

How Buck Regulators with Integrated Capacitors Help Lower EMI and Save Board Space



Harrison Overturf

It's a challenge to create highly efficient and compact designs while also adhering to strict electromagnetic interference (EMI) requirements imposed by groups such as Comité International Spécial des Perturbations Radioélectriques (CISPR). Therefore, component selection becomes a critical part of the design process. As with most design decisions, choosing between different components almost always comes down to an assessment of tradeoffs based on your most critical design goals. Known for high efficiency and good thermal performance, buck regulators are not typically considered low-EMI options. Fortunately, you have several options for reducing the EMI generated by such regulators. To aid further discussion, [Figure 1](#) shows a simplified buck regulator schematic.

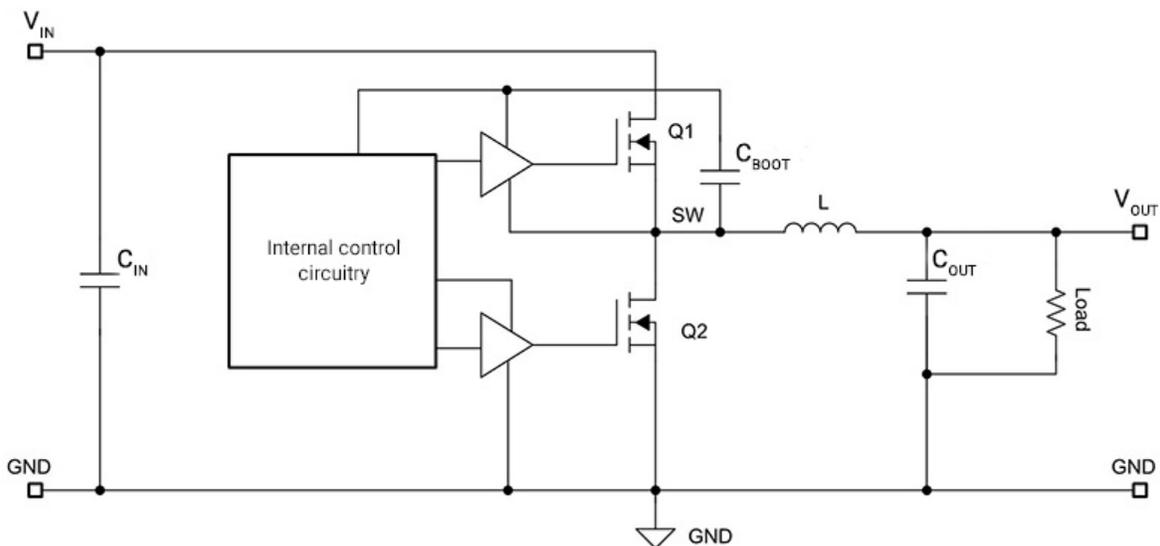


Figure 1. Simplified Buck Regulator Schematic

Board Layout Considerations

Beyond selecting proper passive component values to ensure a functional design, board layout should be your first consideration when your design must fall under EMI limits. There are two general rules that can help minimize generated EMI with all buck regulator board layouts:

- Minimize high transient current (di/dt) loop areas by bringing the input capacitor and boot capacitor as close to the V_{IN} and GND pins of the integrated circuit as possible.
- Minimize the surface area of high transient voltage (dv/dt) nodes by minimizing the area of the switch node.

In instances where board layout optimization is not possible, there are other options. Learn more about them in the technical article, ["How Device-Level Features and Package Options Can Help Minimize EMI in Automotive Designs."](#)

Integrated Input Capacitors

As I mentioned, reducing the area of high di/dt current loops is very important when designing switching regulators to remain under EMI limits. In a buck regulator, it's important to consider the input-voltage-to-ground loop from an EMI perspective. A buck regulator steps down a higher DC voltage to a lower one by switching the connection to the supply on and off, resulting in high-side metal-oxide semiconductor field-effect transistor (MOSFET) (Q1) current, shown in Figure 2.

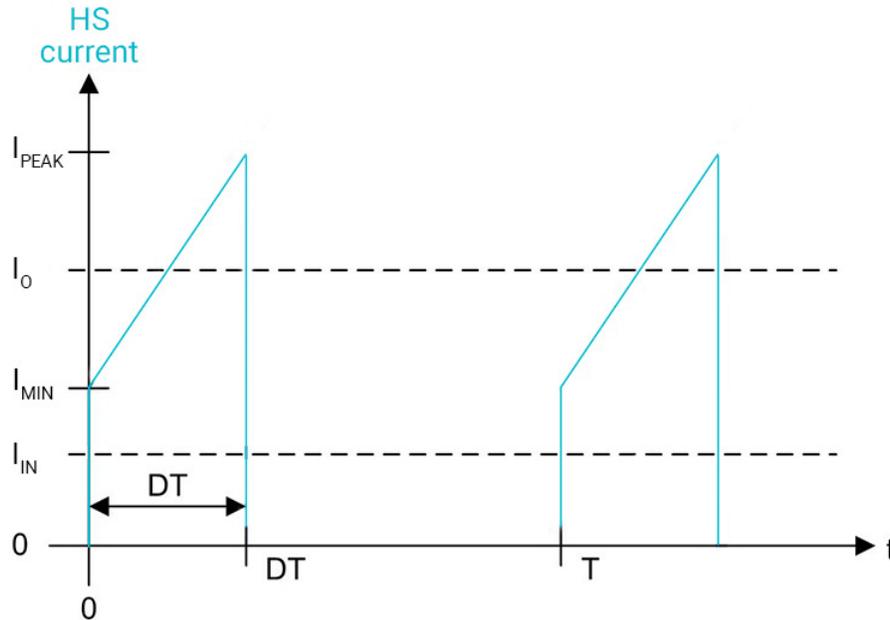


Figure 2. Input current waveform to a buck regulator

The MOSFET switches on and off rapidly, creating very sharp, almost discontinuous currents supplied by the input capacitor. Some devices, such as TI's 3-A LMQ66430-Q1 and 6-A LMQ61460-Q1 36-V buck regulators, integrate high-frequency input capacitors inside the package, resulting in the smallest possible input current-loop area. Reducing the area of this input current loop results in smaller parasitic inductance at the input, which reduces the amount of electromagnetic energy emitted.

Integrated Boot Capacitor

Another high di/dt current loop that you should consider is the boot capacitor loop. The boot capacitor is responsible for supplying charge to the high-side MOSFET gate driver during the on-time. Internal circuitry refreshes this capacitor during the off-time. The source terminal of the high-side MOSFET connects to the switch node rather than GND. Referencing the boot capacitor to the source pin of the MOSFET ensures that the gate-to-source voltage (V_{GS}) is high enough to turn on the MOSFET. With most buck regulators, you will have to leave some switch node area available on the board to connect the bootstrap capacitor, although this can be counterproductive when trying to minimize the area of the switch node for EMI. By integrating the boot capacitor inside the package, the LMQ66430-Q1 follows the two rules that I mentioned earlier, while also reducing the need for an external component.

Conclusion

It can be difficult to design compact power-supply designs capable of remaining under strict EMI limits. Buck regulators with integrated capacitors can make the process of EMI-compliant designs easier, while also helping reduce the overall external component count.

Additional Resources

Check out these technical articles:

- ["How a DC/DC Converter Package and Pinout Design Can Enhance Automotive EMI Performance."](#)
- ["Lowering Audible Noise in Automotive Applications with TI's DRSS Technology."](#)
- For a comprehensive overview of all things related to low EMI, read the e-book, ["An Engineer's Guide to Low EMI in DC/DC Regulators."](#)

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2023, Texas Instruments Incorporated