POWER MONITORS INC.

Ch 3: 119V

Voltage

Ch1 Ch2 Ch3 Ch4 3Ø   Esc

PalmView

Real-time Waveform and Harmonic Software for the Palm OS Platform

Table of Contents

I. Quick Start Guide

Introduction:

PalmView is a software package for the Palm Operating System that displays real-time waveforms and harmonics when connected to a PMI Scanner. The Scanner continues to record normally while the Palm displays real-time waveforms.

Software Installation:

➢ If you haven't already, install the Palm Desktop and HotSync Manager Software by following the instructions in your Palm Handbook.
➢ Find the files sent to you by PMI and double-click on the "PalmView.prc" file. The HotSync Manager will pop up a dialog box asking you which user you want to install the program too. Choose your username and select 'OK' and then select 'Done'.
➢ HotSync your Palm and PalmView will be installed.
➢ To communicate with PalmView, your Scanner must have the latest firmware installed. If you need to upgrade, upload the new firmware to the Scanner by either using PalmScan or WinScan. (See their manuals for uploading instructions.)

Starting PalmView:

To communicate with the Palm, the scanner must have power. Supply power and connect the scanner cable to the scanner. Then connect the Palm Cable to the scanner cable.

Once the scanner is powered and the PDA is "connected" to the scanner, tap the PalmView icon to reach the **Main Form**, which has six buttons:
(The default screen is Ch1 Voltage)

| V | Advances to the Voltage Waveform Screen. |

| A | Advances to the Current Waveform Screen. |

| W | Advances to the Real Power Waveform Screen. |

Advances to the Voltage Harmonic Screen. Pressing a channel button a 2nd time will go to the Current Harmonic Screen. Pressing a channel button a 3rd time will advance to the Power Harmonic Screen. A 4th press will return to the Voltage Harmonic Screen.

Advances to the V-I Curve Screen.

Advances to the Vector Diagram Screen.

You can press a button anytime to get to the screen you desire. The graphing is auto-scaled so no manual settings are necessary. Tapping inside of the graph region puts a crosshair cursor on the waveform and displays the numerical value at that point. To remove the cursor, simply tap outside of the graph region (for example where the Voltage is printed).

II. Installation Instructions

Make sure you have followed all of the instructions in Palm's Handbook that accompanied your Palm. This handbook will walk you through installing the Palm Desktop software and HotSync Manager. Skim the handbook so that you can become familiar with how the Palm operates and which buttons perform which functions.

If your Palm Desktop has been installed and you have had at least one successful HotSync with your Palm, then you are ready to install PalmView. To install PalmView, merely double-click on the 'PalmView.prc' either sent to you via e-mail (Fig. 1) or on the WinScan CD-ROM sent to you with a PMI Scanner. By double-clicking on a '.prc' or '.pdb' file, Install Tool will automatically pop up a dialog box (Fig. 2).
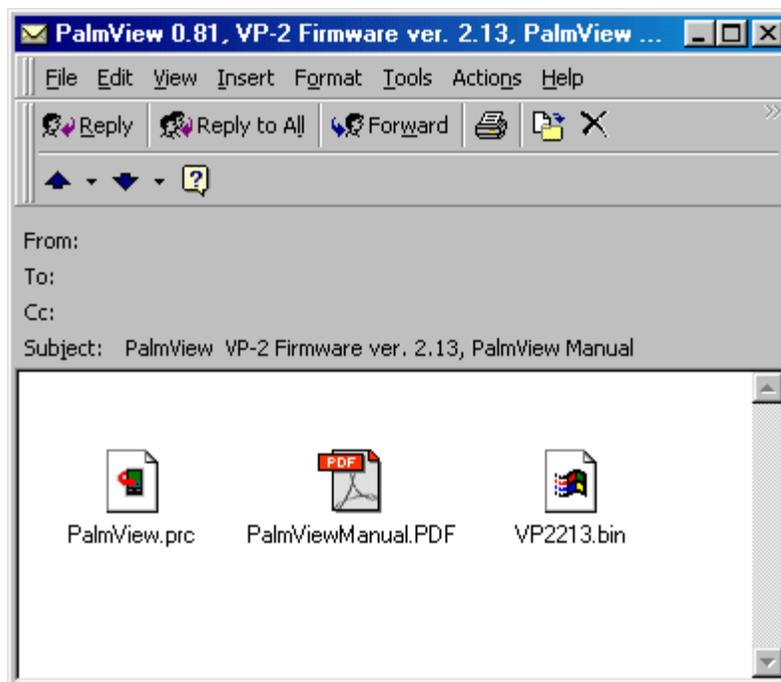
Fig. 1

Note: Palm's HotSync Utility will keep the Com port occupied if you do not manually close the Utility. You can also opt to left click on the HotSync Icon in the bottom right corner of your PC and deselect 'Local Serial'. In order to use WinScan on the same Com port as your HotSync Cradle, you must disable the HotSync Manager everytime you wish to use WinScan and re-enable it when you need to HotSync your Palm.

Fig. 2

Then you must select your Username from the pull down dialog box (Fig. 2). The one selected in this example is 'PMI Engineering.' Then select 'OK'. This will take you to a screen similar to the one in Fig. 3.
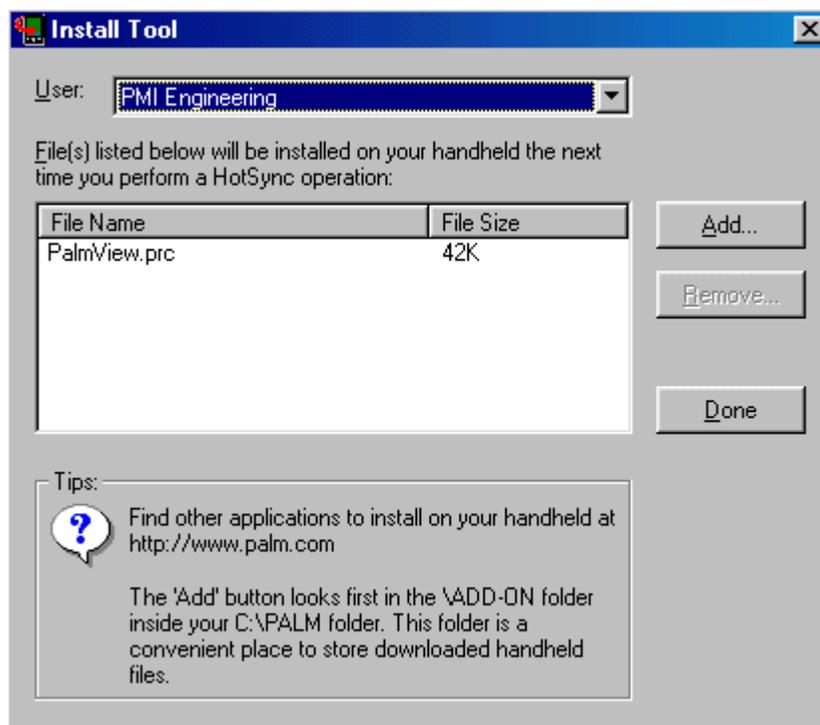

Fig. 3

You will notice that the file you just double-clicked on, 'PalmView.prc', is in the Additions box. Now select 'Done' and the Install Tool will disappear. The next time you perform a HotSync operation, 'PalmView.prc' will be installed on your Palm.

Once PalmView has been installed on your Palm, you may select the PalmView Icon from the Applications Launcher page (Fig. 4). Then a screen will appear that asks you for an unlock key (Fig. 5). This screen is to prevent unauthorized copies of PalmView from being distributed. You will need the Serial Number that this screen displays when you contact PMI to obtain the Unlock Code for PalmView. You may write down your Serial Number and your Unlock Code in the space provided below or in a location you can find easily. This is in case you ever need to perform a hard reset on your palm (which will erase all programs on your Palm and you will need to reinstall PalmView and the Unlock Code).

Serial Number of Palm: _____
Unlock Code for PalmView: _____

Fig. 4

Fig. 5

Once you have obtained the Unlock Code from PMI, tap the 'Enter Key' shown in Figure 5 and a keypad screen will appear. Tap the numbers corresponding to the Unlock Code provided by PMI and after entering the last digit, PalmView will startup. You will not have to enter this key every time you enter PalmView, but rather only when your Palm has had a hard reset, which should be very rare. After you unlock PalmView, you are ready to use the software. Now you need to hook up your PMI Scanner to your Palm. **Note: PalmView shipped from the factory will already have the Unlock Code installed.**

There are four items on the checklist to start using PalmView:

1. The PMI Scanner must be hooked up in a manner that provides you the readings you desire.
    A. ViP -- The voltage leads and current clamps need to be connected to the appropriate channels you wish to measure.
    B. VP-2 -- Plugged into a wall socket with the appropriate load that you wish to measure plugged in the bottom of the unit.
   C. iVS-2S -- Plugged into a meter socket.

2. After making sure the Scanner is powered, plug the supplied cable that came with the individual scanner into the Comm Port of the Scanner
    A. **ViP Comm Cable – PMI Part # 20506002**
    B. **iVS-2S Comm Cable – PMI Part # 30150010**
    C. **VP-2 Comm Cable – PMI Part # 30150008**

3. Then connect the Palm Cable (**Palm IIIxe -- PMI Part # 20508001**) into the corresponding Scanner cable (note that the Palm cable has a male DB-9 connector which mates with the female DB-9 connector on the Scanner cable). If for some reason you are unable to obtain a PMI Custom made Palm Cable and are in urgent need of one, you may do the following:
    A. Obtain two items:
        1. **DB-9 Male to Male Gender Changer**
        2. **Null Modem Adapter**
    B. Merely connect the two items together and plug one end into the PMI scanner cable and plug the other end into the Palm HotSync Cradle or Cable.
    C. Part numbers for RadioShack and CDW (You may have to order them):
        1. **At Radio Shack:**   (http://www.radioshack.com)
            Male to Male DB9 Gender Changer
            Cat.#: 950-0256 Model: G227T, Reg. Price $4.99 (must order)
            DB9 Male to DB9 Female Null Modem Adapter
            Cat.#: 26-264, Reg. Price $5.99 (Available in stores)

        2. **At CDW:**   (http://www.cdw.com)
            Male to Male DB9 Gender Changer
            CDW Part# 072537, Reg. Price $6.78
            Manf. Part# F4A094 (Belkin --- http://www.belkin.com)
            DB9 Male to DB9 Female Null Modem Adapter
            CDW Part# 113064, Reg. Price $6.92
            Manf. Part# 08075 (Cables To Go)

4. Lastly, the Palm Cable plugs into the Palm's Serial Port (on the bottom of the Palm, see Fig. 6).

Figure 6
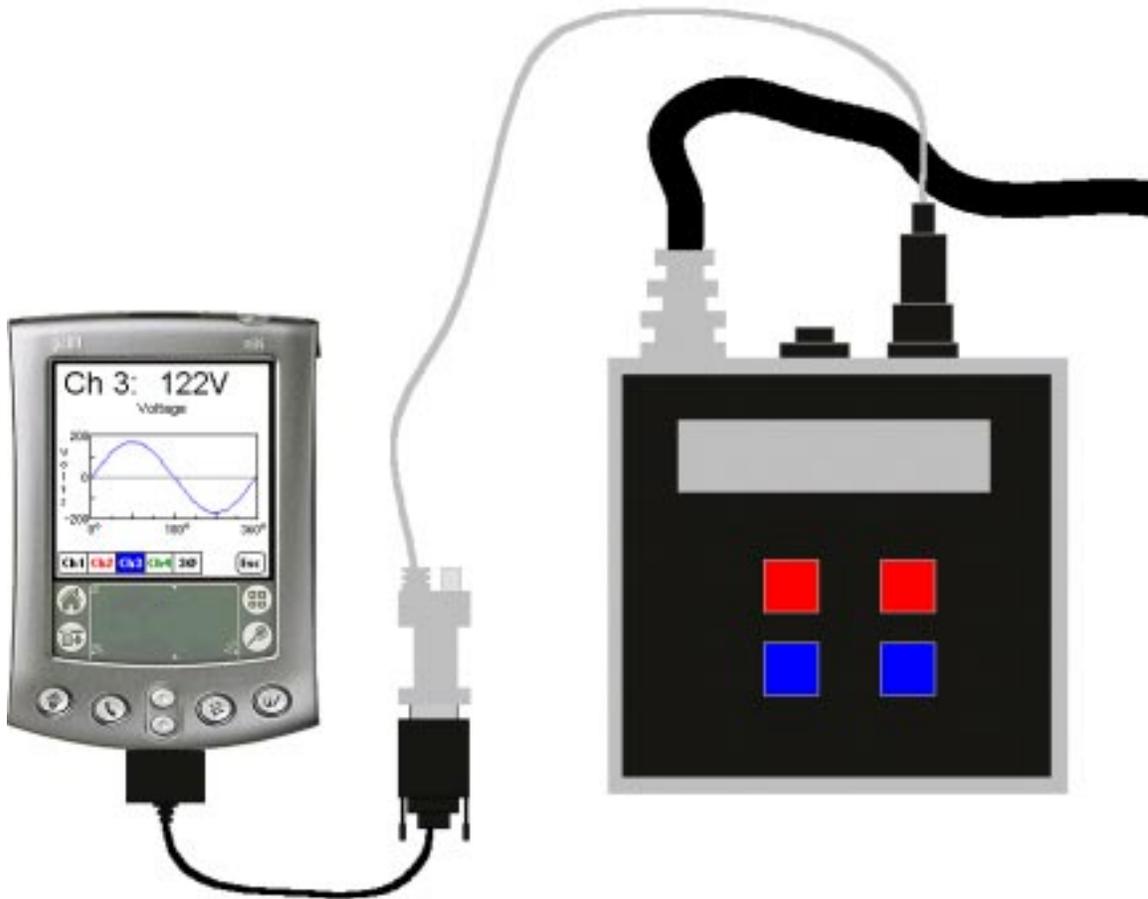
After the Scanner has power and both cables are connected correctly, you may start PalmView by tapping its icon from the Application Launcher screen on the Palm (Fig. 4 and 7):
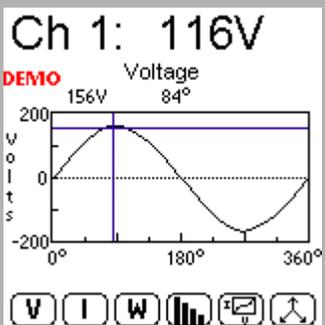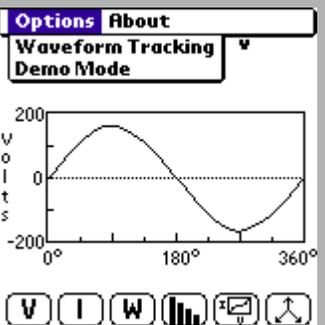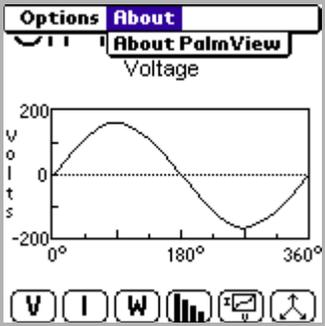

PalmView

Fig. 7

III. Navigating PalmView

Fig. 8

Fig. 9

Fig. 10

Fig. 11

➢ By pressing the menu button in the bottom left hand corner of the graffiti area (Fig. 11), PalmView will release a pulldown menu (Fig. 9).

➢ You can select 'Waveform Tracking' which allows the cursor to follow the waveform.

➢ 'Demo Mode' can be selected which allows the user to see what PalmView can do without actually being connected to a scanner (Notice the 'DEMO' indication in the top left corner as shown in Figure 8).

➢ Under the 'About Menu' (Fig. 10), you can read more about PalmView under 'About PalmView'.

Where do these buttons take me?

Figure 8 shows the main screen when PalmView is first started. The buttons at the bottom of the screen take you to the following places:

 Advances to the Voltage Waveform Screen.

 Advances to the Current Waveform Screen.

 Advances to the Power Waveform Screen.

 Advances to the V-I Curve Waveform Screen.

 Advances to the Voltage, Current, and Power Harmonics Screen.

 Advances to the Vector Diagram Screen.

Note: If you tap in the graphing area, a cursor will appear on the screen and display the readings for that point (Fig. 8). If the cursor is not being placed where you actually tapped the screen, your Palm needs to be "Digitized". Look in your Palm Handbook for "Digitizer Preferences".

IV. Voltage Waveform Screen
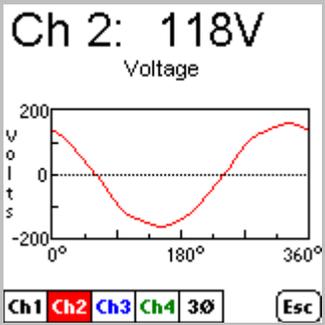
Fig. 12
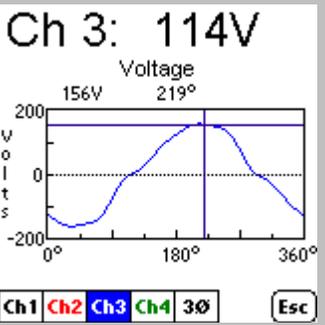
Fig. 13

Advances to the Voltage Waveform series of screens. Once pressed, a screen will appear with channel buttons (Fig. 12) corresponding to the number of channels your Scanner is configured with (the ViP in this example). Press any channel button to view the voltage on that particular channel. By pressing the 3φ button, the first three channels will be drawn on the screen simultaneously. By pressing the ESC key, the screen returns to the original six main buttons. The crosshair (Fig. 13) can be placed anywhere on the waveform by tapping inside of the graphing region. Tap outside of the graph to remove the crosshair.

What Does this Screen Mean?

The Voltage Screen displays the voltage of the selected channel. It has a numerical value printed at the top of the screen. This value is the one second average RMS voltage. In the graphing region, the y-axis is the amplitude of the voltage, auto-scaled on this screenshot to +/- 200 Volts. The x-axis represents time in terms of degrees. A complete 60Hz cycle represents 360 degrees of a sine wave. With the 60Hz line frequency, each degree is (1/60)/360 or about 46 microseconds. A full 360 degrees is 1/60 or 16.67 milliseconds. Using degrees instead of time on the x-axis allows you to measure conduction angles and other quantities without converting from milliseconds.

V. Current Waveform Screen
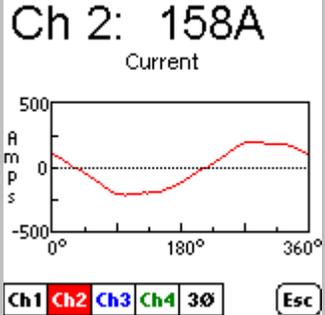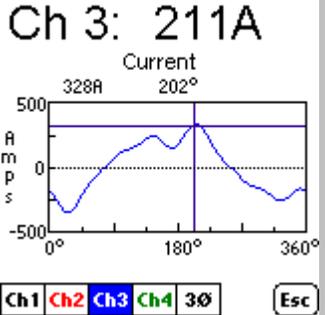
Fig. 14

Fig. 15

 Advances to the Current Waveform Series of screens. Once pressed, a screen will appear with channel buttons (Fig. 14) corresponding to the number of channels your Scanner is configured with (the ViP in this example). Press any channel button to view the current on that particular channel. By pressing the 3ϕ button, the first three channels will be drawn on the screen simultaneously. By pressing the ESC key, the screen returns to the original six main buttons. The crosshair (Fig. 15) can be placed anywhere on the waveform by tapping inside of the graphing region. Tap outside of the graph to remove the crosshair.

What Does this Screen Mean?
The Current Screen displays the current of the selected channel. It has a numerical value printed at the top of the screen. This value is the RMS-current being measured in Amps. In the graphing region, the y-axis is the amplitude of the current, auto-scaled on this screenshot at +/- 500 Amps. The x-axis represents time in terms of degrees. A complete 60Hz cycle represents 360 degrees of a sine wave. With the 60Hz line frequency, each degree is (1/60)/360 or about 46 microseconds. A full 360 degrees is 1/60 or 16.67 milliseconds. Using degrees instead of time on the x-axis lets you measure conduction angles and other quantities without converting from milliseconds.

VI. True-RMS

True-RMS

RMS is an abbreviation for root-mean-square. RMS is defined as $1/\sqrt{2}$ times the peak voltage or peak current, which equals 0.707A, where A is the Amplitude of the sine wave. (Note that this is for sine waves only and that other waveforms have a different formula to calculate RMS-value.) The nominal voltage of a wall socket in the United States is 120 volts RMS at 60 Hz, which calculates to a 170 Volt Amplitude (which means the peak-to-peak voltage is 170 x 2 = 340 Vpp).

Certain products have specifications in RMS-voltage, such as fuses, conductors, bus bars and other heat sensitive items. When measuring the applied voltage, one needs to ensure that the measurements are made with true-RMS measuring equipment. This is because the RMS-value of a waveform is in effect the 'heating value'. For example, if a water heating element is rated to produce 10kW of heat at 240V AC RMS, then the same amount of heat would be produced with a 240V DC supply.

Note that PMI products use True-RMS, which means they will give correct readings for linear and nonlinear loads alike. Examples of linear loads would be incandescent light bulbs, resistive heaters, and common induction motors. Linear loads are classified as a load with a sinusoidal voltage and current waveform. Nonlinear loads are classified as loads without a pure sine wave current, such as a switching power supply.

Nonlinear loads would include light dimmers (Example 4), laser printers (Example 6), computers powered from 120V (Example 7), microwave ovens (Example 8), televisions, solid-state heater controls powered from 240V, and some adjustable speed motor drives carrying a load. Companies that produce measuring equipment that is not True-RMS will measure correctly when the loads are linear, but when nonlinear loads are measured with their equipment, an error of up to 30 to 40 percent can be incurred. These types of measuring devices make the assumption that the waveform is always a sine wave, which is not true for nonlinear loads.

VII. Real Power Waveform Screen
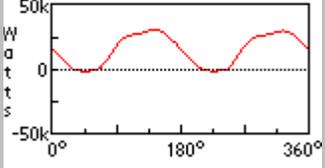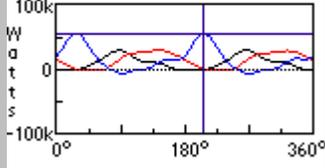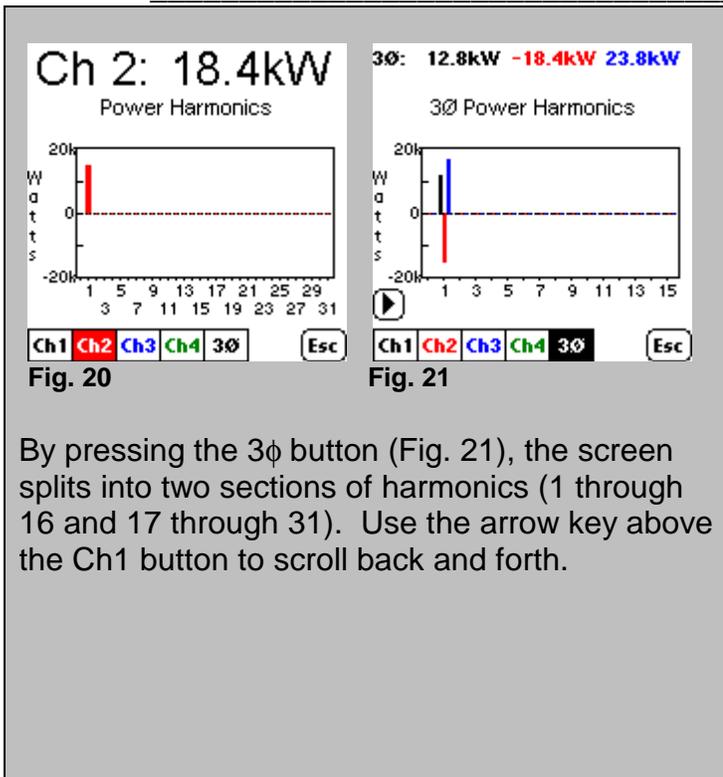

Fig. 16

Fig. 17

[W] Advances to the Real Power Waveform Series of screens. Once pressed, a screen will appear with channel buttons (Fig. 16) corresponding to the number of channels of current that your Scanner is configured with (For example, while using a VP-2 Scanner, only one channel button will appear since only one channel of current is present. On the other hand, the ViP, shown in Fig. 16 and Fig. 17, will display up to 4 channels of power since it can have up to 4 channels of current.). Press any channel button to view the power on that particular channel. By pressing the 3ϕ button, the first three channels will be drawn on the screen simultaneously. By pressing the ESC key, the screen returns to the original six main buttons. The crosshair (Fig. 17) can be placed anywhere on the waveform by tapping inside of the graphing region. Tap outside of the graph to remove the crosshair.

What Does this Screen Mean?
The Real Power Screen displays the power of the selected channel. It has a numerical value printed at the top of the screen. This is the Real Power RMS value being measured. In the graphing region, the y-axis is the amplitude of the Real Power, auto-scaled on these screenshots at +/- 50kW and +/-100kW. The x-axis represents time in terms of degrees.   A complete 60Hz cycle represents 360 degrees of a sine wave. With the 60Hz line frequency, each degree is (1/60)/360 or about 46 microseconds. A full 360 degrees is 1/60 or 16.67 milliseconds. Using degrees instead of time on the x-axis lets you measure conduction angles and other quantities without converting from milliseconds.

VIII. Harmonic Screens
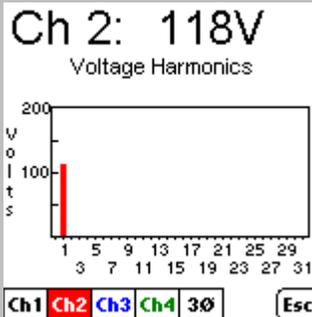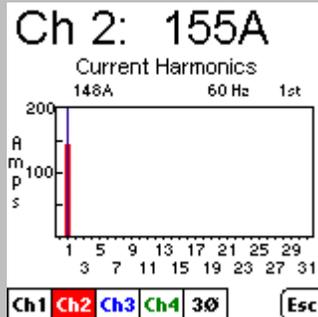
Fig. 18   **Fig. 19**

 Advances to the Harmonic series of Screens. Once pressed, a screen will appear with channel buttons (Fig. 18) corresponding to the number of channels of voltage that your Scanner is configured with (the ViP in this example). By pressing a channel button a second time, the screen will be advanced to the Current Harmonic Screen of that same channel (Fig. 19). By pressing a channel button a third time, the screen will be advanced to the Power Harmonic Screen of that same channel (Fig. 20). By pressing a channel button a fourth time, the screen will advance back to the Voltage Harmonic Screen of the current channel (Fig. 18). By pressing the 3ϕ button, the first three channels will be drawn on the screen simultaneously (Fig. 21). Press the 3ϕ button repeatedly to advance to all three types of harmonics. By pressing the ESC key, the screen returns to the original six main buttons. The crosshair (Fig. 19) can be placed anywhere on the waveform by tapping inside of the graphing region. Tap outside of the graph to remove the crosshair.

What Does this Screen Mean?

The Voltage Harmonic Magnitude Screen (Fig. 18) displays the RMS voltage of the selected channel at the top of the screen. In the graphing region, the y-axis is the magnitude of each voltage harmonic, auto-scaled on this screenshot at +200 Volts. The units are in volts, not percentage of fundamental. The x-axis is the harmonic number (60Hz = 1st harmonic, 120 Hz = 2nd harmonic, etc.). They are in numerical order, so harmonic 1 is on the left and then harmonic 2, then harmonic 3, etc, all the way to the 31st harmonic on the far right of the graph.

What Does this Screen Mean?

The Current Harmonic Magnitude Screen (Fig. 19) displays the RMS current of the selected channel at the top of the screen. In the graphing region, the y-axis is the magnitude of each curent harmonic, auto-scaled on this screenshot at +200 amps. The units are in amps, not percentage of fundamental. The x-axis is the harmonic number (60Hz = 1st harmonic, 120 Hz = 2nd harmonic, etc.). They are in numerical order, so harmonic 1 is on the left and then harmonic 2, then harmonic 3, etc, all the way to the 31st harmonic on the far right of the graph.

Fig. 20

Fig. 21

By pressing the 3φ button (Fig. 21), the screen splits into two sections of harmonics (1 through 16 and 17 through 31). Use the arrow key above the Ch1 button to scroll back and forth.

What Does this Screen Mean?

The Power Harmonic Screen (Fig. 20) displays the RMS power of the selected channel at the top of the screen. In the graphing region, the y-axis is the magnitude of each power harmonic, auto-scaled on this screenshot at +/- 20kW. The units are in watts, not percentage of fundamental. The x-axis is the harmonic number (60Hz = 1st harmonic, 120 Hz = 2nd harmonic, etc.). They are in numerical order, so harmonic 1 is on the left and then harmonic 2, then harmonic 3, etc, all the way to the 31st harmonic on the far right of the graph.

Note that Positive Power Harmonics indicate power flow from the Utility to the Load while Negative Power Harmonics indicate power flow from the Load to the Utility.

IX. Harmonics Explained

What are Harmonics?

Harmonics are a way for us to mathematically describe non-sinusoidal waveforms. They are voltages or currents with frequencies that are integer multiples of the fundamental frequency (60Hz in the United States). When non-linear loads are present, harmonics are created when the current draw is in small pulses or other shapes rather than in a sinusoidal manner (see Fig. 15). Harmonics can cause distortions in the voltage waveform, which will cause harmonic current to flow back into other sections of the system being supplied.

Harmonics allow us to analyze the current draw of electronic devices and other non-linear loads. Since a computer power supply is a type of nonlinear load, it will produce some harmonics. A computer is a nonlinear load because it has a switching power supply which will not draw current constantly, but rather in short pulses. We get the term nonlinear since the current waveform is no longer linear or directly proportional to the voltage waveform. When a nonlinear load is introduced into a facility, the near pure sinusoidal wave being distributed to that facility becomes somewhat distorted due to the system impedance.

Name	1st (F)	2nd	3rd	4th	5th	6th	7h	8th	9th
Frequency	60	120	180	240	300	360	420	480	540
Rotation	+	-	0	+	-	0	+	-	0

Fig. 22 Positive rotation is forward, negative rotation is in reverse, and zero has no rotation. Forward rotation heats conductors while Reverse rotation heats conductors and gives motor problems, and no rotation causes heating and problems with neutral wire.

> **The fundamental frequency is 60Hz in the United States. Each Harmonic of that fundamental frequency is merely:**
>
> **2nd Harmonic = 2x(fundamental frequency) = 2x(60 Hz) = 120 Hz**
> **3rd Harmonic = 180 Hz**
> **4th Harmonic = 240 Hz**
> **5th Harmonic = 300 Hz, etc.**

Fig. 23

The dominate harmonic caused by switching power supply is the third harmonic, which in the United States is 180Hz.

What's so bad about Harmonics?

Harmonics can create voltage distortion within facilities, cause the overheating of transformers, create large magnetic fields around transformers, decrease the distribution capacity, create excessive neutral return currents, and incur penalties on Power Factor.

In short, when electronic equipment has a switching power supply, it only draws current in short pulses. This equipment draws the current during a controlled part of the current waveform. From the equipment side, this is much more efficient because the computer or printer gets current only when it needs it. From the power supply side, this is inefficient because it creates harmonics in the load current. When harmonics are present, we see an overheating of transformers and neutrals as well as more circuit breakers being tripped. This is caused because the return current from a nonlinear load is forced to return through the neutral, because the phases cannot share current. The wiring of a facility is generally not adequate to carry a large amount of return current on the neutral line.   Typically the neutral is undersized with respect to the phase conductors, under the assumption that the neutral current will be much smaller than the phase currents. In a high-harmonic situation the neutral current can actually be higher than the phase conductors! Typically the neutral current will be mostly the 3rd harmonic.

Certain Harmonics are considered worse than others, primarily the 3rd harmonic and its odd multiples (e.g. 9th, 15th, 21st, etc.). These Harmonics are of interest because they are considered 'triplens' (6n-3), which generally return through the neutral and cause overheating of the neutral line and the transformer supplying the power.

Other problems besides heating can occur also. When harmonics of the 5th and 7th order combine inside of a motor, they produce an even 6th harmonic. An even harmonic in a motor can have a drastic impact on the motor and its performance. An even harmonic can cause unusual vibration and wear and tear on the bearings as well as overheat the motor. Other problems in motors and transformers occur with negative sequence harmonics (e.g. 5th, 11th, 17th, etc.) because their rotation opposes the fundamental frequency of 60Hz.

The short duty cycle of the current that is drawn by a nonlinear load creates a low power factor. Power factor is a measurement of the efficiency of an AC source, which is:

where Power   Factor is

$$PF = \frac{\text{Average Power}}{\text{Apparent Power}} \quad (1)$$

Units   PF =   watts/ volt-ampere

Power Factor (PF) becomes low because a short duty cycle of current draw creates a high volt-ampere (VA) rating while the power (watts) does not increase proportionally.

X. V-I Curve Screen
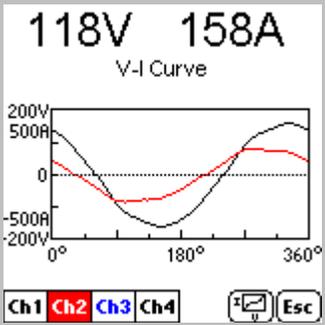
Fig. 24
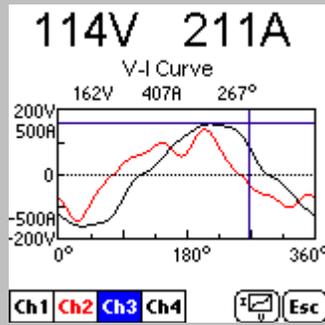
Fig. 25
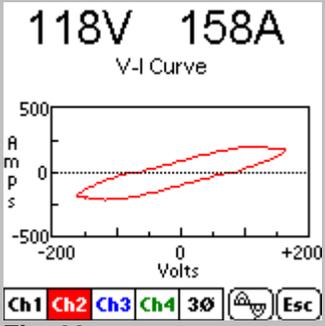
Fig. 26
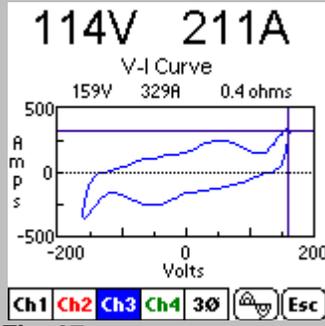
Fig. 27

Advances to the Ch1 Non-Parametric V-I Curve Screen (Fig. 24). By pressing the V-I Toggle mode button (to the left of the ESC key), the screen will advance from the Non-Parametric V-I Screen (Fig. 24) to the Parametric V-I Screen (Fig. 26). By pressing the 3ϕ button (only available on the Parametric V-I Screen), the first three channels will be drawn on the screen simultaneously. By pressing the ESC key, the screen returns to the original six main buttons. The crosshair (Fig. 25 and Fig. 27) can be placed anywhere on the waveform by tapping inside of the graphing region. Tap outside of the graph to remove the crosshair.

What Does this Screen Mean?

The V-I Curve Screen displays a graph of instantaneous voltage versus Current for a selected pair of channels while in Parametric Mode (Fig. 26). When the Non-Parametric V-I Curve is selected (Fig. 24), Voltage and Current are plotted together versus time. The V-I Screens have two numerical values printed at the top of the screen. The values shown are the RMS Voltage and RMS Current values for that particular channel. In the graphing region, the y-axis is the amplitude of the Current (Current and Voltage for the Non-Parametric V-I Screen) auto-scaled on these screenshots at +/- 500 Amps. The x-axis is the amplitude of Voltage (time on the Non-Parametric V-I Screen) auto-scaled on these screenshots at +/- 200 Volts.

The VI graph shows the operating characteristics of the load, and is a kind of signature.   For a suspect piece of equipment, a comparison with known good VI curves can often reveal hidden faults or impending failures.

XI. Vector Diagram Screen

Fig. 28

Fig. 29

Fig. 30

Fig. 31

Advances to the Vector Diagram Screen. By pressing the Voltage button ('V'), the Voltage Vectors are drawn on the screen (Fig. 28). To the top left of the circle are the values of each of the Voltage Vectors. By pressing the Current button ('I'), the Current Vectors are drawn on the screen (Fig. 29). To the bottom left of the circle are the values of each of the Current Vectors. By pressing the Voltage and Current button ('V&I'), both Current and Voltage Vectors are drawn on the screen simultaneously (Fig. 30). By pressing the ESC key, the screen returns to the original six main buttons. The crosshair (Fig. 31) can be placed on the vectors by tapping anywhere inside of the circle. The Cursor values are displayed in the top right corner (indicated by 'M' for marker). Tap outside of the circle to remove the crosshair.

What Does this Screen Mean?

The Vector Diagram Screen allows a user to graphically represent the magnitudes of current and voltage along with their phase angles. The main use for this is to show the phase shift between the current and the voltage. In an AC circuit, the voltage and current do not peak at the same time if the load is not purely resistive but has a capacitor or inductor involved.
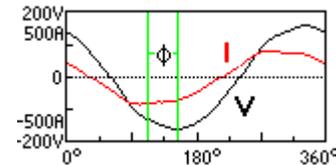
Fig. 32

Fig. 32 shows the voltage 'V' leading the current 'I' in phase by angle ϕ. The difference between the two peaks, which is a fraction of a period, is called the phase difference (which becomes a negative phase for a capacitive circuit since the current leads the voltage and becomes a positive phase for an inductive circuit since the current lags behind the voltage).

The zero angle is the reference point and is associated with a pure resistor since no phase shift exists at that point. The length of the vector is determined by its magnitude while the angle is represented by its phase relative to the current through the resistor.

XII. Examples

Example 1:

Ch 1: 125V
Voltage

Voltage Screenshot
Fig. 33
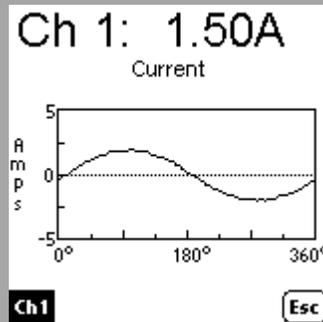
Ch 1: 1.50A
Current
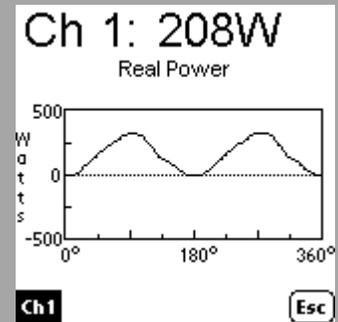
Current Screenshot
Fig. 34
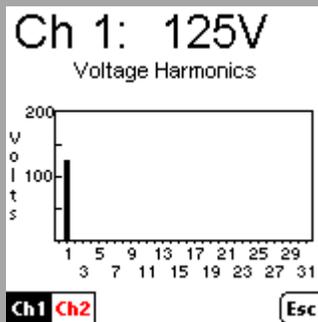
Ch 1: 208W
Real Power

Real Power Screenshot
Fig. 35

Ch 1: 125V
Voltage Harmonics

Voltage Harmonic
Fig. 36

Ch 1: 1.41A
Current Harmonics

Current Harmonic
Fig. 37

Ch 1: 259W
Power Harmonics

Power Harmonic
Fig. 38

126V 1.39A
V-I Curve
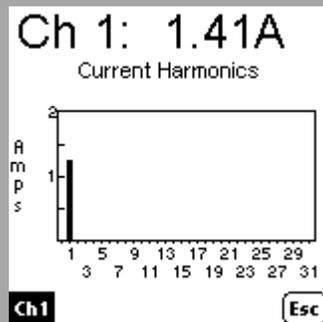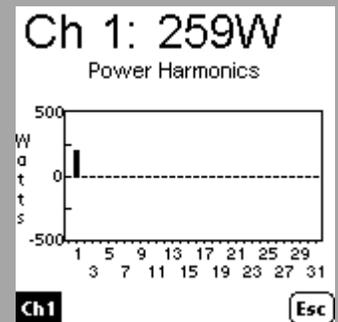
Non-Parametric V-I Curve
Fig. 39

125V 1.44A
V-I Curve

Parametric V-I Curve
Fig. 40

Va 125V ∠0°
Vb 0.20V ∠102°
Ia 1.40A ∠-7°
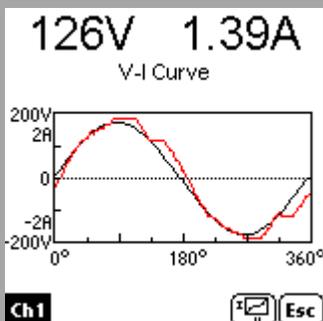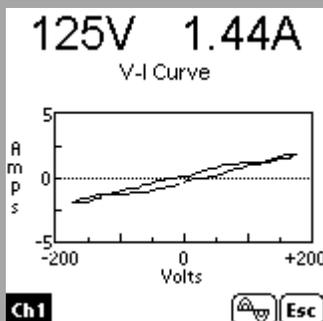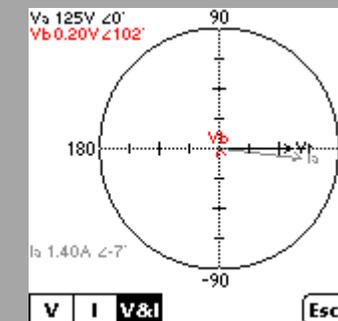
Vector Diagram
Fig. 41

A Refrigerator was plugged into a VP-2 and these are the sample screenshots while the unit was running. There are no Current Harmonics because this load is almost a pure resistive load. Also, there are no Voltage Harmonics – the voltage source is very clean. In Fig. 40, you can see how the line is almost a straight diagonal line. This waveform is a highly resistive load. When looking for a resistive load, look for a straight diagonal or horizontal line. The more resistive the load, the more horizontal the line will become.

Example 2:
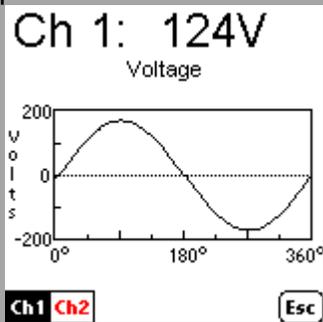
Voltage Screenshot
Fig. 42
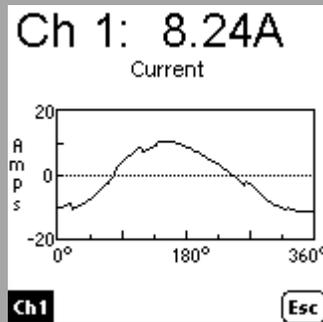
Current Screenshot
Fig. 43
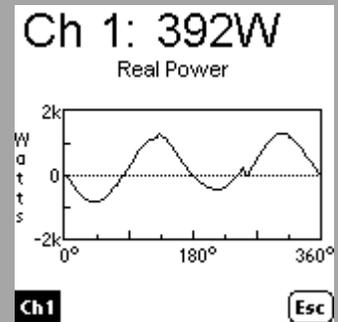
Real Power Screenshot
**Fig. 44**
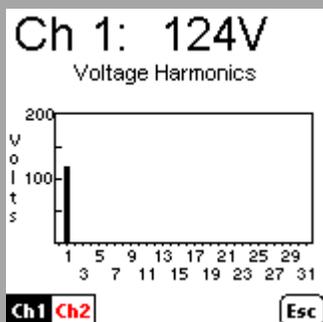
Voltage Harmonic
Fig. 45
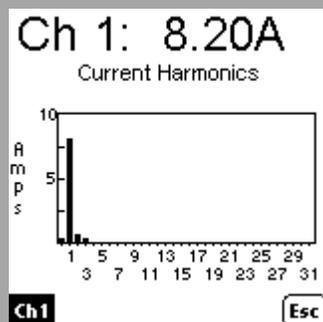
Current Harmonic
Fig. 46
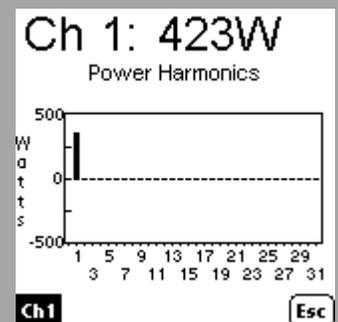
Power Harmonic
Fig. 47
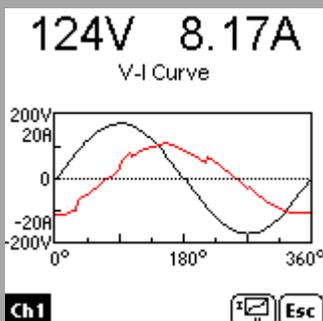
Non-Parametric V-I Curve
Fig. 48
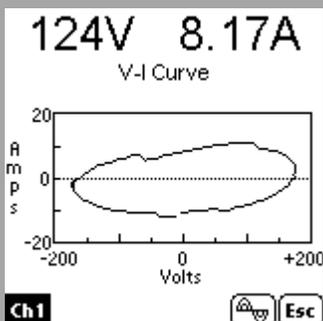
Parametric V-I Curve
**Fig. 49**
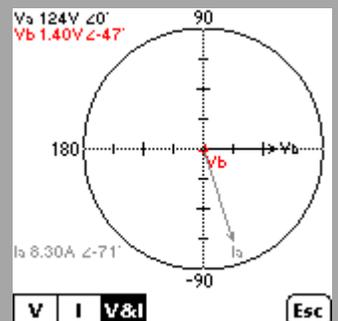
Vector Diagram
Fig. 50

These Screenshots came from a Drill Press that was plugged into a VP-2. The Drill Press is a type of Inductive load because it is using a motor. We can see however, from Figures 43 and 44 that this is not a pure Inductive load because both waveforms are not pure and have small glitches on them. We can also see that the motor creates a few Current Harmonics, but not many. The Drill Press is an example of an Inductive load and the more inductive the load, the more we will see the oval from Figure 49 become more parallel to the x-axis. Also the more resistive the load becomes the flatter the oval will become.
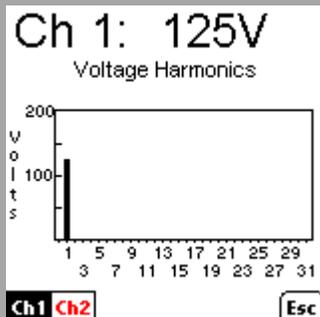
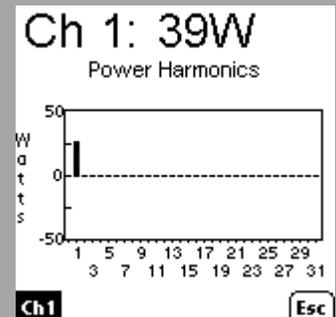Example 3:
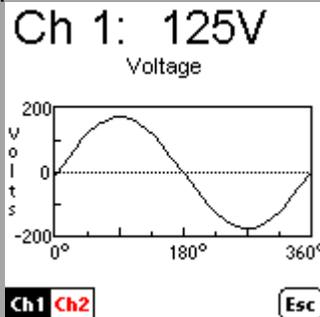
Voltage Screenshot
Fig. 51
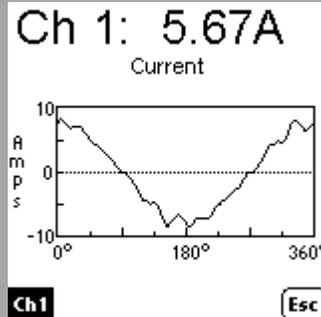
Current Screenshot
Fig. 52
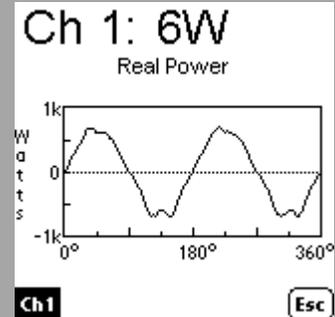
Real Power Screenshot
Fig. 53
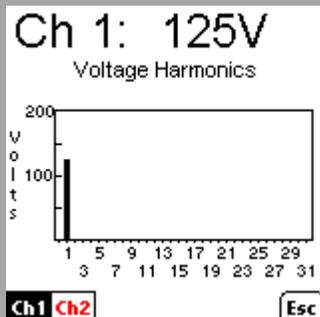
Voltage Harmonic
Fig. 54
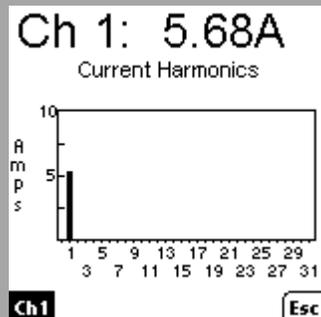
Current Harmonic
Fig. 55
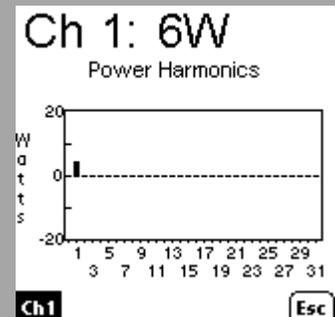
Power Harmonic
Fig. 56
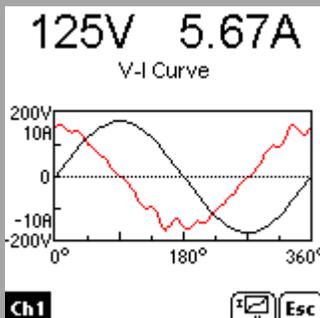
Non-Parametric V-I Curve
Fig. 57
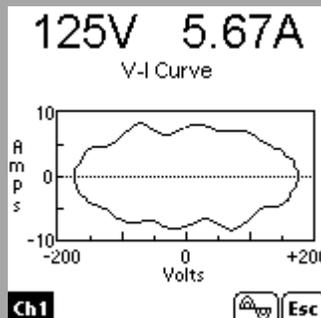
Parametric V-I Curve
Fig. 58
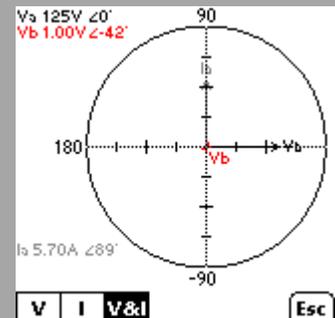
Vector Diagram
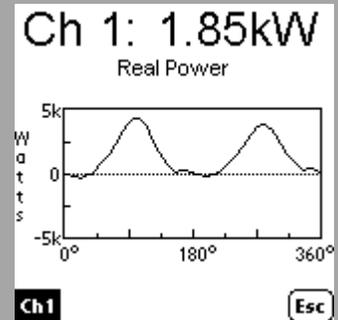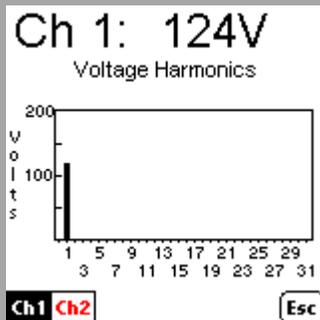**Fig. 59**

These Screenshots are an example of a Capacitive load where capacitors were plugged into the VP-2. The more resistive the load becomes, the flatter the oval becomes in Fig. 58. Because the impedance of a capacitor decreases as the frequency increases, small disturbances in the voltage waveform (i.e. voltage harmonics) are magnified in the current waveform. This is shown in Fig. 52, where the current waveform is distorted. Despite the distorted shape of the current in Fig. 52, no individual harmonics are large enough to be displayed in Fig. 55. Note the 6 watts of power (out of 707 volt-amps) in Fig. 53. A purely capacitive load would draw no power, but the capacitors used in this test were not ideal, resulting in a power factor of 8/(124.7*5.67) = 0.011.

Example 4:
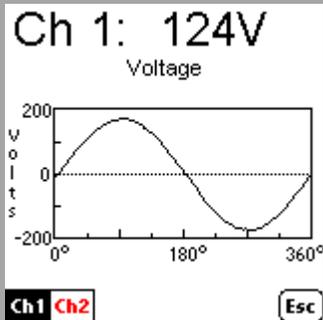
Ch 1: 124V Voltage Voltage Screenshot **Fig. 60**	**Ch 1: 2.21A** Current Current Screenshot **Fig. 61**	**Ch 1: 270W** Real Power Real Power Screenshot **Fig. 62**
Ch 1: 124V Voltage Harmonics Voltage Harmonic **Fig. 63**	**Ch 1: 2.21A** Current Harmonics Current Harmonic **Fig. 64**	**Ch 1: 270W** Power Harmonics Power Harmonic **Fig. 65**
124V 2.20A V-I Curve Non-Parametric V-I Curve **Fig. 66**	**124V 2.21A** V-I Curve Parametric V-I Curve **Fig. 67**	Vector Diagram **Fig. 68**
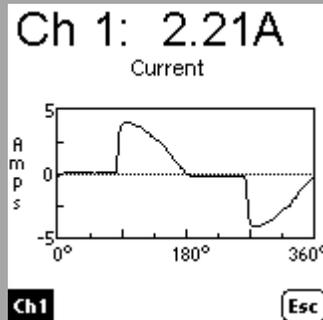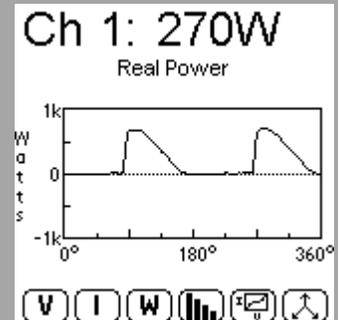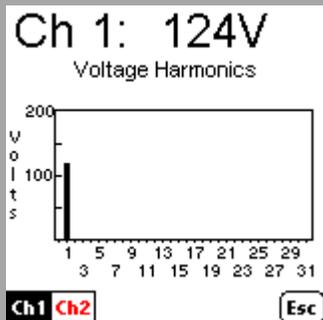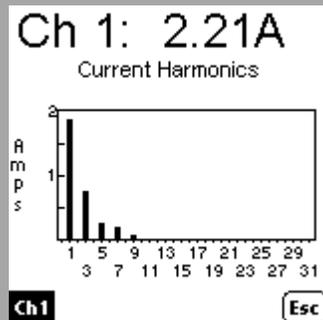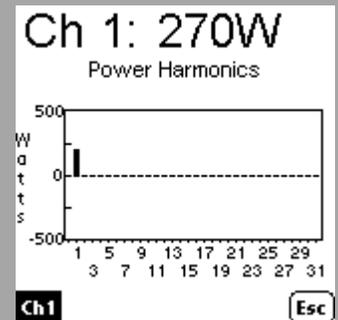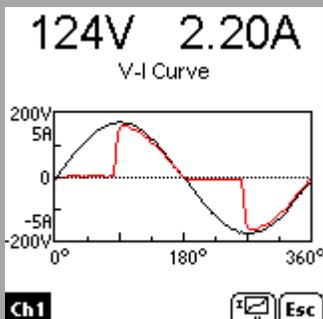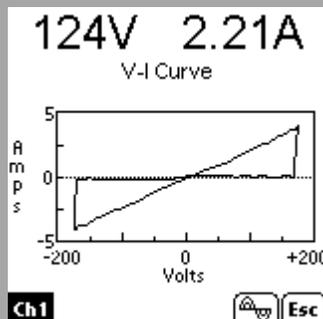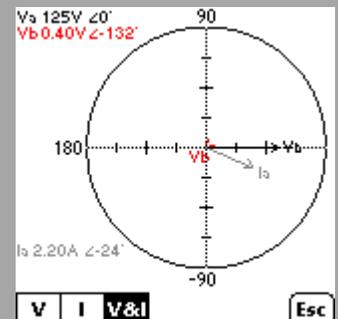
This Screen shot is an example of halogen lamp with an SCR dimmer. The lamp in Fig. 61 has the dimmer switch half way on and is only letting current through in pulses, creating a non-linear load. As the dimmer switch is turned all the way up and allows current to flow freely in a sinusoidal waveform, the V-I Curve in Figure 67 becomes a diagonal line because the voltage and current are proportional.
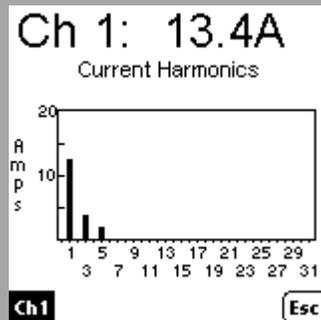
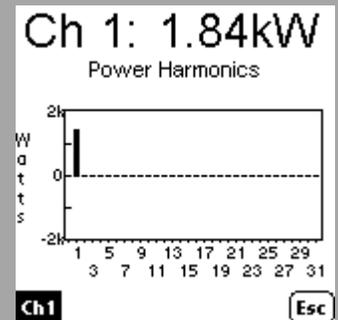Example 5:
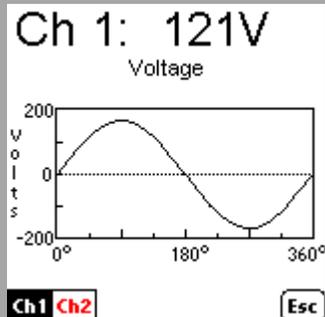
Voltage Screenshot
Fig. 69
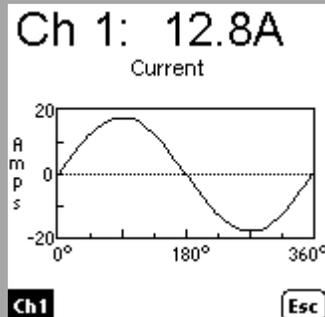
Current Screenshot
Fig. 70
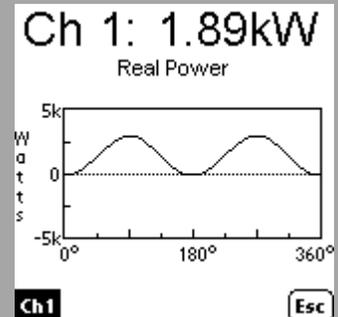
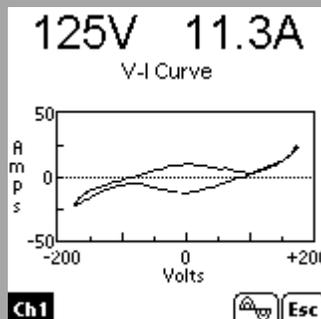Real Power Screenshot
Fig. 71
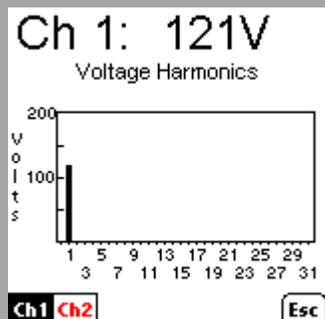
Voltage Harmonic
Fig. 72
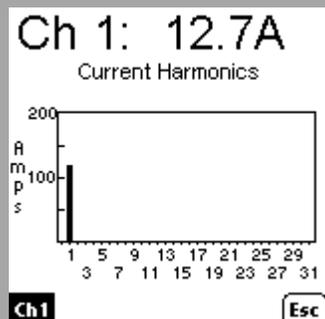
Current Harmonic
Fig. 73
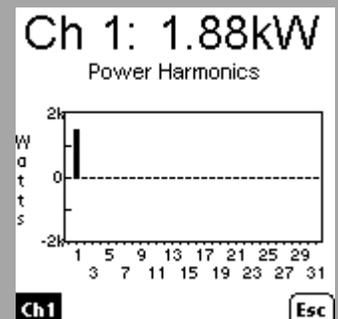
Power Harmonic
Fig. 74
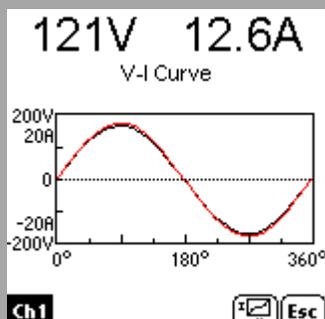
Non-Parametric V-I Curve
Fig. 75
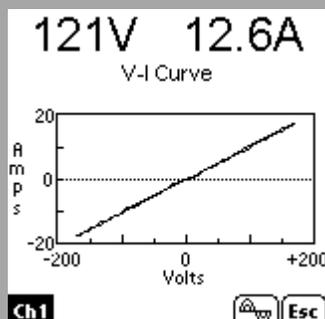
Parametric V-I Curve
Fig. 76
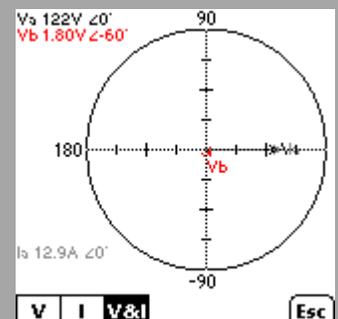
Vector Diagram
**Fig. 77**

This Screen shot is an example of a very stable Resistive Load (which includes lights and heaters for example) and as the resistance in the circuit becomes larger, the diagonal line becomes more and more horizontal. This is a nearly pure Resistive Load because the waveforms are all very smooth and there are no harmonics. Also the V-I Curve in Figure 76 is a very straight diagonal line.
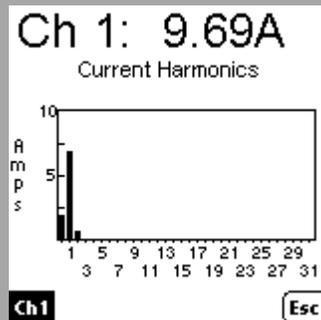
Example 6:
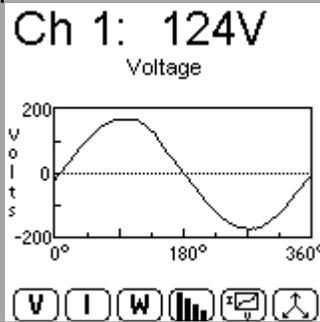
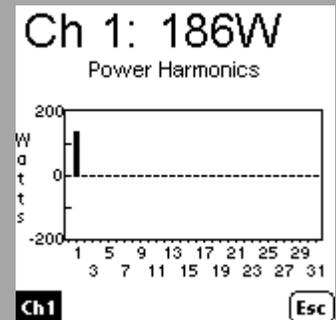Voltage Screenshot
Fig. 78
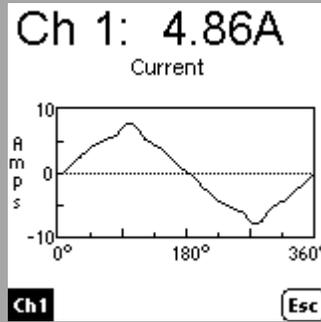
Current Screenshot
Fig. 79
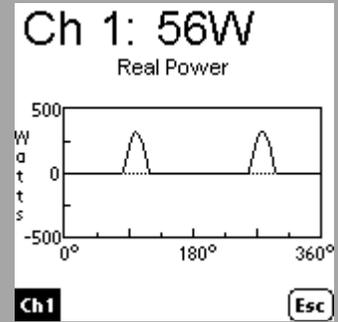
Real Power Screenshot
Fig. 80
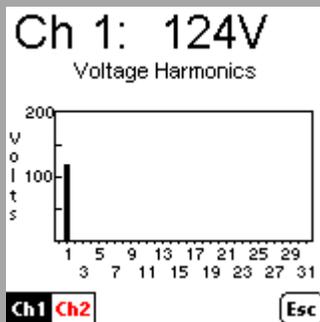
Voltage Harmonic
Fig. 81
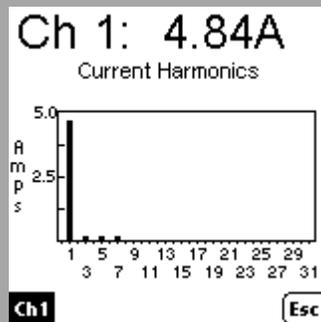
Current Harmonic
Fig. 82
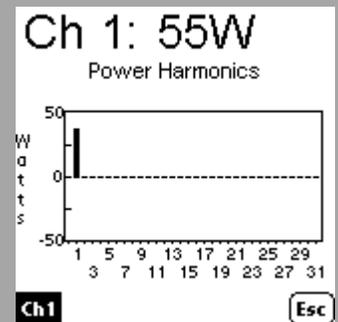
Power Harmonic
Fig. 83
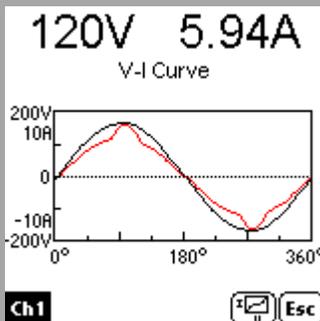
Non-Parametric V-I Curve
Fig. 84
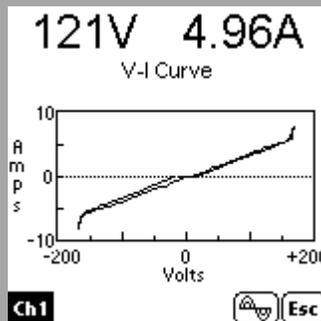
Parametric V-I Curve
Fig. 85
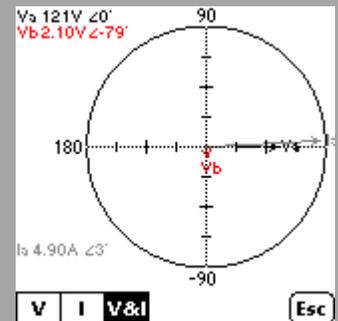
Vector Diagram
Fig. 86

This is a good example of a resistive load that uses electronics at times, as in this instance where. a laser printer has been plugged into a VP-2. For the most part, Figure 79 shows a steady Current being drawn, except at the peaks of the waveform. If it weren't for these dips, the waveform would be sinusoidal and a pure resistive load. However, these dips cause Current Harmonics as can be seen in Figure 82, making this example a non-pure resistive load. In Figure 85, the V-I Curve is characteristic of a Resistive Load except for at the very ends of the diagonal line. The two ends of the line are where the laser printer switch-mode power supply draws power. Everywhere else along the diagonal line the laser printer is using the heater, which we know to be a Resistive Load.

Example 7:

Ch 1: 125V
Voltage
Voltage Screenshot
Fig. 87
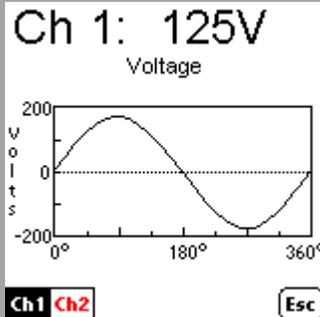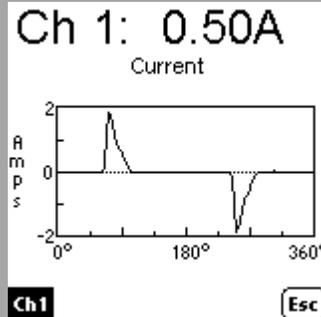
Ch 1: 0.50A
Current
Current Screenshot
Fig. 88
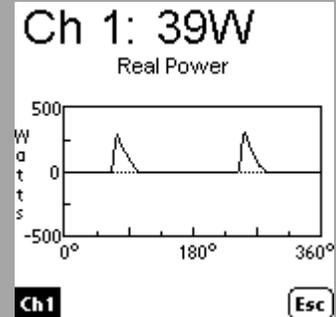
Ch 1: 39W
Real Power
Real Power Screenshot
Fig. 89

Ch 1: 125V
Voltage Harmonics
Voltage Harmonic
Fig. 90

Ch 1: 0.49A
Current Harmonics
Current Harmonic
Fig. 91

Ch 1: 39W
Power Harmonics
Power Harmonic
Fig. 92
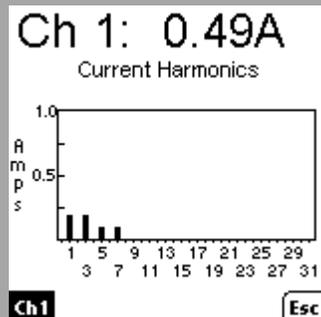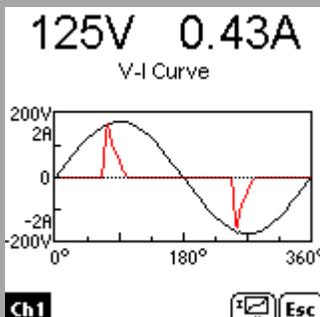
125V   0.43A
V-I Curve
Non-Parametric V-I Curve
Fig. 93
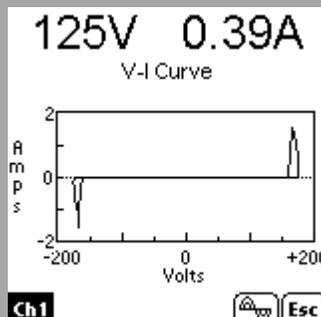
125V   0.39A
V-I Curve
Parametric V-I Curve
Fig. 94
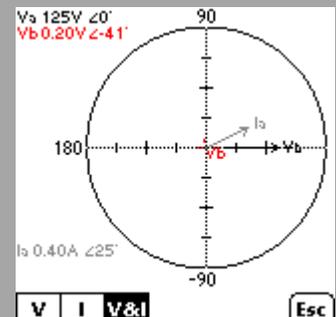
Vector Diagram
Fig. 95

This example has Screenshots from a laptop plugged into the VP-2. As you can see in Figure 88, the laptop is only drawing current at two points along the sine wave. Note the large amount of Current Harmonics and how nearly 75% of all Current Harmonics are drawn from Harmonic 3, 5 and 7 combined. Also pay close attention to Figure 89. The peak current that the laptop is drawing is around 250 Watts as can be seen from the graph. Notice however that the RMS-Current being read at the top of the screen is only 39W.

Example 8:

Ch 1: 125V
Voltage
Voltage Screenshot
Fig. 96
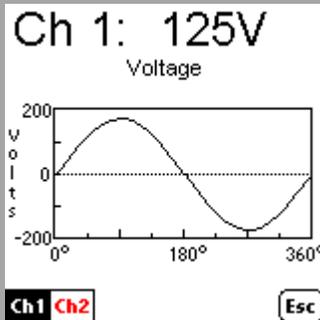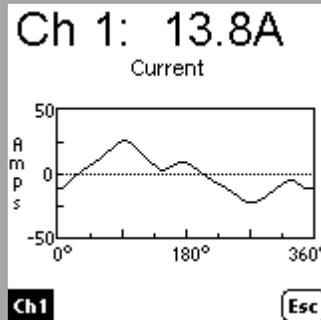
Ch 1: 13.8A
Current
Current Screenshot
Fig. 97

Ch 1: 1.85kW
Real Power
Real Power Screenshot
Fig. 98

Ch 1: 124V
Voltage Harmonics
Voltage Harmonic
Fig. 99

Ch 1: 13.4A
Current Harmonics
Current Harmonic
Fig. 100

Ch 1: 1.84kW
Power Harmonics
Power Harmonic
Fig. 101
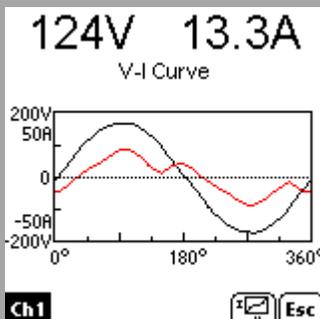
124V 13.3A
V-I Curve
Non-Parametric V-I Curve
Fig. 102

125V 11.3A
V-I Curve
Parametric V-I Curve
Fig. 103
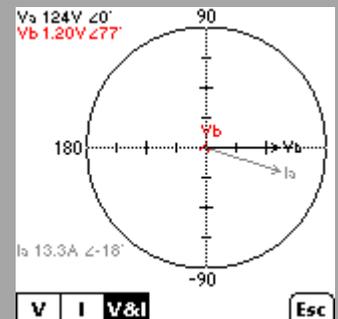
Vector Diagram
Fig. 104

This example has Screenshots from a microwave plugged into the VP-2. Several amps are drawn by Harmonics 3 and 5 due to this non-linear load.

Example 9:
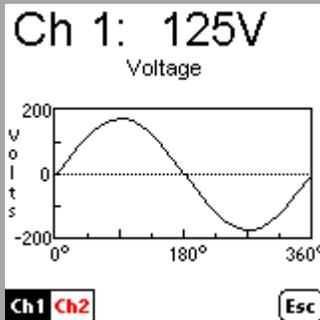
Ch 1: 125V
Voltage Screenshot
Fig. 105
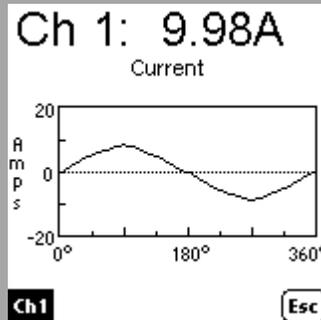
Ch 1: 9.98A
Current Screenshot
Fig. 106
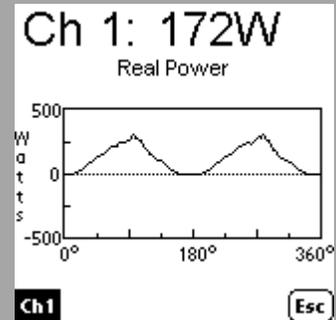
Ch 1: 172W
Real Power Screenshot
Fig. 107

Ch 1: 123V
Voltage Harmonic
Fig. 108
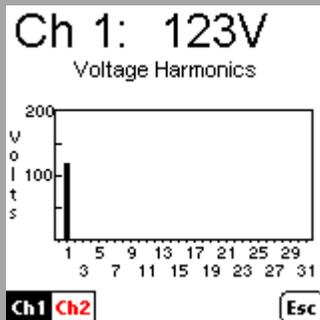
Ch 1: 9.69A
Current Harmonic
Fig. 109

Ch 1: 186W
Power Harmonic
Fig. 110
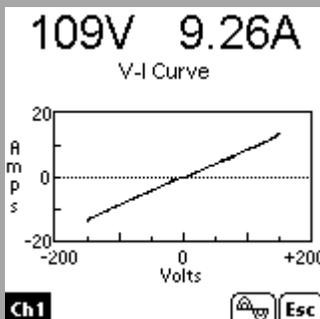
109V 9.26A
Parametric V-I Curve
Fig. 111
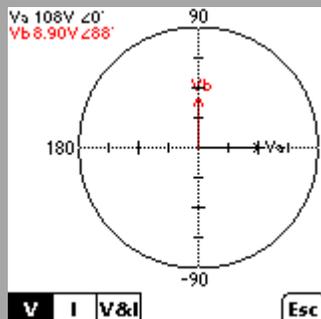
Vector Diagram
Fig. 112
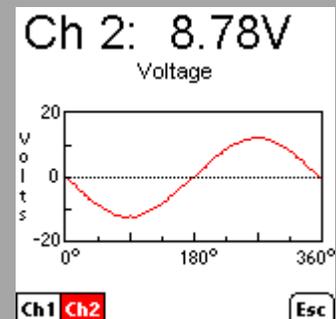
Ch 2: 8.78V
Voltage Channel 2
Fig. 113

This example has Screenshots from a color laser printer plugged into the VP-2. The Current Waveform is almost sinusoidal but has a non-sinusoidal peak. Notice the Channel 2 Voltage (Fig. 113). On the VP-2, Channel 2 measures from Neutral to Ground. Ideally this voltage should be 0, but in this case a very large drop on the neutral wire creates a potential difference between neutral and ground.
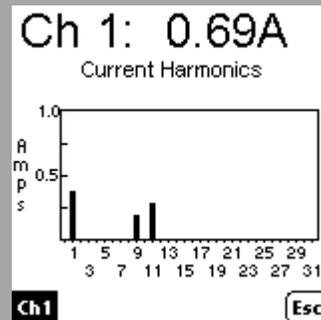
Example 10:
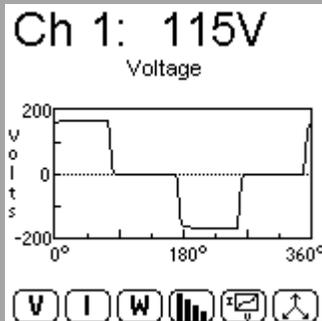

Voltage Screenshot
Fig. 114
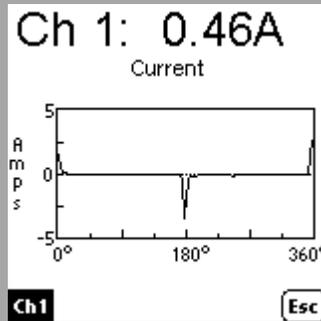
Current Screenshot
Fig. 115
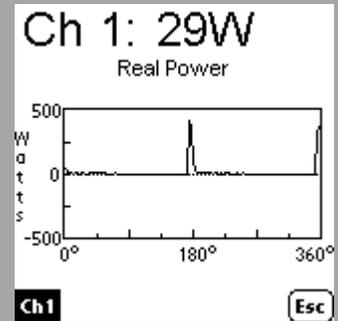
Real Power Screenshot
Fig. 116
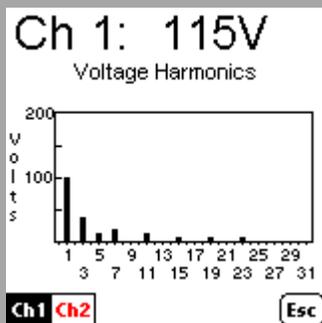
Voltage Harmonic
Fig. 117
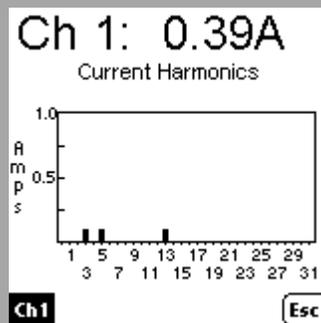
Current Harmonic
Fig. 118
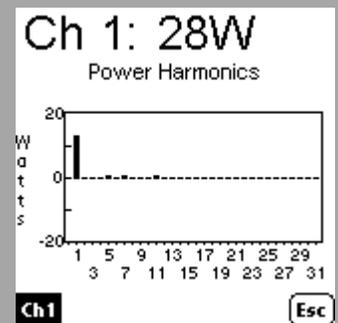
Power Harmonic
Fig. 119
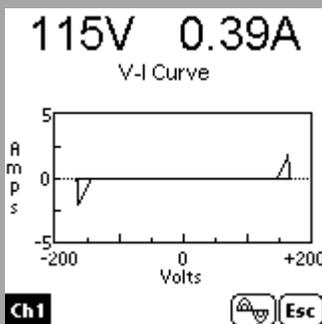
Parametric V-I Curve
Fig. 120
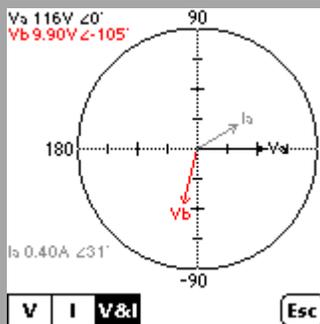
Vector Diagram
Fig. 121
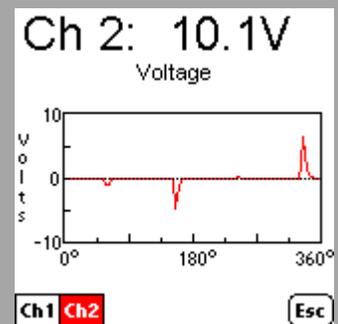
Voltage Channel 2
Fig. 122

This example has Screenshots from a Portable Power Inverter plugged into the VP-2 with a laptop plugged in as a load. There are numerous Voltage Harmonics (Fig. 117) and Current Harmonics (Fig. 118) because the voltage being supplied is not a pure sine wave (Fig. 114). The severely non-sinusoidal waveform causes the laptop switch-mode power supply to draw a burst of current in the second half of the waveform, skewing the current and VI curve waveforms. On the VP-2, Channel 2 measures from Neutral to Ground. Ideally this voltage should be 0, but in this case (Fig. 122) a large drop on the neutral wire creates a potential difference between neutral and ground.

Example 11:
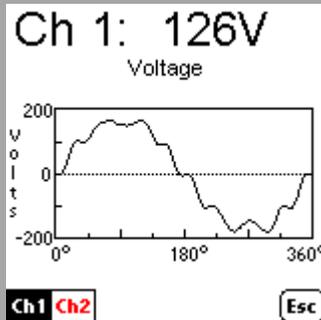
Voltage Screenshot
Fig. 123
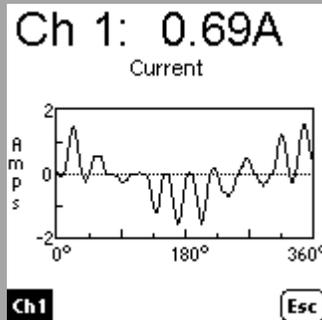
Current Screenshot
Fig. 124
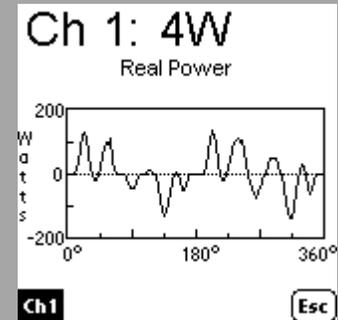
Real Power Screenshot
Fig. 125
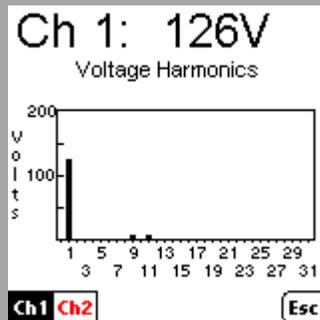
Voltage Harmonic
Fig. 126

Current Harmonic
Fig. 127
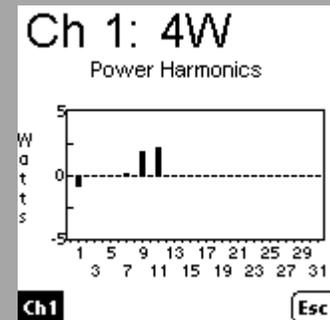
Power Harmonic
Fig. 128
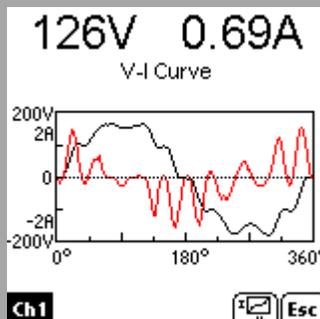
Non-Parametric V-I Curve
**Fig. 129**
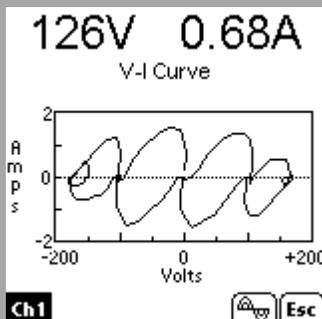
Parametric V-I Curve
Fig. 130
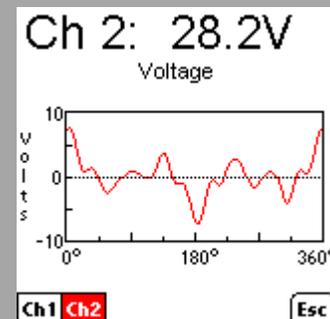
Voltage Channel 2
Fig. 131

This is an extreme example of a capacive load powered by a distored voltage waveform. A capacitive load amplifies voltage distortions in the current waveform, as seen in Example 3. In this example the relatively small 9th and 11th harmonics in the voltage waveform are magnified to almost the same level as the fundamental in the current waveform.

Example 12: ViP Connected to a Breaker Panel of a Commerical Building.
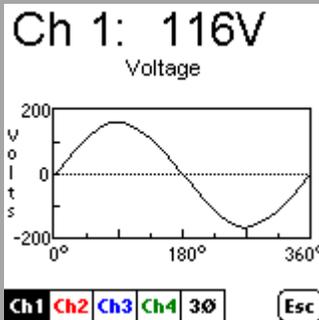
Voltage Channel 1
Fig. 132
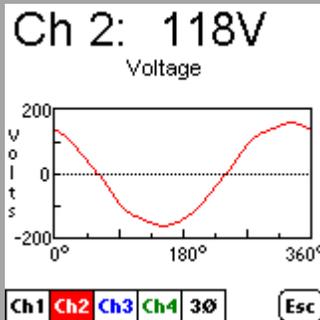
Voltage Channel 2
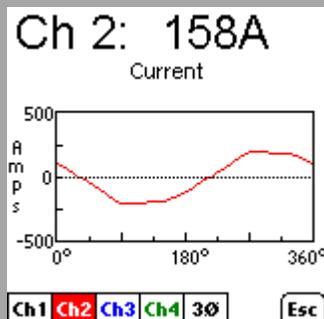**Fig. 133**
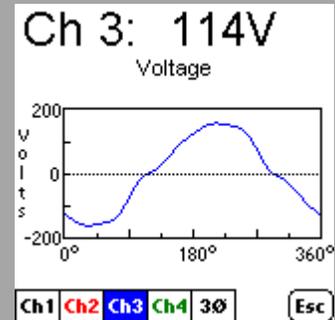
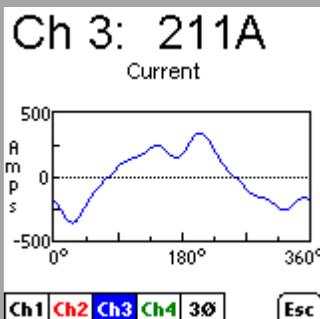Voltage Channel 3
Fig. 134
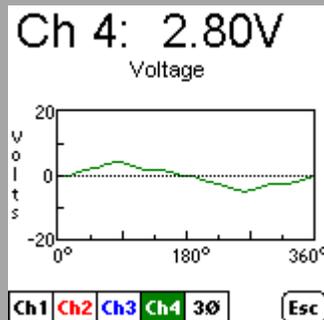
Voltage Channel 4
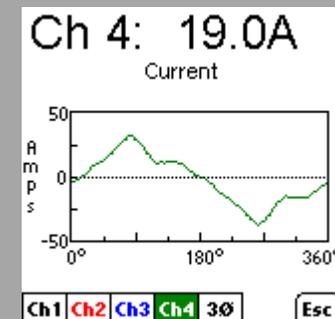**Fig. 135**
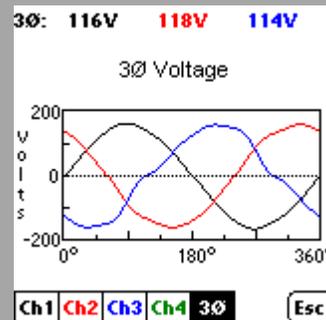
3φ Voltage
Fig. 136
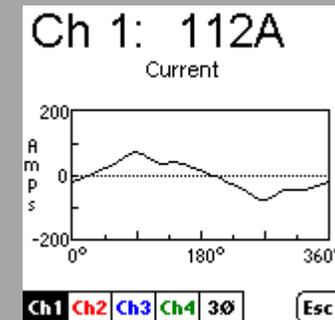
Current Channel 1
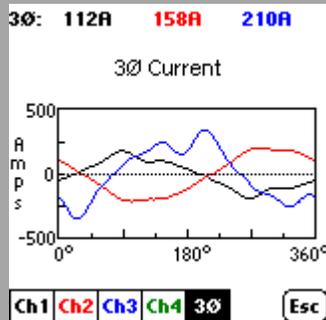**Fig. 137**

Current Channel 2
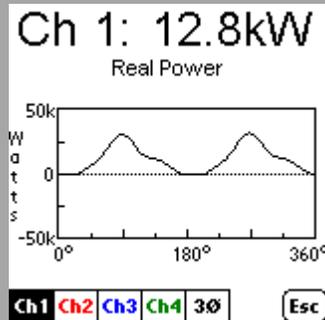**Fig. 138**

Current Channel 3
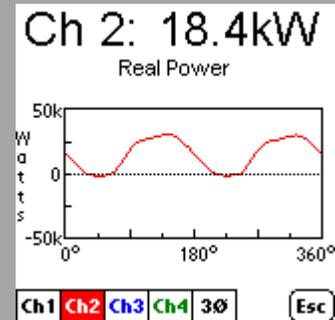**Fig. 139**

Current Channel 4
Fig. 140

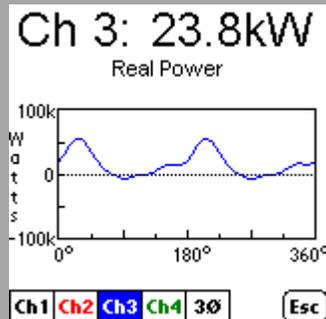Example 12 (continued): ViP Connected to a Breaker Panel of a Commerical Building.
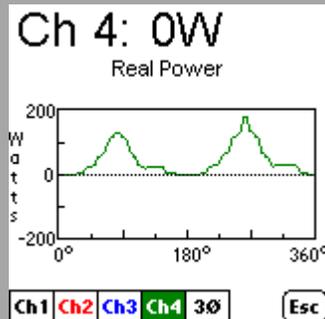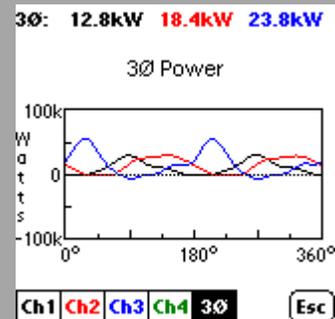

3φ Current
Fig. 141

Power Channel 1
Fig. 142

Power Channel 2
Fig. 143
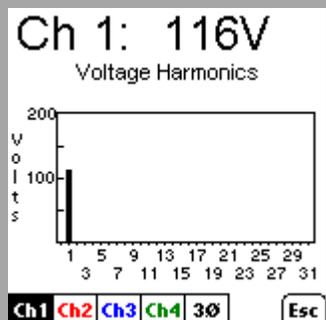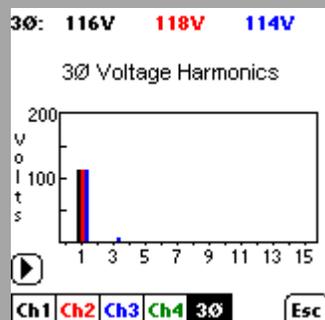

Power Channel 3
Fig. 144

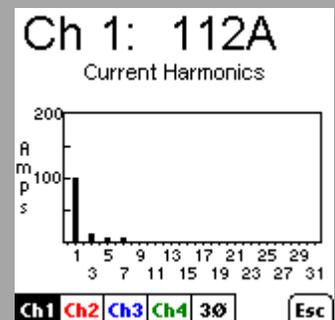Power Channel 4
Fig. 145

3φ Power
Fig. 146

Voltage Harmonic Ch1
Fig. 147

3φ Voltage Harmonic
Fig. 148

Current Harmonic Ch1
Fig. 149

Example 12 (continued): ViP Connected to a Breaker Panel of a Commerical Building.

3φ Current Harmonic
Fig. 150

Power Harmonic Ch1
Fig. 151

3φ Power Harmonic
Fig. 152

Parametric V-I Ch1
Fig. 153

Parametric V-I Ch2
Fig. 154

Parametric V-I Ch 3
Fig. 155

Parametric V-I Ch4
Fig. 156

3φ Parametric V-I
Fig. 157

Vector Diagram
Fig. 158