Digital-to-analog converters (DACs) for high-performance communications

The generation of multiple carriers in UMTS, CDMA, and GSM systems mandates the use of DACs that provide the highest levels of dynamic performance. DACs for these applications must allow high operating frequencies and must supply superior SFDR, IMD, SNR, and ACPR performance. Also, the power amplifiers used in some of these applications benefit from DACs that correct power-amplifier nonlinearity through digital predistortion techniques. Finally, high-speed, high-dynamic-performance DACs are useful in communication systems that employ higher orders of quadrature amplitude modulation (QAM) as well as in applications that use direct digital synthesis (DDS).

Superior information bandwidths—required to support the exchange of digital information in modern communications systems—are achieved through a variety of modulation and encoding schemes. Such schemes demand greater dynamic performance in the transmitter's signal-processing chain. Applications such as UMTS, cdma2000™, and GSM/EDGE also call for greater dynamic performance as they approach the requirement of multicarrier generation from a single, signal-generating source.

UMTS requires up to four carriers per transmitter. For GSM/EDGE and cdma2000 applications, four to eight carriers may be desired for a single transmitter. The generation of multiple carriers requires substantially more dynamic range in the signal path. As the generator of this complex modulation waveform, the DAC has become the performance-limiting element in the signal path.

UMTS base stations are now introducing multicarrier signal generation. These base stations, therefore, require DACs that meet the UMTS standard with adequate margins. Also helpful in this application are DACs that correct power-amplifier nonlinearity by introducing digital predistortion to the signal. That characteristic alone can increase the DAC's required signal bandwidth by a factor of three to five. Thus, the signal bandwidth necessary for four UMTS carriers (as high as 100MHz) demands higher sample rates and higher analog-output frequencies. The 500Msps update rate of the MAX5888 is designed for such applications. This device delivers the performance defined above and surpasses the UMTS specifications for up to four UMTS carriers.

The accuracy and signal bandwidths of such DACs also support communications systems that employ higher orders of QAM. Modulations up to QAM256 require wider dynamic ranges to accurately generate these modulated waveforms.

Transmit waveforms in GSM/EDGE systems demand even more dynamic performance from the DAC. The generation of multicarrier signals pushes SFDR, IMD, and SNR values to extremes. For those demanding applications, the MAX5195 offers the highest SFDR, SNR, and IMD specifications in the industry. Generating instrumentation signals in DDS applications also requires DACs with exceptional dynamic performance; both the MAX588X family (MAX5886/MAX5887/MAX5888) and MAX5195 are well suited for that application.

Advantages of the MAX588X family and the MAX5195

DACs of the MAX588X family offer excellent dynamic performance at low levels of power dissipation with a maximum industry-leading sample rate of 500Msps. For a 50MHz output frequency and 400Msps sample rate, MAX5888 SFDR exceeds 67dBc. Also excellent is the SNR (-155dB/Hz) and 2-tone IMD (-72dBc) at output frequencies of 80MHz. That performance is achieved at a 500Msps sampling rate, from a single 3.3V power supply, and with low power dissipation (235mW).

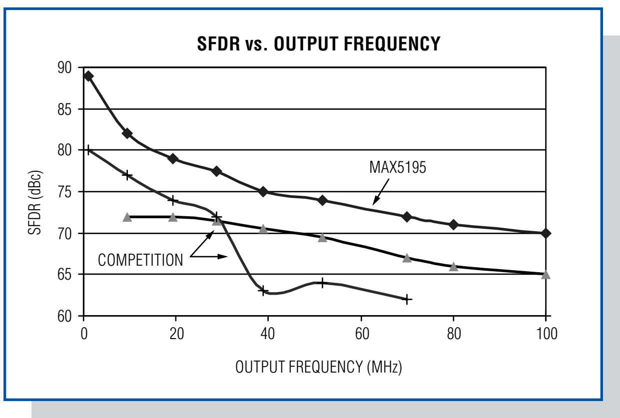

Figure 1. This SFDR graph compares the MAX5195 to the best available competitive devices for a range of output frequencies.

cdma2000 is a registered certification mark of Telecommunications Industy Association.

Digital data is applied through an LVDS interface, which has two beneficial attributes: an LVDS-based logic family supports 500Msps data rates very effectively, and the digital signals' differential-input swings help to reduce system-level noise at the digital interface. Such considerations are important when designing wide-dynamic-range systems.

The dynamic performance of the MAX588X family is exceeded only by that of the new MAX5195, seen in **Figure 1**, which surpasses that of any other device on the market. Besides exemplary SFDR performance, its SNR leads the industry at -160dB/Hz and its two-tone IMD (87dBc at 32MHz output frequency) is unbeaten. The digital interface of this 14-bit DAC incorporates LVPECL, which, like LVDS, reduces the system-level noise associated with high-speed digital data transmission.

All these DACs come in small QFN packages: a 68-pin version for the MAX588X family and a 48-pin version for the MAX5195. The leadless QFN package combines small physical size (down to 7mm x 7mm) with excellent thermal and electrical characteristics. The exposed paddle provides unusually low ground impedance that reduces the spurious output signals even further.

Additional applications

How else might these DACs be used? Consider again a multicarrier UMTS application that includes digital predistortion techniques. Such an application combines demanding dynamic performance with 100MHz signal bandwidths. The UMTS mask for spurious emissions requires that spurious products within a 1MHz measurement bandwidth be no greater than -58dBc. **Figure 2** illustrates the spectral output for a single tone at 60MHz and a sample rate of 300Msps. A part such as the MAX5888, with its margin over a desired 100MHz bandwidth (more than 8dB greater than mask requirements), allows relaxed margins elsewhere in the transmitter signal chain. A spread-spectrum signal further reduces the spurious outputs, providing even more margin to the specification.

Another important specification for this application is the adjacent-channel power ratio (ACPR). **Figure 3** shows a single-carrier UMTS spectral response with the carrier centered at 60MHz. One can see that the ACPR mask levels for first and second adjacent channels (-45dBc and -50dBc) are met with a comfortable margin in excess of 25dB.

Figure 4 illustrates ACPR performance for the MAX5888 in a four-carrier UMTS application—probably the most demanding requirement for any ACPR measurement. The MAX5888 (which offers the highest performance available for this application) meets both the -45dBc and -50dBc mask requirements with a margin in excess of 20dB.

CDMA carrier generation requires similar performance measurements. The dominant specification for this architecture is the spurious emissions mask, which includes the ACPR mask requirements. Mask levels for this standard vary, depending on the frequency band and the transmitter's output-power level. **Figure 5** depicts an eight-

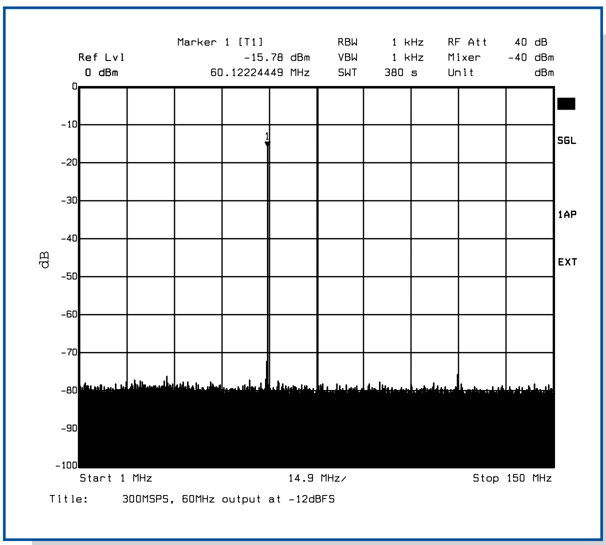

Figure 2. Typical MAX5888 SFDR for a 60MHz output frequency is shown over a 100MHz bandwidth.

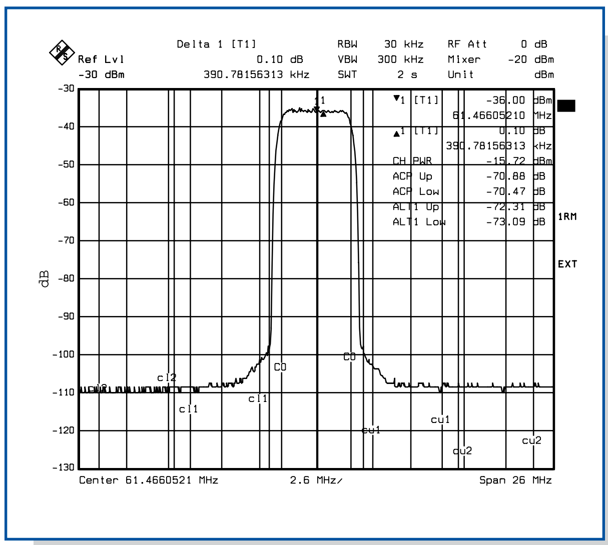

Figure 3. The UMTS ACPR spectral response of the MAX5888 is shown for a single, fully loaded carrier at a 61MHz output frequency.

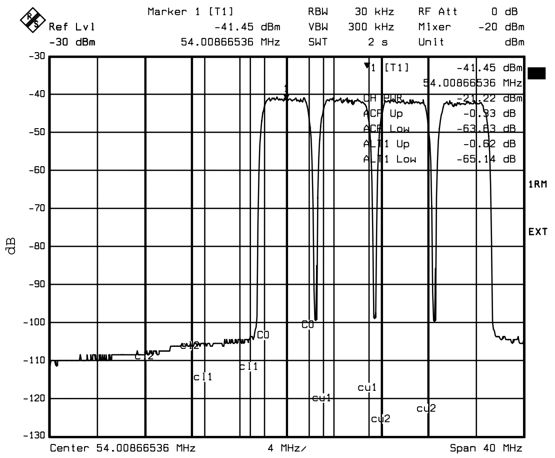

Figure 4. The UMTS ACPR spectral response of the MAX5888 is shown for a test case, with four fully loaded carriers centered at 61MHz.

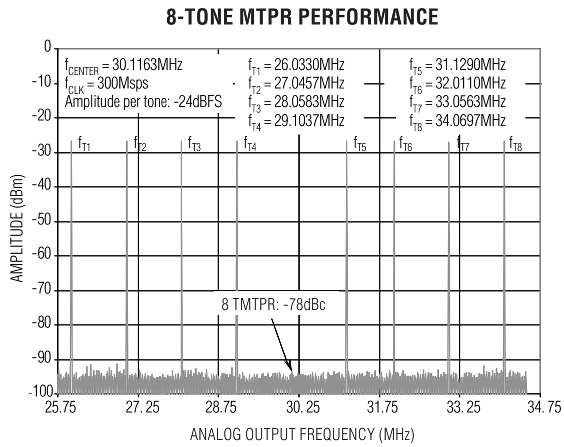

Figure 5. This eight-carrier test-vector spectral plot illustrates the MAX5888's superior multitone IMD performance for CDMA applications. The selected output frequency is centered at 30MHz.

tone system in which the tones are separated by 1MHz at an IF frequency centered at 30MHz. For the various bands' most demanding mask combination, the spurious-emission mask level is -59dBc at an assumed transmitter output-power level of 40W. For this worst-case sinusoidal test-simulation case, the MAX5888 meets CDMA mask requirements with a margin of 19dB.

Among the currently popular wireless-communications protocols, GSM/EDGE-based architectures impose the greatest dynamic-range requirements. Limitations in DAC performance have made multicarrier transmitters impractical in the past, but the MAX5195 lifts that restriction, as shown by its IMD performance for four sinusoid tones with 1MHz spacing between the tones (**Figure 6**). The individual tones have carrier levels of -18dBFS to avoid signal clipping in the DAC's output waveform. This spectral plot covers a 25MHz window, with the tones centered at 48MHz.

The IMD mask limit of -70dBc is easily met with an 8dB margin by the MAX5888. A smaller back-off in output level (only -15dB from full scale) improves performance by 6dB. The MAX5888's -160dB/Hz SNR also leads the industry, making it the highest performance DAC available for demanding, multicarrier GSM-/EDGE-based applications.

Conclusion

Thus, two types of DACs from Maxim offer new options for communication-system designers in the arena of multicarrier signal generation. The MAX5886/MAX5887/MAX5888 family combines excellent dynamic performance with low power dissipation and low-noise system-level operation. The MAX5195 enables multicarrier GSM generation by offering the highest available dynamic range at sample rates up to 260Msps.

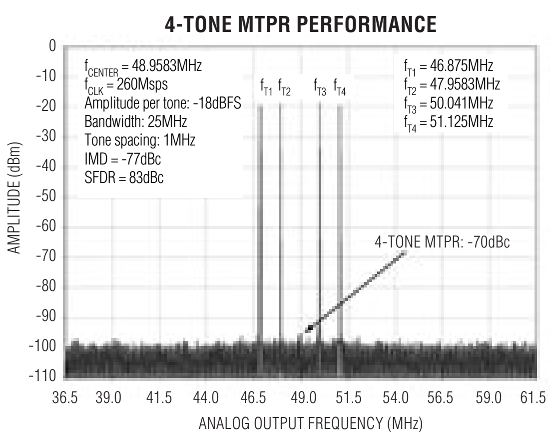

Figure 6. This four-carrier test-vector spectral plot illustrates the MAX5195's superior multitone IMD performance for GSM applications. The output frequency is centered at 48MHz.