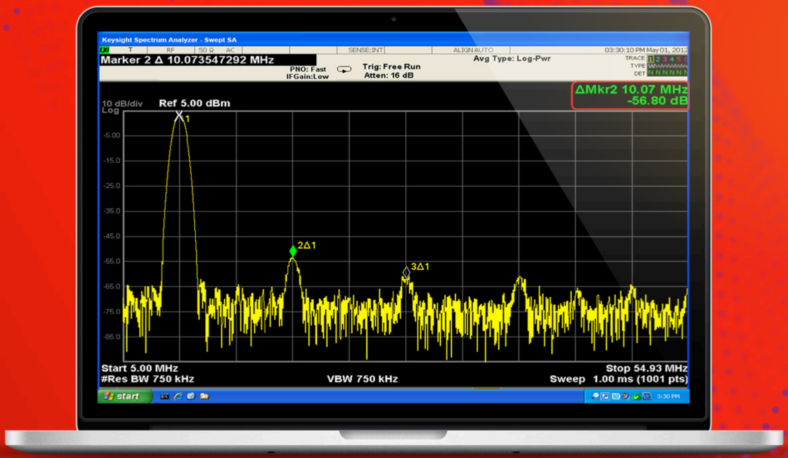
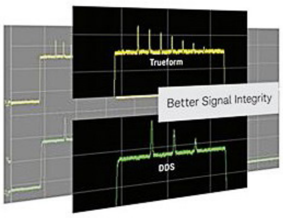


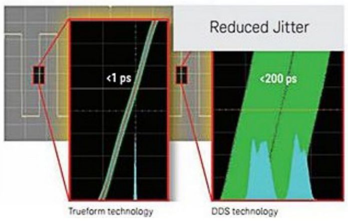
TECHNICAL OVERVIEW

Direct Digital Synthesis (DDS) Generators versus True*form* Waveform Generators

The incumbent technology used in most function generators is known as direct digital synthesis (DDS). Unfortunately, DDS has a number of problems that can cause unexpected and seemingly unexplainable problems in the lab. True*form* technology avoids many of these traps with its lower jitter and true representation of waveforms – no more approximations! Read more to learn about the differences between DDS and True*form* waveform generators and how those differences will affect your testing.

Conceptually, the simplest way to generate a waveform is to store its points in memory and then read those points out one after another and clock them into a DAC. After the last point has been read, the generator jumps back to the first point again to begin the next cycle. This is sometimes called “point per clock” (PPC) generation.



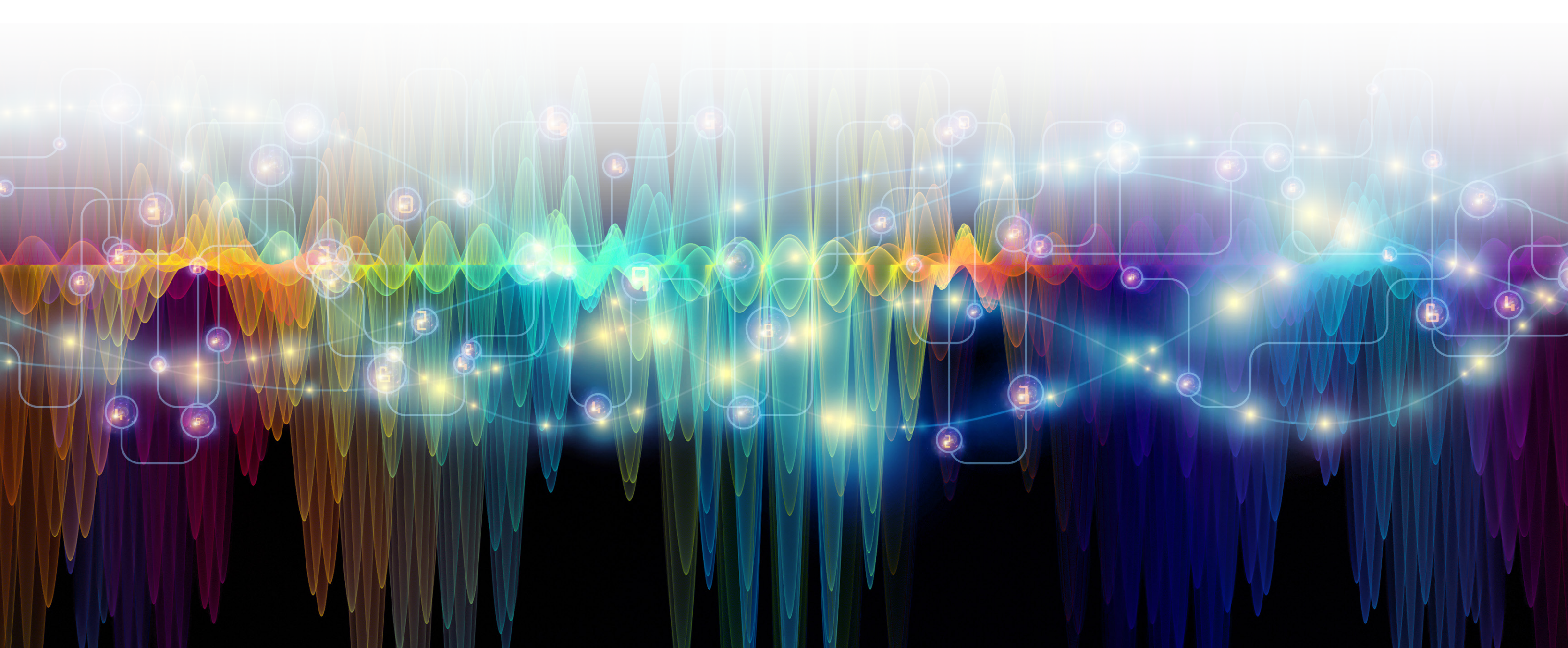


Even though this method seems like the most intuitive way to create waveforms, it has two big drawbacks. First, to change the waveform's frequency or sample rate, the clock frequency has to change, and making a good low-noise, variable-frequency clock adds cost and complexity to the instrument. Second, since the stepwise output of the DAC is undesirable in most applications, complex analog filtering is needed to smooth the steps out. Because of its complexity and cost, this technology is used mainly in high-end waveform generators.

DDS uses a fixed-frequency clock and a simpler filtering scheme, so it's less expensive than the PPC method. In DDS, a phase accumulator adds an increment to its output in every clock cycle, and the accumulator's output represents the phase of the waveform. The output frequency is proportional to the increment, so it's easy to change frequency even though the clock frequency is fixed. The output of the accumulator is converted from phase data into amplitude data typically by passing it through some type of look-up table.

The phase accumulator design allows DDS to use a fixed clock, but still execute waveforms at a perceived faster sample rate than the clock. With DDS, not every individual point in the waveform memory is being expressed in the resulting output waveform. Instead, DDS outputs a best approximation of the waveform, which means small features in the waveform can be partially or completely skipped over. At best case, such approximation can lead to added jitter, while at worst, severe distortion can result.

Keysight's True*form* technology represents the next leap in waveform generation technology, providing you the best of both worlds. It gives you a predictable low-noise waveform with no skipped waveform points like PPC technology, but at the price point of DDS technology. True*form* works by employing a patented virtual variable clock with advanced filtering techniques that track the sample rate of the waveform. In the following sections, we will look at some of the waveform generation advantages True*form* provides over DDS.



Improved signal integrity

One of the key advantages True*form* provides over DDS is overall better signal integrity. You can see the advantage in the frequency domain by comparing spectra and the time domain with a jitter measurement comparison. Figure 1 shows a frequency domain view of a 10-MHz sine wave generated using True*form* technology. Figure 2 shows the same frequency domain view of a 10-MHz sine wave generated with DDS technology.

An ideal sine wave consists of a fundamental frequency without harmonics. In the real world, some amount of harmonics do exist, the smaller, the better. In both figures 1 and 2, circled in red you can see how many dB the second harmonic is from the fundamental frequency. You can see the True*form* second harmonic is > 5 dB lower than the DDS second harmonic. The DDS technology in Figure 2 shows the 4th and 5th harmonics, circled in blue, poking up from the noise floor. Also created is a non-harmonic spur between the two harmonics. These unwanted harmonics and spurs are negligible with the True*form* technology shown in Figure 1.

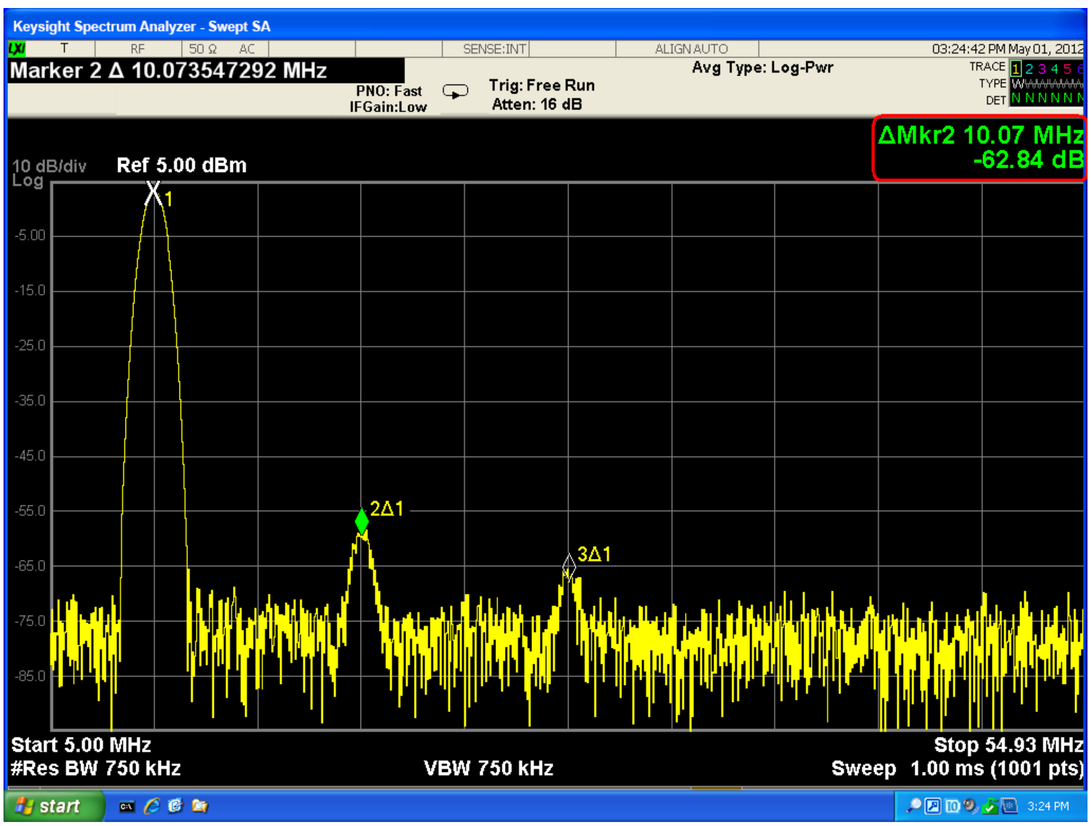


Figure 1. Harmonics from True*form* technology.

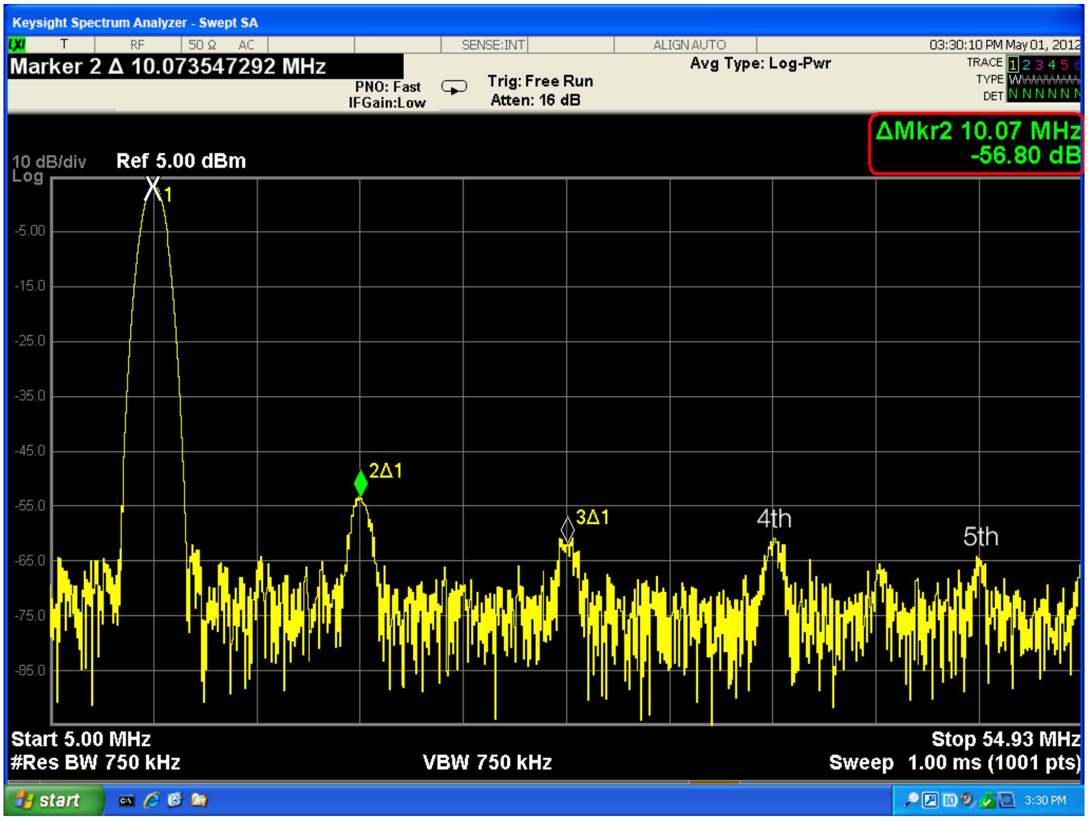


Figure 2. Harmonics from DDS technology.

When we compare the two technologies from a jitter measurement perspective, the True*form* advantage becomes even more pronounced. Figures 3 and 4 show a jitter measurement made on a 10-MHz pulse signal using a high-performance oscilloscope. The scope view is zoomed in on the rising edge of the pulse signal with the persistence setting of the scope turned on. The histogram function of the scope is used to measure the period jitter of the signals. Amplitude and time scales for the scope are set the same for both measurements. The standard deviation measurement in each figure is circled in red and represents the signal's RMS jitter. The True*form* pulse signal jitter measurement is shown in Figure 3 and the DDS pulse signal jitter measurement is shown in Figure 4. The True*form* pulse waveform has more than 10 times less jitter compared to the DDS pulse waveform.

The improved signal integrity True*form* offers over DDS means less uncertainty in your tests. This is especially true when you consider edge-based timing applications like generating a clock signal, trigger signal or communication signal.

Figure 3. Jitter measurement on True*form* signal.

Figure 4. Jitter measurement on DDS signal.

The waveform you create is the waveform you get

As we mentioned earlier, DDS uses a fixed clock and a phase accumulator so it cannot guarantee that every point or feature in a waveform will be played. The higher the frequency, the more gaps you will see in the output waveform compared to the ideal waveform. True*form*, on the other hand, plays every waveform point regardless of the set frequency or sample rate. This becomes critical when you are dealing with a waveform that may have a small detail that is critical to the test you are performing.

As an example, we created an arbitrary waveform consisting of a pulse with seven descending amplitude spikes on top of the pulse. The waveform was then loaded into a True*form* waveform generator and a DDS function generator, and played back at three different frequencies, 50-kHz, 100-kHz, and 200-kHz. The results were captured on a scope, as shown in figures 5, 6 and 7. The yellow trace is the True*form* waveform and the green trace is the DDS waveform.

In Figure 5 at 50 kHz, each generator was able to reproduce the waveform with seven spikes on top of the pulse. You can see that the True*form* spikes reached higher amplitudes.

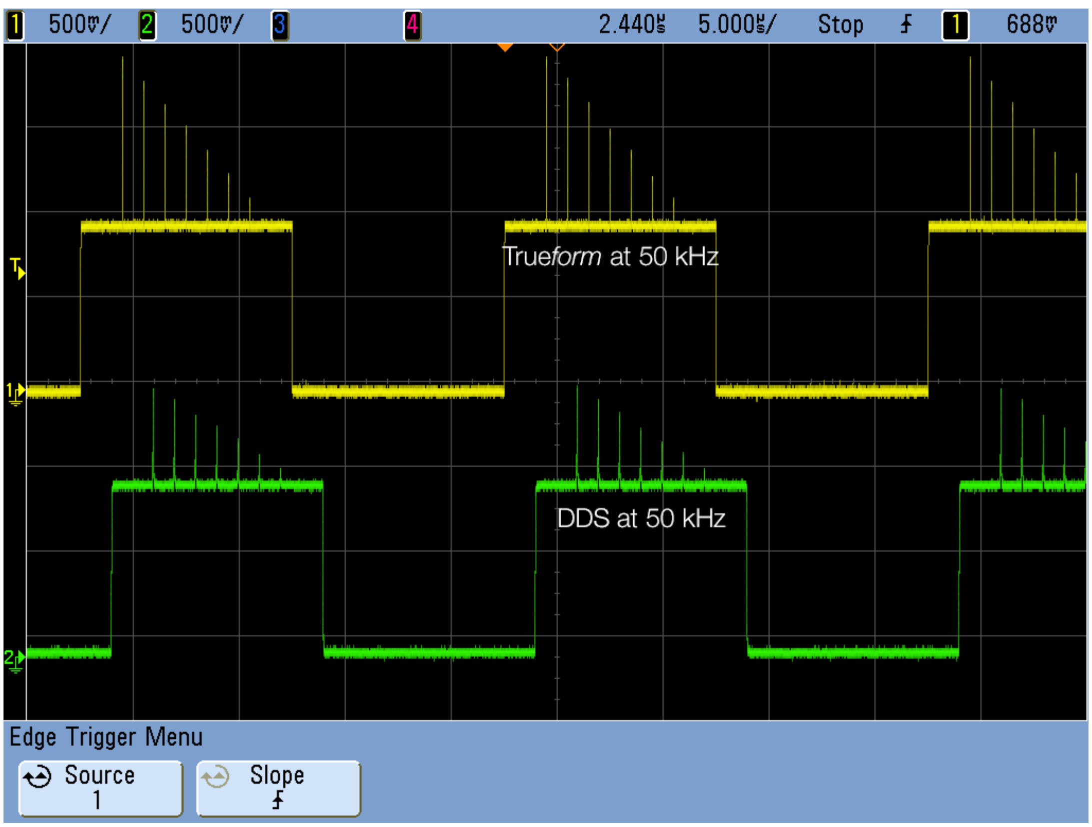


Figure 5. Arbitrary waveform comparison at 50 kHz.

In Figure 6 at 100 kHz, while the True*form* waveform generator played all seven spikes, the DDS generator did not play any of the spikes.

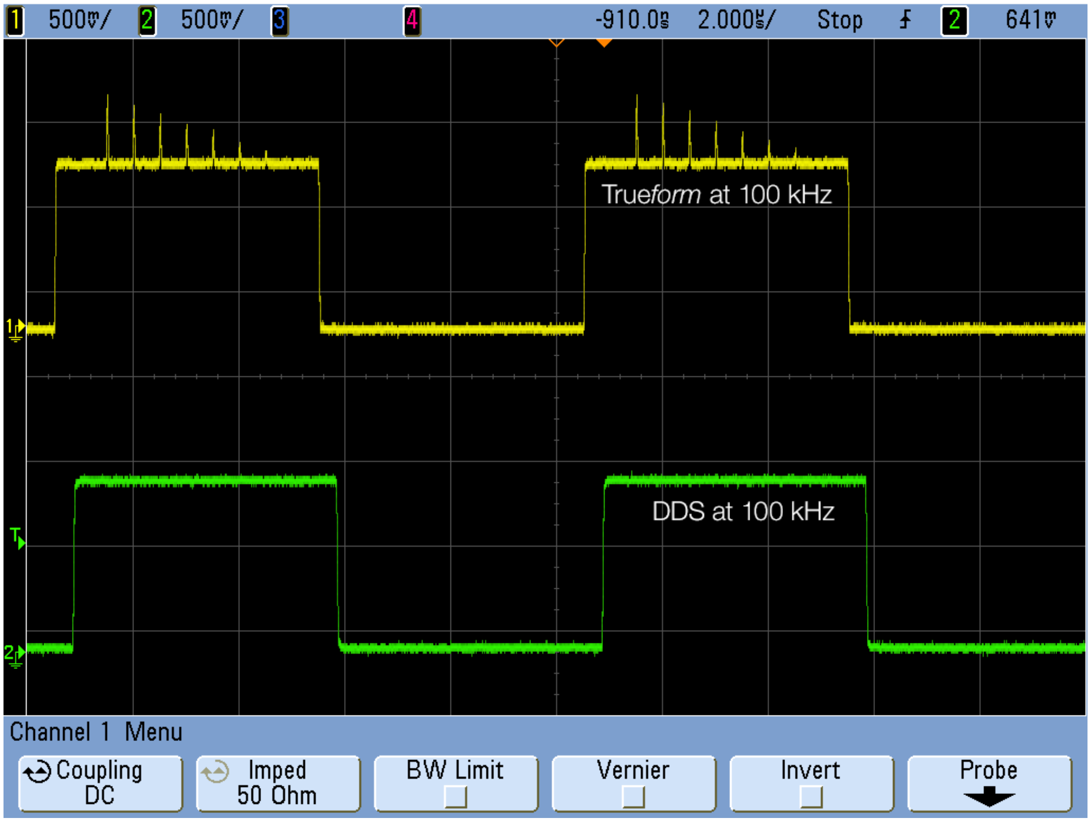


Figure 6. Arbitrary waveform comparison at 100 kHz.

In Figure 7 at 200 kHz, the True*form* waveform generator once again played all seven spikes in the waveform while the DDS generator went from playing no spikes at 100 kHz to playing three spikes at 200 kHz. Notice that the three spikes played in the 200 kHz waveform do not match the correct time location of any of the seven spikes that are in the actual waveform points. This example illustrates how waveforms generated through DDS technology may mask important details that are crucial to the integrity of your design.

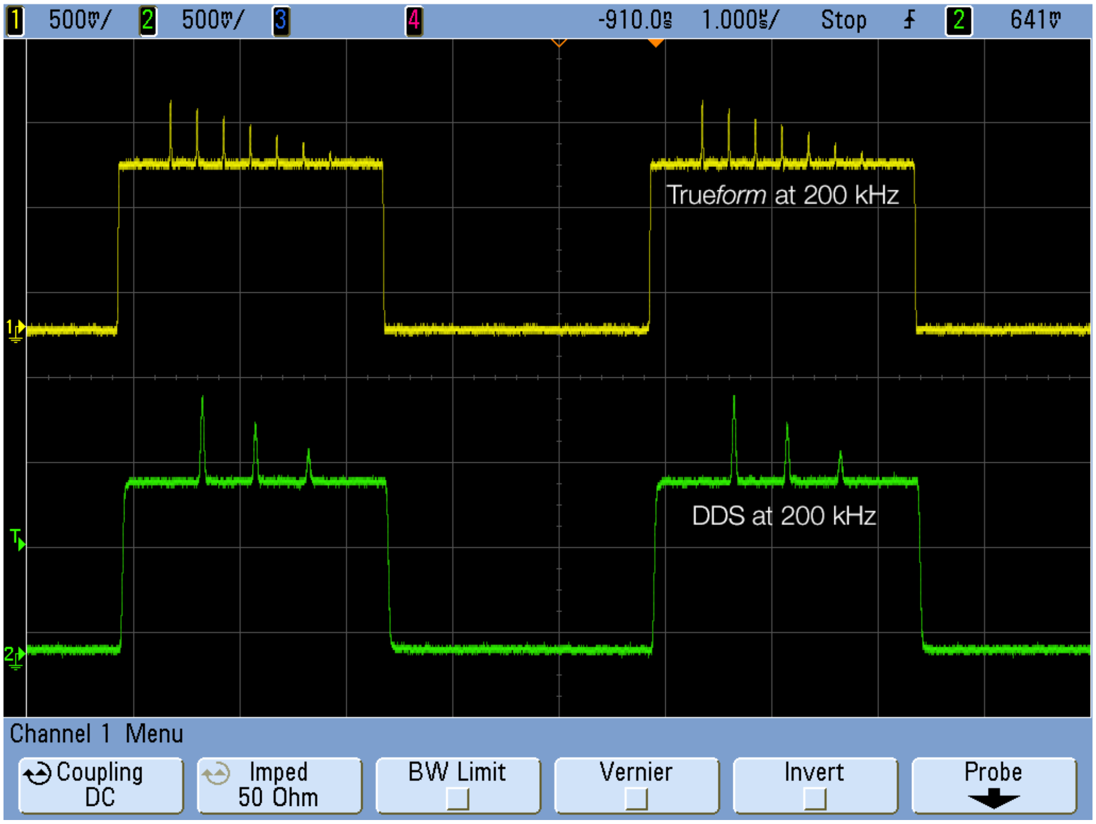


Figure 7. Arbitrary waveform comparison at 200 kHz.

Conclusion

For decades, DDS has been the incumbent technology in function generators because it offered a lower-cost alternative to high-end PPC technology. As we have explored in the examples above, DDS has its set of drawbacks around signal integrity, which includes jitter, harmonic noise and skipped waveform points. These drawbacks conclude that a true representation of a programmed waveform cannot be consistently achieved with function generators utilizing DDS.

Keysight's patented True*form* technology offers an alternative that blends the best of DDS and PPC technologies, using an exclusive digital sampling technique for unmatched performance. Table 1 summarizes side-by-side comparison between True*form* technology and DDS technology.

	DDS: Traditional 25 MHz waveform generator	True*form*: Keysight 20 MHz and 30 MHz waveform generators	DDS: Traditional 100 MHz waveform generator	True*form*: Keysight 80 MHz and 120 MHz waveform generators	Improvement
Edge jitter	< 500 ps	< 40 ps	< 200 ps	< 1 ps	12x to 200x better
Custom waveform replication	Skips waveform points	100% point coverage	Skips waveform points	100% point coverage	Exact waveform replication
Total harmonic distortion	0.2%	0.04%	0.2%	0.03%	Up to 5x better
Anti-alias filtering	Must provide externally	Always anti-aliased	Must provide externally	Always anti-aliased	No anti-aliasing artifacts
Sequenced arb	Not possible	Standard	Not possible	Standard	Easy creation of complex waveform sequences

Table 1. Performance comparisons between the traditional DDS technology versus the True*form* technology.

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