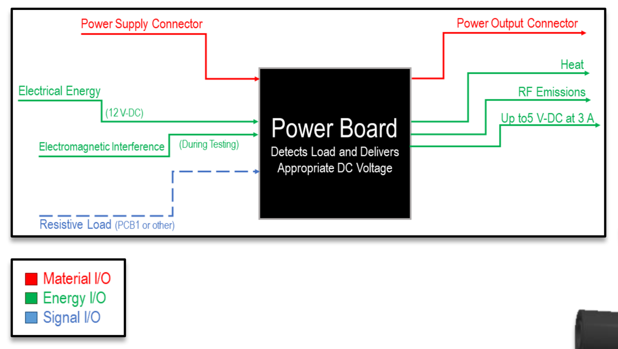


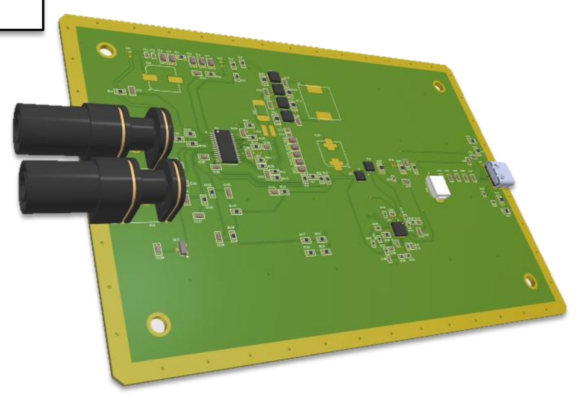


The Analog Measurement Board has 7 variants and is capable of measuring temperature and DC voltage. Temperature is measured using a K-Type thermocouple, and voltage is measured using probe attachments. It features 100mm long traces between the signal inputs and the ICs, which present an opportunity for EMI to hinder functionality. Analog Boards will be tested primarily for radiated immunity and conducted immunity, using the ISO11452-11 and ISO11452-4 standards, respectively.

Variant	Analog Trace Routing Style	Analog Trace Routing Layer	Grounding Method	Ground Split Geometry	Ground Split Layers
1	Differential	Microstrip on top layer	Single Ground Reference (GND)	N/A	N/A
2	Single Ended				
3	Differential	Embedded on layer 3			
4	Single Ended				
5	Single Ended	Microstrip on top layer	Split Ground Reference (AGND and GND)	AGND under analog circuitry, adjacent to GND*	All layers
6				AGND under analog traces, surrounded by GND*	Layer 2 only
7		1-3-1-3-1-3-1-3-1			

Power PCB





The Power Delivery Board uses USB-C power delivery architecture to provide up to 5V-DC at 3A. It has 3 variants which can be tested for radiated and conducted emissions to the CISPR-25 standard.

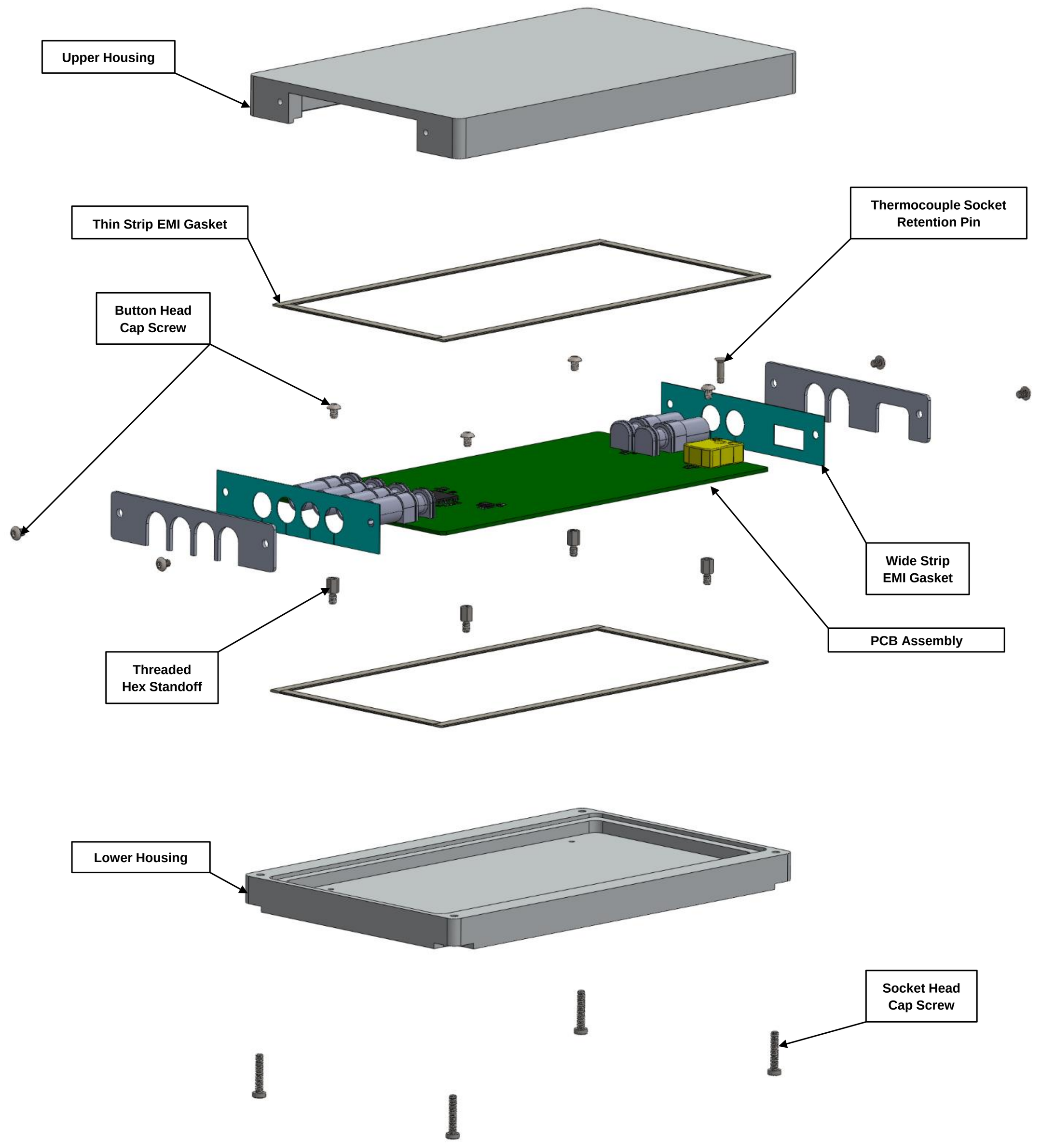
Variant	Power Delivery Method	Primary Power Layer
1	Discrete Routing	1
2	Power Plane	3
3	Discrete Routing	3

Enclosures

Each PCB may be tested using a conductive enclosure or a non-conductive enclosure. Each pair of enclosures was designed to allow for board variants to be swapped in-and-out easily, with minimal tools required.

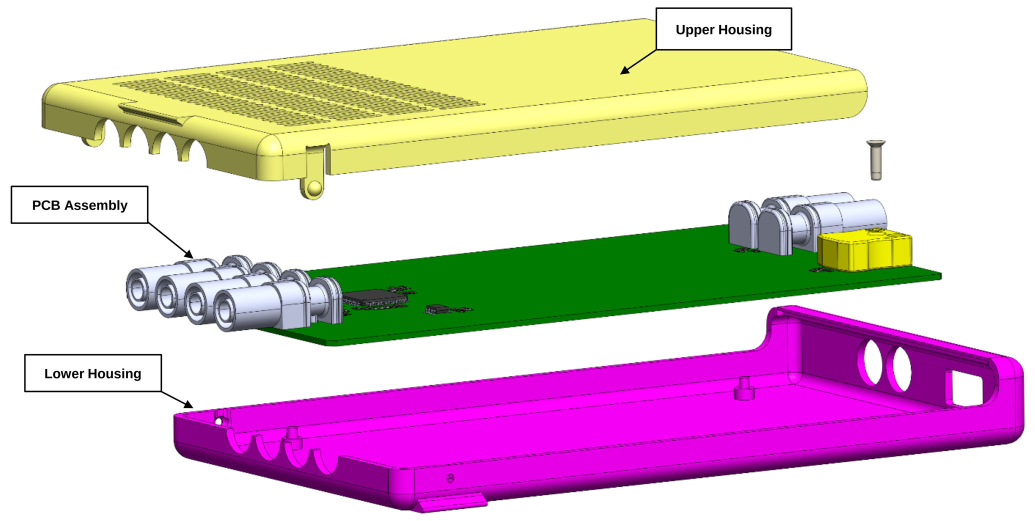
Conductive Enclosure

Outfitting a PCB with a conductive enclosure provides superior EMI shielding. Boards may be grounded to these enclosures using conductive hex standoffs or direct contact EMI gaskets at the board edge. Grounding is a common method used to protect boards with poor EMC performance.

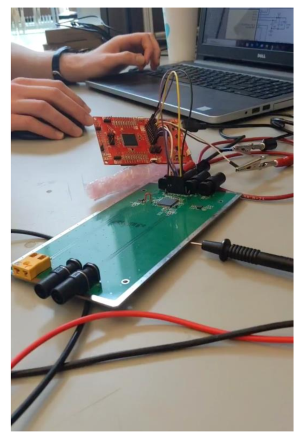


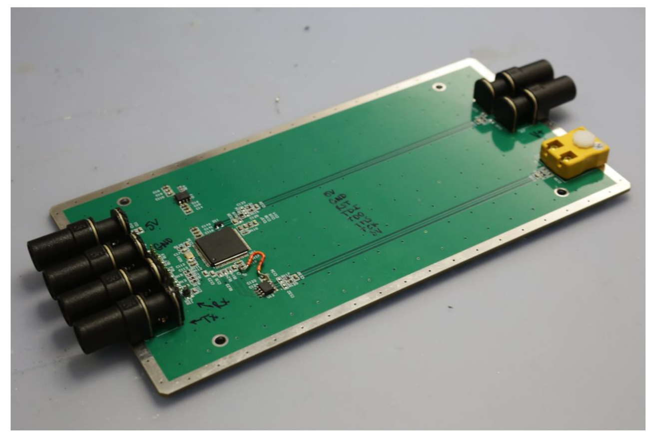
Non-Conductive Enclosure

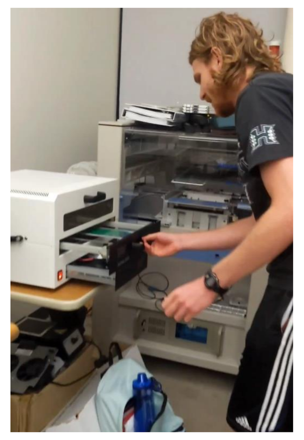
Non-conductive enclosures provide little benefit to EMC characteristics, but they are less expensive to manufacture and implement. Boards which exhibit good EMC performance have lower lifetime production costs because they may be outfitted with non-conductive enclosures.

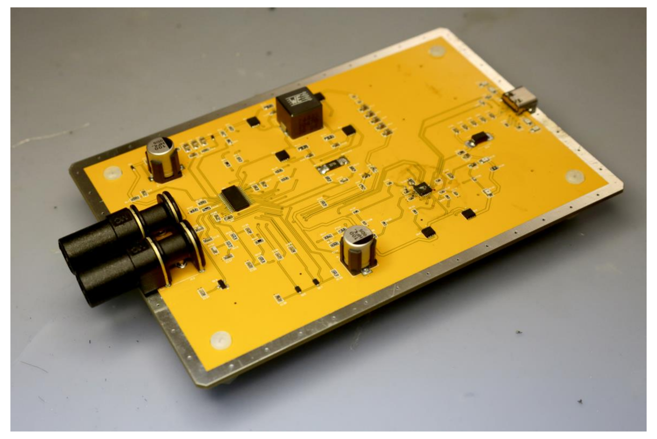


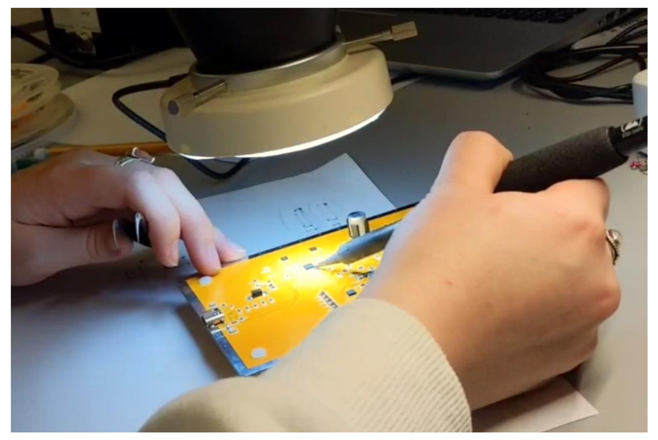
Prototype & Build

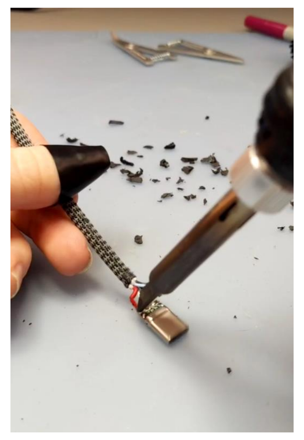












Oversights Identified

- PCBs use direct pad-to-plane connections
- Silkscreens are not labeled thoughtfully
- Selected Power Delivery IC is “not recommended for future designs”
- MCU used to process analog measurements is overly-equipped for this application

Future Work

The testing process focused on designs with poor EMC performance. In the future, the project can be used to obtain a more granular understanding of how different levels of enclosure grounding and signal filtering effect EMC performance.

Acknowledgements

The EMC PCB Design Study Team would like to extend a special thank-you to the following individuals in recognition of support to the success of the project:

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