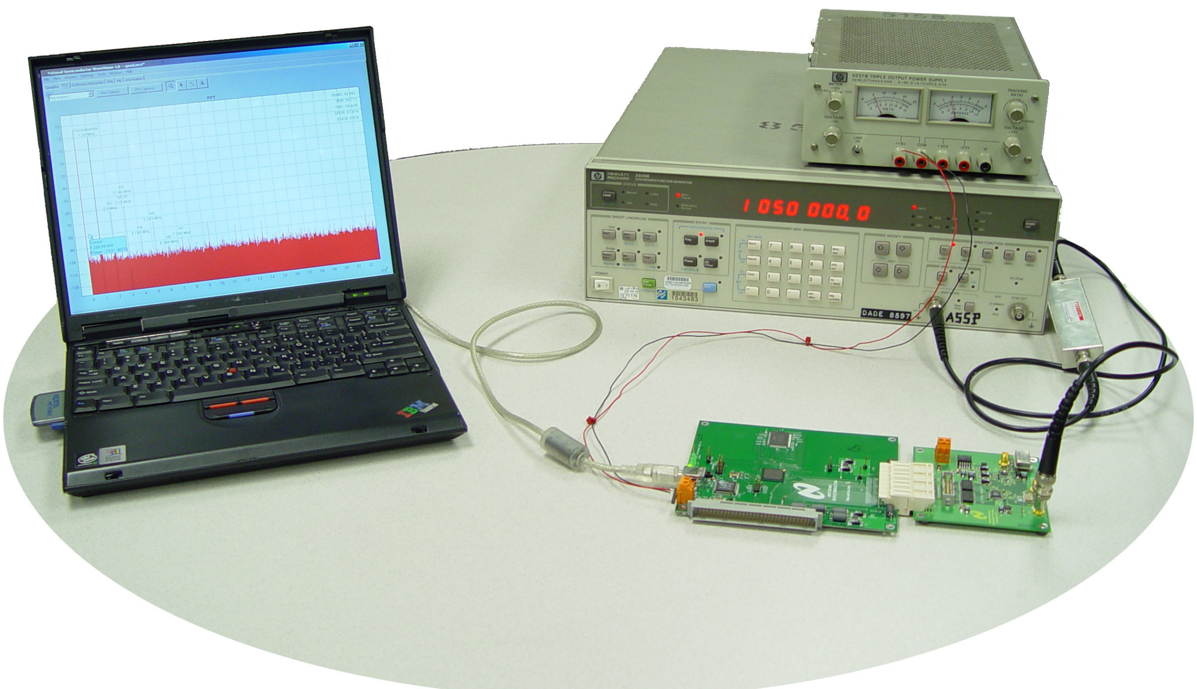
National Semiconductor's

WaveVision 4

Data Capture System



User's Guide

September 2004

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1. WaveVision System

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1.1. What is the WaveVision System?

The WaveVision system is National Semiconductor's platform for evaluating analog-to-digital converters. It is composed of three core components:

- A WaveVision digital capture board, hereon referred to as simply the "WaveVision board."

- A software program that runs on a Microsoft® Windows® XP/2000/ME/98 based personal computer, hereon referred to as simply the "WaveVision software."

- A National Semiconductor ADC Evaluation Board(s)

This manual describes the features and operation of the WaveVision board and software only. Each ADC evaluation board comes with its own manual, which documents its specific features.

1.2. WaveVision Features

- Transfers data rapidly with full-speed USB 1.1.
- Provides jumperless, plug-and-play configuration.
- Supports a wide variety of ADC Evaluation Boards.
- Fast Capture (up to 200 MHz) with wide (36 bit) data bus.
- Capable of performing FFT analysis and hardware histograms.

1.3. Packing List

The WaveVision 4 kit (National order number WAVEVISION BRD4) consists of the following components:

- WaveVision board
- WaveVision software on CD-ROM
- USB cable
- User Manual (This Document)

1.4. Board Layout Overview

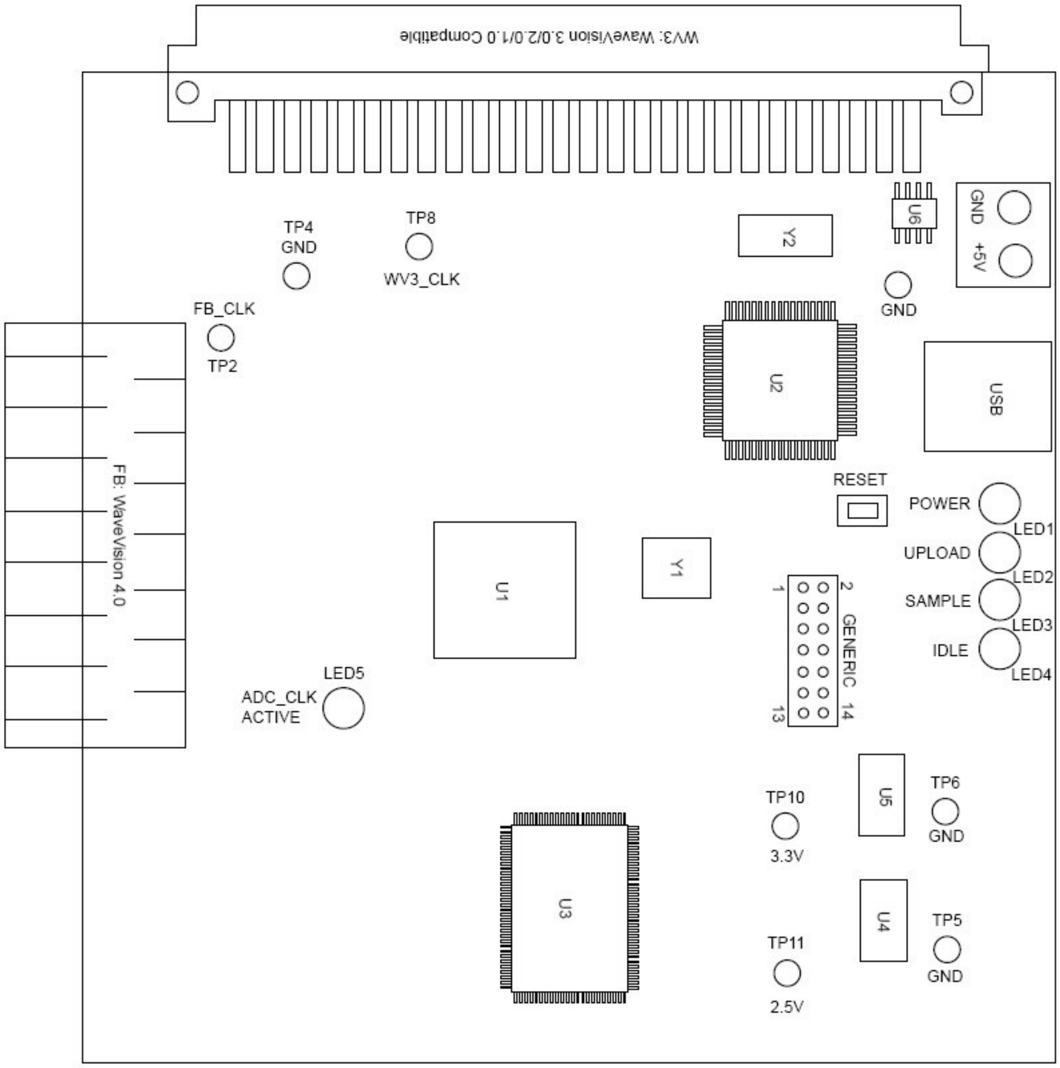

Figure 1 WaveVision Board Layout

1.5. Component Description

The following table describes both the on-board connectors and the main components used in the WaveVision System shown in Figure 1.

Component	Description
J1 (POWER)	+5V Power Supply Connection (See Section 3.2)
J2 (USB)	WaveVision 4 USB cable Connection.
J3 (GENERIC)	General-use header connected to the FPGA (U1). Consult the ADC evaluation board user's guide for more information.
J4 (Future Bus)	WaveVision 4 Future Bus Connector
J5 (WaveVision3)	WaveVision 3/2/1 System (96-pin Euro header) (for future use)
U1	FPGA
U2	USB microcontroller
U3	Synchronous SRAM (200MHz)
U4	National LM1117MPX-2.5 (2.5V Regulator)
U5	National LM1117MPX-3.3 (3.3V Regulator)
U6	Configuration EEPROM
LED1-4	Status LEDs. (See section 2.4)
LED5	ADC Clock Present LED (See section 2.4)

1.6. WaveVision Test Points

The following table describes the main Test Points available.

Testpoint	Description
TP2 (FB_CLK)	Test Point for the clock coming across the FB connector.
TP8 (WV3_CLK)	Test Point for the clock coming across the WV3 connector
TP10	+3.3V (Regulated) test point.
TP11	+2.5V (Regulated) test point.
TP4,5,6,7 (GND)	Ground test points.

2. System Functionality

2.1. System Block Diagram

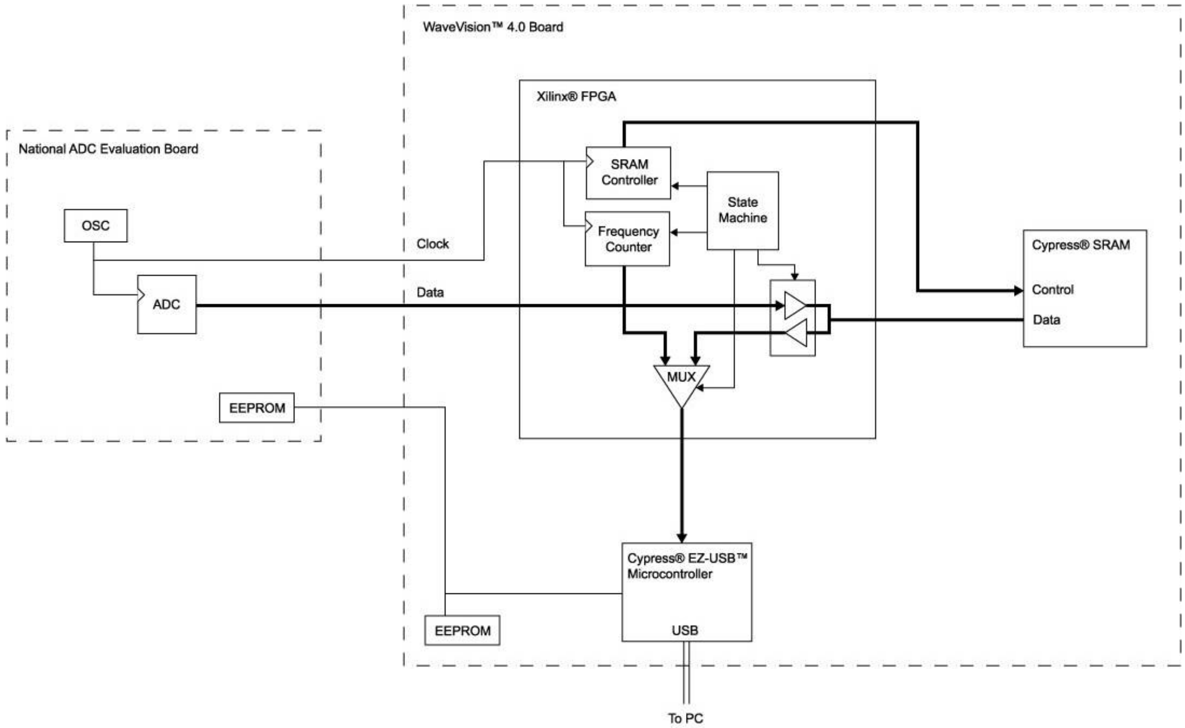

Figure 2: WaveVision System Block Diagram

2.2. General System Overview

The ADC evaluation board (shown in Figure 2) delivers conversion data along with a source-synchronous clock to the Future Bus connector (J4). The data and clock signals are connected directly to the FPGA Device (U1) on the WaveVision Board.

During data capture, the FPGA acts as a Synchronous SRAM controller, which is clocked by the ADC Evaluation Board. The ADC data flows through the FPGA and is stored to the SRAM (U3).

When data is being uploaded to the PC for analysis, the SRAM controller is clocked by an onboard 100 MHz oscillator (Y1). The data is presented to the USB microcontroller (U2), which routes it across the USB bus to the host PC.

A frequency counter function in the FPGA measures the frequency of the incoming ADC clock. This value is used during the FFT calculation to provide an accurate and meaningful signal analysis.

2.3. Automatic Device Detection & Configuration

The WaveVision system provides automatic hardware detection and configuration for the device under test. The FPGA is re-programmed on the fly by the host PC when the WaveVision board is turned on, or whenever the ADC evaluation boards are exchanged.

Normally, the configuration process is totally transparent to the user, and requires no intervention. However, this process can be overridden if required. Refer to the evaluation board manual for more information.

Important Note: Many of our evaluation boards ***do*** require jumper configurations to select channels, voltages, or other options. Please consult the manual that came with the evaluation board for specific information.

2.4. Modes of Operation & LED Indicators

Data acquisition by the WaveVision System can be divided into three phases:

1. **Frequency Count**: The clock frequency of the ADC under test is measured and sent back to the host PC.
2. **Sample**: ADC Data Samples are clocked into the SRAM.
3. **Upload**: Sample data is transferred to the host PC.

Each of these phases is indicated by a LED on the WaveVision board. During the frequency counting phase, LED2 ‘UPLOAD’ will be lit momentarily. The frequency count should take about a tenth of a second to complete.

During the collection phase, LED3 ‘SAMPLE’ will be illuminated. The collection should take less than a quarter second, but may be longer for low-speed parts.

During the upload phase, LED2 ‘UPLOAD’ will be illuminated. The upload takes approximately 20 seconds to transfer the entire SRAM contents (2^{17} samples). For many purposes, 2^{15} samples are adequate.

When no action is being taken by the WaveVision System, LED 4 ‘IDLE’ will be illuminated. This LED also indicates that the FPGA has been programmed correctly and should be ‘ON’ before attempting to start a data acquisition.

LED5 can be used to determine whether an ADC Evaluation Board clock is active. If the LED is flashing it indicates that the FPGA is receiving a clock signal from the Evaluation board.

2.5. Memory

The WaveVision 4 board comes with at least 128k x 36, or 4 Mbit, of 200 MHz SRAM. Some versions may have SRAM of different speed or capacity – the amount present on your board can be queried in the WaveVision software through the Capture Board Settings menu.

2.6. Computer Interface

The WaveVision hardware communicates with a PC via standard USB 1.1 at full speed, or 12 Mbit/s.

2.7. Power requirements

The WaveVision 4 board requires only a single +5V power supply. However, most ADC evaluation boards require additional power supplies. The WaveVision hardware consumes approximately 200 mA of current (1 W of power) when fully configured, with no part evaluation board attached. ADC evaluation boards differ widely in their power consumption – please consult the manual that came with your ADC evaluation board, and ensure that your power supply is capable of adequately supplying the load.

3. **Quick Start Guide**

3.1. Install the WaveVision Software.

- Insert the WaveVision CD-ROM into your computer's CD-ROM drive.
- The WaveVision software requires a Java™ Runtime Environment or Java™ Development Kit, version 1.4 or higher, from Sun Microsystems, Inc. For detailed information on WaveVision's use of Java technology, please see Section 4. If your computer does not have this software, the WaveVision installer will instruct you on how to install it.
- Locate and run the **WaveVision 4 Setup.exe** program on the CD-ROM. Follow the on-screen instructions to finish the install.

3.2. Install the WaveVision Hardware.

- Place the WaveVision 4 board on a clean, level, static-free surface.
- Connect a +5V supply and ground to the orange power block on the corner of the board, observing the silkscreen.
- Connect the WaveVision 4 board to your personal computer with the supplied USB cable.
- Connect the ADC Evaluation Board to the WaveVision Board by mating it to the appropriate connector. Consult the manual that came with your ADC Evaluation Board and supply any additional power supplies or clock sources. Also ensure that DIP switches and/or jumpers are set correctly.
- Turn on the +5V power supply.
- Verify that the RED LED (labeled 'POWER', near the USB connector) is lit.
- You will see a Windows™ message concerning the installation of the WaveVision driver software. Under Windows XP, you will be prompted by the New Hardware Wizard to enter `Next`, `Continue Anyway` (you should ignore the Windows Logo warning), and `Finish`. If for some reason the installation fails, read the Windows Driver section 6.

3.3. Launch the WaveVision Software.

Start the WaveVision software on your computer by selecting the desktop icon "WaveVision 4" or by pressing the Start button, and selecting

`Programs -> WaveVision -> WaveVision 4`

When the WaveVision software is running;

- Select '**`Board Settings`**' from the **`Settings`** pull down menu.

- Select '**`WaveVision 4 (USB)`**' from the **`Board Type`** pull-down menu button to tell the WaveVision software that you are using the USB-compatible WaveVision 4 board.

- The firmware should automatically load. If not, click the '**`Test`**' button in the **`Communication`** section of the window. A small status window will appear. If you do not see a status window, or receive an error message, please see the "Troubleshooting" Section 5.

- Finally Check that LED4 'IDLE' has been illuminated on the WaveVision board. If LED4 remains in the 'OFF' state, please see the "Troubleshooting" section 5.

4. **Java™ Technology**

The WaveVision software uses Sun Microsystems® Java technology. The underlying Java software must be installed on your computer in order for the WaveVision software to run. The software can run on top of either the Java Runtime Environment (JRE) or the Java Development Kit (JDK), version 1.4 or higher. A suitable copy of the JRE is included on your WaveVision CD-ROM.

The WaveVision installer will first look for an existing copy of the JRE or JDK on your computer. If neither is found, the installer will instruct you to first install a JRE. To do this, run the **`J2RE*.exe`** installer program off the CD-ROM. Follow the on-screen instructions to finish the install.

After a suitable JRE or JDK is installed, run the WaveVision installer again. The installer will detect the Java software and configure the WaveVision software to use it.

Java technology can allow software to run on different platforms. However, the WaveVision software contains Windows specific hardware interface code and therefore is only currently supported under Windows.

5. Troubleshooting

National Semiconductor’s WaveVision System provides one of the easiest and fastest ADC evaluation products on the market. If you’re having trouble using the system, please work through the troubleshooting flowchart below. Remedies for each of the possible failure modes are listed after the flowchart. If you continue to have problems, please contact the National Semiconductor Customer Support Center listed on the last page of your National Semiconductor datasheet.

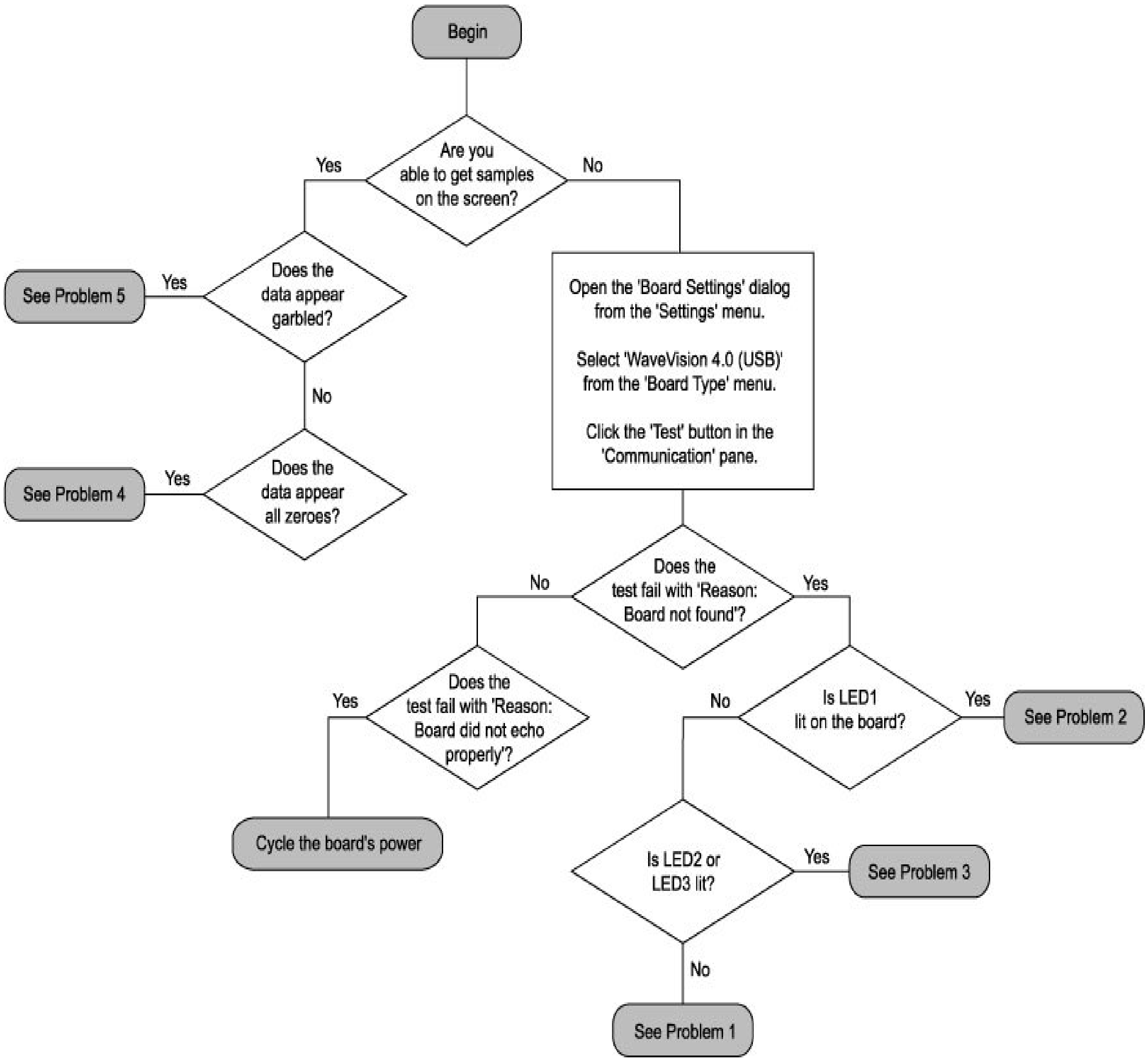

Figure 3: Troubleshooting Flowchart

Problem 1: The board is powered, but no LEDs are lit, and the host PC is unable to communicate with it.

Solutions:

1. Ensure that your power supply is able to source enough current for both the WaveVision board and your part evaluation board. See Section 2.7 for more information about power requirements. You may need to power the WaveVision board and the part evaluation board separately.
2. Ensure that the power supply is connected with the correct polarity. Consult the board's silkscreen.
3. Probe test points TP3 and TP4 and verify that +3.3V and +2.5V are present on each, respectively. If these voltages are incorrect, despite the +5V supply being properly applied, your board may be defective.

Problem 2: The board is powered and LED1 is lit, but the WaveVision software does not detect it.

Solutions:

1. Ensure that the USB cable is firmly connected to both the WaveVision board and the host computer.
2. Ensure that the WaveVision software was properly installed with the WaveVision installer – not simply copied from another computer system.
3. Open the Device Manager (**`Start -> Control Panel -> System -> Device Manager`**), and look under the **`Universal Serial Bus Controllers`** node.
4. Verify that your PC's USB controller and root hub are functioning properly. If they are not, please consult the documentation for your operating system.
5. Verify that the **`National Semiconductor WaveVision 4`** device appears under the **`Universal Serial Bus Controllers`** node when turned on. If it is not present, check to see if an unknown **`USB Device`** appears under the **`Other devices`** node. If the hardware appears this way, your driver software is not installed. Turn off the board, re-run the WaveVision installer to install the driver software, and then turn the board back on. If you continue to have problems with driver software, please see Section 6 for more information.

Problem 3: The board responds to communication tests, but hangs during data collection or upload (LED2 or LED3 lit).

Solutions:

1. Check that LED5 'ADC_CLK ACTIVE' is flashing to verify that the ADC board's clock is making it across the edge connector.
2. If the clock is not present, the LED will not flash and the SRAM controller will not be able to function.
3. Probe the oscillator module or signal generator connected to the ADC Evaluation board to ensure it is functioning properly.
4. Ensure that the WaveVision software is automatically selecting firmware appropriate for your evaluation board.

    - Open the **`Board Settings`** dialog from the **`Settings`** menu.
    - Ensure that **`WaveVision 4 (USB)`** is selected from the **`Board Type`** menu.
    - Click the **`Xilinx Image Settings`** button.
    - Verify that the **`Select images automatically`** checkbox is checked.

5. Cycle the power to the WaveVision board.

Problem 4: Data is collected from the board, but is all zeroes.

Solutions:

1. Check the Information panel for the dataset to see what clock frequency was measured. If zero frequency was measured, it most likely means your ADC clock is not making it onto the WaveVision board. Check the oscillator module or signal generator to ensure it is functioning properly.

2. Ensure that your signal generator is properly configured, and the jumpers on the ADC Evaluation Board are set appropriately

3. Ensure that the WaveVision software is automatically selecting firmware appropriate for your evaluation board. Open the **`Board Settings`** dialog from the **`Settings`** menu. Ensure that **`WaveVision 4 (USB)`** is selected from the **`Board Type`** menu. Click the **`Xilinx Image Settings`** button, and verify that the **`Select images automatically`** checkbox is checked.

Problem 5: Data is collected from the board, but is garbled.

Solutions:

1. Ensure that the WaveVision software is automatically selecting firmware appropriate for your evaluation board. Open the **`Board Settings`** dialog from the **`Settings`** menu. Ensure that **`WaveVision 4 (USB)`** is selected from the **`Board Type`** menu. Click the **`Xilinx Image Settings`** button, and verify that the **`Select images automatically`** checkbox is checked.

2. Ensure that your signal generator is properly configured, and the jumpers on the ADC Evaluation Board are set appropriately. Signal conditioning circuitry on the part evaluation board may be distorting your input signal if configured improperly.

6. Windows Driver

The WaveVision software communicates with the WaveVision hardware through the Windows device driver software. If you are unable to connect to the Wavevision board after installing the software, do the following to uninstall and reinstall the driver. Go to the Windows Control Panel and select System. If you are using Windows 2000/XP select the Hardware tab. Then click on Device Manager and go down to the Universal Serial Bus controllers. With the WaveVision board connected, you will see it (or an unknown device) listed. Right click on it and uninstall the driver. Then unplug and plug in the board again to reinstall the driver.

7. WaveVision Software Basics

Please note: The following sections are a brief tour to highlight all of the basic abilities of the WaveVision software. More specific documentation is also available within the WaveVision software, from the `Help` menu.

7.1. Basic Features

- Operates with a variety of data capture boards, including WaveVision 4.
- Allows inspection of sampled waveforms.
- Calculates FFTs and histograms.
- Provides a wide variety of data import and export abilities.

7.2. Board Settings

Before you can collect samples, WaveVision must know what kind of hardware you're using. To configure WaveVision's interaction with your hardware, open the **`Board Settings`** dialog from the **`Settings`** menu.

Select the type of board you have from the **`Board Type`** pull-down menu.

Depending upon what type of hardware you're using, you will see a variety of options on the right-hand side of the window. For WaveVision 4, the following settings are available:

- Xilinx Image: These settings determine which firmware is used on the WaveVision board.
- Samples collected during data acquisition: This is the number of samples to be uploaded to the host PC. In general, 8k samples are adequate for most measurements, while 32k samples are better suited for precision comparisons.
- Samples accumulated during hardware histogram: The number of samples to count while performing a hardware histogram. In general, **`Stop at first full bin`** is the best option, as it will accumulate the largest number of samples that memory will accommodate. However, it may take a very long time, particularly for low-speed parts; selecting a smaller number of samples will speed up the histogram process.

The Board Settings window also provides a **`Test`** button for testing communication between the PC and WaveVision hardware. Please see Section 3 for more information about setting up a WaveVision 4 evaluation system.

7.3. Capturing Data

To collect a set of samples from the hardware, choose **`Samples`** from the **`Acquire`** menu. To collect a hardware histogram, choose **`Hardware Histogram`** from the **`Acquire`** menu. If you do not have any sort of data capture hardware, you may open a sample dataset by choosing **`Simulated Samples`** from the **`Acquire`** menu. You may, of course, also open a file.

7.4. Viewing Data

Some definitions are in order:

A **dataset** is either a set of samples, or a hardware histogram.

A **view** is a way of looking at a dataset; waveforms, FFTs, and histograms are all different ways of looking at samples.

Each window in the WaveVision software can contain at most one dataset. If you'd like to examine more than one dataset simultaneously, you must open more than one WaveVision window. You can open additional windows by choosing **`New Window`** from the **`File`** menu.

Each WaveVision window can contain multiple views of the same dataset. By default, a waveform, FFT, and histogram view are shown for each dataset.

8. **Using WaveVision Plots**

The WaveVision software provides several tools to help you interact with plots. A toolbar appears above each plot, similar to Figure 4.

Figure 4: WaveVision Plot Tools

Seen from left to right, the following tools are available:

Plot Actions menu: This menu contains commands that pertain to this particular plot. You may export the plot data to a file, print the plot, save it as a graphic, or change the plot's colors.

Plot Options: This button opens a dialog box with options that pertain to this particular plot. You may turn off labels, annotations, or other elements in this dialog. The WaveVision software maintains default options for new plots. You may edit the default options by choosing **`Default Plot Options`** from the **`Settings`** menu.

FFT Options: The toolbar shown in Figure 4 is from an FFT plot, and thus contains a button to edit the options for the FFT calculation. Depending upon the type of plot, various options may be present on the toolbar. Please consult the appropriate section below for more information about these options.

Magnifying glass tool: This tool allows you to zoom in and out to see fine details in the plot. Click and drag a box from upper-left to lower-right to zoom in on a particular region of your plot. Click and drag a box from lower-right to upper-left to zoom out. **With the magnifying glass tool selected, click the right mouse button to return to a normal, 100% view.**

Arrow Tool: The arrow tool is used to select, move, and edit annotations. To edit an annotation, double click it with the arrow tool. To delete an annotation, select it with the arrow tool and press the `Delete` key on your keyboard.

Line Annotation Tool: To draw lines on the plot, select this tool. Drag to draw new lines. To add arrowheads, or fix the endpoints of the line, double-click it with the arrow tool.

Text Annotation Tool: To draw labels on the plot, select this tool and click at the desired location in the plot. To edit the justification, location, or text of an annotation, double-click it with the arrow tool.

8.1. The Waveform Plot

The Waveform plot shows you the raw samples collected from the hardware. This plot is mainly used to verify the integrity of collected data – the waveform is the best view in which to diagnose a distorted signal, an irregular clock, a low-amplitude signal, and many other common ADC system problems.

The Waveform plot also quickly shows you how much of the ADC's dynamic range your signal occupies.

8.2. The FFT Plot

The WaveVision software automatically computes a Fast Fourier Transform (FFT) of the sample set, and displays the results in an FFT plot. The FFT plot is, in many respects, the heart of the software. The FFT shows you the frequency content of your input signal. It marks the fundamental frequency, and a selectable number of harmonics. It also labels their order and frequencies. It shows the power in the fundamental and harmonics. Try hovering your mouse cursor over a harmonic to get information about it.

The FFT can be used to diagnose common ADC problems such as input spectral impurity, clock phase noise, and clock jitter. The FFT plot also shows several statistics on the quality and purity of the collected samples, such as SNR, SINAD, THD, SFDR, and ENOB. These statistics are to be interpreted with the following definitions (which are repeated in every National Semiconductor ADC datasheet):

Signal to Noise Ratio (SNR) is the ratio, expressed in dB, of the RMS value of the input signal to the RMS value of the sum of all other spectral components below one-half the sampling frequency, not including harmonics or DC.

Signal to Noise Plus Distortion (S/N+D or SINAD) Is the ratio, expressed in dB, of the RMS value of the input signal to the RMS value of all of the other spectral components below half the clock frequency, including harmonics but excluding DC.

Total Harmonic Distortion (THD) is the ratio, expressed in dBc, of the RMS total of the first five harmonic levels at the output to the level of the fundamental at the output. THD is calculated as

$$\mathrm{THD} = 20\log\sqrt{\frac{f_2^{\,2} + \Lambda + f_N^{\,2}}{f_1^{\,2}}}$$

where f_1 is the RMS power of the fundamental (output) frequency and f_2 through f_N are the RMS power in the first N harmonic frequencies.

Spurious-Free Dynamic Range (SFDR) is the difference, expressed in dB, between the RMS values of the input signal and the peak spurious signal, where a spurious signal is any signal present in the output spectrum that is not present at the input.

Effective Number of Bits (ENOB, or Effective Bits) is another method of specifying Signal-to-Noise and Distortion or SINAD. ENOB is defined as (SINAD - 1.76) / 6.02 and says that the converter is equivalent to a perfect ADC of this (ENOB) number of bits.

8.3. FFT Options

FFT plots can be configured in many different ways. Clicking the “FFT Options” button at the top of the plot will display a dialog showing the options for that particular plot. The software also maintains default options for new FFT plots, which are editable. You can edit the default FFT options by choosing `Default FFT Options` from the `Settings` menu. The options are:

Windowing: You may choose from one of five different window functions. The window function is applied to the samples before computing the FFT to compensate for the fact that the sample set may not be an integral number of wavelengths of the input signal. In general, Flat-Top will give the best results, but you may find it easier to compare data with other systems when the windowing functions are the same.

dB Scale: You may select to represent power on the FFT in dBc (decibels relative to carrier), in which 0 dB is taken to be the fundamental (carrier) power, or dBFS (decibels relative to full-scale), in which 0 dB is taken to the be power contained in a signal which uses the entire dynamic range of the ADC.

Harmonics: You may select the number of harmonics recognized (and labeled) by the software. You may also select the number of FFT bins excluded around harmonics in, for example, SNR calculations. The exclusion region around each harmonic will be shown in a different color than the rest of the data points.

IMD Calculations: The WaveVision software is capable of performing Intermodulation Distortion calculations. When two fundamental frequencies within 3 dBFS are present in the waveform, The software will normally perform IMD calculations. You may inhibit this behavior by deselecting the "Allow IMD calculation" checkbox. When IMD calculation is enabled, you may also select whether the software will include only 2^{nd} order or both 2^{nd} and 3^{rd} order terms.

8.4. Histogram Plots

Histogram plots are created by counting the number of times each ADC output code appears in a dataset. Histograms may be computed by software, or by hardware. A software histogram is computed from a dataset which is normally 128k samples or smaller. A hardware histogram is collected directly by the hardware, and may include millions of counts per code. The resulting histogram will show discontinuities between comparators, gain or offset errors, and other common ADC system problems.

The Histogram plot also displays the number of codes that were never counted (missing codes), followed by the first ten such missing codes.

8.5. Information Viewer

The information viewer is not a plot, but it displays a variety of useful information about the dataset, such as the sampling rate, and any warnings generated by the software. You may also store comments about the dataset here, to be saved in a WaveVision file.

9. Data Import and Export

The WaveVision software provides a variety of means to share data with others, in both textual and graphical formats.

The most flexible way to import data into the software is from a tab-delimited ASCII text file. The contents can be either a sample set or a histogram, provided with or without time information. The simplest example of this would be a file with a single column of samples. You can open tab-delimited text files by choosing **`Open`** from the **`File`** menu.

There are a variety of ways to export data from the software:

- Save the file as a normal WV4 (*.wv4) file. WV4 files are ASCII, tab-delimited text files. Samples are stored one per line in a single column. You can open a WV4 file directly in a spreadsheet program.
- Save the file as a TXT (*.txt) file. You will produce a one- or two-column tab-delimited ASCII text file of samples or histogram information, without the header information that is contained in a WV4 file.
- You can export the contents of an individual plot by choosing **`Export Data…`** from the plot's **`Plot Actions`** menu. The format of the data is always tab-delimited ASCII text.
- You can export a plot as either a GIF (*.gif) or Encapsulated Postscript (*.eps) graphic by choosing **`Export Plot as Graphic`** from the plot's **`Plot Actions`** menu. GIF files are suitable for the web or for emails. Encapsulated Postscript files are high-resolution scalable files suitable for direct publication.