# Reducing radiated EMI in WLED drivers

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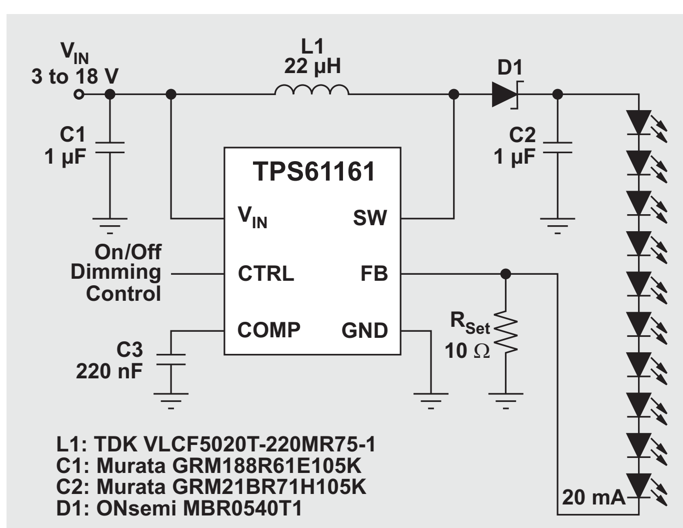
Most mobile phones use white LEDs (WLEDs) as the backlight for their displays. Li-Ion batteries with an output range of 2.7 to 4.2 V are the most common power source for mobile phones. Since several WLEDs in series, each with forward voltages around 3.6 V, are typically used for the backlight, the backlight driver must provide a voltage higher than the Li-Ion range. Therefore, an inductive boost converter is a common power-supply topology for WLED drivers. Figure 1 shows a typical backlight-driver solution that uses the TPS61161 to drive ten LEDs in series.

All inductive switching converters cause radiated electromagnetic interference (EMI) that is directly proportional to output power. As the size of mobile phone displays increases to accommodate more features, the backlight driver's increased output power results in more EMI. Factors at each design step, from driver-IC selection to board layout, impact the WLED driver's EMI. Therefore, minimizing the WLED backlight driver's radiated EMI so that it does not affect other systems is a major concern for manufacturers of both the backlight driver IC and the mobile phone.

Radiated EMI is caused by induced electric fields where capacitors store their energy, and induced magnetic fields where inductors store their energy. The electric-field strength of a capacitor is directly proportional to its capacitance and the voltage across its terminals. The capacitance is inversely proportional to the distance between the terminals. Ideally, the IC and components are laid out on the board to minimize the undesired (often called "parasitic") capacitance. Such capacitance can be created, for example, by a large metal trace or plane on top of a ground trace or plane. Likewise, an inductor's magnetic-field strength is directly proportional to its inductance value and the current flowing through it. The inductance value is directly proportional to the wire or trace length. The board ideally is laid out to minimize parasitic inductance created by long wires, loops, and traces; and shielded inductors are used on the PCB itself. Moreover, the rate of change of the voltages across and the currents through these parasitic components directly impacts their field strengths. Key methods of reducing EMI are to minimize the size of and interaction between these parasitic components and to reduce their voltages and current ramp rates.

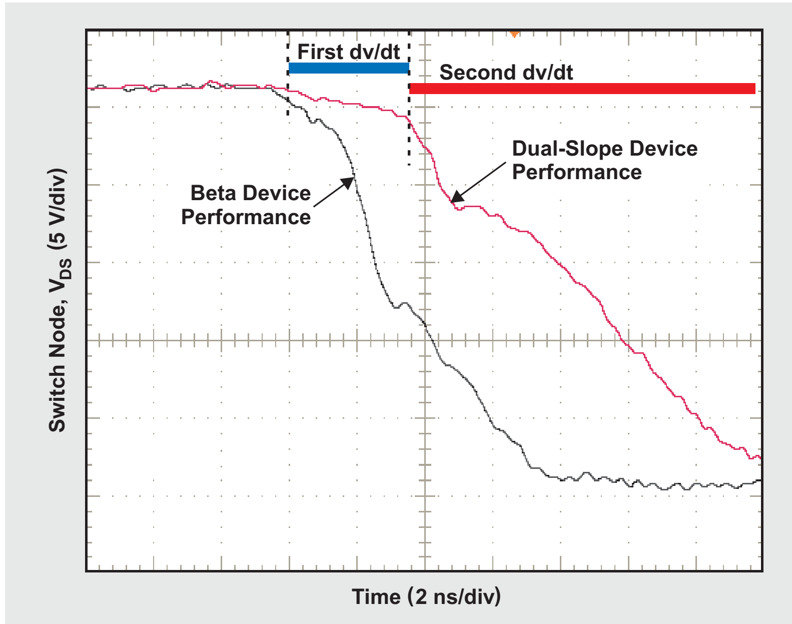
The circuit designer and IC-layout engineer are responsible for minimizing the parasitic inductances and capacitances that occur at high frequencies (greater than 300 MHz) and/or for managing voltage and current ramp rates inside the IC. Otherwise, the IC itself will generate

**Figure 1. TPS61161 backlight driver**



EMI. Consider Figure 2, which shows the drain voltage, $V_{DS}$, of the TPS61161's internal NMOS FET (i.e., the switch node) as the FET turns on. The blue trace is from a test board with beta TPS61161 silicon that has a commonly used high-speed gate drive. The red trace shows the same node on the same test board but with the final TPS61161 silicon that has TI's dual-slope switching technology. This technology controls the switch node's slope on the falling edge (i.e., dv/dt) in two steps. When the internal power FET first turns on, there is a large current spike. During the first step of a dual-slope FET compared to a normal FET, the dv/dt is slowed to reduce the amplitude of the current spike and the EMI that results primarily from parasitic inductance. During the second step, the switch FET returns to its normal, faster dv/dt to minimize the switching losses that would otherwise occur.

**Figure 2. Switch node ($V_{DS}$ of NMOS FET) of TPS61161's WLED driver**




To measure the far-field EMI from a battery-powered evaluation module (TPS61161EVM-243), an IC with a traditional switch (shown in red in Figure 3) and an IC with a dual-slope switch (shown in green) were used in the same test environment. The black curve shows the noise floor of the measurement, and the 850-MHz spike is from a spurious GSM signal. It is clear that the dual-slope switching technology reduced the EMI in the 400-MHz range by 10 dBµV/m.

**Figure 3. TPS61161's EMI measurements with traditional switch and dual-slope switch**

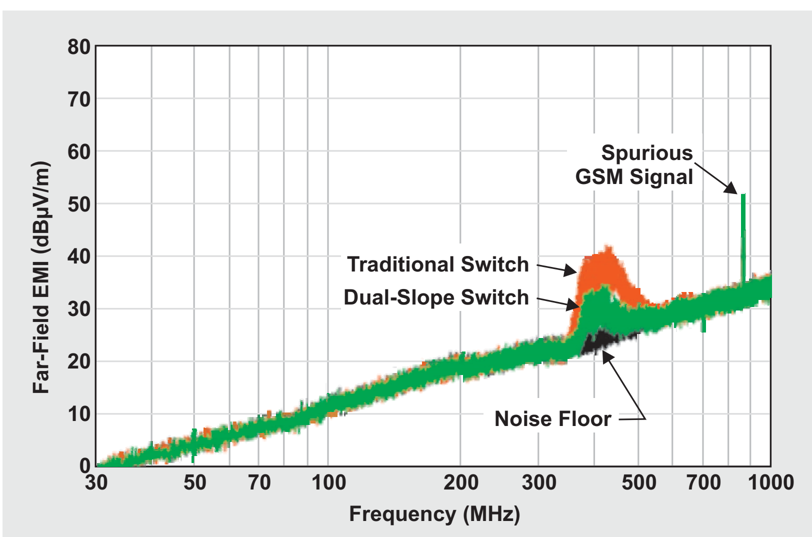
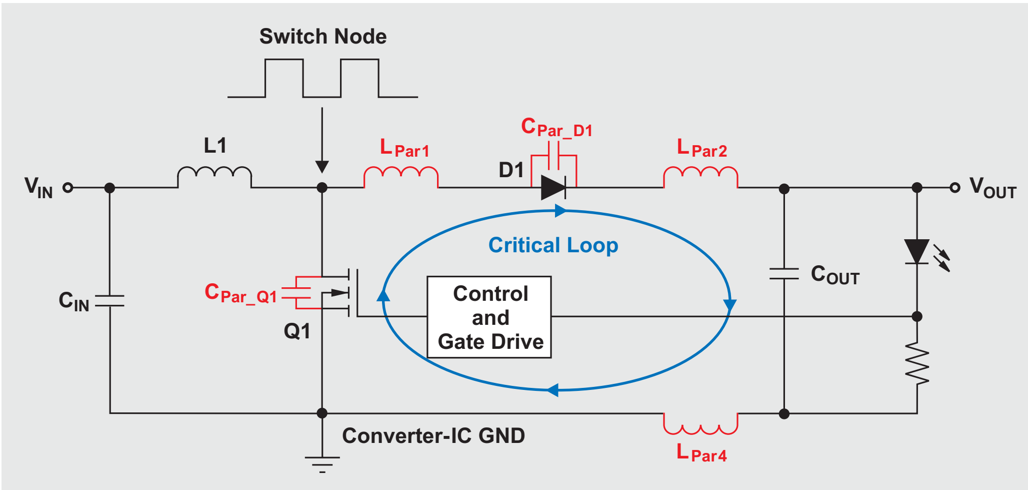


Figure 4. Schematic of boost-converter-based WLED driver




At lower frequencies, the parasitic inductance and capacitance of the PCB's traces and planes are the primary contributors to EMI. Figure 4 shows the schematic for a boost-converter-based WLED driver. The loop created by the parasitic capacitance of Q1 and D1 and the parasitic inductance of the board traces conducts current when switches D1 and Q1 turn on and off. When switch Q1 turns off, inductor L1 is fully charged and ready to continue the current flow. Since the only available element through which current can continue to flow is D1, the inductor voltage quickly switches from GND to $V_{OUT}$, which causes ringing due to the parasitics. The resonance point of the parasitic inductance and capacitance can sometimes be seen on the oscilloscope as ringing at the resonant frequency. In addition to the parasitic capacitance of Q1 and D1, ground planes and the traces over/under them also contribute to parasitic capacitance. A commonly overlooked type of parasitic capacitance is that formed by the switch node—with its large dv/dt—and the ground plane underneath. Figure 5 shows a poor PCB layout that uses the TPS61161, where L1 is the inductor, D1 is the diode, U1 is the TPS61161 controller, C1 is the input capacitor, and C3 and C4 are the output capacitors. The critical loop, highlighted in blue, is long; and there is a large ground plane underneath the large pad for L1 that serves as the high-speed switch node (not shown).

Figure 5. Poor PCB layout with TPS61161

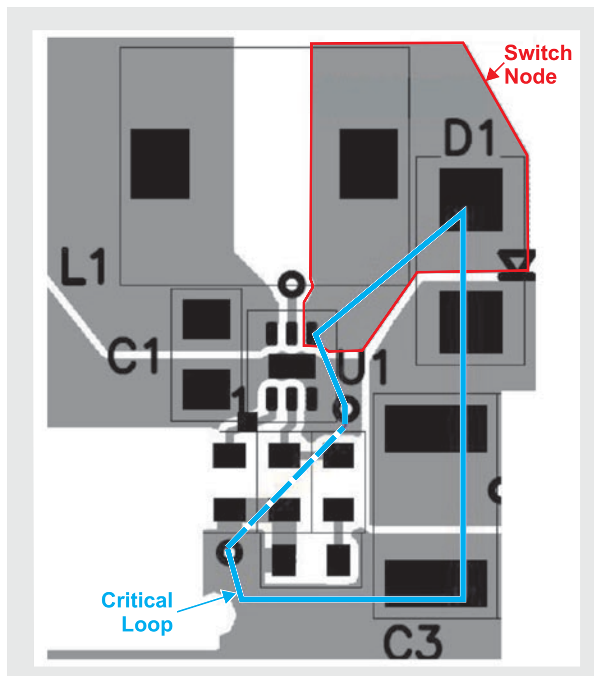


**Figure 6. Improved PCB layout with TPS61161**

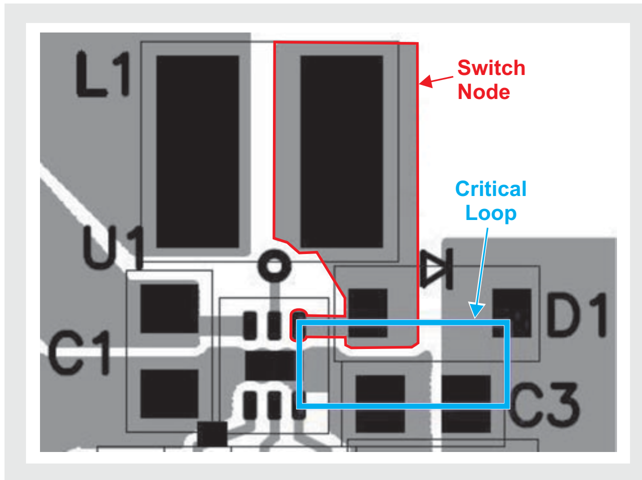



Figure 6 shows the TPS61161 evaluation module with the same components as in Figure 5 but with a smaller switch node, no ground plane underneath, and more compact part placement to reduce the length of the critical loop (shown in blue).

Figure 7 shows the near-field EMI measurements from two battery-powered test boards, one with poor layout and the other with improved layout. The tests were conducted under identical conditions with the same inductor and the TPS61161 (final silicon). Clearly, an improved board layout that minimizes parasitic board capacitance and inductance reduces EMI across multiple frequencies.

A switching converter's EMI cannot be completely eliminated. However, with careful IC and passive-component selection as well as good board-layout techniques, EMI can be reduced to acceptable levels.

## Reference

For more information related to this article, you can download an Acrobat® Reader® file at www-s.ti.com/sc/techlit/*litnumber* and replace "*litnumber*" with the **TI Lit. #** for the materials listed below.

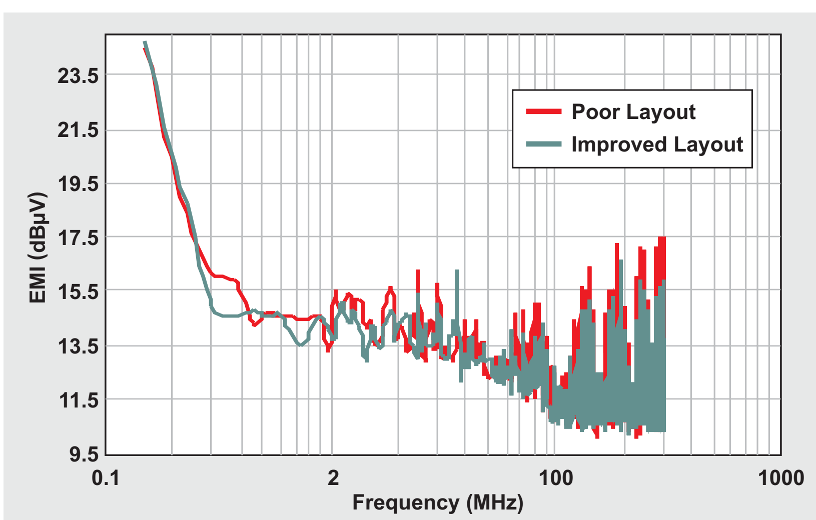
| **Document Title** | **TI Lit. #** |
|---|---|
| 1. "White LED Driver With Digital and PWM Brightness Control in 2mm × 2mm QFN Package for up to 10 LEDs in Series," TPS61160/61 Data Sheet. . . . . . . . . . . . . . . . . . . | slvs791 |

## Related Web sites

**power.ti.com**

**www.ti.com/sc/device/TPS61161**

**Figure 7. TPS61161's EMI measurements with poor and improved layouts**



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