Digital-to-Analog Converters (DACs) for High-Performance Communications

With the following article, Maxim introduces two of the highest performing, high-speed, high-resolution digital-to-analog converters (DACs) in the market. The article displays the excellent AC performance of the MAX5195 (260Msps, 14-bit, LVPECL) and the MAX5886/7/8 family (500Msps, 16-/14-/12-bit, LVDS) of DACs specifically targeted for the digital communications and basestation market.

Two new digital-to-analog converters (DACs) from Maxim address the highest levels of dynamic performance in communications and instrumentation systems. Twelve- to 16-bit converters of the MAX5886-5888 family provide excellent dynamic performance at exceptionally high sample rates and low power levels, and the 14-bit MAX5195 provides the greatest dynamic range available for production DACs operating at sample rates up to 260Msps. Both are available in small surface-mount packages. These DACs also support the generation of multiple carriers in UMTS, CDMA, and GSM systems.

Greater 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 move towards the generation of multiple carriers 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. And 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 multi-carrier signal generation. DACs of the new MAX5888 family support up to four UMTS carriers, including appropriate margins with respect to the UMTS standard. As a further refinement, these DACs allow correction of power-amplifier nonlinearity by introducing digital pre-distortion to the signal. That requirement alone can increase the 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 MAX5888's 500Msps update rate is designed for such applications.

The accuracy and exceptional signal bandwidths of the MAX5888 family also support communications systems that employ higher orders of quadrature amplitude modulation

(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 multi-carrier 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. The dynamic performance of both devices (MAX5888 and MAX5195) is also suitable for generating instrumentation signals in direct digital synthesis (DDS) applications.

DACs of the MAX5886-5888 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 500Msps sampling rates, from a single 3.3V power supply, and with low power dissipation (235mW).

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. That consideration is important when designing wide-dynamic-range systems.

MAX5886-5888 performance is exceeded only by that of the new MAX5195 (Figure 1). As you can see, the MAX5195 dynamic performance is better than that of any other device on the market. Besides exemplary SFDR performance, its SNR leads the industry at -160dB/Hz. Its 2-tone IMD (87dBc at 32MHz output frequency) is unsurpassed. 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.

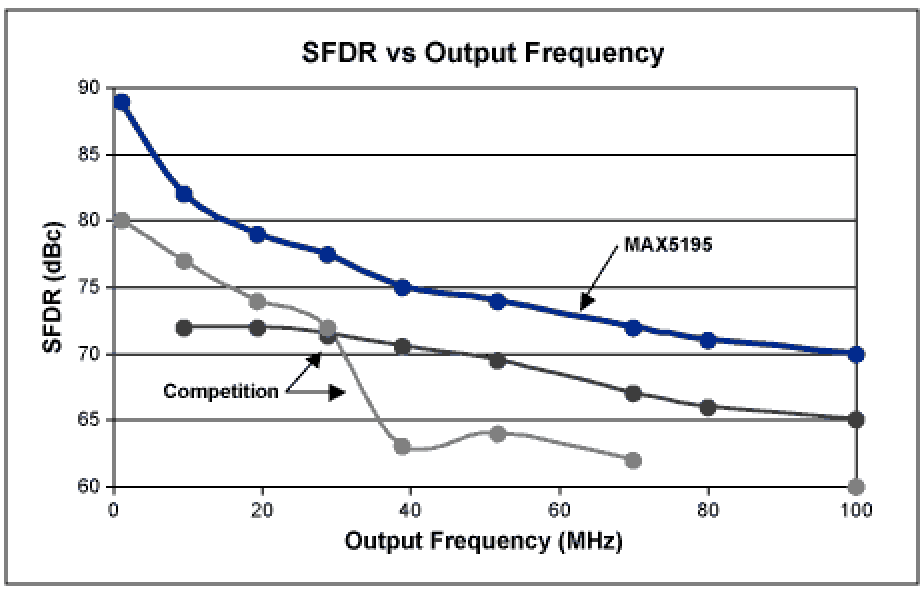

Figure 1. This SFDR graph compares the MAX5195 to the best available competitive devices for a range of output frequencies.

Both DACs employ small QFN packages: a 68-pin version for the MAX5886-5888 DAC family, and a 48-pin version for the MAX5195. The leadless QFN package combines small physical size (down to 7x7 mm) with excellent thermal and electrical characteristics. The exposed paddle confers an unusually low ground impedance that reduces the spurious output signals even further. How do these abstract specifications translate to actual performance in an application?

Consider a multi-carrier UMTS application that includes digital pre-distortion techniques. Such applications combine 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. See Figure 2, which illustrates the spectral output for a single tone at 60MHz and a sample rate of 300Msps. Clearly, the MAX5888 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.

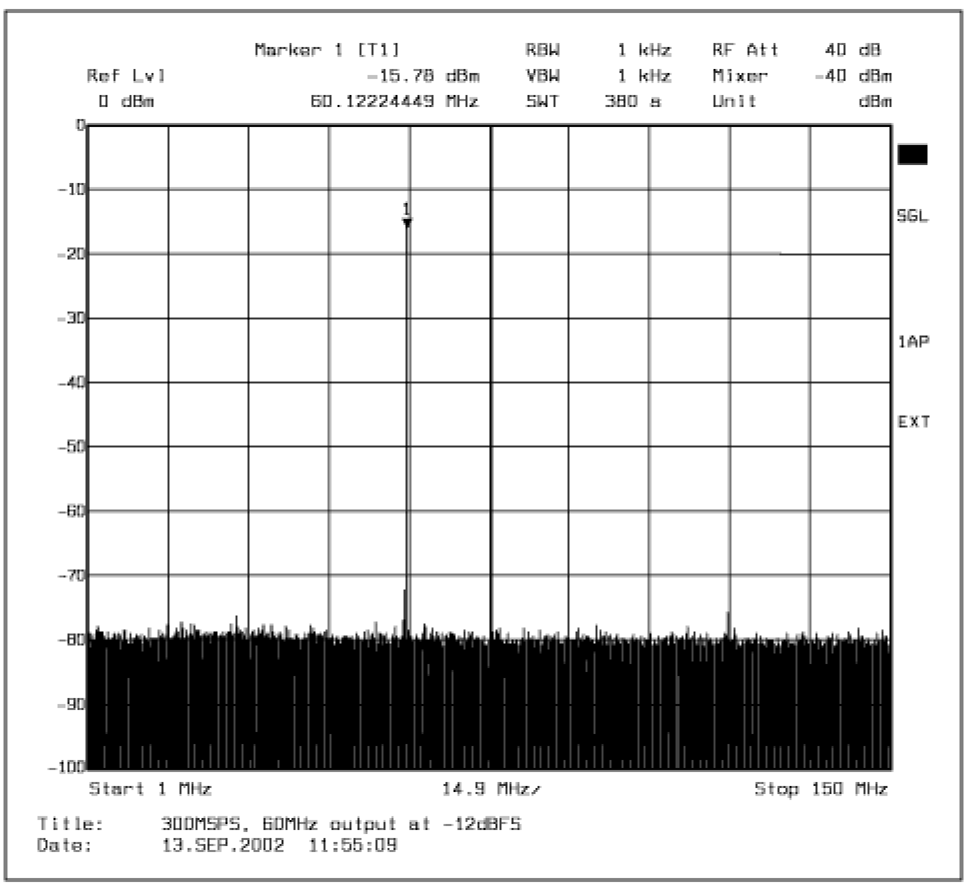

Figure 2. Typical MAX5888 SFDR for a 60MHz output frequency is shown over a 100MHz bandwidth.

Another important specification to be met in this application is the adjacent-channel power ratio (ACPR). Figure 3 illustrates 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.

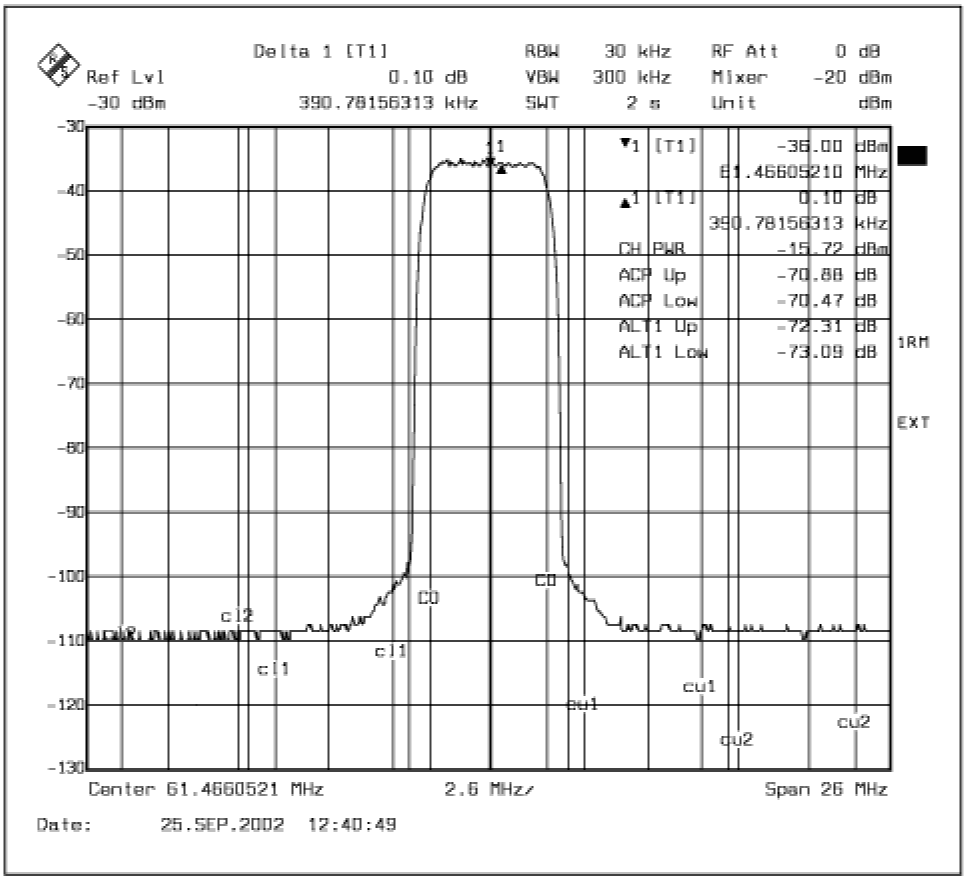

Figure 3. The UMTS ACPR spectral response of the MAX5888 is shown for single fully loaded carrier at a 61MHz output frequency.

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

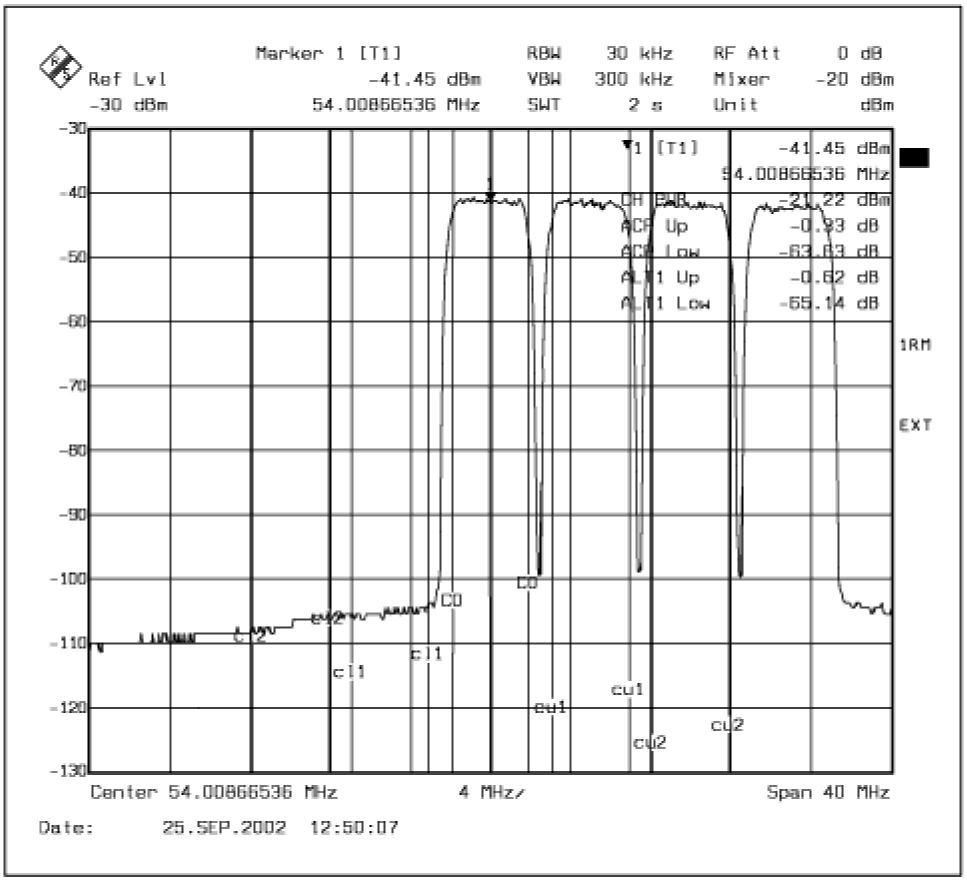

Figure 4. The UMTS ACPR spectral response of the MAX5888 is shown for a test case, with four fully loaded carriers centered at 61MHz.

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

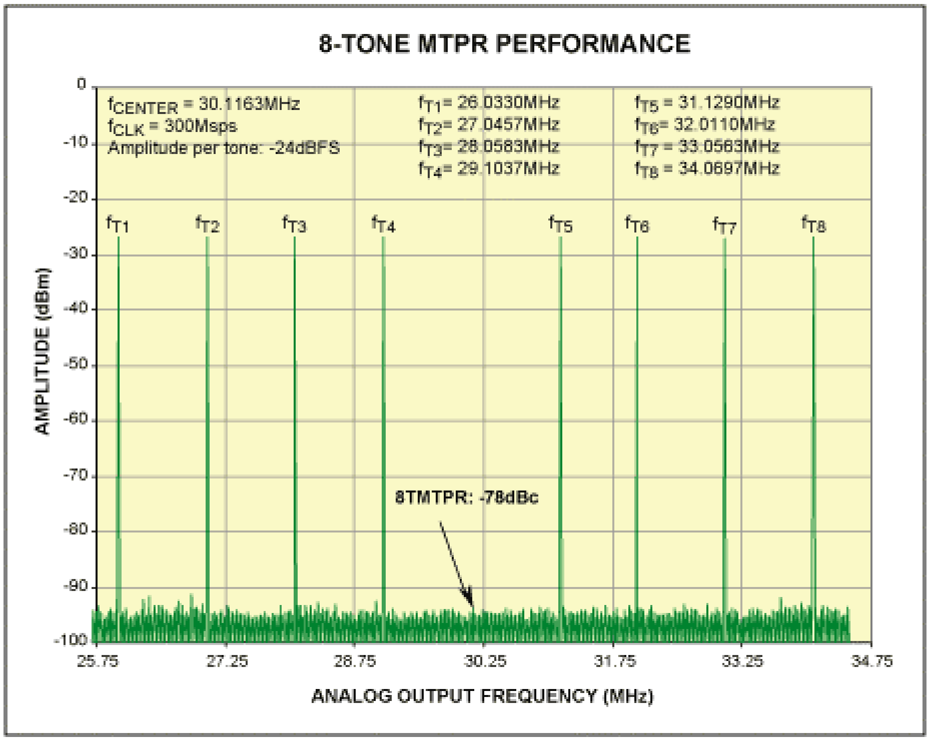

Figure 5. This 8-carrier test vector spectral plot illustrates the MAX5888's superior multi-tone IMD performance for CDMA applications. The selected output frequency is centered at 30MHz.

Among the currently popular wireless-communications protocols, GSM/EDGE-based architectures impose the greatest dynamic-range requirements. Limitations in DAC performance have made multi-carrier transmitters impractical in the past, but the MAX5195 lifts these restrictions 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.

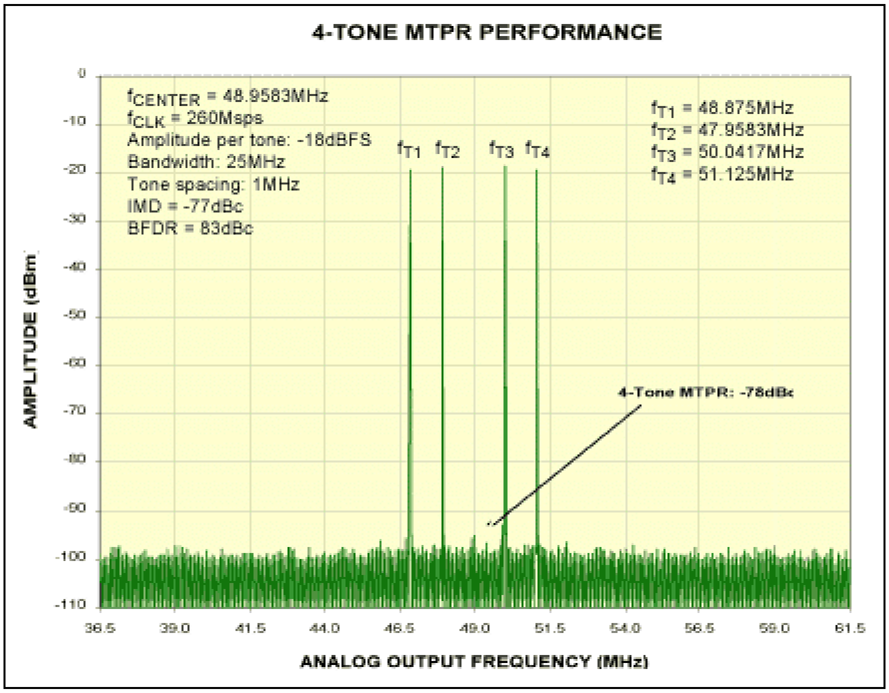

Figure 6. This 4-carrier test vector spectral plot illustrates the MAX5195's superior multi-tone IMD performance for GSM applications. The output frequency is centered at 48MHz.

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 device's -160dB/Hz SNR also leads the industry. MAX5888 is the highest-performance DAC available for this demanding multi-carrier application.

Thus, two DACs from Maxim offer new options for communication-system designers in the arena of multi-carrier signal generation. The MAX5888 family combines excellent dynamic performance with low power dissipation and low-noise system-level operation, and the MAX5195 enables multi-carrier GSM generation by offering the highest available dynamic range.

MORE INFORMATION

MAX5195: QuickView -- Full (PDF) Data Sheet (600k) -- Free Sample

MAX5886: QuickView -- Full (PDF) Data Sheet (632k) -- Free Sample

MAX5887: QuickView -- Full (PDF) Data Sheet (720k) -- Free Sample

MAX5888: QuickView -- Full (PDF) Data Sheet (760k)