Y.I.C. Technologies

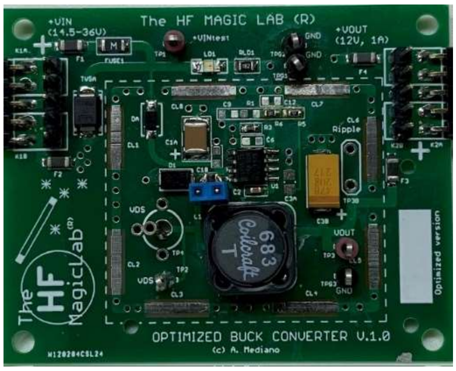
Comprehensive Application Note

Exploring the importance of the Ground Layer (GND) beneath a Buck Converter inductor.

ABSTRACT

In power electronics, where efficiency and performance are paramount, the design of buck converters holds significant importance.

This application note explores the significance and impact of a Ground Layer beneath a buck converter inductor.
Despite its critical role, a proper design of the Ground Layer (GND) often goes unnoticed.



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Introduction

Buck Converters, also known as step-down converters, are widely used in various electronic devices to efficiently regulate voltage levels. They operate by converting a higher input voltage to a lower output voltage by means of pulse-width modulation (PWM). Central to their design is the inductor, which plays a pivotal role in energy storage and transfer.

While much attention is given to the selection and positioning of the inductor in buck converter designs, the importance of the ground layer beneath it is often underestimated. The ground layer serves as a reference point for the entire circuit, providing a return path for current flow. However, its significance extends beyond mere connectivity:

EMI Reduction: One of the primary roles of the ground layer beneath the inductor is to mitigate electromagnetic interference (EMI). Inductors, by their nature, generate magnetic fields during operation. Placing the ground layer strategically beneath the inductor helps to contain these fields, reducing EMI emissions and ensuring compliance with electromagnetic compatibility (EMC) standards.

Improved Thermal Management: Efficient dissipation of heat is crucial in power electronics. The ground layer acts as a heat sink, dissipating thermal energy generated during converter operation. Proper thermal management helps prevent overheating, ensuring the reliability and longevity of the buck converter.

Minimization of Parasitic Effects: In high frequency switching applications typical of buck converters, parasitic effects such as parasitic capacitance and inductance can degrade performance. The ground layer serves to minimize these parasitic effects by providing a low-impedance path for return currents, thereby enhancing the converter's efficiency and transient response.

Enhanced Signal Integrity: Maintaining signal integrity is crucial in power electronics, particularly in high-speed switching circuits. The ground layer also helps to minimize voltage drops and impedance mismatches, ensuring stable and accurate signal propagation throughout the circuit.

The Controversy

Advocates of incorporating a hole beneath the inductor emphasize its potential advantages, particularly in facilitating improved heat dissipation and thermal management by optimizing airflow around the inductor. Conversely, proponents of removing the GND plane beneath the inductor contend that currents in the GND plane may lead to increased losses and a reduction in the nominal value of inductance due to induced currents.

Critics of this approach often express reservations, primarily due to concerns about the spread of the magnetic field across the entire PCB. They caution that this could potentially impact connectors and sensitive components, such as filter inductors, compromising the EMI/EMC performance of the design. Additionally, concerns about signal reflections, manufacturing complexity, cost implications, and potential compromise to mechanical stability are highlighted.

In conclusion, the debate underscores the nuanced nature of engineering decision-making, where trade-offs between conflicting objectives must be carefully weighed. While opinions vary, it is essential to consider that a GND plane positioned as close as possible to the inductor offers numerous benefits, particularly in containing stray magnetic fields within the system. For instance, Figure 1 illustrates a four-layer PCB with Buck converter components on the top layer, showcasing the magnetic field containment facilitated by the proximity of a GND plane on the adjacent layer (layer 2).

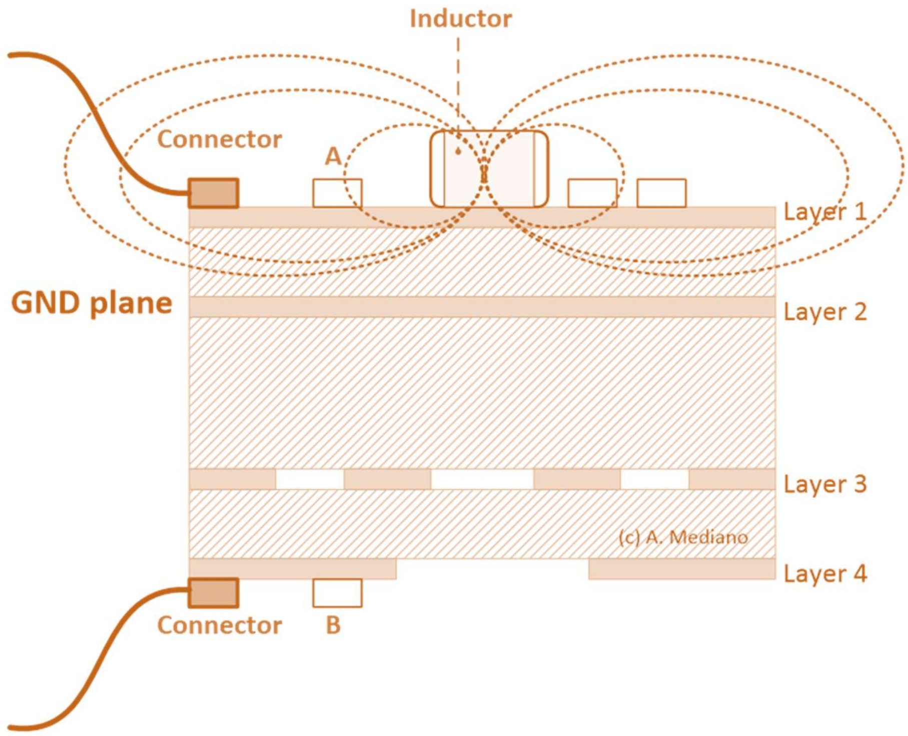


Figure 1 - A PCB with GND under inductor of Buck converter

In the depicted scenario, the components and traces situated on layers 3 and 4 remain shielded from the magnetic fields emanating from the inductor. Consequently, components such as B and the connectors/cables on layer 4 are inherently less susceptible to absorbing this energy, thereby reducing the likelihood of inducing conducted or radiated electromagnetic compatibility (EMC) issues.

Conversely, components or connectors/cables positioned on the top layer, such as component A, may be subject to exposure to the magnetic fields generated by an unshielded inductor. In such cases, increasing the distance between these components and the inductor serves as a prudent strategy to minimize coupling.

In Figure 2, the removal of the ground (GND) layer beneath the inductor is illustrated. This removal results in the dispersion of magnetic fields throughout the entirety of the system.

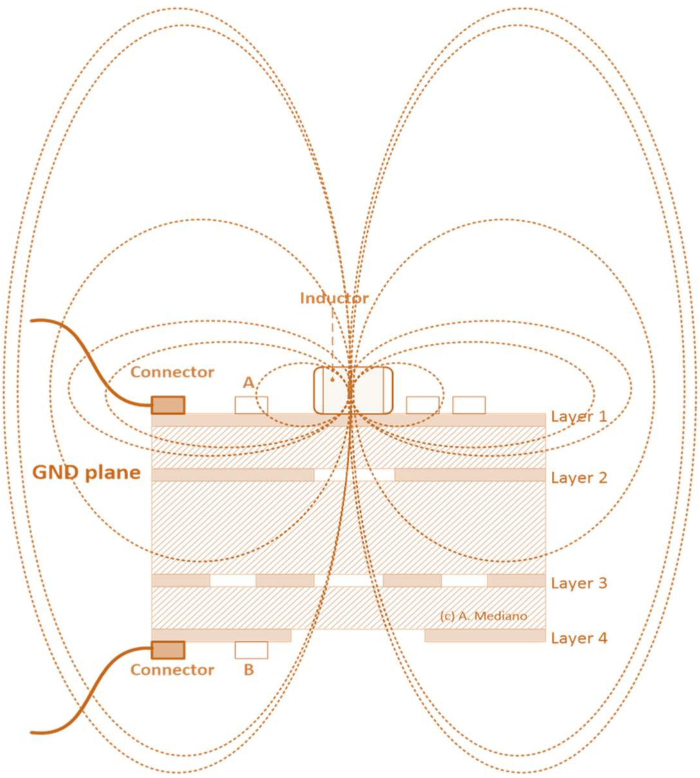


Figure 2 - A PCB without GND under inductor of Buck converter

Essentially, any activity associated with the inductor, including switching frequency, harmonics, and ringing phenomena, possesses the potential to affect sensitive components adversely. This interference can significantly challenge efforts to control or minimize emissions from the product.

Simple Buck Converter Design

To investigate the implications of adding or omitting a ground (GND) layer beneath the inductor on the distribution of fields around a PCB featuring a Buck converter, a prototype board was designed to allow for the inclusion or exclusion of GND directly below the inductor.

Utilizing a Near-Field Magnetic Scanner provides an effective means to study such issues. For this analysis, an **EM**Scanner equipped with the latest **EM**Viewer software was employed.

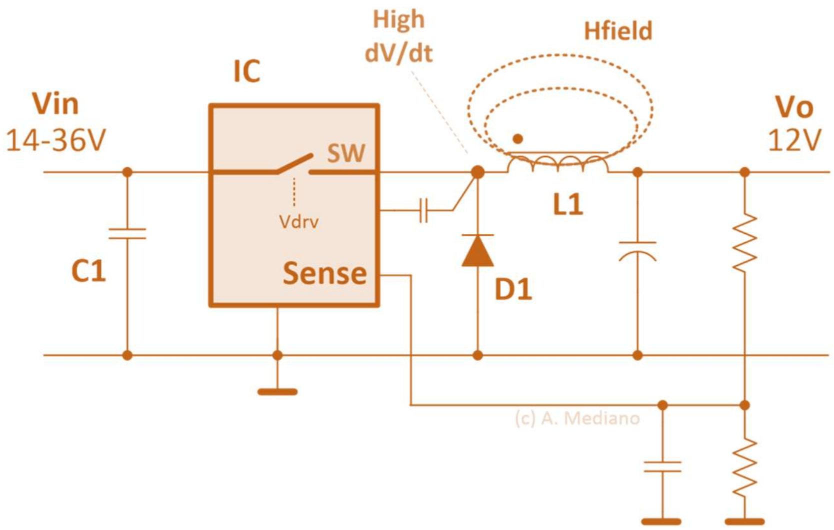


Figure 3 - A simple Buck converter schematic

This setup highlights the presence of high dV/dt switching nodes and the magnetic fields surrounding the inductor.

Figure 4 includes an image of the PCB, clearly marking the locations of the integrated circuit (IC), the inductor, and the diode integral to the converter's functionality.

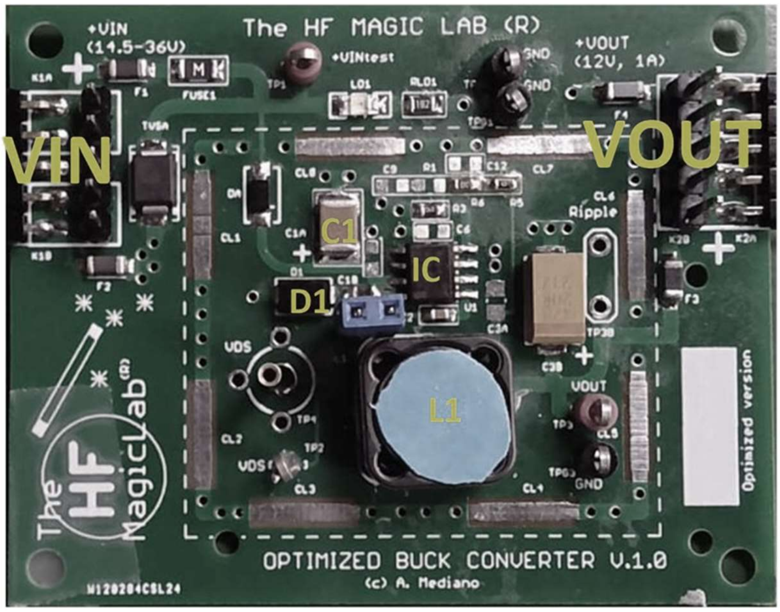


Figure 4 - The Buck converter prototype to be measured.

This is a two layers board with the bottom layer with a GND plane and the possibility to open/close the GND area below the inductor with a small piece of shielding tape.

GND Layer Beneath the Inductor

Spectral scan

Using **EM**Scanner, an initial analysis was conducted on the PCB configured with a ground (GND) layer beneath the inductor. The findings revealed significant broadband activity centred around the 100MHz frequency, as depicted in Figure 5.

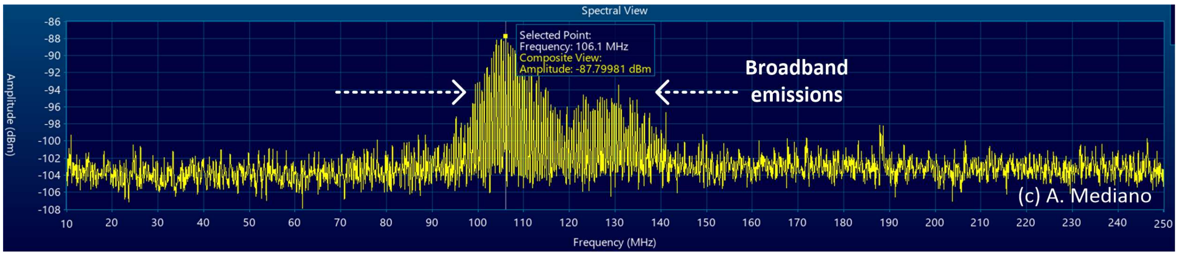


Figure 5 - Emissions detected from the PCB with a GND plane.

Note the observed activity beneath the PCB, however, in practical applications, this energy is likely to be radiated by cables connected to the PCB.

Spatial scan

With the spatial scan we can identify the hot areas in the PCB so a review of the layout can be easily proposed (*Figure* 6):

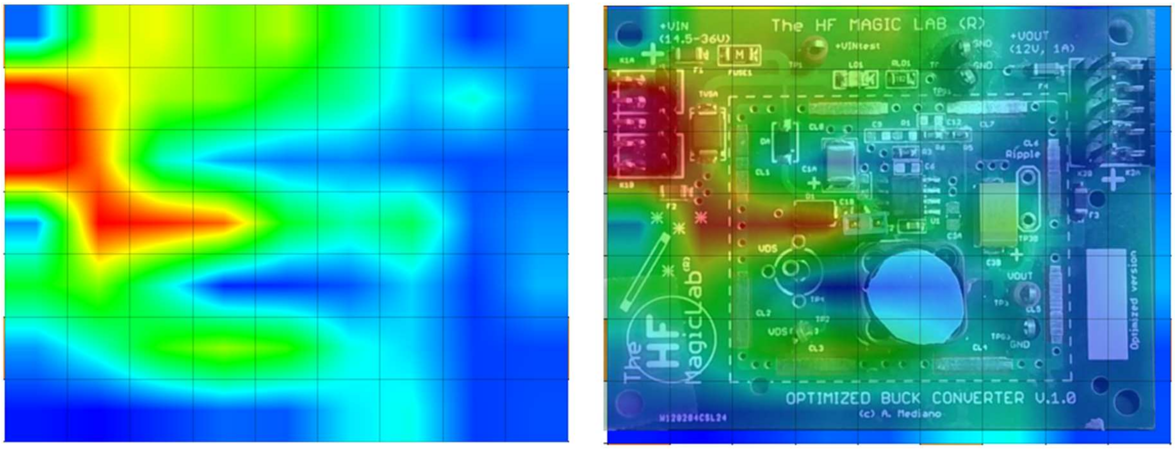


Figure 6 - Spectral scan of the Buck converter without (left) and with (right) overlay.

Note the area below the inductor is clean. A high activity is detected close to the input cable so risk for radiated emissions is present.

With No GND layer Beneath the inductor

Spectral scan

Now the experiment is repeated removing the GND area below the inductor. Again, the broadband energy is detected by the scanner (Fig. 8):

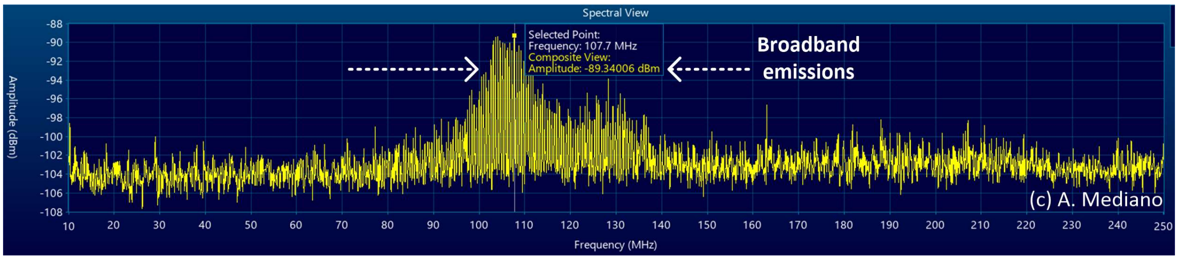


Fig. 8. Emissions detected from the PCB with a GND plane.

Spatial Scan

With the spatial scan the spreading effect in the whole PCB is clearly identified (Fig. 9):

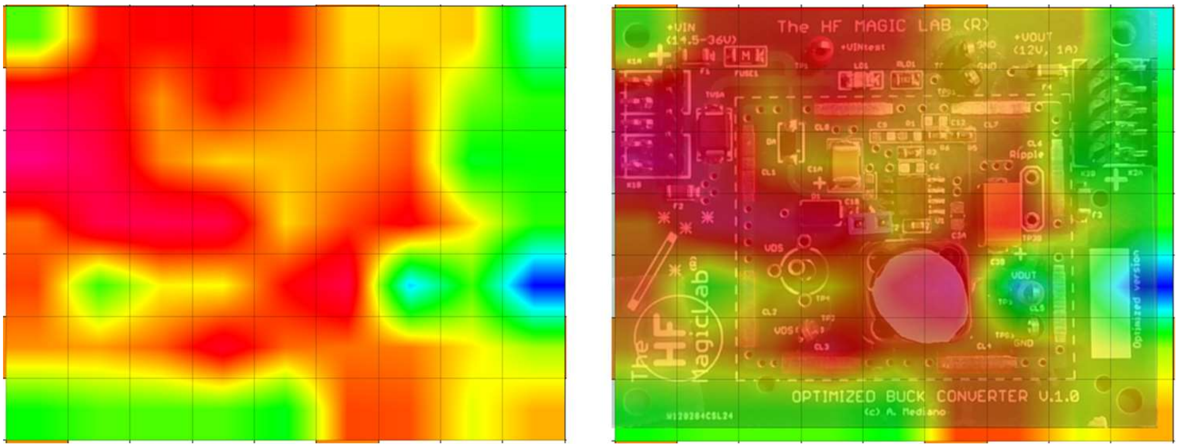


Fig. 9. Spectral scan of the Buck converter without (left) and with (right) overlay.

Note how removing the GND below inductor contributes to a spreading effect in the PCB components, in the PCB edges and close to connectors.

The GND below the inductor is easily identified with a 3D scan (Fig. 10):

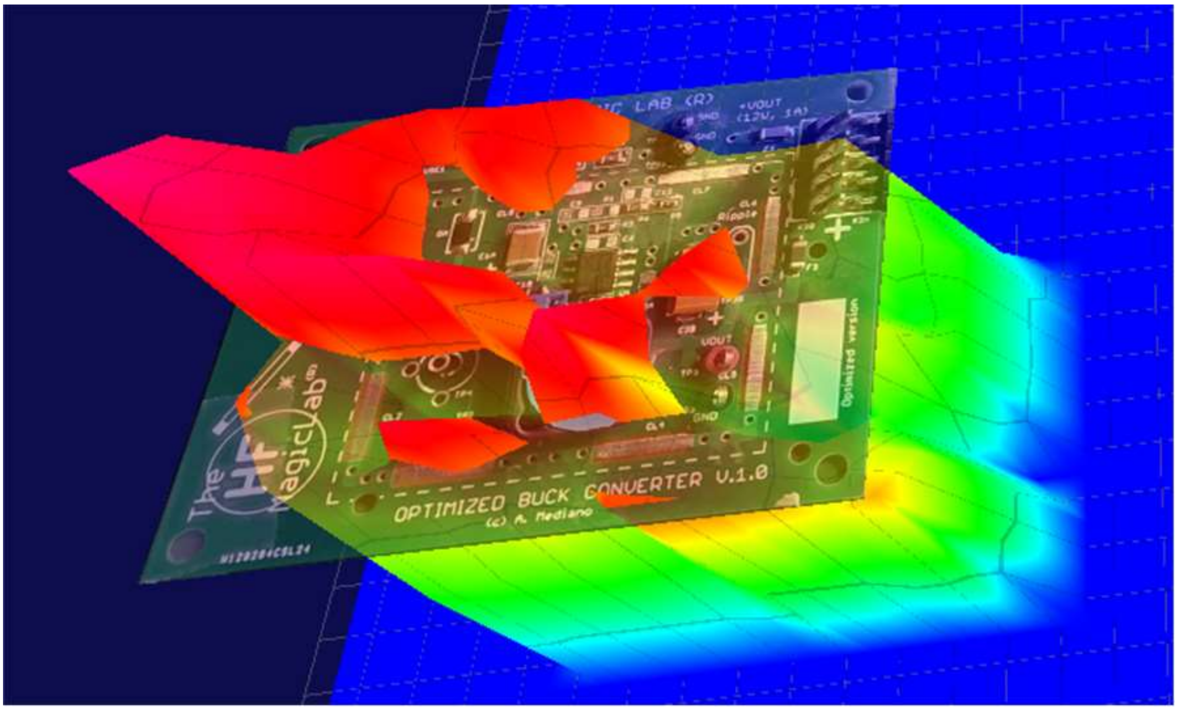
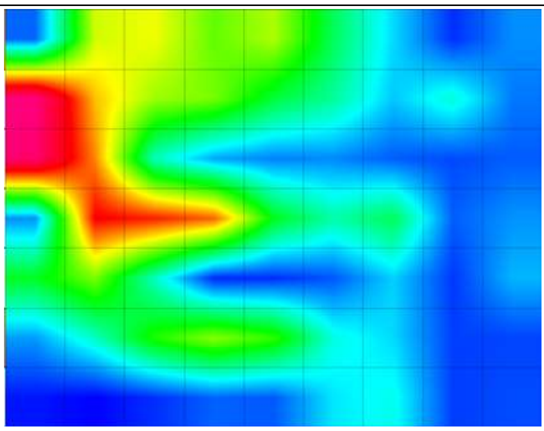
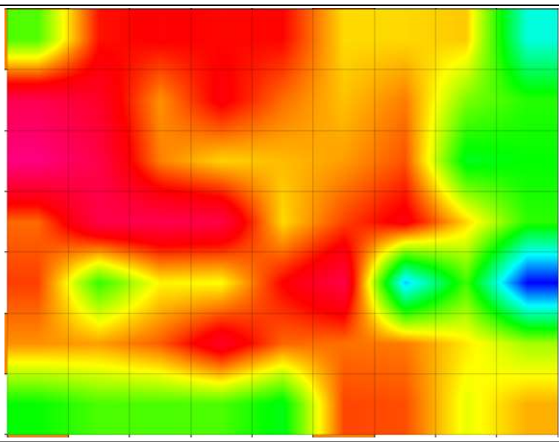
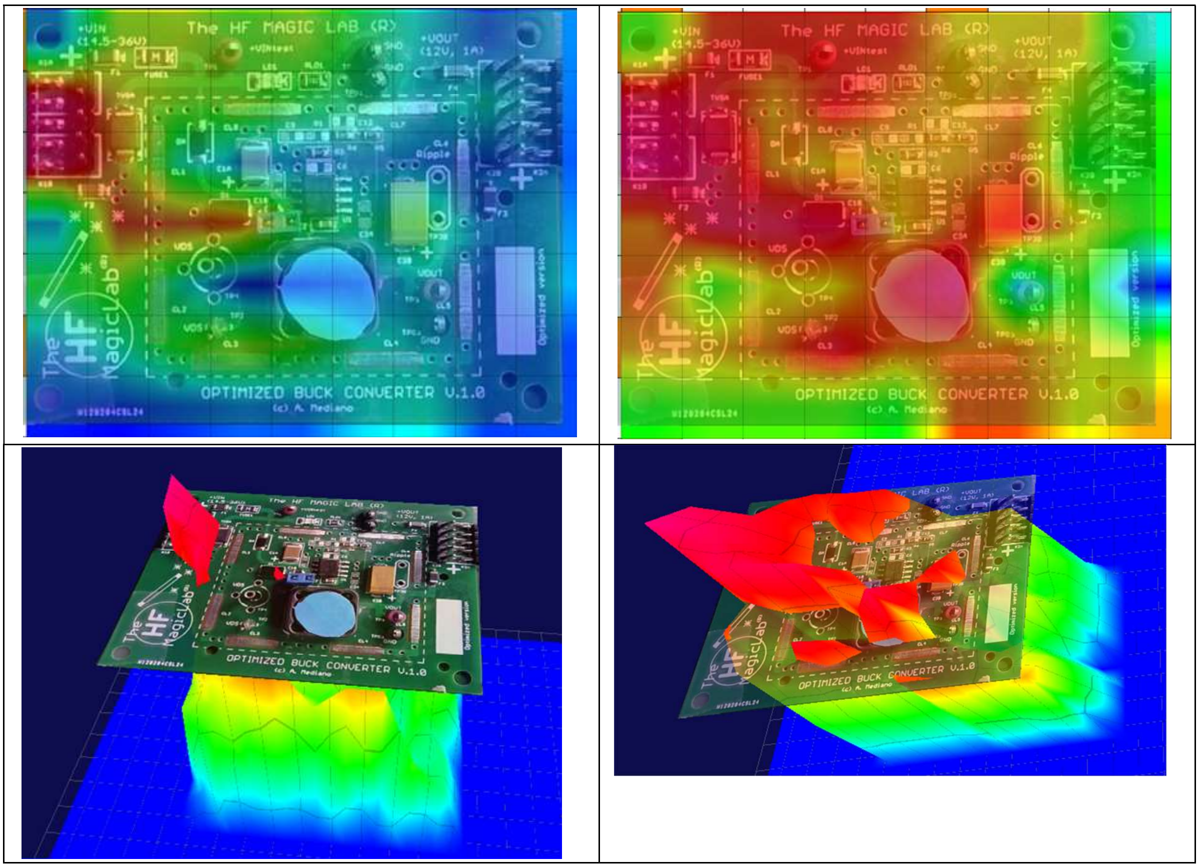


Fig. 10. A 3D view of emissions without GND below inductor.

Comparison of results

Let's see all the previous results in a table to compare the situation with/without GND below inductor.

WITH GND BELOW INDUCTOR	**WITHOUT** GND BELOW INDUCTOR
	



Conclusion

With the increased complexity of buck converter designs, every component plays a vital role, including the often-overlooked ground layer. By understanding and optimizing the design of this critical element, engineers can achieve enhanced performance, efficiency, and reliability in their power electronics applications. As the demand for compact, efficient, and reliable power solutions continues to grow, the significance of the ground layer in buck converter designs cannot be overstated.

Utilizing the **EM**Scanner, we can effectively illustrate how the fields associated with the inductor propagate throughout the entire PCB, thereby coupling with sensitive components such as EMC filters, connectors, and cables.

Given these observations, if EMI/EMC considerations are paramount, maintaining a GND layer below the inductor emerges as a prudent strategy.

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