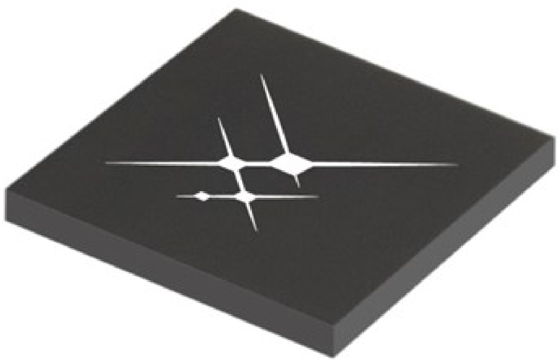
November 14, 2014

Selecting DC-DC Step-Down Voltage Regulators For WiFi RF Power Amplifier Applications



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Wireless local area network (WLAN) radio frequency (RF) links have been integrated into almost all facets of portable and mobile products today. Operating in 802.11ac requires greater RF power amplifier (PA) linearity compared to legacy 802.11a/b/g/n systems which, in many cases, has reduced the RF PA input supply voltage range while drawing more input current with increased power dissipation demands.

New 802.11ac RF PAs often pose a challenge to portable product designers, because the RF PA input supply range is no longer compatible with direct connection to a Li-Ion/poly battery supply voltage range. This means that a voltage regulator must now be employed. Performance for an 802.11ac RF PA can be affected by the voltage regulator operation, but regulator integration can be simplified if the designer knows which key performance characteristics to evaluate in a DC-DC step-down voltage regulator. An additional benefit of a DC-DC switching voltage regulator is reduced system power dissipation, which reduces the WLAN circuit thermal footprint and saves power drawn from the battery source supply. Many very small footprint DC-DC voltage regulators are available today to fit the need of the 802.11ac WiFi PA application.

The current generation of 802.11ac RF PAs for use in mobile applications typically has optimized RF performance over a 2.9 V to 3.6 V range. At the same time, typical Li-Ion/poly batteries have an operating range of 4.3 V to 2.7 V, but most systems cut off the battery around 3.4 V. This sets an ideal situation to use a fixed voltage DC-DC voltage regulator with the output of 3.3 V. When the battery is at the maximum-to-average voltage levels of 4.2 V to 3.7 V, the RF PA load current can be reduced by a high efficiency DC-DC switching voltage conversion. Typically, a good DC-DC regulator will have efficiencies greater than 90 percent. At a battery supply level of 4.0 V, the PA current drawn from the battery is reduced by 20 mA, and the system power added efficiency is improved (Figures 1 and 2).

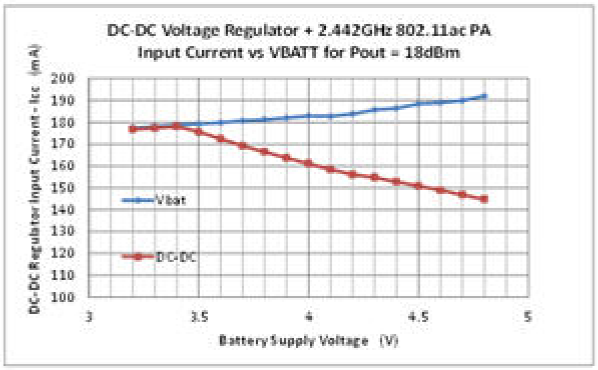

Figure 1: Supply current versus battery voltage for an 18 dBm transmit power level

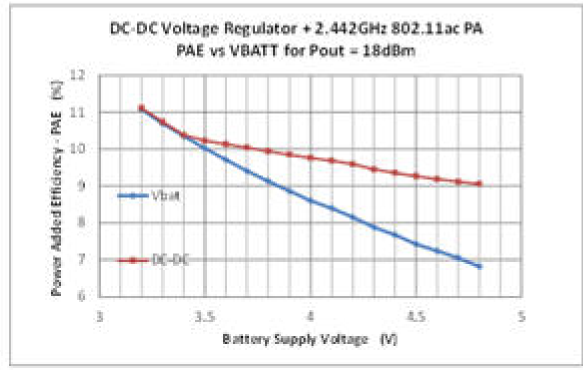

Figure 2: Corresponding power added efficiency versus battery voltage for an 18 dBm transmit power level

An added side benefit to using a DC-DC voltage regulator with high power conversion efficiency is that it can reduce the overall system power dissipation and, more importantly, the system thermal footprint when an RF PA is placed under adverse high VSWR operating conditions. When the PA input supply voltage is stepped down from the input battery, the current is reduced as outlined in Figure 1. When the RF PA is placed under an extreme 10:1 VSWR output mismatch condition, the input current increases to maintain the output power level. The increased power dissipation is released in the form of heat. Figures 3 and 4 show a 7.4° C reduction in RF PA case temperature by stepping the PA input supply voltage down to 3.3 V from 4.0 V.

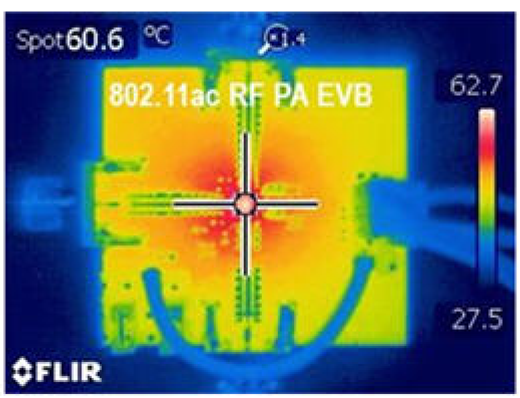

Figure 3: 802.11ac RF PA temperature under a 10:1 VSWR mismatch for an 18 dBm output power level. PA is directly connected to a VBATT source supply at 4.0 V, and the PA case temperature is 60.6° C.

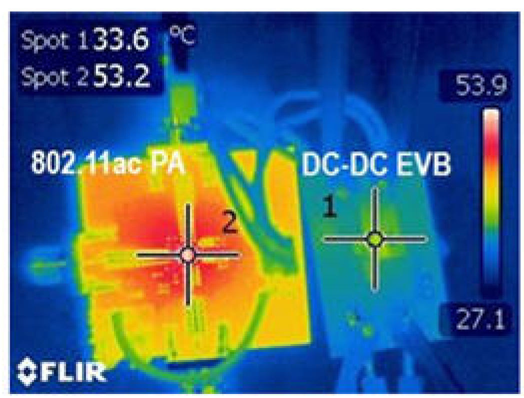

Figure 4: 802.11ac RF PA temperature under a 10:1 VSWR mismatch for an 18 dBm output power level. PA is powered from a DC-DC regulator at 3.3 V with the input supply at 4.0 V, and the PA case temperature is reduced to 53.2° C.

Applications in 802.11ac typically enable the RF PA for the duration of WiFi operation with a fixed output power level. Modulated data burst is applied to the PA, taking it from a stand-by load condition to a maximum load condition in a very short period of time. A DC-DC voltage regulator must have a very fast load transient response characteristic to maintain the output voltage regulator in less than 20 µs. If the regulator takes longer than 20 µs for the output voltage to settle after a large load step is applied, the supply voltage to the RF PA will sag at the beginning of transition and will compromise the dynamic error vector magnitude (DEVM) of the transmit signal. For the example shown in Figures 5 and 6, an 802.11ac RF PA idles near no-load conditions and steps up to 170 mA with the applied modulation. The DC-DC voltage regulator output voltage is able to settle in 12.4 µs, allowing the RF PA to achieve a DEVM of 1.78 percent, which is acceptable for most systems.

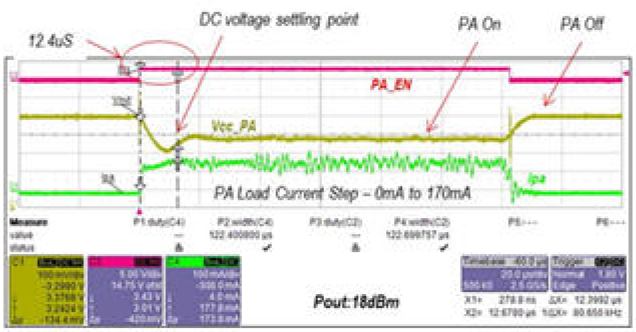

Figure 5: DC-DC voltage regulator load transient response corresponding to a 0 to 170 mA RF PA load step for an 802.11ac transition measured for an RF PA output at 18dBm

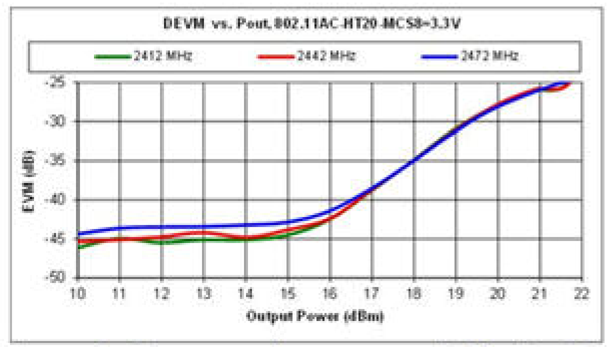

Figure 6: Corresponding measured 802.11ac RF PA DEVM plot. DEVM level of -35 dB at 18 dBm equates to a DEVM = 1.78 percent.

When discussing the use of a DC-DC switching regulator in RF applications, regulator output switching noise or ripple-created PWM or PFM switch mode control is often a concern. Most small and compact DC-DC step-down switching regulators use a base switching frequency in the range of 2 MHz to 6 MHz to enable them to use the smallest possible external components (inductor, input, and output capacitors). The switching noise or ripple from these regulators usually falls within the modulated bandwidth of the WiFi transmit signal. The end effect of ripple, if too high, would be decreased Error Vector Magnitude (EVM) performance and increased spurious response for the transmit carrier. For this reason, a low noise DC-DC switching regulator should be used. An example of a good low noise performance DC-DC switching regulator would be the SKY87003. This device replaces a conventional low-side synchronous switch with a low noise rectifier circuit that greatly reduces output switching ripple and subsequent harmonics.

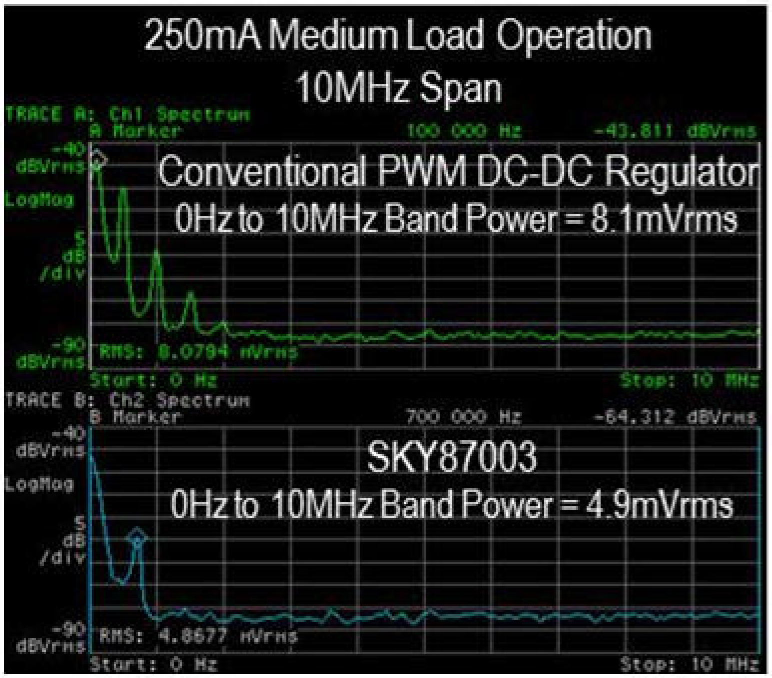

Figure 7: DC-DC switching converter output noise spectrum (0 to 10 MHz) for a conventional PWM switch mode regulator and a specialized low noise DC-DC switching regulator

For mobile applications, one final attribute to consider when selecting a DC-DC voltage regulator for an 802.11ac RF PA is performance under drop-out conditions. DC-DC regulator drop-out is defined by the point where the output can no longer maintain output regulation from the input supply. The 802.11ac RF PA in a mobile application is prone to this condition. Since the DC-DC regulator is typically set for a fixed 3.3 V output and the input supply from the battery supply can drop to 3.4 V or 3.3 V before it is cut off, the system can run into a drop-out state. Because of this, it is imperative to select a DC-DC step-down regulator that is capable of 100 percent duty-cycle operation and has the ability to transition in and out of drop-out conditions smoothly. Some regulators have increased instability and ripple as they approach 100 percent duty-cycle operation, which will lead to adverse RF PA signal integrity in the form of decreased EVM and ACLR performance.

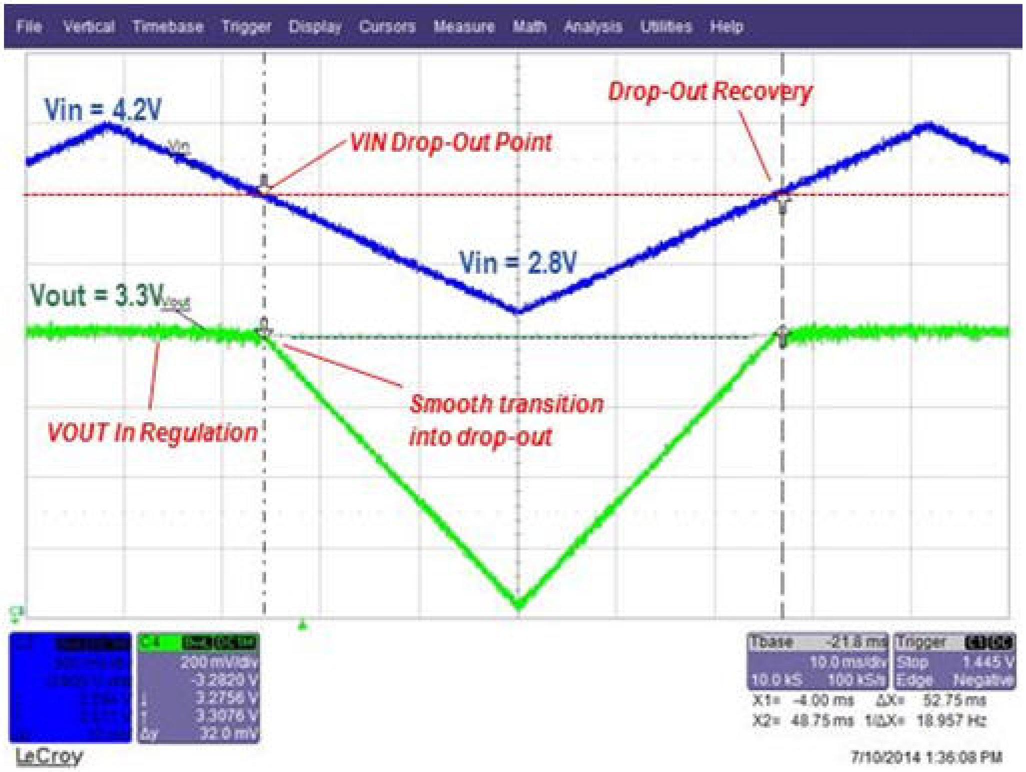

Figure 8: Good 100 percent duty cycle operation for DC-DC voltage regulator. This device enters and recovers from an input drop-out condition while maintaining stability and minimum output ripple or noise.

Adding a DC-DC step-down switching regulator to an 802.11ac RF PA application in a portable product does not need to add risk or complexity to the system design if the selected regulator can provide a few key performance characteristics. When selecting a DC-DC step-down regulator, the device should have the following characteristics:

- High power conversion efficiency
  - Typically better than 90 percent
- High switching frequency for minimum external components sizing
  - 2 MHz to 6 MHz range
- Very fast load transient response to achieve good DEVM performance
  - <20 µ for a no-load or light load to full load current step
- Specialized for low noise and output switching ripple performance
  - 20 mVpp or less
- Clean, 100 percent duty-cycle operation to cover low battery voltage drop-out conditions

The addition of a DC-DC switch mode step-down power conversion device allows an 802.11ac RF PA to operate over the wide input supply voltage range of a mobile device battery supply. At the same time, the regulator aids to reduce current consumed from the battery and extends the system life between charge cycles. Reduced current and subsequent power dissipation reduces the thermal footprint of the PA under adverse operating conditions.