



**CircuitMaster 4000M
Precision Active Oscilloscope**

OPERATOR'S MANUAL

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1. Preface

Thank you for purchasing the ABI CircuitMaster 4000M Precision Active Oscilloscope. Please refer to this manual before attempting to turn on or operate the equipment.

1.1. How to use this manual

This manual is divided into sections describing all aspects of the CircuitMaster operation. There is a getting started guide, designed to get you up and working quickly, followed by more detailed instructions on the various operating modes and functions. Later on there is a fault-finding guide and summary of the equipment specifications. We recommend you read at least sections 1 to 3 before turning on the CircuitMaster for the first time.



This symbol is used where high voltages are involved and care should be taken in operation.



This symbol is used where the information given is important to prevent damage to the system or board under test, or to ensure accurate results.

For the latest product information, including an up to date copy of this manual and the latest software, please visit www.abielectronics.co.uk.

1.2. Precautions

1.2.1. Power supply



The CircuitMaster operates from a mains supply and contains hazardous voltages inside. Do not open the cover at any time. See the rear panel label for information on operating voltage specifications and fuse ratings. The CircuitMaster must be earthed at all times and should not be used with a 2 core mains cable under any circumstances.

1.2.2. CE compliance

The CircuitMaster is designed to comply with the latest European EMC and safety standards. However, ABI cannot guarantee compliance in all circumstances when customer supplied external cables or probes are connected or the equipment is used in conjunction with other equipment not supplied by ABI. We recommend that you use ABI supplied accessories and use shielded external cables where possible.

The CircuitMaster is designed to operate in "Residential, Commercial and Light Industrial" environments and is not approved for operation in heavy industrial, medical, automotive or aircraft environments unless confirmed in writing by ABI.

1.2.3. Location

The CircuitMaster should be installed indoors on a suitable workbench with a permanent mains supply. Do not use outside or in damp conditions. Do not block the rear fan exit as this may cause the unit to overheat.



*Do not subject the inputs/outputs to voltages exceeding 200V DC or peak AC, or exceeding 25V DC or peak AC when using stimulus. The **LogicView** inputs and **MultiWay** inputs/outputs have an absolute maximum rating of +/-12V DC with the power on. Do not apply any signals to the MultiWay connector with the power off.*

1.2.4. Environmental limits

The CircuitMaster is a precision measuring instrument, but as with all electronic equipment the calibration and accuracy can be affected by extreme environmental conditions. For best results, we recommend: -

- Use in temperatures from 10°C to 30°C, humidity from 20% to 80%
- Ensure there is space around the unit for ventilation, and do not block the fan vent at the rear
- Avoid exposure to direct sunlight or sources of heat such as radiators
- Avoid exposure to strong magnetic fields such as from loudspeakers

1.2.5. Mobile phones

Use of a mobile telephone in close proximity may cause equipment malfunction and/or give inaccurate readings. We recommend a minimum distance of 50cm from the nearest mobile telephone in use.

1.2.6. Power switching



As with any mains powered equipment there is a power surge on switch on. Do not switch the unit rapidly on and off repeatedly, instead wait at least 5 seconds after power down before switching on again. Failure to observe this precaution may blow the mains fuse and/or damage the equipment.

1.3. Interfaces

The CircuitMaster has two rear panel interfaces to enhance its range of operating functions.

1.3.1. USB

The CircuitMaster can be connected to a PC equipped with an industry standard USB interface for software updates and data storage. A suitable USB cable is supplied.

1.3.2. Footswitch

The supplied footswitch can be used to allow hands-free saving of waveforms and results. It is connected via a jack socket on the rear panel.

1.4. Maintenance and calibration

1.4.1. Warranty

The CircuitMaster hardware is covered by a return to base warranty for a period of 1 year from the date of purchase. During this period it is guaranteed to be free from hardware defects and to be of good quality. During the warranty period, the unit will be repaired or at the option of ABI replaced free of charge, including parts and labour but not transportation costs. Use of the equipment outside the recommendations in this manual or any attempted repair or modification will invalidate the warranty

1.4.2. Hardware

The CircuitMaster requires no routine or regular hardware maintenance other than calibration. To maintain accuracy of results, in particular when comparing results with previously stored data, we recommend calibration every year of use to be carried out by ABI or by your local distributor at a nominal charge. Alternatively, a calibration kit is available for purchase on request.

1.4.3. Software

The CircuitMaster software is not warranted as being fit for any particular purpose, although ABI will make every effort to ensure that it is suitable for use in the test and measurement field. Updated versions of the software are available on our website (www.abielectronics.co.uk) free of charge for the 1st year of ownership. Thereafter updates can be purchased from ABI or from your local dealer. Unlimited software updates are available on-line to customers who purchase an annual software maintenance plan – contact sales at ABI or your local dealer for further information.

1.5. Copyright and disclaimers

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Whilst ABI makes every effort to ensure the accuracy of this manual, we will not accept liability for damages incurred directly or indirectly from errors, omissions in this manual, or discrepancies between the manual and the CircuitMaster itself.

2. Introduction

Congratulations on your decision to purchase the CircuitMaster 4000M Precision Active Oscilloscope.

2.1. What is the CircuitMaster?

The CircuitMaster is a completely new type of circuit test instrument, designed with several aims in mind: -

- To simplify the safe probing of fine pitch PCBs
- To enhance the available measurement capability
- To automatically acquire waveforms/voltages from several pins at once with no user intervention
- To allow waveforms/voltages to be saved for comparison and or analysis purposes

On fine pitch ICs and tiny components, probing IC pins and component packages is becoming more and more difficult, and there is an ever-present risk of damage by shorting pins together. Furthermore, with traditional instruments you have to probe “blind” because you normally have to adjust instrument controls and ranges while probing. The CircuitMaster is equipped with automatic range switching to ensure that you don’t need to take your eyes off the pin during probing. Measurement data can be stored using the **WaveStack** so you can review readings later after removing the probe.

On unfamiliar boards, you often have to use different instruments on the same pin, compounding the probing problem. The CircuitMaster includes DC and AC voltage analysis, and also a stimulus function allowing it to not just measure but also actively inject signals onto the board under test.

Although it resembles a traditional oscilloscope, and can be used as such if needed, it is capable of much more. The ability to inject signals onto the board allows new types of test to be carried out, including Active mode, FirmFlex, and VI tests which will be described in full later. In addition to looking at 2 analogue or digital signals, you can also look independently at 4 digital signals on the same waveform using the **LogicView** 4 channel logic analyser function. In **MultiWay** mode you can acquire and store “hands-free” up to 40 signals from different test points on a board.



The CircuitMaster can (in Active, FirmFlex and VI modes) generate signals up to 50V peak-peak with various waveforms and source impedance down to 100 Ohms. Before applying the probe to a powered board, ensure that the output signal is adjusted to a level which will not damage the board under test.

2.2. What can the CircuitMaster do?

The new test functions in the CircuitMaster allow tests and measurements that would be difficult with traditional equipment. Some simple examples: -

2.2.1. Example 1

A pin on a board should be connected to 0V through a 10k resistor. On 1 board the resistor is missing, on another a 1k resistor has been fitted by mistake, on another it is shorted to 0V. If we use a multimeter to measure the voltage at the pin with the power on, it reads 0V in all cases including the correct one. An oscilloscope would show also the same reading. However, the CircuitMaster would use Active or FirmFlex modes to dynamically measure the source impedance at the node, quickly identifying the differences between the faulty boards in this example.

2.2.2. Example 2

A precision ADC voltage measuring circuit is checked with a multimeter and found to have the correct input and reference voltages. However, the measured results are erratic. On investigation with the CircuitMaster, it is found that the reference input to the ADC is oscillating, causing the errors. In a precision circuit, a traditional oscilloscope is not accurate enough, but a multimeter cannot show such oscillations as they are averaged to give a reading which looks about right. The CircuitMaster combines DC accuracy and waveform acquisition into a single measurement to quickly identify the problem.

2.2.3. Example 3

A clock signal is driven off a board via an edge connector using an open-drain buffer. This buffer is prone to damage because of static and voltage spikes on the external cable in normal use. Checking this buffer on a bench is difficult with a normal oscilloscope, because the buffer output remains low as there is no pull up resistor connected. The CircuitMaster operating in Active mode can apply a suitable pull up resistor and pull up voltage to allow the signal to be seen clearly.

2.2.4. Example 4

A board contains several multi-pin connectors which have various waveforms and/or voltages present which need to be checked. This is a long process with a single probe on each pin at a time. By making up a series of suitable cables, the CircuitMaster can be used in **MultiWay** direct mode to acquire up to 40 signals at a time which are stored in the **WaveStack** for later analysis.

2.2.5. Example 5

A test procedure requires 10 test points (with a variety of DC and AC signals) on a board to be checked. Normally this requires an oscilloscope for the AC signals and a multimeter for the DC signals. For each test point, the operator has to set up the measuring instrument, apply the probe, observe the reading/signal and record the result. With the CircuitMaster, the operator just has to probe each test point in turn and use the footswitch to auto-range and store the signal. All 10 signals can be stored quickly and the voltages checked afterwards. It will be found that this process is much quicker and safer as the operators eyes remain focused on the board.

2.3. Test strategies

With traditional test equipment, the choice of operating mode and settings is often left up to the user, who may be relatively inexperienced. Even an experienced user may take time to set up an instrument for particular task. The CircuitMaster contains several preset test strategies to automate the setup for common tasks, simplifying operation. We will describe the various strategies briefly here – detailed descriptions are given later.

2.3.1. Standard test strategy

The simplest test strategy is Standard. In this mode, the instrument is used purely in passive mode, and is then similar to using a traditional digital oscilloscope and multimeter together. A typical application for this would be to look at signals or voltages at points in a working circuit and make measurements or do comparisons accordingly.

2.3.2. Active test strategy

In Active mode a programmable stimulus voltage is applied to either channel 1 or channel 2 via a selectable resistor. This is in effect a programmable active load which can be used to discover more information about the test point in a circuit. The stimulus voltage can also be AC (10Hz to 100kHz) which means the CircuitMaster can also inject signals into a circuit if required.

2.3.3. FirmFlex test

The FirmFlex test uses the built-in stimulus generator in DC mode to analyse the impedance at the node under test. The waveform and/or voltage at the node is also displayed. This allows the unit to differentiate between a 0V signal caused by an open circuit and a 0V signal caused by a short circuit – two extremely different circuit conditions which do not show up well on conventional test equipment.

2.3.4. VI test

The VI test uses the stimulus in AC mode and plots a graph of current into a node against the applied voltage. Comparison of the shape of this graph with a known good component leads to rapid identification of faulty components or boards. This test would normally be used on boards without power to find severe faults which prevent the board from being powered, such as short circuits or overloads due to faulty components.

2.3.5. LogicView test

The **LogicView** test adds 4 digital channels to the 2 normal analogue channels on the display, making 6 channels in all. Since many signals which you wish to examine will be digital, you can use this strategy when looking at digital circuits. For example, the digital inputs to a DAC can be examined using logic view, and the analogue outputs using the normal channels, all on the same time scale so you can get the maximum amount of information.

2.3.6. MultiWay test

Most of the available tests can be executed in **MultiWay** mode using the supplied cable and IC test clip, or you can make your own interface to suit the board under test. This allows waveforms to be captured for each pin of an IC under the same conditions, greatly speeding up circuit analysis and minimising probing. The **MultiWay** pin connections can be found in appendix 12.4.

2.4. Circuit Types

With traditional instruments the measuring ranges have to be manually set up prior to making a measurement, which takes time. On the CircuitMaster you can select one of several preset settings to speed up this process. Settings are provided for various digital logic families.

When you have chosen a digital setting, the display includes a bar graph showing the logic thresholds for the family chosen, so you can quickly see if a signal is outside the thresholds. The thresholds are preset but can be adjusted to suit your circuit.

2.5. Input Channels

This option allows you to quickly choose the input configuration of the instrument, including the **MultiWay** options for using IC test clips.

2.6. WaveStack

The **WaveStack** is one of the key features of the CircuitMaster and differentiates it from most traditional instruments. Using internal memory in conjunction with a foot switch, information can be stored either on command or automatically into an internal waveform “stack”. The waveforms and information stored can then be recalled and viewed, or downloaded to a PC for permanent storage or printing.

The **WaveStack** allows you to concentrate on probing while doing measurements, rather than trying to look at the display and circuit at the same time. This helps to reduce the risk of damage to a board and also allows one off events to be captured when they otherwise might be missed. It is also very useful when looking at very slowly changing signals where a history of the signals changing over time can be recorded.

3. Getting started

This section is intended to get the system up and running quickly. Please read carefully before switching on for the first time.

3.1. Checklist

The following items are included in the CircuitMaster package: -

- CircuitMaster 4000M Mixed Signal Circuit Analyser
- Mains power lead with plug according to international region
- 2x oscilloscope probes X10/X1
- **MultiWay** cable assembly with and integral **LogicView** IC pin clips
- 40 pin 0.6" and 16 pin 0.3" DIL test clips
- BNC to 4mm lead adapter
- Red/black 4mm probe set
- USB cable
- Footswitch
- Operator's manual
- CD with PC **CircuitLink** software and drivers

3.2. Installation

Unpack the unit and identify the various items in the package. At this stage only the main unit and the mains lead are required.

3.2.1. Supply voltage

Insert the mains lead into the socket at the rear of the unit and into a suitable mains power supply. The equipment is designed for 230/240V AC or 115V AC 50/60Hz operation. The mains power supply automatically detects which voltage is being used and switches itself over accordingly.



Do not rapidly turn the unit off and on – this may cause the power supply voltage to be incorrectly detected and may blow the mains fuse and/or cause damage to the unit.

3.2.2. Input ratings

Remember that the CircuitMaster can be used to generate output signals and not just for measuring input signals. The maximum input ratings are therefore different depending on the operating mode.



*With stimulus turned on (Active, FirmFlex, VI modes) do not connect the probes to voltages outside the range +/-25V DC or peak AC. With stimulus off (Standard mode) the maximum input voltage is 200V DC or peak AC. The **LogicView** inputs and **MultiWay** inputs/outputs have an absolute maximum rating of +/-12V DC.*



*The **MultiWay** inputs/outputs should not be connected to signals when the CircuitMaster is turned off. If voltages are injected into the MultiWay connector with the unit turned off, damage may result. Always turn on the unit before inserting the MultiWay connector, and remove the connector before turning off.*



You can measure higher voltages than this (up to the rating shown on the probe itself) by using the X10 setting on the probe. For even higher voltages special high voltage probes are available – contact ABI or your dealer for details. The measurement accuracy will be reduced because of the tolerance of the probe impedance.

3.3. Switching on

Switch on the unit. After a short pause the main sign on screen will be displayed showing the software version number. This screen will clear after 60 seconds, but you can also press any key or the footswitch to begin operation.

3.3.1. Using the controls

Before going any further, a quick explanation of the front panel controls, consisting of knobs and buttons. Most of these have defined functions which are shown on the front panel, but the 2 knobs and 3 buttons to the right of the display have context related functions which are indicated on the display, and change depending on the current operating mode. These will be referred to as menu knobs or buttons elsewhere in this manual.

The knobs are endless types which can be rotated continuously. The unit will issue an audible warning when you reach the end of a range or adjustment. The knobs can also be pushed in like the buttons to activate other functions. For example, the channel range knobs are rotated to select the range, and pushing them turns the channel on or off.

3.3.2. Using menus

Several functions are configured using menus which appear on the right of the display. The lowest menu button is used to close the displayed menu or to return to a higher level menu. The other menu knobs and buttons are used to select options or adjust values depending on the menu displayed.

The menu knobs can also be pressed. Depending on the context, this can either select a sub menu or reset the selection when a list of items is displayed. A symbol is displayed alongside the menu knob when more functions are available by pressing the knob.

Note that depending on the operating mode some menu options may not be available if they have no meaning in the current context.

3.4. Connecting accessories

The most common accessory you will use will be a normal oscilloscope probe. Connect the probes to channels 1 and 2 of the CircuitMaster and set the probes to X1 mode using the small switch on the probe. If you wish to use the external trigger input, you will need an additional probe which is available from ABI or from your dealer.

To use the **MultiWay** or **LogicView** functions, use the **MultiWay** cable which has **LogicView** grabber clips and connectors for a range of IC test clips.



Most oscilloscope probes have quite a high impedance even in X1 mode (in the range of a few hundred Ohms). This can affect the measurements when using active stimulus since this impedance is unknown to the system.

We recommend using the supplied BNC to 4mm lead adapter when using FirmFlex or VI modes to ensure best results. For best results with high speed signals, a normal oscilloscope probe should be used.

3.5. Choosing test strategy

The test strategy depends on the type of board you are working on and the nature of the tests you want to carry out. Refer to section 2.3 for a summary. To see a signal on the screen straight away, select Active by rotating the upper menu knob.



The CircuitMaster can (in Active, FirmFlex and VI modes) generate signals up to 50V peak-peak with various waveforms and source impedance down to 100 Ohms. Before applying the probe to a powered board, ensure that the output signal is adjusted to a level which will not damage the board under test.

3.6. Choosing circuit type

The circuit type (see section 2.4) can be used depending on the type of circuit you are working on. For now, leave it set to General.

3.7. Selecting input channels

Set this to Ch1 + Ch2 to see signals on both channels

3.8. Starting operation

Now you are ready to go. Do not connect the probes to a circuit at this stage. Press **Start**, and you will see the main display appear with both channels at 0V. This is Active DC mode, where the CircuitMaster outputs a DC voltage on channel 1 through a selectable resistor which you can use to apply an active load to the circuit under test. The initial setting defaults to 0V through a 10k resistor, but if you adjust the **Vpk-pk** control you will see the channel 1 voltage changes. The approximate setting is displayed at the bottom left of the waveform display and the channel 1 DVM reading shows the exact voltage. A cursor line is displayed indicating the voltage and impedance, but this will normally be obscured by the channel 1 trace (you can set the oscilloscope to AC coupling by pressing the **Coupling** knob to see the DC cursor line). You can also adjust the Impedance knob to change the source impedance of the DC stimulus voltage.

Press the **ac/dc** knob to change to AC stimulus and adjust the frequency to 1kHz with the **Frequency** knob. You can now adjust the controls to change the sine wave display as you wish. For example, you can move the waveform up or down using the **CH1 Offset** control. Note that the axis labels change so you always know what voltage levels you are looking at. The **CH1 Range** control can also be adjusted to alter the size of the waveform, and the **Time/div** control will change the number of cycles on the screen. If you use a traditional oscilloscope these controls will be familiar to you.

In the 4 corners of the waveform display you will see the current settings for the various controls. At the top are the settings for channel 1 and 2 controls, at the bottom right the timing and trigger settings, and at the bottom left the stimulus settings. You can try changing the waveform frequency, voltage and shape with the controls and observe the effect on the screen.

You are now up and running with the CircuitMaster, but much more is possible. On each channel there are buttons for storing waveforms, setting up automatic signal measurements and changing display settings.

3.9. Returning to the initial screen

Provided no menu is displayed, the lowest menu button (with a tool symbol) can be used to go back to the main settings screen. This allows you to change any of the chosen settings quickly and easily

The remainder of the manual is for reference and describes all the features of the CircuitMaster in detail.

4. Using the digital storage oscilloscope (DSO)

The built-in digital storage oscilloscope is a sampling oscilloscope with a bandwidth of 100MHz, base sampling rate of 50MS/s and a maximum vertical resolution of 10 bits.

4.1. Input probes

2 standard oscilloscope probes are supplied with X1/X10 switching. Select the probe attenuation required for each channel by adjusting the small switch on the probe. If you press the **Setup** button for either channel you can set the probe attenuation chosen. The system will then allow for this when displaying axis readings and calculating measurements.



Most oscilloscope probes have quite a high impedance even in X1 mode (in the range of a few hundred Ohms). This can affect the measurements when using active stimulus since this impedance is unknown to the system.

We recommend using the supplied BNC to 4mm lead adapter when using FirmFlex or VI modes to ensure best results. For best results with high speed signals, a normal oscilloscope probe should be used.

4.1.1. Probe compensation

When using the probes in X10 mode, they will require compensating. To do this, set up the system in Standard mode and press the **Timing Setup** button to display the general menu. Enable the **Cal output**, which applies a 1kHz 1V pk-pk square wave to both pulse outputs. View either pulse output with the oscilloscope probe in X10 mode and adjust the trimmer on the probe for the best square wave. Turn off the cal signal and close the menu.

4.2. Channel controls

4.2.1. Input range and visibility

The basic input range can be adjusted from 10mV/division to 10V/division with the **Range** control. This should be set according to the expected magnitude of the signal you are viewing. In auto ranging mode, this will be set automatically by the system. Pushing the **Range** knob will hide or show the waveform on the screen. If you are not using a channel you can hide it to simplify the display.

The colour of each channel can be set with the Trace Colour option on the Display menu.

4.2.2. Offset and coupling

To adjust the vertical position of the waveform on the screen, turn the **Offset** knob. The waveform axes levels change to indicate the new value of the offset. The ground position of the waveform is indicated by a dotted line on the display – you may find it convenient to adjust the offset to one of the graticule lines when using the axis values.

Pushing the **Offset/Coupling** knob cycles the coupling through the 3 settings AC, DC and ground. In DC mode the signal is DC coupled so that the on screen voltage is correct for the signal. In AC mode the DC component is removed so that small signals with large DC offsets can be viewed.

4.3. Timing and trigger controls

4.3.1. Time/div selection (timebase)

The basic timing for the horizontal display is stated in time units per division, and can be adjusted from 2s per division for viewing slowly changing signals to 1ns per division for extremely fast signals. Adjust this control for the desired number of cycles of the waveform you are viewing, or to expand the detail on a waveform edge.

4.3.2. ERS sampling mode

On timebases from 0.2us/div and faster, the CircuitMaster uses extended resolution sampling (ERS) mode to increase the effective sampling rate for accurate capture of repetitive signals. This works by acquiring multiple copies of the waveform and interleaving the points according to their random time difference from the trigger point (see appendix 12.3 for full details). The effective sampling rate is then 125M/s on the 0.2us/div range, rising to 25GS/s on the 1ns/div range.

Due to the nature of ERS timebases they can only be used on repetitive signals. No special action is required to activate ERS mode – it will be used automatically when you select a fast timebase. Auto acquisition mode (see section 4.3.6) is not available in ERS mode.

4.3.3. Aliasing



In all sampled data systems, the reconstructed data can be an "alias" (see appendix 12.2) of the real signal if the input frequency is too high for the sample rate. Ensure that the timebase is correct for the signal you are viewing.

The data is reconstructed by sampling the input at a fixed rate. In the case of the CircuitMaster this is a maximum of 50MHz or 1 sample every 20ns on the 0.5us/div range, but reduces for slower timebase settings. If the waveform is changing faster than the sampling speed, the displayed waveform will not correspond to the input signal and measurements of frequency will be inaccurate – the resulting display is called an alias. You should ensure that the timebase is correct for the signal you are viewing to ensure you are not seeing an alias of the main signal. Please refer to the appendix 12.2 for further information.

4.3.4. Trigger setting

In order for the CircuitMaster to display useful information, it has to synchronise the data acquisition with the input signal so that the waveform is stable on the screen. It does this by starting at a fixed voltage on the waveform for each acquisition. There are several controls which can configure the trigger point on the display.

Rotating the **Trig Level/Slope** control adjusts the voltage at which the trigger occurs, and the adjusted voltage is shown at the bottom right of the waveform and as a horizontal line on the display when triggering from either input waveform. Pressing the knob changes between positive and negative edge triggering.

Rotating the **Delay/Source** knob changes the horizontal position of the trigger on the display, and is indicated by a marker at the bottom of the waveform display. This allows information before and/or after the trigger to be displayed. Pressing the knob changes the source of the trigger signal which can be set to channel 1 or 2, or the external trigger input. In Active AC mode, a further trigger source setting allows the trigger to be derived internally from the AC stimulus function generator.



In Active AC mode, the trigger for the display can be derived internally from the output waveform. Most of the trigger controls have no effect in this mode.

4.3.5. Trigger coupling

The trigger coupling can be set to one of 4 options, DC, AC, LF reject and HF reject to further control the triggering of the system. In DC mode, the selected trigger source is DC coupled, while in AC mode the signal as AC coupled so that a DC offset can be removed. In LF reject mode, only high frequency signals are passed through and low frequency signals, including DC, are rejected. In HF reject mode, only low frequency signals are passed through to eliminate triggering on noise pulses on slow waveforms.

Press the **Timing Setup** button and adjust the upper menu knob until the desired setting is obtained. Note that in AC and LF reject modes no trigger line is visible on the display since there is no DC path for the trigger signal.

4.3.6. Acquisition mode

Pressing the **Time/div** knob changes the acquisition mode between the settings auto, normal and single.

In normal mode, the system waits for a trigger signal before acquiring the waveform. If no trigger is received, the system will wait indefinitely and the display will not be updated. After the waveform is displayed the system repeats the process for the next trigger. This ensures that the displayed waveform is always stable.

In auto mode, the system behaves as in normal mode but will generate a trigger internally after a time delay if no trigger is detected. This ensures that the waveform is visible on the screen but may not be stable depending on the trigger settings. The process is repeated after the waveform is displayed. Auto trigger mode is not available in ERS timebase settings (see section 4.3.2) because a stable trigger is required for ERS acquisitions.

In single mode, the system behaves as in normal mode, but only 1 acquisition is performed so that the resulting waveform can be observed. This is useful for capturing one-off events such as initial power-up of a board.


The **Stop/Start** menu button (3rd menu button from the bottom on the right of the display) can be used to start and stop the acquisition process if required. In single mode, this allows you to capture another waveform whenever you choose. The button is indicated by a **I** (**Start**) or **III** (**Stop**) symbol on the display. If you wish, you can configure the footswitch to act like the **Stop/Start** button for hands-free control of acquisitions (see section 9).

At the top of the display in the centre there is a square symbol which indicates using colours the status of the current acquisition as follows: -

- Light green – a valid trigger has recently been received.
- Dark green – the DSO is waiting for the next trigger.
- Yellow – trigger not received within a preset time.
- Red – acquisitions have been stopped, either by pressing the **Stop** button or in single mode.

The dark green and/or yellow symbols may only be visible on the slower timebase settings.

4.4. Measurements and Waveform Comparison

At the bottom of the display beneath the waveform display you will see the **Measurements Window**. This can display different information depending on the context. To change the information displayed in the measurements window, press the  button (2nd menu button from the bottom on the right of the display). The window cycles round all the available measurement options.

The following measurement and comparison functions can be displayed in the measurements window.

- The DVM voltage readings for each channel (see section 5).
- Time or voltage cursor measurements (if selected) per channel.
- Automatic measurements (if selected) per channel.
- Comparison results between the current waveform and a previously stored waveform, per channel.
- Live comparison results using channel 1 as a master waveform and comparing channel 2 against it.

Note that not all displays are valid in some operating modes, so they may not appear.

4.4.1. Cursor Measurements

The CircuitMaster can automatically calculate voltage and/or time measurements between points on a waveform, by displaying cursors which you can position to get the measurement you want.



When using cursor measurements, ensure that the entire waveform is visible on the screen by adjusting the range and/or offset controls. If the waveform goes off the screen above or below the display, the cursors cannot be positioned accurately on the waveform.

To set up a cursor measurement, press the **Measure** button and use the upper menu knob to select either Volt Cursors or Time Cursors. The cursor positions can then be adjusted by the menu knobs once the measure menu has been closed. Note that if **WaveStack** or **MultiWay** is enabled, the cursor menu knobs are used for other functions, but the cursors can still be adjusted by pressing the **Measure** button followed by the **Cursors** button.

The CircuitMaster displays the positions of the two cursors in the measurement area of the display and the voltage or time difference between the two cursors. In addition, if Time Cursors are used to measure the period of a waveform, the frequency of the waveform is displayed.

If the Track option is selected, only cursor 1 can be adjusted independently. Adjusting Cursor 2 will cause Cursor 1 to move with it to maintain the voltage or time difference between them

4.4.2. Automatic measurements

One of the most powerful features of the CircuitMaster is its ability to calculate automatic measurements from the acquired waveform. This eliminates the need for you to count divisions on the screen and allows complex signal analysis. The results are display in a grid at the bottom of the screen and are updated after every new acquisition.



When using automatic measurements, ensure that the entire waveform is visible on the screen by adjusting the range and/or offset controls. If the waveform goes off the screen above or below the display, the automatic measurements may not be accurate.

To set up an automatic measurement, press the **Measure** button and use the upper menu knob to select Auto. Either press the knob or press the **Select** menu button to go to the measurement menu. Now use the upper menu knobs to select the type of measurement and the display line, and select the channel with the button shown. Pressing **Add** will then add this measurement to the display. You can have up to 4 measurements for each channel.

To remove a measurement, select None from the menu and press **Add**. Note that you can quickly go to the top of the list by clicking the menu knob.

If a measurement cannot be calculated from the input signal then “...” will be displayed for the measurement result. For example, the frequency measurement requires at least one full waveform cycle to be visible before the frequency can be displayed.

A full list of the available measurements with a description of how they are calculated is given in appendix 12.1.

4.4.3. Comparing waveforms

As an alternative to comparing measurements from an acquired waveform, you can also compare the shape of the waveform itself. This is especially useful for VI curves or non-repetitive waveforms where measurements are difficult or impossible to make directly. With this facility you can store a waveform from a known good circuit, create a tolerance mask, and then compare each acquisition with the mask. You can also directly compare the channel 1 and channel 2 waveforms, using channel 1 as a master signal and comparing channel 2 against it. In this live comparison mode, the comparison mask for channel 2 automatically updates if the channel 1 signal changes.

4.4.4. Storing a waveform

Once you have the desired waveform on the screen, press the **Store** button for the channel you want to save. The waveform will be automatically stored in memory and the store menu will appear. In addition, a mask will appear around the waveform on the display. Use the vertical menu knob and horizontal menu button to adjust the size of the mask, and the **Enable** button to turn the waveform comparison on or off. If the input signal changes you can press **Update mask** to re-store the waveform and create a new mask. If required you can configure the footswitch (see section 9) to update the mask for either or both channels.

4.4.5. Comparison results

The results of the comparison are displayed in the measurement area as a percentage. This figure indicates the percentage (by length) of the waveform that falls inside the mask. A comparison result above the chosen pass % target value is regarded as a PASS result, and a result below the value will show a FAIL result. The pass % target defaults to 85%, but can be set on the **Timing Setup** menu.

4.4.6. Live comparison

Live comparison allows 2 waveforms to be compared directly without storing a previously acquired waveform. In this mode, the channel 1 waveform is regarded as a master waveform and the comparison mask is generated automatically from it. For example, if you are comparing a signal on a known good board you should attach the channel 1 signal to this board. Use channel 2 to examine the same signal on a suspect board, and the comparison result for channel 2 will indicate the degree of correspondence between the 2 waveforms. Press either **Store** button to change the comparison mask tolerances or the pass level.

4.5. Setting thresholds

If you know you are going to be looking at digital signals, you can set logic thresholds to help identify logic levels on the displayed waveforms. For example, for 5V TTL logic you can set the low threshold to 0.8V and the high threshold to 2.0V. A colour coded bar graph is displayed alongside the axis to help you interpret the signal being displayed.

To set up logic thresholds, press the **Setup** button for the desired channel, then press the **Thresholds** button to display the thresholds sub-menu. The top two menu knobs are dual purpose – by default they are used to adjust the low and high threshold voltages, but if you press either knob you can then adjust the extreme maximum and minimum values of the threshold bar graph. This allows you to adjust the threshold display exactly as you want within the range –12V to +12V.

Once you have set the thresholds as you wish, you can enable or disable the display with the **Enable** menu button. When thresholds are enabled, the **Cursors** button can be used to extend the programmed logic levels as cursor lines on the display to improve analysis.



You can set threshold values which are not sensible, for example where the low threshold is higher than the high threshold. The bar graph display may not indicate correctly in these conditions, but this situation is allowed as it might occur temporarily while adjusting the thresholds.

4.6. Using LogicView

The **LogicView** feature is similar to a built-in 4 channel logic analyser, which can be used to add 4 further channels to the display for digital signals. While the main analogue waveforms are being acquired, the system also stores the state of 4 digital inputs that are available on the **MultiWay** connector (see appendix 12.4 for pin connections). These signals can then be displayed using the same timebase as the main waveforms.

As an example, you want to analyse the performance of a serial digital to analogue converter (DAC). The IC has some digital inputs (clock, data, chip select) and an analogue output voltage. With **LogicView**, you can clip into the 3 digital inputs with the **LogicView** grabber probes, and view the analogue output with the normal probe. When you run the system, you can see the digital data changing on the **LogicView** signals and the response of the analogue output can be seen on the same display.

To use **LogicView**, press the **MultiWay Setup** button, then the **LogicView** button to display the **LogicView** menu. The threshold can be adjusted in the range +/-4V with the upper menu knob. Voltages above the value are regarded as logic high, otherwise logic low. The other 3 parameters set the position and size of the logic traces on the display, and also the number of channels to view. Select these values so that the displayed **LogicView** traces do not interfere with the main waveform display. To clear the **LogicView** traces, set the Traces parameter to zero.



*The **LogicView** inputs are designed for digital input signals in the range 0 to 5V. However, they can also be used for higher voltage digital signals (e.g. CMOS or RS-232 circuits) up to a maximum of +/-12V. Voltages outside this range may damage the unit.*

5. Using the digital voltmeter (DVM)

The CircuitMaster contains a built in 2 channel digital voltmeter working from the same inputs as the DSO. Unlike traditional oscilloscopes this allows it to measure DC voltages to a high degree of accuracy, which means you don't have to use a separate multimeter when working on mixed DC and AC circuits. See section 2.2.2 for an example of how the DVM and DSO combination provides more reliable circuit analysis information.

5.1. Connecting the input signal

The DVM input is derived from the main channel inputs, so no special connection is necessary. The range switching and input ratings are identical to that shown for the DSO. Ensure that you use the DSO on DC coupling when using the DVM, otherwise the DVM will not be able to measure the DC component of the signal correctly.



When using a x10 probe, the DVM readings are nominally correct if you have adjusted the Probe Attenuation accordingly – see section 4.1. However, the accuracy will suffer due to impedance tolerances of the probe and the CircuitMaster, so for best accuracy we recommend using a x1 probe for DVM measurements.

5.2. Result display

The DVM readings are acquired continuously during operation and are displayed in the **Measurements Window** (see section 4.4) when selected. A warning is displayed if the relevant channel input coupling is set to AC or ground. The DVM results are also included in the automatic measurements function of the CircuitMaster. You can display the current DVM reading by adding a measurement as described in section 4.4.2, and the measurements are described in detail in appendix 12.1.

The statistics (minimum, maximum and average value of a series of readings) are also available as automatic measurements. They are useful for analysing issues such as drift and stability in DC circuits. These statistics are reset by changing the input range.



The DVM readings are still available when displaying AC signals, but will then represent the electrical mean of the input signal. For high speed signals this will be a fair measure of the average value of the signal, but for slow signals the results will be inaccurate as the DVM input will be changing during measurement.

We recommend you use the mean and rms automatic DSO measurements for better results with AC waveforms of all shapes.

6. Using the stimulus

Unlike traditional oscilloscopes, the CircuitMaster can generate waveforms and voltages as well as measuring them. This allows a whole new range of measurement techniques to be implemented.



The stimulus can generate signals up to 50V peak-peak with various waveforms and source impedance down to 100 Ohms. Before applying the probe to a powered board, ensure that the output signal is adjusted to a level which will not damage the board under test.

The stimulus output is applied internally to either channel and can then be acquired along with the normal signal. DC voltage in the range +/-10V can be produced, and AC signals up to 100kHz with bipolar or unipolar waveforms and amplitudes from 0.5V to 50V peak to peak can also be output. A key feature of the stimulus is the source impedance, which can be set from 100R to 1M or off (open circuit), which allow the stimulus to be applied to circuit outputs without damage. This allows the response of the circuit under load to be evaluated.

Note that the stimulus can be used regardless of whether the board under test is powered or not. Older generation VI type testers used a similar principle, but could only be used on unpowered boards, which resulted in many circuit faults and problems remaining undetected.

6.1. Setting the stimulus type

To use the stimulus, select Active test strategy from the start screen. The stimulus can be set to AC or DC by pressing the **ac/dc** knob. In Standard test strategy, stimulus is turned off and the CircuitMaster behaves like a normal DSO and DVM combination. In Active mode the CircuitMaster uses either DC or AC stimulus to apply to the selected channel. In FirmFlex test strategy the CircuitMaster uses DC stimulus, and in VI mode AC stimulus is used. The stimulus signals are applied via the channel input/output sockets to the board under test and acquired along with the normal acquisition data. The results are then displayed in a variety of ways.

6.1.1. Active mode (DC or AC stimulus)

In Active mode, either DC or AC stimulus is applied through a selected impedance to the desired channel. This allows a controlled load to be applied to the signal for improved analysis of certain circuit conditions.

6.1.2. FirmFlex testing (DC stimulus)

DC stimulus is used in FirmFlex testing (see below). The actual DC voltage used is determined automatically by the CircuitMaster, but you can adjust the source impedance to set the maximum current allowed in the test.

6.1.3. VI testing (AC stimulus)

AC stimulus is used in VI testing, which is used on unpowered boards to analyse the voltage-current characteristics of components on the board.

6.2. Active testing



Most oscilloscope probes have quite a high impedance even in X1 mode (in the range of a few hundred Ohms). This can affect the measurements using Active mode since this impedance is unknown to the system. We recommend using the 4mm BNC adapter cable and probes when using Active mode below 10k.

In section 2.2.1 we described an example of a circuit where a resistor connecting a point to ground could range in value. If we use an oscilloscope to probe such a point we will always see a horizontal line at 0V. However, if DC stimulus is enabled we could, for example, arrange to pull the node to 5V through a 10k resistor. The information about the circuit is then much improved as shown in the following table: -

Circuit Condition	Standard Mode (no DC stimulus)		Active mode (5V DC through 10k stimulus)	
	DVM reading	DSO display	DVM reading	DSO display
Open circuit	0V	Line at 0V	5V	Line at 5V
10k to 0V	0V	Line at 0V	2.5V	Line at 2.5V
1k to 0V	0V	Line at 0V	0.45V	Line at 0.45V
Short to 0V	0V	Line at 0V	0V	Line at 0V

The DVM and DSO readings in active mode give very different results for the 4 circuit conditions, resulting in a simple and quick fault diagnosis on the board. Note that the mid range voltages (2.5V and 0.45V) may vary slightly when using a normal scope probe due to the probe resistance.

The chosen stimulus voltage (either DC or AC) can be adjusted by rotating and/or pressing the **Vpk-pk** knob, and the source impedance can be adjusted from 100R to 1M then off (open circuit) by rotating the **Impedance** knob. In AC mode, you can also use the **Frequency** and **Shape** knobs to configure the signal. Pressing the **Setup** knob will also allow you to configure the signal and select the stimulus channel. This mode allows you to apply a controlled active load (AC or DC) to the point under test. Additionally, AC mode also allows the CircuitMaster to inject a signal into a circuit via one channel, then use the other channel to trace the signal.

Note that if the DSO input is set to AC coupling, the DC stimulus is still applied to the channel as selected, but any DC component will be blocked.

6.3. FirmFlex testing



Most oscilloscope probes have quite a high impedance even in X1 mode (in the range of a few hundred Ohms). This can affect the measurements using the FirmFlex test since this impedance is unknown to the system. We recommend using the 4mm BNC adapter cable and probes for the FirmFlex test.

In section 2.2.1 we described an example of a circuit where a resistor connecting a point to ground could range in value from zero Ohms (short circuit) to infinity (open circuit). The voltage in such a circuit is always 0V, but the circuit conditions are highly different and need to be identified for proper circuit analysis. If you think of it another way, a multimeter will display 0V readings with the probes either separate or shorted together – the reading is not much help in finding out exactly what is happening in the circuit.

With FirmFlex testing, the CircuitMaster can use channel 1 to measure the “stiffness” of the node on the circuit under test, by injecting a small current into the node. The amount (if any) by which the node voltage changes is then measured and is used as a measure of the strength of the node. The result is displayed as a colour graph on the screen. In the example above, the incorrect resistor will cause an instant difference in the stiffness reading, identifying the fault quickly. The actual voltage or signal present at the node under test is also measured normally. Note that the FirmFlex test operates on channel 1 only – channel 2 can be used for normal signal acquisition and display.



In FirmFlex mode the CircuitMaster still acquires waveforms and measures voltages. For DC and slowly changing voltages, the indicated stiffness of the node may track changes in the signal, but for higher frequency signals an average reading will be displayed.

The stiffness of a node can be considered as a passive value (made up of passive components such as resistors or capacitors) or a dynamic value (outputs of ICs or active components on the board). For most points on a board, the actual stiffness will be a combination of these two types. Passive stiffness values can be measured in power off conditions, but the real value of the FirmFlex test is in measuring drive strength in power on conditions. A wide variety of circuit problems can be identified in this way, including incorrect value components, PCB faults such as broken or high impedance tracks and vias, faulty IC outputs, low gain transistors to name just a few.

6.3.1. Configuring the FirmFlex test

To activate the FirmFlex test, select FirmFlex test strategy from the start screen. You can then adjust the maximum test current using the Impedance knob. Before you attach the probe to a circuit, select the channel 1 range according to the likely voltage you will be measuring.

Note that you can quickly switch off FirmFlex, if required, by clicking the **Frequency/Shape** knob on the front panel.

6.3.2. Interpreting the FirmFlex results

The FirmFlex test results are different to the others in that the display contains two types of information. The channel 1 trace shows the measured voltage (AC or DC) as usual, but the *background* colour of the display is used to give a visual indication of the stiffness of the point being measured. On the left hand side there is a scale showing the grades, from purple to yellow. On this scale, purple represents no stiffness, corresponding to an open circuit, while yellow represents maximum stiffness, corresponding to a short circuit. The colours in between indicate varying degrees of stiffness for the chosen range.

Note that it is not important to calculate or display accurate numerical values of stiffness – they will vary quite widely anyway between circuits because of normal component tolerances. What is important is that the result is in the correct region. This is best achieved by comparing the board under test with a known good board. Severe faults, such as missing components, will however show up immediately without comparison.

In normal operation, channel 2 shows normal voltage information and not FirmFlex results, so you need to use channel 1 for probing when using FirmFlex. However, if **MultiWay** mode is enabled then this uses channel 2 and channel 1 shows normal voltage information.

6.4. VI testing



Most oscilloscope probes have quite a high impedance even in X1 mode (in the range of a few hundred Ohms). This can affect the measurements using the VI test on the lower ranges since this impedance is unknown to the system. We recommend using the 4mm BNC adapter cable and probes for the VI test.

VI testing is a well-established circuit diagnostic technique intended for use on unpowered boards. It applies an AC signal to a node on the board and measures the resulting current over the waveform. The results are displayed on a graph of current plotted against applied voltage. The shape of the resultant curve can provide useful information about the circuit, particularly when boards have been damaged by static or over voltage. See appendix 12.5 for a detailed description of VI testing with recommended settings for various types of components.



The VI test generates signals up to 20V peak-peak on the 100R range, and 50V peak-peak on other ranges. Before applying the probe to a board, ensure that the output signal is adjusted to a level which will not damage the board under test.

By default, the VI test is carried on both channels alternately to allow the curves for good and bad boards to be compared visually, and you can also use the built-in comparison functions to compare VI curves (see section 4.4.3). If you are working on a single PCB you can turn off the unused channel by pressing the **Range/On/Off** knob for the channel. This speeds up the acquisition and display of the VI curve.

6.4.1. Adjusting the VI stimulus

To activate the VI test, select VI test strategy from the main settings screen. Select the required stimulus voltage using the **Vpk-pk** knob, and choose the desired waveform and frequency by pressing and/or rotating the **Frequency/Shape** knob. Finally, set the desired source impedance using the **Impedance** knob.

By default, the display is plotted as current against voltage (V-I display). However, if you wish you can display voltage against time (V-T display) by pressing the **Impedance/Setup** knob to open the **Stimulus** menu, then selecting **V-T Display**.

6.4.2. VI scan mode

If you are not sure which stimulus voltage to use, you can use **Scan Mode** to automatically cycle the stimulus voltage through a pre-defined range of settings. To do this, press the **Impedance/Setup** knob to open the **Stimulus** menu. Rotate the top encoder to select **Scan** mode. The VI stimulus voltage is then adjusted automatically between the default settings of 1V peak-peak and 10V peak-peak. To adjust the scan limit voltages, press the top menu knob and adjust the Vmax and Vmin values with the menu knobs. You can also adjust the time between scan steps to 0.5 seconds (default), 1, 2 or 5 seconds to allow time for the display to be viewed at each step.



*The scan time starts after all relevant data has been acquired for the current settings. Therefore, on low frequency VI settings (e.g. 10Hz) or on **MultiWay** settings (e.g. clip 8) the scan time may appear longer than selected since the data acquisition may take a considerable time.*

6.4.3. Using the VI pulse outputs



The VI pulse output generates signals up to +/-10V with a source impedance of 56 Ohms. Before applying the pulse to a board, ensure that the pulse signal is adjusted to a level which will not damage the board under test. Do not apply the pulse output to a powered board or damage to the CircuitMaster may result.

On the front panel there are two 4mm pulse output connectors, one for each channel labelled P1 and P2. They are also duplicated on the **MultiWay** connector. They can be used to output a programmable pulse which is phase related to the AC stimulus signal used in the VI test. This is useful for activating devices such as thyristors and transistors which need to be turned on during the test to get suitable results.

The pulse can be set to output positive, negative or both voltages during a single VI cycle. To enable the pulse outputs, press the **Impedance/Setup** knob to display the **Stimulus** menu. Select the pulse channel to either channel 1, channel 2 or both using the second menu knob, then press the knob to open the **Pulse** menu. The upper menu knobs set the positive and negative pulse voltages. To adjust the pulse timing, press the **Positive** or **Negative** knobs. The start and stop phase (in degrees) can then be adjusted, and the pulse can also be enabled or disabled at this point.

6.4.4. Compensation

On high frequencies and/or high source impedances, the stray capacitance of the probe and internal circuitry may cause the VI curve to become elliptical or circular in shape. This is perfectly normal and does not represent a fault. It cannot be calibrated out at the factory because it varies depending on the type of probe being used and the working environment. On the Setup menu there are controls which you can use to adjust the gain and phase of the signal to eliminate this behaviour for a given setting. However, we recommend you use lower values of frequency and/or source impedance where possible to eliminate this issue.

7. Using WaveStack

With **WaveStack**, you can store acquired waveforms in the CircuitMaster internal memory for reviewing later. This feature allows you to concentrate on the circuit under test rather than on the display, reducing the risk of damage due to probes shorting adjacent component pins. It is also very useful for capturing intermittent events or random problems.

The footswitch can be set (see section 9) to activate **WaveStack** to leave your hands free for probing. While the system is running, each press of the footswitch will store the latest acquired waveform in the stack, which will appear at the top of the display once the first waveform is stored. You can add more waveforms by repeated pressing of the foot switch.

Once you have created a waveform stack, pressing the **Options** knob will display the **WaveStack** menu. The **Review** knob will then allow you to select an entry in the waveform stack for display. Pressing **Delete** will allow a previously stored **WaveStack** entry to be deleted.

When viewing an entry in the **WaveStack**, any automatic and DVM measurements that were programmed will also be recalculated and their values shown. You can also add new measurements to a stored waveform, and the results will be calculated from the stored data.

To exit **WaveStack** mode, turn off the **Visible** option and press the lower menu button to close the **WaveStack** menu.

8. Using MultiWay



The **MultiWay** inputs/outputs should not be connected to signals when the CircuitMaster is turned off. If voltages are injected into the MultiWay connector with the unit turned off, damage may result. Always turn on the unit before inserting the MultiWay connector, and remove the connector before turning off.

MultiWay is designed for rapid multiple acquisitions on components with several pins, particularly for ICs. It uses the **WaveStack** to acquire signals for each pin on the component under test, which can then be examined using the review facility.



- **MultiWay** uses internal multiplexers in conjunction with the channel 2 input to acquire the data. Remove any probe connections from channel 2 when in **MultiWay** mode.
- Do not apply signals above +/-12V to the **MultiWay** I/O connector otherwise damage could result. Do not connect any signals when the CircuitMaster is turned off.

To use **MultiWay**, select one of the clip sizes from the initial settings screen or press the **MultiWay Setup** button and select the **MultiWay** mode from the following options: -

- **Clip**: This allows the standard **MultiWay** cable (included) to be used with an 8, 16, 20 or 40 pin test clip for attaching to an IC in circuit.
- **Split**: This allows a special split **MultiWay** cable (optional extra) to be used with dual 8, 16 or 20 way clips, to give rapid signal comparison between 2 different boards.
- **Direct**: This allows you to make up a cable for acquiring signals of your choice up to 40 pins, for example to connect directly to a card edge connector.

Once you have chosen the mode, select the number of channels you wish to use. Insert the **MultiWay** test lead with the appropriate clip and attach to the IC you wish to examine. The CircuitMaster immediately starts acquiring the waveforms and automatically generates a **WaveStack** with one waveform for each pin of the IC under test. Use the **WaveStack** facilities to review the individual waveforms as described in section 7.

In **MultiWay** mode it is difficult to get the DSO to trigger correctly from every pin of the **MultiWay** clip if the signals are different. If Auto trigger mode is selected the CircuitMaster will still acquire waveforms but will slow down as there is a delay before the auto trigger occurs for each pin. To speed up the acquisition, use channel 1 or the external trigger to connect to a suitable signal whilst using **MultiWay** mode.

The full bandwidth specifications may not be achieved in **MultiWay** mode – we recommend using normal DSO mode for high speed signals. This can be done by using channel 1 to look at a point of interest in more detail once it has been identified by the **MultiWay** connector.

Note that for hardware reasons Active mode cannot be used in conjunction with **MultiWay** mode.

9. Customising operation

The CircuitMaster can be customised so you can get the best out of it for your particular application. To do this, press the **Timing Setup** button to enter the General menu, and if required press the **More** menu button to access further menus.

The parameters that can be set are: -

- Trig Couple – The trigger coupling can be set to AC, DC, LF reject or HF reject (see section 4.3.5).
- Auto Zero interval – the DSO hardware uses precision low drift components. However, as the equipment warms up slight drift may occur – the system automatically removes this by periodically doing an auto zero calibration. You can set this to 30 seconds, 2 or 5 minutes, or to a range change, or turn it off altogether if required.
- Cal output – When enabled, the CircuitMaster outputs a 1V pk-pk 1KHz square wave on both pulse outputs for X10 probe adjustment.

Pressing the **More** button opens a sub menu with the following settings: -

- Brightness – the LCD brightness can be adjusted over a small range to suit your taste.
- Pass % Target – the target percentage for waveform comparison pass result can be set here.
- Language – the system language can be set from the currently available list depending on the country of use.
- Footswitch – the function of the footswitch can be set from the following options: -
 - **WaveStack** – pressing the footswitch stores the currently displayed waveforms in the **WaveStack** menu (see section 7).
 - **Stop/Start** – the footswitch acts like the **Stop/Start** button (see section 4.3.6).
 - Mask C1 – the footswitch acts like the **Update mask** button for the channel 1 waveform (see section 4.4.4).
 - Mask C2 – the footswitch acts like the **Update mask** button for the channel 2 waveform.
 - Mask C1/C2 – the footswitch acts like the **Update mask** button for both channel waveforms.

10. Linking to a PC

The CircuitMaster is equipped with a USB interface, allowing exchange of information with a PC. A host software package, **CircuitLink**, is available which is installed on your PC to handle the transfer of data. Your PC must be running Microsoft Windows XP™ to use the **CircuitLink** software. There are two steps to the installation – installing the CircuitMaster USB drivers and installing the **CircuitLink** software.

10.1. Installing CircuitMaster drivers

Before using **CircuitLink** you must install the USB drivers required for operation. To do this, follow this step by step procedure: -

- Turn on your PC and the CircuitMaster.
- Connect the CircuitMaster USB socket at the back to a USB port on your PC with the USB cable supplied.
- On the PC, the “Found New Hardware Wizard” should appear. Follow the instructions on the screen to install the CircuitMaster drivers from the CD included.
- If you are asked to connect to Windows Update to find a driver, select “No, not this time” and click “Next”.
- Insert the CD containing the drivers, select “Install the software automatically”, and click “Next”. Wait while the PC finds the drivers.
- If you see a warning about Windows™ Logo testing, click “Continue Anyway” and wait for the installation to complete.
- Click “Finish” to complete the driver installation.

10.2. Installing CircuitLink software

To install the **CircuitLink** software, follow this step by step procedure: -

- Insert the **CircuitLink** CD and wait for the installation screen to appear, which should happen automatically.
- If it does not, click “Start, Run, Browse” on your PC and navigate to your CD ROM drive with the **CircuitLink** CD inserted.
- Select the file “setup.exe” and click “Open”, then click “OK” to start the installation.
- Follow the installation instructions on the screen. We recommend that all options are left at their default values.

10.3. Updating the CircuitMaster software

The latest version of the CircuitMaster software is available for download (free of charge in the first year of ownership) from www.abielectronics.co.uk. To upgrade the software on your unit, follow this procedure: -

- Turn on your PC and download the latest software from www.abielectronics.co.uk save the file in a location of your choice on your PC.
- If the file is a compressed format (e.g. a ZIP file), extract the file to recreate the original file which should be called “CircuitMaster.cms”.
- Turn on your CircuitMaster, run the **CircuitLink** software on the PC and connect the CircuitMaster to your PC with a USB cable.
- Check that the CircuitMaster status is shown as “Connected”
- Click the “Browse” [...] button and navigate to the downloaded CircuitMaster.cms file.
- Click the “Send” button to automatically update the CircuitMaster software via the USB interface. Do not attempt to turn off your PC or CircuitMaster, or remove the USB cable, until the operation completes successfully.
- If an error occurs, a message will be shown and the CircuitMaster will revert to its previous version of software. Double check that everything is connected and try again.

10.4. Capturing CircuitMaster screen displays

If you wish you can capture CircuitMaster screen displays for saving on your PC. To do this, click the “Capture” button when the desired display is present. The captured display will then appear after a short delay on the display window on your PC. If you wish you can then save this on your PC hard disk by clicking “Save snapshot”

11. Troubleshooting and support

If you suspect your unit has developed a hardware fault, in the first instance power down the unit and remove all probes and cables. Check the fuse in the rear panel connector and if necessary replace with the same type and rating – see the rear panel label for details.

Power up the unit after a minimum 5 seconds and check its operation again. If it is still faulty contact ABI or your dealer for advice. Please email support@abielectronics.co.uk or your local dealer with full details of the apparent problem. We will respond as soon as possible with advice.

Many apparent faults may in fact be software related and can easily be solved by a software update, so to avoid inconvenience you should always contact us before sending your unit for repair. Software updates can be downloaded free of charge in the first year of ownership and the CircuitMaster can be updated via a USB interface from a PC.

Specifications

11.1. General

Supply voltage	110V AC or 230/240V AC (auto switch) 50/60Hz
Interfaces	USB, footswitch, BNC, MultiWay, 4mm
Display type	Colour LCD 320 x 240 pixel
Controls	Rotary encoders (30 step) and push buttons

11.2. DSO

Bandwidth	100MHz to 10V/div
Sample rate	50MS/s single shot, 250MS/s – 25GS/s in ERS mode
ADC resolution	10 bits maximum, 7 bits on 10mV/div and 8 bits on 20mV div
Maximum input	200V DC or peak AC
Accuracy	1% of full scale, 5% on 10mV and 20mV ranges
Channels	2 analogue, 4 digital plus external trigger
Input impedance	1M // 50pF
Timebase	1ns/div to 2s/div in 1-2-5 sequence
Sensitivity	10mV/div to 10V/div in 1-2-5 sequence
Input coupling	DC, AC, ground
Trigger coupling	DC, AC, LF reject, HF reject
Trigger source	Ch1, Ch2, ext (also FG internal in Active AC mode)
Trigger mode	Auto, normal, single shot
Ext trigger range	+/-2V

11.3. DVM

Ranges	Uses DSO range switching
Maximum input	200V DC or peak AC
Resolution	24 bits (approx 0.1uV on 10mV/div, 16uV on 10V/div)
Basic accuracy	0.1% of full scale range

11.4. Stimulus

Bipolar voltage	+/-0.5V (1Vpp) to +/-25V (50Vpp)
Unipolar voltage	+0.5V to +25V (pos) or -0.5V to -25V (neg)
Frequency	10Hz to 100kHz in 1-2-5 sequence
Waveforms	Sine, triangle, ramp, square, pulse
Source impedance	100R to 1M in decade sequence
Modes	DC/AC (Active), DC (FirmFlex), AC (VI)
Voltage accuracy	+/-2%
Freq accuracy	0.1% (crystal controlled)

12. Appendices

12.1. Automatic measurements

DC V	DC voltage measured by digital voltmeter
DC V min	Minimum DC voltage since last reset
DC V max	Maximum DC voltage since last reset
DC V mean	Mean (average) DC voltage since last reset
Base	The dominant low voltage of a pulse or square waveform, ignoring undershoot. For waveforms with no dominant level (e.g. sine or triangle waveforms) this is the same as the Base Peak.
Top	The dominant high voltage of a pulse or square waveform, ignoring overshoot. For waveforms with no dominant level (e.g. sine or triangle waveforms) this is the same as the Top Peak.
Base peak	The lowest voltage of the waveform, regardless of its shape.
Top peak	The highest voltage of the waveform, regardless of its shape.
Amplitude	Top - Base.
Pk-pk	Top Peak - Base Peak.
Mean	Sum of all voltages / Number of points per acquisition.
Cyclic mean	Sum of all voltages within an integral number of cycles / Total number of points within this number of cycles (provided that a periodic waveform is detected).
RMS	Square root of the sum of the squares of all voltages / Number of points per acquisition.
Cyclic RMS	Square root of the sum of the squares of all voltages within an integral number of cycles / Total number of points within this number of cycles (provided that a periodic waveform is detected).
Overshoot	$100 \% * (\text{Top Peak} - \text{Top}) / \text{Amplitude}$.
Undershoot	$100 \% * (\text{Base} - \text{Base Peak}) / \text{Amplitude}$.
Crest factor	$\text{Pk-pk} / 2 * \text{Cyclic RMS}$ (provided that a periodic waveform is detected).
Volts/div	Voltage per vertical division on current range.
Cycle count	Number of complete cycles detected in the acquisition.
Period	Total time between 50% amplitude points on successive rising or falling edges of a cyclic waveform / Cycle Count (provided that a periodic waveform is detected).
Frequency	$1 / \text{Period}$.
Rise time	Total time between 10% and 90% amplitude points on rising edges / Number of rising edges.
Fall time	Total time between 10% and 90% amplitude points on falling edges / Number of falling edges.
Pos width	Total time between 50% amplitude points on positive pulses (rising then falling edge) / Number of positive pulses.
Neg width	Total time between 50% amplitude points on negative pulses (falling then rising edge) / Number of negative pulses.
Pos slew	Voltage difference between 10% and 90% amplitude points on rising edge / Time difference between these points.
Neg slew	Voltage difference between 10% and 90% amplitude points on falling edge / Time difference between these points.
Bandwidth	$0.35 / \text{Rise Time}$. This formula is valid only for a first order system (i.e. with no overshoot on a rising edge) and can be used to give a VERY approximate estimate of the system bandwidth.
Duty cycle	$100\% * \text{High Pulse Width} / \text{Period}$.
Tresolution	Resolution of time measurements on this time/div range.
Pos Tconst	Rising time constant (time from the base to 63% of the amplitude) of an exponential rising edge.
Neg Tconst	Falling time constant (time from the top to 37% of the amplitude) of an exponential falling edge.

12.2. Aliasing

Aliasing is a term used to describe a sampling phenomenon which can occur with digital storage oscilloscopes or any sampled data system. Nyquist sampling theory suggests that the sampling rate must be at least twice the frequency of the highest frequency in the input signal in order for it to be reproduced in sampled form with the correct frequency. A high frequency signal which violates this sampling criteria (under sampled) can result in a lower frequency signal being displayed. This can fool even the most experienced user. Note that as the sweep speed (timebase) is reduced the

sampling rate starts to reduce, which means that even low frequency signals can cause aliasing if the timebase setting is set too low.

It is important that the user has some idea about what the signal being displayed is, and what frequency content to expect. Setting the timebase appropriate to the expected waveform will help eliminate problems with aliasing. Try turning the timebase to a faster setting (increasing the sampling rate) to check if a higher frequency signal is present. Often, aliased waveforms appear to drift across the screen as if they are not triggered properly, and this is another way of assessing if a waveform is aliased.

12.3. ERS timebase operation

For timebase settings of 0.2us/div and faster, the DSO uses extended resolution sampling to acquire a high speed waveform with more resolution than the normal single-shot sampling rate (50MS/s) will allow. This is achieved by taking repeated samples of a repetitive waveform and measuring the time difference between the waveform and an internal clock. This time difference will be random on each cycle (provided the waveforms are not synchronous). By accurately measuring this time, the points on the waveform can be interleaved with points from repeated acquisitions to reconstruct the waveform. The CircuitMaster contains a high speed time measuring circuit capable of measuring time intervals as short as 50ps required on the 1ns/div range, giving a maximum effective sample rate of 25GS/s

For a stable waveform display in ERS mode, a highly stable trigger is necessary, and the waveform must itself be highly stable with minimum timing jitter or noise. If any of these conditions are not met, the reconstructed ERS waveform will appear noisy. Auto triggering is not possible in ERS mode.

Note that an ERS acquisition of a low frequency signal will take a long time to construct, because a large number of acquisitions are necessary before the resulting waveform can be displayed.

In extremely rare cases, the ERS system may not be able to interleave the points on a waveform if it is an EXACT multiple of the internal 50MHz clock. In this event the points would always be in the same position and could not be interleaved. This is in practice extremely unlikely but could happen if, for example, the ERS timebase was used to examine the Active AC output signal which is synchronous with respect to the system 50MHz clock.

12.4. MultiWay connector pin out

The **MultiWay** connector looks like this (viewed from the front): -

P1	L4	L3	L2	L1	39	37	35	33	31	29	27	25	23	21	19	17	15	13	11	9	7	5	3	1
P2	G	G	G	G	40	38	36	34	32	30	28	26	24	22	20	18	16	14	12	10	8	6	4	2

Key: -

G = ground

P1/2 = pulse outputs channel 1 and 2

L1-4 = **LogicView** inputs 1 to 4

12.5. VI testing – detailed description

12.5.1. Test method

VI testing is a technique which is excellent for fault finding on PCBs, and is ideal when diagrams and documentation are minimal. When using VI testing, no power is applied to the device under test. Therefore this technique is an extremely effective test for so called dead boards which cannot safely be powered up. A current-limited, ac signal (usually a sine waveform) is applied to the device under test and the characteristic impedance is displayed by plotting voltage against current on an X-Y graph (the X axis representing voltage and the Y axis representing current).

The resulting characteristic represents the impedance of the node under test (NUT). For frequency dependent components such as capacitors and inductors, the impedance is frequency related. Therefore a variable frequency stimulus source is required for these types of components. It can also be seen that the current limiting resistor and the NUT form a potential divider. To achieve a reasonable trace the current sense resistor should be the same order of magnitude as the impedance of the NUT at the test frequency. Thus, in order to use this technique on a wide range of NUTs, a wide range of current limiting (or source) resistors are required. On the CircuitMaster the source impedance can be adjusted from 100R to 1M in decade steps.

It is not necessary to understand the technique to be able to use VI testing for fault diagnosis. Most applications use VI testing in a comparative manner where understanding the displayed characteristic is not important. Indeed, in real board fault diagnosis situations, many components will be connected to a particular node and the resulting analogue VI curve will be a complex composite of the individual components' VI characteristics making it extremely difficult to completely understand it.

12.5.2. Understanding The Display

The VI curve display plots the voltage across the device under test on the horizontal axis, and the current through the device under test on the vertical axis. Different devices in different configurations produce different signatures, depending on the current flow through the device as the applied voltage changes. A short circuit, for example, would be displayed as a vertical line, because the current flow for any applied voltage would be theoretically infinite, whereas an open circuit would display a horizontal line because the current is always zero irrespective of the applied voltage. A pure resistor would give a diagonal line whose slope is proportional to the resistance, because the current is proportional to the applied voltage. More complex curves are obtained with frequency dependent components such as capacitors and inductors, and also for non-linear devices such as diode and transistor junctions.

Even though the curves can sometimes be quite complex, it is not necessary to understand them in order to use the VI test. The comparison of the curves for a known good board and a suspect board can often identify faults with a minimum of knowledge. Bear in mind that in a typical circuit the displayed VI curve would normally be for a number of components in parallel. A better understanding of the operation of the VI test can be gained by using the system with known components out of circuit.

12.5.3. Component VI Tests

The signatures of resistors are straight lines. The value of the resistor under test affects the slope of the line, the higher the value, the closer the line gets to the horizontal (open circuit). The source impedance of the VI test should be selected so the slope of the line, for a good resistor, is as close as possible to 45 degrees. A difference in the slope of the curve when comparing a good and suspect board would indicate a difference in the resistor values on the two boards.

Capacitors with relatively low values have flattened, horizontal, elliptical signatures and capacitors with relatively high values have flattened, vertical, elliptical signatures. The optimal signature is a nearly perfect circle which can be obtained by selecting the appropriate test frequency and source impedance. Typically, the higher the capacitance, the lower the test impedance and frequency. A leaky capacitor would give a sloping curve due to the effective resistance in parallel with the capacitor.

The signature of an inductor is elliptical or circular, sometimes showing hysteresis. Inductors with relatively high values have flattened, horizontal, elliptical signatures similar to those of capacitors. The optimal signal is a perfect circle. Inductors may have ferrite, iron, brass or air cores, which may or may not be adjustable. Inductors with the same value may have very different signatures if they use different core materials or if the core is positioned differently. Inductors usually require a low source impedance and higher test frequencies to exhibit an elliptical signature. An open circuit inductor (a common fault with small PCB mounting devices) can easily be detected by the sharply contrasting VI curves when comparing two boards.

The signature of a silicon diode can be identified easily. The vertical part of the curve shows the forward bias region, and the turn-on voltage and the forward voltage drop can be easily identified. The curved area of the trace shows the changeover from fully off to fully on as the applied voltage increases. The horizontal part of the curve is the reverse voltage region where the diode is non-conducting and is effectively an open-circuit. Faulty diodes can easily be identified by a deviation from this characteristic, for example a diode which exhibits significant reverse leakage would have a diagonal curve in the reverse region, similar to a resistor.

Zener diodes conduct in both directions. The forward current characteristic is similar to that for a diode (see above). The characteristic in the reverse direction is also similar to a diode until the breakdown or Zener voltage is reached, at which point the current increases rapidly and the diode voltage is clamped. The test voltage should be chosen to be higher than the Zener voltage for this curve to be obtained. A suspect Zener diode may not have a well-defined "knee" and the horizontal part of the curve in the reverse region may exhibit leakage effects in a similar way to a normal diode.

NPN and PNP bipolar transistors have a signature similar to that of the diode when tested between the base-collector and base-emitter junctions. If tested between the collector-emitter terminals the signature would appear to be open circuit. The pulse output (available on the **MultiWay** connector or on the P1/P2 4mm sockets) can be used to apply a bias voltage, via a suitable resistor, to the base of the transistor, so that the switching action can be observed. The pulse outputs can also be used to trigger devices such as triacs and thyristors, so that again the switching action can be observed. Transistors with open circuit or leaky junctions can easily be identified by the marked differences between curves.

12.5.4. Suggested VI test parameters

There are numerous combinations of VI test parameters which can be chosen by the operator. This flexibility allows the widest range of components to be tested but also presents some difficulty to the inexperienced operator. The following table presents typical test parameters for a number of different types of components to be tested. The table may be used to quickly obtain a representative VI curve for a given component. Often, a different combination of test parameters will give the same characteristic. Experienced operators will be able to quickly deduce the appropriate test parameters by observing the obtained VI curve and adjusting the controls.

Capacitors (voltage 4V pk-pk, sine wave)

Value	Stimulus frequency	Source impedance
10uF - 1000uF	50Hz – 500Hz	100R
10uF - 100uF	50Hz – 500Hz	100R
1uF - 10uF	50Hz – 500Hz	1k
10nF - 1000nF	50Hz – 2kHz	10k
1nF - 10nF	50Hz – 2kHz	100k
100pF – 1000pF	50Hz – 500Hz	1M

Inductors (voltage 2V pk-pk, sine wave)

Value	Stimulus frequency	Source impedance
10mH - 100mH	200Hz – 5kHz	100R
1mH - 10mH	2kHz – 10kHz	100R
100uH - 1000uH	5kHz – 10kHz	100R

Resistors (voltage 4V pk-pk, sine wave)

Value	Stimulus frequency	Source impedance
0R – 500R	100Hz	100R
500R – 5k	100Hz	1k
5k – 50k	100Hz	10k
50k – 500k	50Hz	100k
500k – 5M	20Hz	1M

Active components (100Hz sine wave)

Value	Stimulus voltage	Source impedance
Digital ICs	6V pk-pk	10k
Analogue ICs	10V pk-pk	10k
Diodes	2V pk-pk	10k

12.5.5. Summary

In order to employ the VI test strategy to its full potential as a fault diagnosis tool, it is important to focus on differences between curves for good and suspect boards, rather than analysing in great detail the meaning of the curves. The majority of nodes on a PCB will contain parallel and series combinations of components, making exact analysis difficult. The majority of faults on failed boards are gross failures such as short or open circuits, which are easy to detect with the VI technique without complex analysis.

13. Glossary

AC	Alternating Current
Active	Operating mode where a DC or AC signal is output on either channel 1 for applying to the circuit under test
Alias	An incorrect waveform caused by using a timebase which is too slow. See 12.2
Auto-Zero	Automatic function where any small offsets on the DSO are removed
CircuitLink	PC based software package for updating the CircuitMaster and capturing screen displays
DC	Direct current
DSO	Digital Storage Oscilloscope
DVM	Digital Volt Meter
ERS	Extended Resolution Sampling. Used for high speed repetitive signal acquisition
FirmFlex	Operating mode where the drive strength of a circuit node is measured and displayed as a colour
LogicView	Digital inputs (4 channel) which can be displayed in addition to the 2 analogue channels
MultiWay	Sequential of signals from IC pins via an IC test clip and the MultiWay cable
Pulse	Programmable pulse output, used in V-I mode for triggering certain semiconductor devices
Stimulus	AC/DC output signal applied to either or both inputs, used in Active, V-I, and FirmFlex modes
V-I	Voltage current curve test, normally used on unpowered boards
WaveStack	Memory for stored waveforms allowing later review and analysis

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