The Fundamentals of Mixed Signal Testing

Course Information

The *Fundamentals of Mixed Signal Testing* course is designed to provide the foundation of knowledge that is required for testing modern mixed signal devices using ATE equipment.

Many engineers are intimidated when confronting mixed signal test for the first time. However, the percentage of VLSI and SOC devices containing analog functions, data converters, DSPs, and similar circuits continues to grow. No longer a specialty or niche, mixed signal technology has entered the mainstream.

The Course

The course first introduces the instrumentation of a Mixed Signal Test System, with emphasis on the DSP (digital signal processing) capabilities. Ample time is spent explaining the mathematics necessary to fully understand signal sampling and waveform synthesis. Specifications for mixed signal devices are discussed and the method of verifying each individual parameter is explained in detail.

The testing of Digital to Analog and Analog to Digital converters is covered step by step including device conditioning, analog filtering, grounding issues and noise effects. These details are fundamental to most all types of mixed signal circuits. Practical aspects of test development and debug are also discussed.

To insure that each student gains a complete understanding of the concepts presented, virtual test instrumentation is used. Laptop computers play an essential role during the class to provide actual "hands on" lab experience. The labs demonstrate the principles of sampling, Fourier series, sinusoidal waveforms, FFT/DFT/Inverse Fourier transforms, signal generation and other mixed signal testing concepts. Each student receives a personal copy of the DSP Lab software, which can be kept for later use and a 300+ page reference manual titled "Fundamentals of Mixed Signal Testing".

Who Should Attend

Test and Product Engineers, Engineering Managers and Sales Engineers have all benefited from this course – it is the logical follow-on to Soft Test's *Digital Test Technology* class. In addition, Design, Verification, and DFT Engineers find these courses to be a valuable resource for bettering their understanding of the IC test process.

When & Where

Soft Test offers training services at our Sunnyvale, CA facility on a regular basis and we can also offer on-site training at your facility. Give us a call for additional information and class schedules or visit our web site at **www.soft-test.com**.

The Cost

Tuition is $2,000 per attendee and includes all course material including the *Fundamentals of Mixed Signal Testing* text and the *DSP Lab Software* diskette. Contact Soft Test for on-site pricing.

Class Registration

Registration forms are available on our web site or contact the West Coast sales office at 408.377.1888. For technical questions please call our East Coast office at 386.478.1979. Email inquires to **admin@soft-test.com**.

Summary

Mixed Signal Test Engineering demands more math, theory, and rigor than its digital counterpart. Attending this class helps cut through the confusion and gives you the tools you need to create, work with, and *understand* mixed signal tests. There is a better way. Now you can jump start your educational process and receive what can take years of on-the-job training in just one week.

There's More

Please visit our web site at **www.soft-test.com** for additional information on this course. Soft Test also offers technical training and publications for Digital Test, Memory Test and a variety of subjects related to the semiconductor industry.

The Fundamentals of Mixed Signal Testing

Course Content

Course Length: 5 days

Purpose

This course is designed to explain the concepts and techniques used in testing mixed signal semiconductor devices with automated test equipment (ATE). Practical information is presented pertaining to test program development, debugging techniques and test result interpretation. Static, Dynamic and AC tests are discussed in detail. Digital-to-Analog Converters (DAC) and Analog-to-Digital Converters (ADC) are used as sample devices to develop a full suite of test techniques for use with any mixed signal device.

Our Goal

Our goal is to provide useful, practical information that will quickly improve the skill set required to be a productive Test, Product or Applications Engineer. We present an environment where questions and interactions are welcome and everyone is treated with respect regardless of their experience level.

Content

The course information presented includes the following:

- Introduction to Mixed Signal Testing and the Components of a Mixed Signal Test System
- The Mathematical Basis of Digital Signal Processing
- Principles of Analog Signal Theory
- Static Parameters Testing of a DAC
- Static Parameters Testing of an ADC
- Sampling theory and how to correctly sample an analog signal
- Dynamic Parameters Testing of a DAC
- Dynamic Parameters Testing of an ADC
- Creating Analog Signals with a Waveform Generator
- DUT Connections to Reduce Analog and Digital Signal Interference
- How to Use Analog Filtering and Other Signal Conditioning
- Typical DSP Algorithms and When and How to Use Them
- Extracting Test Measurements from Sampled Data and Relating Them to Device Specifications

Distribution Materials

The *Fundamentals of Mixed Signal Testing* text, *DSP Lab Software* diskette, and all classroom materials are provided with the course

Prerequisites

Students should have completed the Soft Test *Digital Test Technology* class or have equivalent experience. Prior exposure to engineering mathematics is assumed.

The Fundamentals of Mixed Signal Testing

Course Syllabus

Overview of Mixed Signal Testing

- Digital Signals
- Digital Test Systems
- Analog Signals
- Traditional Analog ATE
- Mixed signal devices
- Mixed Signal Test Systems
- Waveform Digitizer
- Waveform Generator
- Digital Signal Processor

The Mathematics of DSP

- Logarithms and exponents
- Decibels (dB)
- Time and Frequency
- Periodic Motion
- Root-Mean-Square Calculations
- Time to frequency translation
- Fourier series
- Dirichlet conditions
- Complex numbers
- Conversion between polar and rectangular

Basic Device Specifications

- Digital Devices
- Analog Devices
- Input Offset Voltage
- Input Bias Current
- Input Offset Current
- Common Mode Rejection
- Power Supply Rejection
- Gain Bandwidth
- Noise
- Harmonic Distortion
- Signal-to-Noise Ratio
- Slew Rate
- Settling Time
- Filter Specifications

The Fundamentals of Mixed Signal Testing
Course Syllabus

Digital to Analog Converter Static Parameters
- DAC Static Specifications
- Resolution
- Gain and Offset
- Differential and Integral Non-Linearity
- Least Significant Bit
- Monotonicity
- Test System Configuration for DAC Static Parameter Tests
- Example DAC Data Sheet
- DAC Architecture Considerations
- Fast Measurement Techniques

Analog to Digital Converter Static Parameters
- ADC Static Specifications
- LSB Size
- Full Scale Range
- Offset and Gain
- Code Transitions and Code Widths
- Differential and Integral Non-Linearity
- No Missing Codes
- Transition Noise
- Segmented Ramp
- Test System Configuration for ADC Static Tests
- Example ADC Data Sheet
- Unique ADC Testing Issues
- Histogram Testing for DNL and INL
- ADC Architecture Considerations

Sampling
- Limits of Sampling
- Shannon's theorem
- Nyquist's theorem
- Periodicity
- Converting a time sample set to frequency
- Discrete Fourier transform (DFT)
- Fast Fourier transform (FFT)
- Spectral replication and Aliasing
- Prevention of aliasing errors
- Leakage
- Time sample windowing
- Coherent Sampling
- Coherency relationships
- Fs, N, Ft and M
- UTP, Fourier Frequency, frequency bins and resolution
- The Inverse FFT (IFFT) algorithm

The Fundamentals of Mixed Signal Testing

Course Syllabus

Digital to Analog Converter Dynamic Parameters

- Measuring SINAD, THD, SNR, IM
- Generating the DUT output signal
- Calculating the desired output signal as an array of points
- Using a sine wave equation
- Using an Inverse FFT
- What to do with the list of codes
- Filtering the output signal
- Using a Waveform Digitizer to capture the DAC output
- Conditioning the analog signal for the waveform digitizer
- Digitizing the (filtered) analog signal
- Calculating the result parameters
- Creating a Spectral Graph
- Synchronization Issues

Analog to Digital Converter Dynamic Parameters

- Dynamic parameters
- Creating an input signal
- Adjusting for zero and full scale
- Input signal filtering
- Acquiring and holding the input signal
- An ADC with no track and hold
- Adding track and hold
- Dynamic impedance problems
- Capturing the digital output data
- Coherent sampling revisited
- Undersampling
- SINAD, THD, and SNR
- Intermodulation Distortion
- DUT noise, system noise and averaging
- Effective Number Of Bits (ENOB)
- Sparkle Codes
- Sine Histogram Technique

General Mixed Signal Test Issues

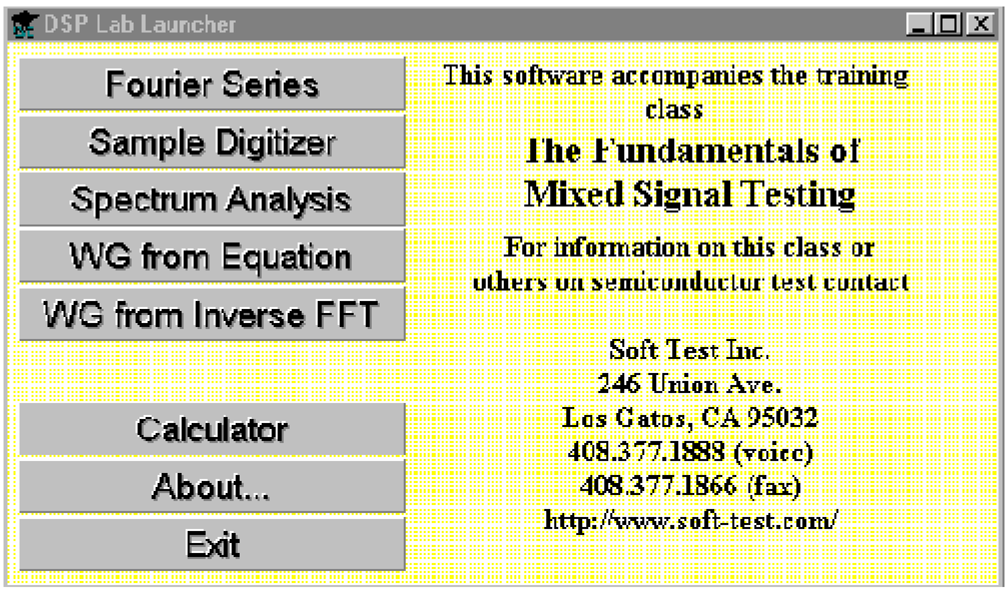
- Does the measurement reflect the conditions of the DUT or the test system?
- Noise in the test environment
- Amplifiers amplify noise too
- Ground Issues
- Current Paths
- Power Supplies
- Reference Signals
- Averaging and Repeatability
- Troubleshooting
- War Stories

Soft Test

The Fundamentals of Mixed Signal Testing

DSP Lab Software

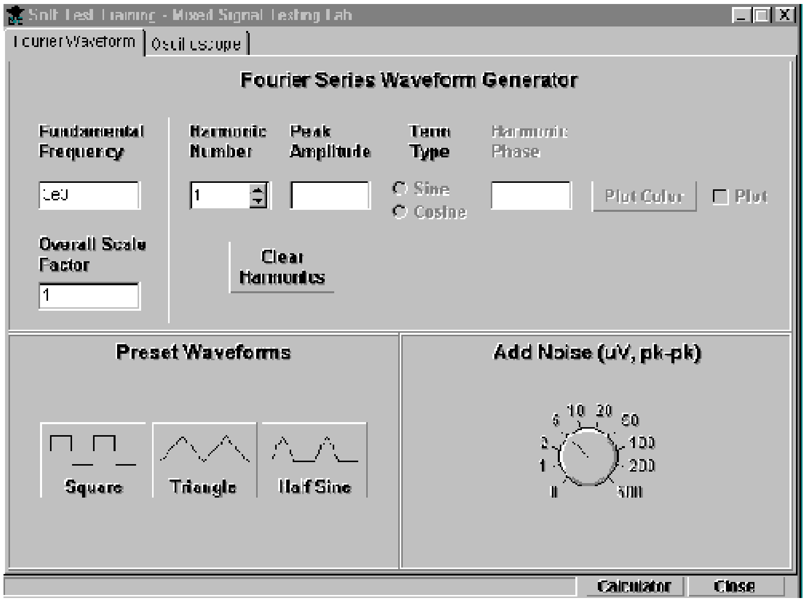
The *DSP Lab Software* consists of a set of Virtual Test Instruments designed specifically for Soft Test's *Fundamentals of Mixed Signal Testing* course. The DSP Lab software is included with the ***"Fundamentals of Mixed Signal Testing"*** textbook, and is used to provide a hands-on programming experience throughout the training class. It helps the student visualize the concepts associated with waveform generation, signal sampling and signal analysis.



The Microsoft Windows-based software allows the student to perform interactive laboratory exercises which demonstrate the principles of Sampling, Fourier Series, Sinusoidal Waveforms, Fast Fourier Transforms, Inverse Fourier Transforms, Signal Generation and other mixed signal testing concepts.

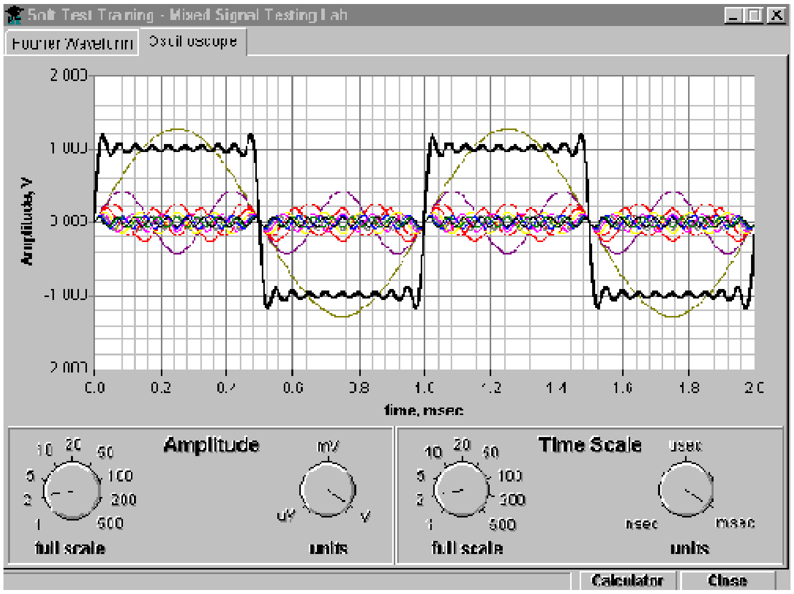
Note: The screen images appear distorted because they have been resized to fit this document.

Fourier Series



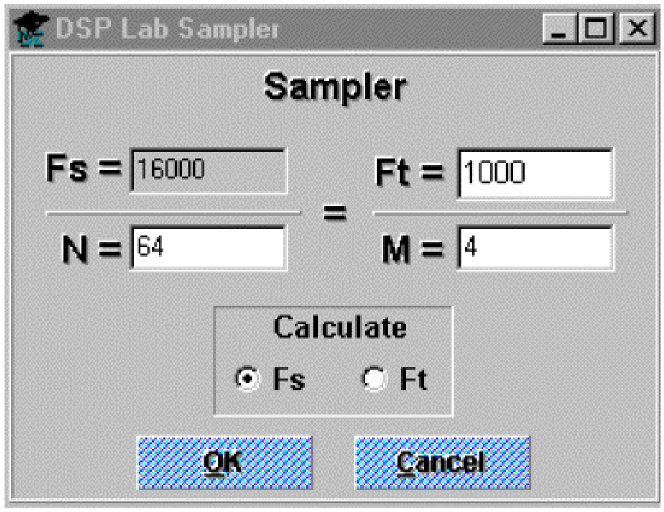
The Fourier Series function is used to create sine waves of various frequencies. Harmonics and noise can also be added to the signal. Several predefined signals are also available for analysis. Once a signal is defined it can be viewed via the Oscilloscope.

The Oscilloscope Showing a Square Wave



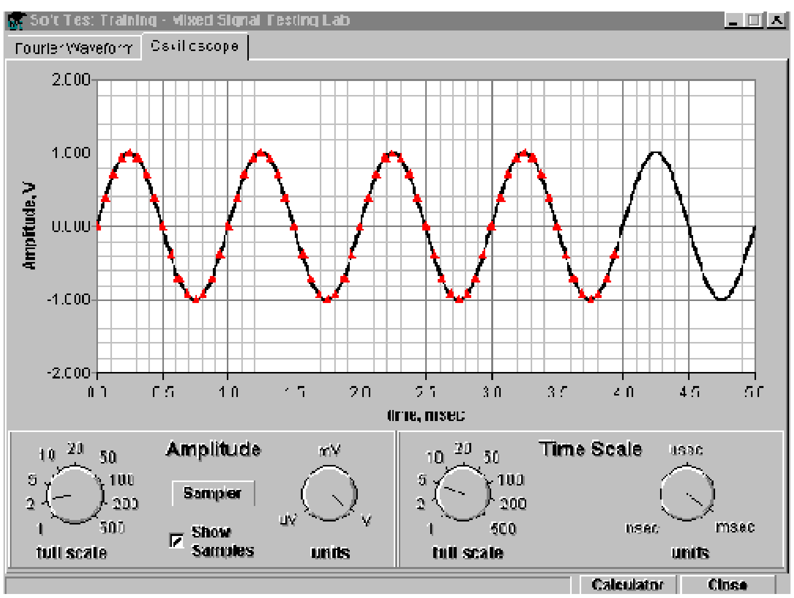
The Oscilloscope is available for viewing waveforms. In this example a 1 KHz square wave is shown. Notice the fundamental and each harmonic frequency is shown in a unique color.

The Sampler



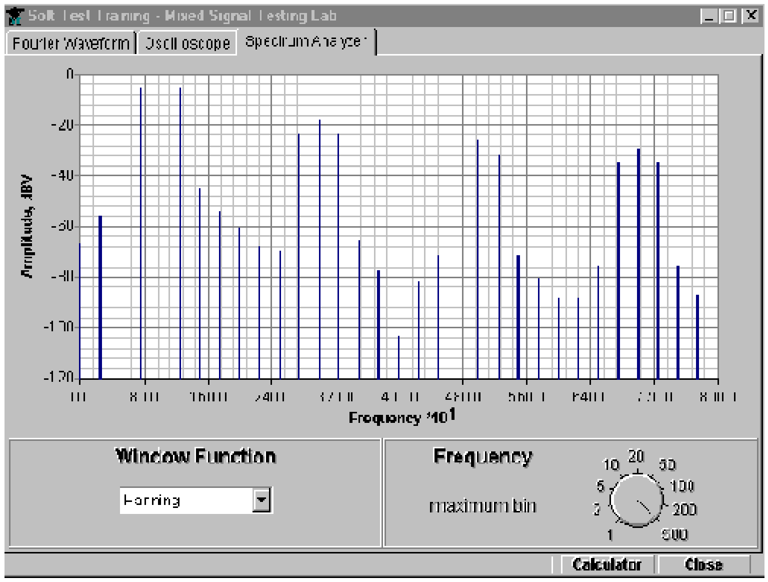
Signal sampling is an important step in the process of mixed signal testing. The Sampler function is designed to allow the user to experiment and visualize results, via the Oscilloscope.

The Oscilloscope Showing Sample Points



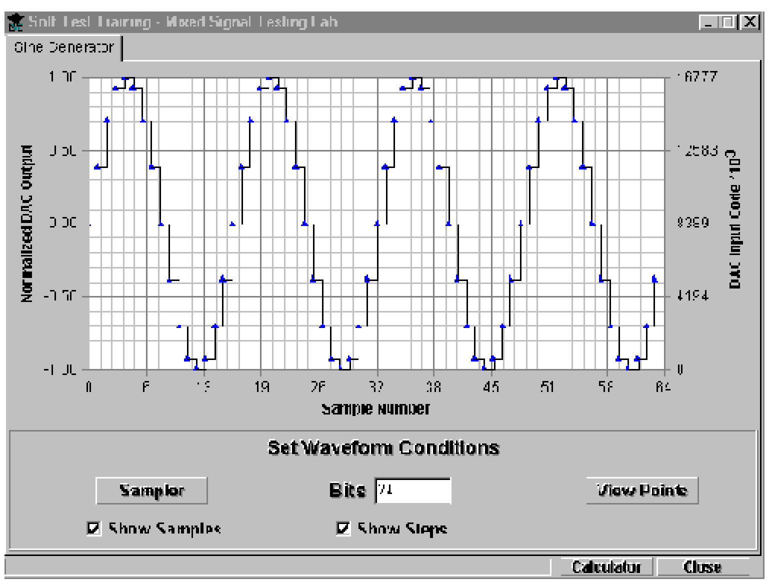
This example shows the Sample Points for a 1 KHz sine wave, as defined above in the Sampler Window.

The Spectrum Analyzer



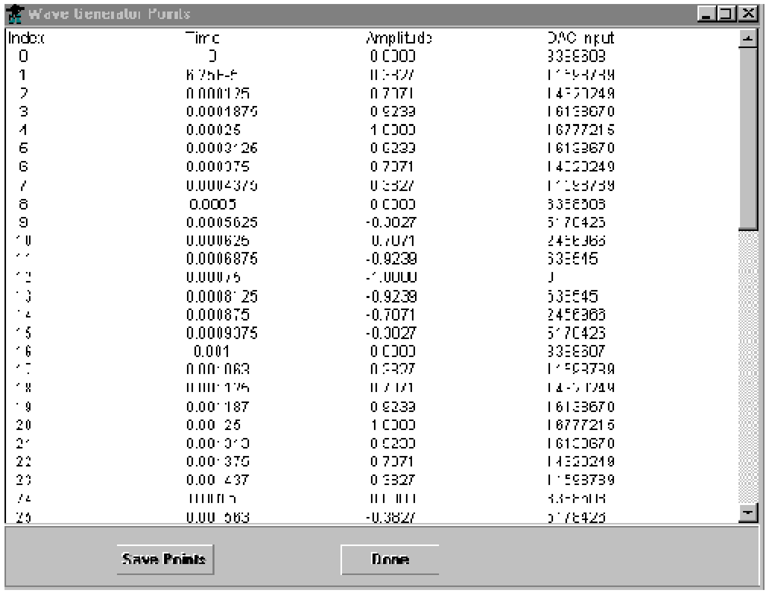
The Spectrum Analyzer displays signal data in the frequency spectrum. When used in conjunction with the Oscilloscope, a signal can be viewed in both the Time and Frequency domains. This instrument also illustrates the effects of various windowing functions.

The Sine Generator



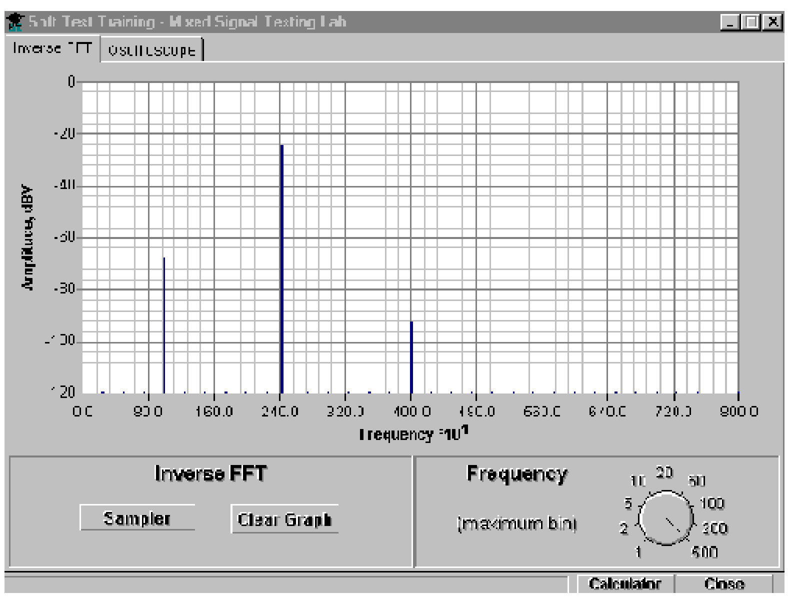
Signal generation is an important step in the process of mixed signal testing. The Sine Generator is designed to allow the student to experiment with sine wave creation. This activity is similar to using the Arbitrary Waveform Generator of a mixed signal test system.

Waveform Generation Data Points



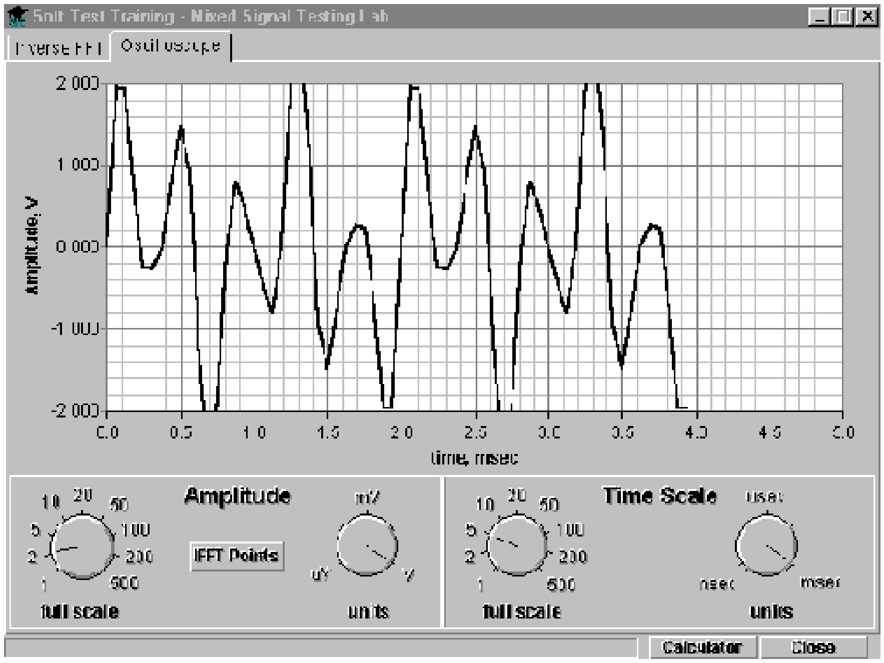
During the signal generation process the data points used to create a waveform can be written to a file. This data can be compared to the data points shown in the Sine Generator window. This example shows data points used to construct the signal as seen in the Sine Generator Window.

The Inverse FFT



The Inverse FFT function offers a means of creating a signal via the frequency spectrum, then viewing the results in the time spectrum using the Oscilloscope

The Oscilloscope Showing IFFT Waveform



The frequency data defined in the Inverse FFT function above is displayed in the time domain using the Oscilloscope.

Summary

Many engineers find the DSP Lab software a very effective aid in understanding the complex issues associated with signal generation, signal sampling and signal analysis. It allows the user to experiment with various test concepts and methods in a safe environment and it eliminates the need for expensive test system time. This software is included with the textbook *Fundamentals of Mixed Signal Testing* distributed in the training class, or it can be purchased separately.

The Fundamentals of Mixed Signal Testing

If you miss more than 3, you are a good candidate for the Fundamentals of Mixed Signal Testing class.

1. The term "resolution" is typically used to describe which of the following DAC characteristics?
- ***a)*** Voltage Range
- ***b)*** Accuracy
- ***c)*** Number of Bits
- ***d)*** Maximum Clock Frequency

2. The sine of an angle in a right triangle is the ratio of sides given by:
- ***a)*** Opposite over adjacent
- ***b)*** Opposite over hypotenuse
- ***c)*** Adjacent over hypotenuse
- ***d)*** Adjacent over opposite

3. Sampling can be used to get information about all of the following ***except***:
- ***a)*** Signal Amplitude
- ***b)*** Nyquist frequency of a signal
- ***c)*** Magnitude of a signal at various frequencies
- ***d)*** Phase of a signal at various frequencies

4. What is the "Fourier Frequency"?
- ***a)*** The highest frequency component of a frequency spectrum
- ***b)*** The lowest frequency component of a frequency spectrum
- ***c)*** The frequency of interest in a frequency spectrum
- ***d)*** The frequency resolution of a frequency spectrum

5. Time Windowing functions can be used to reduce:
- ***a)*** Aliasing
- ***b)*** Spectral leakage
- ***c)*** Distortion
- ***d)*** Quantization error

6. The following is a requirement for coherent sampling:
- ***a)*** A high bandwidth waveform digitizer
- ***b)*** An integer number of signal cycles
- ***c)*** Samples from more than one cycle of a signal
- ***d)*** A lowpass filter

7. A filter's "3dB point" is:

a) The frequency at which the signal is completely attenuated

b) The frequency at which the signal is not attenuated at all

c) The frequency at which half the signal power is attenuated

d) The frequency at which half the signal voltage is attenuated

8. Which of the following is ***not*** a Differential Nonlinearity test method for Analog-to-Digital Converters?

a) Servo Loop

b) Segmented Input Ramp

c) Histogramming

d) Thermal Tail

9. A DAC LSB is calculated as:

a) (Full scale output - zero scale output) * (2^{bits} - 1)

b) (Full scale output - zero scale output) / (2^{bits} - 1)

c) (Full scale output - zero scale output) / 2^{bits}

d) (Full scale output / bits)

10. A Sine Histogram test is often used to:

a) Find superposition problems with R/2R DACs

b) Find distortion problems with sigma-delta ADCs

c) Find noise problems with partially decoded DACs

d) Find sparkling problems with flash ADCs

11. Pi radians equals:

a) 45°

b) 90°

c) 180°

d) 360°

12. A low pass filter with 6 poles has a voltage roll-off of:

a) 36dB per decade

b) 120dB per octave

c) 120dB per decade

d) 6dB per octave

13. A value of 80dB represents a ratio in volts of

a) 10000 : 1

b) 80 : 1

c) 8 : 1

d) 4 : 1

14. The frequency resolution of a spectrum, FF, is given by:

a) M / F_t

b) N / F_s

c) 1 / UTP

d) All of the above

15. The Fast Fourier Transform uses how many calculations?

a) N^2 calculations

b) (N / 2) $\log_2$ N

c) (N / 2) $\log_{10}$ N

d) (N) $\log_2$ N

16. For a given F_t and F_s, what is the effect of increasing M?

a) The number of samples N is decreased, leading to lower frequency domain resolution

b) The number of samples N is increased, leading to higher frequency domain resolution

c) The Unit Test Period is decreased, leading to lower test time

d) The Fourier Frequency is increased, leading to higher noise measurements

17. What is a "sparkle code"?

a) A glitch in a DAC's output due to superposition error

b) A glitch in an ADC's output due to superposition error

c) A glitch in an ADC's output due to illegal states in the output decoder

d) A glitch in a DAC's output due to major carry transitions

18. A device LSB for an ADC is calculated from the:

a) Zero and full scale measurements

b) Gain measurement

c) Zero and full scale transition measurements

d) Datasheet

19. When using the histogram method to test an ADC, "average hits per code" is analogous to:

a) Total number of samples taken

b) DNL

c) Device LSB

d) Tester LSB

20. To use a 12-bit waveform digitizer to dynamically test a 14-bit DAC, you will probably need

a) Waveform generator

b) Notch filter

c) Phase locked loop

d) Bandpass filter

To check your answers please visit our web site – the direct link is

http://www.soft-test.com/mixanswers.html