Tektronix

Tektronix RSA306 Spectrum Analyzer with DPX Gives TransSiP Breakthrough Insight into Power Conversion Switching Noise

Customer Solution Summary

CHALLENGE

TransSiP's Desmond Wong needed to investigate supply bias noise associated with a pulse-frequency modulated (PFM) DC-DC converter as part of a wireless IoT chipset for a major semiconductor company. Conventional analytical methods were unable to display the weak and transient signals involved, presenting a significant challenge in determining the root cause.

SOLUTION

In order to capture and analyze short time varying transient events, TransSiP turned to a Tektronix RSA306 USB-based spectrum analyzer with DPX real-time analysis provided by SignalVu-PC.

BENEFITS

Using the Tektronix solution, TransSiP was able to detect and confirm, for the first time, the presence of switching noise jitter (SNJ) in switching mode power supply bias noise and its significance. This led to development of TransSiP's JC-PFM and Harmony devices: circuit topologies that condition the noise signature of DC-DC power converters, providing potentially significant gains in efficiency and battery life for low-power devices.

Improving DC-DC power conversion efficiency

Based in Irvine, Calif, TransSiP has developed a new approach to noise reduction and switching noise jitter (SNJ) conditioning in switched-mode DC-DC power conversion that provides an alternative to existing methods and brings advances in battery life, transceiver range, and overall system performance to remote, portable, wearable, Internet of Things (IoT), and other power-constrained devices such as sensors.

TransSiP's JC-PFM micro DC-DC converter and Harmony SNJ Conditioner shown in Fig. 1 incorporate TransSiP's patent-pending jitter conditioning technique. This breakthrough was made possible by a combination of the capabilities of a Tektronix RSA306 spectrum analyzer and the intuition and determined research effort of the company's founder and CEO, Desmond Wong.

Wong is a recognized pioneer in the field of 3D system-in-package heterogeneous integration for complex RF devices, involving embedding of both active and passive components in an organic polymer substrate. TransSiP uses the term "organic fab" to describe this combination of silicon, polymer substrate, and passive components to improve performance, including use of parasitics normally regarded as unwanted circuit elements. During previous work on wireless IoT and GPS systems, Wong observed anomalies in system behavior linked to the power supply: something was interfering with the downstream circuit's ability to maintain optimum system performance under boundary or limiting conditions. However, the test and measurement tools he had on hand at the time were unable to provide strong and clear enough indications of the root cause.

The phenomenon surfaced again in conjunction with a consulting project Wong took on in mid-2015 to investigate supply bias noise associated with a switched-mode pulse-frequency modulated (PFM) type DC-DC converter for a wireless IoT device. Although PFM DC-DC converters provide the highest conversion efficiencies of any DC-DC technology across the range of load profiles commonly used in power-constrained portable and wearable applications, they also produce a chaotic noise signature on the supply bias that can cause problems for noise-sensitive circuitry. Because of this, most designers opt for less-efficient linear regulators ("low drop out" or "LDO") and, where circuitry could meet minimal or regulatory requirements, PWM (pulse width modulated) or dual mode PFM/PWM regulators/converters. If the noise problems of PFM DC-DC conversion could be solved, a whole new generation of IoT/portable/wearable devices would benefit from significantly improved battery life and enhanced user experience without compromising maximum wireless and system performance.

A new noise component

As the project moved forward, Wong followed the accepted industry methodology of spectral noise density and other noise amplitude analysis using a spectrum analyzer and oscilloscope to evaluate power supply switching noise. There are several types of noise associated with PFM DC-DC converters that are well-defined and documented:

- Output voltage ripple
- Harmonics of switching frequency/frequencies
- Ringing (due to parasitics)
- Spurious or transient events

> “We would not be where we are today without the insights made possible by the RSA306."
>
> Desmond Wong, CEO TransSiP

Since these are well known, they can easily be filtered and suppressed. However, in this case Wong noticed that at a certain point fine-tuning the attenuation circuitry stopped yielding an improvement. Some noise was still getting through, but what was the source and how could it be characterized? “When the ripples or noise in the supply bias came down to a certain level, noise amplitude was no longer the dominant factor- there was something left behind that was still having a significant impact,” Wong relates.

Drawing from his RF experience, Wong decided he would attempt to use a real-time spectrum analyzer to more accurately visualize the noise he was seeing. This led him to a local Tektronix seminar on the newly introduced RSA306 USB spectrum analyzer. Impressed by the combination of desktop-level performance, advanced SignalVu-PC software and affordability, Wong moved forward and acquired an early production unit. The software upgradable vector signal analysis features of the RSA306 are ideal for small companies and startups on limited budgets with limited bench space.

The use of the RSA306 proved to be a pivotal breakthrough. SignalVu-PC software provides a DPX display that uses color coding to show the intensity of signals, similar to analog digital phosphor displays. SignalVu-PC also includes a powerful spectrogram display that enables the user to observe even the smallest frequency aberrations over time. These display technologies enabled TransSiP to capture and clearly see, for the first time, very short, varying interval transient and spurious events associated with a time domain component in supply bias noise using the setup shown in Fig. 2. The component, which TransSiP has termed “switching noise jitter” or “SNJ,” is a major contributor to the chaotic noise signatures that compromise powered system performance.

While the DPX display enabled TransSiP to see something previously undetectable in the chaotic noise signature associated with supply bias output from PFM DC-DC converters, the origins of the events were not self-evident. With the right tool in hand, Wong then spent the next six months investigating and developing methods for “conditioning” SNJ and modifying the SNJ signature to reduce the chaotic noise element. This effort included capture and analysis of SNJ from varying circuit topologies and correlation of these observations with actual performance testing over intervals ranging from 24 hours to up to 3 to 4 days. He substantiated observed system behavior through mathematical modeling of the relationships between output ripple and feedback voltage to validate the presence of SNJ.

This effort in turn led to systematic refinement of circuit topology and the development of TransSiP’s JC™ SNJ conditioning technology. Both DPX observations and field testing of downstream circuit performance demonstrate that TransSiP’s combination of JC technology with a PFM DC-DC converter provides a quality of supply bias equal if not superior to the LDO regulators used in nearly all power-constrained portable, wearable, and remote electronics today. The technology was first shown at the 2016 APEC show in Long Beach, Calif (Fig. 3), following submission of a patent application and publication of a research paper.

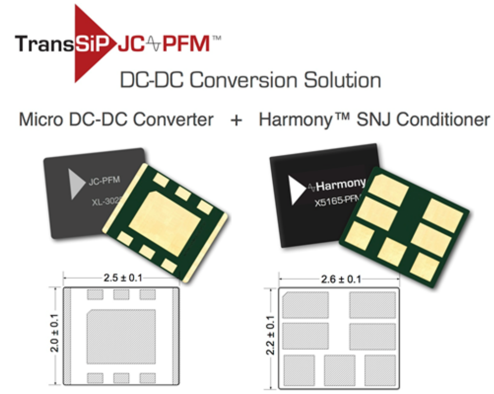

Figure 1. TransSiP JC-PFM chipset.

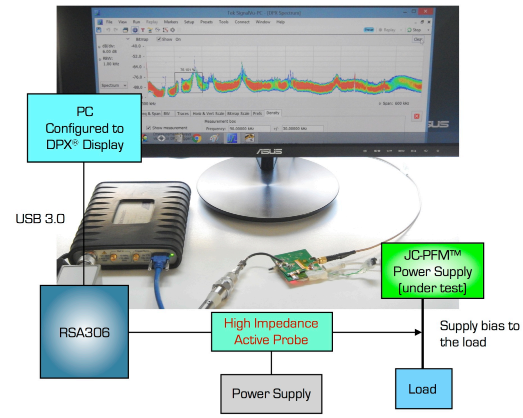

Figure 2. TransSiP analytical setup.

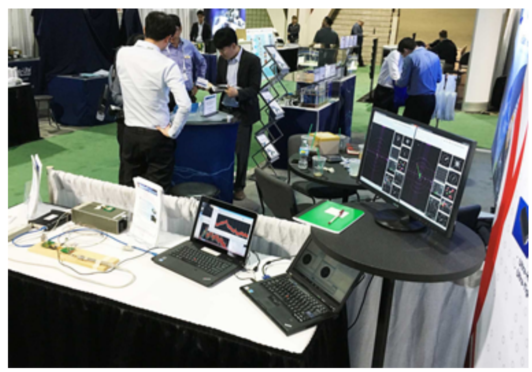

Figure 3. Real-time JC-PFM powered GPS performance demo at APEC 2016 in Long Beach, Calif.

Breakthrough efficiency

LDO regulators are used to power noise-sensitive circuitry today because the resistive nature of linear regulation generates supply bias noise levels adequate to satisfy system performance requirements. The problem with this in devices that spend a lot of time in low-power modes is that conversion efficiency is directly proportional to the ratio between input and output current and voltage. Therefore, at the standby power levels where all power-constrained products spend most of their life, conversion efficiencies may be as low as 5%. Switching-mode DC-DC converters have much higher efficiencies, with PFM types running between 80 to 95% across the full range of system power requirements. But the chaotic noise on the supply bias means these aren't suitable for the noise-sensitive circuitry at the heart of remote, portable/wearable and IoT devices, including most spread-spectrum wireless communications, navigation, and positioning applications.

TransSiP's JC technology is set to change all that. The DPX plots in Figure 4 show that TransSiP's JC "conditions" the noise signature of PFM converters, not only enabling their use in noise-sensitive applications, but also providing demonstrable performance equal or superior to LDO regulators. This means improved user experience thanks to, for example, less dropout due to body mass interference in wearables, improved stability and range of wireless links, and what appear to be as much as 5X increases in battery life.

The "Real McCoy"

TransSiP's previous work with GPS/GNSS systems has shown that supply bias fidelity can be directly observed in the form of position drift and time-to-first-fix (TTFF). With extensive experience in GPS/GNSS microsystem and system-in-package (SiP) design, TransSiP chose this function as the test vehicle for validation of the reduced/conditioned SNJ signature shown on the DPX display.

Over three thousand hours of testing at limiting conditions (minimum detectable satellite signal) generated the results shown in Figure 5. These field tests demonstrate that TransSiP's JC-PFM™ topology gives equivalent if not better performance than conventional LDO regulators used in commercial GPS/GNSS systems in terms of both position drift and TTFF.

State of play

Currently TransSiP is involved in the design and buildout of JC-PFM and Harmony evaluation boards which are needed to verify performance characteristics of variations in component placement, layout, structure, and wiring.

"The RS306 and SignalVu-PC combination give us real-time feedback on the impact of these variables on SNJ, and will continue to be an integral part of our development process. We would not be where we are today without the insights made possible by the RSA306," said Wong.

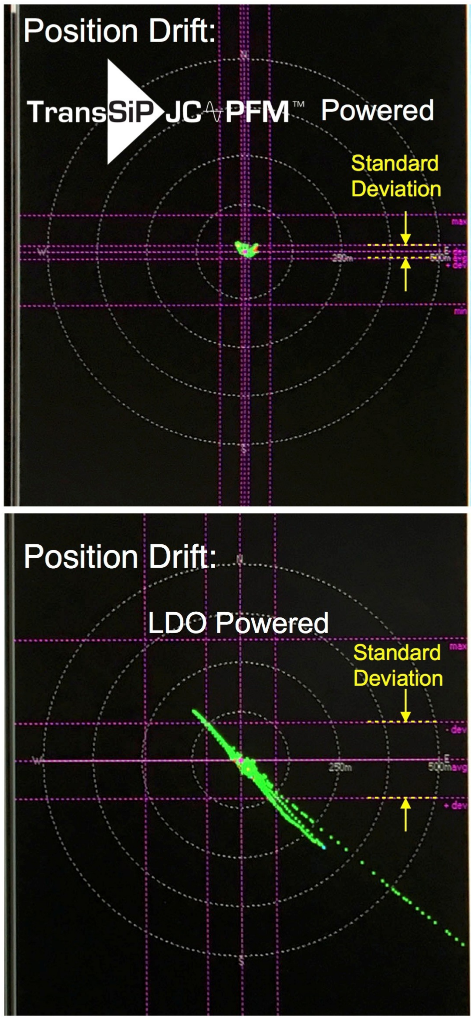

Figure 5. Real-time performance results, JC-PFM vs. LDO supply.

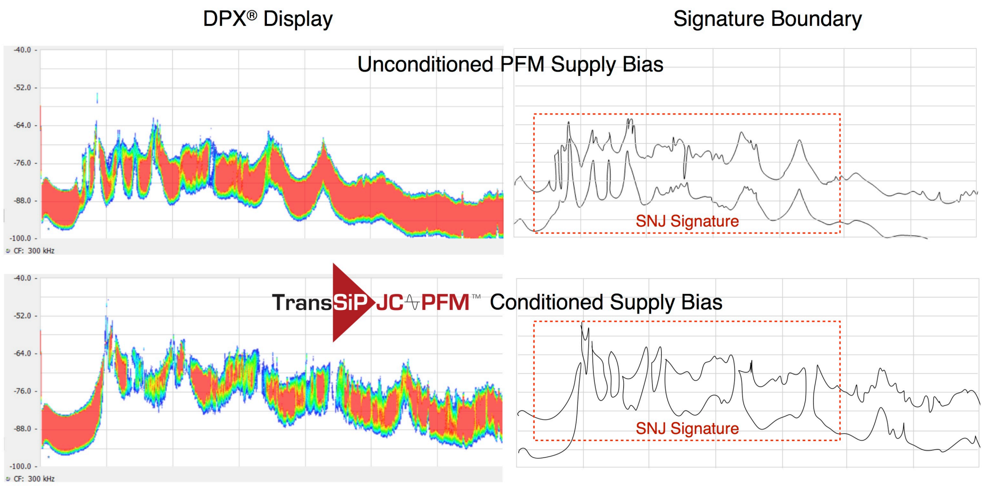

Figure 4. DPX displays for Unconditioned and Conditioned Supply Bias

For Further Information

Tektronix maintains a comprehensive, constantly expanding collection of application notes, technical briefs and other resources to help engineers working on the cutting edge of technology. Please visit **www.tektronix.com**

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