Silent Switcher Meets CISPR Class 5 Radiated Emissions While Maintaining High Conversion Efficiency

Tony Armstrong & Christian Kück

When minimizing EMI is a design priority, a linear regulator can be a low noise solution, but heat dissipation and efficiency requirements may preclude that choice and point to a switching regulator. Even in EMI-sensitive applications, a switching regulator is typically the first active component on the input power bus line, and regardless of downstream converters, it significantly impacts overall converter EMI performance. Until now, there was no sure way to guarantee that EMI could be suppressed and efficiency requirements attained via power IC selection. The LT8614 Silent Switcher™ regulator now makes this possible.

The LT8614 reduces EMI by more than 20dB compared to current state-of-the-art switching regulators. In comparison, it lowers EMI by 10x in the frequency range above 30MHz without compromising minimum on- and off-times or efficiency in an equivalent board area. It accomplishes this with no additional components or shielding, representing a significant breakthrough in switching regulator design.

A NEW SOLUTION TO EMI ISSUES

The tried and true solution to EMI issues is to use a shielding box for the complete circuit. Of course, this adds a significant costs in required board space, components and assembly, while complicating thermal management and testing. Another method is to slow down the switching edges. This has the undesired effect of reducing the efficiency, increasing minimum on-, off-times, and their associated dead times and compromises the potential current control loop speed.

The LT8614 Silent Switcher regulator delivers the desired effects of a shielded box without using one (see Figure 1). The LT8614 features a low I_Q of 2.5μA total supply current consumed by the device, in regulation with no load—important for always-on systems.

Its ultralow dropout is only limited by the internal top switch. Unlike alternative solutions, the LT8614's V_{IN}-V_{OUT} limit is not limited by maximum duty cycle and minimum off-times. The device skips its switch-off cycles in dropout and performs only the minimum required off cycles to keep the internal top switch boost stage voltage sustained, as shown in Figure 6.

At the same time, the minimum operating input voltage is only 2.9V typical (3.4V maximum), enabling it to supply

Figure 1. The LT8614 Silent Switcher minimizes EMI/EMC emissions while delivering high efficiency at frequencies up to 3MHz.

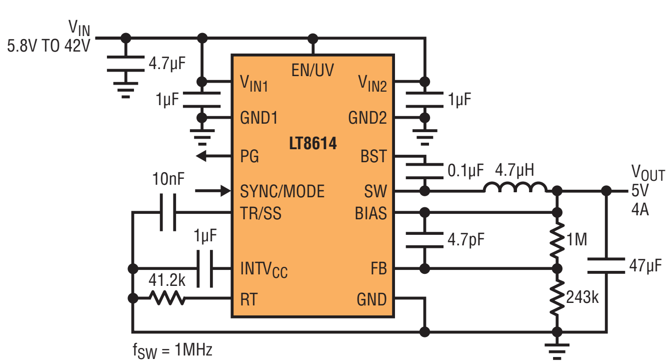
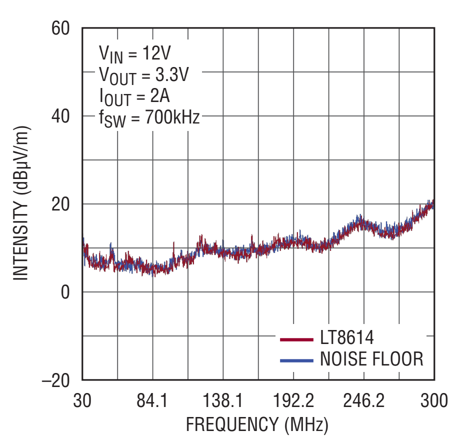


Figure 2. LT8614 board meets CISPR25 radiated standard in an anechoic chamber. Noise floor is equal to LT8614 radiated emissions.



The LT8614 reduces EMI by more than 20dB when compared current state-of-the-art switching regulators. In comparison, it lowers EMI by 10x in the frequency range above 30MHz without compromising minimum on- and off-times or efficiency in an equivalent board area. It accomplishes this feat with no additional components or shielding, representing a significant breakthrough in switching regulator design.

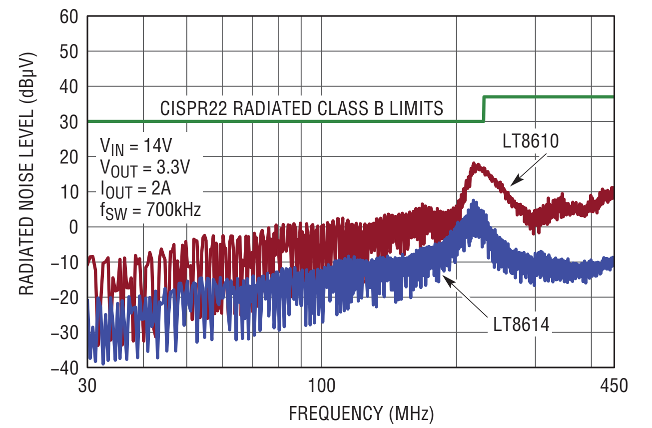


Figure 3. Comparison of radiated emissions for LT8614 and LT8610

a 3.3V rail with the part in dropout. At high currents, the LT8614 has higher efficiency than comparable parts since its total switch resistance is lower.

The LT8614 can be synchronised to an external frequency operating from 200kHz to 3MHz. AC switching losses are low, so it can be operated at high switching frequencies with minimal efficiency loss. In EMI-sensitive applications, such as those commonly found in many automotive environments, a good balance can be attained and the LT8614 can run either below the AM band for even lower EMI, or above the AM band. In a setup with 700kHz operating switching frequency, the standard LT8614 demo board does not exceed the noise floor in a CISPR25, Class 5 measurement.

The Figure 2 shows measurements taken in an anechoic chamber at 12V input, 3.3V output at 2A with a fixed switching frequency of 700kHz. To compare the LT8614 Silent Switcher technology against another current state-of-the-art switching regulator, the part was measured against the LT8610 (see Figure 3). The test was performed in a GTEM cell using the same load, input voltage and the same inductor on the standard demo boards for both parts.

One can see that up to a 20dB improvement is attained using the LT8614 Silent Switcher technology compared to the already very good EMI performance of the LT8610, especially in the more difficult to manage high frequency area.

In the time domain, the LT8614 shows benign behavior on the switch node edges, as shown in Figures 4 and 5. Even at 4ns/div, the LT8614 Silent Switcher regulator shows minimal ringing. In contrast, the LT8610 successfully damps

Figure 4. Comparison of switch node rising edges for LT8614 Silent Switcher and the LT8610

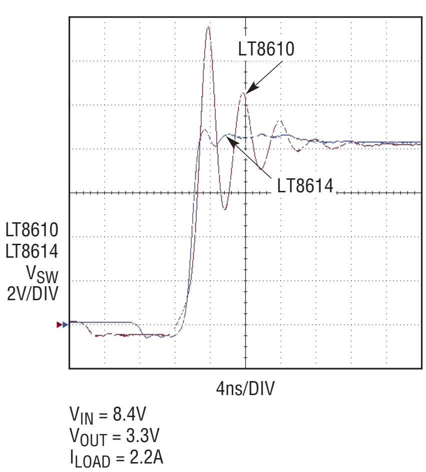


Figure 5. Near ideal square wave switch waveform of LT8614 enables low noise operation

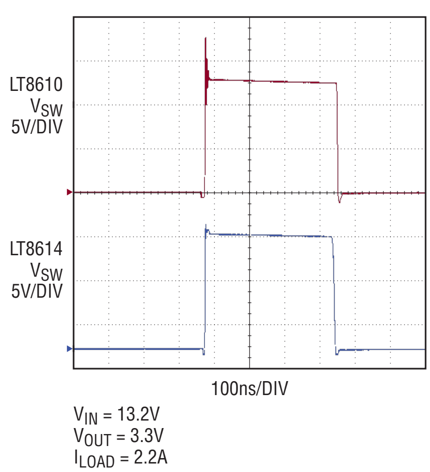
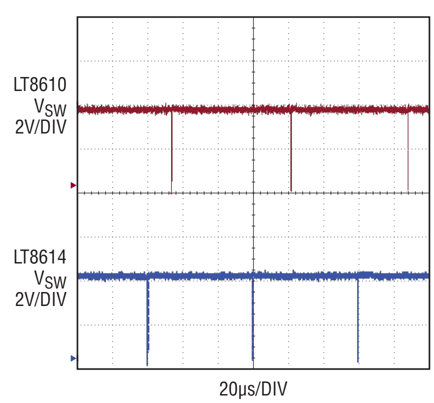


Figure 6. Dropout behavior of switch node for LT8614 and LT8610

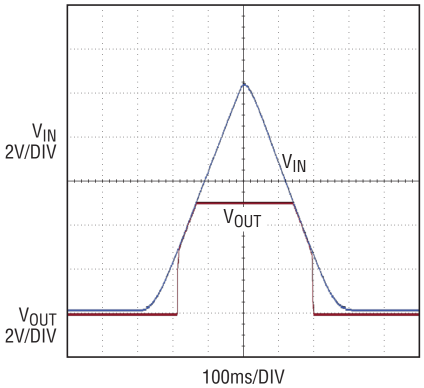


ringing as shown in Figure 4, but one can see the higher energy stored in the hot loop compared to the LT8614 (Figure 4).

Figure 5 shows the switch node at 13.2V input, and how the LT8614 achieves a near ideal square wave at the switch node. All time domain measurements in Figures 4, 5 and 6 are performed with 500MHz Tektronix P6139A probes with close probe tip shield connection to the PCB GND plane. Off-the-shelf demo boards are used for both parts.

The 42V absolute maximum input voltage ratings of the LT861x family is important for automotive and industrial environments. Just as important, especially in automotive situations, is dropout behavior. Often critical 3.3V logic supplies must be supported through cold crank situations. The LT8614 Silent Switcher regulator maintains the close to ideal behavior of the LT861x family in this case. Instead of higher undervoltage lockout voltages and maximum duty cycle clamps of alternative parts, the LT8610/11/14 devices operate down to 3.4V and start skipping off cycles as soon as necessary, as shown in Figure 6. This results in the ideal dropout behavior as shown in Figure 7.

Figure 7. LT8614 dropout performance. Like other LT861x devices, it operates down to 3.4V and starts skipping off cycles as soon as necessary.



The LT8614's low minimum on-time of 30ns enables large step-down ratios even at high switching frequencies. As a result, it can supply logic core voltages with a single step-down from inputs up to 42V.

CONCLUSION

It is well known that EMI considerations require careful attention during the initial converter design in order to pass EMI testing at system completion. The LT8614 Silent Switcher regulator makes it possible to ensure success with a simple power IC selection. The LT8614 reduces EMI from current state-of-the-art switching regulators by more than 20dB, even as it increases conversion efficiencies—no additional components or extra shielding are required. ■

Switching Regulators and EMI

Printed circuit board layout determines the success or failure of every power supply. It sets functional, electromagnetic interference (EMI) and thermal behavior. While switching power supply layout is not a black art, it can often be overlooked in the initial design process. Since functional and EMI requirements must be met, what is good for functional stability of the power supply is also usually good for its EMI emissions. It should be noted that good layout from the beginning does not add cost, but can actually produce cost savings, eliminating the need for EMI filters, mechanical shielding, EMI test time and PC board revisions.

There are two types of EMI emissions: conducted and radiated. Conducted emissions ride on the wires and traces that connect to a product. Since the noise is localized to a specific terminal or connector in the design, compliance with conducted emissions requirements can often be assured relatively early in the development process with a good layout and filter design.

Radiated emissions, however, are another story. Everything on the board that carries current radiates an electromagnetic field. Every trace on the board is an antenna, and every copper plane is a mirror. Anything, other than a pure sine wave or DC voltage, generates a wide signal spectrum. Even with careful design, a designer never really knows how bad the radiated emissions are going to be until the system gets tested. And radiated emissions testing cannot be formally performed until the design is essentially complete.

Filters are often used to reduce EMI by attenuating the strength at a certain frequency or over a range of frequencies. A portion of this energy that travels through space (radiated) is attenuated by adding sheet metal as magnetic shields. The lower frequency part that rides on PCB traces (conducted) is tamed by adding ferrite beads and other filters. EMI cannot be eliminated, but can be attenuated to a level that is acceptable by other communication and digital components. Moreover, several regulatory bodies enforce standards to ensure compliance.

Modern input filter components in surface mount technology have better performance than through-hole parts. Nevertheless, this improvement is outpaced by the increase in operating switching frequencies of switching regulators. Higher efficiency, low minimum on- and off-times result in higher harmonic content due to the faster switch transitions. For every doubling in switching frequency, the EMI becomes 6dB worse while all other parameters, such as switch capacity and transition times, remain constant. The wideband EMI behaves like a first order high pass with 20dB higher emissions if the switching frequency increases by 10 times.

Savvy PCB designers will make the hot loops small and use shielding ground layers as close to the active layer as possible. Nevertheless, device pinouts, package construction, thermal design requirements and package sizes needed for adequate energy storage in decoupling components dictate a minimum hot loop size. To further complicate matters, in typical planar printed circuit boards, the magnetic or transformer style coupling between traces above 30MHz will diminish all filter efforts since the higher the frequencies become the more effective the unwanted magnetic or antenna coupling becomes.

The potential problem for interference and noise can be exacerbated when multiple DC/DC switch mode regulators are paralleled for current sharing and higher output power. If all are operating (switching) at a similar frequency, the combined energy generated by multiple regulators in a circuit is concentrated at that frequency and its harmonics. Presence of this energy can become a concern especially to the rest of ICs on the PC board and other system boards close to each other and susceptible to this radiated energy. This can be particularly troubling in automotive systems which are densely populated and are often in close proximity to audio, RF, CAN bus and various receiving systems.