Microwave DAC simplifies direct digital synthesis from DC to 26.5 GHz covering X-, Ku-, and K-bands

A technical article from e2v

This short article describes the latest ultra-wideband (UWB), microwave capable DAC from e2v showing how it extends direct conversion capabilities all the way into the K-band and brings with it significant SWaP benefits and system design simplification.

Introduction

Until recently, it was rather unusual to find a data converter that claimed viable operation in Nyquist zones beyond the first two 'baseband' zones. In fact, it's so unusual that many engineers may not even be aware of the potential benefits that derive from such a capability. That's easy to explain, as most traditional, high speed CMOS designs are limited to bandwidths of a few gigahertz. This is fine for use in a wide variety of RF designs, but it certainly limits the use of such converters in the microwave domain. Ultra-wideband system design has therefore been driven to adopt complex multi-channel approaches with multiple local oscillators, mixers and converters operating in 'parallel' to cover the broadband range.

Fast Facts: EV12DS460 Specifications

- World's first K-band DAC
- 12-bit resolution
  - 6 Gsps guaranteed sampling rate
- 7.5 GHz -3dB bandwidth
  - Signal synthesis up to 12 GHz (X-band)
  - K-band (26.5 GHz) signal synthesis at reduced output power
  - 30 ps step response time
- High spectral purity – 58 dBc SFDR @5940 MHz (RF mode)
- >44 dB NPR in first Nyquist zone (NRTZ mode), 8.8 bits equivalent
- Low latency, 1 ns at 6 GHz
- Selectable output modes enable output waveform shaping & optimization

Radio technology has transitioned from complex analog, super-heterodyne designs into software defined, highly flexible digital architectures. For many RF engineers who have grown up experiencing this transformation, there's a pent-up demand to see a similar development at microwave frequencies. We are entering a period when software defined microwave systems (SDMS) are fast becoming a reality. Their development is spawning new applications, creating new system price points.

The twin advantages of deploying a different process and architectural design choice

e2v, a specialist purveyor of high speed data converters has eschewed the CMOS design paradigm, preferring instead to take the path less well trodden. Their philosophy exploits the speed advantages of a silicon-germanium bipolar process sourced from Infineon (the 200 GHz B7HF200 process) and widely used for standalone microwave components. With iterative design advancements over the last few years, e2v can now rightly claim to be facilitating some truly extraordinary system developments.

Noteworthy of e2v's design approach, is the deliberate use of a single core, calibration free architecture rather than the widely used, interleaved approach beloved of many CMOS designs. This choice gives e2v a natural performance edge, delivering enhanced spectral performance (e.g. high SFDR), especially when the device is subjected to a varying thermal environment. Interleaved designs require recalibration when there's a significant thermal shift. Furthermore, the markets served by e2v often demand low-latency processing for data throughput. Here the single core is a key advantage as it delivers a minimum output latency of 3 clock cycles. Most interleaved designs struggle to keep latency below 12 cycles. On the downside, the single core requires a slightly larger die area, translating into a modestly higher chip manufacturing cost.

EV12DS460 Extends dynamic performance

In 2015, the company announced the launch of the EV12DS400. This 12-bit device guaranteed a 4.5 Gsps sample rate that permitted the synthesis of an instantaneous 2.25 GHz bandwidth, whilst also being able to maintain a 3 dB full power bandwidth up to 7 GHz.

In e2v's latest 12-bit DAC iteration, the EV12DS460 extends the analog bandwidth a step further. Guaranteed sample rate is increased by 1500 MHz up to 6 Gsps enabling a 3 GHz wide synthesized bandwidth. The -3 dB full power analog bandwidth now tops out at 7.5 GHz. Additionally, the EV12DS460 achieves usable output power at 12 GHz (in the X-band) and can even achieve 39 dBc spurious free dynamic range in the K-band at twice that frequency (Figures 1 & 2).

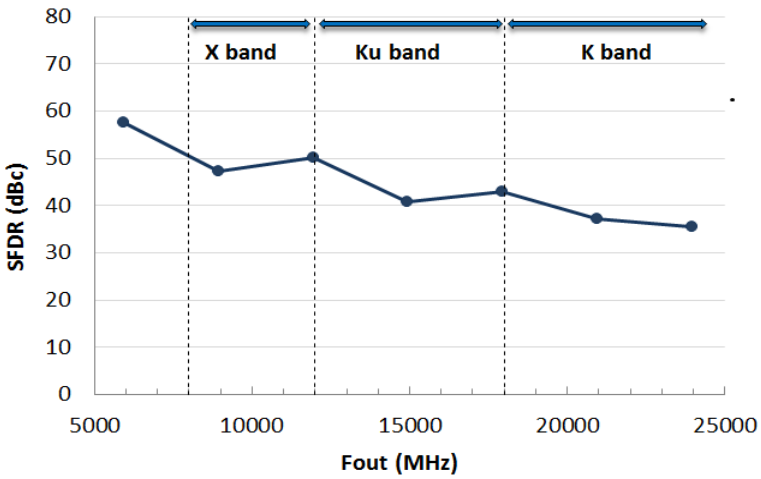

Figure 1 Broadband SFDR of the EV12DS460

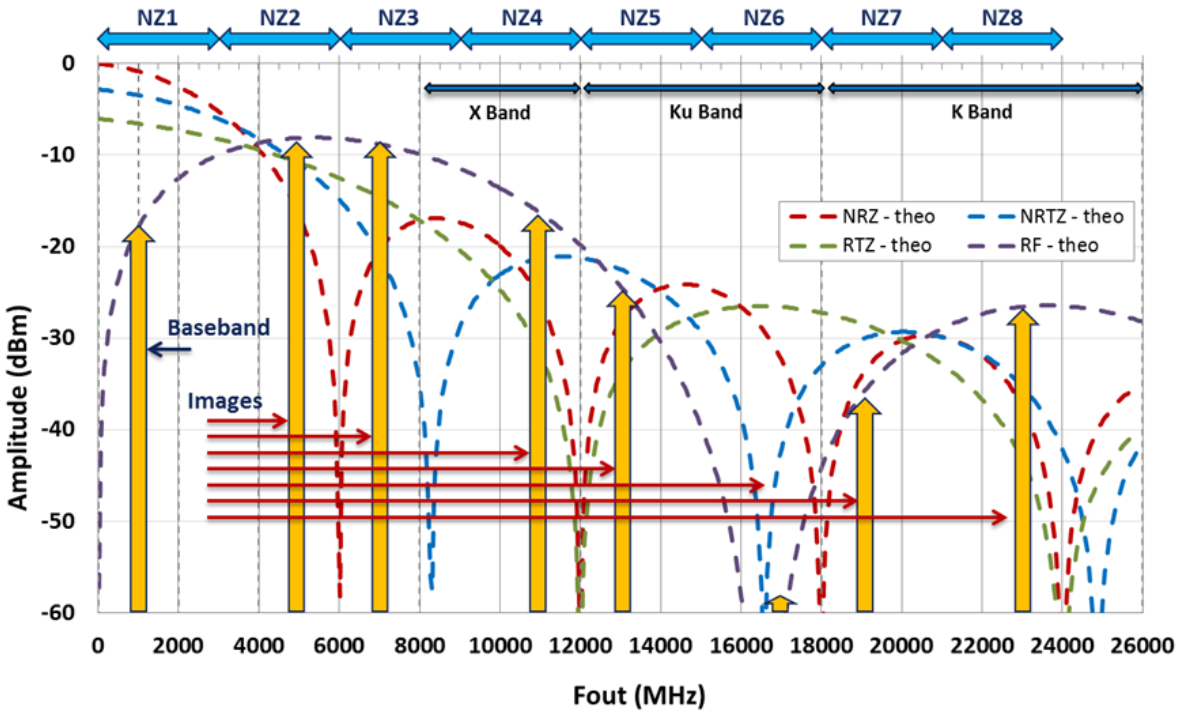

Figure 2 EV12DS460 noise power extends beyond 8th Nyquist zone (fs =6 Gsps)

Signal aliasing can transform microwave system design

The mathematics that emerges from Nyquist-Shannon sampling theory shows that alias signals from sampled data systems appear in frequency zones of width fs/2 out to infinity, where fs is the sampling rate. Figure 2 shows the seven alias images of a 400 MHz test signal across the first eight Nyquist zones when output from the EV12DS460 sampling at a rate of 6 Gsps.

The dotted blue curve depicts the classic sinc(x) response typical of a DAC using a standard Non-Return to Zero (NRZ) coding. Here, an output null appears at the sample frequency (6 GHz). The baseband signal

at 1000 MHz is present in the first Nyquist zone but an aliased image also appears at 5.0 GHz (NZ2). Repeated alias images are clearly visible in the third Nyquist zone and beyond.

Applying bandpass filtering to the DAC's output spectrum thus provides the means to project synthetic analog signals into the microwave domain without resorting to expensive analog mixers and local oscillators. The application of this direct conversion technology brings about distinct benefits over traditional approaches called out in the summary box.

Benefits of Direct Conversion

- Operating diversity –digitally generated variable modulation schemes and frequencies are easily accommodated
- Fast switching between frequencies enables high rate, frequency hopping
- A single DAC to encode multi-channel systems provides simplification and savings in board space, weight and power (SWaP)
- Performing digital in-phase and quadrature (IQ) modulation eliminates gain and phase sensitivities seen in analog IQ modulators

Tailored spectrum with pulse shaping

As in previous UWB DACs from e2v, four output operating modes that give designers the flexibility to tailor the DAC's dynamic performance to targeted output frequencies are offered. These modes affect how the output data is coded. Doing so, signal spurs can be suppressed and settling time effects of the DAC can be mitigated for improved waveform performance. A detailed description of these controls is available[1], but the characteristic curves shown in figure 3 illustrate the impact on power spectrum of output pulse shaping. This data covers the frequency spectrum across four discrete Nyquist zones indicated, out to 12 GHz (fs = 6 Gsps).

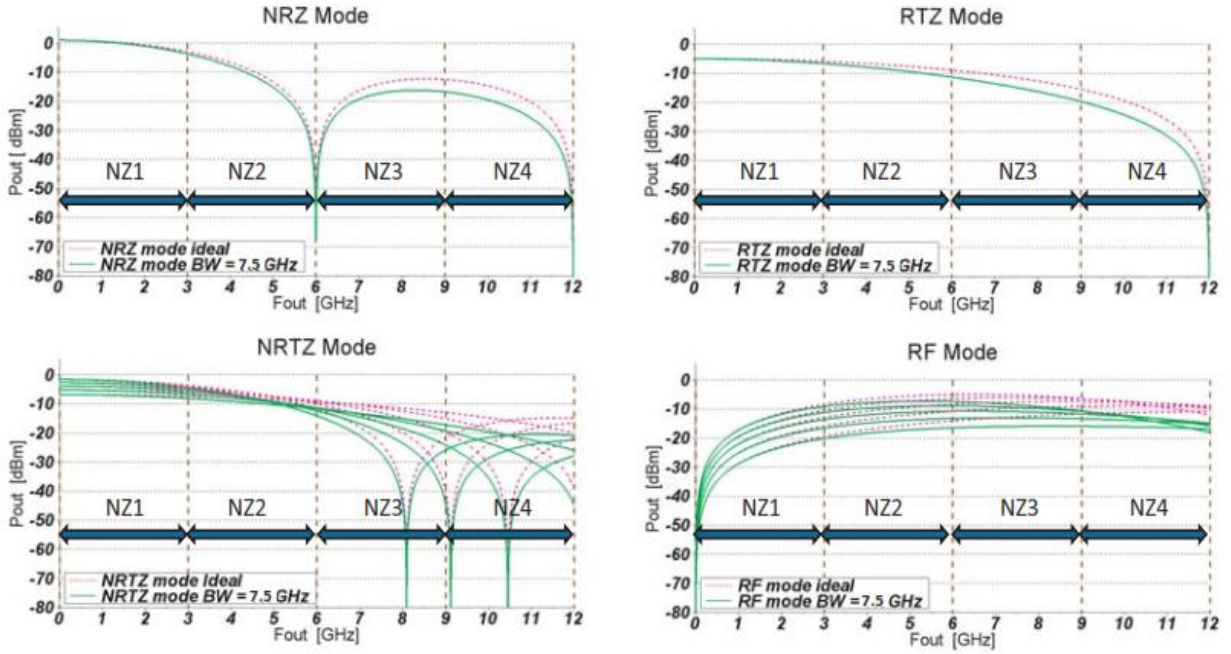

Figure 3 Effect on DAC output power spectrum of the four pulse shaping modes of EV12DS460 (at 6 Gsps)

[1] Microwave DAC promises direct digital synthesis from DC to 7GHz and beyond, a white paper from e2v.

Typical UWB DAC Applications

- Radar/Lidar system design and testing, where waveform agility is desirable
- Electronic warfare systems where both a wide instantaneous bandwidth and output bandwidth improves operational effectiveness
- Wireless base stations, particularly for microwave backhaul links where system simplification is desirable
- RF signal and Arbitrary Waveform Generation (AWG) for system testing
- Implementing advanced, complex digital modulation schemes (e.g. for DOCSIS cable modems & gigabit radio)

Applications for UWB DACs

The list of applications given here range from the exotic to the mundane. Sometimes the most desirable attribute is the frequency reach of the DAC. However, there are digital testing roles where the device's step response is what counts.

In the case of military radar, frequency agility is extremely useful in improving threat assessment and detection in noisy environments or those where stealth technologies are being used. On the other hand, UWB techniques are hugely influential where space and weight constraints dominate system design decisions such as typified by space-born, broadband communication payloads.

Advancing microwave design for nearly 70 years

With the release of the EV12DS460 DAC coupled to its long-standing commitment to innovation, e2v is creating an environment where microwave engineers can reap significant SWaP benefits in their designs. Moreover, e2v is helping shape the future of microwave technologies, maintaining a company tradition that extends back almost 70 years.

For more specific product information check out the following link:

http://www.e2v.com/products/semiconductors/dac/ev12ds460/