

# Sophisticated Arbitrary Waveform Generation Requires Sophisticated Hardware

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## Introduction

Arbitrary waveform generation is becoming increasingly important for test and measurement applications. Current advances have made multi-channel wideband arbitrary waveform generation very easy and cost-effective. This promises a paradigm shift for test and measurement applications and also opens up unparalleled opportunity for scenario generation and simulation and stimulators. The main driving force behind this has been high speed digital to analog data converters (DAC), fast hardware implementation of digital up converters (DUC), very fast data buses and fast disks.

## Technology

The key technology is the digital upconversion process that enables the user to generate signals at the baseband rate and use digital signal processing to upconvert the signal at the desired intermediate frequency (IF).

The modulator multiplies the input baseband signal ( $I + jQ$ ) with the in-phase ( $\cos(\omega_c t)$ ) and quadrature carrier ( $\sin(\omega_c t)$ ) and provides the summed output:

$$I * \cos(\omega_c t) \pm Q * \sin(\omega_c t)$$

This corresponds to the real part of:  $(I + j * Q) * e^{j\omega_c t}$ , which is applied to the DAC. The positive sign may be used for spectral inversion. The upconversion process is shown in Figure 1 and Figure 2.

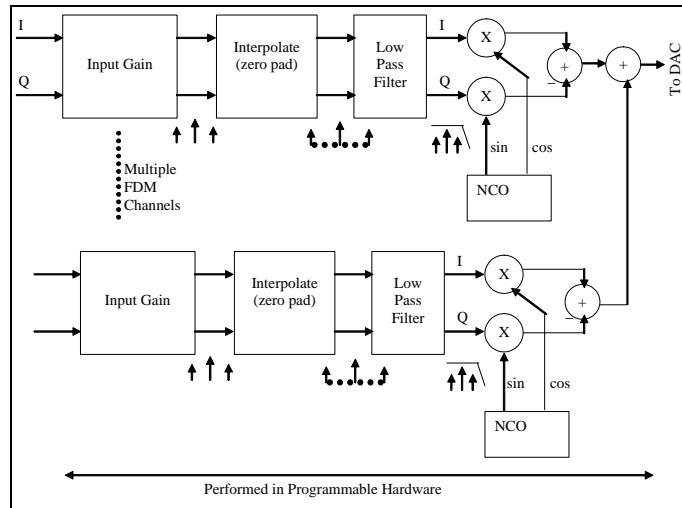
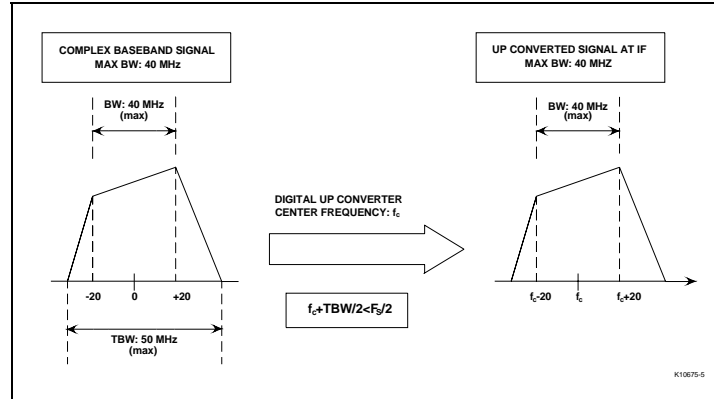


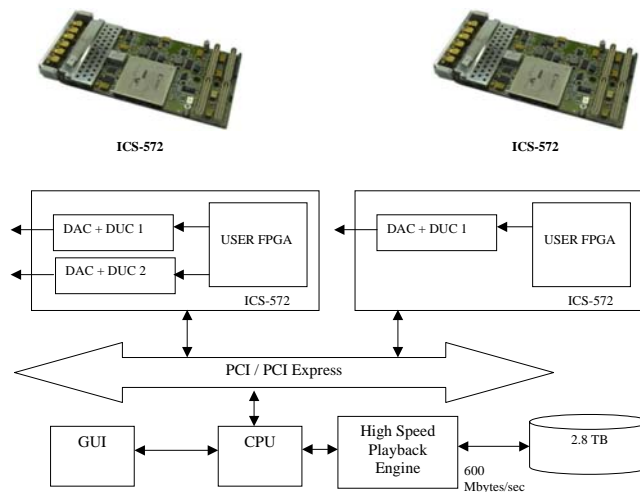
Figure 1: Digital Upconversion



**Figure 2: Generating an IF using Digital Upconversion**

Digital upconversion ensures that the data may be generated at the baseband rate and not at the final DAC data rate. Thus, transfer bandwidths are reduced and storage capability is extended. For example, if a 40 MHz bandwidth signal needs to be created around an IF of 70 MHz (as shown in Figure 2), the classical direct data generation method would require a data rate of 200 Msamples/second (at the Nyquist rate). Assuming a 2-byte per sample precision, the data rate is 400 Mbytes/second. With the digital upconverter, a baseband signal of bandwidth 40 MHz needs to be generated and the digital upconverter will interpolate the data and multiply the signal with the quadrature carrier and generate the signal centered around the desired IF. The data rate in this method is only 50 Msamples/second (complex) requiring a data rate of only 200 Mbytes/second. This implies that the equipment can now generate two channels of wideband data or the playback time is doubled (for the same storage).

For multi channel wideband signals, the data rate using digital upconversion techniques is very high. For example, to generate three 40 MHz signals, the data rate is 600 Mbytes/second (=50 Msamples/second complex per channel \* 3 channels \* 4 bytes per complex sample). Ensuring that sustained playback is possible at this rate requires high speed buses and high performance software. Of course multiple disks are required to ensure that this high data rate is sustained.



**Figure 3: 3-channel wideband (40 MHz) playback system**

## Sophisticated scenario generation requires powerful hardware

An example of the type of hardware needed for these sophisticated applications is the ICS daqPC, a PC-based software radio development platform that facilitates arbitrary waveform generation by playing back pre-stored data from a RAID storage subsystem, as shown in Figure 3. The data is pre-computed and stored, enabling expensive DSP hardware for real-time computing to be eliminated. The stored data is played back at base band rate. The current version of the daqPC supports play back rates up to 600 MBytes/second. The sustained play back rate requirement is a function of the signal bandwidth. For example, three channels at 40 MHz bandwidth will require 600 Mbytes/second. The same data rate will also handle four channels at 30 MHz bandwidth. With a maximum storage capacity of over 2.8 terabytes, the daqPC can support long-term scenario generation in most applications. The 2.8 TB storage at the 600 Mbytes/second playback rate means a playback duration in excess of 1.2 hours.



## Applications

One of the areas where arbitrary waveform generation finds enormous use is long-term receiver testing under various channel impairments. The multichannel capabilities described earlier allow the user to very easily generate multichannel signals that could be used to test the receiver in the presence of interference. Interference testing by classical means requires multiple signal generators. Using test equipment like the daqPC eliminates the need to have expensive signal generators. It also offers more flexibility as programmable interference patterns may be generated. Test equipments like the daqPC based arbitrary waveform generators are also ideally suited to simulate channel impairments for wireless communications. Thus short term and long term channel characteristics like fading, Doppler, shadowing, rain loss etc. can be modeled and simulated and receiver performance may be tested without conducting expensive field tests. The programmability and arbitrary generation capability ensures that the test equipment can be reused in multiple applications.

Radar simulators and operator training equipment are another application where large bandwidth and long playback time are essential. Modern radar systems have bandwidths in excess of tens of MHz and multiple channels are essential for phased array applications. A wideband multichannel arbitrary waveform generator is thus an important requirement for simulators and operator training needs. The large playback capability allows the designers to generate multiple

scenarios and the large playback bandwidth allows multiple wideband channels to be generated for system test or training purposes.

## **Conclusion**

Historically, the sophistication of the applications for which arbitrary waveform generation can be used – especially in the test and measurement arena – has not been matched by the availability of equally sophisticated hardware. However, today's hardware is allowing complex applications such as scenario generation to be implemented, delivering high performance and flexibility.