Troubleshooting EMI in Embedded Designs

White Paper

Abstract

Today, engineers need reliable information fast, and to ensure compliance with regulations for electromagnetic compatibility in the most economical way later in the design, appropriate measures must be taken early in the design phase.

This paper provides a brief introduction to embedded EMI debugging / troubleshooting challenges and how to use a digital oscilloscope to debug the two key culprits of EMI – switching power supplies and power amplifiers.

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ROHDE&SCHWARZ

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1 The Challenge

Increased competition, more dense designs and integration of different technologies in a small space combined with market regulatory pressures are creating new challenges for original equipment manufacturers. As a result, implementing the necessary transient immunity protections to prevent application malfunction due to transients on power and signal lines is becoming ever more challenging.

The impact of increasing microcontroller (MCU) sensitivity and low-cost application design is being felt in all markets: consumer, industrial, automotive, etc. While there are significant differences in the design and use of products for these markets, the susceptibilities induced in all microcontroller-based applications are essentially the same. Typical susceptibilities include unexpected state changes on input pins (reset, interrupt request, or general purpose inputs) and corruption of on-chip clock signals, which can all cause various operational issues on the design itself, in addition to resulting in failure to meet regional compliance regulations for electromagnetic compatibility (EMC).

2 Digital, Analog and RF Analysis Without Compromise

Understanding the complex behavior in embedded RF designs has often required complex test setups and careful calibration. Now the RTO series of oscilloscopes are available to provide time correlated measurements across the embedded design, simplifying the most complex multi-domain challenges.

The problem with using a typical mixed-signal or mixed-domain oscilloscope in troubleshooting embedded designs is that these oscilloscopes are not fundamentally good scopes! They display data in multiple domains but they often lack simultaneous high sample rates, fast waveform update rates, stable triggers and deep memory, which are all basic requirements for successful troubleshooting . The limitations all combined make the task for design engineers more cumbersome, struggling to capture the data and ensuring it is accurate. The R&S®RTO is the only oscilloscope to offer mixed-signal analysis while maintaining incredible performance – digital, analog and RF (multiple domain) analysis without compromise.

Historically, another limitation on using oscilloscopes for spectrum analysis has been the noise floor and limited dynamic range of FFT displays due to nonlinear Analog-to-Digital (A/D) converters resulting in reduced Effective Number of Bits (ENOB). Designed by Rohde and Schwarz and implemented within the R&S®RTO is a unique single core A/D converter which eliminates artifacts caused by interleaving and therefore allows for significantly improved noise and dynamic range.

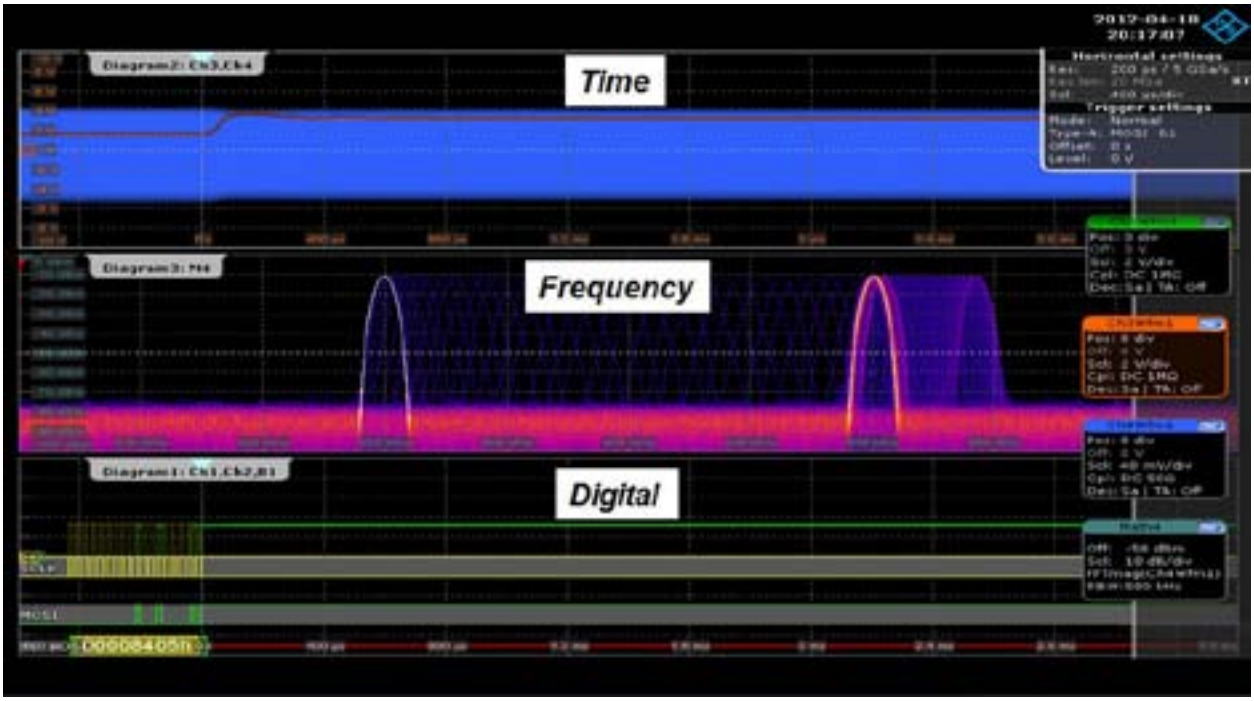

Figure 1 Revealing unintentional EMI radiators requires fast update rates in order to visualize the real-time multi-domain spectrum. The RTO series oscilloscope with its 10Gs/sec per channel delivers up to 1 million waveforms per second.

3 Revealing Your Device's Radiated Behavior

EMC/EMI problems can be classified mainly as current-related or voltage-related. Current-related issues are usually associated with differential mode situations and radiates primarily in the H, or magnetic, field. Voltage problems are normally associated with common mode and detected most strongly in the E field.

Rohde & Schwarz offers a family of near-field E and H field probes (or "sniffer" probes, Figure 2) which can be used to diagnose the cause of an electromagnetic interference problem. Sniffer probes help isolate where there are issues on the board for further investigation. They can tell you if the source impedance is most likely high or low, making the selection of the R&S®RTO probe easier. A primarily H field or magnetic field indicates a lower source impedance whereas a predominately E field radiator indicates the impedance is higher (and thus a higher impedance probe should be used). Near field probe results can point in the right direction for a remedy.

One challenge in using near field probes has traditionally been measurement dynamic range, easy to use FFT and full BW and resolution at low voltage gain settings. The R&S®RTO oscilloscope offers a unique 1mV/div gain setting; most digital oscilloscopes use digital zoom to get 1mv/div, since this actually is a gain stage of the R&S®RTO oscilloscope amplifier, it allows for very low noise floor at this setting.

Figure 2 Rohde & Schwarz offers a family of near-field E and H field probes (or "sniffer" probes R&S®HZ15) which can be used to diagnose the cause of an electromagnetic interference problem.

4 Power Supplies: Shockingly Problematic

One of the most common reasons for EMC problems with microcontroller products is that the power supply is not good enough. Correct and sufficient decoupling of power lines is crucial for stable microcontroller behavior, and for minimizing the emitted noise from the device.

Looking at the datasheet for a typical microcontroller, one may believe that selection of a power supply is not critical. The device has a very wide voltage range, and draws only a few milliamps of supply current. But as with all digital circuits, the supply current is an average value, but in real value depends on the speed of the transitions. The current is drawn in very short spikes on the clock edges, and if I/O lines are switching, the spikes will be even higher. The current pulses on the power supply lines can be several hundred milliamps if all of the I/O lines of an I/O port change value at the same time. If the I/O lines are not loaded, the pulse will only be a few nanoseconds, making it even more challenging to detect without a high sample rate oscilloscope, such as the R&S®RTO which samples at 10Gs/sec per channel, delivering up to 1 million waveforms per second even with all 4 channels enabled.

The R&S®RTO oscilloscope also offers the unique feature of correlated multiple gated FFT measurements, which allows simultaneous viewing of multiple spectrums. The ability to apply multiple gated FFTs to the captured waveform makes it possible to easily monitor the radiated RF spectrum simultaneously at different time periods as a result of the power supply switching. (Figure 3) Not just one, fixed-length FFT window, but up to four, fully-configurable ones!

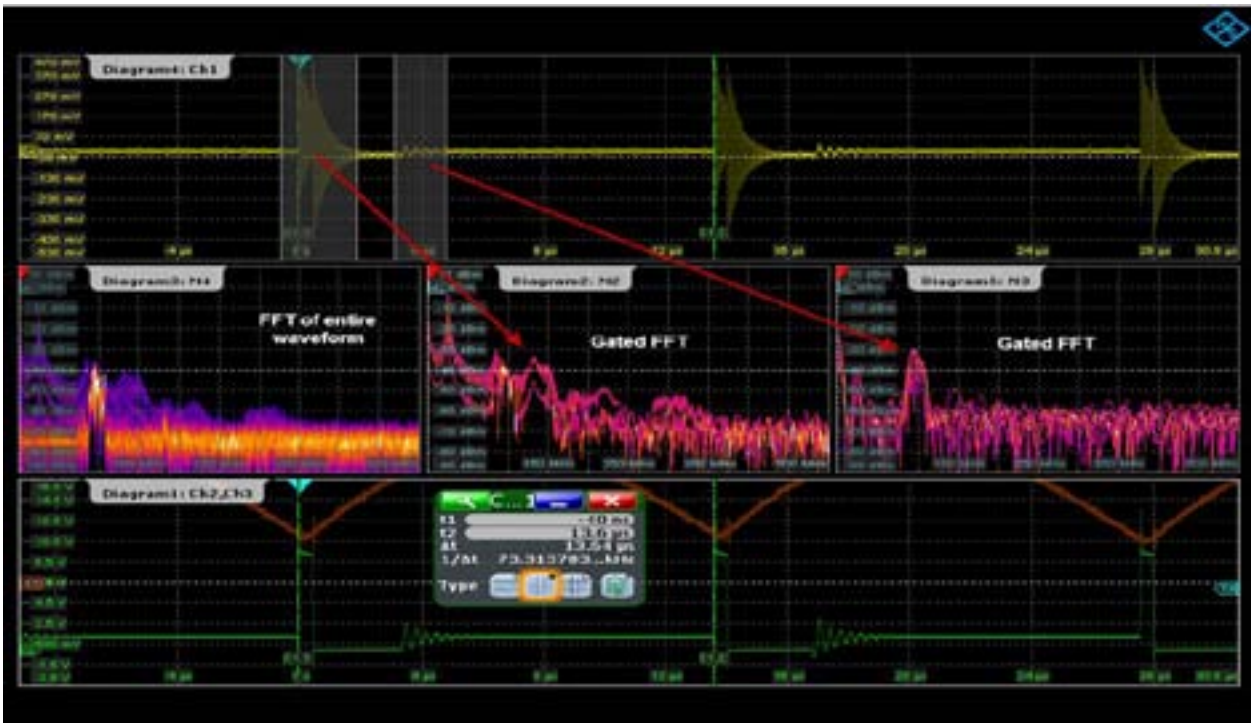

Figure 3 Observing the FFT of a full waveform as well as a gated FFT in one view makes it possible to monitor the radiated RF spectrum simultaneously at different time periods as a result of the power supply switching

5 Power Amplifiers: Amplifying the Issues

Today, even though many wireless radios are implemented as a single IC or "System-on-Chip" (SoC), they still require an external power amplifier (PA) to achieve the desired transmit power. PA's and improper filtering, or lack thereof, are another common cause of wireless designs failing to meet EMC compliance certification.

One of the key PA parameters to troubleshoot is the ramp-up and ramp-down characteristics of the amplifier. (Figure 4) The ramp-up will normally include a fast rise in RF power during the open-loop gain and then some adjustment steps as it enters closed loop gain. The best approach for testing this is to use the PA ramp control voltage as the trigger on one channel and monitor the RF power on another channel. There is also the option to monitor the digital control messaging on the two wire bus if desired.

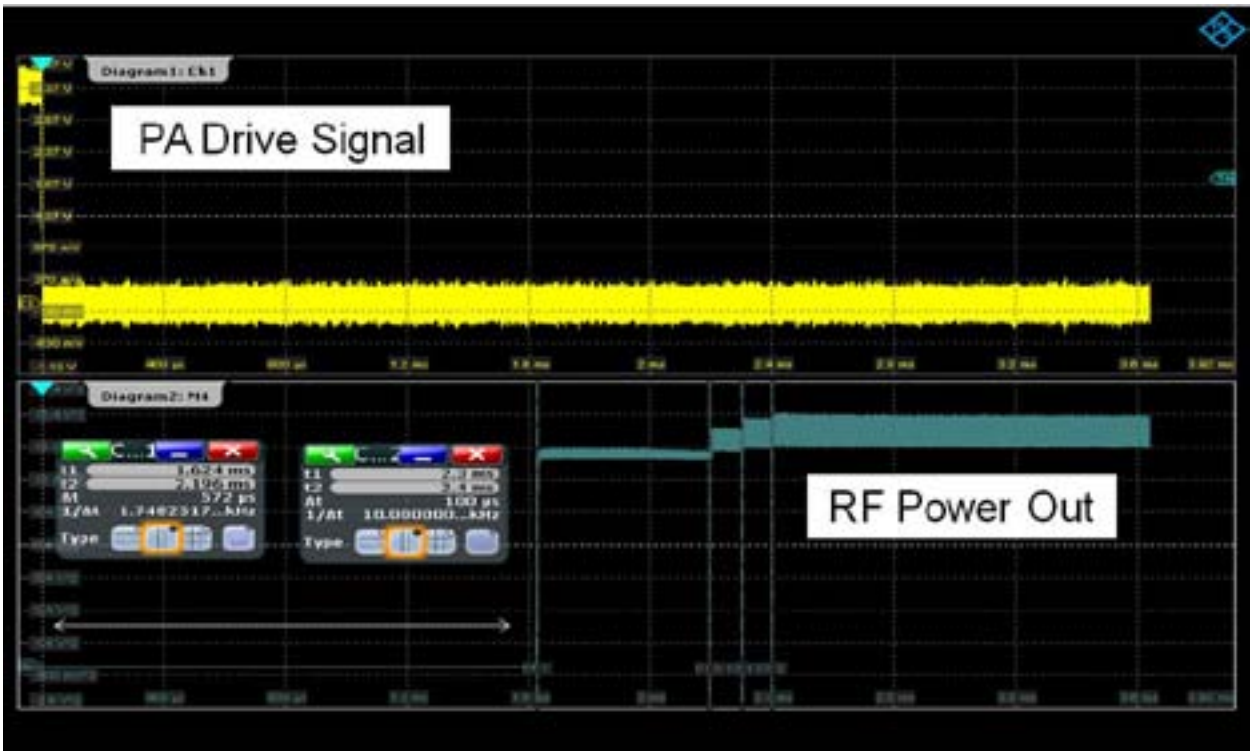

Figure 4 The power-on and ramp-up characteristics are easily measured with the R&S®RTO . Here we see that there is just over a 1.6ms delay after PA ramp voltage before the RF turns on. The open loop lasts for 572us (Δt C1.1 – C1.2) and two closed-loop steps lasting 100us.

The RF ramp-down behavior of a PA is an issue which often introduces challenges for engineers attempting to get embedded wireless radio designs to pass the ETSI regulatory compliance specification. The R&S®RTO allows you to monitor the control voltage to ensure that a turn off condition is not occurring before the PA has completed a smooth power-down. If this were to occur it would be equivalent to an impulse response of a sharp rise time – meaning spurs and/or a wider spectral width would be generated. There is in fact some delay after RF power-down before it goes high (turning off PA drive current) – this is the correct behavior.

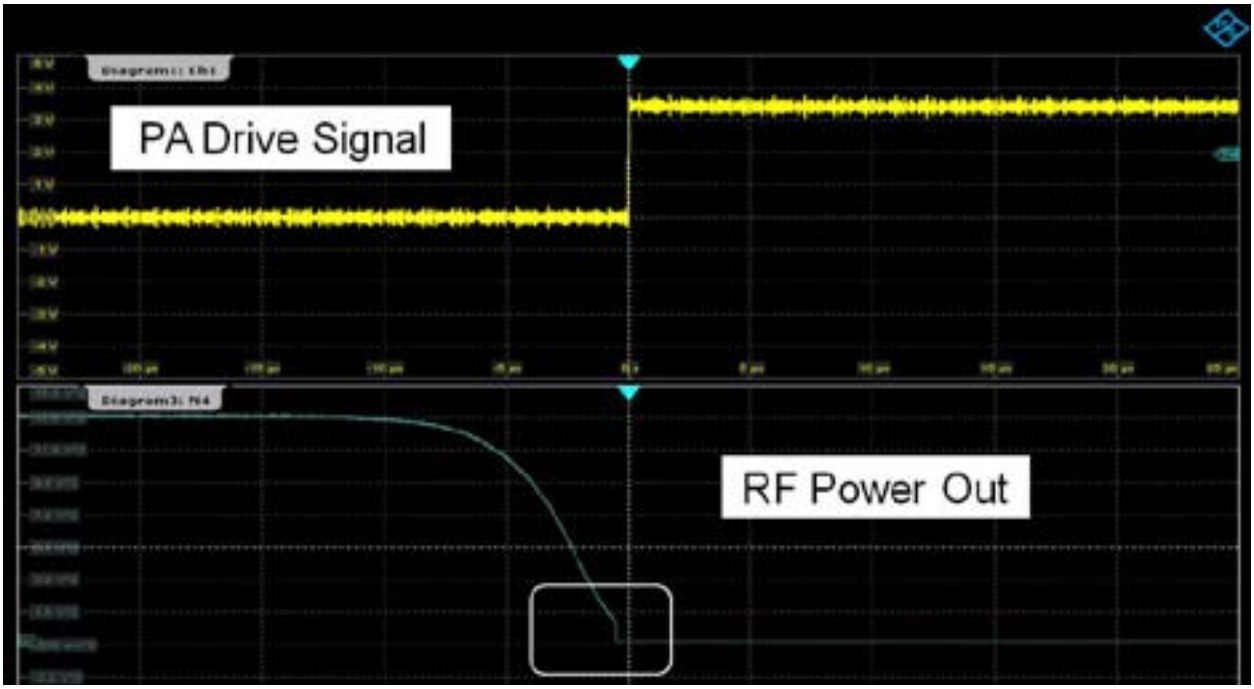

Figure 5 This ramp-down measurement example shows a sudden droop just before turn-off, which can be the equivalent to an impulse response of a sharp rise time.

Summary

This paper provided a brief introduction to EMI troubleshooting challenges in embedded designs, and how an R&S®RTO digital oscilloscope can be used to troubleshoot two common sources of EMI problems - switching power supplies and power amplifiers. To learn more about using the R&S®RTO to troubleshoot your EMI challenges, please visit rohde-schwarz-scopes.com for more detailed information, or visit rohde-schwarz-scopes.com/contact to find a Rohde & Schwarz expert near you.

About Rohde & Schwarz

Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radiomonitoring and radiolocation, as well as secure communications.

Established more than 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

- Environmental commitment
- Energy-efficient products
- Continuous improvement in environmental sustainability
- ISO 14001-certified environmental management system

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