IQ Signal Generation
Made Easy
Introduction

In-phase quadrature modulation, or IQ modulation, is the dominant modulation scheme in communication applications. Its efficient use of bandwidth, a critical challenge in our data-hungry world, makes IQ modulation necessary. Testing with simulated IQ signals is critical because designers face a bandwidth crunch in a spectrum filled with interference.

As a design engineer, you need to test the limits of your design to ensure real-world performance. To accomplish this, you generate an ideal signal to test the design’s performance with a high-quality, known-good signal. By adding real-world characteristics to the signal, you can test your design under nonideal conditions.

This white paper will cover how to generate both ideal and nonideal IQ signals using Keysight Trueform Series waveform generators with an IQ signal.

With a sample rate of 250 MS/s, the Keysight 33522B Trueform Series waveform generator’s usable IQ signal bandwidth goes beyond the specified analog bandwidth of 30 MHz.
Jitter and Waveform Generation Technology

Two key functions you need to consider when choosing a waveform generator for IQ signals are bandwidth and signal integrity.

**Bandwidth**

You want a generator with a flat analog waveform bandwidth and a flat frequency response. The Keysight 33522B Trueform Series waveform generator used in this example has a bandwidth of 30 MHz and a sample rate of 250 MS/s. For your test scenario, ensure your waveform generator has ample bandwidth.

**Signal integrity**

When choosing a waveform generator for IQ signals, two critical capabilities to consider are bandwidth and signal integrity. Numerous components contribute to signal integrity waveform generation technology, which includes jitter.

Avoid direct digital synthesis (DDS) generators for IQ signals because they can skip and repeat points. The Trueform Series waveform generators provide a true representation of a waveform that gives you high accuracy and low jitter.

Jitter is a measurement that gives you visibility into the consistency and stability of a signal — the lower the jitter, the more stable the signal. Figure 1 is an example of a jitter measurement using a 10 MHz pulse signal from a 33522B using a high-performance oscilloscope.
Figure 1. Jitter measurement results using the 33522A waveform generator

The histogram function of the scope measures the jitter of the pulse signal; the standard deviation represents the RMS jitter of the signal. Figure 1 shows the RMS jitter signal quality of the waveform generator is 4.1 ps.

Once you have your waveform generator selected, it is time to create and generate your IQ signals.
Creating and Generating IQ Baseband Signals

Most designers create their IQ signals using a software tool, then transfer the signals to a waveform generator.

Transferring data

Many waveform generators provide USB, LAN, and GPIB I/O interfaces to connect to a PC. They also support major drivers such as IVI for transferring IQ waveforms remotely from the software. Confirm your waveform generator supports the transfer method you need.

Many generators allow you to upload waveforms from a USB storage device. Doing so lets you avoid connecting to the waveform generator remotely. You can accomplish this by using the USB connector on the front panel. With the 33522B, you can easily upload waveforms from file formats such as comma-separated value (CSV) files, data (DAT) files, and ActionScript Communication (ASC) files. These file formats are available in communication and signal engineering software packages such as MATLAB.
Generating IQ signals

You can create your signals once the signals pass to the waveform generator. For example, using an IQ signal player option gives you an easy-to-use interface. The interface allows you to configure and control both channel 1 and channel 2 as if they were a single channel or waveform. Figure 2 is a screenshot from the 33522B with the IQ signal layer option. In Figure 2, the waveform generator is outputting a 64QAM IQ baseband signal at a sample rate of 1 MHz.

![Figure 2. 33522B display for the IQ signal player](image1)

![Figure 3. Constellation diagram and EVM of a 64QAM baseband signal](image2)
Figure 3 displays the IQ baseband signal captured with a high-performance oscilloscope running signal analysis software. You can see the resulting constellation diagram in the top left display and the measured error vector magnitude (EVM) of only 0.3% in the lower right display. The two additional displays, lower left and top right, show the plotted magnitude error in millipercent and the phase error in millidegrees.

This high-quality IQ signal is an excellent choice for testing your designs with an ideal signal. Once that phase of testing is complete, it is time to test with nonideal signals.

**Simulating nonideal signal and channel conditions**

When you need to understand the limits of your design, the goal is to simulate a signal with quantitative, nonideal characteristics. This allows you to test the response of the design under nonideal conditions. When simulating nonideal IQ baseband signal conditions, you want to modify three parameters:

1. **Balance adjust**: You can specify the amplitude gain balance between the two channels and the amplitude offset adjustment for each channel (Figure 4).
2. **Skew adjust**: This feature allows you to shift either the I or Q baseband signal in time with picoseconds of resolution.
3. **Advanced modulation**: Modulation features such as sum or phase modulation let you add noise, random jitter, or deterministic jitter to the signal.

![IQ balance adjust screen](image)

**Figure 4. IQ balance adjust screen**
Figure 5 is an additive noise example on the 64QAM signal from Figure 3. The generator contains added Gaussian noise waveform with a crest factor of 4.3 and adjustable bandwidth up to 30 MHz. The noise signal will not repeat for more than 50 years of continuous play.

Using the sum modulation capability of the 33522B waveform generator, we added 30 MHz bandwidth of noise at 10% of amplitude to the I and Q baseband signal (Figure 5). Comparing Figure 3 with Figure 5, you can see the constellation points are more significant and obscure; EVM has increased to 1%. The noise amplitude adjustment on the 33522B provides resolution down to 0.01%. With these controls, you can zero in on the exact amount of error you would like to simulate.

![Figure 5. Constellation diagram and EVM of 64QAM baseband signal with added noise](image-url)
Conclusion

If you want to create IQ signals, you need a waveform generator with adequate bandwidth and high signal integrity. You also want to ensure that you can quickly and easily generate IQ signals to simulate nonideal conditions. Keysight Trueform Series waveform generators with a built-in IQ signal player option has the capabilities you need to test your designs.

The Trueform Series waveform generators with the IQ signal player provides an easy-to-use, low-cost solution for generating high-quality, low-EVM IQ signals. The exclusive Trueform waveform generation technology offers a true representation of signal points with low jitter and noise levels compared with the most common waveform generation technology available.