



Simplifying A/D Converter Evaluation

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Good day, everyone. We believe that you will find this presentation helpful both from a standpoint of understanding constraints when evaluating A/D converters and in understanding some of the things that National has to help you with evaluating and selection of ADCs.



Agenda

- **Previous Evaluation Methods**
- **The Need for Something Different**
- **National Semiconductor's Response**
 - WaveVision3
 - WaveVison4
- **Sampling Inconsistency**
- **Windowing**
- **Getting Consistent Dynamic Performance**
- **Garbage In – Garbage Out**
 - ADC Input Filtering Needed for Evaluation
- **Portfolio Summary**



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This presentation will briefly mention some of the previous ADC evaluation methods and the need for something a bit more simple. Then we will discuss National Semiconductor's response to those needs and move on to some potential problem areas and how to address them. We will end with some brief information on our general purpose data conversion portfolio.



Previous Evaluation Methods

- **Use Logic Analyzer to capture data from Evaluation Board**
- **View Time & Frequency Domain Plots**
- **Get Data Into Third Party System**
 - **Logic Analyzer to 3rd Party System Interconnect**
 - **Floppy Disk Transfer**
 - **IEEE-488 Interconnect**
- **Jury-Rig Into Your Own Circuit**



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Prior to 1998, all suppliers of evaluation boards for ADCs provided boards that were intended for data capture with the aid of a logic analyzer or some other medium. In order to evaluate that data, it was necessary to use third-party solutions. Such systems allowed the user to view both time and frequency domain plots. The alternative was for the user to write his or her own program to analyze the data. Frequency domain plots are commonly called FFT plots or, somewhat inaccurately, FFTs.

Getting the data from the logic analyzer might entail transfer from one machine to another via floppy disk or in an interconnect such as the IEEE-488. Of course, the user could jury-rig his or her own circuit. Doing this was sometimes seen as a less expensive approach than obtaining the equipment otherwise needed, but this became more and more difficult as speeds increased and a new printed circuit board was really needed for each new device to be evaluated, making the jury-rig impractical. The obvious result is that third-party systems were the choice of many, if not most, of those who desired to evaluate ADCs.



The Need for Something Different

- **Third-Party Systems**
 - Too Expensive for Some
 - Systems are Large and Not Portable
- **An Inexpensive System Would Help Smaller Users**
- **A Portable System Could be Easily Moved**



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But third-party systems were expensive for those who did not have a need for extensive use of them and they were large enough that they must have their fixed place where they were used. An inexpensive system would be a solution that would greatly help the smaller users of ADC evaluation systems who could not afford the expense of third-party systems. Furthermore, a solution that could be used with a personal computer would capitalize on the fact that every business had PCs. The evaluation board itself, with its own ADC clock source, would be fairly small and the PC would provide the computing power and the display mechanism. The only other things needed were a laboratory generator, which all engineering laboratories have, and a filter between the signal source and the evaluation board itself.

The evaluation board would be connected to the PC by way of a serial port. Such a system would not only be small and inexpensive, but it could be very portable. Each PC that would use the system would have the software loaded.



National Semiconductor's Response

- **WaveVision Introduced (1998)**
- **Initially Served Three Product Families**
- **WaveVision2 and WaveVision3 Expanded Sample Rates & Improved Data Capture**
- **WaveVision4: Complete Redesign, More Functionality**



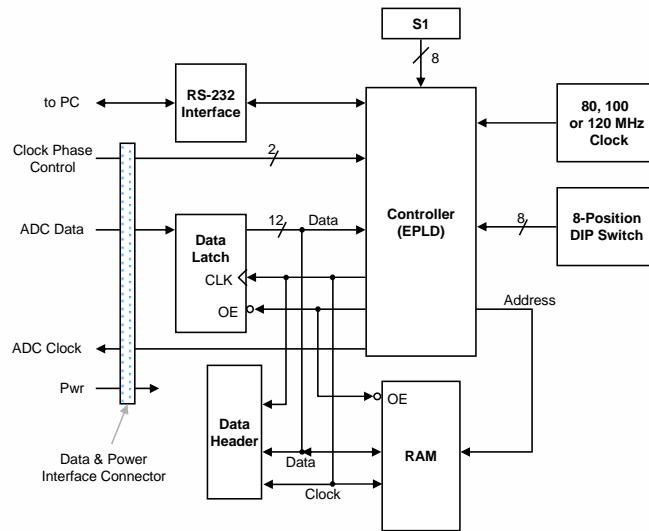
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In early 1998, National Semiconductor introduced the WaveVision package for evaluating analog to digital converters. This system consists of a data capture board, a DUT board, and software. WaveVision2, a software and firmware upgrade to the original WaveVision, and WaveVision3, another firmware upgrade, expanded the sample rates supported and improved data capture. Because WaveVision3 is only a firmware upgrade to the PLD involved, the WaveVision2 software is used with that WaveVision3 hardware.

WaveVision4 is a complete redesign with a lot of added functionality. Both the WaveVision2 and the WaveVision4 software are free and downloadable from our Web site.



WaveVision2/3 Capture System



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This block diagram of the WaveVision2/3 board shows the basic simplicity of the hardware. The complexity lies within the controller, an EPLD. Upon command from the PC, the system acquires data at the desired rate, up to 60 Msps, and stores it into an 8K RAM. When the RAM is full, the controller serializes the data and uploads it to the PC via RS-232 port. A DIP switch is used to tell the system clock frequency used and the clock divider for the ADC clock.



WaveVision2/3 Capabilities

- **Display of**
 - **Wave Form**
 - **FFT/DFT**
 - **Software Histogram**
 - **Dynamic Performance Parameters:
SINAD, SNR, THD, SFDR**
- **Click-and-Drag View**
- **Area View Selection**

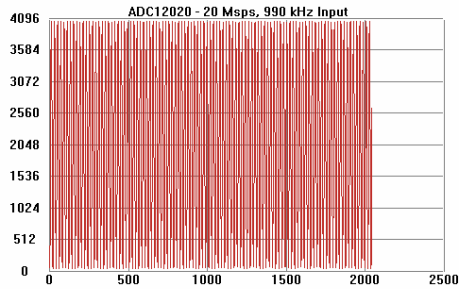


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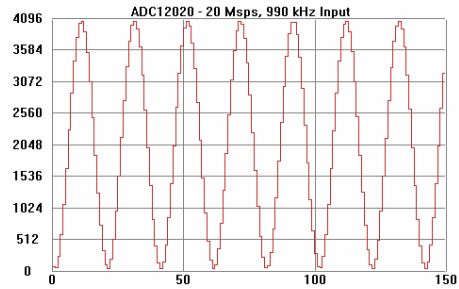
This system has the capability of providing displays of the captured waveform, an FFT or DFT plot of the data with a display of dynamic performance parameters, and a software histogram. With all of these displays the user may click and drag on it to display any desired portion of the display or a dialog box may be opened to describe what part of the display is to be zoomed in upon.



WaveVision3 Data Capture



Normal Display



Zoomed In Display

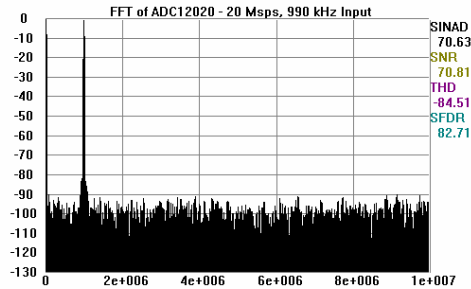


8

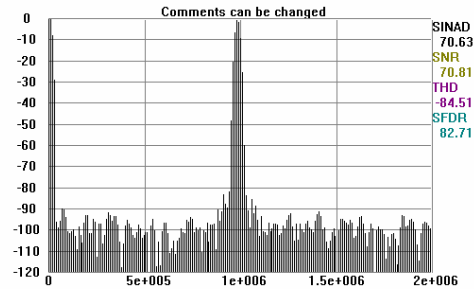
The default display is a plot of the captured data, as seen here on the left. Comments may be added to this data as shown here just above the plot. The user may click and drag across any portion of the display to examine it more closely as shown to the right.



WaveVision3 Frequency Domain Display



Normal Display



Zoomed In Display



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The frequency domain display is shown here on the left. The default comments for this plot is "FFT of" and then whatever the comments were on the time domain plot. These comments can be easily changed if desired. As with the time display, the user may click and drag across any portion of the plot to examine it more closely as again shown here to the right.



WaveVision2/3 Shortcomings

- **Only 12 Discrete Sample Rates:
(5 to 60 Msps)**
- **Manual Adjustment of Clock
Phase Control**
- **Not Easy to Locate Harmonics in FFT Plot**
- **No Support of Serial Interfaces**



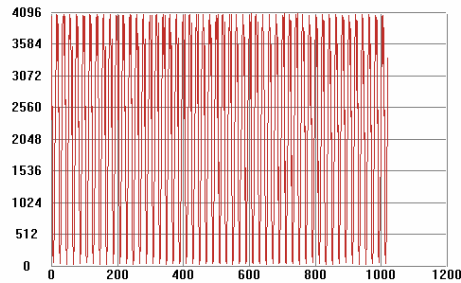
10

No system is perfect and inexpensive systems seem to have some things desired. While the shortcomings of this system were minor for some time, more recently the 60 Msps limitation became a serious one since we began introducing products with sample rates much higher than this, the foremost example being the 0.5 to 1.0 Gsps ADCs and the coming 1.5 Gsps ADC.

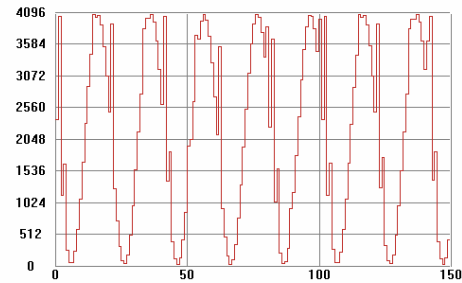
Other minor inconveniences were the fact that we had a manual clock phase adjustment and that locating the harmonics on the frequency domain plot was not easy. Additionally, the system did not support devices with a serial data interface or sample rates less than five Msps and we were about to introduce many new general purpose ADCs with serial interfaces.



Problem (Some Sample Rates)



Normal Display



Zoomed In Display

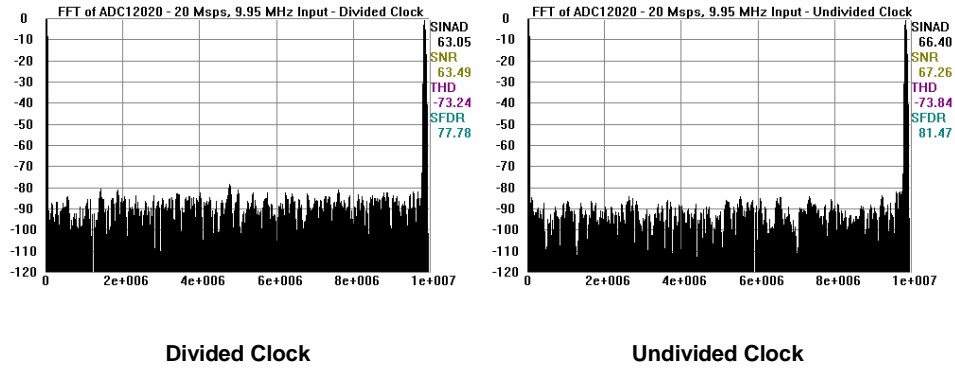


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At some sample rates, data capture is not as clean as it should be. This was remedied with two jumpers that could be used for adjustment of capture timing.



WaveVision2/3 Jitter Problem

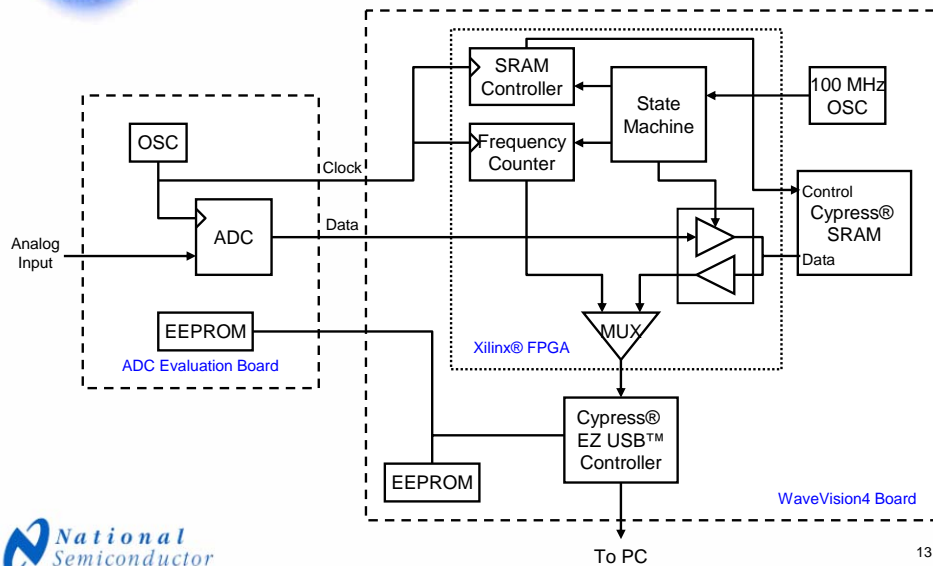


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Dividing the sample clock can improve clock jitter, if it is done correctly. However, dividing with circuitry that is not capable of toggling much faster than is demanded of it can increase clock jitter, resulting in degradation of SNR, as seen here, where SNR is 63 with the divided clock and 67 with the undivided clock.



WaveVision4 Capture System



This block diagram of the WaveVision4 board shows the basic simplicity of the hardware. Like its predecessor, upon command from the PC, the system acquires data at the desired rate, up to 150 Msp/s, and stores it into a 128K RAM, 16 times the depth of the previous system. When the required amount of samples have been taken, the controller serializes the data and uploads it to the PC via the USB port. The frequency counter and the USB controller eliminate the need for the DIP switch that was used with the previous system.



WaveVision4 Capabilities

- **Same Capabilities as WaveVision2/3**
 - **Display of**
 - **Wave Form**
 - **FFT/DFT**
 - **Software Histogram**
 - **Dynamic Performance Parameters:
SINAD, SNR, THD, SFDR**
 - **Click-and-Drag View**
 - **Area View Selection**
- **Many Enhancements over WaveVision2/3**



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WaveVision4 has the same capability as does WaveVision2 and 3 and then some, making it more user-friendly.



WaveVision4 Enhancements over WaveVision2/3

- **No Manual Adjustments**
 - Automatically Detects Clock Rate
 - Board Type Automatically Recognized
 - No Capture Timing Problem
 - Sample Rate Automatically Measured
- **No Addition of Jitter**
- **ENOB is Displayed**
- **Hardware Histogram**
- **Supports Virtually Any Sample Rate to 150 Msps**
- **Supports Serial Interfaces**
- **Highlights of Fundamental, Harmonics
and Highest Spur on Frequency Domain Plot**
- **Can Support the driving of DACs**

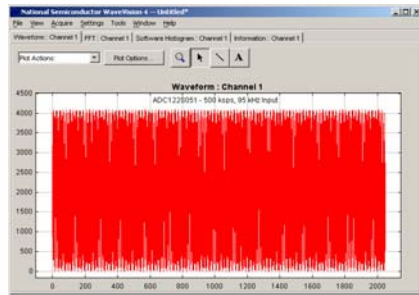


15

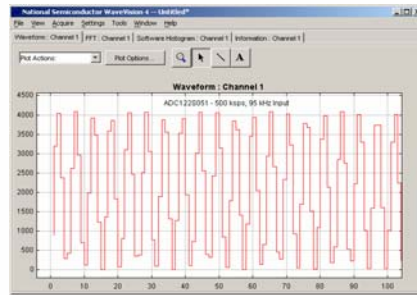
The manual adjustments in the form of the eight-position DIP switch and the clock phase control jumpers have been eliminated. There is no crude division of the sample clock to add jitter. We have added a display of ENOB, which is just a calculation based upon SINAD, and a hardware histogram capability. We can now support sample rates up to 150 Msps and serial interfaces. Critical frequencies are highlighted with a different color making them easier to locate and the system can be used to supply a digital word stream to DACs.



WaveVision4 Data Capture



Normal Display



Zoomed In Display

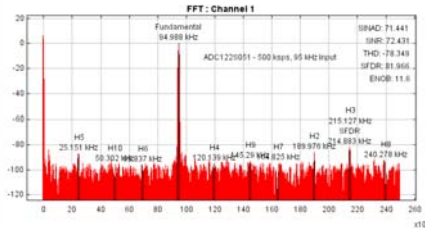


16

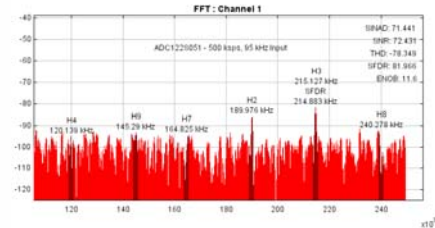
Here we see screen shots of a WaveVision4 data capture. On the left is the display as it appears upon data capture, plus there has been a comment added. The comment font size can be changed and the location of any comment is easily moved to anywhere desired within the display. To the right is a zoomed display to ease examination of portions of the time domain plot.



WaveVision4 Frequency Domain Plot



Normal Display



Zoomed In Display



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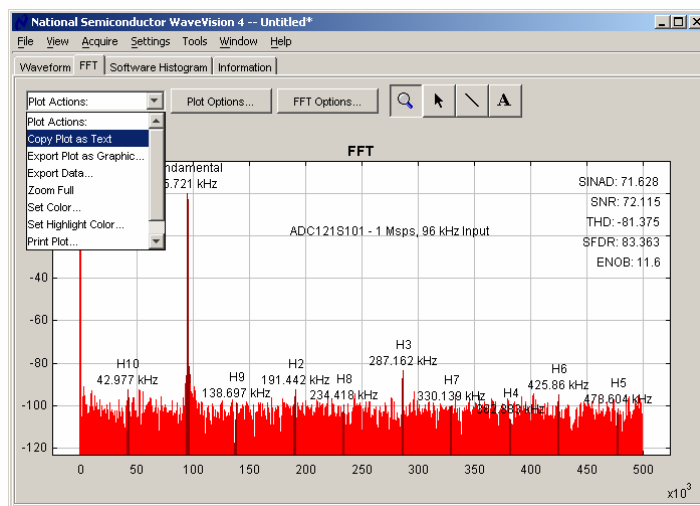
Here we see the active portion of a frequency domain. On the left is the normal display, to the right is a zoomed in portion of that display. This particular display indicates the performance of our ADC122S051 operating at 500 kpsps with a 95 kilohertz input frequency. This device is a dual 12-bit ADC that is fully specified for sample rates of 200 kpsps to 500 kpsps, but will function down to as low a sample rate as the user desired.

Now, let's look at the plot actions possible with this system



WaveVision4 Plot Options: Copy Plot as Text

Copies time and capture data to computer clipboard.



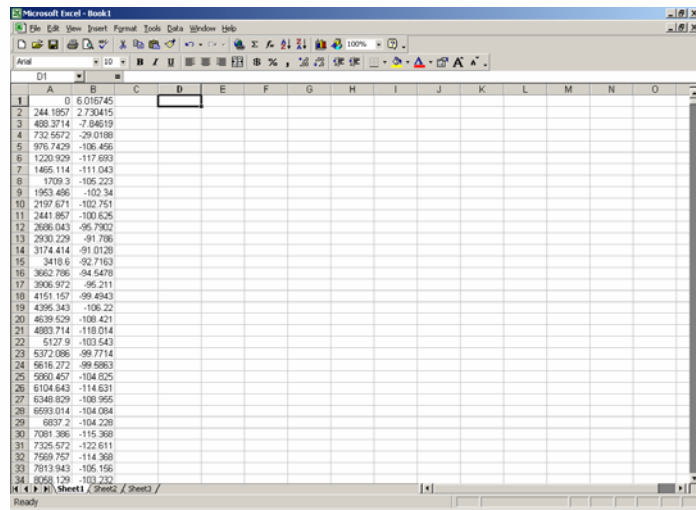
18

The "Copy Plot as Text" option copies time and captured data to the PC clipboard. The data is in two columns: time is in the first column and data in the second column. This data may be pasted into any application desired.



Pasting Plot Into Spreadsheet

First column is time, second column is individual data points.



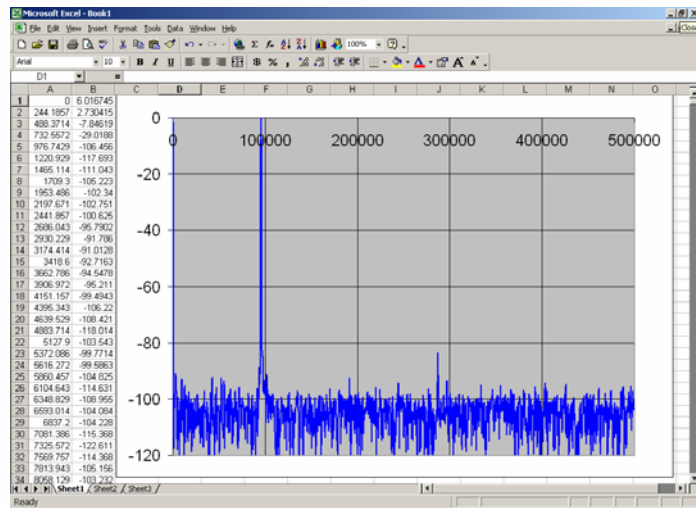
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Here we see the data from the previous slide pasted into a Microsoft Excel spreadsheet. In the spreadsheet, we can plot the data. We see here that the plot is virtually the same as obtained with the WaveVision4 software.



Plotting the Data in Excel

Excel plot
same as
WaveVision
plot.

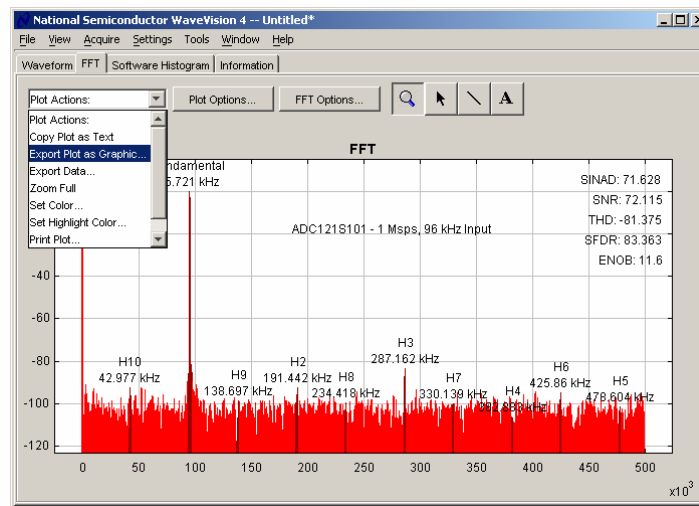


20



WaveVision4 Plot Options: Export Plot as Graphic

This graphic was saved with this action. Graphics are saved as .GIF



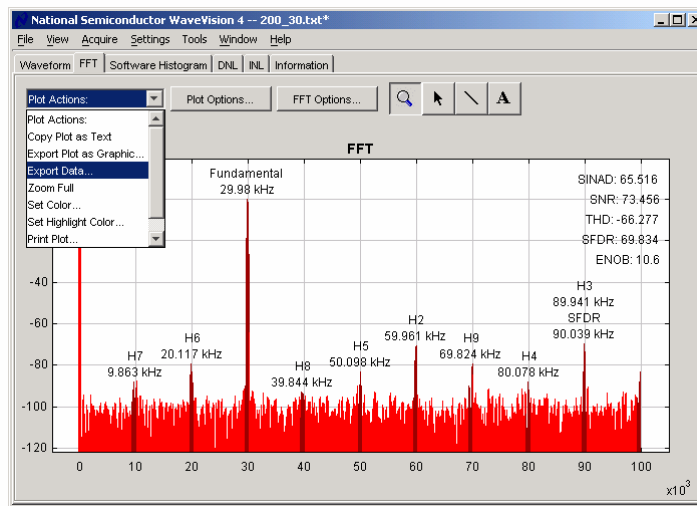
21

The next item is "Export Plot as Graphic." This action saves the plot area in GIF format.



WaveVision4 Plot Options: Export Data

“Export Data” saves the data as a .TXT file in the same format as does the “Copy Plot as Text” option.



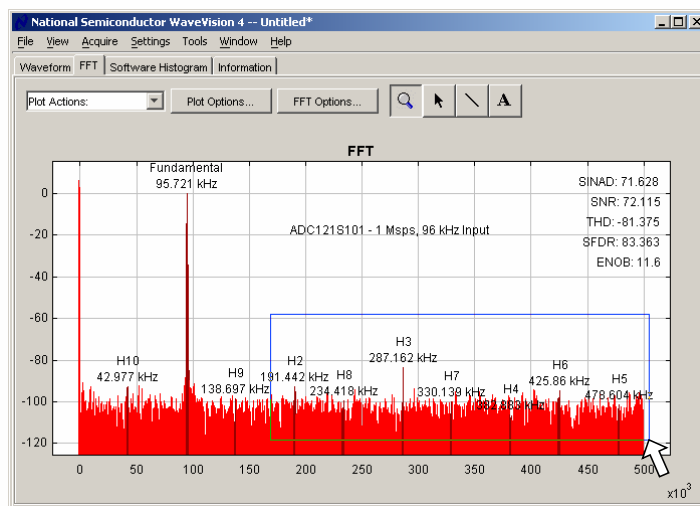
22

The “Export Data” action saves the data as a .TXT file, a text file, in the same format as does the “Copy Plot as Text” option. The difference is that the previously discussed option copies the data to the clipboard, where this action saves the data to a text file in the folder of your choice.



Click-and-Drag

To zoom in on a given area, simply click and drag across that area, starting at the top left of the area.



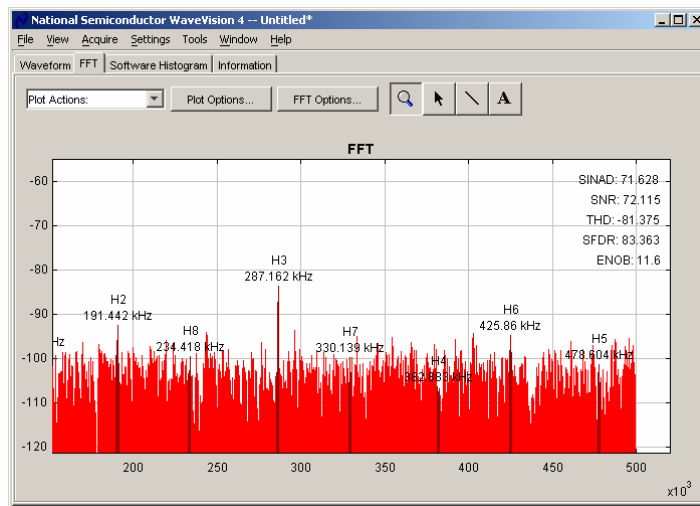
23

To zoom in on a specific area, just click and drag across that area, then release the mouse button. The zoom in allows closer examination of desired areas of the plot.



Zoom

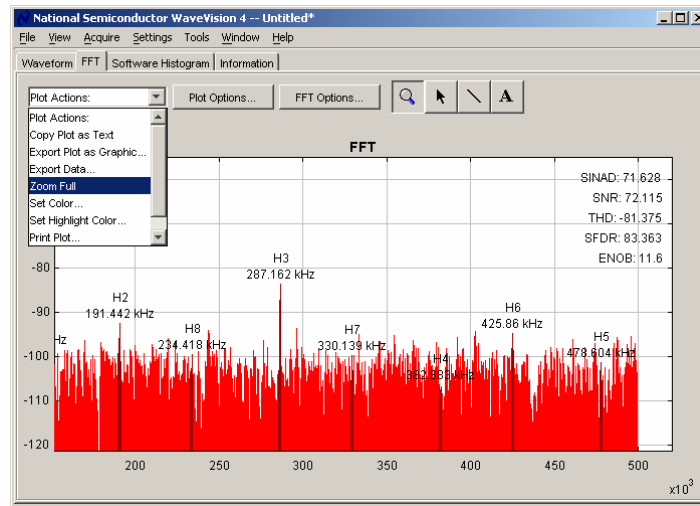
Upon release of the mouse button after clicking and dragging, you have a zoom in of the area selected.





WaveVision4 Plot Options: Zoom Full

The “Zoom Full” action brings you back to the full plot. The same thing may be achieved by clicking the right mouse button



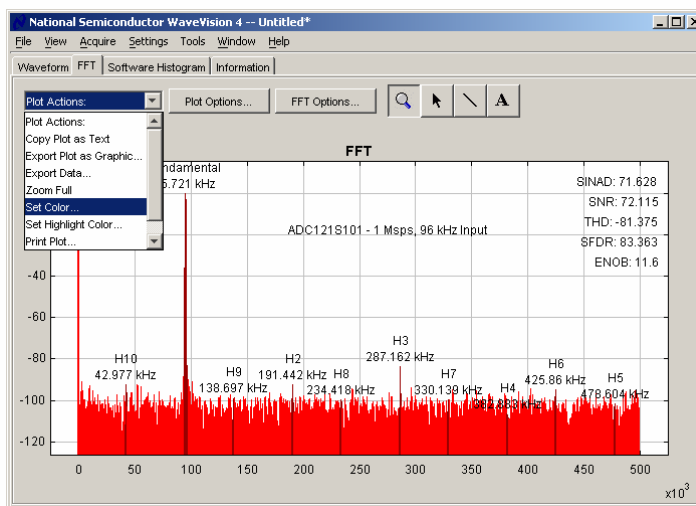
25

To go back to the full view, you may either choose the “Zoom Full” option shown here or simply click on the right mouse button with the cursor over the display area.



WaveVision4 Plot Options: Set Color

The “Set Color” option allows you to select the main color of the plot.

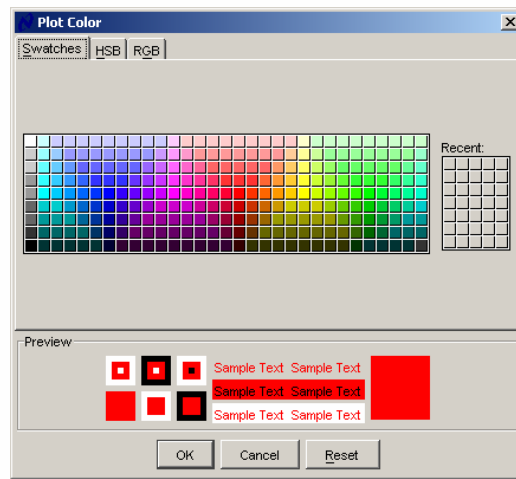


26

The “Set Color” option allows you to set the main display color as desired. The default color is red. The extensive color palate allows a choice of just about any color desired. Here we have chosen green as the main color. Some color combinations are better than others for those who are color blind or for black and white print copy. The green will print as a medium grey, and the brown highlights will be a very dark grey, nearly black, with a black and white printer.



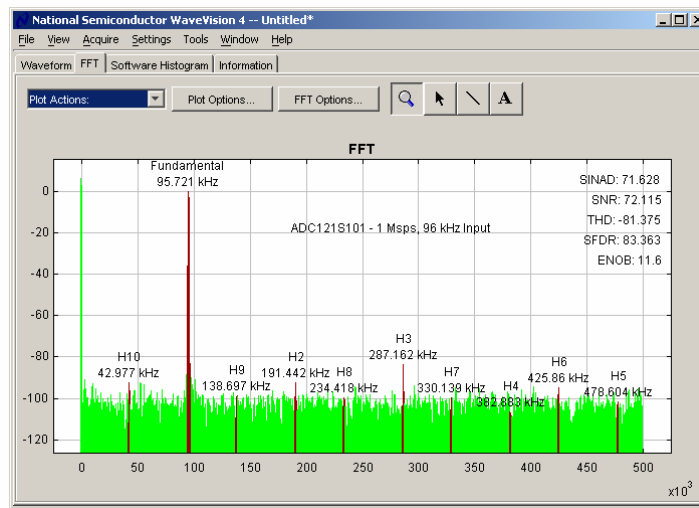
The WaveVision4 Color Palette



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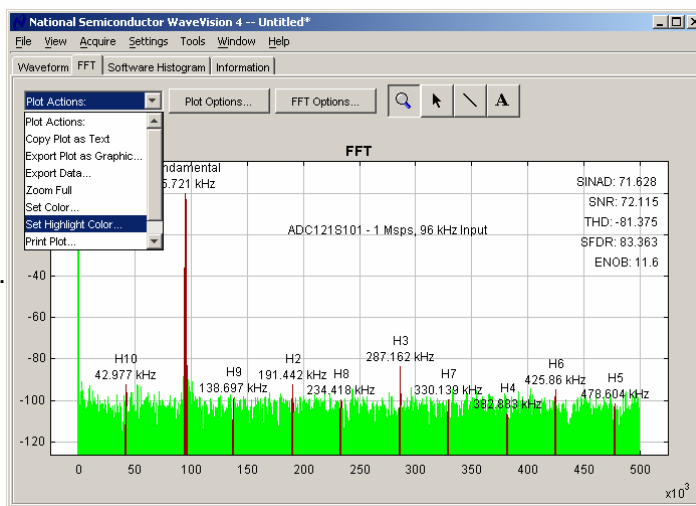
Here we have chosen green as the main color.





WaveVision4 Plot Options: Set Highlight Color

The “Set Highlight Color” option allows selection of the highlight color from the same palette as before.



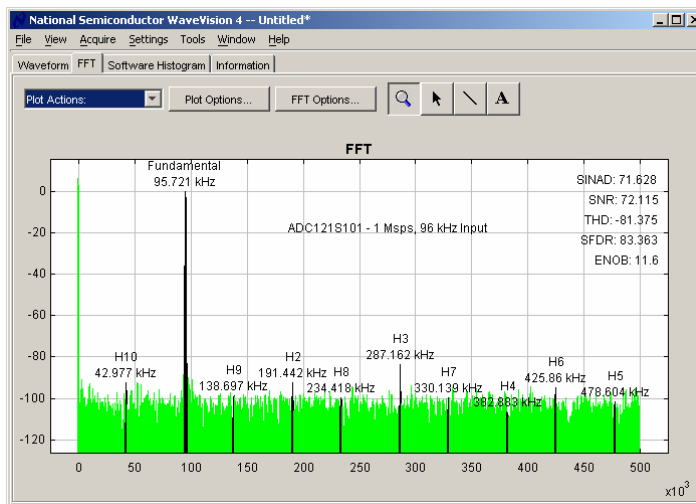
29

The “Set Highlight Color” option allows selection of the color used to highlight the fundamental, harmonic, and highest spur frequencies. The default color is brown. Here we changed the highlight color from brown to black; admittedly, hardly much of a change.



Black and Shades Of Grey Are Some of the Options

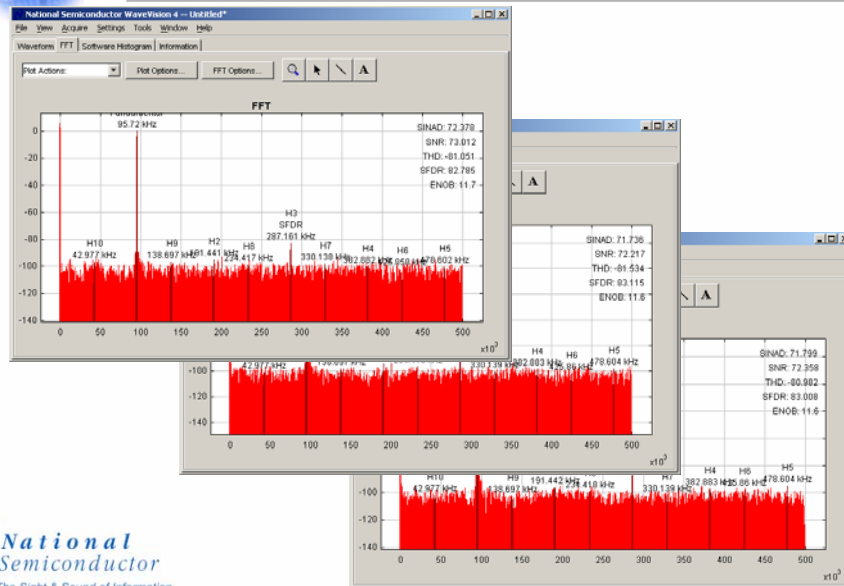
In this case we have chosen Black as the Highlight Color



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Non-Repeatable Dynamic Performance



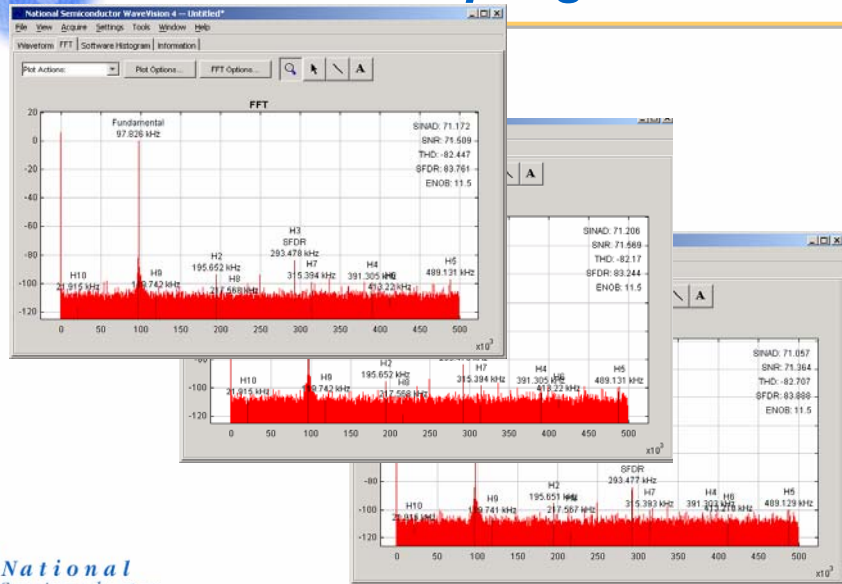
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One of the problems with frequency domain analysis is the fact that we usually window the data causing multiple captures of the same data to be marginally repeatable. We see here that the SINAD varies from about 71.8 to nearly 72.4. While this variation may not be much, the variation tends to be higher as performance deviates more from the ideal.

So, what can we do about this?



Coherent Sampling



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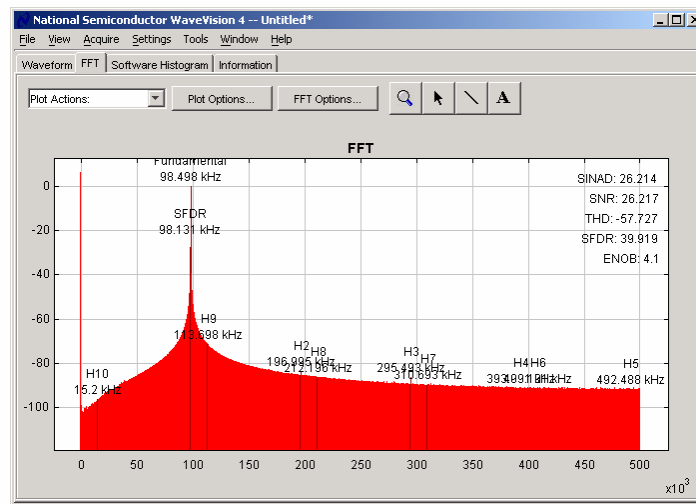
The best solution is to use coherent sampling and use a rectangular window, sometimes rather incorrectly referred to as “no windowing.” We see here that the variation is much less. If our sampling was perfectly coherent, there would be virtually no variation from sample to sample.

Coherent sampling is having an integer number of data periods in the sample record. We will shortly describe how to ensure coherent sampling.



Meaningless Frequency Domain Plot

Rectangular window



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If we use a rectangular window on non-coherent data – that is, if we do not window the data – we can expect a frequency domain plot that might look something like this. Any harmonic energy that is very high will show up correctly, but harmonic energy that is very low will be masked by what might be called “noise” or a rise in the floor level.

As we will see shortly, the problem is in the discontinuity of the waveform as it is folded and the algorithm looks at this data. Because the Fourier Transform assumes that the information started at minus infinity and continues to plus infinity, but we only take a snapshot in time of this data, the algorithm, once it gets to the end of the data record, continues at the beginning of that record. If there is no smooth transition from the end to the beginning, there is a discontinuity. It is this discontinuity that causes the problem.



Frequency Domain Plot Problem

- **FFT Operation and Wave Form Discontinuity**
- **Solutions:**
 - **Windowing**
 - **Hann (Hanning)**
 - **Hamm (Hamming)**
 - **Blackman-Harris**
 - **Flat Top**
 - **Coherent Sampling**

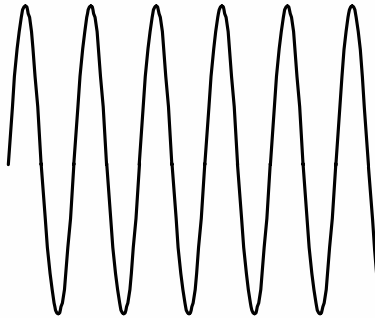


34

The solution to this problem are to window the data or to use coherent sampling. Four popular windowing functions are named here.



Sampling Inconsistency (1)

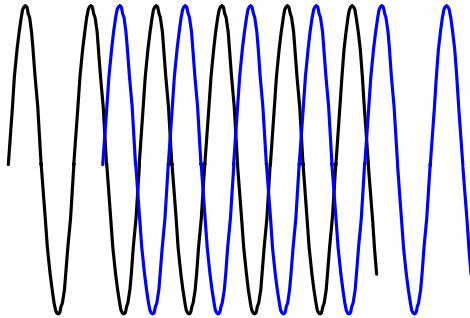


35

If we take the portion of the signal that we have captured and put it onto a cylinder, after we get to the end of the data record, we start again from the beginning.

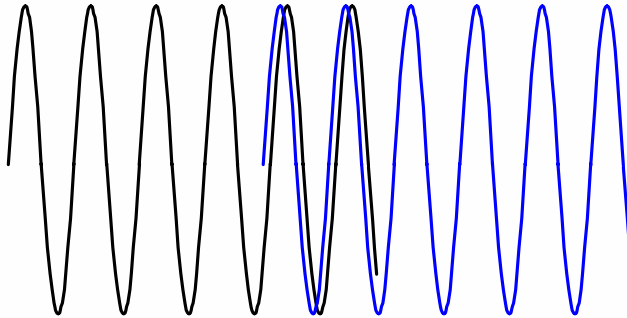


Sampling Inconsistency (1)



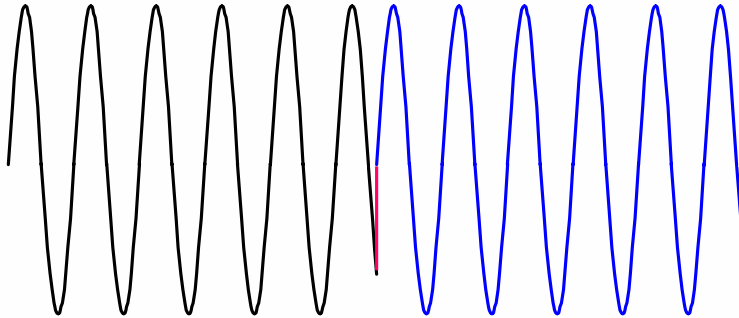


Sampling Inconsistency (1)





Sampling Inconsistency (2)

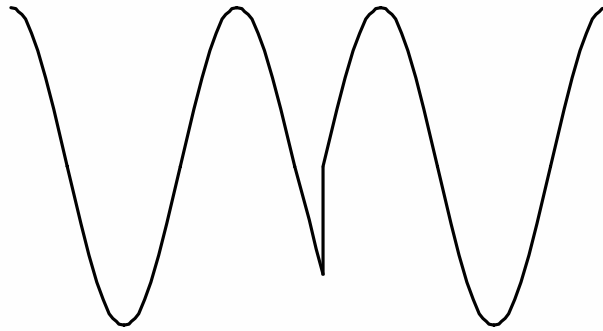


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We see in the red section here a discontinuity in the waveform. If we expand the waveform so that we can see the connection at the end and the beginning, we can more easily see this discontinuity. Larger discontinuities will cause the floor of the frequency domain plot to rise.

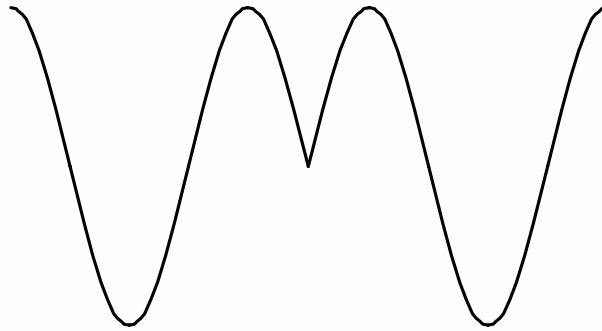


Sampling Discontinuity (1)





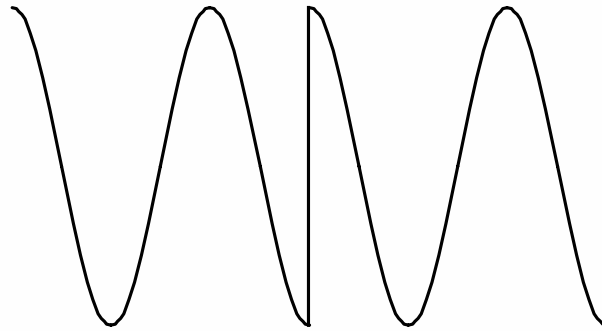
Sampling Discontinuity (2)



This is another sort of discontinuity where there is a rather sudden change of slope. This will cause a more serious problem with the frequency domain plot than will the previous discontinuity we saw.



Sampling Discontinuity (3)

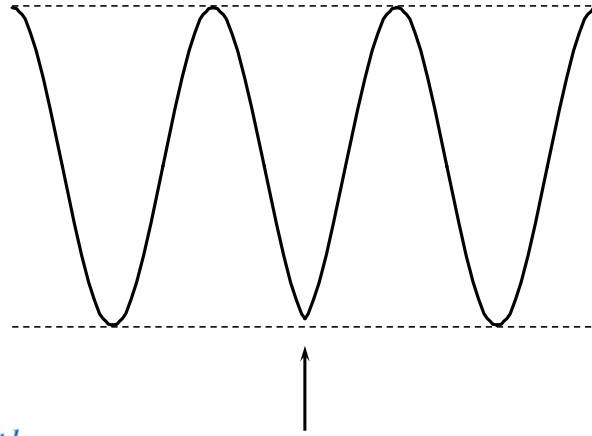


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Here is another serious type of discontinuity. This discontinuity can give us a sudden change of slope when the data is nearly coherent, but not quite so.



Sampling Discontinuity (4)





Windowing Can Improve the Frequency Domain Display

- **Windowing – Controlling the Data Record End Points for Smooth “Wrap Around”**
 - Multiplication with a COS^2 Function
 - Reduces or Eliminates Discontinuity
 - Reduces Resolution
- **Many Windowing Functions, Each With Advantages**
- **WaveVision Windowing Functions**
 - None (Rectangular, Square, Box Car, Uniform)
 - Hamm (Hamming)
 - Hann (Hanning)
 - Blackman – Harris
 - Flat Top



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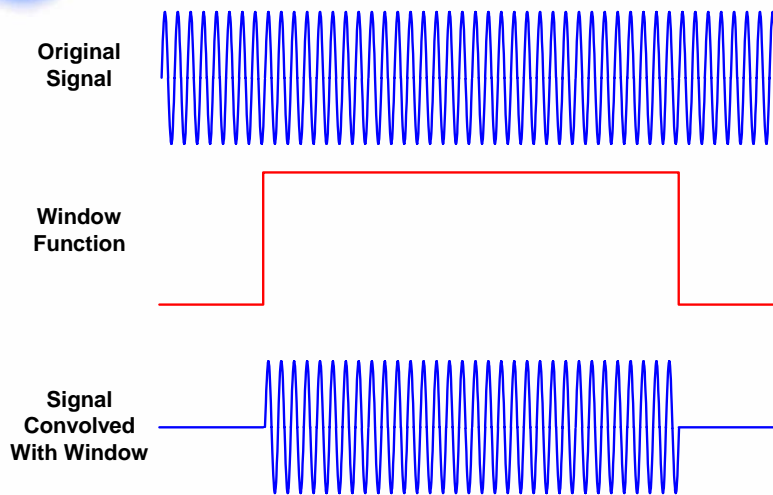
Windowing is controlling the data record end points for a smooth wrap around as the algorithm looks at the data. Windowing is a convolution of the data with a windowing function that is generally of the cosine squared variety. The idea is to eliminate the discontinuity as the algorithm goes from the end of the data record back to the beginning of that record.

The Fourier Transform takes a time domain waveform and converts it to its frequency domain information, providing us with a number of bins. Each bin represents a small range of frequencies. The number of frequency bins is equal to the number of half the sample rate. One of the results, in addition to the smoothing of the transition as we go from the end to the beginning of the data record, is a reduction in what is called “spectral resolution.” This means that some of the information that should be in one frequency bin leaks over into adjacent bins. So we must consider any given frequency to cover a number of bins. The problem is that it is difficult or impossible to separate very closely spaced frequencies and the accuracy of the dynamic performance parameters becomes suspect.

There are many windowing functions, each with its own advantages and disadvantages. Delving into the advantages and disadvantages of these functions is beyond our scope here. WaveVision provides the four popular windowing functions mentioned here.



Rectangular Window

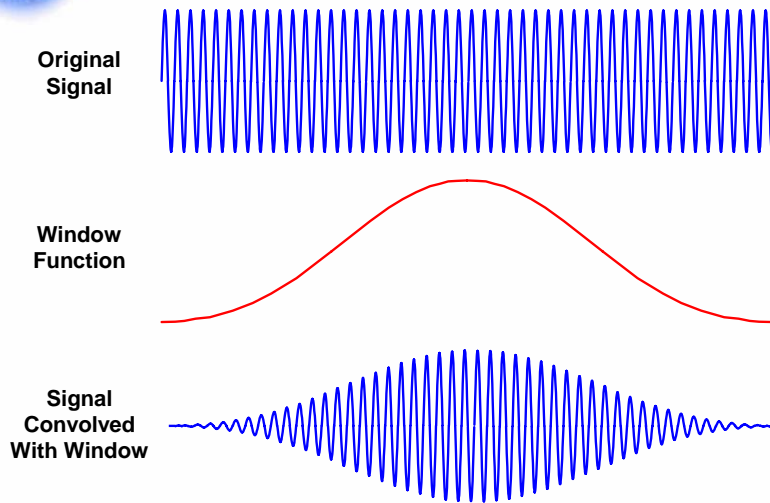


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The rectangular window (or “no window”) essentially turns the data on and off. This is what we are doing when we gather a finite data record. Any discontinuity from end to beginning will be a problem, as we have seen.



Generalized Window

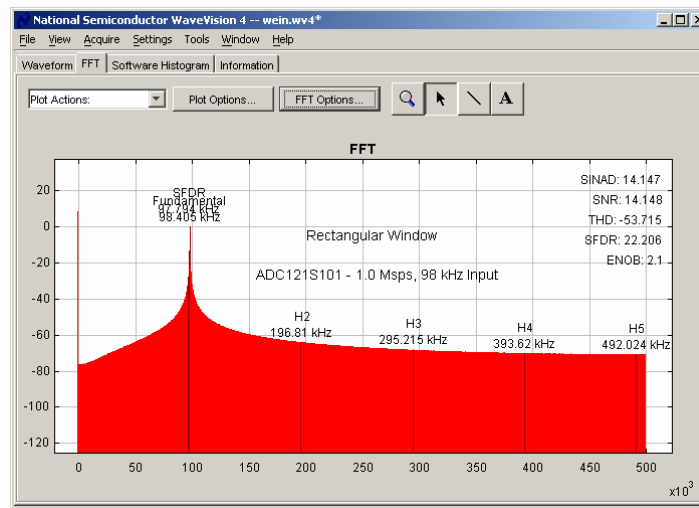


45

Other windowing functions gradually increase and decrease the amplitude of the data so that there is no discontinuity at the ends. The function is, as we have said before, generally some form of a cosine squared function. The exact function will determine the nature of the frequency domain plot that results.



Rectangular Window

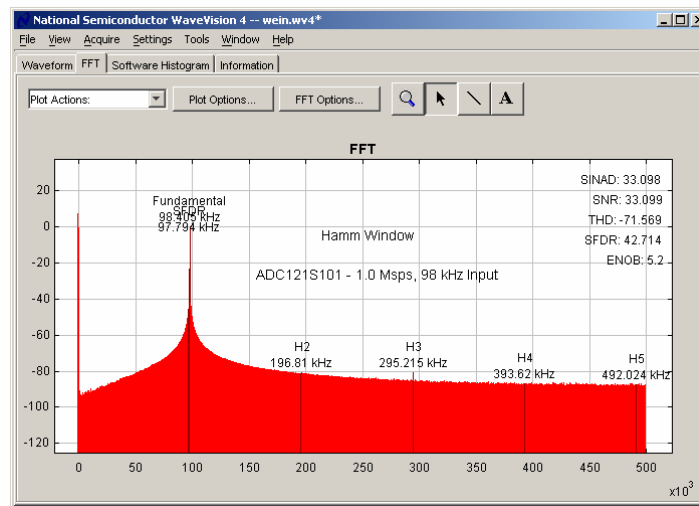


46

Without windowing, the end-to-end discontinuity can cause a lifting of the entire plot such that it is not possible to tell the true level of the harmonics or to measure the noise.



Hamm (Hamming) Windowing

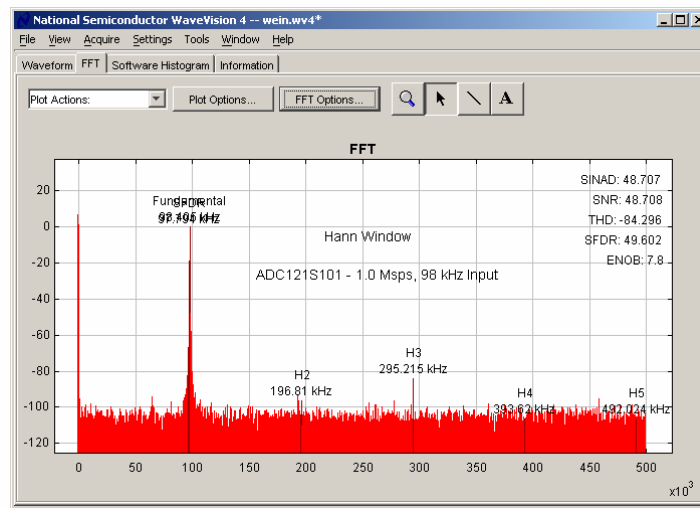


47

The Hamm window, generally referred to as the “Hamming window,” seems to be the least useful of the popular windowing functions. The Hann window, generally referred to as “Hanning window,” appears to be a bit more useful than the Hamm function, but does not give us a good estimate of dynamic performance.



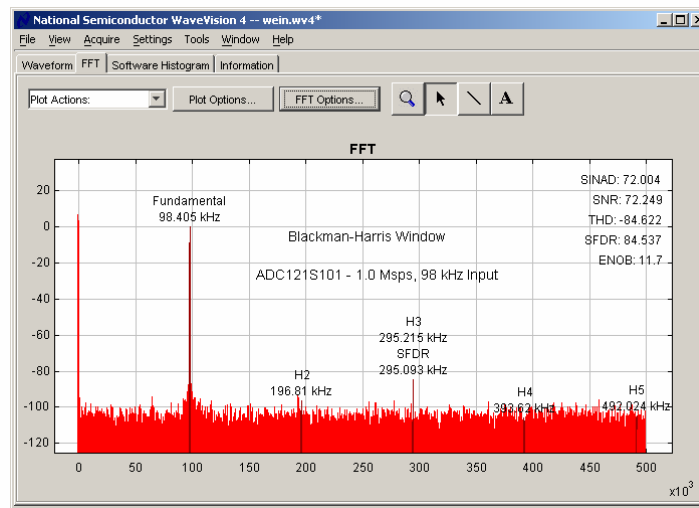
Hann (Hanning) Windowing



48



Blackman-Harris Windowing

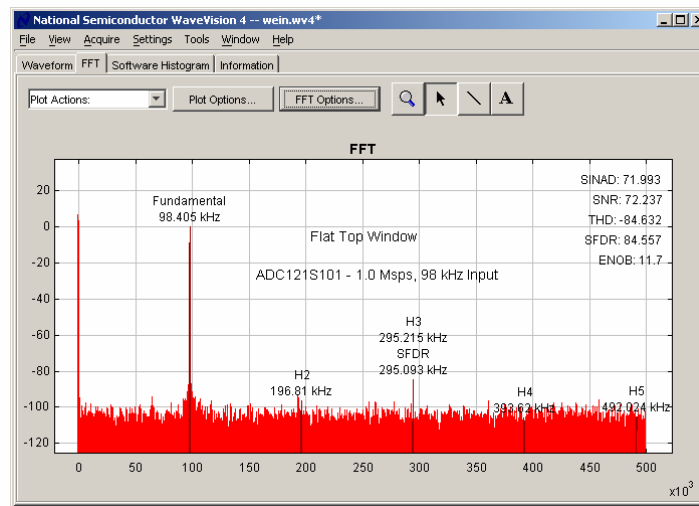


49

The Blackman-Harris is a popular windowing function that has proven to be a good all-around function and gives good estimate of dynamic performance. Separating two very closely spaced frequencies, however, is still a problem.



Flat Top Windowing



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The Flat Top is another popular windowing function that has proven to be a good all-around one with about the same good estimate of dynamic performance as the Blackman-Harris function. Separating two closely spaced frequencies, however, is still a problem. It does a little better, however, with SNR performance estimates and tends to be favored for use with ADC evaluation.



Reason for Inconsistency in Dynamic Readings

- **FFT Operation and Wave Form Discontinuity**
- **Solutions:**
 - **Windowing**
 - **Hann (Hanning)**
 - **Hamm (Hamming)**
 - **Blackman-Harris**
 - **Flat Top**
 - **Many Others**
 - **Coherent Sampling**



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We have seen that the FFT goes through the data over and over again, wrapping around from end to beginning many times. Windowing helps to smooth out the end-to-end transitions at the expense of spectral resolution.

The best solution, however, is coherent sampling, which we will now address.



Getting Consistent Results

- **Coherent Sampling**

$$\frac{\text{Input Frequency}}{\text{Sample Rate}} = \frac{\text{Cycles in Record}}{\text{Sample Size}}$$

- **Sample Size (Number of Data Samples) and Number of Cycles Sampled Relationship**
 - No Common Divisor
 - Prime Number of Cycles Sampled
- **Ratio of f_{IN} to f_S should not be a Whole Number**



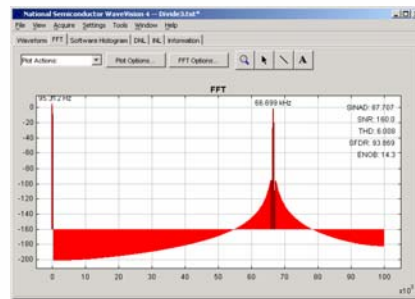
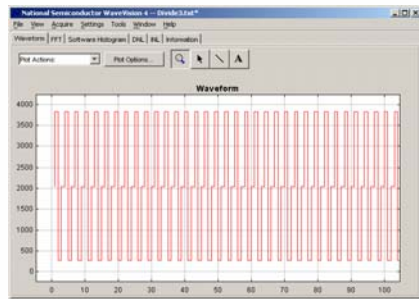
52

When the ratio of input frequency to the number of samples is equal to the ratio of the number of cycles in the data record to the number of samples taken, provided that the number of cycles is a whole number, we have coherent sampling.

In addition to coherency, there must be no common divisor of the number of cycles in the data record and the sample size that would provide a whole number for both of these. The easiest way to ensure this is to have a prime number of cycles in the data record. Another requirement is that the ratio of the input frequency to the sample rate should not be a whole number



Sampling Integer Times Input Frequency (3x)



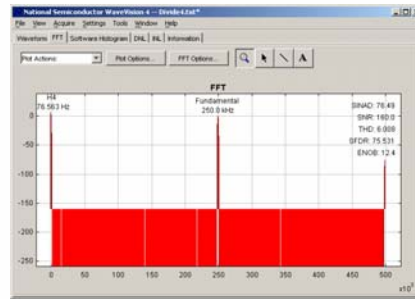
53

If the sample rate is an integer times the input frequency, we get meaningless data. The number of discrete samples in the data record would be equal to the ratio of the sample rate divided by the input frequency.

Here we see the results of sampling at exactly three times the input frequency.



Sampling Integer Times Input Frequency (4x)

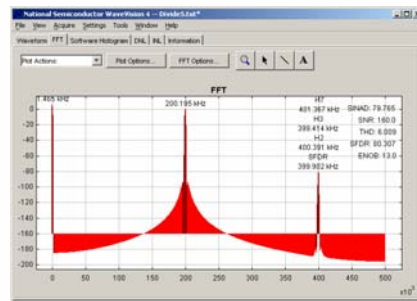
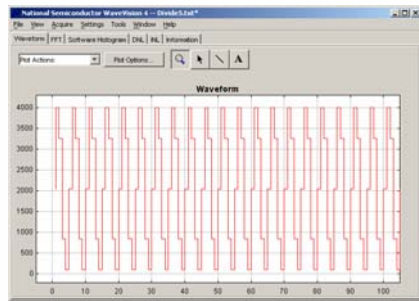


54

Here is the result of sampling at exactly four times the input frequency.



Sampling Integer Times Input Frequency (5x)

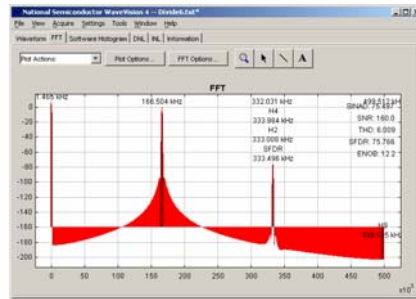
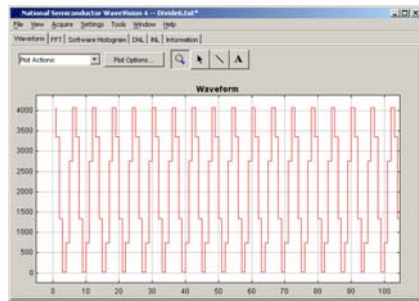


55

At five times the input frequency.



Sampling Integer Times Input Frequency (6x)

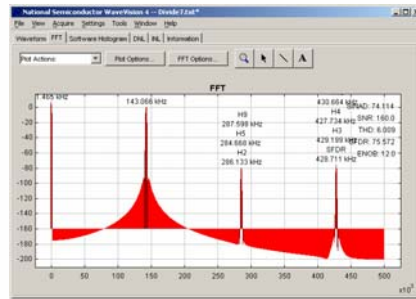
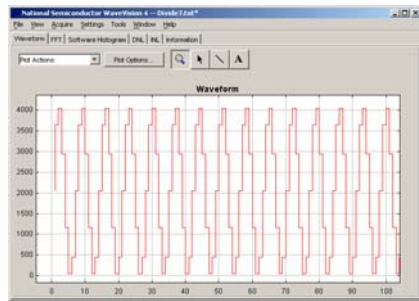


56

Six times the input frequency.



Sampling Integer Times Input Frequency (7x)

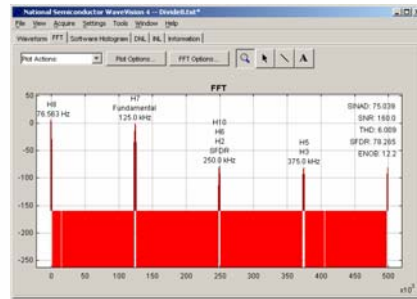
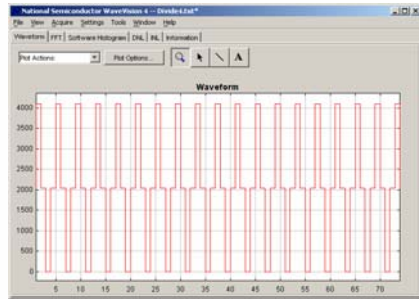


57

Seven times the input frequency.



Sampling Integer Times Input Frequency (8x)



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And at eight times the input frequency.

One thing you will note, if you think back to four times the input frequency, you'll note that the fundamental was halfway between the end of the plot. This is a popular method in finding the exact frequency when you don't want the harmonics to bother you.



Garbage In – Garbage Out

- **Signal Generators DO NOT Have Spectrally Pure Output**
- **Many Signal Generators Have Noisy Outputs**
- **Filter Needed for Evaluation**
 - **Band Pass with Most Signal Sources**
 - **Low Pass for Some Signal Sources**



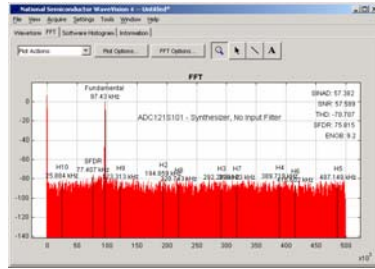
59

One thing that is very important when it comes to evaluating ADCs is to realize that signal generators simply do not have spectrally pure outputs. In addition to harmonics, some signal sources have a lot of noise. To minimize the noise and distortion products from signal generators, it is very important to use a filter before the ADC input when evaluating that ADC. Generally, a band-pass filter is needed, but some signal sources have very little energy below the set output frequency, in which case a low-pass filter will suffice.



Performance Evaluation Without A Filter

Synthesizer Without a Filter



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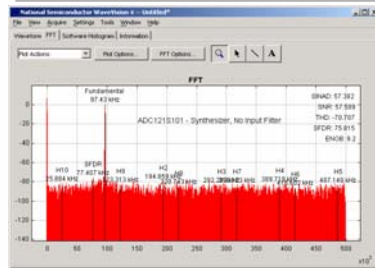
Here is an example of what can happen when using a synthesizer without a filter. Note that the effective number of bits, or ENOB, is 9.2. This is with a 12-bit ADC. Note the ADC type, it is our ADC121S101.

The performance loss is primarily in the noise level, but the rising noise floor also raises the apparent level of the harmonics. The Fourier Transform cannot tell that the bins corresponding to harmonics contain more energy because of the raised noise floor so the reported total harmonic distortion suffers as does the SNR.

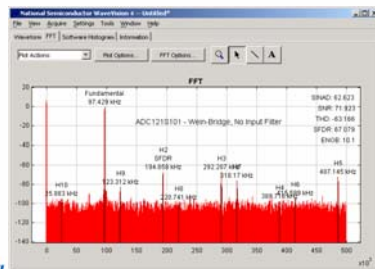


Performance Evaluation Without A Filter

Synthesizer Without a Filter



Wein-Bridge Oscillator Without a Filter



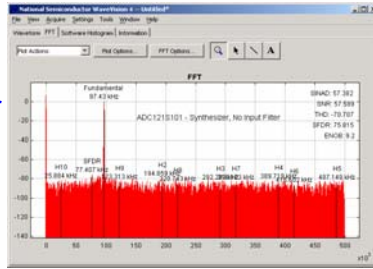
61

An analog signal source generally does not produce as much noise as does a synthesized source, but can produce more harmonics. So while the signal-to-noise ratio is not bad at the bottom plot here, the harmonic level is prohibitive. This slight noise and total harmonic distortion content combine to give us an ENOB of 10.1 in this case. This is hardly impressive performance.

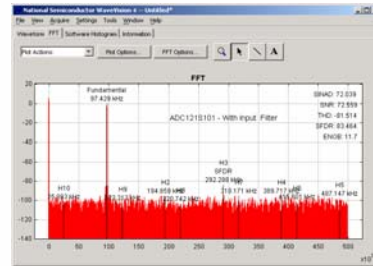
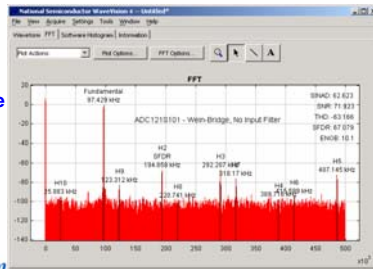


Performance Evaluation Without and With A Filter

Synthesizer Without a Filter



Wein-Bridge Oscillator Without a Filter



Wein-Bridge Oscillator with an Input Filter



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Using the Wein-Bridge signal source with an in-line band pass filter will improve the dynamic performance and give us meaningful results. We see here an ENOB of 11.7 from the 12-bit ADC122S101 – I’m sorry, ADC121S101, a 12-bit, A/D converter fully specified for performance over the sample rates of 500 ksp/s to one Msp/s.



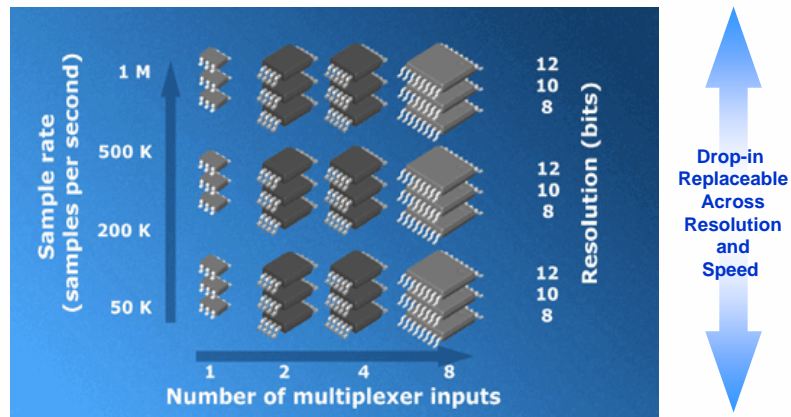
National's Newest General Purpose (GP) ADCs

National Semiconductor has introduced a number of new general purpose ADCs and a few new DACs in the last year. So we thought it would be a good idea to provide you with a general overview of those products, some of which have been featured in the previous part of this presentation.

Our new general purpose ADCs have guaranteed performance over a range of speeds, as opposed to the industry standard practice of guaranteed performance at a single sample rate.



8/10/12 Bit GPADC Family



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This family of 36 devices are provided in resolutions of 8, 10, and 12 bits with guaranteed performance over the speed ranges of 50 ksp/s to 200 ksp/s, 200 ksp/s to 500 ksp/s, and 500 ksp/s to one Msp/s, and with one to eight multiplexer inputs. All devices with the same number of mux inputs are pin compatible with each other. You see here an unusually full matrix of products.



12 Bit Differential Input General Purpose ADC Family SPI Interface, External Reference

Res	Speed	Channels			
		1	2 Simultaneous Sampling	4 Simultaneous Sampling	8 Simultaneous Sampling
12 bit	50 to 200ksps	ADC121S625			
	200 to 500ksps				
	500ksps to 1Msps				
	Package / Type	MSOP-8	MSOP-8 MSOP-10		

Products in shaded areas are planned



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This family of differential input ADCs currently only has one member, but will grow rapidly. The ADC121S625 has high impedance inputs and is specified for reference voltages from 100 millivolts to 2.5 volts, making it ideally suited for directly digitizing the output of bridge-type transducers without the need in some applications for an intermediate amplifier.

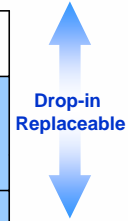


GP ADCs

Features

- **Guaranteed Monotonic**
- **Low Power Operation**
- **Rail-to-Rail Output**
- **SPI Interface**
- **Supply is Reference**
- **+2.7V to +5.5V Supply**
- **Small Packages**
- **Power Down Feature**

Resolution	Settling Time	Single Channel
12 bit	10uSec	DAC121S101
10 bit	7.5uSec	DAC101S101
8 bit	5uSec	DAC081S101
Package		SOT-23-6, MSOP-8



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These new low-power DACs feature small packages and economic performance over a wide power supply range, making them ideal candidates for trim applications. Additionally, the dynamic performance of these DACs make them well-suited to a variety of control and waveform synthesis applications.



Future GP Product Areas

- **8 / 10 / 12 bit ADCs and DACs**
- **High Speed 8 / 10 / 12 bit ADCs**
- **Lower Speed 8 / 10 / 12 bit DACs**
- **8 / 10 / 12 bit Multi-Channel DACs (SPI)**
- **I²C DACs**

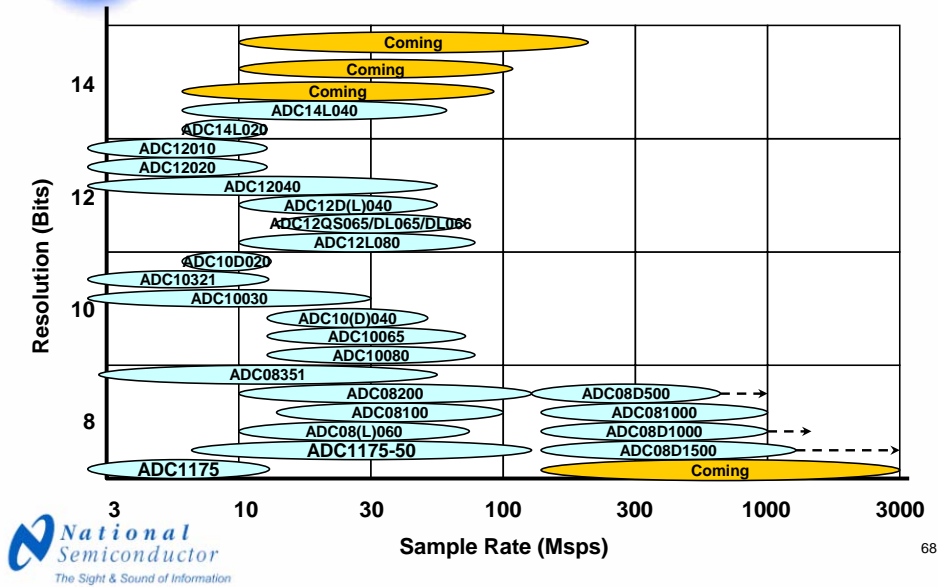


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Keep an eye on us as we introduce more and more in the area of general purpose data converters.



High Speed ADCs



Our high-speed portfolio of ADCs continues to grow as well. Our Gsps products have taken the market by storm. The arrows beyond these indicate the speeds that they will operate at in what we call the "dual-edged sampling mode," that is when the two converters on the die are interleaved to function as a single converter. The performance of these products in the interleaved mode is quite impressive. Note also that we have started an expansion beyond 12 bits.



National Semiconductor Data Converter Web Site

- **National Semiconductor's Data Conversion web site: www.national.com/adc**
 - Application Notes
 - Data Conversion Calculator
 - Definitions of Terms (ADC / DAC)
 - Evaluation Boards, Manuals, Software
 - Press Releases
 - Selection Guides
 - Technical Articles
 - Technical Presentations
 - Technical Support Link



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National Semiconductor is just as committed to providing useful information to our customers as we are to providing leading-edge solutions in silicon. Visit our data conversion Web site for useful information. Check out this Web site periodically as we are continually adding to it and making improvements to it. We believe we have an extremely useful website.

Visit us and click on the "Feedback" at the bottom of the page and let us know what you think. Please be sure to mention that it is the ADC Web site about which you are making comments. We welcome all feedback, positive and negative, that will help us make this site more useful for you.

Our evaluation boards and free WaveVision software provide the easiest means available to evaluate the performance of ADCs. Technical articles are there as well and also presentations. These can help you in gaining more design knowledge.



Summary

- **Previous Evaluation Methods**
- **The Need for Something Different**
- **National Semiconductor's Response**
 - WaveVision3
 - WaveVison4
- **Sampling Inconsistency**
- **Windowing**
- **Getting Consistent Dynamic Performance**
- **Garbage In – Garbage Out**
 - ADC Input Filtering Needed for Evaluation
- **Portfolio Summary**



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This presentation has briefly mentioned some of the previous ADC evaluation methods and the need for something a bit more simple and discussed National Semiconductor's response to those needs and some potential problem areas and how to address them. We ended with information on our portfolios and Web site.

Thank you for your presentation. Please feel free to contact us with any questions or concerns.



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