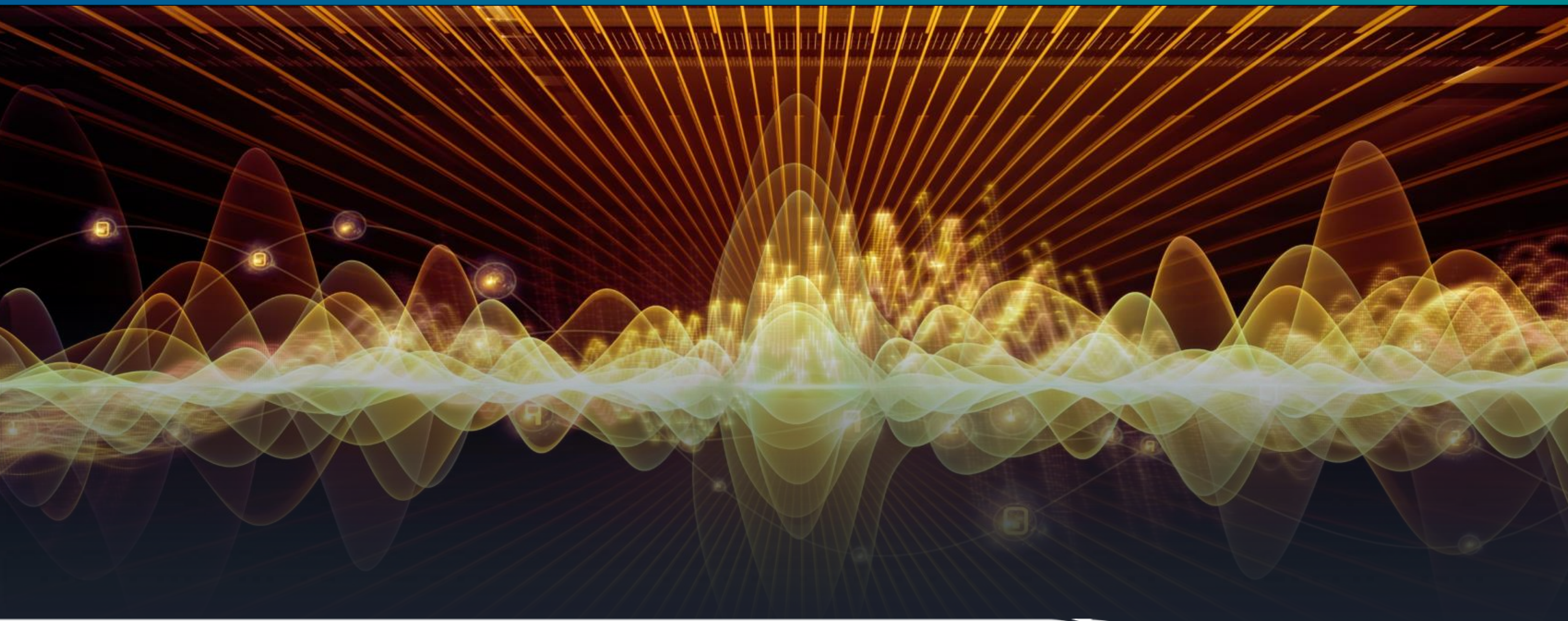

WHITE PAPER

How Have Function Generators Evolved?

Function generators fit into a category of low-frequency or baseband sources. They produce frequencies barely into the RF range and are distinguishable from signal source instruments by the frequency range and variety of signal shapes.

Function generators have come a long way. They evolved from a humble beginning of low-frequency audio oscillator in the late 1930s — only producing sine waves but had great low-harmonic distortion to create high fidelity sound. These oscillators are based on vacuum tube components and continue to improve in harmonic distortion performance till the 1950s. The schematic of the audio oscillator shown in Figure 1 is a Wien bridge oscillator circuit with a patented incandescent light bulb used to control the gain stability.

What is a Function Generator?

A function generator is a tool that provides stimulus to a device under test (DUT). You can evaluate your DUT's performance by inputting a known good signal and monitoring the output. This requires that the function generator output be clean, stable, and represent the real signals that will ultimately be in the final application of the device.

KEYSIGHT TECHNOLOGIES

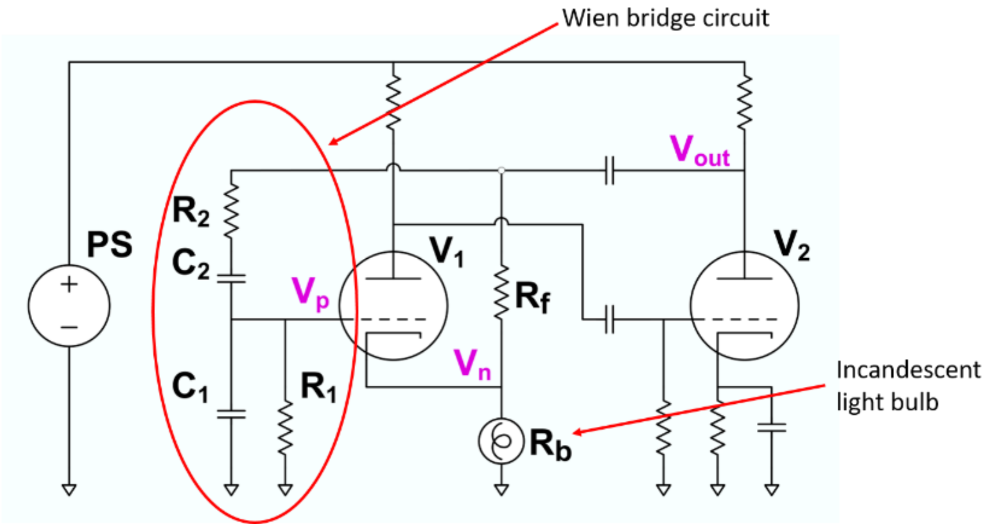

Figure 1. HP200 audio oscillator and the Wien bridge circuit (Wikipedia)

Then came along the need for function generators that provide basic waveforms; sine, square, triangle, and ramp waves. In the 1960s, commercial transistors resulted in miniaturization of instrument boxes. The technology used in analog function generators is a current source charging and discharging a capacitor.

The “natural” waveform resulting from this technology is a linear ramp. The ramp is passed through a carefully designed circuit to distort and create a sine wave. The triangle integrator has the upper current source to ramp up the voltage and the lower current source to ramp down the voltage to generate a triangle wave as shown in Figure 2. A comparator with hysteresis is used to transform the triangle wave into a square wave.

A ramp-based source function generator requires a non-linear device to transform the triangle wave into a sine wave. As a result, the ramp-based source function generator does not produce the same quality of sine wave as a pure sine-wave oscillator source. However, the ramp-based source function generator can produce multiple wave shapes.

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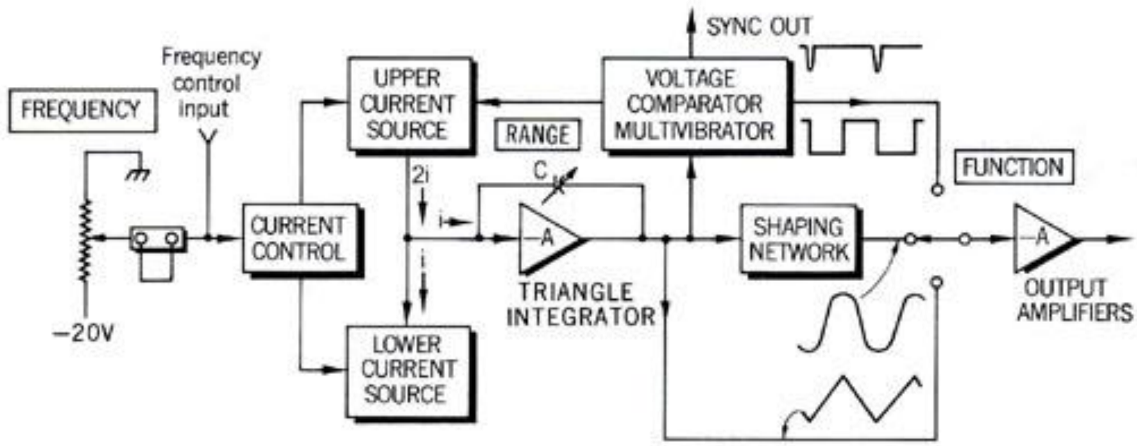

Figure 2. Analog function generators

In the 1980s, the frequency synthesized analog function generator entered the market. The technology works on fractional-N phase lock loop technology. Fractional-N is a way to take a frequency-controlled crystal oscillator and multiply it up by an arbitrary amount, synthesizing the frequency. The excellent control over frequency in the micro-Hz resolution made it very popular. It even had an oven oscillator option for higher accuracy.

The “natural” waveform resulting from this technology is a sine wave. The sine wave passes through a comparator to generate a square wave. The generated sine waves from the voltage-controlled oscillator (VCO) and reference are processed through a logic function circuitry and then a low pass filter to create a triangle wave.

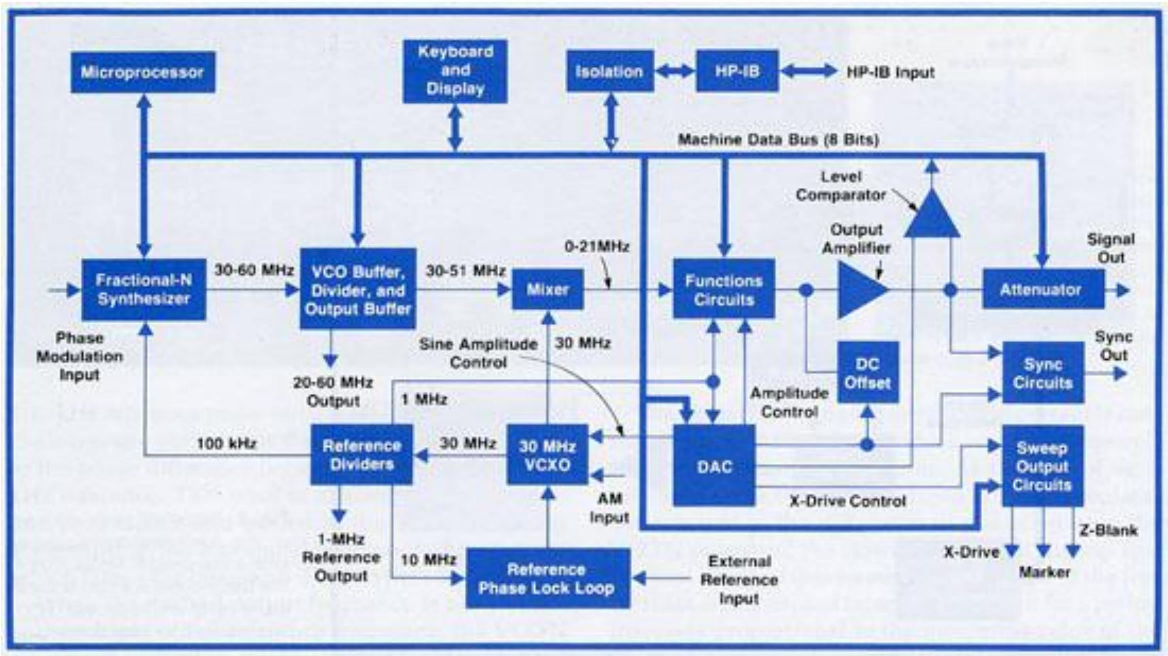

Figure 3. Frequency synthesized analog function generator

During the 1980s and 1990s, there were more introductions of a digital "point per clock" arbitrary waveform generators (AWGs) due to the lower cost of digital to analog converter (DAC) and microprocessor components. These "point per clock" AWGs are still too expensive to use as general purpose function generators.

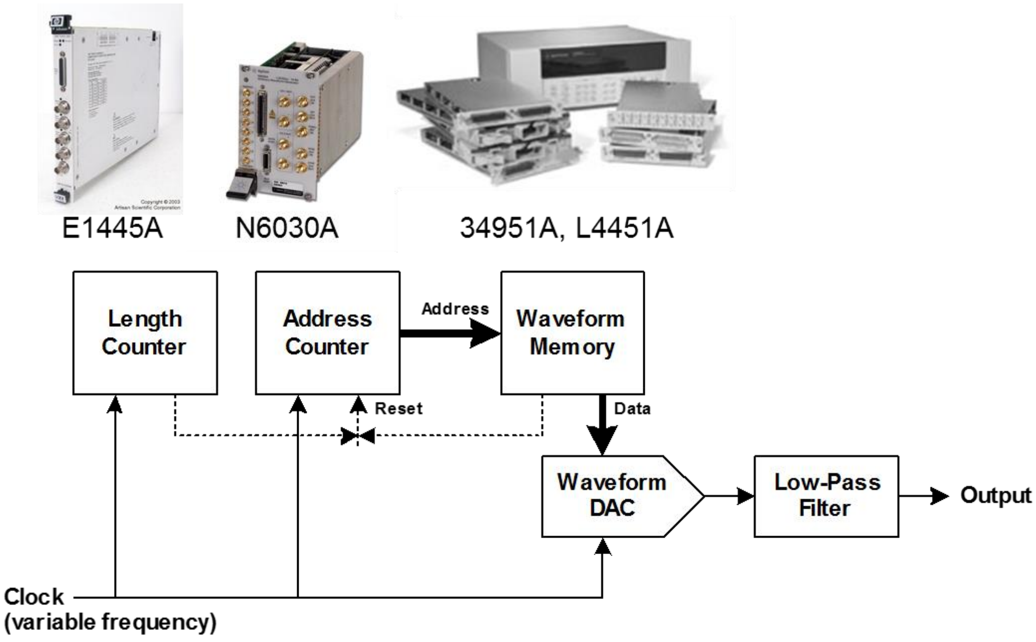

Figure 4. Point-by-point function/arbitrary waveform generator

In the 1990s, direct digital synthesis (DDS) based function generators became the mainstream technology replacing the analog function generators. It quickly took over the market by providing common waveforms as well as noise and arbitrary waveforms. With

DDS, a waveform is created in digital form and then sent through a DAC to convert to an analog waveform. DDS provides excellent frequency resolution. DDS did not have a “natural” waveform, sine, or ramp, unlike other generators. All waveforms are stored in the instrument’s memory, allowing arbitrary waveforms to be quickly and practically implemented.

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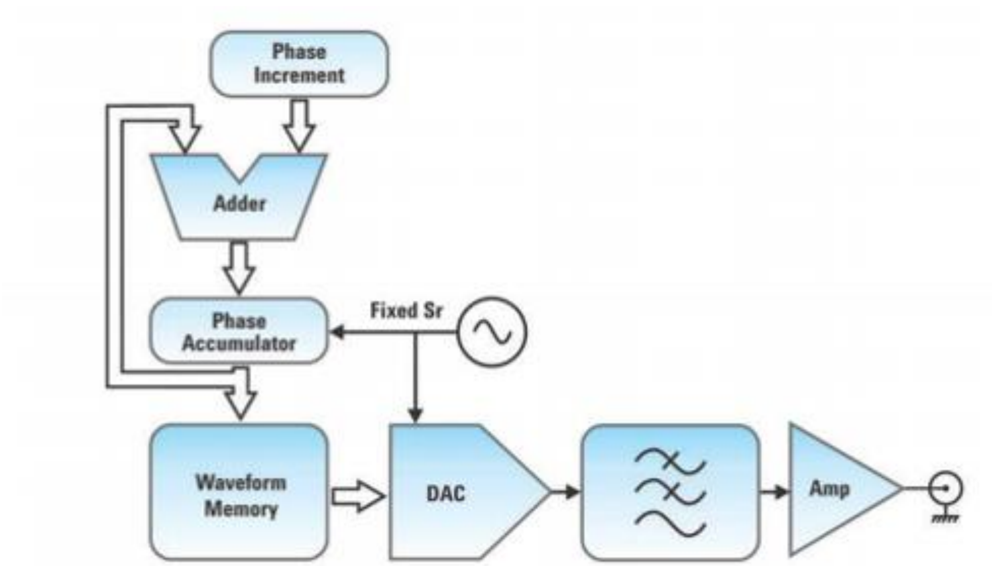

Figure 5. DDS based function generator

In recent years, several micro-evolutions to the DDS technology were initiated to improve or overcome some of its flaws; such as skipping and repeating of points or aspects of the waveform. These DDS flaws create noise and jitter on the signal which is especially problematic when you require sharp edges of a pulse or square wave. You want confidence that every point of the waveform is accurately generated.

For example, Keysight came out with the True*form* technology to replace all its DDS based function generators. True*form* builds on the foundation of DDS to allow generators using this technology to create a much closer approximation of a signal. Improved performance is achievable by interpolating the samples stored in waveform memory in real-time through DSP in conjunction with a low pass filter. The resulting waveform can reproduce accurately with superior signal integrity, lower jitter, and lower total harmonic distortion than DDS based generators.

Figure 6 shows the introduction of stable vacuum tube-based oscillators, the transition to transistorized analog function generators, and the transition from analog to digital era of synthesized waveforms.

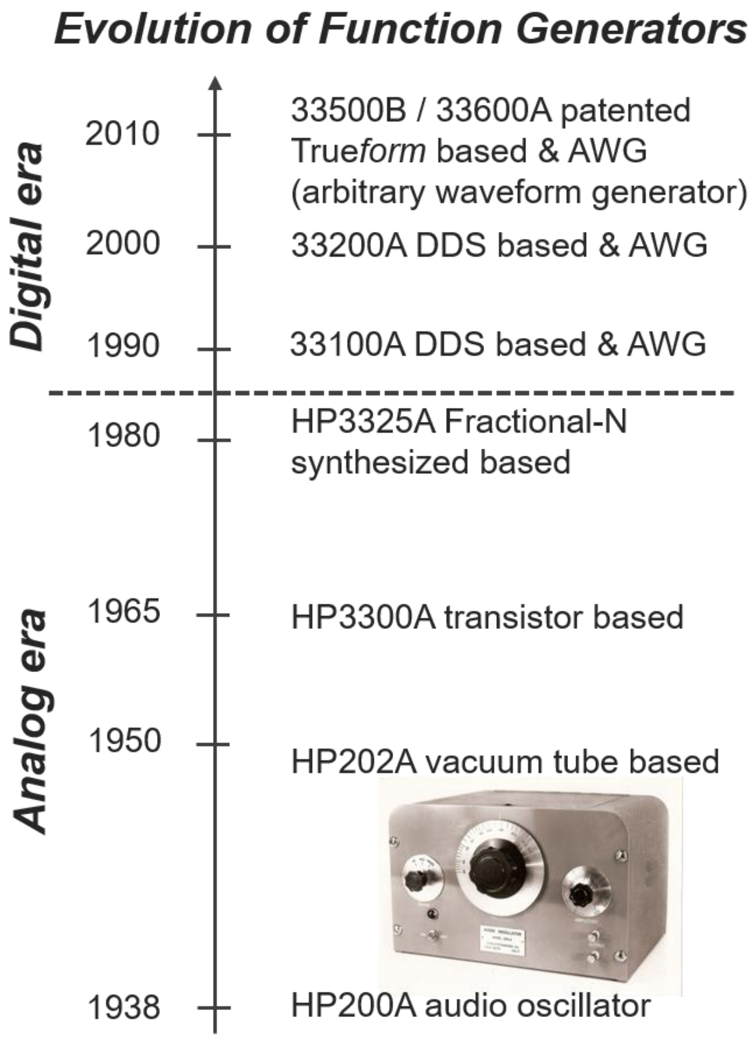

Figure 6. Timeline evolution of function generators

Conclusion

Function generators have come a long way since eight decades ago, with vacuum tube technology to generate low harmonic distortion sine wave. Commercial transistors available in the 1960s started to revolutionize test instrumentation by miniaturizing analog function generators.

Cost of the DAQ and microprocessor components became low enough in the 1980s to make it viable for producing digital function generators commercially.

In the 1990s, direct digital synthesis (DDS) based function generators became the mainstream technology replacing the analog function generators. In recent years, there have been several micro-evolutions on top of the DDS technology to overcome some of its technical flaws.

Keysight has introduced True*form* technology and replaced all its DDS based function generators with this technology. It has superior signal integrity, lower jitter, and lower total harmonic distortion when compared with the DDS based function generators. To learn more, please read our article on *Direct Digital Synthesis (DDS) Generators* versus True*form Waveform Generators*, 5991-0852EN.

For more information about Keysight's 33600A True*form* function generators, please go to http://www.keysight.com/find/function-generators

Learn more at: www.keysight.com

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