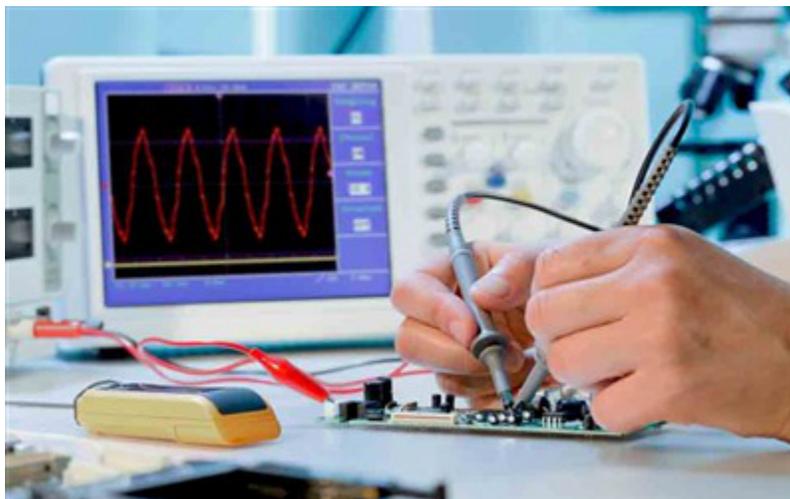


# Powering up the Performance of Sensitive Test and Measurement Systems



George Chen



When creating high-performance test and measurement equipment, the last thing on your mind is what is powering the board. It may be hard to believe, but the power supply can have a **drastic** impact on the performance of high-precision successive-approximation-register (SAR) analog-to-digital converters (ADCs) that are downstream to the power supply. Using an electromagnetic interference (EMI)-optimized power supply can be tremendously valuable for a number of different applications, including data-acquisition systems, semiconductor test equipment, spectrum analyzers and oscilloscopes.

By using a DC/DC switching buck converter optimized for EMI performance instead of a standard buck converter, you can achieve an improvement of as much as 2dB and 12dB for the signal-to-noise ratio (SNR) and spurious-free dynamic range (SFDR), respectively. For the analysis, I used two 20-bit SAR ADC ([ADS8900B](#)) channels, the [THS4551](#) fully differential amplifier and the [LM53635](#) EMI-optimized 36V buck converter followed by the [TPS7A30](#) low-dropout regulator (LDO); see [the Multi-Rail Power Reference Design for Eliminating EMI Effects in High Performance DAQ Systems](#).

There are three key developments in the LM53635 buck converter that lead to its excellent EMI performance:

- HotRod™ packaging.
- Symmetrical pinout enabling concentric current loops for the input capacitors.
- Spread-spectrum feature.

The LM53635 uses HotRod packaging, which is TI's implementation of a flip-chip on-lead (FCOL) frame device. Instead of having a bond wire connecting the die to the lead frame, the die is flipped over and directly soldered to the lead frame; see [Figure 1](#) and [Figure 2](#). Removing the bond wire reduces the amount of parasitic inductance, which is a source of high-frequency noise that is difficult to filter out. Another benefit of HotRod packaging technology is that it reduces the drain-source on-resistance ( $R_{DS(on)}$ ) of the device, which actually improves device efficiency.

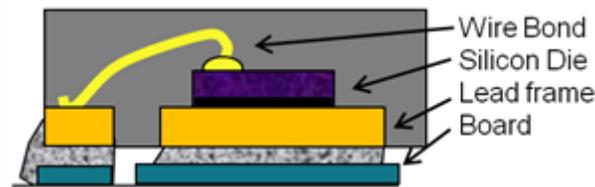


Figure 1. Standard Wire-bond Quad Flat No-lead (QFN) Device

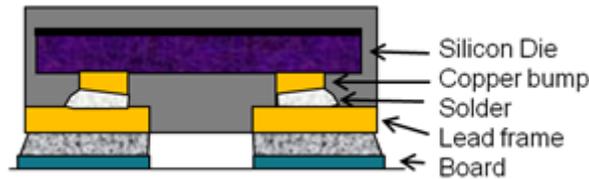


Figure 2. HotRod FCOL QFN Device

Figure 3 shows the immediate benefit of the HotRod package in the switch node of the LM53635 buck converter.

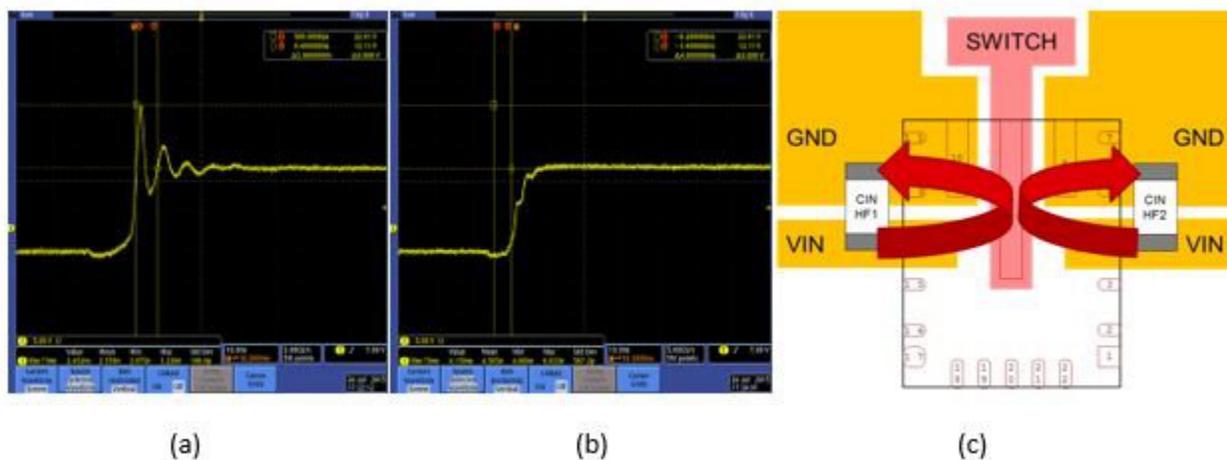
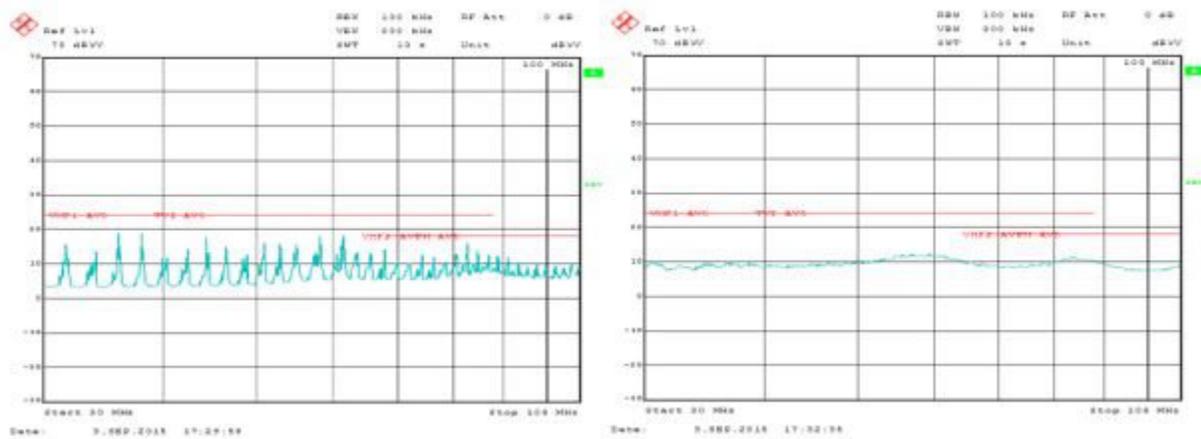


Figure 3. Switch node of standard buck converter with bond wire (a); switch node of the EMI-optimized LM53635 with HotRod packaging (b); symmetrical  $V_{IN}$ /ground planes provide an EMI-optimized pinout for the LM53635 (c)

While HotRod packaging improves EMI performance, another optimization is in the pinout of the device. The  $V_{IN}$ /ground planes of the LM53635 are designed to be symmetrical, which enables you to place input capacitors in parallel and thus reduce the size of the input current loops. Putting this parasitic inductance in parallel also reduces ringing and helps mitigate high-frequency EMI.

Another great feature of the LM53635 is the spread-spectrum feature, which enhances EMI performance by dithering the frequency  $\pm 3\%$  to help reduce the fundamental energy peaks. The spread-spectrum feature can reduce high-frequency peak emissions by up to 6dB and slightly less than 1dB at lower frequencies. With a  $36V_{IN}$  maximum operating voltage, the LM53635 is optimized for systems up to  $18V_{IN}$  and can efficiently convert that voltage down to  $3.3V_{OUT}$  at 2.1MHz. When the voltage exceeds 18V, the device will smoothly fold the frequency back from 2.1MHz.

Another device, the [LMS3655](#), is a 400kHz version of the LM53635 and can efficiently convert a  $24V_{IN}$  down to  $1V_{OUT}$  without any frequency fold-back, since there will be no minimum on-time violations while switching at 400kHz. While the LM53635 offers a smaller solution in inductor and total solution size due to its 2.1MHz frequency, the LMS3655 is optimized for efficiency – with a peak efficiency of 96% with a  $12V_{IN}$  to  $5V_{OUT}$  conversion. Both the LM53635 and LMS3655 share the EMI performance-optimizing features.



**Figure 4. High-frequency-conducted EMI Results (30-108MHz) without Spread Spectrum (Left) and with Spread Spectrum (Right). the Red Lines Superimposed on the Graph Denote Limits from the Stringent Comité International Spécial Des Perturbations Radioélectriques (CISPR) 25 Class 5 Standard, with 28dB Limits from 30-54MHz and 18dB Limits from 70-108MHz.**

TI tested the LM53635 in the exact same configuration as a similar buck converter not as optimized for EMI with a 24V input, with the output connected to the same LDOs, and tested the performance of the ADCs. [The Performance of the LM53635 vs. a non-EMI Optimized Switching Buck Regulator in the Exact Same Configuration](#) and [Figure 6](#) and [Figure 7](#) show the impact of the optimizations in the LM53635.

3.8V buck position	Voltage source	ADC channel	SNR	Signal-to-noise and distortion (SINAD) ratio	Total harmonic distortion (THD)	SFDR	Effective number of bits (ENOB)
Position 1	Normal switching regulator	Differential	98.86dB	98.84dB	-123.4dB	112.66dB	16.13
Position 1	LM53635	Differential	100.13dB	100.11dB	-123.06dB	126.48dB	16.34

**Figure 5. The Performance of the LM53635 vs. a non-EMI Optimized Switching Buck Regulator in the Exact Same Configuration**

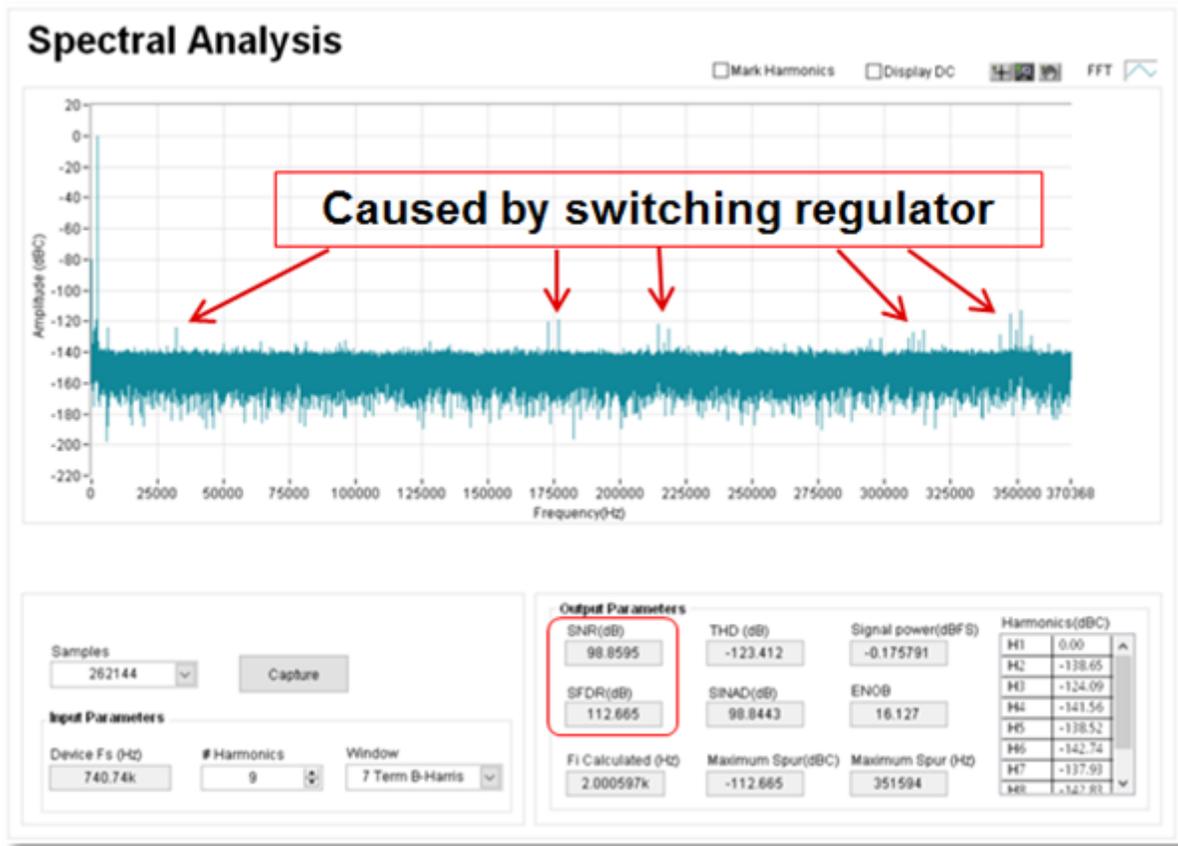
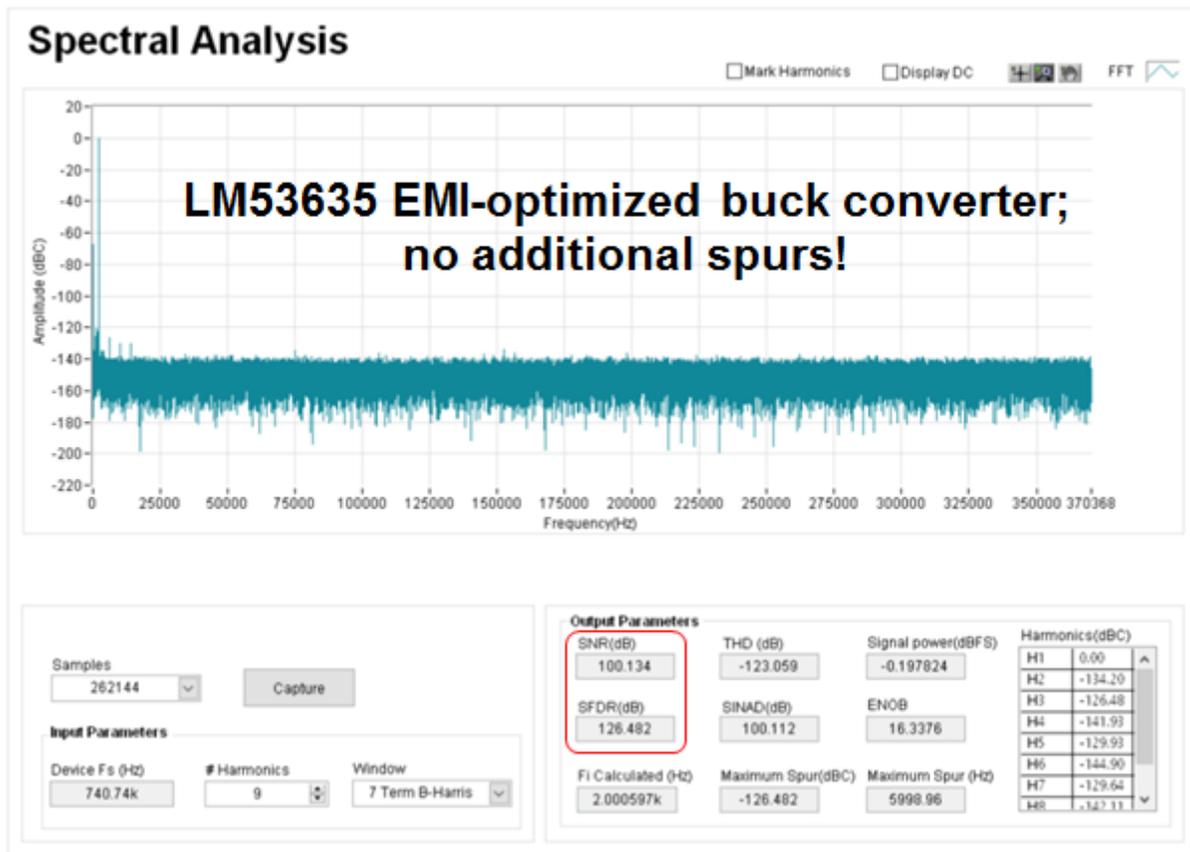


Figure 6. Spectral Analysis of a non-EMI Optimized Buck Converter, Showing a Number of Spurs Spiking Out



**Figure 7. The LM53635 EMI-optimized Buck Converter with No Additional Spurs (unlike Figure 6)**

You can easily see the performance enhancements of using the LM53635 buck converter for a high-precision application. Using this EMI-optimized device results in a +1dB gain in SNR and a +13dB gain in SFDR vs. a similar buck converter not optimized for EMI. While the power tree is not generally an area that most designers spend a lot of time on, choosing the right switching regulator can have a huge impact on the overall sensitivity of a system.

#### Additional Resources

- Watch the video, [“Designing Low-EMI Power Converters for Industrial and Automotive Systems.”](#)
- Check out the [Reference Design Optimizing FPGA Utilization and Data Throughput for Automatic Test Equipment.](#)
- [Demonstrate optimized density](#) and integration for your test equipment with our reference design

## 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