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Understanding Signals

Student Guide

VERSION 1.0

PARALLAX 

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- [BASIC Stamps](#) – With over 2,500 subscribers, this list is widely utilized by engineers, hobbyists and students who share their BASIC Stamp projects and ask questions.
- [Stamps in Class](#) – Created for educators *and* students, this list has 500 subscribers who discuss the use of the Stamps in Class curriculum in their courses. The list provides an opportunity for students to ask educators questions, too.

- Parallax Educators – This focus group of 100 members consists exclusively of educators and those who contribute to the development of Stamps in Class curriculum. Parallax created this group to obtain feedback on our curriculum development and to provide a forum for educators to develop Teacher's Guides.
- Parallax Translators – Consisting of less than 10 people, the purpose of this list is to provide a conduit between Parallax and those who translate our documentation to languages other than English. Parallax provides editable Word documents to our translating partners and attempts to time the translations to coordinate with our publications.
- Toddler Robot – A customer created this discussion list to discuss applications and programming of the Parallax Toddler robot.
- SX Tech – Discussion of programming the SX microcontroller with Parallax assembly language tools, compilers (BASIC and C). Approximately 600 members.

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Preface

This text demonstrates how to use the OPTAscope 81M as an oscilloscope by viewing common signals generated by sensors and the Parallax BASIC Stamp. Most of the circuits and examples used in this guide are drawn from other Parallax Stamps in Class educational texts: *What's a Microcontroller?*, *Basic Analog and Digital* and *Applied Sensors*.

Students completing this text should be able to accomplish the following:

- Configure an oscilloscope to trigger and capture a signal.
- Measure waveform frequency and amplitude for single and dual sine waves.
- View a repetitive signal as it is changed using BASIC Stamp code or by varying sensor inputs.
- Understand the differences between synchronous and asynchronous serial signals.
- Know two common uses of Operational Amplifiers (op-amps).
- Make viewable infrared communication from handheld remote controls.

Signals and waveforms are discussed throughout the Stamps in Class series, but truly understanding their form and speed requires capturing and viewing the signals on an oscilloscope. The knowledge gained will allow students to take the leap from using pre-written BASIC Stamp code to using a datasheet to develop their own synchronous serial code, or even to choosing resistive sensors most suitable for their own projects. Viewing the signals that power servos can lead students to better understanding and utilization of programming techniques used for robotics and control systems applications.

The OPTAscope 81M is a low-cost, USB-based oscilloscope made by Optimum Designs. Parallax generally has kept the hardware kits for the Stamps in Class texts under one hundred dollars (excluding robots), but the OPTAscope 81M provides a great opportunity to support the texts and complete students' electronic kits at a relatively low cost.

The OPTAscope is a small, affordable oscilloscope that can help students to create and work with advanced electronic systems. Even if students have used an oscilloscope once or twice before, these OPTAscope 81M exercises will provide a greater understanding of oscilloscopes as tools and of electronics in general. This in turn will enhance the

students' educational experiences while working with BASIC Stamp-generated signals in projects found throughout the Stamps in Class series of textbooks

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SPECIAL CONTRIBUTORS

Doug Pientak of Optimum Designs in Forest Grove, Oregon wrote the initial draft of this curriculum. Optimum Designs provides custom electronic design and consulting services, and also manufactures PC-based test equipment such as the OPTAscope 81M. Doug Pientak gained six years of experience working with high speed digital storage oscilloscopes in the Research and Development labs at Intel Corporation.

Optimum Designs would like to provide special thanks to the entire Parallax Team, who has provided a great amount of support and ideas to Optimum Designs, Inc. In particular, Aristides Alvarez, Ken Gracey, Andy Lindsay and Stephanie Lindsay lent extensive aid in the formatting and technical editing of the final revision. The Parallax Team strives to design, manufacture, and sell the BASIC Stamp line of products with the customer truly in mind. They are a great group of people.

In addition, recognition and thanks must go to our customer Sid Weaver, whose volunteer beta-testing provided valuable insight that allowed us to enrich the contents of this text.

Chapter #1: Oscilloscope Basics

Using an oscilloscope makes it much easier to characterize and understand the signals coming from a sensor or microcontroller. *Understanding Signals* assumes you've never used an oscilloscope. For the OPTAscope 81M to be of value to you, we must first teach you how to use an oscilloscope.

WHAT IS AN OSCILLOSCOPE?

An oscilloscope is an electronic device that displays graphical representations of electrical signals or waveforms. These graphical representations have two components, time and voltage. Time is represented by the horizontal axis, and voltage is represented by the vertical axis. There are two main types of oscilloscopes: analog oscilloscopes, and digital storage oscilloscopes.



Analog Oscilloscope: traditionally an instrument that creates a waveform display by applying the input signal (conditioned and amplified) to the vertical axis of an electron beam moving across a cathode-ray tube (CRT) screen horizontally from left to right. The inside of the CRT is coated with phosphor to create a glowing trace wherever the beam hits.

Digital Oscilloscope: a type of oscilloscope that uses an analog-to-digital converter (ADC) to convert the measured voltage into digital information. There are three types: digital storage, digital phosphor, and digital sampling oscilloscopes. The Tektronix *XYZs of Oscilloscopes* article at www.tektronix.com contains a detailed discussion of oscilloscope features and example applications.

The OPTAscope 81M is a digital storage oscilloscope that will be the focus of *Understanding Signals*, shown in Figure 1-1. Digital storage oscilloscopes record the voltage for a period of time and then display it, allowing you to review the fluctuations of the signal during the period recorded with great detail.



Figure 1-1:
The OPTAscope 81M

This portable oscilloscope connects to your PC via a USB cable. It comes with 3 sets of 1x probes, a USB cable, and a software CD (not shown).

Figure 1-2 provides an example of 1 ms (millisecond) of time, read from left to right. To accomplish this, the oscilloscope samples the input signal, or waveform, at a very specific rate called the sample rate. The OPTAscope has a maximum sample rate of one million samples per second, (1Ms/s) when using one channel, half that when using both channels at once. The sample rate is the limiting factor that determines the maximum signal frequency that the OPTAscope can capture and display. This means that, with the OPTAscope, you can view any sine wave with a frequency of 60 kHz or less. Square waves can be viewed if they are 100 kHz or less. In either case, using the Zoom feature produces nice waveform images even at these extreme speeds.

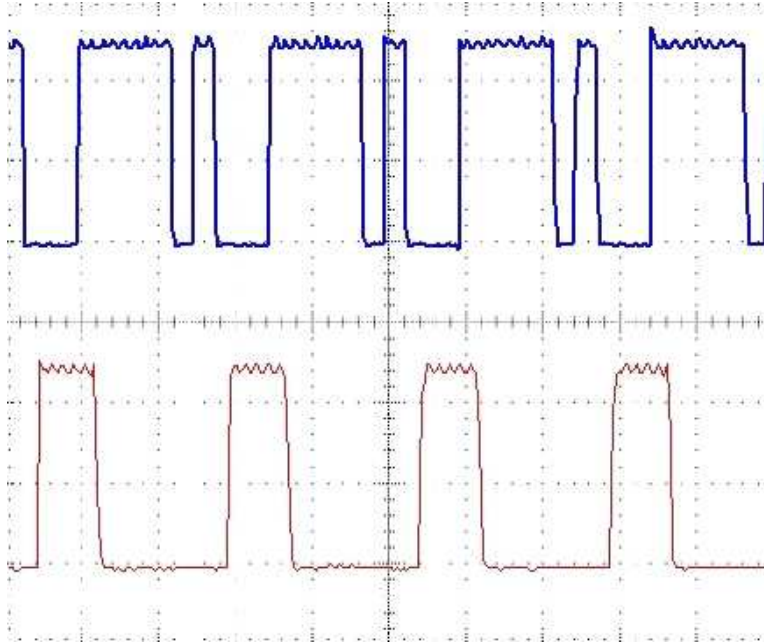


Figure 1-2:
OPTAscope 1Ms/s
example.

*Here is an example
of the output of the
OPTAscope. It is
displaying the
characteristics of
two signals during
the same period of
1 ms.*

*This dual signal
display ability
allows you to see
what the signals
look like and their
relationship to each
other - very
important in some
applications.*

HOW DOES AN OSCILLOSCOPE WORK?

We have said that digital oscilloscopes sample and record signals, and then display these signals for viewing. Functionally, this is very similar to a simple datalogger. The difference between the two is that dataloggers record data all of the time, but oscilloscopes may be *triggered* to store data at particular times.

The trigger controls *when* the oscilloscope will start recording the input signal. The trigger allows you to capture and view only the segment in which you are interested. The criteria controlling the trigger action is called a trigger event. The OPTAscope 81M has edge-triggered events. More advanced oscilloscopes have several types of configurable trigger events: pulse width events, pulse sequence events, and even more exotic event triggers that can trigger on the start of a video packet in a composite TV signal. This text will focus on the OPTAscope's edge-trigger event ability.

There are two types of trigger events supported by the OPTAscope: rising edge, and falling edge. A rising edge is described as the point at which a relatively low voltage signal ascends to a relatively higher voltage. The converse is a falling edge. A rising edge trigger event will occur when the voltage of the signal rises above the set trigger point, and a falling edge trigger event occurs when the voltage falls below the trigger point. Upon a valid trigger event, the OPTAscope will begin recording the sampled signal input and continue until its memory is full.

When the OPTAscope displays the captured signal, the trigger event will be centered in the display for you to see. A rising edge-triggered signal is depicted in Figure 1-3.

Anything to the left of the trigger event is called “pre-trigger” because it happens before the trigger event. Anything to the right of the trigger event is called “post trigger”. This is important because when attempting to trigger the oscilloscope to capture a specific event, you need to set your trigger level to get as close as possible to the event you want to see.

In Figure 1-3, only one signal is displayed on the screen. With OPTAscope 81M you can have two signals displayed on the screen at the same time. Both signals are sampled or recorded concurrently, which allows you to view both signals (called channels) during the same period of time.

During the exercises in this text, you will use the OPTAscope to trigger, capture, and display signals. In doing so, you will learn the function and use of oscilloscopes, and gain a greater understanding of the different signal types you will encounter. Ultimately, you will also see how these skills can be useful working with different electronics applications.

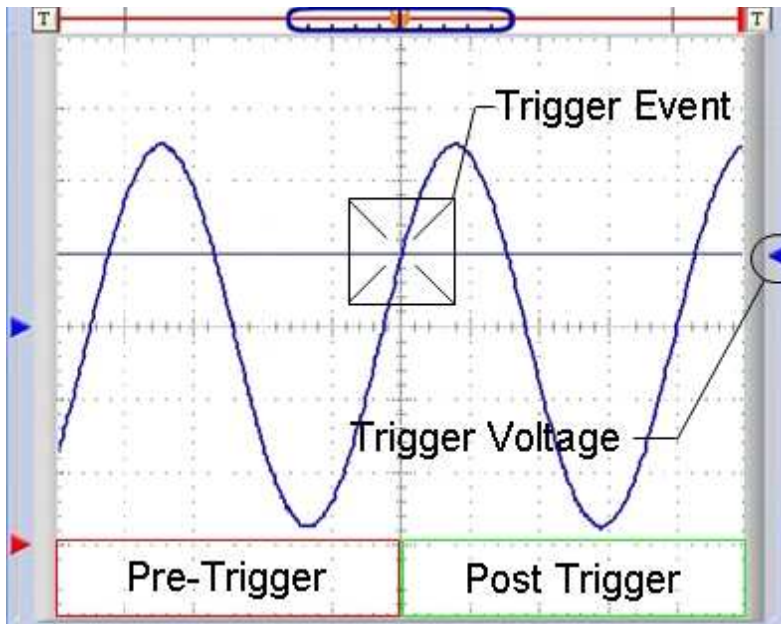


Figure 1-3:
Example of a
rising trigger
event, and the
resulting
waveform

OSCILLOSCOPE SAFETY

Before test-driving your OPTAscope 81M, it is important for you to be aware of the general safety guidelines for working with oscilloscopes. Working with oscilloscopes requires you to work on circuits with live voltage. Live voltage can and does KILL people every day. It is your responsibility to learn the following safety guidelines and practice them faithfully while working with live circuits. Failing to do so can result in equipment damage, and severe personal injury or death. Below you will find a list of safety rules that you are to use as a guideline while working with live circuits and the OPTAscope.

- Remove metallic jewelry and watches before starting.
- Make sure your hands are clean and dry while working with the OPTAscope.
- Work upon an anti-stat pad that is properly grounded.
- Keep your work area free from food and beverages.
- Do not attempt to measure any voltage that could be 20 Vpp or higher.
- If anything you are working on gets hot, turn it off immediately.
- ALWAYS disconnect the power supply to the circuit you are measuring before walking away from your workstation.

RUNNING THE OPTASCOPE 81M FOR THE FIRST TIME

Setting up the OPTAscope is a matter of installing the software from the CD provided, and connecting the OPTAscope to your PC via a standard USB cable (included). You may also obtain the latest version of the software from www.parallax.com. If the OPTAscope is not immediately recognized after driver installation see the “Hardware Installation” section of the on-line help file from your Start → Programs → Optimum Designs folder.

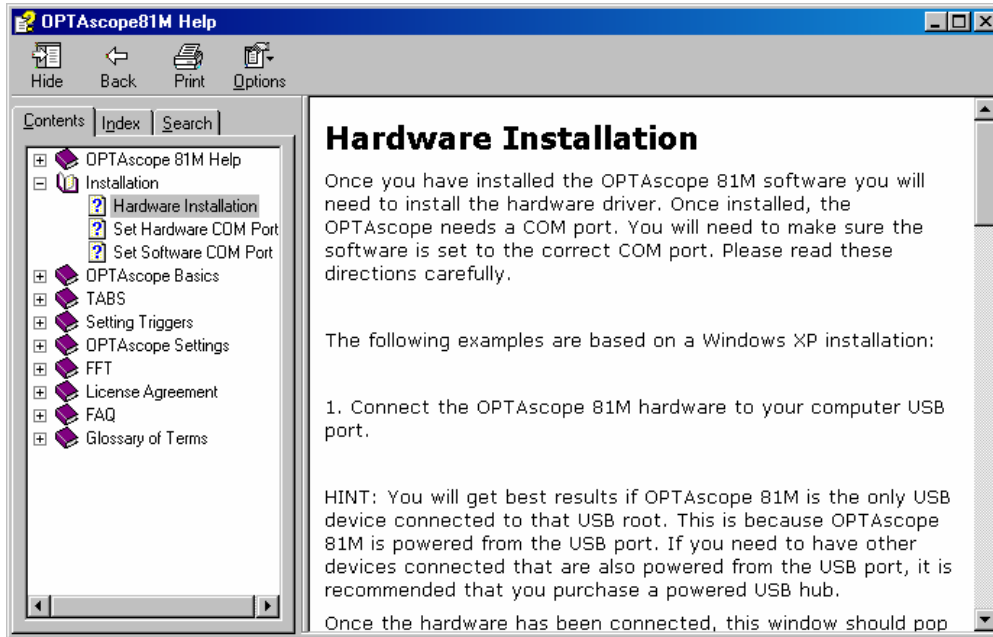



Important note to lab instructors and system administrators: Each OPTAscope has a unique USB-ID. If the computers in the lab are configured so that the students are not permitted to install new hardware, make sure that each OPTAscope has a label indicating which PC it was installed to. Students should then be instructed to use the PC indicated on the OPTAscope's label (or check out the OPTAscope with a label that corresponds with one on the PC they are using).

The reason unique IDs are used is because it gives you the option of running more than one OPTAscope on a single PC. This can be accomplished because the OPTAscope software assigns a unique COM port to each OPTAscope. This means you can open more than one instance of the OPTAscope software and use each to monitor signals using a different OPTAscope.

This section will guide you through the OPTAscope's basic hardware and software settings. This will give you an overview of how the OPTAscope works, and point out the various features you will be using in the upcoming exercises.

Figure 1-4: The OPTAscope hardware setup detailed in the on-line help file



 **Don't be afraid** if you change the settings to an unknown state. You can always reload the factory default settings. To do this, select File → Load Factory Default Settings from the pull down menu. Follow the directions and this will bring you back to a default installation state. Resetting to defaults will erase your calibration data and can reset your COM port setting if you answer yes to both questions.

Plot Area

The Plot Area is where the signals are displayed after the oscilloscope samples and records them. Notice the graph made up of 10 divisions horizontally and 8 divisions vertically. These divisions can be used to measure the signal's voltage (vertical divisions) and time duration (horizontal divisions). With the OPTAscope 81M you can have one or two signals in the Plot Area (Figure 1-5).

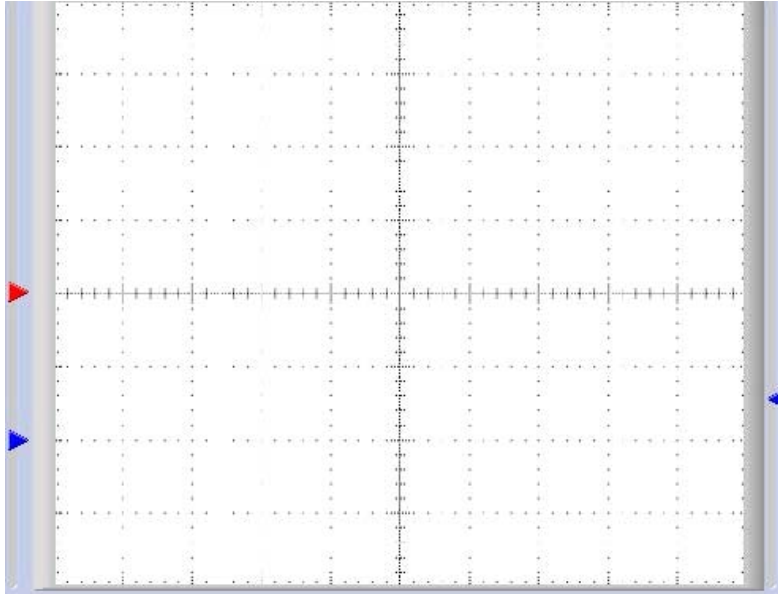


Figure 1-5:
The Plot Area

Note the horizontal and vertical divisions grid.

The red and blue arrows to the left are handles that allow you to adjust the vertical position of the signals. This will allow you to arrange the signals within the Plot Area as you wish, perhaps separating them for clarity or overlaying them for comparison.

The blue arrow to the right adjusts the trigger voltage. When you move this arrow a line will be displayed on the Plot Area representing the trigger voltage, then it will disappear three seconds after you stop moving the arrow. The trigger voltage arrow will change color depending on which channel you have selected as the trigger source. This arrow will not show if you set the Trigger Source switch to External.

Horizontal Dial, Vertical Dial (Volts/Div), Channel Buttons and Run/Stop Button

Recall that the OPTAscope can display graphs of two signals, each with two components: voltage and time. The Horizontal dial sets the time base of the oscilloscope, by choosing the amount of time represented by each division in the Plot Area. See Figure 1-6.

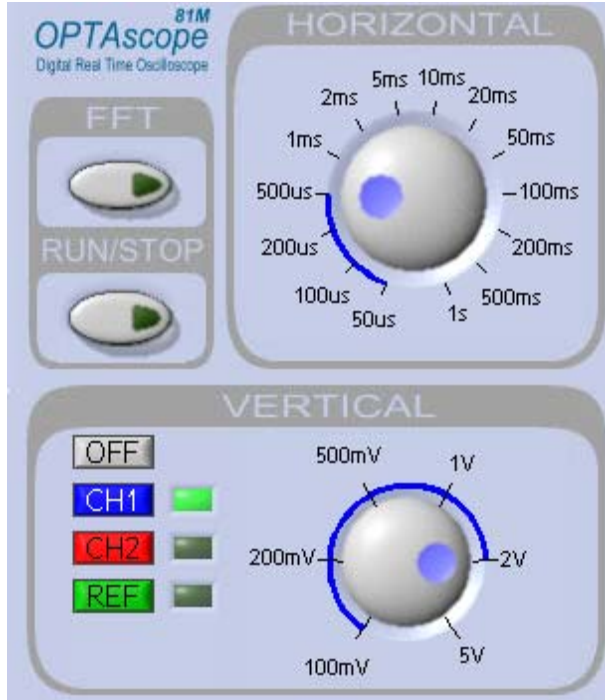


Figure 1-6:
Horizontal, Vertical, FFT
and Run/Stop controls

The Vertical dial, representing volts per division, sets the voltage scale on which the input signal will be displayed. Example: if the Vertical dial is set to 2 V (2 V/Div) and the signal displayed is 2½ divisions above the channel indicator, then the voltage of that input channel is equal to 5 Volts. It is possible to have different scales set for each signal, so that while Channel 1 is set to 2 V per division you can have Channel 2 set to 5 V per division.

The channel buttons, CH1 and CH2, select the active channel. The active channel is the last channel button clicked (with the green LED), and is also the selected channel for the Vertical dial, cursors, and automatic measurements in the display screen. The OFF button will turn off the active channel.

The Run/Stop button starts and stops the OPTAscope 81M. When the button is pressed, the OPTAscope 81M acquires data as indicated by the green LED in the button. To stop

the oscilloscope, press the Run/Stop button again. You will see it depress, indicating the oscilloscope is idle.

The FFT button opens the Fast Fourier Transformation window (Figure 1-7). The OPTAscope's Fast Fourier Transformation (FFT) function emulates a device called a spectrum analyzer by displaying the sine wave frequencies contained by a signal.

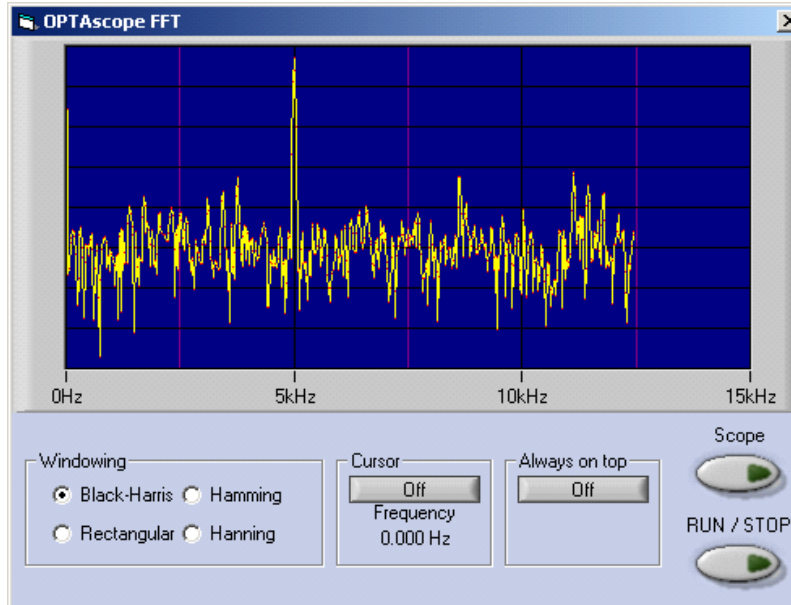


Figure 1-7:
The
OPTAscope's
FFT Window.

Plot Area Indicator

The Plot Area Indicator bar depicts the portion of the signal visible in the Plot Area. The OPTAscope 81M acquires 1,500 points every trigger event. The Plot Area automatically displays the center 500 points, represented by the blue slider bar. The red line represents the entire 1500 points captured. You may view these portions of the signal to the left or right of center by sliding the blue bar along the red line.

The orange arrow within the Plot Area Indicator bar indicates the trigger position and its relative location within the 1,500 points of data acquired. The “T” buttons on each end of the Plot Area Indicator bar move the trigger position to 10%, 50% (default) and 90%. Figure

1-8 shows the trigger position set to 50%. When the vertical line in the blue bar is lined up with the “T” in the trigger position arrow, the trigger event will line up in the center of the Plot Area.



Figure 1-8:
Plot Area
Indicator

Display Screen

The Display Screen (Figure 1-9) tabulates information regarding the OPTAscope’s settings and the measurements of the signals captured. The Channel Settings box displays the current volts per division setting for each channel. The Sample Rate box displays the number of samples taken each second. The Trigger Settings box displays the trigger channel selected and the trigger voltage level. The Automatic Measurements box displays the results of the automatic measurements taken. The Cursors box displays the statistics of the cursors positioned by the users. The Δ (delta) represents the difference in time between the two cursors. The f represents the frequency ($1/\Delta$) depicted by the relative cursor position. The cursor readouts are in reference to the active channel.

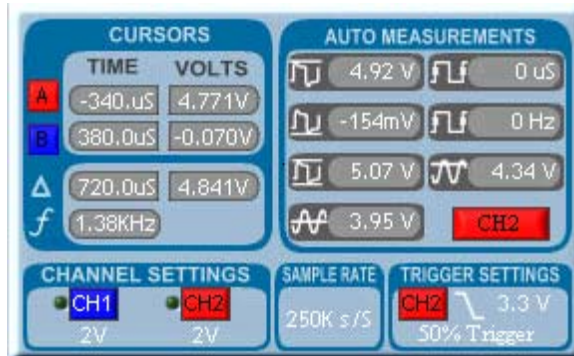


Figure 1-9:
Display screen

Files / Settings Tab

The Files/Settings tab gives you direct access to the Export Picture, Export Data, Print, Print Preview and OPTAscope Settings buttons, as shown in Figure 1-10 . For more detail on these features, review the OPTAscope help file. By clicking on the OPTAscope Settings button, a menu will appear giving you access to the Calibration, Hardware Setup, and Save/Load options.

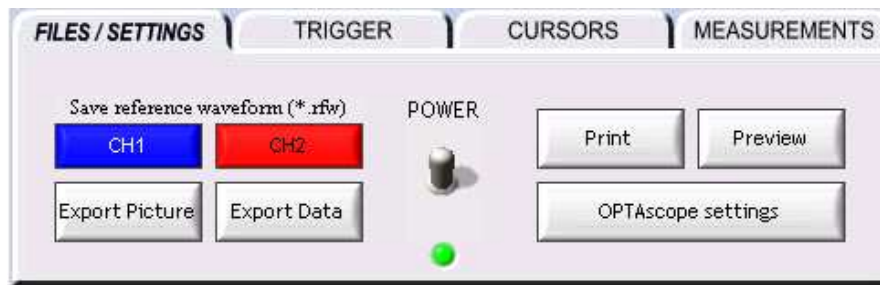


Figure 1-10:
Files /
Settings
Tab

Trigger Tab

Clicking the Trigger tab brings up a menu which allows you to set the Trigger Source, Trigger Edge, Trigger Mode, and Run/Stop Mode switches (Figure 1-11). The Trigger Source switch selects the channel monitored by the OPTAscope for a trigger event. (The external trigger is not displayed in the Plot Area and, when selected, is limited to rising-edge trigger events only.) The Trigger Edge switch configures the OPTAscope to wait for either a rising edge or a falling edge to use as a trigger event.

The Trigger Mode switch selects how long the OPTAscope will wait for a trigger event. In Normal mode the oscilloscope will wait for a trigger event until it finds one. This could take a fraction of a second, a minute, or even a week. If the trigger event never occurs the oscilloscope will never trigger, and you will never see a waveform in the Plot Area.

In Auto mode the oscilloscope will wait only a small portion of time for a trigger event. If the trigger event is not detected, the oscilloscope will trigger itself automatically. Whatever signal is being received at the time will be captured and displayed in the Plot Area.

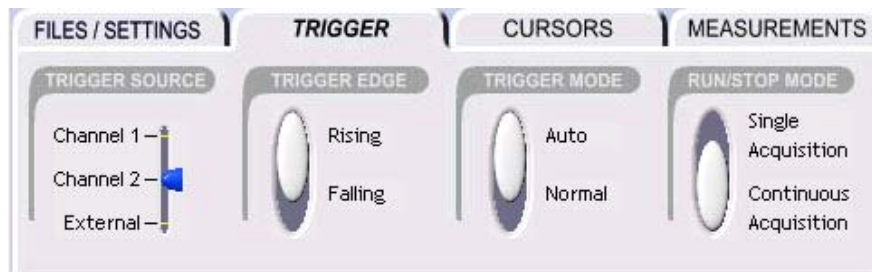


Figure 1-11:
Trigger
Tab



Auto mode is great as a first step to make sure you have the oscilloscope setup correctly. However, if the trigger event occurs infrequently, you may never see the signal you are looking for while in Auto mode. In that case, Normal mode is the better choice.

Cursors Tab

The Cursors tab shown in Figure 1-12 allows you to select the type of cursors you wish to use. The Cursor Settings switches give you several options. Snap to Plot will make the cursors snap to the closest data point on the active channel. Floating cursors are free to be placed anywhere within the Plot Area by you, the user. The other Cursor Settings switch gives you three cursor options, Horizontal Bars, Vertical Bars and Paired Bars, all of which will be used in the upcoming experiments.

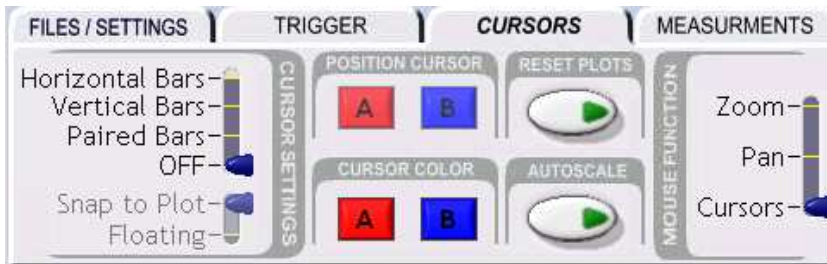


Figure 1-12:
Cursors Tab

The Position Cursor buttons will select and place the cursor(s) anywhere on the screen by clicking the associated button and then clicking in the Plot Area. Use Cursor Color to change the color of each cursor.

The Autoscale button will allow you to view all 1,500 data points in the Plot Area at once, where normally you would have to slide the Plot Area Indicator bar to see the 500 points to the left and right. Additionally, Autoscale will automatically adjust the volts per division setting such that the signal is displayed advantageously in the Plot Area.

The Mouse Function switch allows the mouse to operate in three different modes in the Plot Area. Zoom mode allows you to drag and draw a box around an area, then zoom in on that area to view detail. Pan mode lets you pan around the Plot Area while the cursors stay in place, while Cursors mode lets you move the cursors around.

The Reset Plots button will reset all plots to their default values. This button allows you to zoom out after you have zoomed in, and will also reset the Autoscale.



Cursor menu functions can also be accessed by right-clicking on the Plot Area.

Measurements Tab

The Measurements tab displays the automatic measurements for both channels. Each time a new screen shot of data is displayed the measurements are recalculated. Here is a quick description of each measurement:

MAX is the maximum the signal reached in the acquisition.

MIN is the minimum the signal reached in the acquisition.

Pk - Pk is the peak to peak voltage of the signal, calculated from MAX and MIN.

MEAN is the mean average voltage of the signal.

PERIOD is the time measured between two rising edges.

FREQ is the frequency of the signal (1/PERIOD).

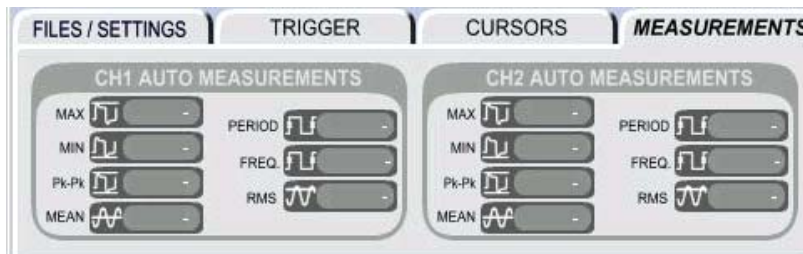


Figure 1-13:
Measurements
Tab

ACTIVITIES PREPARATION

You should already have your OPTAscope 81M connected to your PC and its software up and running. You may also check for the latest OPTAscope software at www.parallax.com

You will also need to have your Board of Education with a BASIC Stamp 2, or your HomeWork Board, connected to your PC. You will need the BASIC Stamp Editor v 2.0, available on a May 2003 or newer Parallax CD, or as a free download from www.parallax.com.

All activities in this text assume that you are using a fresh 9 V battery as your power supply. Please be aware that using worn-out batteries or alternative power supplies may alter your voltage signals somewhat from those shown in the book.

For detailed instructions on setting up your BASIC Stamp hardware and software, see *What's a Microcontroller?* under the Further Investigation section at the end of this chapter.

The Board of Education, BASIC Stamp and HomeWork Board are sold separately. For a complete list of system and equipment requirements, see Appendix A.

ACTIVITY #1: VIEWING HIGH AND LOW SIGNALS

In this activity we will verify the proper operation of your OPTAscope by viewing simple high and low signals from the BASIC Stamp.

Parts Required

- (1) OPTAscope CH1 probe and ground cable
- (2) Jumper wires



Which probe is which? The OPTAscope probes are color-coded to correspond with controls and signals graphics in the software. Connect the blue-tipped probe cable to the CH1 jack on the OPTAscope, and the red one to the CH2 jack. The green-tipped cable plugs into the External Trigger TTL jack. In the wiring diagrams, the probes are labeled for clarity. The active channel probes are colored (CH1 is blue, CH2 is red); the Ground probes are black.

Building the High and Low Signals Circuit

This circuit is built the same way for the Board of Education and the BASIC Stamp HomeWork Board.

- √ Plug the probe cable into the CH1 jack on the OPTAscope.
- √ Build the simple circuit shown in Figure 1-14 and Figure 1-15.
- √ Connect the OPTAscope CH1 probe to I/O Pin 14 of your BASIC Stamp.
- √ Connect the black probe to the BASIC Stamp's Vss connection (ground).

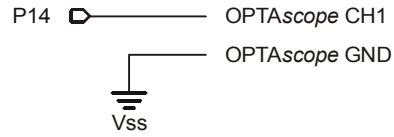


Figure 1-14:
High and Low signals
circuit schematic

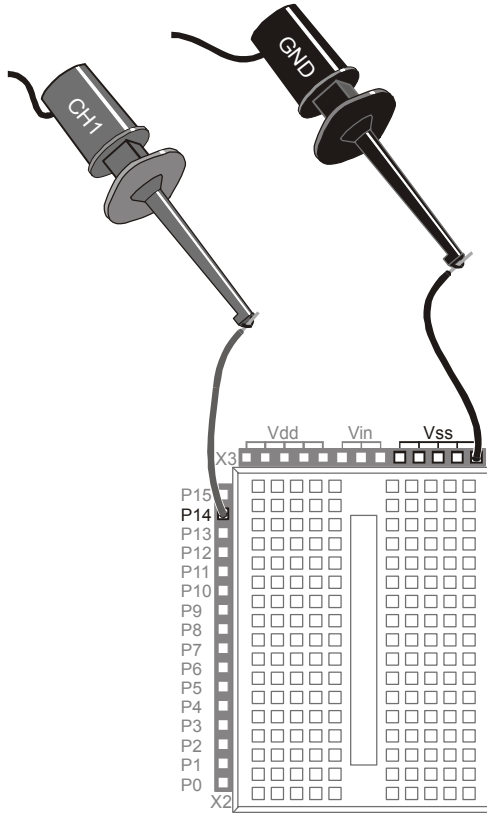


Figure 1-15:
High and Low signals
wiring diagram

Configuring the OPTAscope Software

- √ Open the OPTAscope software.

- √ Set up the OPTAscope to display the signal as shown in Figure 1-16. Remember, click on and drag the arrow to the left of the Plot Area to set the trigger voltage.

CH1	5 V / division
CH2	Off
Horizontal Dial	5 ms / division
Trigger Source	None
Trigger Edge	Falling
Trigger Mode	Auto
Run / Stop Mode	Continuous
Trigger Voltage	2 V

Figure 1-16:
Configuring the OPTAscope to view high and low signals

Measuring 5 V with PinHigh.bs2 Program

- √ Run the program PinHigh.bs2.

```
' Understanding Signals - PinHigh.bs2
' Make I/O pin high to demonstrate 5V measurement

' {$STAMP BS2}
' {$PBASIC 2.5}

DO

    HIGH 14

LOOP
```

In the OPTAscope Plot Area, you should see a line across the screen one division up from the blue arrow on the left (Figure 1-17). Your Vertical dial should be set to 5 V per division. A BASIC Stamp output pin should read about 5 V when it is “driving high”.

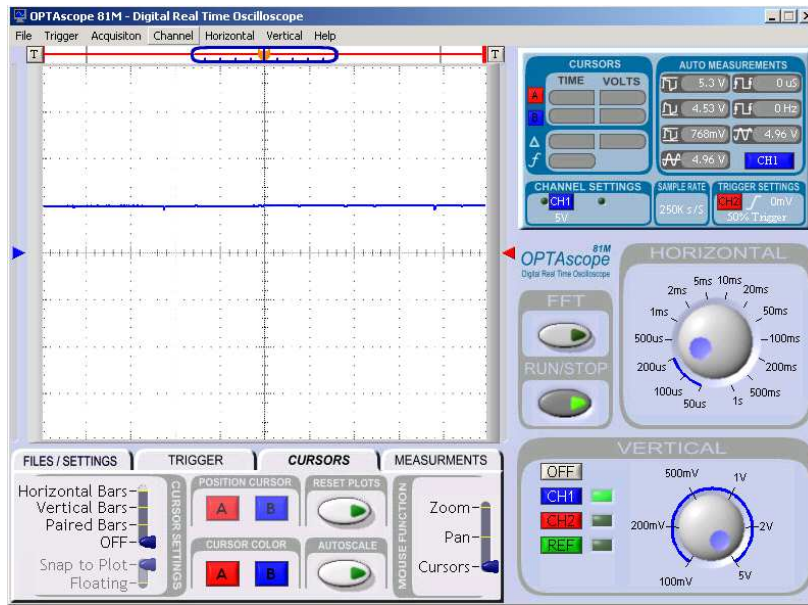


Figure 1-17:
High signal
example from a
BASIC Stamp

√ Change the **HIGH 14** command to **LOW 14**. What do you see now?

If you could watch the OPTAscope Plot Area while you programmed the BASIC Stamp, you would see the signal change from high (5 V) to low (0 V). Now you can see that the oscilloscope displays a low (0 V) as a line starting right at the blue arrow to the left. Since the BASIC Stamp is not changing the voltage level on this I/O pin during the program, you see a flat line. The next activity will generate a voltage that changes over time to make the plotted signal more interesting.