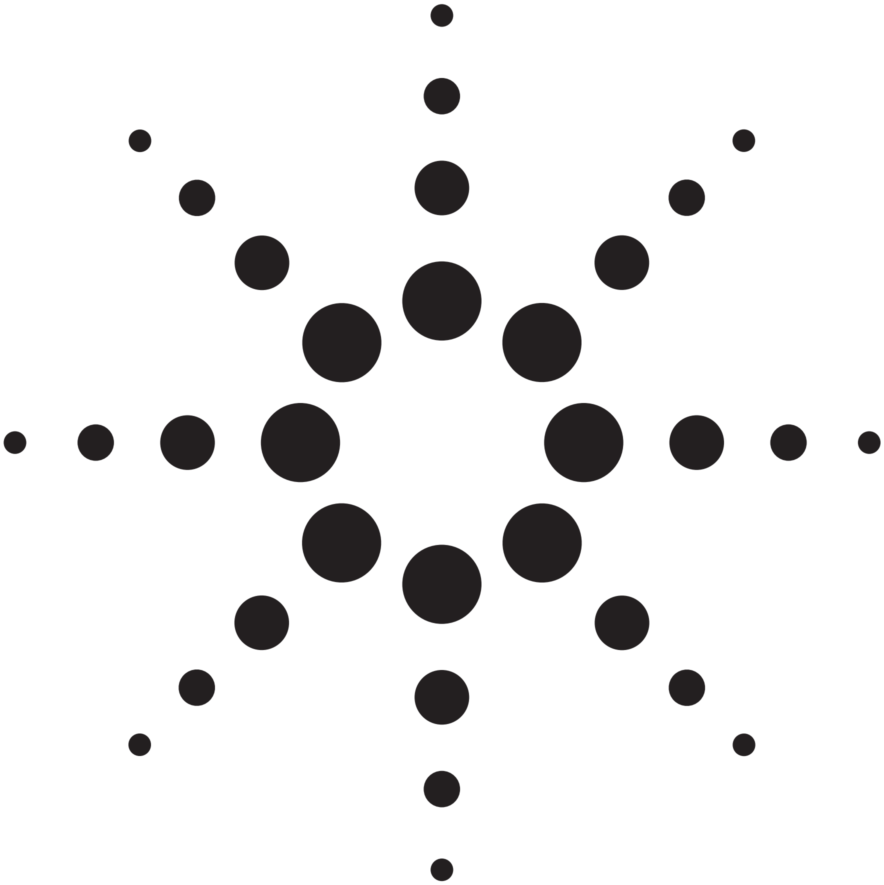
Agilent
Generate CW Signals With the N6030A Arbitrary Waveform Generator and N7509A Waveform Generation Toolbox

Application Note



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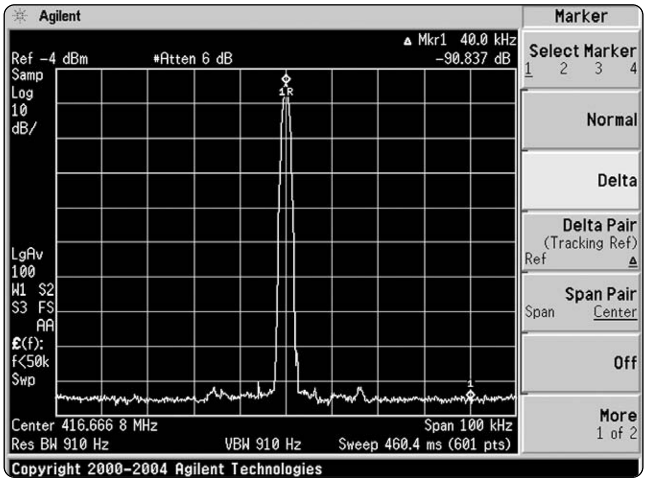
Introduction

The N6030A arbitrary waveform generator is a numerically-controlled digital machine that converts mathematical formulae into analog signals. Its ability to function as a frequency synthesizer depends primarily on three things: (1) how good is the phase noise of the sample clock, (2) how many effective bits is the DAC, and (3) how much memory it has.

Phase Noise of the Sample Clock

The phase noise of the ceramic resonator oscillator (CRO) used in the N6030A can be easily measured using an E5052A signal source analyzer. From a practical sense, the phase noise needs to be) lower than the quantization noise floor and b) ultra-low jitter. If the output of the N6030A, in this case a CW signal at $F_S/3$ (416.666667 MHz), is measured using a performance spectrum analyzer (PSA) as in Figure 1, the noise floor of the PSA clearly dominates at approximately –90 dBm. This demonstrates the superior phase noise performance of the N6030A.



Ref –4 dBm #Atten 6 dB

Δ Mkr1 40.0 kHz –90.837 dB

Samp Log 10 dB/

LgAv 100

W1 S2 S3 FS AA

£(f): f<50k Swp

Center 416.666 8 MHz

Span 100 kHz

Res BW 910 Hz

VBW 910 Hz

Sweep 460.4 ms (601 pts)

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Figure 1. PSA noise floor at ~–90 dBm

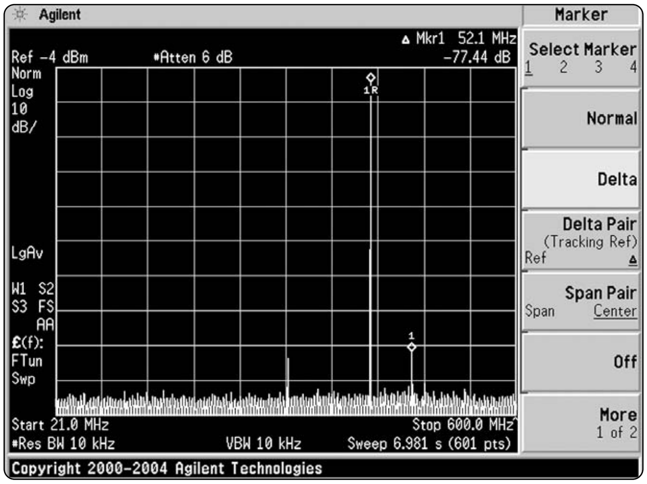
Effective DAC Bits

There are a couple rules of thumb that can be used to demonstrate how the effective DAC bits impact the customer experience. If the DAC is perfect, its dynamic range is approximated by 6.02dB x N where N is equal to the number of DAC bits. The following example serves to explain this. Assume an AWG is using a 10 bit DAC. We want to generate a sine wave and have it look pure on a spectrum analyzer. The 10-bit DAC is capable of $2^{10}–1$ different voltage levels. Doing a best-fit curve of these levels to the real sine wave we get to the *Least Significant Bit* and it doesn't fit quite right. It effectively "truncates" the sine wave and creates a little square wave piece of the signal. Square waves create distortion products like harmonics. So what is produced are a series of distortion products starting at approximately –63 dBc. In the case of the N6030A, it has a 15 bit DAC, so it has $2^{15}–1$ possible voltage levels. This reduces the level of this truncation effect down to –93 dBc. If the noise floor of the analyzer being used to measure the signal is –90 dBm or so in this mode, then these products won't be seen above the noise floor.

If the DAC and its associated support circuitry were perfectly linear, the analysis above would be all that is necessary. Unfortunately, non-linearities creep into the system in the form of baluns, amplifiers, filters, power supply currents, leakage, and so forth. These combine to increase the levels of spurious signals coming from the DAC. There may also be spurs due to power supply contamination with line frequency and clock leakage into the path. These can mix in the non-linear components and create more spurious signals. This can be a serious degradation. For example, if an AWG had only –35 dBc between the signal being measured and the undesireable signals you didn't want, that would erode the "effective number of bits" from 10 down to 5.3. The N6030A is specified at –65 dBc worst case, so its "effective number of bits" is ~10.3. In most cases, the real value is closer to 12. Figure 2 of a sine wave at $F_S/3$ shows one spur that is actually from leakage, and no "truncation" spurs at all. They are all below the –91 dBm noise floor.

Memory

Because the N6030A uses digital circuitry to produce an analog output, it doesn't have the ability to generate the exact frequency in all cases. The following example explains the limitation. Using the $F_S/3$ that was used before, it is readily apparent that it doesn't have a nice integer value. Its frequency is 1.25e9 / 3 = 416,666,666.666... Hz. With a frequency synthesizer we can expect to get within 1 Hz of the desired frequency. With the N6030A, as with other digital machines, the limitation is how much memory is available to divide the sample clock with. This will determine how close the AWG can get to some arbitrary non-integer frequency. The rule is simple: (F_S ÷ memory size = minimum frequency resolution). So, 1.25e9 Hz ÷ 16e6 samples = 78.125 Hz/sample. This is the finest setability for the N6030A. This means that for integer multiples of 78.125 Hz and integer sub-multiples of F_S, we can get exactly on frequency, and for others we can get very close. For frequency resolution less than 100 Hz it probably won't be right on.



Δ Mkr1 52.1 MHz
Ref –4 dBm *Atten 6 dB –77.44 dB
Start 21.0 MHz Stop 600.0 MHz
*Res BW 10 kHz VBW 10 kHz Sweep 6.981 s (601 pts)
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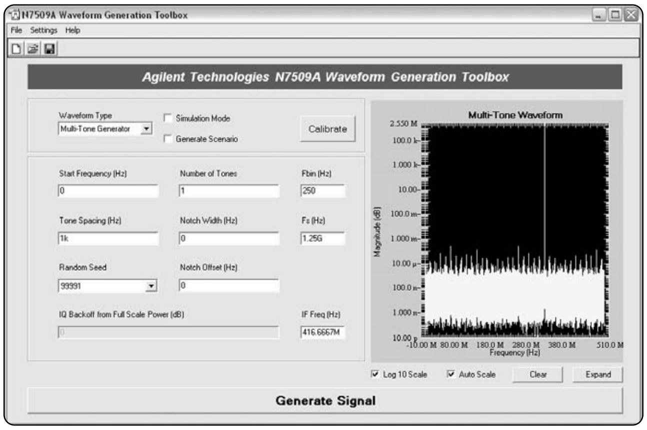
Figure 2. $F_S/3$ and a spur

Generating CW Tones With the N7509A

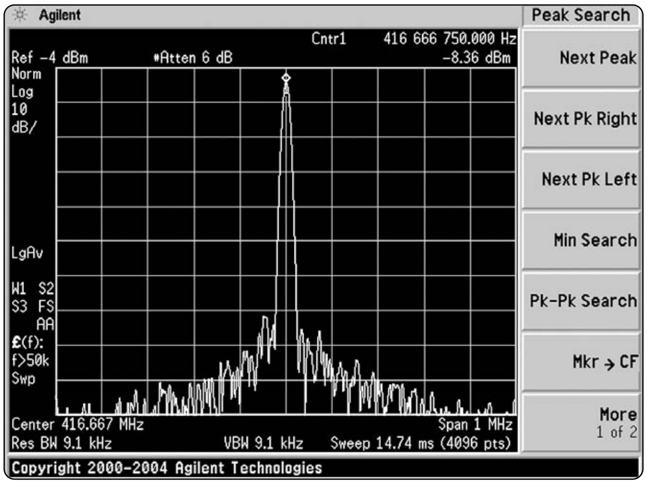
The N7509A can be used to generate CW tones, or sine waves, with very good resolution and purity. To do this, select the Multi-tone Generator waveform type and set the number of tones equal to 1 as in Figure 3. The best quality signal comes from using a single channel of the N6030A, rather than both channels in I/Q mode and up-converted. This is done using IF mode. Here's how the setup would look for generating $F_S/3$.



Waveform Type: Multi-Tone Generator
☐ Simulation Mode
☐ Generate Scenario
Start Frequency (Hz): 0
Number of Tones: 1
Fbin (Hz): 250
Tone Spacing (Hz): 1k
Notch Width (Hz): 0
Fs (Hz): 1.25G
Random Seed: 99991
Notch Offset (Hz): 0
IQ Backoff from Full Scale Power (dB): 0
IF Freq (Hz): 416.6667M
☑ Log 10 Scale
☑ Auto Scale

Figure 3. N7509A screen showing CW tone setup

If Matlab® were used, the N6030A could generate the exact frequency because the sine wave is created in the time domain and $F_S/3$ is an integer sub-multiple of F_S. The multi-tone engine in the N7509A creates the sine wave in the frequency domain. It cannot manipulate the length of the waveform to make this frequency come out exactly and still function as a multi-tone engine, so instead gets as close as possible. Figure 4 demonstrates how close our AWG gets to $F_S/3$ with a rounding error of ~83 Hz. This is more then would be expected based on the example above where the minimum frequency resolution was calculated to be 78.125 Hz. This can be explained by the fact that the AWG used in this example only had 8 Msamples of memory, and consequently, 156.25 Hz of resolution. So the conclusion to draw here is that the N7509A can be used to generate CW sine waves as long as they don't always have to be exactly on frequency.



Cntr1 416 666 750.000 Hz
-8.36 dBm
Ref -4 dBm
#Atten 6 dB
Norm
Log
10
dB/
LgAv
W1 S2
S3 FS
AA
£(f):
f>50k
Swp
Center 416.667 MHz
Span 1 MHz
Res BW 9.1 kHz
VBW 9.1 kHz
Sweep 14.74 ms (4096 pts)

Figure 4. Frequency counted at marker

Web Resources

For more information, go to:
www.agilent.com/find/awg

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