PROGRAMMABLE DIGITALLY SYNTHESIZED SOURCE FOR LOW-FREQUENCY CALIBRATIONS

N.M. Oldham, P.S. Hetrick, and M.E. Parker
National Institute of Standards and Technology[1]
Gaithersburg, MD 20899-0001

Summary Abstract

A digitally synthesized source (DSS) designed to calibrate low-frequency (0.1 Hz to 1 kHz) digital voltmeters and thermal converters is described. The DSS output voltage, frequency, and waveform are programmable over the General Purpose Interface Bus (GPIB). The rms value of the output voltage is calculated, with an uncertainty of less than 5 ppm, by measuring the dc voltage of each of the steps used to create the waveform.

Introduction

Digitally synthesized sources (DSSs) have been employed in precision electrical measurements for a number of years [1]. Waveforms are created by applying a set of digital values, such as sine functions, to a digital-to-analog converter (DAC) to produce a staircase approximation of the function. While there are a number of commercial instruments that use this technique to produce waveforms, they are not optimized for low-voltage and low-frequency performance.

DSS

The DSS described in this paper is an extension of an earlier source designed to provide a calculable ac voltage [2]. A simplified block diagram of the new DSS is shown in Fig. 1.

Various waveforms, stored in programmable read-only-memory (PROM), are applied to latching multiplying digital-to-analog converters (MDACs) to generate staircase approximations of the stored waveforms. The control logic generates three clocks: one that runs the PROM address counter, two others, at half the counter clock frequency, that latch alternate PROM data into the MDACs, and a fourth that controls the electronic switch S. This dual-DAC scheme minimizes glitches that occur during step transitions by allowing one MDAC to supply the stable output step while the other MDAC is switching and settling on the next step.

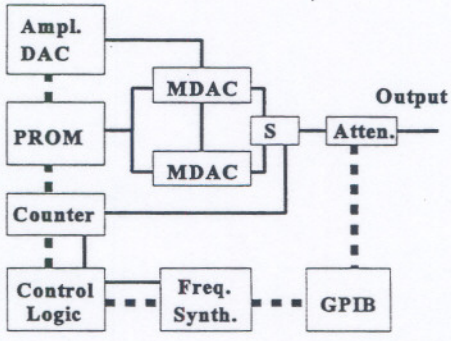

Fig. 1. Block Diagram of the DSS. The dashed line is a data bus generated by the GPIB module.

Amplitudes between 1 mV and 7 V are obtained using a 16-range programmable attenuator. Nearly continuous amplitude adjustment is possible by adjusting the MDAC reference dc voltages using the amplitude DAC. The signal frequency is set using an on-board frequency synthesizer module. Amplitude, frequency, and waveform functions are all programmable through the General Purpose Interface Bus (GPIB).

At low clock frequencies, it is possible to measure the dc voltage of each of the waveform steps. Commercial digital multimeters (DMMs) are available that have dc voltage linearity better than ±1 ppm, and sufficient stability to maintain a ±1 ppm calibration for a few hours. Thus it is possible to measure the step voltages V_i to an uncertainty of about ±1 ppm of full scale. The rms value V_{rms} of the DSS output voltage is given by:

$$V_{rms} = \left[\sum_{1}^{N} V_i^2 / N\right]^{1/2},$$

where N is the total number of steps per period.

[1]Electricity Division, Electronics and Electrical Engineering Laboratory, Technology Administration, U.S. Department of Commerce. Official contribution of the National Institute of Standards and Technology; not subject to copyright in the United States.

Low-Frequency Measurements

The calculated rms value of the DSS agrees with the rms value measured using thermal voltage converter (TVC) standards to better than ±5 ppm (2σ) in the 50 Hz to 1 kHz range. The amplitude flatness below 50 Hz down to 0.1 Hz and lower is expected to be even better. The short-term amplitude stability and temperature coefficient are on the order of ±1 ppm, so the DSS is an excellent tool to probe the low-frequency performance of TVCs and DMMs.

To demonstrate this, measurements between 1 Hz and 50 Hz were performed at 7 V on a single junction TVC (TVC_S), a multijunction TVC (TVC_M), an electronic sensing TVC (TVC_E), a DMM that measures ac voltage using a log/antilog rms converter (DMM_L), and a DMM that uses waveform sampling (DMM_S). The difference between the low-frequency errors of the device under test (DUT) and those measured at 50 Hz are given in the Table below.

Low-Frequency Errors Relative to 50 Hz (in ppm)

DUT	Frequency (Hz)				
	1	**2**	**5**	**10**	**20**
TVC_S	*	*	160	20	6
TVC_M	*	240	30	1	1
TVC_E	*	*	*	120	18
DMM_L	5	3	2	0	1
DMM_S	-3	-3	-3	-2	-1

* >1000 ppm

Conclusion

A programmable DSS, with amplitude flatness to within a few ppm, has been developed for use as a low-frequency voltage standard. It has been used as an ac-dc transfer standard to characterize TVCs and DMMs below 50 Hz.

References:

1. J.R. Kinard and L.A. Harris, "Impedance comparator using digitally generated sinewaves with accurate phase relationships," *Electron Lett.*, vol. 10, no. 9, pp. 146-147, 1974.

2. N.M. Oldham, P.S. Hetrick, and X. Zeng, "A calculable, transportable audio-frequency ac reference standard," *IEEE Trans. Instrum. Meas.*, vol. IM-38, pp. 368-371, 1989.