Mathcad and Agilent BenchLink Generate Multisine Test Functions

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Purpose:

1. To study numerical signal synthesis and analysis in practice.
2. To show the difference between real and simulated measurements.
3. To show how Mathcad files can be combined with Agilent BenchLink

Description:

Linking software files between Agilent's BenchLink and MathSoft's Mathcad[1] can result in a very powerful analysis/synthesis technique. This experiment will examine the use of Mathcad to create a parabolic-phase signal, which is then loaded into the arbitrary waveform generator via Agilent BenchLink software.

Equipment:

- Agilent 33120A Function/ARB generator
- Agilent 54600-series oscilloscope with FFT (and GPIB) option
- Personal computer with GPIB card & cables
- Agilent 34820A BenchLink/Suite Software (Consists of Agilent 34810B BenchLink/Scope + Agilent 34811A BenchLink/Arb +Agilent 34812A BenchLink/Meter)
- Mathcad ® (MathSoft Inc.) Software (see Note)

Procedure (see Fig 1):

It is possible to analyze the performance of a DUT (Device Under Test) by examining its response to well-designed test signals. In this case, we will generate a comb of frequencies in order to see the DUT's response over its entire bandwidth. This is a convenient way to test the DUT using only one signal. Digital synthesis and analysis techniques are the powerful tools that make it possible (**Fig. 1**):

1. **CREATE** a waveform numerically by using Mathcad[1] software.
2. Transfer that waveform in a file to the **Agilent 34811A** BenchLink/Arb Software
3. Download the waveform to the **Agilent 33120A** Function/ARBitrary Waveform Generator and **GENERATE** the signal.
4. **MEASURE** the system response using the **Agilent 54602B** Digitizing Storage Oscilloscope with a plug-on **Agilent 54657A (FFT/GPIB)** Measurement/Storage Module, and capture the screen data with **Agilent 34810B** BenchLink/Scope software.

[1][Note: Mathcad is a trademark of Mathsoft Corporation.]

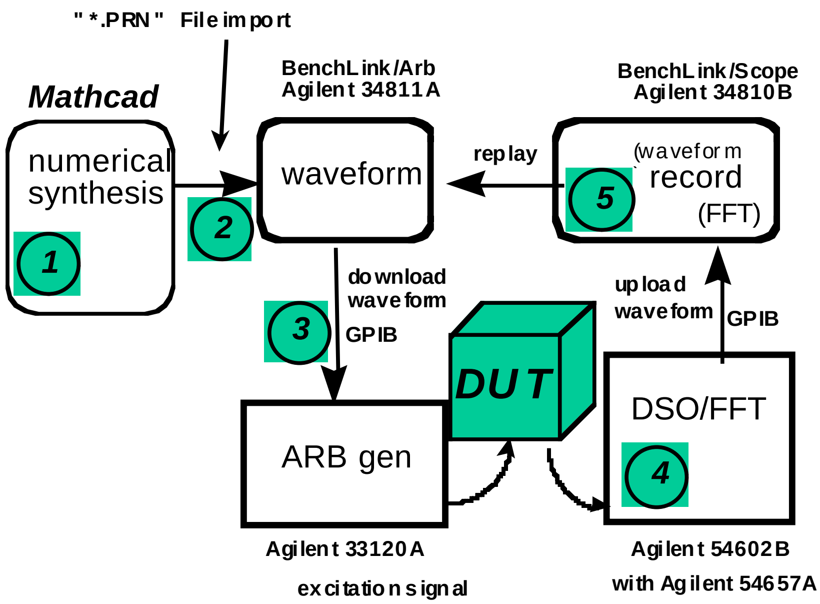


Fig. 1: Experiment Setup

Experiment:

Part I: Synthesize the test signal with Mathcad:

Generate a **comb of tones** over the desired bandwidth, making possible system characterization with one measurement. To use the system's dynamic range efficiently and to improve quantizing error, use **parabolic phase to minimize the crest-factor** of the multisine waveform. **(***Reference:* S. Boyd, "Multitone Signals with Low Crest Factor" IEEE Trans on Circuits and Systems, Vol. CAS-33, No. 10, Oct. 1986, 1018-1022.**)**

See Fig 2 for the Mathcad parameters:

> **Create** waveform (R, "*.PRN" file) with Mathcad:
> num = **10** tone comb with m = **8000** sample points,
> and *simulate* DSO/FFT (with hanning window):
> b = **7.5** effective bits and N = **1024** sample points
>
> *Note:* Amplitude must be normalized to take advantage of full ARB resolution.

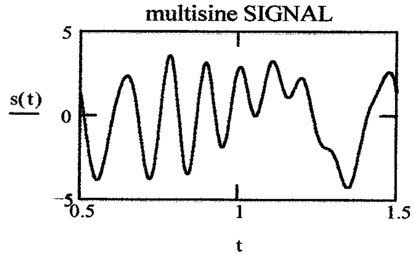
Exercise: Compare multisine signal with and without crest-factor minimization.

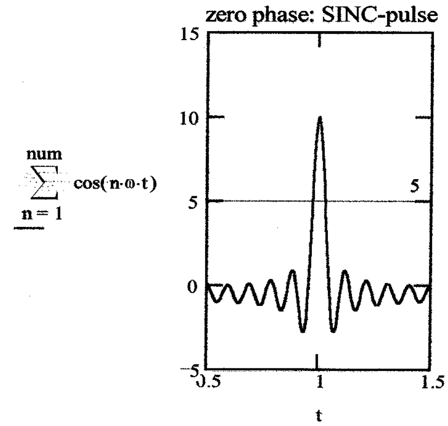
Parabolic Phase Minimizes Crest-Factor of Multisine *(Mathcad)*

$num := 10 \qquad f := 1 \qquad \omega := 2\cdot\pi\cdot f \qquad t := 0.5, 0.505 .. 1.5$

Time domain:

$$s(t) := \sum_{n=1}^{num} \cos\left[n\cdot\omega\cdot t - \frac{\pi}{num}\cdot\left(n^2 - 1\right)\right]$$





Frequency domain [simulation of DSO/FFT]:

$N := 1024 \qquad i := 0 .. N - 1 \qquad To := 0.5 \qquad Tv := 39.3 \qquad \Delta t := \frac{Tv - To}{N}$

ENOB(Effective No.Of Bits) of DSO: $b := 7.5 \quad D := 2^b$

digitizing: $ms_i := s(To + i\cdot\Delta t) \qquad Hi := \max(ms) \qquad Lo := \min(ms)$

$$ns_i := \left(ms_i - \frac{Hi + Lo}{2}\right)\cdot\frac{2}{Hi - Lo} \qquad \max(ns) = 1 \quad \min(ns) = -1 \qquad ds_i := \frac{\text{floor}\left(\frac{D}{2}\cdot ns_i + 0.5\right)}{\frac{D}{2}}$$

hanning:

$$w_i := 1 - \cos\left(\frac{2\cdot\pi}{N}\cdot i\right) \qquad han_i := w_i\cdot ds_i$$

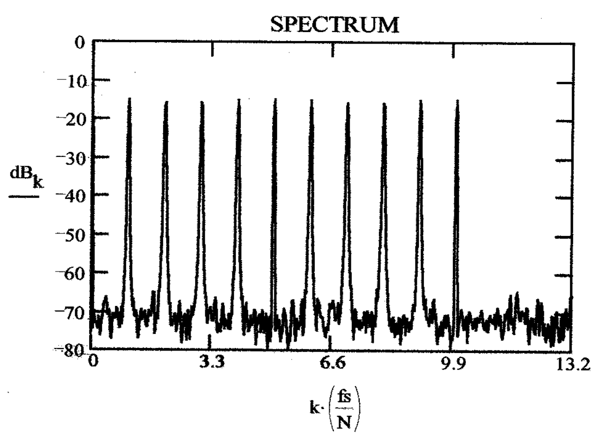
fft:

$c := \text{FFT}(han) \qquad M := \text{last}(c) \qquad k := 0 .. M$

sample rate:

$$fs := \frac{1}{\Delta t} \qquad fs = 26.4$$

$$dB_k := 20\cdot\log\left(\sqrt{2}\cdot\left|c_k\right| + 10^{-4}\right)$$



Waveform ["*.PRN" file]:

$m := 8000 \qquad j := 0 .. m - 1$

$$R_j := s\left(0.5 + \frac{j}{m}\right) \qquad HI := \max(R) \quad LOW := \min(R)$$

$$R_j := \left(R_j - \frac{HI + LOW}{2}\right)\cdot\frac{2}{HI - LOW}$$

WRITEPRN(*) := R

Fig. 2: Mathcad creates waveform and computes spectrum

Part II: The real measurement

Import the Mathcad "*.PRN" file with BenchLink/ARB, download it into the Agilent 33120A Function/Arb Gen. and **generate** the waveform at **1** kHz base frequency. (Remember, the Arb treats the entire downloaded waveform as a single cycle, so when the Agilent 33120A Arb's frequency is set to 1kHz, it is repeating everything in the Mathcad waveform window 1000 times per second.) Then **measure** the signal vs. time and show its frequency spectrum with the Agilent 54602B DSO. (See examples in Figs 3a and 3b.)

Exercise: Compare the simulated and directly measured spectra.

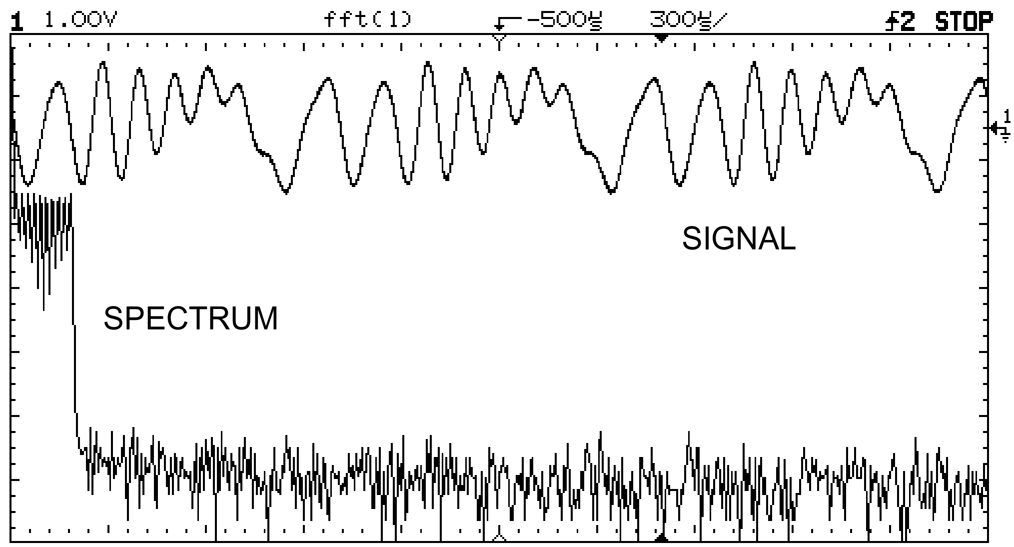


Fig. 3a: Measuring multisine signal and spectrum

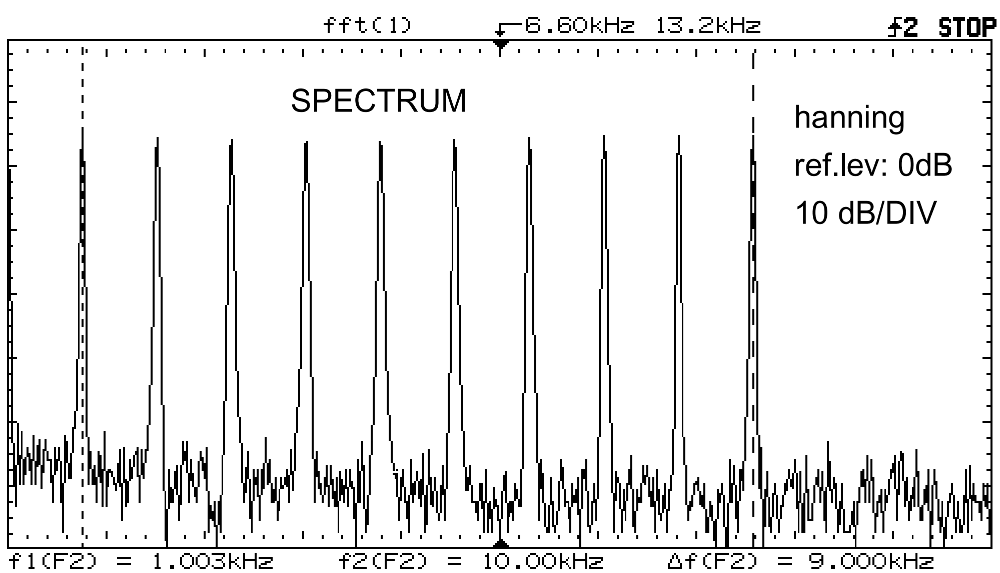


Fig. 3b: Comb of tones ("zoom" spectrum of Fig. 3a)