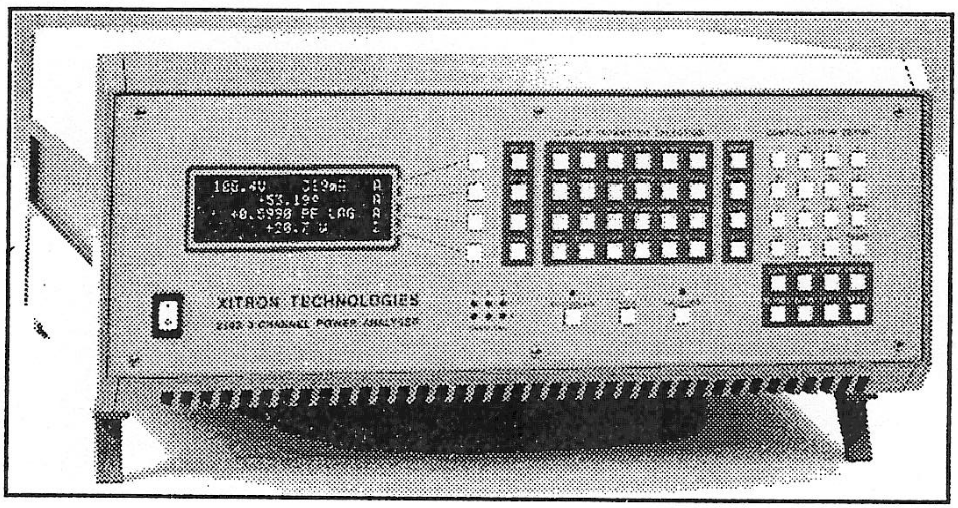
XITRON TECHNOLOGIES
2501/2/3 OPERATING INSTRUCTIONS



2503 FAMILY MANUAL ADDENDUM

This addendum is applicable to software revisions 63.60 and later

Calculation Speed

Versions 63.60, and higher, of the software have been compiled with the latest technology optimizing compiler. This has resulted in a 50% to 100% improvement in mathematics execution speed. The user will acheive between 1.5 and 3 times the throughput of data using these versions of software vs. prior versions.

Measurement Timing Synchronization

The 2503 family of instruments are "free-running" measuring devices. The user may read the latest data at any time. In previous versions, the uncertainty as to when the received data was actually measured was within one measurement period plus mathematics overhead (typically 30ms in these earlier versions). With the new versions, the overhead time is reduced to a typical value of only 5ms, yielding an improvement in the timing uncertainty. In order to further reduce this uncertainty, a new "readable" parameter, and a new command have been added to the interface command set.

READ=TIME[ch]

A new parameter has been added to the list of available data for access via the IEEE-488 or RS232 interfaces. This parameter (*TIME*) indicates the latest time at which measurement data was updated for the specified channel. This parameter returns the contents of a time counter which free runs, and has less than 2ms of uncertainty.

The *[ch]* portion of the command is optional (channel A data is returned if not specified) and may be *[A]*, *[B]* or *[C]*. The data returned has the units of seconds, and has a resolution of less than 1ms.

RSTTIME[ch]

This new command allows the user to reset a specific channel's time counter to zero. This is immediately performed upon receipt of the command.

The *[ch]* portion of the command is optional (channel A data is reset if not specified) and may be *[A]*, *[B]* or *[C]*.

It must be noted that issuing this command and then immediately reading the respective channel's time counter will not yield a zero result. This is due to the fact that a new measurement data set may not have become available between the ***RSTTIME*** command and reading the data.

These commands enable the user to correctly identify the exact (within 2ms) timing of the end of the specific measurement period in which the retreived data was measured.

Increased Interface Buffer Sizes

Previous versions limited the overall length of a set of data read by the IEEE-488 or RS232 interface to 99 characters, and the length of the data set definition (the ***READ=string*** command) to 49 characters. Versions 63.60 and higher increase these limits to 199 and 99 characters respectively, allowing almost twice as much data to be read from the instrument in a single instruction.

Increased Setting Storage

Versions prior to 63.60 had three storage locations for used settings for the instrument (numbers 0, 1 and 2). Version 63.60 and higher allow for four storage locations (numbers 0, 1, 2 and 3). Storage location #3 can be accessed by pressing the **STO** (or **RCL**) key followed by the **3** key from the front panel, or by the *SAVE=3* or *RECALL=3* commands via an interface.

Option HA (High Accuracy)

This is a newly available option within the family, yielding an improved accuracy in the 20 to 400Hz frequency range at the expense of reducing the crest factor ability to 1.5:1 at full-scale (i.e., 150:1 at 1% of full-scale). The following amendments to the standard specifications apply.

Operating Temperature Range

Enhanced Accuracy :	18 to 28°C
Standard Accuracy :	0 to 18°C and 28 to 45°C
Warm Up Period :	30 minutes

Voltage

Enhanced Accuracy :	0.05% of input (25 to 100% of range, 20 to 400Hz)
Standard Accuracy :	0.1% + 0.0025%/KHz of range
Crest Factor :	1.5:1 at 100% rng, increasing linearly to 150:1 at 1% rng

Current

Enhanced Accuracy :	0.05% of input (25 to 100% of range, 20 to 400Hz, <10A)
Standard Accuracy :	0.1% + 0.0025%/KHz of range
Crest Factor :	1.5:1 at 100% rng, increasing linearly to 150:1 at 1% rng

Power Factor

Enhanced Accuracy :	0.0002 (20 to 400Hz, VA > 6.25% of $V_{rng}.A_{rng}$)
Standard Accuracy :	0.001 + 0.00005/KHz

Watts, VAR and VA (-1 ≥ Power Factor ≥ +1)

Enhanced Accuracy :	0.08% of VA (20 to 400Hz, VA > 6.25% of $V_{rng}.A_{rng}$)
Standard Accuracy :	0.3% + 0.01%/KHz of $V_{rng}.A_{rng}$

Added Interface Commands

Version 63.60 (and later) implement additional commands which allow the user to completely setup the instrument from the interface (IEEE488 or RS232).

THD[ch]=n

This command sets the maximum number of harmonics over which the THD is computed for each channel. The channel is optional, defaulting to channel A if not specified. The equals sign character is optional. *n* may be any number between 3 and 255.

Example :

To set the returned THD for channel C to cover 14 harmonics only (i.e. 2nd thru' 15th inclusive) - *THD[C]=14* should be sent to the instrument.

SWITCH=action/active

This command allows the user to configure the Rear Panel Control Switch to the desired state via the interface. This was previously only available via the front panel.

The equals sign character is optional.

The ***action*** portion of this command is optional, and (if present) may be one of the following :

OFF	Disables the Rear Panel Control Switch input.
RUN	Places the instrument in the Run state when the Rear Panel Control Switch is in the active state, and places the instrument in the Hold state when the Rear Panel Control Switch is in the inactive state.
ACCUM	Places the instrument in the Accumulate mode when the Rear Panel Control Switch is in the active state.

The / character is optional.

The ***active*** portion of this command is optional, and (if present) may be one of the following :

OPEN	Sets the active state of the Rear Panel Control Switch to Open.
CLOSED	Sets the active state of the Rear Panel Control Switch to Closed.

Example :

To enable the use of the Rear Panel Control Switch to control accumulation, with the instrument accumulating while the switch is open. Send the string *SWITCH=ACCUM/OPEN* to the instrument.

CODE[ch]=n

This command allows the user to alter the MIB Configuration Code for each channel. Previously this was only available from the front panel. Changing channel A automatically adjusts the connection code such that the same "*CONNECT=*" code is maintained (see the Operating Manual for details). This command would normally be used to configure the instrument for multiple configurations, e.g., 3-phase/4-wire, or 3-phase/3-wire, or efficiency measurements. ***n*** may be any integer from 0 to 999. The equals sign character is optional. The channel identifier is optional, channel A being affected by default.

Example :

To setup the instrument for 3-phase/3-wire measurements, allowing channel C to be used for measurements of the remaining phase 'arm', send the following to the instrument -

CODE[A]=110,CODE[B]=120,CODE[C]=109

ANALOG[n]=chl/parameter/zero/span

This is an extension of the previous *ANALOG* command syntax, allowing each individual analog output channel to be completely setup via the interface. The ***chl/parameter*** syntax is the same as that for the *READ=* command (see the Operating Manual for details). The ***zero/span*** portion of the command takes the form of two floating point numeric quatities seperated by the / character. The first quantity sets the zero offset, and the second sets the span for the analog output denoted by the *[n]* portion.

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2. WARRANTY INFORMATION

This Xitron Technologies instrument is warranted against defects in material and workmanship for a period of two years after the date of manufacture. Xitron Technologies agrees to repair or replace any assembly or component (except batteries) found to be defective, under normal use, during this period. Xitron Technologies' obligation under this warranty is limited solely to repairing any such instrument which in Xitron Technologies' sole opinion proves to be defective within the scope of the warranty when returned to the factory or to an authorized service center. Transportation to the factory or service center is to be prepaid by the purchaser. Shipment should not be made without prior authorization by Xitron Technologies.

This warranty does not apply to any products repaired or altered by persons not authorized by Xitron Technologies, or not in accordance with instructions furnished by Xitron Technologies. If the instrument is defective as a result of misuse, improper repair, or abnormal conditions or operations, repairs will be billed at cost.

Xitron Technologies assumes no responsibility for its product being used in a hazardous or dangerous manner, either alone or in conjunction with other equipment. Special disclaimers apply to this instrument, Xitron Technologies assumes no liability for secondary charges or consequential damages and, in any event, Xitron Technologies' liability for breach of warranty under any contract or otherwise, shall not exceed the original purchase price of the specific instrument shipped and against which a claim is made.

Any recommendations made by Xitron Technologies, or its' representatives, for use of its products are based upon tests believed to be reliable, but Xitron Technologies makes no warranty of the results to be obtained. This warranty is in lieu of all other warranties, expressed or implied, and no representative or person is authorized to represent or assume for Xitron Technologies any liability in connection with the sale of our products other than set forth herein.

Software ver 64.60

INSTRUMENT SERIAL # : 2503390005

Issue C - 11/91 MO2503H +IE +PR

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3. CHANGE INFORMATION

This information provides a summary of changes to the 2501/2/3 instruments. The software version of the instrument is shown during the initial power on messages. The two digits to the left of the decimal point is the revision of the main processor software, and the two digits after the decimal point is the revision of the DSP software.

MAIN SOFTWARE REVISION	DSP SOFTWARE REVISION	INTRODUCTION DATE	DETAILS OF CHANGE
40	40	11/8/91	Calculation resolution of frequency measurement changed. Was previously 0.018Hz, now is 0.1ppm of measured frequency. Added 50Hz low pass, 4th order Butterworth filter (interface command FILT=8). Added ability to synchronize to, and measure, frequencies down to 0.2Hz (was 10Hz) when 50Hz filter is commanded. Added ability to synchronize to, and measure frequency of, current waveform in addition to the voltage waveform. Limited upper frequency for inter-phase phase measurements to 30KHz.

4. INTRODUCTION

The **2501/2/3** family offer high precision (0.1% accuracy), very wide bandwidth (DC to in excess of 200KHz), and a wide range of measurement, waveform analysis and data retrieval capabilities. Using the latest in Digital Signal Processing (DSP) technologies, this instrument offers the user the widest range of measurement capabilities to be found in today's power analysers. Coupled with the ability to form a multi-instrument network for multi-phase and power efficiency analysis, this instrument can change with the needs of tomorrow's technology.

A comprehensive algorithm based autoranging system removes the user from deciding the range requirements of the input signals, while maintaining the utmost in measurement resolution. The very wide measurement capabilities of the instrument may be further enhanced by using PT, CT or external current shunts, with non-volatile user entered scaling constants.

The wide range of filtering and input coupling capabilities allow the user the flexibility of tailoring the response of the power measurements to user requirements, and finding the harmonic and spectral content of signals.

The 3µs, peak capture ability with virtually continuous coverage offers the user the capability of measuring the fastest of transients (e.g., turn on inrush surges). The long term digital accumulation mode allows measurements over periods of several months to be taken without the inaccuracies normally associated with analog integrator systems.

The ability to synchronize the measurements to the voltage or current waveform, coupled with the DSP techniques used, allows the instrument to track changing and very low frequency power frequencies with unerring accuracy.

The implementation of automatic internal calibration and simple front panel (covers on) external calibration, enable the user to maintain the high accuracy of the instrument with ease, and with the minimum of costly calibration equipment.

The user should read this manual before attempting to use this equipment.
In particular the user should read the UNPACKING & INSTALLATION, GETTING STARTED - STANDARD APPLICATIONS and FRONT PANEL CONTROLS & CONNECTIONS chapters.

5. UNPACKING & INSTALLATION

5.1. Unpacking

If there is visible damage to the shipping carton, you should request that the carriers' agent is present when unpacking the instrument. If the instrument appears damaged when unpacked, then notify the carriers' agent, who should then authorize repairs before returning the instrument to Xitron Technologies or an authorized service center. Even if the instrument appears undamaged, it may have suffered internal damage in transit that may not be apparent until operating the instrument. If the instrument fails to achieve its' published specifications then notify the carriers' agent and Xitron Technologies or an authorized service center and retain the shipping carton for the carriers' inspection.

A label attached to the rear panel of the instrument shows the actual model within the **2501/2/3** family, the serial number and any attached options. This label should be checked against the original order and any discrepancy should be reported to Xitron Technologies or its' authorized agent.

5.2. Preparation For Use

The **2501/2/3** instrument requires no special preparation for normal use, other than checking that the line voltage selection within the rear panel power connector is correct for the local power supply voltage.

> **WARNING**
>
> **Operation from an incompatible power supply voltage may result in serious damage to the instrument.**

The **Preliminaries** procedure described in the **GETTING STARTED - STANDARD APPLICATIONS** Chapter should be followed to ensure correct operation of the instrument. This also ensures that the correct instrument options are fitted.

5.3. Returning For Repair or Maintenance

The **2501/2/3** is warranted against defects for two years from the date of shipment. Prior to returning any equipment to Xitron Technologies or an authorized service center, for any reason, authorization must be obtained. When contacting Xitron Technologies, please have the following information available.

❶ The model number of the instrument (e.g., **2501** or **2501H**), and any installed options.

❷ The serial number of the instrument.

❸ The nature of the problem.

Attempted repair by unqualified personnel may void your warranty. Unless otherwise specified, returns should be made freight pre-paid, with the previously obtained authorization code clearly marked on the outer surface of the packing. The owner of the instrument, the name of a person to contact, and a description of the service required, should be identified on an external "tag" or on documentation within the packaging.

If the instrument is shipped by commercial transportation for any reason, then repackage it in the original shipping carton and packing material. If these are not available, or are unfit for use, then these should be replaced by equivalent materials.

6. SPECIFICATIONS

6.1. Input Specifications

All accuracy specifications given below are valid throughout the specified operating temperature range of the instrument, for one year, following a ten minute warm up period.

6.1.1. General

Frequency Range :	DC to 200KHz (typical performance to 1MHz).
Isolation :	All inputs are isolated from each other (both between channels and between V and I inputs on a channel), and to ground, for voltages <1500V peak.
Min. Input :	Specifications are valid for input signals with RMS values >10% (>1% when filtered) of the selected range.
Max. Input Slew Rate :	Specifications are valid for input voltage signals (either series or common mode) having <300V/µs slew rate.
Measurement Period :	User specified, 0.05s to 6.5s. Optionally synchronized to voltage or current input waveform (>20% of range for synchronization). Unsynchronized measurement period is accurate to within 200µs.
Settling Time :	2.9µs (unfiltered), 7.7824ms (filtered).

6.1.2. Optional Filters

Low Pass Filters :	20KHz, 10KHz, 5KHz, 2KHz, 1KHz and 50Hz, applied to both voltage and current inputs simultaneously.
Band Pass Filters :	120Hz to 5KHz, and 800Hz to 10KHz, applied to both voltage and current inputs simultaneously.
Other Filters :	DC only, AC only, or the total AC+DC content, may be selected for individual parameters.
Filter Frequency Accuracy :	Upper and lower frequencies accurate to within 0.1%.
Filter Amplitude Accuracy :	Add 0.01% per KHz above 5KHz to voltage and current accuracy figures. >40dB rejection at three times the upper cutoff frequency, >50dB rejection at half the lower cutoff frequency (band pass filters only).

6.1.3. Voltage Input

Ranges :	15V, 30V, 60V, 150V, 300V and 600V RMS full-scale.
Resolution :	10mV on 15V, 30V and 60V ranges, 100mV on other ranges.
Accuracy :	0.15% of range at DC, 0.1% + 0.0025%/KHz of range up to 200KHz. Typically within 10% between 200KHz and 1MHz.
Crest Factor :	Better than 2.5:1 at full-scale. 1500V peak max. input.
Protection :	1800V peak continuously on any range.
Input Impedance :	600KΩ on all ranges, from either terminal to the Current Low terminal.
PT Capability :	Ratios between 10000:1 and 0.0001:1 may be used. 9999V max., 0.0001V min. displayable voltage.

6.1.4. Current Input

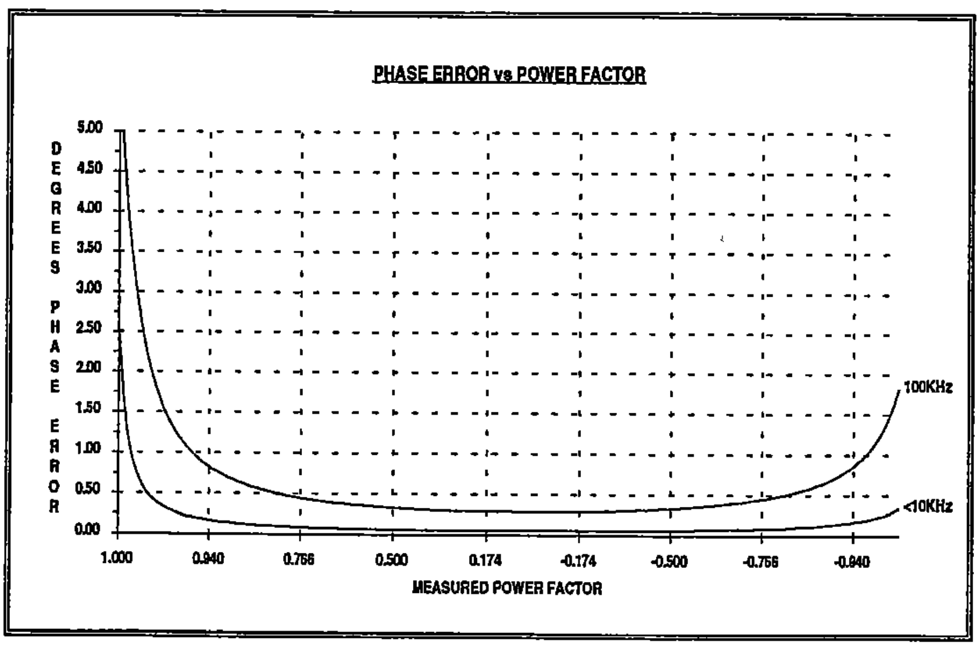
Current Ranges :	0.05A, 0.1A, 0.2A, 0.5A, 1A, 2A, 5A, 10A and 20A RMS full-scale.

Voltage Ranges :	0.25V, 0.5V and 1V RMS full-scale (1.25V, 2.5V and 5V for Option 5V, 25mV, 50mV and 100mV for Option LV).
Current Resolution :	10µA, 100µA, 100µA, 100µA, 1mA, 1mA, 1mA, 10mA and 10mA on each range respectively.
Voltage Resolution :	100µV on 0.25V range, 1mV on other ranges (1mV for Option 5V, 10µV on 25mV range, 100µV on 50mV and 100mV ranges for Option LV).
Accuracy :	0.15% of range at DC, 0.1% + 0.0025%/KHz of range up to 200KHz. Typically within 10% between 200KHz and 1MHz.
Crest Factor :	Better than 2.5:1 at full-scale. 50A peak max. input.
Protection (autoranging) :	50A peak (25A RMS) on current input. 100V peak (10V RMS) when configured as voltage input.
Protection (fixed range) :	5A peak, 1A RMS (0.05A, 0.1A and 0.2A ranges). 10A peak, 4A RMS (0.5A, 1A and 2A ranges). 50A peak, 25A RMS (5A, 10A and 20A ranges). 100V peak, 10V RMS when configured as voltage input.
Input Impedance (voltage) :	9KΩ on all ranges.
Input Burden (current) :	0.05, 0.1 and 0.2A ranges : 1Ω max.
	3.5, 1 and 2A ranges : 0.15Ω max.
	3.6, 10 and 20A ranges : 0.05Ω max.
CT Capabilities	Ratios between 10000:1 and 0.0001:1 may be used (either Amp:Amp or Amp:Volt). 9999GA max., 0.001µA min. displayable current.

6.1.5. Power Factor and Phase Angle

Power Factor is accurate to within 0.001 for frequencies <10KHz (5KHz when filtered), increasing linearly to 0.01 at 200KHz (20KHz when filtered). The accuracy of Power Factor determines the accuracy of "effective phase data".

Inter-phase voltage or current measurements are also available, the accuracy of these are valid for signals >10% of full-scale and is better than 0.25° + 0.002°/Hz (i.e. 0.37° at 60Hz).



6.1.6. Power

The VA, Watts and VAR accuracies can be approximated as 0.3% of full-scale VA at DC, 0.25% of full-scale VA up to 10KHz (5KHz when filtered), increasing linearly to 1.5% of full-scale VA at 200KHz (20KHz when filtered). The exact accuracy specifications are given by the following equations :

If S is the relevant percentage voltage/current accuracy specification, V_R and I_R are the voltage and current ranges respectively, V and I are the actual RMS voltage and current levels and, P is the Power Factor accuracy (0.0 for computing DC accuracies),

$$\text{then Watts or VAR Accuracy} = \left(\frac{S(V_R I + V I_R)}{100} + \frac{S^2 V_R I_R}{10000} + PVI\right)\text{Watts or VAR}$$

$$\text{and VA Accuracy} = \left(\frac{S(V_R I + V I_R)}{100} + \frac{S^2 V_R I_R}{10000}\right)\text{VA}$$

Example, for AC, at 1KHz, with 115V RMS (150V range) and 1A (2A range) input (115VA)

$$\text{VA Accuracy} = \frac{0.1*(150*1 + 115*2)}{100} + \frac{0.01*150*2}{10000} = 0.38\ \text{VA}$$

$$\text{Power Accuracy} = \frac{0.1*(150*1 + 115*2)}{100} + \frac{0.01*150*2}{10000} + 0.0005*115*1 = 0.4378\ \text{W or VAR}$$

Example, for DC, with 1.2V (15V range) and 1mA (0.05A range) input (i.e., 1.2mVA)

Accuracy = 114.1875 μW or μVA

6.2. Harmonic & Spectrum Analysis Specifications (H Versions Only)

6.2.1. Harmonic Analysis

Technique :	8192 point Fast Fourier Transform using "Flat Top" windowing function, with post-processing reduction to 1022 points, increasing "frequency bin" separation to >50dB.
Sample Rate :	512 times fundamental or 340KHz (whichever is lower)
Frequency Range :	Fundamental Frequency between 10Hz and 85KHz.
THD Bandwidth :	User selectable, up to 254th harmonic or 170KHz (whichever is smaller)
THD Accuracy :	Better than 0.05% of full-scale times $\sqrt{\text{Number of Harmonics}}$ for fundamental frequencies less than 800Hz, increasing linearly to 2.5% of full-scale for a fundamental frequency of 85KHz. THD is referred to amplitude of fundamental component.
Harmonic Amplitude :	0.05% of full-scale additional to applicable amplitude measurement specification.
Harmonic Phase :	Referred to fundamental voltage waveform. Accuracy determined as follows : $\left((0.1*N + 0.05*F)*\frac{\text{Full-Scale Level}}{\text{Fundamental Level}}\right)$degrees F = Frequency of harmonic in KHz N = Harmonic Number (Fundamental = 1)
Harmonic Bandwidth :	±0.075 times fundamental frequency for harmonics below 25th and harmonic frequencies less than 15.4KHz. For 25th harmonic and above, or harmonic frequencies greater than 15.4KHz, bandwidth is ±0.15 times fundamental frequency.
Measurement Period :	16 times fundamental period, or user defined period, whichever is longer.
Computation Time :	Less than 0.4 + (0.0015 * Number of harmonics in THD) seconds.

6.2.2. Spectrum Analysis

Technique :	8192 point Fast Fourier Transform using "Flat Top" windowing function, with post-processing reduction to 1022 points, increasing "frequency bin" separation to >50dB.
Frequency Span :	User selectable, 2.4Hz - 2.45KHz, 4.8Hz - 5.0KHz, 9.7Hz - 9.9KHz, 19Hz - 19.5KHz, 39Hz - 40KHz, 77Hz - 79.5KHz, 154Hz - 157KHz or AUTO (0.25 to 254 times fundamental frequency). Spectrum available in frequency steps equal to minimum frequency of span.
Spectrum Amplitude :	0.025% of full-scale additional to applicable amplitude measurement specification (see also Noise Floor specification below).
Noise Floor :	0.01% of full-scale * $\sqrt{\text{Frequency Step}}$
Measurement Period :	4 times Frequency Step period, or user defined period, whichever is longer.
Computation Time :	<0.4 seconds (if THD also computed then add 0.0015 * Number of harmonics in THD).

6.3. Accumulation Specifications

Accumulation Period :	Up to 9999.9GVA-Hr.
Start/Stop Time :	Within 10ms. of the command.
Accumulation Accuracy :	Better than 0.05%.

6.4. Available Data

The following data may be displayed on the front panel -

6.4.1. Base Measurement Data

Frequency	Resolution of $\left(\frac{0.02}{\text{measurement period}}\right)$% and an accuracy of 0.05%. Max. measurable frequency is 150KHz, min. is 10Hz (0.2Hz with 50Hz low pass filter commanded).
RMS Voltage	$\sqrt{\frac{1}{T}\int_0^T V(t)^2}$
Peak Voltage	Max [V(t)]
RMS Current	$\sqrt{\frac{1}{T}\int_0^T I(t)^2}$
Peak Current	Max [I(t)]
True Power (Watts)	$\frac{1}{T}\int_0^T (V(t)I(t))$
Peak Power	Max [V(t)I(t)]
Apparent Power (VA)	RMS Voltage * RMS Current
Reactive Power	$\sqrt{VA^2 - W^2}$
Power Factor	$\frac{W}{VA}$

Effective Phase Angle $\cos^{-1}\left(\frac{W}{VA}\right)$

6.4.2. Accumulated Data

Mean RMS Voltage $\sqrt{\frac{1}{(t_{stop} - t_{start})} \int_{t_{start}}^{t_{stop}} V(t)^2}$

Peak RMS Voltage $\mathrm{Max}\left(\sqrt{\frac{1}{T}\int_{0}^{T} V(t)^2}\right)$

Peak Voltage $\mathrm{Max}\,[\,V(t)\,]$

Mean RMS Current $\sqrt{\frac{1}{(t_{stop} - t_{start})} \int_{t_{start}}^{t_{stop}} I(t)^2}$

Peak RMS Current $\mathrm{Max}\left(\sqrt{\frac{1}{T}\int_{0}^{T} I(t)^2}\right)$

Peak Current $\mathrm{Max}\,[\,I(t)\,]$

Mean True Power (Watts) $\frac{1}{(t_{stop} - t_{start})} \int_{t_{start}}^{t_{stop}} (V(t)I(t))$

Total True Power (Watt-Hr) $\int_{t_{start}}^{t_{stop}} (V(t)I(t))$

Peak Power $\mathrm{Max}\,[\,V(t)I(t)\,]$

Mean App. Power (VA) $\frac{1}{(t_{stop} - t_{start})} \int_{t_{start}}^{t_{stop}} (\text{RMS Voltage} * \text{RMS Current})$

Total App. Power (VA-Hr) $\int_{t_{start}}^{t_{stop}} (\text{RMS Voltage} * \text{RMS Current})$

Mean Rea. Power (VAR) $\frac{1}{(t_{stop} - t_{start})} \int_{t_{start}}^{t_{stop}} (\sqrt{VA^2 - W^2})$

Total Rea. Power (VAR-Hr) $\int_{t_{start}}^{t_{stop}} (\sqrt{VA^2 - W^2})$

Mean Power Factor $\frac{1}{(t_{stop} - t_{start})} \int_{t_{start}}^{t_{stop}} \left(\frac{W}{VA}\right)$

Mean Phase Angle $\cos^{-1}\left(\frac{1}{(t_{stop} - t_{start})}\int_{t_{start}}^{t_{stop}}\left(\frac{W}{VA}\right)\right)$

6.5. General Specifications

6.5.1. Power

Input Voltage :	115V or 230V nominal, ±10%.
Input Power :	25VA nominal, 35VA maximum.

6.5.2. Physical

Overall Size :	17.6" (447mm) wide by 7.5" (191mm) high by 16.7" (424mm) deep.
Weight :	18lbs. (8.2Kg) in use, 25lbs. (11.4Kg) shipping.

6.5.3. Environmental

Operating :	0°C to 45°C, less than 85% RH @ 40°C (non-condensing).
Storage :	-30°C to +65°C, less than 95% RH @ 40°C (non-condensing).

6.5.4. Digital Interface

With either IEEE488 or RS232 interface, multi-instrument systems may be controlled via a single interface. Each instrument also may be controlled by individual interfaces.

IEEE488 :	Full Talk/Listen capabilities. SH1AH1T6TE0L4LE0SR1RL1PP0DC1DT1C0.
RS232 :	Full Talk/Listen capabilities. Selectable baud rate of 1200, 2400, 4800, 9600 or 19200 baud.

6.5.5. Analog Interface

Number of Channels :	8.
Output Voltage :	-5V to +5V DC. Common ground.
Resolution :	5mV.
Accuracy :	0.1% of output + 5mV.
Usage :	Each output may be independently "connected" to any displayable parameter, with non-volatile, user definable, offset and span constants. Each output may be controlled via the IEEE488 or RS232 interface.
Settling Time :	Within accuracy specifications <0.5 seconds following measurement period changing parameter.
Output Drive :	2mA max. load on each output, 10mA max. total load.
Output Impedance :	Less than 0.2Ω.

6.5.6. Rear Panel Control

A contact closure input is provided on the rear panel. This input may be configured to control either the accumulation or the run/hold function, and also for active when closed or open. The maximum contact resistance for contact closure is 470Ω, the minimum resistance for contact open is 47KΩ. The current flowing when closed is nominally 1mA from 5V DC.

6.6. Internal Calibration

The user may command an automatic internal calibration of zero offsets whenever desired. The accuracy specifications presented in the preceding tables assume the use of this function at least every ten days, or for a temperature change of greater than 5°C from that at the previous internal calibration.

6.7. External Calibration

The user may command an external calibration whenever desired. To prevent unauthorized access, the user may use an optional password protection scheme. A one year external calibration interval is recommended for normal use. While calibration at 23°C ambient is recommended, this may be performed at any temperature from 10°C to 35°C without degradation of accuracy specifications.

7. Options & Accessories

7.1. Main Unit

7.1.1. 2501, 2502 and 2503

These are the basic models in the family, having no harmonic or spectral analysis capabilities. The **2501** has a single channel, the **2502** has two channels and the **2503** has three channels.

7.1.2. 2501H, 2502H and 2503H

These are the same as the **2501**, **2502** and **2503** respectively, with the addition of harmonic and spectrum analysis capabilities.

7.2. Interface Options

Either of the following interface options may be installed in any of the above instruments.

7.2.1. RS

This option enables the **2501/2/3** to be controlled or interrogated by any RS232 interfaced computer or terminal. This interface may be connected to a modem, enabling the **2501/2/3** to be controlled or interrogated remotely, via a telephone link. Baud rates of 1200, 2400, 4800, 9600 or 19200 baud may be selected.

7.2.2. IE

This option enables the **2501/2/3** to be controlled or interrogated by any IEEE488 interfaced computer.

The following interfaces may be in addition to the interfaces listed above.

7.2.3. PR

This option enables the **2501/2/3** to print in several different formats using a RS232 printer. If option **RS** is fitted as the controlling interface, then this ability adds to the standard abilities of that interface.

7.2.4. AN

This option contains eight +/-5V DC analog outputs, each of which may independently "connected" to any available data within the instrument or controlled by the IEEE488 or RS232 interface. The user may define a non-volatile offset and span quantity for each output.

7.3. Current Shunt Bypass Options

One of the following options may be specified. Each option affects all channels. Additional options are also available to special order, please contact Xitron Technologies for details.

7.3.1. LV

This option replaces the standard 0.25V, 0.5V and 1.0V full-scale ranges with 25mV, 50mV and 100mV ranges. This option is especially useful when using low burden external current shunts.

7.3.2. 5V

This option replaces the standard 0.25V, 0.5V and 1.0V full-scale ranges with 1.25V, 2.5V and 5V ranges. This option is especially useful when using amplified CT's and Hall Effect Sensors.

7.4. Accessories

7.4.1. MO2503

This option is an additional copy of this manual. If not ordered at the time of placing the order for the basic unit, please have the serial number of the unit available when ordering.

7.4.2. MS2503

This option is a full service manual, incorporating schematics, assembly diagrams, fault diagnosis aids and full servicing information. If not ordered at the time of placing the order for the basic unit, please have the serial number of the unit available when ordering.

7.4.3. RC4000

A 10ft. long RS232 cable for connecting the **RS** option to an IBM® (or compatible) RS232 serial port (either 9-pin or 25-pin).

7.4.4. MI2500

This is a 6ft. cable for inter-connecting **2501/2/3** or **2500M** instruments. Cable lengths of up to 50ft. are possible for this interface, contact Xitron Technologies Inc. for details regarding the availability of longer cables.

8. REAR PANEL CONTROLS & CONNECTIONS

8.1. Power Connector

This connector, located on the rear panel, is the receptacle for the AC power cord.

> **Before attempting to power the instrument, the user should check the supply voltage selection.**

8.1.1. Changing the Power Supply Voltage Setting

This is achieved by changing the setting in the rear panel power connector. This may be changed by following the following procedure :

➊ Remove the power cord (if inserted in the connector).

➋ Pull out the cover surrounding the voltage selection indicator.

➌ Rotate the voltage selector until the desired voltage setting is displayed.

➍ Ensure that the correct fuse is fitted. For a 115V nominal supply this should be a 0.25A SLO BLO fuse. For a 230V nominal supply this should be a 0.125A SLO BLO fuse.

➎ Replace the cover surrounding the voltage selection indicator.

8.2. Channel Terminals

These terminals are located on the rear panel, four terminals per channel. For details as to application specific methods of connecting to these terminals the user should refer to later chapters of this manual.

> **CAUTION - LETHAL VOLTAGES MAY BE PRESENT**
>
> **The user should ensure that no voltage exists on these connections prior to attempting to connect to these terminals.**

8.2.1. Channel Voltage Measuring Terminals

These are the upper (smaller) pair of terminals for each channel. The RED terminal is the HI terminal. These terminals may be directly connected to the voltage desired to be monitored, or may be connected via an external Potential Transformer (PT). See the FRONT PANEL OPERATION Chapter for further details on the usage of a PT.

8.2.2. Channel Current Measuring Terminals

These are the lower (larger) pair of terminals for each channel. The RED terminal is the HI terminal. These terminals may be directly connected in series with the load, or via an external Current Transformer (CT), or an external current shunt. See the FRONT PANEL OPERATION Chapter for further details on the usage of a CT.

> **CAUTION**
>
> Prior to applying any voltages or currents, the user should ensure that the 2501/2/3 has been correctly configured regarding voltage and current measurement ranging and PT/CT selection.
>
> The user should ensure that current is not passed through the internal current shunt (i.e. between the current terminals) when the instrument is not powered, otherwise severe damage to the instrument may result.

8.3. Multi-Instrument Networking Connectors

These connectors are the pair of miniature 6-pin DIN connectors. These connectors are wired to allow several instruments to be "daisy chained" together to form a single instrument network. Cables may be purchased from Xitron Technologies Inc. under the order code MI2500. See the MULTI-INSTRUMENT CONFIGURATION Chapter for details regarding this interface prior to connecting multiple instruments.

> The user should ensure that each "MIB-OUT" connector is connected to a "MIB-IN" connector in a networked set of instruments.

8.4. Interface Connectors

These connectors are only present when either option **IE** or **RS** and/or option **AN** is fitted in the instrument.

8.4.1. IE Connector

This is a standard IEEE488 connector, and is present if option **IE** is fitted in the instrument. A description of the usage of this connector, and the method of using the IEEE488 interface is in the DIGITAL INTERFACING Chapter.

8.4.2. RS Connector

This is a female 9-pin sub-miniature "D" type connector, and contains the RS232 connections for the **RS** or **PR** option of the instrument. The connections are as follows.

① Data Carrier Detect (Output from **2501/2/3**).

② Transmit Data (Output from **2501/2/3**).

③ Receive Data (Input to **2501/2/3**).

④ Data Terminal Ready (Input to **2501/2/3**).

⑤ Ground (Common return for these signals).

⑥ Data Set Ready (Output from **2501/2/3**).

⑦ Request To Send (Input to **2501/2/3**).

⑧ Clear To Send (Output from **2501/2/3**).

⑨ Ring Indicate (Output from **2501/2/3**).

A description of the usage of this connector and the RS232 interface is in the DIGITAL INTERFACING Chapter.

8.4.3. Option PR Connector

The printer should have an RS232 interface that is capable of operating at a baud rate of either 1200, 2400, 4800, 9600 or 19200 baud. The printer should also support the "DTR" method of hardware handshake of data. Most printers support these baud rates and handshake mode, consult the manual for your printer if you are uncertain. The cable between the **2501/2/3** and the printer should be connected as follows :

Printer	2501/2/3
25 pin Male	9 pin Male
3	2
7	5
20	7

Some printers use pin 11 instead of pin 20 as the handshake line, in these cases the connection between pin 20 of the printer and pin 7 of the **2501/2/3** should be replaced by a connection between pin 11 of the printer and pin 7 of the **2501/2/3**.

8.4.4. AN Connector

This is a male 9-pin sub-miniature "D" type connector, and contains the analog output connections for the **AN** option of the instrument. Pins 1 through 8 are analog outputs 1 through 8 respectively, and pin 9 is the common ground for all 8 outputs.

A description of the usage of this connector and the **AN** interface is in the ANALOG INTERFACING Chapter.

8.5. Rear Panel Control Connector

This connector is a 0.101" sub-miniature phono socket, the recommended mating plug is obtainable from Switchcraft as part number **850**. Xitron Technologies provides one with each instrument as standard. Additional parts may be ordered from Xitron Technologies under part number **C109001001000001**.

> **This input should be used with an isolated contact closure (i.e. a switch or relay contact). Under no circumstances should voltages be input into this connector, otherwise severe damage may result.**

This input is internally debounced for 10ms, switches having "bounce" periods of longer than this should be externally debounced. The description of the method of configuring the use of this input is in the FRONT PANEL CONTROLS Chapter.

9. Getting Started - Standard Applications

This chapter is intended to assist users in quickly getting started using their **2501/2/3** instrument in a standard, single instrument, application. Later chapters deal in detail with all of the procedures outlined in this chapter and describe in detail the many additional features of these instruments.

> Users who are not conversant with Xitron Technologies Power Analysis instruments should read this chapter carefully prior to using the instrument.

9.1. Preliminaries

Before connecting the instrument to a power source, the user should follow these simple steps to verify that the instrument is of the correct type for the application and is correctly functioning.

❶ ✔

Ensure that all rear panel input connectors and interface connectors are disconnected from external circuitry.

❷ ✔

Ensure that the power supply voltage selector (in the rear panel power connector) is showing the correct nominal voltage for the local supply. Ensure that the front panel *POWER* switch is in the *OFF* position.

❸ ✍

Apply power to the instrument and press the front panel *POWER* switch to the *ON* position. Carefully watch and take note of the power-on messages.

❹ ✔

Check that there are no error messages displayed during the power-on sequence, and that the instrument number (i.e. **2501, 2501H, 2502, 2502H, 2503** or **2503H**) is consistent with the desired application. The last digit of the instrument number shows the number of channels, and the **H** character shows if harmonic and spectrum analysis capabilities are available.

❺ ☞

On each channel, short each pair of voltage terminals together, and each pair of current terminals together. Any suitable gauge of wire may be used. Press the front panel *CALIBRATION* key. The display will now show a selection of calibration procedures that may be performed. Press the key immediately next to the ***Internal Calibration*** selection (the second key down in the column next to the display).

❻ ✍

The instrument will now perform an Internal Calibration and system check. If the instrument finds any errors, it will abort the check, emit a short beep sound and display an error message. Note any displayed error message.

❼ ✔

If there were no error messages, and the correct instrument number was shown, then the instrument is correctly functioning and the user may configure it for the desired use. If there was an error, then take any actions suggested within the error message and retest the instrument.

The remainder of this chapter is arranged in four sections.

❶ The first section describes how to configure and connect the instrument for the most common power measurement applications (single phase, 3-Φ 3-wire, and 3-Φ 4-wire). It is assumed that no PTs or CTs are being used, thus the measured voltages and currents must be within the capabilities of the instrument.

❷ The second section describes how to configure the instrument to display the desired data.

❸ The third section describes how to save and recall the selections made in the first two sections.

❹ The last section describes the basic methods by which the user may "fine tune" the configuration of the instrument to obtain the optimum performance in the users' application.

9.2. Configuring and Connecting the Instrument

9.2.1. Single Phase Applications

This section is applicable to all instruments in the **2501/2/3** family. In this configuration only channel A is used.

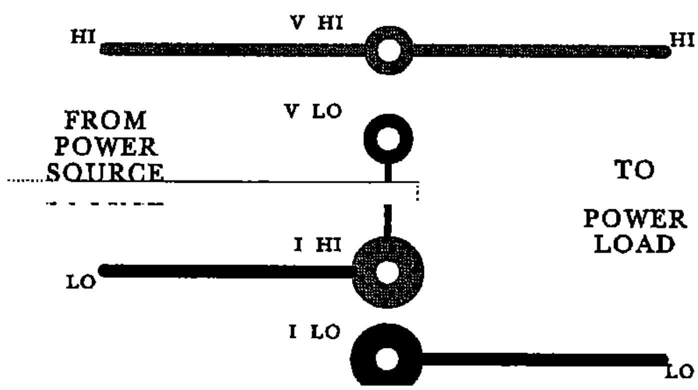
❶ Press the *QUICK* key on the front panel. The instrument will display a responding message for a short while before returning to normal operation.

This sets up the instrument to the factory default settings. The actual setup selected is dependent on the instrument model and option content. All these possible configurations are compatible for this application, however the user may wish to alter the displayed data and then "fine tune" the configuration.

❷ Ensuring that no voltages or currents exist, carefully connect the rear panel *Channel A* terminals to the power lines to be monitored as shown in the following diagram.

It should be noted that this configuration measures the power supplied by the source. If the user requires the power in the load, then the link between the V LO and I HI terminals should be replaced by a link between the V LO and I LO terminals.

CHANNEL A



❸ The instrument is now configured and connected for use, the user may now apply power to the measuring terminals. The user may wish to change the displayed parameters before applying power to the measurement terminals, in this case refer to the relevant later section.

❹ When using the instrument, the user should note the front panel *OVERLOAD* indicators. The procedure described above placed the instrument in the autorange condition. If an indicator is illuminated (a beep sound is also emitted) this is an indication of a severe overload. **THIS CONDITION MUST BE IMMEDIATELY REMEDIED.**

9.2.2. 3-Phase 3-Wire (Often Known as "Delta") Applications

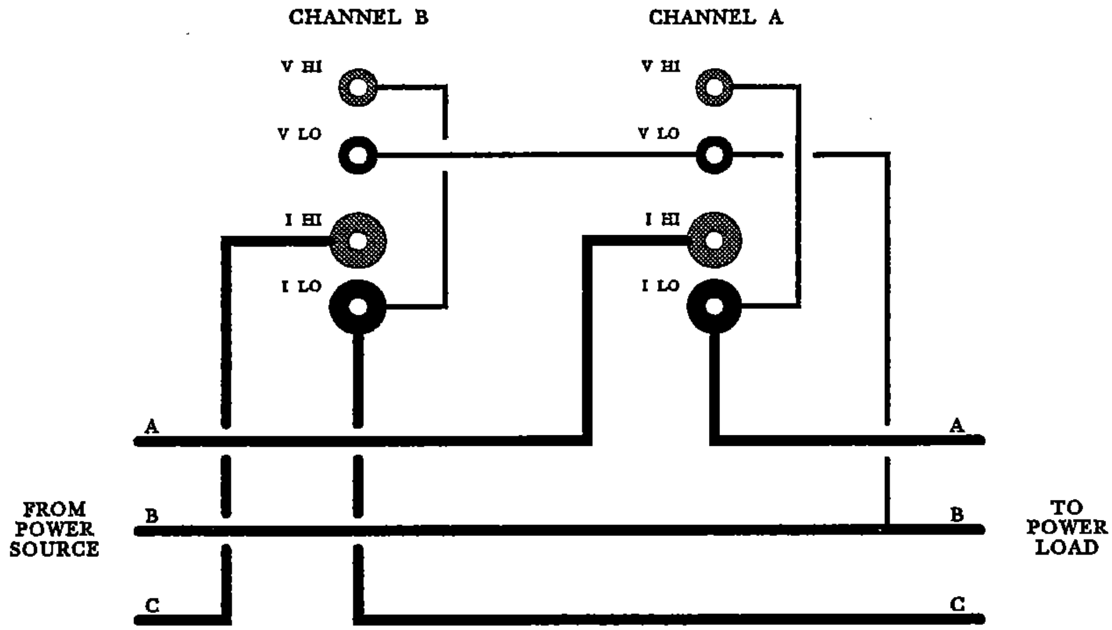
This section is not applicable to the **2501** or **2501H** instruments. This configuration uses channels A and B only.

❶ Press the *QUICK* key on the front panel. The instrument will display a responding message for a short while before returning to normal operation.

This sets up the instrument to the factory default settings. The actual setup selected is dependent on the instrument model and option content. All these possible configurations are compatible for this application, however the user may wish to alter the displayed data and then "fine tune" the configuration.

❷ Ensuring that no voltages or currents exist, connect the rear panel *Channel A* and *Channel B* terminals to the power lines to be monitored as shown in the following diagram.

It should be noted that this configuration measures the power delivered to the load. If the user requires the power supplied by the source, then the link between the V LO and I LO terminals should be replaced by a link between the V LO and I HI terminals on each channel.



❸ The instrument is now configured and connected for use, the user may now apply power to the measuring terminals. The user may wish to change the displayed parameters before applying power to the measurement terminals, in this case refer to the relevant later section.

❹ When using the instrument, the user should note the front panel *OVERLOAD* indicators. The procedure described above placed the instrument in the autorange condition. If an indicator illuminates (a beep sound is also emitted) this is an indication of a severe overload. **THIS CONDITION MUST BE IMMEDIATELY REMEDIED.**

9.2.3. 3-Phase 4-Wire (Often Known as "Wye") Applications

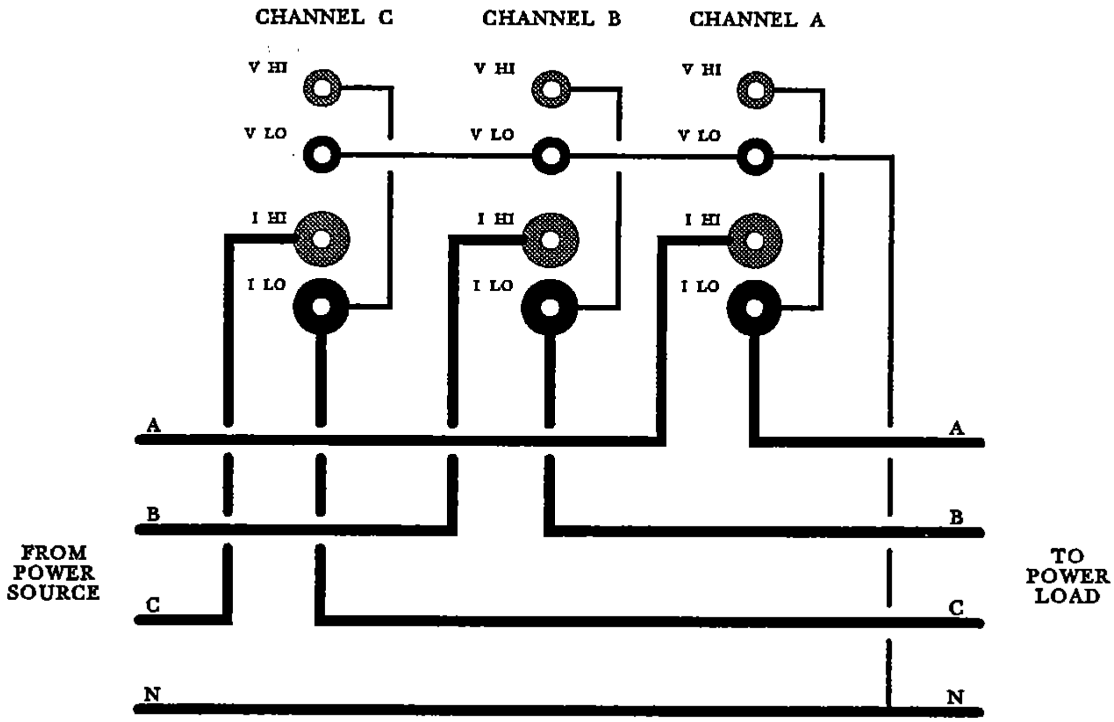
This section is only applicable to the 2503 or 2503H instruments.

❶ Press the *QUICK* key on the front panel. The instrument will display a responding message for a short while before returning to normal operation.

This sets up the instrument to the factory default settings. The actual setup selected is dependent on the instrument model and option content. All these possible configurations are compatible for this application, however the user may wish to alter the displayed data and then "fine tune" the configuration.

❷ Ensuring that no voltages or currents exist, connect the rear panel *Channel A, Channel B* and *Channel C* terminals to the power lines to be monitored as shown in the following diagram.

It should be noted that this configuration measures the power delivered to the load. If the user requires the power supplied by the source, then the link between the V LO and I LO terminals should be replaced by a link between the V LO and I HI terminals on each channel.



❸ The instrument is now configured and connected for use, the user may now apply power to the measuring terminals. The user may wish to change the displayed parameters before applying power to the measurement terminals, in this case refer to the relevant later section.

❹ When using the instrument, the user should note the front panel *OVERLOAD* indicators. The procedure described above placed the instrument in the autorange condition. If an indicator illuminates (a beep sound is also emitted) this is an indication of a severe overload. **THIS CONDITION MUST BE IMMEDIATELY REMEDIED.**

9.3. Selecting the Displayed Data

The *2501/2/3* family has a four line display, each line of which may display any measured (or computed) parameter. In general, data is displayed as one data item per line of the display. Voltages and currents are displayed on the same line. The user may change the data displayed on any particular line by using the *DISPLAY PARAMETER SELECTION* keys on the front panel.

In this section, the user is shown some examples of changing displayed data. A full listing of all available display data parameters can be found in the FRONT PANEL CONTROLS Chapter of this manual.

❶ **Select the display line to change.**

Press the key located immediately next to the selected display line. The display now shows the details pertinent to the selected display lines present data.

❷ Select the parameter to display.

Press the desired data parameter key in the central portion of the DATA PARAMETER SELECTION section of the keyboard.

As an example, we shall change the selected display line to show VA data. Press the *VA* key. This selection (and many others), requires that the user select the bandwidth for the data. The display prompts the user to select whether the ***DC Component Only, AC Component Only*** or ***Both DC & AC*** data is to be displayed.

❸ Select the bandwidth for the selected parameter, if required.

Press the key that is next to the desired bandwidth. Here we desire to view the total VA data, thus we select ***Both DC & AC***. Press the third key down next to the display (i.e. the key next to the ***Both DC & AC*** selection).

❹ Select the source for the selected parameter.

We now need to select which VA data to display. This is achieved by using the ***Ch A, Ch B, Ch C, TOTAL, INPUT*** or ***OUTPUT*** keys.

The ***Ch A, Ch B*** and ***Ch C*** keys select that the previously selected parameter from channel A, B or C (respectively) is to be displayed.

The action of the ***TOTAL, INPUT*** and ***OUTPUT*** keys are dependent on the selected configuration of the instrument. In these "standard" applications only the ***TOTAL*** key needs to be considered. The other keys are for complex situations where the instrument is used for testing power supplies etc.. Refer to later chapters if more details are needed.

As an example, we shall choose to display the VA data for channel A, so we press the ***Ch A*** key.

❺ Complete the selection.

The selection is now completed. Press the lowest key next to the display (the key next to the ***Done*** selection).

❻ The user should now change the remaining display lines similarly to described above.

Certain of the display parameters are associated with the Accumulation mode of the instrument. These parameters are ***Pk W, Pk Vrms, Pk Arms, W Hr, VA Hr, VAR Hr, Wavg, VAavg*** and ***VARavg***. For a description of these data the user is referred to later chapters of this manual.

9.4. Saving & Recalling Complete Configurations

Up to three complete configurations of the instrument can be saved and recalled for later use. One of these saved configurations is used as the power-on configuration.

❶ Press the ***STORE*** key (located in the lower right-hand corner of the front panel).

❷ The display now shows the selection of store locations available. The user may either select the location by pressing the key next to the desired location, or by pressing the numeric key associated with the location.

After the user has pressed the desired key, the instrument stores the configuration and returns to normal operation.

The user may recall a configuration from any of these storage locations by the following procedure.

❶ Press the *RECALL* key (located next to the *STORE* key in the lower right-hand corner of the front panel).

❷ The display now shows the selection of store locations available. The user may either select the location by pressing the key next to the desired location, or by pressing the numeric key associated with the location.

After the user has pressed the desired key, the instrument retrieves the selected configuration and returns to normal operation using it.

By using this capability of the instrument, the user can quickly change applications, without having to reprogram the configuration and display data selections associated with each application.

9.5. "Fine Tuning" a Configuration

In the sections above, we used the default configuration setup by using the *QUICK* key. The settings used by this are primarily intended for line power measurements and normal speed manual operation. The **2501/2/3** family offers a wide range of measurement capabilities beyond these.

9.5.1. Input Synchronization, Digital Filtering & Measurement Period

The configuration set by the *QUICK* key places a 20KHz low-pass filter in use. While this is a good choice for line applications, high frequency convertor applications require the removal of this filter. In some line applications a lower frequency cut-off may be desirable. The **2501/2/3** family has a range of filters that the user may select.

❶ Press the *SYSTEM* key (this is location in the lower right-hand corner of the front panel). The display now shows a selection of menu choices. These choices may be selected by pressing the key next to the desired choice.

❷ Select the *Configure Channels* choice. A new set of choices are displayed.

❸ Select the *More* choice. At this point the choices are dependent on the actual instrument being used, and on any previously set configuration.

For a **2501** instrument, the display will now be showing the present configuration of input configuration, filter, and measurement period for the measurement channel. For this instrument the user should proceed from step ❻ below.

For a **2502** or **2503** instrument, the display will be showing choices associated with "locking" the channels to channel A. In these standard applications channels B and C (only channel B in a 2502) need to be "locked" to channel A. This ensures that measurements made by all channels occur simultaneously.

❹ If either channel B or channel C are shown as *UNLOCKED* from channel A, then this should be changed by pressing the key next to the displayed selection.

❺ Press the *More* choice.

❻ The display will now be showing the present configuration of input configuration, filter, and measurement period for the measurement channel(s). The user may change any of these selections by pressing the key next to the item to be altered.

Input Synchronization. Pressing this key toggles the display between the available selections. ***Voltage*** is recommended for a low frequency (below 1KHz) applications, and ***None*** is recommended for high frequency applications (above 1KHz). In applications where the voltage waveform is a high frequency signal which is Pulse Width Modulated at low frequency (e.g. PWM controlled electric motors) the ***Current*** selection should be made.

Filter. Pressing this key toggles the display between the available filters. The low-pass filters are intended for applications where the signal contains significant unwanted high frequency content. The band-pass filters are intended for 50/60Hz line (the 120Hz to 5KHz filter) or 400Hz line (the 800Hz to 10KHz filter) distortion measurements without using the Harmonic Analysis capabilities (if fitted). The ***None*** choice should be used when high frequency response in excess of 20KHz is required. The 50Hz low pass filter is required if the fundamental frequency is below 10Hz and automatic synchronization to the waveform period is required.

Measurement Period. Pressing this key enables the user to enter the desired measurement period (between 0.05 and 6.5 seconds), using the numeric keys located on the right-hand side of the front panel. Complete the entry by pressing the *ENTER* key. For normal manual operation, a measurement period of 0.5 seconds is recommended. When measuring a signal having significant short-term variations, the user may wish to extend the measurement period to one or two seconds to obtain more stable results. For remotely controlled applications requiring high speed, the measurement period can be reduced to the minimum of 0.05 seconds. If the user selects ***Voltage*** or ***Current*** synchronization, the measurement period is automatically and continuously adjusted to be an integer number of input cycles of the voltage or current waveform (with a minimum of the selected period).

❼ When the channels have been configured to the desired input synchronization, filtering and measurement period, then pressing the *SYSTEM* key returns the instrument to normal operation, using the entered configuration. The user may now wish to store this configuration as previously described.

9.5.2. Range Selection

In most applications, the use of the autoranging capabilities of the instrument is recommended. When the user requires fast measurement of inrush currents (for example) the user may wish to "force" the use of a high range to eliminate the time required for the instrument to select this range at the onset of the inrush.

> **WARNING**
>
> Selecting a low full-scale current range, and then passing a high current into that input may cause significant internal damage to the instrument. Although these instruments possess internal overload protection schemes, these should never be totally relied upon to save the instrument. It is the responsibility of the user to ensure that a safe ranging condition is present always.
>
> If the application requires holding a low full-scale current range, then it is HIGHLY RECOMMENDED that the user becomes fully conversant with the method used to command autorange. This should be performed if the respective OVERLOAD LED on the front panel becomes illuminated (the instrument also "beeps" during this condition).
>
> **RANGE "HUNTING"**
>
> Under some circumstances (usually when the instrument is measuring the input power to a direct line rectification system having active power factor correction circuitry) it has been found that the ranging system of the 2501/2/3 instrument interferes with active feedback loops within the instrument under test. The user should "hold" the highest range (i.e. the 20A range) while initially applying power, and then enable autoranging or select a lower range when the system has settled to a steady state condition. It is HIGHLY RECOMMENDED to use this procedure when applying power to systems having these characteristics.

Changing the range status of the instrument can be achieved as follows :

❶ Press the *RANGES* key located in the lower right-hand corner of the front panel.

The instrument now displays the present ranges being used and the autorange status, for the voltage and current inputs on each channel. A * character displayed next to the relevant range value indicates that Autorange is selected.

2501 or **2501H** only. Proceed from step ❺.

❷ Channels which are "locked" to channel A use the same ranges as channel A, thus their range information is not displayed here. If these channels are *UNLOCKED* from channel A then the user can individually select ranges for each channel. Press the key next to the channel range data to be changed.

❸ Either press the key next to the voltage range data, or next to the current range data, whichever is to be altered.

❹ The instrument now displays the present range in use for the selected input, along with selections for ***Uprange, Auto / Held,*** and ***Downrange.***

Pressing the key next to the ***Auto*** or ***Held*** selection toggles the selection. ***Auto*** shows that the selected input is enabled to autorange, ***Held*** indicates that the selected input is "forced" to use the displayed range.

Pressing the key next to the ***Uprange*** or ***Downrange*** selections changes the range to the next higher or lower range respectively, and "forces" the use of this range.

❺ The user can now either select the ***Previous*** choice to return to the previous menu choices, or press the *RANGES* key to return to normal operation.

10. MEASUREMENT TECHNIQUES

10.1. General

The **2501/2/3** family employs real-time Digital Signal Processing techniques to perform the measurement of the various quantities. The instrument performs these actions during three distinct periods as described below. For a full understanding of the detailed use of the various data available from the **2501/2/3** the user should be familiar with this section of the manual.

10.2. Measurement Periods

10.2.1. Sampling Period

The **2501/2/3 family** samples the voltage and current waveforms simultaneously at 2.9µs intervals. This data is not only collated to obtain the various measurement data, but also directly used to obtain the *Peak Voltage, Peak Current* and *Peak Watts* data.

10.2.2. Measurement Period

The instrument collates the data obtained each sample period over a user defined measurement period. The user may define this interval as any period from 50ms to 6.5 seconds with 200µs resolution. The user may optionally select for the instrument to adjust this measurement period to be automatically synchronized to the period of the voltage or current waveform. The available measurement data are calculated from these collated samples, and the display is updated, while the next measurement period is in progress.

The circumstances under which the user should adjust the measurement period are as follows -

❶ To obtain filtering of fluctuating data. Since the instrument collates data during the entire measurement period, longer periods yield less fluctuation when monitoring data that has significant short term variation.

❷ To manually synchronize the measurement to a low frequency content to which the **2501/2/3** cannot automatically synchronize. For example, if the signal contains a known 1.28Hz signal then the measurement period could be set to 781.2ms (or multiples of, e.g. 1.5624s, 2.3436s etc.), thus filtering out the fluctuations caused by this very low frequency signal.

10.2.3. Accumulation Period

The user may optionally start and stop accumulation of the parameters obtained each measurement period. During this period, ALL parameters are accumulated (for *WHr* data etc.), averaged (for *Mean RMS* data etc.) and the maximum values captured (for *Max. RMS* data etc.). The results of these accumulations are held after the accumulation period is stopped, and may be displayed any time, either during the accumulation, or following it. Synchronization of the start and stop times to the measurement period is not required, the accumulation data being obtained separately.

Examples of the use of the accumulation period are -

❶ To establish the peak inrush power and current during the start-up of an electric motor. Here the accumulation is started prior to starting the motor and is stopped after the motor has established steady state conditions. The *Max. Peak Current* and *Max. Peak Watts* data will then show the highest data retrieved during the start-up period (the highest applicable current range should be held in this usage, such that no data is lost during autoranging).

❷ To establish the mean and peak power requirements of a building over a twenty four hour period. Here the accumulation will be started and then stopped later. During the accumulation the data can be checked at any time. After the accumulation has been stopped the final data can be retrieved. Here the major data items of interest are normally the *Mean RMS Current* (average current requirement during the accumulation), *Total W-Hr* (total energy requirement), *Mean Watts* (average power requirement), *Peak RMS Watts* (peak power requirement), *Mean VAR* (average reactive power requirement), and *Total VAR-Hr* (total reactive power requirement).

❸ Checking the calibration of Watt-Hour meters. Here the Watt-Hour meter and the **2501/2/3** are connected in series, and the accumulation is started prior to applying power to the Watt-Hour meter and **2501/2/3** measurement circuit. A reading is then taken from the Watt-Hour meter. Power is then applied for a reasonable length of time, such that the total Watt-Hours consumed may be accurately read from the Watt-Hour meter, after which power should be removed, and the accumulation stopped. The actual Watt-Hours can then be read from the **2501/2/3**, and the final Watt-Hour reading of the meter can be taken. The meter calibration is then easily checked by comparison of the change in Watt-Hour reading of the meter and the actual Watt-Hour consumption shown by the **2501/2/3** (using the *WHr* key).

❹ The accumulation capability of the **2501/2/3** may be used as a "sample and hold" capability if desired. Here the *Mean RMS* and *Peak RMS* data can be interrogated after a short period between the start and stop commands, these data are retained for analysis until a further accumulation is started, or power is removed from the **2501/2/3**.

11. SYSTEM CONFIGURATION

Details as to the method of configuring the instrument for the specific purpose intended by the user are in the Chapters describing Front Panel Operation later in this manual. The user should understand the basic idea behind the method used by all Xitron Technologies Power Analysis instruments before attempting configuration.

11.1. General

Most Xitron Technologies Power Analysis instruments allow several instruments to be interconnected to build power measurement and analysis systems ranging from the very simple to the extreme complex. The interconnecting "bus" used for this purpose is named the Multi-Instrument Bus (MIB). Within the **2502, 2502H, 2503** and **2503H**, the individual channels are considered as separate instruments. The **2500M, 2501** or **2501H** can be considered as either separate instruments or channels, as desired. Thus the internal channels are controlled by the same system, and thus in the same manner as, external channels or instruments.

11.2. "MIB" or "System Configuration" Code

Within the MIB (as in most multi-instrument bus topologies), channels are discriminated by means of an "address". Within the MIB this code is a three digit code that not only discriminates between channels, but also identifies the purpose of the channel. It also should be noted that this is a "masterless" bus, that is all instruments have equivalent priority and data access on the bus.

11.2.1. 1st Digit - "Group" Code

This digit serves to group channels together, allowing the user to obtain "group" totals when desired. This digit also may be used to identify whether a particular channel is monitoring "input" or "output" power, thus allowing the user to obtain totals across all "input" groups or "output" groups. The following defines the usage of this digit :

❶ All channels having the same 1st digit are totaled as a "GROUP" total.

❷ All groups having a 1st digit of 0, 1, 2, 3 or 4 are totaled as the "INPUT" total.

❸ All groups having a 1st digit of 5, 6, 7, 8 or 9 are totaled as the "OUTPUT" total.

11.2.2. 2nd Digit - "Phase" Code

This digit controls the method by which channels are totaled, in a multi-phase system the mathematics used is dependent on the number of phases and the rotation of those phases. The second digit defines both the number of phases and the rotation.

The following defines the usage of this digit :

❶ All channels within different groups are considered phase unrelated if totaled. This means that only Watts and VAR related data may be totaled, no other totals obtain mathematically valid data.

❷ All channels within the same group, and having a 0 second digit, are considered phase unrelated if totaled.

❸ All channels within the same group, and having a non-zero second digit, are considered phase related if totaled.

It should be noted that the methods used to obtain the Watts and VAR data from each individual instrument or channel in the Xitron Technologies instruments is such that the only parameter that requires the correct use of this second digit is the "remnant" current. If the user does not require the "unmeasured" or "remnant" current, then this second digit becomes irrelevant.

The method used to calculate "remnant" current is dependent on the number of channels having a non-zero second digit as follows :

❶ If only one channel has a non-zero second digit, then it is considered the same as having a 0 second digit (i.e., it is considered phase unrelated).

❷ If exactly two channels have a non-zero second digit, then these channels are assumed to be measuring a 3-Φ 3-wire power system. In general, the three phases are identified as A, B and C, in order of phase rotation. Thus phase A has a voltage zero crossing prior to that of phase B, whose zero crossing is similarly prior to that of phase C. When using the "2 wattmeter" method of measuring these systems, one of these phases is arbitrarily chosen as the reference phase. When connecting Xitron Technologies power analysers in this configuration, phase B should be chosen as the reference phase (i.e. the phase connected to the common voltage LO terminals of the two channels). Which channel is measuring phase A or phase C is determined by the second digit of this code. The channel having the lower value for the second digit is considered as measuring phase A, while the higher value is considered as measuring phase B. If the "remnant" (i.e., phase B) calculated current figure is significantly larger than expected, then these phases are reversed and should be exchanged.

❸ If three or more channels have a non-zero second digit, then these channels are assumed to be measuring a conventional "star" configuration power system (equivalent to 3-Φ 4-wire or 'Y'). Here the calculated "remnant" current is the neutral current, and the channels should be connected in phase rotation order (i.e. lower value second digits should have earlier voltage zero crossings than higher value second digits). Similarly to the two channel case shown above, if excessive "remnant" current is shown, then the phase rotation is probably incorrect.

11.2.3. 3rd Digit - Channel Identifier

This digit is rarely used, and is normally set to zero. This digit is used when it is required (for totalling purposes) to have two (or more) channels having the same 1st and 2nd digits; here they must be separately identified by means of separate 3rd digits. The hardware MIB will be rendered inoperative if this is not correctly performed and two or more channels have the same three digit code.

11.3. Example Configurations

It should be noted that, in the following discussion no mention is made to the physical location of a channel within an instrument, or which type of instrument is being described. It should be noted that this is actually irrelevant, each channel is identified by its' code, not by its physical location, thus channels may be distributed among instruments freely. Where complex systems are to be formed, which are combinations of these configurations, then simply follow the descriptions for each individual group. If assistance is required in configuring more complex systems than described here, then contact Xitron Technologies Technical Assistance for details (please be ready to transmit a facsimile of a drawing of your exact configuration, complex configurations are often difficult to describe effectively).

11.3.1. 3-wire ("Delta") Configuration Power Analysis

❶ Set the two channels to have the same 1st digit.

- a If the channels are measuring the power in a load, then use an unused digit in the range 5 through 9 inclusive.
- b If the channels are measuring the power delivered by a source, or being input to a source, then use an unused digit in the range 0 through 4 inclusive.

❷ a If it is not required to measure the "unmeasured" phase current, or the phase rotation is unknown, then set both second digits to 0 and set the third digits to any two differing digits. Usually the two channels will be set to have 2nd and 3rd digits of "01" and "02" respectively.

- b If it is required to obtain the "unmeasured" phase current then the phase rotation must be known. Phase B should be chosen as the reference phase (i.e. the phase connected to the common voltage LO terminals of the two channels). The second digit determines which channel is measuring phase A or phase C. The channel having the lower (non-zero) value for the second digit is considered as measuring phase A, while the higher value is considered as measuring phase C. If the "remnant" (i.e., phase B) calculated current figure is significantly larger than expected, then these phases are reversed and should be exchanged. The third digits should normally both be set to 0.

Individual phase data (referenced to the reference phase) is obtainable at each respective channel or instrument. The overall Watts, VAR, VA, Power Factor etc. data and the "unmeasured" phase current is available as the ***TOTAL*** **(2501/2/3)** or ***GROUP*** **(2500M)** data from any instrument.

11.3.2. 4-wire ("Wye") Configuration Power Analysis

➊ Set the three channels to have the same 1st digit.

a If the channels are measuring the power in a load, then use an unused digit in the range 5 through 9 inclusive.

b If the channels are measuring the power delivered by a source, or being input to a source, then use an unused digit in the range 0 through 4 inclusive.

➋ a If it is not required to measure the "neutral" current, or the phase rotation is unknown, then set all three second digits to 0 and set the third digits to any three differing digits. Usually the channels will be set to have 2nd and 3rd digits of "01", "02" and "03" respectively.

b If it is required to obtain the "neutral" current then the phase rotation must be known. The channels should be connected in phase rotation order (i.e. lower (non-zero) value second digits should have earlier voltage zero crossings than higher value second digits. If the "neutral" calculated current figure is significantly larger than expected, then one or more phases are reversed and should be exchanged. The third digits should normally both be set to 0.

Individual phase data is obtainable at each respective channel or instrument. The overall Watts, VAR, VA, Power Factor etc. data and the "neutral" current is available as the ***TOTAL*** **(2501/2/3)** or ***GROUP*** **(2500M)** data from any instrument.

11.3.3. Single Input, Single Output Power Supply/Convertor Testing

This configuration is typically used for the testing of single output AC-AC, AC-DC, DC-DC or DC-AC power supplies, voltage convertors, transformers or electronic ballasts.

➊ Set the channel monitoring the power input as follows :

a Select an unused 1st digit in the range 0 through 4 inclusive.

b Set the 2nd and 3rd digits to 00.

➋ Set the channel monitoring the power output as follows :

a Select an unused 1st digit in the range 5 through 9 inclusive.

b Set the 2nd and 3rd digits to 00.

Individual data is obtainable at each respective channel or instrument, or may be obtained from any instrument as *INPUT* or *OUTPUT* totals. The Power Loss (*LOSS*) or Efficiency (*EFF*) data is available from any instrument.

11.3.4. Single Input, Multiple Output Power Supply/Convertor Testing

This configuration is typically used for the testing of multiple output AC-AC, AC-DC, DC-DC or DC-AC power supplies and transformers.

❶ Set the channel monitoring the power input as follows :

a Select an unused 1st digit in the range 0 through 4 inclusive.

b Set the 2nd and 3rd digits to 00.

❷ Set the channels monitoring the power outputs as follows :

a Set each channel to an unused, unique 1st digit in the range 5 through 9 inclusive.

b Set the 2nd and 3rd digits to 00.

c Set each 3rd digit to any unique value for each channel.

Individual data is obtainable at each respective channel or instrument, or totals may be obtained from any instrument as *INPUT* or *OUTPUT* totals. The Power Loss (*LOSS*) or Efficiency (*EFF*) data is available from any instrument.

11.3.5. Multi-Phase Input Power Supply/Convertor Testing

These configurations are the same as for the single input configurations shown above, but the input channels should be configured as described for the 3-Φ 3-wire or 3-Φ 4-wire configurations described earlier.

11.3.6. Multiple Input/Output Power Supply Systems

Multiple power sources are commonly encountered in power distribution systems, in these cases there may be multiple types of sources (e.g., an AC line input and a DC battery backup input).

The Xitron Technologies MIB code system encompasses these complex systems readily. The user should setup each input and output supply as a separate group (i.e., separate 1st digits) as described in the previous paragraphs for the particular configuration of that supply. Examples of these systems are described below :

❶ A single phase AC input, an auxiliary DC input and a single AC output (i.e., a U.P.S.). Here the three channels would be setup as follows :

a The channel monitoring the AC input should be set to code 100.

b The channel monitoring the DC input should be set to code 200.

c The channel monitoring the AC output should be set to code 600.

Individual data is obtainable at each respective channel or instrument. Totals may be obtained from any instrument as *INPUT* or *OUTPUT* totals. The Power Loss (*LOSS*) or Efficiency (*EFF*) data is available from any instrument.

❷ A multi-phase power distribution system (or transformer) having a single 3-Φ "delta" input and three 3-Φ "wye" outputs.

a The two channels monitoring the input power should be set to codes 110 and 120 (noting phase rotation if the "unmeasured" phase current is desired).

b The three channels monitoring each output power group should be set to x10, x20 and x30 (noting phase rotation if the "neutral" currents are desired). The 1st digit should be set to unique digits for each group within the range 5 through 9 inclusive.

Individual data is obtainable at each respective channel or instrument. Group totals may be obtained from any member of the respective group as the *GROUP* total. Totals may be obtained from any instrument as *INPUT* or *OUTPUT* totals. The Power Loss (*LOSS*) or Efficiency (*EFF*) data is available from any instrument.

12. FRONT PANEL CONTROLS

12.1. General

There are several functional sections in the front panel keyboard of the 2501/2/3. This chapter provides a brief overview of the basic uses of these sections.

> The 2501/2/3 may be commanded (either via the front panel, or the interface) to store the present settings in one of three "stores". One of these "stores" (#0) is used as the power on default status of the instrument. Settings made without storing them will be lost when power is removed, thus (for example) PT and CT ratios should be set and then stored after being checked for correct results.
>
> It is not recommended to set a fixed current range having a low full-scale value in this default "store". If excessive current is present following application of power this could cause damage to the instrument.

12.2. SELECT Keys

These four keys, located immediately next to the four lines of the display, perform the following actions :

❶ Allow the user to change informative data displayed in each respective display line.

❷ Allow the user to select from the displayed MENU style actions.

12.3. DISPLAY PARAMETER SELECTION Keys

This section of the keyboard is used whenever a selection of the source of data is required (e.g. when selecting displayed data). These keys are divided into two sub-sections as described below.

12.3.1. DATA SOURCE Keys

These keys are contained in the columns located on each side of the central block in this section. These keys are used to select the source of the selected data parameter. A brief explanation of each key follows :

Ch A This key selects that the selected data from channel A will be the source.

Ch B This key selects that the selected data from channel B will be the source. This key operates the same as the *Ch A* key in the **2501** and **2501H** versions of this family.

Ch C This key selects that the selected data from channel C will be the source. This key operates the same as the *Ch A* key in the **2501, 2501H, 2502** and **2502H** versions of this family.

TOTAL This key selects that the selected data from the "group" to which channel A belongs (i.e. all channels, both internal and external, having the same first digit for the "System Configuration" or MIB Code) will be the source. When the channels have been configured using the built-in setups for 3-Φ 3-wire or 3-Φ 4-wire operation, then this is the total across all phases.

INPUT This key selects that the selected data from all channels (either internal or external) having a MIB Code first digit of between 0 and 4 inclusive will be the source.

OUTPUT This key selects that the selected data from all channels (either internal or external) having a MIB Code first digit of between 5 and 9 inclusive will be the source.

LOSS This key selects that the computed Power Loss data will be the data source and parameter (i.e. Total Input Power - Total Output Power).

EFF This key selects that the computed Power Efficiency data will be the data source and parameter (i.e. Total Output Power / Total Input Power).

12.3.2. DATA PARAMETER Keys

These keys are contained in the columns located in the central block of this section. These keys are used to select the data parameter. A brief explanation of each key follows :

Vrms This key selects either the DC, RMS AC or RMS AC+DC voltage. This parameter is not available from sources other than *Ch A, Ch B* or *Ch C.*

Arms This key selects either the DC, RMS AC or RMS AC+DC current. This parameter is not normally available from sources other than *Ch A, Ch B* or *Ch C.* When selected from a data source of ***GROUP,*** and the group (i.e., instruments having the same 1st digit in their MIB code) has been defined as phase related, then this selects the "remnant" current (RMS AC+DC, either "unmeasured" phase or "neutral" current dependent on the number of phase related channels).

W This key selects either the DC, AC or AC+DC power. This parameter is available from all sources.

PF This key selects either the AC or AC+DC power factor. This parameter is available from all sources.

VA — This key selects either the DC, AC or AC+DC apparent power. This parameter is available from all sources.

VAR — This key selects reactive power. This parameter is available from all sources.

Hz — This key selects the frequency. This parameter is not available from sources other than ***Ch A, Ch B*** or ***Ch C***. This is normally the frequency of the Voltage waveform, if the channel is configured for synchronization to the current waveform then this parameter becomes the frequency of that waveform.

PHASE — This key selects either the AC or AC+DC Effective Phase ($\cos^{-1}$(PF)), or the inter-phase voltage phase relationship (**2502, 2502H, 2503** and **2503H** only). The Effective Phase parameter is available from all sources.

W Pk — This key selects the peak detected instantaneous V*A. It should be noted that this parameter is the furthest excursion detected from the zero level, thus this may result in a negative quantity. This parameter is not available from sources other than ***Ch A, Ch B*** or ***Ch C***.

V Pk — This key selects the peak detected instantaneous voltage. It should be noted that this parameter is the furthest excursion detected from the zero level, thus this may result in a negative quantity. This parameter is not available from sources other than ***Ch A, Ch B*** or ***Ch C***.

A'Pk — This key selects the peak detected instantaneous current. It should be noted that this parameter is the furthest excursion detected from the zero level, thus this may result in a negative quantity. This parameter is not available from sources other than ***Ch A, Ch B*** or ***Ch C***.

V CF — This key selects the voltage crest factor (i.e., ***V Pk / Vrms***). This parameter is not available from sources other than ***Ch A, Ch B*** or ***Ch C***.

Pk W — This key selects the highest detected DC, AC or AC+DC power measured either :

a During the previous accumulation (if not accumulating).

b To date, during this accumulation (if accumulating).

This parameter is available from all sources.

Pk Vrms — This key selects the highest detected DC, RMS AC or RMS AC+DC voltage measured either :

a During the previous accumulation (if not accumulating).

b To date, during this accumulation (if accumulating).

This parameter is not available from sources other than ***Ch A, Ch B*** or ***Ch C***.

Pk Arms — This key selects the highest detected DC, RMS AC or RMS AC+DC current measured either :

a During the previous accumulation (if not accumulating).

b To date, during this accumulation (if accumulating).

This parameter is not available from sources other than *Ch A, Ch B* or *Ch C*.

A CF This key selects the current crest factor (i.e., *A Pk / Arms*). This parameter is not available from sources other than *Ch A, Ch B* or *Ch C*.

W Hr This key selects the totalled DC, AC or AC+DC power measured either :

a During the previous accumulation (if not accumulating).

b To date, during this accumulation (if accumulating).

This parameter is available from all sources.

VA Hr This key selects the totalled DC, AC or AC+DC apparent power measured either :

a During the previous accumulation (if not accumulating).

b To date, during this accumulation (if accumulating).

This parameter is available from all sources.

VAR Hr This key selects the totalled reactive power measured either :

a During the previous accumulation (if not accumulating).

b To date, during this accumulation (if accumulating).

This parameter is available from all sources.

V THD This key selects the voltage total harmonic distortion. This data is only available for instruments **2501H**, **2502H** or **2503H**, and only for data sources *Ch A, Ch B* or *Ch C*.

Wavg This key selects the DC, AC or AC+DC average power measured either :

a During the previous accumulation (if not accumulating).

b To date, during this accumulation (if accumulating).

This parameter is available from all sources.

VAavg This key selects the DC, AC or AC+DC average apparent power measured either :

a During the previous accumulation (if not accumulating).

b To date, during this accumulation (if accumulating).

This parameter is available from all sources.

VARavg This key selects the average reactive power measured either :

a During the previous accumulation (if not accumulating).

b To date, during this accumulation (if accumulating).

This parameter is available from all sources.

A THD — This key selects the current total harmonic distortion. This data is only available for instruments **2501H, 2502H** or **2503H,** and only for data sources *Ch A, Ch B* or *Ch C.*

12.4. CONFIGURATION SETUP Keys

This section of the keyboard (located on the right hand side of the front panel) enables the user to affect the configuration of the instrument.

12.4.1. Numeric Keys

These keys (located in the "un-highlighted" section of the CONFIGURATION SETUP keys) are used during prompted numeric entry of data into the instrument.

12.4.2. *QUICK* Key

If the user is uncertain as to the particular settings that are required, or is inexperienced in using the **2501/2/3,** then the usage of the ***QUICK*** set up is recommended. This operation will automatically set up all settings to the following conditions -

❶ 0.5 second measurement period, synchronized to the input voltage waveform on channel A (other channels, if applicable, are "locked" to channel A).

❷ 20KHz low pass filter (i.e. frequency response limited to DC to 20KHz).

❸ Autoranging on both voltage and current inputs, not using either PT or CT devices.

❹ a — **2501** and **2501H** only. The MIB code is set to 101. The display lines are set to RMS AC+DC Voltage & Current, Frequency, AC+DC Power and AC+DC Power Factor respectively.

b — **2502** and **2502H** only. The MIB codes are set to 101 and 102 respectively (ready for 3-Φ 3-wire usage). The display lines are set to RMS AC+DC ***Ch A*** Voltage & Current, RMS AC+DC ***Ch B*** Voltage & Current, ***TOTAL*** AC+DC Power and ***TOTAL*** AC+DC Power Factor respectively.

c — **2503** and **2503H** only. The MIB codes are set to 101, 102 and 103 respectively (ready for 3-Φ 4-wire usage). The display lines are set to RMS AC+DC ***Ch A*** Voltage & Current, RMS AC+DC ***Ch B*** Voltage & Current, RMS AC+DC ***Ch C*** Voltage & Current and ***TOTAL*** AC+DC Power respectively.

❺ PT and CT ratios are cleared.

12.4.3. *RANGES* Key

The use of this key enables the user to view the status of and/or change the ranging system of the channels.

When first pressed the display shows the present status of all "changeable" channels. When channel B or C (in a **2502, 2502H, 2503** or **2503H**) is "locked" to channel A, then all operating parameters in use by channel A are copied by channels B and/or C and the measurement periods are forced to be synchronous. This is particularly useful when using the channels in a multi-phase power monitoring application. Here the affected channels are not "changeable", thus are not displayed (acting as a further indication of the "locked" condition). It should be noted that the display will continuously update, following any changes in range status. A * character next to the indicated range shows that the autorange condition has been enabled for that input. The *PT* or *CT* characters next to the indicated range show that a PT or CT (as applicable) is in use on that input, the displayed full-scale range value does not incorporate the PT or CT scale factor.

In this display, as in all displays within this section, the lowest display line choice returns the display to that previously selected (normal operation in this case). Pressing the lowest *SELECT* key causes this action to take place.

Pressing the RANGES key while viewing the present range status returns the display to normal operation.

2502, 2502H, 2503 or **2503H** only : If the user wishes to alter the status of a channel, then the *SELECT* key immediately next to the display line of the channel to be altered should be pressed. The instrument now displays the voltage input and current input ranges for the selected channel on separate lines of the display.

If the user wishes to alter the status of a particular input, then the *SELECT* key immediately next to the display line of the data to be altered should be pressed. The instrument now displays the selected input data, along with the selections ***Uprange*** and ***Downrange***, and the selection ***Auto*** or ***Hold*** (as relevant to the present status of the input).

Pressing the *SELECT* key next to the ***Uprange*** or ***Downrange*** selections causes the next higher or lower (respectively) range to be selected and held (i.e., if autorange was previously enabled, then it is disabled). The display is updated to the newly commanded status.

Pressing the *SELECT* key next to the ***Auto*** or ***Held*** (as applicable) selection causes the selection to be changed. If the input previously had autoranging enabled (***Auto*** displayed), then the present range is held. If the input previously had autoranging disabled (***Held*** displayed), then autoranging is enabled.

After setting the input to the desired state the user may either select the lower *SELECT* key to "backup" one display level (enabling other inputs to be altered) or press the *RANGES* key to exit the range control system and revert to normal operation.

12.4.4. *SYSTEM* Key

This key enables all detailed measurement and interfacing considerations to be altered to those desired by the user. Pressing this key is the first step in a multi-level set of menu selections that the user may make.

Throughout these selections, certain display lines show selections of ***More*** and ***Previous***, selecting these (using the respective *SELECT* keys) causes either more selections or the previous set of selections to be displayed.

Completing the selection of any change in operating parameter takes immediate effect. Thus, returning the instrument to normal operation by pressing the ***SYSTEM*** key offers a quicker method than repeatedly selecting the ***Previous*** selection.

The table below outlines the menus available by selecting the respective ***SELECT*** keys. Where display lines show actual data then these are altered by one of two methods (dependent on the data type) :

❶ **Non-numeric data** : Pressing the respective *SELECT* key selects the next available choice for the entry.

❷ **Numeric data** : Pressing the respective *SELECT* key enables the user to enter revised numeric data using the *Numeric* Keys in the **CONFIGURATION SETUP** section of the keyboard. After pressing the *ENTER* key, the display returns to the "informative" display state present when numeric entry was started, with the affected data updated.

It should be noted that some menu selections may not be available. This may be caused by the particular instrument being used (there are no channel selections to make in a **2501** or **2501H**), or by previously made menu selections (channels that are "locked" to channel A cannot be individually configured), or by the option content of the instrument (e.g. interfaces). In the following paragraphs, the effect of selecting the ***Previous*** selection is not shown for clarity. The indentation level of the text shows the level at which the particular set of selections occurs.

Beeper On or *Beeper Off*

This selection toggles the option (the selected value is non-volatile).

Configure Channels

More

More

Setup Channel A

Sync :

This toggles the displayed option. The ***Voltage*** option is recommended for most applications. The *None* option should only be used for high frequency or DC applications. The *Channel A* option is only available for channels B and C, and should be used where the selected channel should be synchronous to channel A but not otherwise forced to use the same configuration. The *Current* option is similar to the Voltage option but uses the current waveform.

Filter :

This toggles the displayed option. The ***None*** option should only be used when significant signal content occurs above 20KHz. With no filter selected, the unfiltered measurement bandwidth is several MHz and may cause unwanted signal content to be included.

Period :

This selection allows the user to enter the desired measurement period (in the range 0.05 to 6.5 second) using the numeric keys. The user should note that the actual measurement may be longer than this figure, after synchronization and autoranging.

Setup Channel B

The actions following this selection are the same as for the *Setup Channel A* selection described above.

Setup Channel C

The actions following this selection are the same as for the *Setup Channel A* selection described above.

Ch B is LOCKED to A or *Ch B UNLOCKED from A*

This toggles the displayed option. The displays shows the presently active state of Channel B. When a channel is "locked" to channel A, all of its operating parameters (measurement period, range, filters etc.) are set to be the same as those used by channel A.

Ch C is LOCKED to A or *Ch C UNLOCKED from A*

This toggles the displayed option. The display shows the presently active state of Channel C. When a channel is "locked" to channel A, all of its operating parameters (measurement period, range, filters etc.) are set to be the same as those used by channel A.

Setup PTs & CTs

Setup Channel A

PT Ratio or *No PT*

This either enables the user to enter a PT Ratio (if the ***PT Ratio*** selection is displayed), or toggles the ***No PT*** selection to the ***PT Ratio*** selection (i.e., enables the use of a previously entered PT ratio). If the user selects to alter the PT ratio, then this is achieved by using the numeric keys. If the user presses the *CLEAR* key prior to pressing any other numeric key, then this toggles the selection back to the *No PT* selection. The entry selected for the PT ratio should be the V rms required at the input to the PT that produces an output of 1V rms.

CT Ratio or *No CT*

This either enables the user to enter a CT Ratio (if the *CT Ratio* selection is displayed), or toggles the ***No CT*** selection to the *CT Ratio* selection (i.e., enables the use of a previously entered CT ratio). If the user selects to alter the CT ratio, then this is achieved by using the numeric keys. If the user presses the *CLEAR* key prior to pressing any other numeric key, then this toggles the selection back to the *No CT* selection. The numeric entry portion of the displayed CT Ratio (if present) shows whether the selected CT is of the current or voltage output type. The user may terminate the numeric entry of a CT ratio by using the *ENTER* key (this leaves the previously selected CT type unchanged), the *Vrms* key (this selects the voltage output type), or the *Arms* key (this selects the current output type). The entry selected for the CT ratio should be the A rms required at the input of the CT to produce an output of either 1A rms (current output type) or 1V rms (voltage output type).

Clear PT&CT Entries

This disables the usage of PT and CT ratios for the selected channel.

Setup Channel B

The actions following this selection are the same as for the *Setup Channel A* selection described above.

Setup Channel C

The actions following this selection are the same as for the *Setup Channel A* selection described above.

System Configuration

3-phase 3-wire

This automatically sets the channels for typical 3-Φ 3-wire operation.

3-phase 4-wire

This automatically sets the channels for typical 3-Φ 4-wire operation.

Detailed Setup

Setup Channel A

Output Wire Group or *Input Wire Group*

This selection increments this digit. This is the 1st digit of the MIB code described in the preceding SYSTEM CONFIGURATION Chapter.

Phase

This selection increments this digit. This is the 2nd digit of the MIB code described in the preceding SYSTEM CONFIGURATION Chapter.

Unit

This selection increments this digit. This is the 3rd digit of the MIB code described in the preceding SYSTEM CONFIGURATION Chapter.

Setup Channel B

The actions following this selection are the same as for the *Setup Channel A* selection described above.

Setup Channel C

The actions following this selection are the same as for the *Setup Channel A* selection described above.

Configure Interfaces

IEEE488 Address or *RS232 Baud*

This either allows numeric entry of the desired IEEE Address (option IE) or toggles the RS232 Baud Rate (option **RS**) among those available.

Setup Analog Output

This enables the selection or display of the data source & parameter, and the Zero and Span levels for each output of option AN. When completed, the user should press the *SYSTEM* key to return to normal operation.

Analog Output : Ch

This increments the selected analog output channel number.

Source

This selection allows the user to change the selected data source and parameter.

Cancel

This selection discards any change made, and returns to the previous menu.

Source :

This changes the selected data source. The user also may press any of the *DATA SOURCE* keys to alter this item.

Data :

This changes the selected data parameter. The user also may press any of the *DATA PARAMETER* keys to alter this item.

Zero :

This enables the user to enter the desired zero offset for the selected channel. This is achieved using the numeric keys, and terminated by pressing the *ENTER* key. When the selected data source parameter has this value, the respective analog output channel will have a zero output level.

Span :

This enables the user to enter the desired span for the selected channel. This is achieved using the numeric keys, and terminated by pressing the *ENTER* key. When the selected data source parameter is offset by this value from the *Zero* level, the respective analog output channel will have a full-scale output level (either positive or negative dependent on whether the data source parameter is larger than or smaller than the *Zero* level).

Setup Rear Control

Effect :

This toggles the displayed selection between those available. The *None* selection causes the rear panel **CONTROL** input to have no effect on the operation of the instrument. The ***Accum*** selection causes the instrument to be in the Accumulation mode of operation when the rear panel input is in its active state. The ***Run*** selection causes the instrument to make normal measurements when the rear panel input is in its active state, and to be in the Hold state when in its inactive state.

Active :

This toggles the display between the *Closed* and *Open* selections. This shows the state of the rear panel **CONTROL** input during which the selected action takes place.

12.4.5. *HARM* Key

This key enables the user to configure THD, Harmonic and Spectrum analyses, and enables the user to display harmonic or spectrum analysis detailed results. The usage of this key is only enabled in **2501H**, **2502H** and **2503H** instruments.

The selections available after pressing this key are as follows (in a similar format to that used to show the *SYSTEM* key)

Configure Analysis

Channel A

Analyzing

Selecting this choice toggles the display between the *AUTO* and *ALWAYS* selection. When the *AUTO* selection is used, the instrument only performs the analysis when required (i.e. when displaying analysis results). When the *ALWAYS* selection is used the instrument always performs the analysis. It is recommended that the *AUTO* selection is used, as the analysis results in slower measurements.

Max THD Harmonic :

Selecting this choice enables the user to enter the effective bandwidth of the displayed THD data. This is entered using the numeric keys. The number entered limits the THD computation to using this number of harmonics, e.g., if 5 were entered then the displayed THD data would use the 2nd through the 6th harmonics inclusive.

Freq Increment

Selecting this choice toggles through the available frequency increments for the analysis. Selecting *AUTO* enables the instrument to automatically set the frequency increment to ¼ of the fundamental frequency, this is recommended when THD data or detailed harmonic analysis is required. Selecting a fixed frequency increment forces the use of the selected increment, this is recommended for detailed spectrum analysis but may be incompatible with accurate THD results.

Channel B

The actions following this selection are the same as for the *Channel A* selection described above.

Channel C

The actions following this selection are the same as for the *Channel A* selection described above.

Display Harmonics

Channel A

This selection enables the user to display detailed data regarding the harmonic content of the voltage, current and power signals for channel A. While this data is displayed, the user can change the displayed harmonic by pressing the uppermost *SELECT* key and then using the numeric keys to enter the desired harmonic number. Pressing any of the three other *SELECT* keys toggles the displayed data between a display of the absolute quantity and phase, and a display of the percentage (and relative dB) relative to the fundamental data.

Channel B

The actions following this selection are the same as for the *Channel A* selection described above.

Channel C

The actions following this selection are the same as for the *Channel A* selection described above.

Display Spectrum

Channel A

This selection enables the user to display detailed data regarding the spectral content of the voltage, current and power signals for channel A. While this data is displayed, the user can change the displayed frequency by pressing the uppermost *SELECT* key and then using the numeric keys to enter the desired frequency (in Hz). Pressing any of the three other *SELECT* keys toggles the displayed data between a display of the absolute quantity, and a display of the percentage (and relative dB) relative to the fundamental data (if available).

Channel B

The actions following this selection are the same as for the *Channel A* selection described above.

Channel C

The actions following this selection are the same as for the *Channel A* selection described above.

12.4.6. *STORE* Key

Pressing this key enables the user to store the complete configuration (including the source and parameter for each display line) in one of three storage areas. The user may select the storage area to be used by pressing either the key next to the displayed storage area choice, or by pressing the ***0, 1*** or **2** keys.

It should be noted that storage area 0 is used as the power-on configuration for the instrument.

12.4.7. *RECALL* Key

Pressing this key enables the user to recall a complete configuration (including the source and parameter for each display line) from one of three storage areas. The user may select the storage area to be recalled by pressing either the key next to the displayed storage area choice, or by pressing the ***0, 1*** or **2** keys.

12.4.8. *OPT.A* Key

This key initiates the selection of the printout format when option PR is fitted. The user is referred to the relevent section of the next chapter for more information concerning this option.

12.4.9. *OPT.B* Key

This key is reserved for future use, and is disabled in standard instruments at this time.

12.5. *ACCUMULATE* Key

This key toggles the "Accumulate" mode of operation of the instrument. The LED immediately above this key is illuminated when in the "Accumulate" mode. Starting an accumulation (i.e., pressing this key, or changing the state of the rear panel **CONTROL** input) clears all accumulated parameters automatically. Accumulation parameters may be displayed during an accumulation and are maintained at their final values when the accumulation is terminated. This function also may be controlled by the rear panel CONTROL input, in which case this key becomes inactive.

It should be noted that, although accumulation parameters are held when the accumulation is terminated, the displayed data will not be updated until the end of the measurement period in progress at that time.

12.6. *HOLD* Key

The use of this key enables the user to "hold" the parameter database at the values present at the time at which the "hold" state is commanded. It should be noted that this includes any "accumulation" that may be in progress. The LED above this key is illuminated when the instrument is in this "hold" state. This function also may be controlled by the rear panel CONTROL input, in which case this key becomes inactive.

12.7. *CALIBRATE* Key

This key enables the user to perform an Internal Calibration of internal DC offset errors and a check of proper operation of the instrument, or an External Calibration of the instrument. The user is referred to the **CALIBRATION** Chapter for details regarding performing these functions.

12.8. OVERLOAD Indicators

These indicators, located in the center of the front panel, toward the bottom edge, are illuminated whenever an overload condition exists on the identified input (either *V* or *I*) and the identified channel. During this condition, the instrument also "beeps" each measurement period.

These indicators are illuminated if the peak capability of the selected range (or the highest range if autorange is selected) has been exceeded. Often, this shows that the displayed measurement data is invalid, and probably shows that a potentially damaging input signal is present.

For overloads on the current inputs, the RMS input level is checked continuously against the highest allowable limit for the current shunt being used internally. If the RMS level exceeds what the shunt can withstand for that period, then any "forced" ranging is overridden automatically and a higher capability shunt selected. During this "gross" overload condition the instrument will continuously "beep".

WARNING

If the application requires holding a low full-scale current range, then it is HIGHLY RECOMMENDED that the user becomes fully conversant with the method used to command autorange, and that this is performed if the respective OVERLOAD LED on the front panel becomes illuminated (the instrument also will "beep" during this condition).

13. DETAILED FRONT PANEL OPERATION

The previous chapter showed, in detail, the operation of each key on the front panel. This chapter details the operation of these keys in performing specific operations.

When the user has obtained the best configuration for the application, then this should be stored in a configuration storage location accessed by the *STORE* key described in the preceding chapter. If this is not performed, then the configuration will be lost when power is removed from the instrument.

13.1. Selecting the Displayed Data

The *2501/2/3* family has a four line display, each line of which may display any measured (or computed) parameter. Generally, data is displayed as one data item per line of the display. Voltages and currents are displayed on the same line. Changing the data displayed on any particular line is accomplished by using the *DISPLAY PARAMETER SELECTION* keys on the front panel.

❶ **Select the display line to change.**

Press the key located immediately next to the selected display line. The display now shows the details pertinent to the selected display lines present data.

❷ Select the parameter to display.

Press any of the data parameter keys or the *EFF* or *LOSS* keys. The data parameter keys are contained in the central portion of the DATA PARAMETER SELECTION section of the keyboard. If either the *EFF* or *LOSS* key is selected then neither bandwidth nor a data source is required and the user may complete the entry by selecting the *Done* choice.

❸ Select the bandwidth for the selected parameter, if required.

Press the key next to the desired bandwidth.

❹ Select the source for the selected parameter.

This is achieved by using the *Ch A, Ch B, Ch C, TOTAL, INPUT* or *OUTPUT* keys.

The *Ch A, Ch B* and *Ch C* keys select that the previously selected parameter from channel A, B or C (respectively) is to be displayed.

The action of the *TOTAL, INPUT* and *OUTPUT* keys are dependent on the selected configuration of the instrument.

❺ Complete the selection.

Select the *Done* choice.

No following sub-sections detail each individual data parameter choice, and describes the method by which the instrument derives the data.

13.1.1. *Vrms* & *Arms* (True RMS Voltage & Current) Parameters

These parameters both result in a display of both parameters on the same line. The user has a choice of the true RMS DC Only, AC Only or the total AC+DC content of the input waveforms for the selected channel. This data is generally only available from individual internal channels (see below for the exception to this).

The DC Only and total AC+DC data are directly obtained from the input waveforms by real time computation. The AC Only component is mathematically derived from these. It should be noted that only the DC Only data has an associated polarity.

If the *Arms* parameter is selected from the ***GROUP*** data source then the "remnant" current is displayed and the result is the total AC+DC content. The calculation of this parameter is dependent on the configuration of the constituents of the group, refer to the **SYSTEM CONFIGURATION** Chapter earlier in this manual for details regarding this computation.

13.1.2. *W* (True Power) Parameter

When selecting this parameter the user has a choice of the DC Only, AC Only or the total AC+DC content. This data is available from all sources. This data always has an associated polarity, independent of frequency content or data source.

For each individual channel, the total AC+DC content of power is directly obtained from the input voltage and current waveforms by real time computation. The DC Only component is simply the multiplication of the DC Only voltage and current components. The AC Only component of power is the subtraction of the DC Only component of power from the total AC+DC power.

For multi-channel totals (i.e., ***GROUP, INPUT*** or ***OUTPUT***) these data are the summation of the group(s) data.

13.1.3. *VA* (Apparent Power) Parameter

When selecting this parameter the user has a choice of the DC Only, AC Only or the total AC+DC content. This data is available from all sources.

For individual internal channels this data is computed by the multiplication of the relevant *Vrms* and *Arms* parameters. It should be noted that only the DC Only data has an associated polarity.

For multi-channel totals there are many different definitions in use at this time. The definition used by Xitron Technologies is the normally accepted one defined by

$$VA^2 = (\Sigma W)^2 + (\Sigma VAR)^2$$

Thus multi-channel total VA is derived from multi-channel total W and VAR data. Multi-channel VA has no associated polarity.

13.1.4. *VAR* (Reactive Power) Parameter

This parameter is available from all sources and has no associated frequency content (in reality it is only applicable to AC Only signal content).

Individual internal channel data is computed from the computed AC Only VA and W data using the equation :

$$VAR^2 = VA^2 - W^2$$

The polarity of the result is determined by whether the channel has a leading or lagging power factor.

Multi-channel total data is obtained by summing the individual channel data (respecting the individual channel data polarities).

13.1.5. *PF* (Power Factor) Parameter

This parameter is available from all data sources and the user has a choice of this parameter derived from the AC Only or AC+DC content of the input signals. It should be noted that DC Only input signals always have a power factor of 1.

This parameter is computed from the division of the relevant W data divided by the relevant VA data.

This data also has an associated *LEADING* or *LAGGING* indication. For individual internal channels this is derived by a proprietary real time computation technique which yields a correct indication with distorted waveforms (unlike the "zero crossing" technique employed by many instruments). For multi-channel totals this indication is derived from the polarity of the total VAR and total W data.

13.1.6. *PHASE* Parameter

There are two types of parameter accessed by this key.

Effective Phase

This parameter is computed from the relevant PF parameter (including the LEADING or LAGGING indication), being the inverse cosine of that data. This has a choice of AC Only or AC+DC signal content, and is available from all data sources.

Inter-Channel Phase

This parameter is available between channels A and B (not **2501** or **2501H**) or between channels A and C (**2503** and **2503H** only) and is computed using real time computation techniques.

13.1.7. *Hz* (Frequency) Parameter

This parameter is only available for individual internal channels. This is computed by counting the number of input cycles during each measurement period, and dividing the result by the actual measurement period. Normally this is the frequency of the voltage waveform on the selected channel. If that channel has been selected to synchronize to its current waveform, then this data is the frequency of the current waveform.

13.1.8. *W Pk* (Peak Instantaneous Power) Parameter

This parameter is only available for individual internal channels. This is computed in real time by maintaining the highest deviation from zero of the instantaneous V*A data during each measurement period.

13.1.9. *V Pk* & *A Pk* (Peak Instantaneous Voltage & Current) Parameters

These parameters result in the display of both parameters on the same line. These parameters are only available for individual internal channels. These are computed in real time by maintaining the highest deviation from zero of each signal during each measurement period.

13.1.10. *V CF* & *A CF* (Voltage & Current Crest Factor) Parameters

These parameters result in the display of both parameters on the same line. These parameters are only available for individual internal channels. These are computed as *V Pk / Vrms* and *A Pk / Arms* respectively.

13.1.11. *Pk Vrms* & *Pk Arms* (Highest RMS Voltage & Current) Parameters

These parameters both result in a display of both parameters on the same line, and are the highest recorded *Vrms* and *Arms* parameters respectively, during an accumulation. The same frequency content and data sources apply as for the *Vrms* and *Arms* parameters respectively. The *Pk Arms* parameter is effectively peak demand data. These data are automatically reset when an accumulation is initiated, and held when an accumulation is terminated. These parameters are also reset following application of power to the instrument.

13.1.12. *Pk W* (Highest True Power) Parameter

This parameter is the highest recorded *W* parameter during an accumulation. The same frequency content and data sources apply as for the *W* parameter. This parameter is effectively peak demand data, and is automatically reset when an accumulation is initiated, and held when an accumulation is terminated. This parameter is also reset following application of power to the instrument.

13.1.13. *W Hr, VA Hr & VAR Hr* Parameters

These parameters are the computed integrated values of the relevant W, VA and VAR parameters over time (in hours) during an accumulation. The same frequency content and data sources apply as for the ***W, VA*** and ***VAR*** parameters respectively. These data are automatically reset when an accumulation is initiated, and held when an accumulation is terminated. These parameters are also reset following application of power to the instrument.

13.1.14. *Wavg, VAavg & VARavg* Parameters

These parameters are the computed averaged values of the relevant W, VA and VAR parameters during an accumulation. The same frequency content and data sources apply as for the ***W, VA*** and ***VAR*** parameters respectively. These data are automatically reset when an accumulation is initiated, and held when an accumulation is terminated. These parameters are also reset following application of power to the instrument.

13.1.15. *VTHD & ATHD* (Voltage & Current Distortion) Parameters

These data are only available in **2501H, 2502H** and **2503H** instruments, and are only available from individual internal channel data sources.

These Total Harmonic Distortion data are computed from the relevant Fast Fourier Transform results using the frequency step and number of harmonics specified by the user. The result is displayed as both a percentage of the fundamental amplitude and in decibels.

13.1.16. *LOSS & EFF* (Power Loss & Efficiency) Parameters

These data are only meaningful when channels exist in the INPUT and the OUTPUT groups of channels.

Power Loss is computed as the result of the subtraction of the ***OUTPUT W*** total from the ***INPUT W*** total. Efficiency is computed as the percentage result of dividing the ***OUTPUT W*** total by the ***INPUT W*** total.

13.2. *LOCKED* and *UNLOCKED* Channels

This section is not applicable to the **2501** and **2501H** instruments.

13.2.1. Advantages & Disadvantages

In most applications all of the internal channels of the instrument are used for essentially the same purpose, i.e. measuring different phases of the same supply system, connected to the same load system. In these applications it is of benefit to ensure that all channels are measuring during the same periods of time, on the same range, and using the same measurement configuration.

The benefits from *LOCKING* the channels together in this way are as follows :

❶ Peak data (*V Pk, A Pk* and *W Pk*) are collected during the same period, and thus can be correlated.

❷ The user only has one channel to configure, thus simplifying the task of changing the configuration.

❸ The user cannot be accidentally measuring a different phase of a supply (or load) with differing bandwidths.

❹ Multi-channel totals are only updated once per measurement cycle, rather than each time a single channel has data available. This results in a higher throughput of data, which is of benefit in automated systems.

When the channels are being used independently however, it is usually beneficial to *UNLOCK* the channels. This allows the user to separately configure each channel specifically for the measurements to be performed.

An example of this situation is where one channel is measuring the input to a line voltage to high frequency power convertor (e.g., an electronic lighting ballast). Here it is advantageous to limit the bandwidth of the input channel to some low frequency (usually 20KHz) and to select a slower (e.g., 1 second) measurement period to reduce the effect of short term variations in supply voltage. Also when measuring at these lower frequencies it is advantageous to synchronize the measurement period to the input voltage waveform to eliminate errors due to the supply frequency. This configuration is not suitable for the channel measuring the output however. The bandwidth limit probably introduces significant error, a faster measurement period can usually be used, and synchronization is not required at these high frequencies (usually in excess of 25KHz). In these cases the user should *UNLOCK* the channels.

13.2.2. *LOCKING* Channels to Channel A

❶ Press the *SYSTEM* Key.

❷ Select the ***Configure Channels*** choice.

❸ Select the ***More*** choice.

❹ If the channel to be *LOCKED* to channel A is displayed as *UNLOCKED* then selecting that display line will toggle the selection.

❺ When the channel(s) to be *LOCKED* to channel A have been set, press the *SYSTEM* key.

If the default settings (described in the GETTING STARTED - STANDARD APPLICATIONS Chapter) are acceptable then selecting the *QUICK* Key provides a fast alternate method of *LOCKING* all channels to channel A.

13.2.3. UNLOCKING Channels from Channel A

❶ Press the SYSTEM Key.

❷ Select the *Configure Channels* choice.

❸ Select the *More* choice.

❹ If the channel to be *UNLOCKED* from channel A is displayed as *LOCKED* then selecting that display line will toggle the selection.

❺ When the channel(s) to be *UNLOCKED* from channel A have been set, press the *SYSTEM* key.

13.2.4. Synchronizing Channels to Channel A

If the user wishes to have the speed and synchronization benefits of *LOCKING* to channel A, but desires individual control of configuration then this is also achievable by setting the channel to be *UNLOCKED* to channel A as described above, and then selecting *Ch A* for the Input *Synch :* choice in that channels configuration menu. This action will synchronize the measurements the same as *LOCKING* to channel A, but allows individual configuration control.

❶ Press the *SYSTEM* Key.

❷ Select the *Configure Channels* choice.

❸ Select the *More* choice.

❹ Select the *More* choice.

❺ Select the channel to be configured.

❻ Repeatedly select the *Synch :* selection (the top line) until *Ch A* is displayed.

❼ Press the *SYSTEM* Key.

13.3. Setting up for use with CTs or PTs

The 2501/2/3 family can measure over a wide range of voltages and currents, however some applications require measurements outside these ranges. In these cases the user may use PTs or CTs (or both). The 2501/2/3 family allows the use of these with the user providing a numeric scale factor that is used in converting the measured input into the actual quantity.

13.3.1. CT (Current Transformers) or Current Shunt Selections

The 2501/2/3 family of instruments can accept the output of either CT type devices (with current output) or current shunt type devices (with a voltage output). The configuration of a channel for use in this manner is accomplished as described below. It should be noted that the instrument allows for separate configuration of each channel, even if the channels are otherwise *LOCKED* to channel A.

❶ Press the *SYSTEM* Key.

❷ Select the *Configure Channels* choice.

❸ Select the *Setup PTs & CTs* choice.

❹ 2502, 2502H, 2503 and 2503H ONLY. Select the channel to be configured.

❺ If the display shows *No CT*. Select the display line with the *No CT* data (the 2nd line).

❻ Select the display line with the *CT Ratio* data (the 2nd line).

❼ Enter the desired conversion ratio for the CT being used. Terminate the entry by pressing either the *Arms* key (for a current output CT) or the *Vrms* key (for a voltage output CT or current shunt).

❽ Terminate the entry by pressing the *SYSTEM* Key.

The required CT conversion ratio should be the input current to the CT which causes an input to the instrument of 1A or 1V (dependent on the type). If the device is a current shunt, then it should be noted that this data is the conductance of the shunt (i.e. 1 / Resistance). Sometimes, the CT is specified in terms of a particular input current and a particular output current/voltage (e.g., 500A : 5A or 200A : 200mV). In these cases, the user should divide the specified input current by the specified output level (in Amps or Volts), in the examples shown this would result in entries of 100.0A : 1A and 1000A : 1V respectively.

The user may note that the **2501/2/3** family allows the user to enter this data with 1 part in 100,000 resolution. This can be used to enhance the accuracy of the CT by adjusting the entered scaling factor for any known calibration factors.

13.3.2. PT (Potential Transformer) Selection

The configuration of a channel for use in this manner is accomplished as described below. It should be noted that the instrument allows for separate configuration of each channel, even if the channels are otherwise ***LOCKED*** to channel A.

❶ Press the *SYSTEM* Key.

❷ Select the *Configure Channels* choice.

❸ Select the *Setup PTs & CTs* choice.

❹ **2502, 2502H, 2503 and 2503H ONLY.** Select the channel to be configured.

❺ If the display shows *No PT*. Select the display line with the ***No PT*** data (the top line).

❻ Select the display line with the ***PT Ratio*** data (the top line).

❼ Enter the desired conversion ratio for the PT being used. Terminate the entry by pressing the *ENTER* key.

❽ Terminate the entry by pressing the *SYSTEM* Key.

The required PT conversion ratio should be the input voltage to the PT which causes an input to the instrument of 1V. Sometimes, the PT is specified in terms of a particular input voltage and a particular output voltage (e.g., 50KV : 250V). In these cases, the user should divide the specified input voltage by the specified output voltage, in the example shown this would result in an entry of 200V : 1V.

The user may note that the **2501/2/3** family allows the user to enter this data with 1 part in 100,000 resolution. This can be used to enhance the accuracy of the PT by adjusting the entered scaling factor for any known calibration factors.

13.3.3. Deselecting CTs or PTs

This is achieved as follows :

❶ Press the *SYSTEM* Key.

❷ Select the *Configure Channels* choice.

❸ Select the *Setup PTs & CTs* choice.

❹ **2502, 2502H, 2503 and 2503H ONLY.** Select the channel to be configured.

❺ If the display shows that either a CT or PT is configured and it is not wished to use a PT or CT, then continue below, otherwise the instrument is already correctly configured and the user should press the *SYSTEM* key to exit this menu.

❻ Select the *Clear PT&CT Entries* choice. This will clear both the CT and PT entries. The user need not be concerned about loosing a desired ratio, this is not affected and may be retrieved by selecting the CT or PT choice.

13.4. Selecting an Input Filter, Measurement Period & Synchronization

The effective bandwidth of the **2501/2/3** instruments without filtering is typically in excess of 5MHz, which may be in excess of the users' requirements. This may result in the measurement of unwanted signals such as line borne noise and local AM radio stations.

The default measurement period of 0.5 seconds is suitable for most applications. Sometimes, the user may wish to either shorten this period (e.g., for computer monitoring of high frequency supplies), or lengthen this period (e.g., to obtain increased filtering of short-term variations). Refer to the MEASUREMENT TECHNIQUES Chapter for further information on this subject.

When operating from low frequency sources (typically below 1KHz) the measurement period may be adjusted such that an integer number of voltage input cycles are measured. Alternatively, when operating from high frequency sources with little low frequency content the measurement may be unsynchronized from the voltage waveform. Also, as previously discussed, when a channel is operating *UNLOCKED* from channel A it may still be advantageous to synchronize its' measurement period to that of channel A. It should be noted that operating a channel with Voltage or Current synchronization enabled, but with no measurable waveform frequency, will cause the measurement period to be extended by up to 0.3 seconds.

As previously mentioned, channels may be *LOCKED* to channel A. Here only channel A need be configured. Alternately, any channels that are *UNLOCKED* to channel A will need to be separately configured.

❶ Press the *SYSTEM* key.

❷ Select the *Configure Channels* choice.

❸ Select the *More* choice.

For a **2501** or **2501H** instrument the user should proceed from step ❻.

❹ Press the *More* choice.

❺ In any channels remain *UNLOCKED* from channel A, then select the channel to be configured.

❻ Selecting the ***Filter*** choice toggles the display between the available filters. The low-pass filters are for applications where the signal contains significant unwanted high frequency content. The band-pass filters are for 50/60Hz line (the 120Hz to 5KHz filter) or 400Hz line (the 800Hz to 10KHz filter) distortion measurements without using the Harmonic Analysis capabilities (if fitted). The ***None*** choice should be used when it is known that high frequency response in excess of 20KHz is required. The 50Hz low pass filter should be used if automatic synchronization to frequencies below 10Hz is required.

❼ Press the *SYSTEM* key to return the instrument to normal operation.

13.5. Selecting Input Measurement Range Controls

In most applications, the use of the autoranging capabilities of the instrument is recommended. When the user requires fast measurement of inrush currents (for example) the user may wish to "force" the use of a high range to eliminate the time required for the instrument to select this range at the onset of the inrush. This also may be desirable when performing a computer controlled test sequence where the expected current or voltage level is known for each step in the test sequence (thus saving autoranging time).

❶ Press the *RANGES* key.

The instrument now displays the present ranges being used and the autorange status, for the voltage and current inputs on each channel. Autorange is shown by means of a * character displayed next to the relevant range value. Any inputs that have been configured as having a PT or CT are also denoted.

This key may be used as a "quick" check of the ranging and PT/CT status of the measurement channels, the display showing all these details for all channels (unless ***LOCKED*** to channel A). Here, pressing the ***RANGES*** key a second time will return the instrument to normal operation.

2501 or **2501H** only. Proceed from step ❸.

❷ With channels B and C (channel B only in a **2502** or **2502H**) ***LOCKED*** to channel A, these channels use the same ranges as channel A, thus only channel A range information is displayed here. If these channels are *UNLOCKED* from channel A then the user can individually select ranges for each channel. Select the channel range data to be changed.

❸ Either select the voltage range data, or the current range data, whichever is to be altered.

❹ Selecting the *Auto* or *Held* choice toggles the selection. *Auto* shows that the selected input is enabled to autorange, *Held* indicates that the selected input is "forced" to use the displayed range.

Selecting the *Uprange* or *Downrange* choices, changes the range to the next higher or lower range respectively, and "forces" the use of this range.

❺ The user can now either select the *Previous* choice to return to the previous menu choices, or press the *RANGES* key to return to normal operation.

WARNING

Selecting a low full-scale current range, and then passing a high current into that input may cause significant internal damage to the instrument. Although these instruments possess internal overload protection schemes, these should never be totally relied upon to save the instrument. It is the responsibility of the user to ensure that a safe ranging condition is present always.

If the application requires holding a low full-scale current range, then it is HIGHLY RECOMMENDED that the user becomes fully conversant with the method used to command autorange, and that this is performed if the respective OVERLOAD LED on the front panel becomes illuminated (the instrument also will "beep" during this condition).

RANGE "HUNTING"

Under some circumstances (usually when the instrument is measuring the input power to a direct line rectification system with active power factor correction circuitry) it has been found that the ranging system of the 2501/2/3 instrument interferes with active feedback loops within the instrument under test. The user should "hold" the highest range (i.e. the 20A range) while initially applying power, and then enable autoranging or select a lower range when the system has settled to a steady state condition. It is HIGHLY RECOMMENDED to use this procedure when applying power to systems having these characteristics. This "interference" effect can be readily noted by the instrument continually selecting different current shunts, and the resultant relay selections being audible as "clicks" emitted from the instrument.

13.6. Performing Harmonic or Spectral Analyses

This section is only applicable to the **2501H**, **2502H** and **2503H** instruments.

The user should note that both harmonic and spectral analysis of the input waveforms are available in this instrument. This means that the user may investigate either the actual harmonic content of the input signals, or may finely investigate the frequency (including non-harmonic) contents of these signals. The methods used in these analyses are slightly different, but the overall methods used to obtain these data are very similar. The user should use the correct analysis method for the particular application as inappropriate results can be obtained by an improper configuration for the analysis performed.

13.6.1. Obtaining Total Harmonic Distortion

The method of displaying the voltage and current total harmonic distortion data (*V THD* and *A THD*) was previously described in this chapter. To recap, the user should select the display line to display the data, select the channel to be measured (the *Ch A, Ch B* or *Ch C* data source keys) and then select the input to be measured (the *V THD* or *A THD* data parameter keys). This section describes how to configure the instrument prior to displaying the desired THD.

❶ Press the *HARM* Key

❷ Select the *Configure Analysis* choice.

❸ **2502H** and **2503H** only. Select the channel to configure.

❹ Repeatedly select the *Analyzing* choice, until *AUTO* is selected. The *ALWAYS* choice may be used if consistent timing is desired between when analysis results are displayed and when they are not, or if analysis results are required from an interface.

❺ Select the *Max THD Harmonic* choice and, using the numeric keys, enter the desired highest harmonic to include in the displayed resultant THD data. As an example, selecting *15* configures the selected channel such that the displayed THD data contains the 2nd through the 15th harmonics inclusive. The numeric entry is terminated by pressing the *ENTER* key. Altering this number may have considerable affect on the displayed THD data, the user should ensure that the correct data is used here. If the user is using the instrument to perform tests to IEC555, then the user should refer to the latest version for details (at the time of writing IEC555.2 was not completed regarding this data).

❻ Repeatedly select the *Freq Increment* choice until *AUTO* is selected.

❼ Press the *HARM* Key to complete the entry and return the instrument to normal operation.

The user should use an internal digital filter having an upper frequency above that of the highest harmonic of interest, as this will eliminate the slight errors caused by any significant noise at these frequencies.

Also note that the displayed THD data is relative to the amplitude of the fundamental signal content and not the overall signal content. Thus percentages in excess of 100% are possible.

13.6.2. Inspecting Individual Harmonic Content of the Input Signals

Besides providing the user with a configurable bandwidth THD computation, the user also may individually inspect the voltage, current and power content at any harmonic of the input signals for any channel. This is configured as shown in the preceding section, and is displayed as shown below.

❶ Press the *HARM* Key.

❷ Select the ***Display Harmonics*** choice.

❸ **2502H** and **2503H** only. Select the channel for which the data is to be displayed.

The instrument now displays the True RMS amplitude and phase data for the fundamental frequency content of the voltage and current waveforms, the frequency of the fundamental component, and the True Power (W) and Reactive Power (VAR) components. The user may select these display lines (using the adjacent keys) to alter the displayed data as follows.

❶ **1st Line / Harmonic Number and Frequency Data.** Selecting this line allows the user to enter the harmonic number of interest using the numeric keys and terminating the entry by the *ENTER* key. It should be noted that, as conventionally notated, the fundamental is the 1st harmonic. If, after entering the desired harmonic number, the frequency is displayed as 0.0Hz, then the requested harmonic data was not available due to upper frequency limitations (170KHz or 254th harmonic).

❷ **2nd Line / Voltage Amplitude and Phase Data.** Selecting this line toggles the display between the actual amplitude and phase data, and the percentage and dB amplitude data relative to the amplitude of the fundamental. This selection is only valid when a measurable fundamental frequency was encountered.

❸ **3rd Line / Current Amplitude and Phase Data.** Selecting this line toggles the display between the actual amplitude and phase data, and the percentage and dB amplitude data relative to the amplitude of the fundamental. This selection is only valid when a measurable fundamental frequency was encountered.

❹ **4th Line / Power and VAR Data.** Selecting this line toggles the display between the actual Power and VAR data, and the percentage and dB power data relative to the power of the fundamental. This selection is only valid when a measurable fundamental frequency was encountered. The user should note the following points regarding this data :

The data is applicable to the power and VAR generated by the voltage and current signals having the requested harmonic. The actual frequency of the power waveform is twice this frequency.

The dB data is computed using the normally accepted method for ratios, i.e. 10% is -20dB, and not the method normally used in HF power where 10% would be -10dB.

The display may be returned to normal by pressing the *HARM* key.

13.6.3. Inspecting the Spectral Content of the Input Signals

At first sight the investigation of spectral content may appear the same as harmonic content. While the user may view some aspects of spectral content using the same configuration as previously described for harmonic analysis, these instruments also offer the user the ability to view details in the spectral (i.e. non-harmonic) content of these signals.

The difference between these analyses are as follows :

❶ The analysis makes no assumptions regarding the frequency or phase relationship between the selected display data and the fundamental signal. In fact the signal need not even contain a fundamental signal content.

❷ The user may select a fixed frequency step for the analysis, rather than an automatically produced step, related to the frequency of the fundamental. Thus the user has control over the spread of frequencies covered by the analysis.

The difference in the configuration is solely in the choice selected for the *Freq Increment* selection.

❶ Press the *HARM* Key

❷ Select the ***Configure Analysis*** choice.

❸ **2502H and 2503H only.** Select the channel to configure.

❹ Repeatedly select the ***Analyzing*** choice, until ***AUTO*** is selected. The ***ALWAYS*** choice may be used if consistent timing is desired between when analysis results are displayed and when they are not, or if analysis results are required from an interface.

❺ Repeatedly select the ***Freq Increment*** choice until the desired frequency increment is displayed. The available range of spectral data is from this frequency to a maximum of 1021 times this frequency (or 170KHz, whichever is lower). The AUTO selection (used for harmonic analysis) also may be used, in which case the frequency increment will effectively be ¼ of the fundamental frequency (or 156Hz, whichever is lower) if a fundamental frequency can be established (or 39Hz if not).

❻ Press the *HARM* Key to complete the entry and return the instrument to normal operation.

Displaying spectral content is the same as displaying individual harmonic data, except that the ***Display Spectrum*** choice is selected, i.e., press the *HARM* Key, select the ***Display Spectrum*** choice and select the channel.

When displaying spectrum data, the display is different from that when displaying harmonic data. The displayed data and the effects of selecting each display line are as follows while displaying spectrum data :

❶ **1st Line : Frequency Data.** This is the frequency of the displayed spectrum data. Selecting this line allows the user to select, by using the numeric keys and the *ENTER* key, another frequency to display. The effective bandwidth of the displayed amplitude data is given by the frequency increment.

❷ **2nd Line : Voltage Data.** This is the True RMS Voltage at the desired frequency. Selecting this line, when a fundamental frequency component has been established, toggles the displayed data between this data and the percentage and dB ratio of this data to the amplitude of the fundamental component.

❸ **3rd Line : Current Data.** This is the True RMS Current at the desired frequency. Selecting this line, when a fundamental frequency component has been established, toggles the displayed data between this data and the percentage and dB ratio of this data to the amplitude of the fundamental component.

❹ **4th Line : Power & VAR Data.** Selecting this line toggles the display between the actual Power and VAR data, and the percentage and dB power data relative to the power of the fundamental. This selection is only valid when a measurable fundamental frequency was encountered. The user should note the following points regarding this data :

The data is applicable to the power and VAR generated by the voltage and current signals having the requested frequency, the actual frequency of the power waveform is twice this frequency.

The dB data is computed using the normally accepted method for ratios, i.e. 10% is -20dB, and not the method normally used in HF power where 10% would be -10dB.

The display may be returned to normal by pressing the *HARM* key.

The following should be considered when evaluating spectral content :

❶ As discussed above, the bandwidth of each data is defined by the frequency increment. This may be defined to be such that significant non-harmonic content may contaminate measurements of the fundamental, even to the point where the 2nd or higher harmonics become included. The frequency step may, alternatively, be significantly higher than the actual fundamental frequency, precluding the measurement of this data totally.

❷ No "searching" for higher harmonic content is performed by the instrument. Thus attempting to manually "find" the content of the 200th harmonic of a 60Hz waveform (i.e. the content at 12KHz) may be difficult since a 1% change in the line frequency will cause a 120Hz shift in the frequency of this harmonic.

❸ When displaying harmonic content, the instrument has internal algorithms that automatically widen the effective bandwidth of displayed data for higher harmonics of signals having significant cycle to cycle frequency variance (e.g. standard line voltage). This is disabled when displaying spectral content, thus higher harmonics may appear as having less amplitude than during a harmonic analysis, but will have significant amplitude at more than one frequency.

❹ If the user displays (or interrogates using an interface) any THD data or individual harmonic data, while the instrument is configured with a fixed frequency increment (i.e. for a spectral analysis), then the resultant harmonic analysis results will be erroneous.

The user is referred to the following discussion of the advanced FFT techniques used in these instruments for more regarding these points.

13.6.4. Fast Fourier Transforms - A Brief Overview

The **2501H/2H/3H** family uses Fast Fourier Transform techniques to obtain the harmonic and spectral content of the input waveforms. A full discussion of these mathematical techniques is beyond the scope of this document. If the user is interested in more details, then college level mathematics textbooks on the subject can usually be found in most libraries and technical bookstores.

The following describes the basics of the technique (for the more mathematically inclined, this describes the "real" FFT method, not the full "complex" method).

If a signal is sampled at equally spaced time intervals, and each signal level is digitized, then the resultant set of digitized signals levels is mathematically operated on to produce half that number of real and imaginary amplitude pairs at equally spaced frequencies. The "classical" relationship between H_n (the n^{th} discrete Fourier transform result) and h_k (the discrete sampled data) is given by :

$$H_n = \sum_{k=0}^{N-1} h_k e^{2\pi ikn/N}$$

The frequency increment between each pair of amplitude results (i.e., real and imaginary data pair), is the inverse of the time step used in the digitized levels times the number of samples taken (i.e., the inverse of the overall measurement period). For example, if the input signal were digitized at 10µs increments, and 1000 samples were taken, then the resultant frequency step would be 1/10ms or 100Hz. Each of these resultant amplitude pairs is often called (as in this document) a *"frequency bin"*.

The phase relationship implied by the resultant real and imaginary data is the relationship of the particular frequency content of that *bin* to the overall measurement period.

At this point the technique appears to offer all that one could desire, unfortunately there are certain errors associated with the "real world" application of the technique. One major error source is that of *"frequency leakage"*. With only a finite number of sampled input data, the technique is unable to fully differentiate between signals in adjacent *frequency bins* and results in a signal having a pure single frequency content appearing to have a spectral content that is "smeared" over adjacent *bins*, with decreasing amplitude as the deviation from the actual *bin* increases. This effect is the similar to having FM noise. The effect of this is that many bins must exist between successive harmonics, otherwise over estimation of the harmonic content will result. A further error source is if the input signal period is not exactly an integer fraction of the overall measurement period. Here the actual frequency will not be centered within the respective *bin*, resulting in parts of the amplitude data being found in the adjacent *bins*, and the phase relationship also will be seriously affected. Both error sources can be considerably reduced by a mathematical technique called *"windowing"*, which is basically a method of manipulating the sampled input data. Within these instruments the type of *window* function used is often called a *"flat top window"*. This type of *window* function produces negligible amplitude error when the actual frequency content of the signal lies off the center of the *bin*, and produces a very fast attenuation of leakage into *bins* more than three or four from the center. These gains are achieved at the expense of vast leakage into the immediately surrounding *bins*.

To virtually eliminate all these effects, these instruments employ a proprietary post-FFT data manipulation technique that compresses the 8192 point FFT into a final data set having 1022 *frequency bins* with virtually no leakage and with the phase relationship of harmonically related signals being maintained, even if slightly off center.

13.6.5. Harmonic Analysis Techniques

When performing a Harmonic Analysis, the instrument "locks" the input sampling rate to the fundamental frequency content of the input waveform. This provides the user with stable phase correlation data between the voltage and current inputs of each channel and ensures that even the highest frequency harmonic is correctly positioned within the respective *bin*.

In practice, typical waveforms encountered in power waveforms do not have particularly stable frequency content, and thus there is an actual real leakage into adjacent *bins*. The effect of this is that the measurement of the fundamental and lower harmonics is not seriously affected, but the amplitude content of high harmonics tends to be spread among several *bins*. The overall affect of this is to understate the actual amplitude of higher harmonics. These instruments automatically overcome this problem by adjusting the effective bandwidth of each harmonic dependent on the amplitude data of the surrounding *bins* using a proprietary algorithm.

13.6.6. Spectrum Analysis Techniques

The mathematical techniques employed by these instruments when displaying a spectral analysis are very similar to those used during harmonic analysis, but the following difference should be noted :

❶ When displaying spectral content of the input signals, the user will normally select a fixed frequency increment. The instrument selects the corresponding period for sampling the input waveforms from this data rather than adjusting it as in the harmonic analysis. This shows that few (if any) major frequency components of the input signals will be found in the center of the *bins*.

❷ Although the 8192 point FFT is processed in the same manner, and the resultant frequency spectrum is post-FFT processed down to 1022 points (as is the harmonic analysis), the method used to reduce the spectrum is different.

In harmonic analysis, the reduction is carried out such that the integrity of the phase data is not lost and has allowance for recombining leakage that was not mathematically produced. This produces accurate amplitude and phase data at the harmonic frequencies at the expense of introducing some leakage in the resultant non-harmonic *bins*.

In spectrum analysis, the integrity of the phase data is not maintained, and no attempt is made to recombine leakage. This produces the expected result of correctly showing any spreading of high harmonics among several *bins*, but yields an apparent reduction in the amplitude at the expected exact harmonic frequency.

13.7. *HOLDING* Data

At the completion of every measurement cycle, all possible available data (except harmonic and spectral analysis data) are computed and stored. This takes place for each channel, and any totals affected by the channel are also updated. Because of this, the user may perform a measurement over a very short time (potentially as short as 0.05 second, practically down to 0.15 second) and then *HOLD* this data for retrieval or inspection at a slower rate.

This capability is important in applications where the power level being measured cannot be produced for lengthy periods of time (either for fiscal or safety reasons) and either -

a Several data are to be manually inspected, which may take longer than desired.

or

b A substantial amount of data is to be transferred by an interface, which may take longer than desired.

In either of these circumstances, the ability of the **2501/2/3** family to *HOLD* its' database of results provides a useful method of performing these tests. The sequence of events, and the timing required to perform them are detailed below :

❶ If not already achieved, release the 2501/2/3 from the HOLD state, and command the instrument to the desired ranges. Commanding the ranges is not required, but will save autorange delays following the time that the signals are initially applied.

❷ If ranges were commanded, delay for at least one measurement period plus 0.05s.

❷ Apply the signals to be measured.

❸ Delay for a time no shorter than one measurement period plus 0.01s. If the instrument is allowed to autorange, then this minimum period must be extended by 0.075s per range (note that this could be as long as 0.6s).

❹ Apply the HOLD command to the instrument.

❺ Delay for a time no shorter than one measurement period

❻ Remove the input signals from the instrument.

❼ Interrogate all of the required parameters.

❽ It is recommended that step 1 is repeated at this time.

13.8. Printing Data (Option PR only)

The printout option (option PR) enables the user to perform seven different styles of printout on a RS232 interfaced printer. The seven different styles are listed below :

1. A printout of the present data for a single channel.
2. A printout of both the present and the accumulated data for a single channel.
3. A printout of the total present data for a group of channels.
4. A printout of the total present and accumulated data for a group of channels.
5. A printout of the total present data for both the input and output groups of channels, with power loss and efficiency data.
6. A printout of the absolute voltage, current, power and VAR harmonics for a single channel.
7. A printout of the relative voltage, current and power harmonics (relative to the fundamental) for a single channel.

The RS232 may also be used for control of the instrument in the normal manner unless an IEEE488 interface is also fitted. If an IEEE488 interface is fitted, then this interface will be used for instrument control and the RS232 interface may only be used for printout purposes.

The user should note that the data that is printed is compiled at the moment that the printout is initiated. Thus the data throughout the printout is consistent and was captured at the same instant.

13.8.1. Configuring the Baud Rate

The user should select an appropriate baud rate on the printer as shown in the operating manual for the printer. The **2501/2/3** should then be set to the same baud rate as selected for the printer. This is achieved as follows :

1. Press the *SYSTEM* key. The display will show several choices of further action.
2. Select the *Configure Interfaces* choice (press the key next to the choice).
3. The information displayed is dependent on the interface configuration of your instrument. If there is no IEEE488 interface fitted, then the presently selected baud rate is displayed in the top line of the display. If an IEEE488 interface if fitted then *Setup IEEE or RS232* is displayed as a choice, select this choice and the presently selected IEEE address and the RS232 baud rate are displayed. If the displayed baud rate is correct, then press the *SYSTEM* key to return to normal operation.
4. If the displayed baud rate is not that desired, select this display line. The second line of the display now shows the presently selected baud rate, which may be changed by pressing the *SELECT* key next to the second line of the display until the desired baud rate is shown. The user should then select the *Done* choice.

13.8.2. Performing a Printout

Press the *OPT.A* key. The display now shows the presently selected data source and type of printout data. The selections for either the data source or printout type may be changed by pressing the *SELECT* key next to the respective line of the display. The available selections are as follows :

Data Source :

Ch A	The individual channel data for channel A will be printed.
Ch B	This selection is only available for a **2502** or **2503** instrument. The individual channel data for channel B will be printed.
Ch C	This selection is only available for a **2503** instrument. The individual channel data for channel C will be printed.
Σ	The total data for the group of channels of which channel A is a member will be printed.
Input	The total data for the group of channels that have been selected as monitoring input wire groups will be printed.

Output — The total data for the group of channels that have been selected as monitoring output wire groups will be printed.

I/O Data — This data is only available for a **2502** or **2503** instrument that has channel A configured as monitoring an input wire group and channel B configured as monitoring an output wire group. The total data for both the input and output wire groups will be printed.

Printout Type :

Basic — This selection selects that the presently measured (and optionally the accumulated) data for the selected data source will be printed.

Harmonic — This selection is only available when a single channel has been selected as the data source and if the instrument has harmonics capabilities. This selects that the printout will show the individual harmonic content of the voltage, current and power signals in either absolute or relative formats.

After obtaining the desired combination of data source and printout type the user should select the ***Print*** choice. If the ***I/O Data*** data source was selected then no further is required, the printout is immediately compiled and printing commences.

If the ***Basic*** printout type was selected, then further choices of either ***Present Only*** or ***Present+Accum*** are presented on the display. The user should select the desired choice by pressing the key next to the displayed choice, and then select the ***Print*** choice.

If the ***Harmonic*** printout type was selected, then further choices of either ***Absolute*** or ***Relative*** are presented on the display, along with the selection as to how many harmonics are to be printed. The user may change between the ***Absolute*** and ***Relative*** choices by pressing the key next to that display line. Changing the number of printed harmonics is achieved by pressing the key next to that display line, then using the numeric keys to enter the desired quantity, then pressing the ***ENTER*** key. When the display shows the desired choices, the user should select the ***Print*** choice to initiate the printout. The user should note that harmonic type formats have the capability of printing more than one page, in this case the headings and fundamental frequency data are reprinted at the top of each page.

13.8.3. Printing Harmonic Data

When printing harmonic data it is important that the user has previously commanded that analysis is to be performed. This may be achieved by displaying THD data for the selected channel, or by configuring the selected channel to

ALWAYS perform analysis. The user should also ensure that the correct analysis conditions exist for harmonic analysis. The user is referred to the **Harmonic Analysis** section of the **Operating Manual** for further details regarding this.

13.8.4. Printout Format

The user should note that harmonic type formats have the capability of printing more than one page, in this case the headings and fundamental frequency data are reprinted at the top of each page.

14. CALIBRATION

This chapter specifically describes the front panel method of performing either an Internal or External Calibration of the instrument. The IEEE488 and RS232 commanded methods follow essentially the same methods, using the commands described in the **DIGITAL INTERFACING** Chapter.

14.1. Internal Calibration

14.1.1. When to Perform an Internal Calibration

The user may command an automatic Internal Calibration of DC zero offsets whenever desired. The accuracy specifications presented in the **SPECIFICATIONS** Chapter assume the use of this function at least every ten days, or for a temperature change of greater than 5°C from that at the previous internal calibration. The user also should note that an Internal Calibration procedure should be performed both before and after an External Calibration procedure is performed.

14.1.2. Preparing for an Internal Calibration

The Internal Calibration procedure of the **2501/2/3** family requires that the user remove all external inputs to the instrument and apply short circuits to each individual input. Often this simply implies turning off the source of power that is being monitored, and then allowing sufficient time for any stored current flow to subside to zero.

If an external current shunt or CT type device is being used, then it is recommended that this remains connected but with zero input current flow. This will ensure that any internal offsets within this external device are accounted for.

14.1.3. Performing the Internal Calibration

❶ Press the CALIBRATE key on the front panel.

❷ Ensure that the input signals are configured as explained above.

❸ Select the ***Internal Calibration*** choice by pressing the *SELECT* key immediately next to the display line.

❹ The instrument will then perform the entire Internal Calibration sequence without further user interaction. The display will show any errors detected during this sequence.

14.2. External Calibration

14.2.1. When to Perform an External Calibration

The user may command an External Calibration whenever desired, however a one year External Calibration interval is recommended for normal use. While calibration at 23°C ambient is recommended, this may be performed at any temperature from 10°C to 35°C without degradation of accuracy specifications.

14.2.2. Equipment Required for an External Calibration

The instrument may be calibrated at any frequency within the measurement range of the instrument below 20KHz. The factory recommended frequency is 400Hz. The 20KHz digital filter option is automatically selected during the External Calibration procedure.

The calibration procedure requires inputs of the following voltage levels to each channel fitted in the instrument :

Standard Version : 600V, 300V, 150V, 60V, 30V, 15V, 1V, 0.5V and 0.25V.
2500-5V Option : 600V, 300V, 150V, 60V, 30V, 15V, 5V, 2.5V and 1.25V.
2500LV Option : 600V, 300V, 150V, 60V, 30V, 15V, 100mV, 50mV and 25mV.

The calibration procedure requires inputs of the following current levels to each channel fitted in the instrument :

10A (twice), 5A, 2A, 1A, 500mA, 200mA, 100mA and 50mA.

The external calibration standards should be certified to within an accuracy of 0.05% (0.025% is recommended for a 4:1 uncertainty ratio) at the calibration levels shown above, and at the frequency selected by the user. The usage of a Fluke 5700A with the 5725A extension unit is highly suitable for this task. The user should note that many calibration standards exhibit "warming" drift at the 10A and possibly the 5A levels, the user should ensure that a similar delay is given during the calibration of the instrument as was used when certifying the calibration standard at these levels. The user also should ensure that the cabling used between the external calibration standard and the instrument is sufficient for the voltage or current used. It is recommended that at least 14AWG wire is used at the 10A level (to reduce temperature rise in the cables). Also, a twisted pair should be used at all current levels (to reduce compliance at the calibration standard caused by lead inductance).

14.2.3. Preparing for an External Calibration

Prior to initiating an External Calibration sequence the user should perform the following steps :

❶ If the optional password protection scheme has been enabled, then the user should ensure that the correct password is known. If it is not known, then a ***Global Password*** is available, which is printed on a removable page at the rear of this manual.

❷ The instrument being calibrated should have been operated continuously in the calibration environment for at least one hour prior to initiating the External Calibration sequence.

❸ The external calibration standards against which the instrument is to be calibrated should be fully stabilized (see the manufacturers recommended warm up interval) and should be within its certified calibration period. If necessary, any calibration offsets should be obtained and applied as required during the procedure.

❹ The instrument being calibrated should have the ***Internal Calibration*** procedure performed, the preceding section of this chapter shows the details of this procedure.

14.2.4. Initiating an External Calibration

After performing the preparation steps outlined above, the user may initiate an External Calibration procedure. This is achieved by pressing the *CALIBRATE* key, and then selecting the ***External Calibration*** option.

14.2.5. Entering a Previously Selected Password

If the instrument had previously been set for password protection of the External Calibration function, then the instrument will now prompt the user to enter this password (if the password has been mislaid, then the user may enter the ***Global Password,*** which is always active). If prompted to do so, the user should sequentially press the required numeric keys and the press the *ENTER* key. It should be noted that, although the cursor character moves across the front panel display each time a key is pressed, the actual entered numeric is not displayed. If the user did not enter the correct password then the procedure is aborted and the instrument displays a warning message for two seconds.

14.2.6. Selecting a New Password

The instrument then prompts the user if the password is to be changed. If the user selects this option, then the password may be changed, enabled or disabled, as desired. As an added level of security, the instrument prompts the user for entry of the ***Global Password*** prior to allowing the user to change the password. After successfully entering this, by using the numeric keys followed by the *ENTER* key, the user may now select the desired password.

If the user wishes to disable the password protection scheme, then the ***CLR*** key should be pressed at this time.

If the user wishes to enable the scheme, or change an existing password, then the required password should be carefully selected using the numeric keys (up to eleven digits) and then the *ENTER* key.

14.2.7. Calibration Against the External Standards

After successfully completing the steps outlined above, the instrument will initiate the prompted External Calibration sequence. Each calibration step follows the same procedure, which is outlined below :

❶ The instrument prompts the user to input the desired voltage or current into the indicated channel. The user should take careful note of the input to which the requested level is to be presented, as the current inputs require a few voltage input levels during this procedure.

> **DANGER**
>
> When the user changes the connections, take care that no excessive voltage exists prior to touching any connections or terminals. The voltage levels used during the External Calibration procedure are potentially LETHAL.
>
> Care also should be taken that the correct input level is provided to the correct terminals, otherwise severe damage to the instrument may result.

❷ The user should provide the requested input and then select the line showing the desired input (i.e., the second line on the display). Selecting the third line (*Skip*) at this time will skip to the next calibration step without affecting the stored calibration data for this step. Selecting the lowest line (*Abort*) aborts the entire External Calibration sequence, discarding all adjustments made.

❸ The instrument now continuously displays the measured input level, and the percentage deviation from nominal.

❹ When the user is satisfied that the correct input level has been established, and that any required stabilization time has expired (particularly at 10A), then the user should select the second line of the display to command the instrument to accept the input as the correct input level.

> Note that no adjustment of the input level is required during an External Calibration procedure, other than that required to produce the actual requested output level from the external calibration standard.

Selecting the lowest display line (*Abort*) at this time will abort the calibration procedure without affecting any of the stored calibration data.

If the calibration constant obtained from the measured input level is outside the range allowed by the instrument (either due to an internal malfunction, or misapplication of the requested input level) the instrument will abort the calibration without affecting the previously stored calibration constants, and display a relevant message for two seconds.

14.2.8. Completing the External Calibration

After completing (or skipping over) the last step of the External Calibration procedure, the instrument updates the calibration constants and returns to normal operation, using the previously saved default operating parameters. The user should repeat the ***Internal Calibration*** procedure at this time, following which the calibration of the instrument is complete.

15. DIGITAL INTERFACING

The 2501/2/3 family has an optional IEEE488 or RS232 interface, allowing the instrument (or several instruments when inter-connected via the Multi-Instrument Bus) to be both controlled and interrogated by a computer.

Both interfaces operate in similar manners, using basically the same command set. The major difference between the operation of these interfaces is in the ability of the IEEE488 interface to switch between remote and local command states (which the RS232 interface does not offer), and the ability of the controller to continuously read the same data from the IEEE488 interface (the controller must always prompt the instrument to transmit the desired data from the RS232 interface).

Throughout this chapter it is assumed that the user is conversant with manual operation of the instrument, and with the methods of operating the controller for the particular interface being used.

15.1. RS232 Data Format Selection

When the **RS** interface is fitted in the instrument, the baud rate may be set as described below :

➊ Press the *SYSTEM* key.

➋ Select the *Configure Interface* choice.

➌ Repeatedly select the display line showing the present baud rate, until the desired rate is shown.

➍ Press the *SYSTEM* key.

The user should ensure that the computer connected to the RS232 port is set to the same baud rate, 8 bit data with no parity, 1 stop bit and 1 start bit. In normal operation the user should select the highest baud rate (19200 baud), however it should be noted that some IBM PC compatible computers do not operate correctly at this speed, particularly when operating in a multi-tasking environment (such as *Microsoft Windows*® or when connected to a network such as *Lantastic*®). When operating in environments having severe interference, when using very long cable lengths, or when the user is unsure whether the computer is capable of the highest baud rate, the user may wish to decrease the selected baud rate to reduce data transfer error rates.

15.2. IEEE488 Address Selection

When the **IE** option is fitted, the interface address may be set as described below :

➊ Press the *SYSTEM* key.

➋ Select the *Configure Interface* choice.

❸ Select the menu item showing the present IEEE488 interface address.

❹ Enter, using the numeric keys and the *ENTER* key, the desired IEEE488 address.

❺ Press the *SYSTEM* key.

15.3. Remote/Local Operation

With the **RS** option there are no defined REMOTE or LOCAL states, thus the instrument will respond to commands from either the front panel or the interface as applicable. The IEEE488 interface defines separate REMOTE and LOCAL states for the instrument thus this paragraph is only applicable to this interface.

While in the LOCAL state (e.g., following the initial application of power) the instrument will only respond to commands from the front panel of the instrument. After placing the instrument in the REMOTE state (via the defined interface command) the instrument will only respond to commands received via the interface (until released into the LOCAL state by the defined interface command). In either state, the instrument may have its present status read by the interface. If the instrument is in the REMOTE state (and LOCAL LOCKOUT has not been commanded) then pressing the *SYSTEM* key will return the instrument to the LOCAL state, all other keys simply cause the IEEE address setting to be displayed temporarily.

The REMOTE state is entered in the manner defined by the IEEE488 interface bus, normally this is achieved automatically when the instrument is correctly addressed to "listen" to a command string.

15.4. Configuring the Instrument and Controller (IE only)

Throughout this section of the manual, the use of a National Instruments AT-GPIB® IEEE488 controller board in an IBM AT (or compatible) is assumed. If the user is using a different controller or a controller card from another vendor, then the exact methods used will differ from those shown. If the user is using a computer with a built-in interface (such as the Hewlett-Packard series 300 and similar computers) then no configuration is usually required.

15.4.1. Configuring the Instrument

Other than setting the desired address and connecting the IEEE488 cable, the user need not perform any specific configurations on the instrument. As with all IEEE488 instruments and devices, the user must ensure that the selected address does not conflict with any other devices in the system. When using the instrument with the National Instruments controller card (and with many other cards for the IBM AT) the user should not select an instrument address of 0, as this will conflict with the address of the card.

15.4.2. Configuring the Controller Card

The user should follow the manufacturers recommended installation procedure when installing the card in the computer. Where an IBM PC (i.e., 8-bit) card is to be installed into an IBM AT type machine (i.e. 16-bit or higher), the user should take particular note of the hardware interrupt and DMA channel selected for the card.

Most manufacturers of these cards set these parameters to those compatible with the IBM PC, unfortunately these usually conflict with other cards normally found in the IBM AT class computers. In particular the user should beware that the first parallel port in an IBM AT class computer uses interrupt IRQ7.

When a conflict occurs between interrupts and DMA channels, the problems may not appear for some time, or may only cause intermittent operation. When any doubt occurs the user is recommended to first deselect the DMA channel, and then (if the problem persists) deselect the IRQ. Although this will perform slightly slower than the published specifications for the card, this will ensure that no conflicts occur.

The user also should note that some 8-bit cards will not reliably operate in high speed computers (such as 80386 based machines), the user should consult the manufacturer of the card regarding this issue.

When operating using hardware interrupts and DMA channels, and the computer is operating under the control of multi-tasking software (such as *Microsoft Windows*), then there are many other issues that require attention. In these circumstances the user should consult with the vendor of the controller card for specific configuration details.

15.4.3. Configuring the Controller Software

With the National Instruments AT-GPIB controller card, and with many other cards, there is a configured *device driver* installed in the computer. This driver must be correctly configured to ensure reliable operation with the **2501/2/3**. This section describes the settings that have been tested with the National Instrument AT-GPIB driver revision 1.5 accessed with the *ibconf* program supplied with the controller card, other drivers and revisions may be similar to those shown below :

Controller Card Configuration (*GPIB0*) : Note that these settings may be varied dependent on other instrumentation using the IEEE488 bus.

Primary Address	*0.*[1]
Secondary Address	*NONE.*[1]
Timeout Setting	*T10s.*[1]
EOS	*00H.*[1]
Terminate on EOS	*no.*[1]
Set EOI with EOS on Write	*no.*[1]

Type of Compare on EOS	*7-bit.*[1]
Set EOI w/last byte of Write	*yes.*[1]
System Controller	*yes.*[2]
Assert REN when SC	*no.*[1,2]
Enable Auto Serial Polling	*yes.*[3]
Timing	*500ns.*[4]
Enable 488.2 Protocols	*yes.*[5]
CIC protocol	*no.*[2]
Interrupt Setting	*11.*[6]
Base I/O Address	*02C0H.*[6]
DMA Channel	*5.*[6]

NOTES:

1 These selections are only for data transfers regarding the controller card itself. Thus other settings may be used, but have not been fully tested by Xitron Technologies Inc..

2 These selections assume the use of a single controller. In configurations where a second controller exists these may be altered, other settings have not been fully tested by Xitron Technologies Inc..

3 The Xitron Technologies 2501/2/3 family does not currently use the SRQ and Serial Poll capabilities of the IEEE488 bus. This setting will be dependent on other instruments, thus does not affect the 2501/2/3 instruments.

4 Timings of longer than this are also valid. The 350ns selection has been tested on shorter cable lengths by Xitron Technologies Inc. and may be used, however in normal operation there is little overall performance gain by using it with the 2501/2/3 instruments. If other, very high speed, devices exist in the system then this shorter time may be selected.

5 The 2501/2/3 do not use the IEEE488.2 specifications, thus this setting has no affect on these instruments if the user has otherwise ensured that no IEEE488.2 type transfers take place with the 2501/2/3. If all other devices also do not use the IEEE488.2 type transfers, then this setting should be set to *no* to ensure compatibility.

6 Although these settings have no affect on the 2501/2/3 instruments, the user should ensure that no hardware conflicts exist with other installed devices in the computer. The settings shown above are highly recommended, as the probability of conflict is lowest with these settings.

Settings for the 2501/2/3. The user should note that, as documented in the National Instruments manual, the name given for the device should not exist as a file, directory, or subdirectory within the computer system. If this occurs then unreliable operation of both the bus and the computer may result. Especially when operating in a network environment, it is recommended that the name given is cryptic to reduce the probability of this occurring.

Primary Address	*2.*[1]
Secondary Address	*NONE.*[1]
Timeout Setting	*T1s.*[2]
EOS Byte	*0AH.*[3]
Terminate read on EOS	*yes.*[4]
Set EOI with EOS on Write	*no.*[5]

Type of Compare on EOS *7-bit.*[4]

Set EOI w/last byte of Write *yes.*[5]

Repeat Addressing *no.*[6]

NOTES:

1 The address should be that configured in the instrument. The 2501/2/3 does not use secondary addressing.

2 The only command that may hold the bus handshake for longer than 20ms. is the device clear command. If this command is not used then even shorter timeout periods can be used to detect a failure. The device clear command may hold the bus handshake for up to three seconds. When using the command pass-through feature of the MIB (i.e. controlling another instrument via the MIB) then longer timeout periods may be required.

3 The 2501/2/3 always sends a carriage return (0DH) and a line feed (0AH) with EOI asserted at the end of each data transfer from the 2501/2/3.

4 Terminating a data read with the defined EOS byte ensures that data transfers are correctly terminated. This ensures that the user does not have to specify the exact number of characters for each transfer. Data transfers from the 2501/2/3 are all 7-bit ASCII data with no parity.

5 The 2501/2/3 will terminate a data receive operation with either a line feed character (0AH), or any character with EOI asserted, or with a device trigger. Selecting the EOI w/last byte of Write option ensures the shortest possible data transfer.

6 The 2501/2/3 does not "unaddress" at the completion of a transfer. Thus, assuming no other device has been subsequently addressed, there is no requirement to re-address the instrument.

15.5. Reading Data From the 2501/2/3

With either interface the user may interrogate the various data held by the instrument. This is achieved by sending a "data read" command string (see the next section), which defines which data is to be interrogated, and then reading the data from the instrument.

In the **RS**, this data is automatically transmitted from the instrument to the controller, the instrument will then wait for a further "data read" command before sending further data.

In the **IE** interface, the controller may immediately attempt to read the requested data, the controller will then be held for a short delay (typically less than 1ms) until the requested data is available, then the requested data will be read by the controller. This data may be read by the **IE** interface any number of times, the data transmitted will always be the latest available data (unless the instrument is in the HOLD state).

In either interface, the instrument typically responds by sending a single "space" character, followed by a numeric string (with a preceding polarity symbol), followed by the respective "engineering format" exponent data in the form *"e+3"*, and terminated by the "carriage return" and "line feed" characters (with the **IE** interface this last character is sent with the EOI line asserted). Certain data do not follow this format, these are described in the following paragraphs (see the *READ=* and *STATUS* command descriptions, and the *SPECTRUM* and *HARMONIC* descriptions). The user also may request more than one item of data is transmitted, here the individual items are separated by means of the comma (,) character.

15.6. Sending Data to the 2501/2/3

Both the **RS** and **IE** interface operate similarly with regards to sending data to the instrument. The only difference being the previously mentioned requirement to place the instrument in the REMOTE state with the **IE** interface. ASCII characters transmitted to the interface are stored in a "buffer" until either a "line feed" or "carriage return" character is received (or a character with the EOI line asserted, or a "Group Execute Trigger" command is received, in the **IE** interface), the received characters then are decoded and actioned. If both a "line feed" and a "carriage return" character are transmitted to the instrument, then the preceding command string will be actioned when the first of these characters is received, the remaining character is simply discarded when received, there being no command strings between them.

Up to 100 characters may be stored in the "receive buffer," which may contain more than one complete command string type if desired. If the user sends conflicting commands within the same command string, then the last effective command will be used.

It should be noted that the **2501/2/3** operates with the received ASCII characters, the command used to send these characters via the designated interface is dependent on the computer system and peripheral used.

15.7. Special Considerations When Using Option RS

The **RS** interface is configured to use the RS232 hardware "handshake" lines RTS and CTS to handshake data. The usage of these hardware "handshake" lines ensures that data will not be lost due to different speeds in the **2501/2/3** and the computer. Sometimes the particular computer used is not able to use these handshake lines properly (e.g., some computer systems continue to transmit a few characters after being "held off" from transmitting). The user should place delays between sending individual command strings in these cases to prevent "data overrun."

15.8. Special Considerations When Using Option IE

There are several differences between the **IE** and **RS** interface operation, these are all due to the extended capabilities of the hardware interface of the IEEE488 standard.

15.8.1. Bus Timing

Almost all of the timing requirements of the bus interface are handled by the hardware handshake system used by the IEEE488 interface. During decode of a command all further received data are "held-off" by this hardware handshake until the decode has been completed. Typically data transfer rates of up to 50,000 characters per second are attainable with the **2501/2/3**.

15.8.2. Bus Commands

As previously mentioned, the IEEE488 interface can perform many tasks that the RS232 does not, those used by the **2501/2/3** are as follows -

Remote/Local. This has been previously described.

Device Clear. The IEEE488 defined Device Clear functions (both selective and global) force the **2501/2/3** to perform a power-on reset function. The user should note that this also will return the instrument configuration to the power-on configuration stored in location 0.

Interface Clear. The IEEE488 standard defines this command, which causes the interface portion of the **2501/2/3** to be reset to the power on conditions, aborting any bus activity in progress.

It should be noted that these bus commands only affect the **2501/2/3** which contains the IEEE488 interface, other instruments connected via the Multi-Instrument Interface are not affected.

15.8.3. Other IEEE488 Specific Items

Should a handshake sequence be improperly completed during a transfer of data to or from the **IE** interface, then the **2501/2/3** will automatically perform a power on reset sequence. This facility prevents the interface becoming "locked out" should the interface cable be removed or become faulty during a data transfer.

15.9. Command Set

The various features of the **2501/2/3** may be controlled by the controller sending certain command "strings" to the **2501/2/3**. The user may freely distribute "space" and non-printing characters throughout the command string (including within the actual command itself), and may send more than one command before sending the termination character.

Commands are terminated by the reception of a "line feed" or "carriage return" character, the reception of a character with the EOI line asserted (IE only), or by the reception of the "Group Execute Trigger" command (**IE** only).

Command strings may be separated by any "non-command" character, e.g. a "comma" character or "semi-colon" character. The user may freely use either lower or upper case characters, as desired.

The commands listed below are shown in alpha-numeric order, the upper-case portion of the command is the actual command operator, the lower case portion(s) of the command represents the optional parameter(s) for the command. These optional portions of the commands are denoted as follows :

[c]	This shows that the command affects a specific channel. If this optional portion is not included, then channel A is affected. If *[A]*, *[B]* or *[C]* is included then channel A, B or C respectively are affected. If the selected channel does not exist (e.g., specifying *[C]* to a **2501**), then channel A is affected.
=	In most commands, unless specifically stated otherwise, the = character is optional. The use of this character is

recommended as it considerably increases the readability of the command.

chl/parameter — This shows that the user should place the required parameter descriptor (with optional channel descriptor) in the specified position. The user is referred to the end of this section for a complete list of the available parameter and channel descriptors.

n — An integer number having the specified range. In cases where more than one digit is possible, the user may optionally place the leading zero characters. This data may not have a preceding polarity sign character.

numeric — A floating point number having the specified units. This data may have an optional preceding polarity character. The decimal point is optional, and may be in any desired position. "e" format numbers are not accepted (e.g., +1.0e3).

string — One of the specified possible character strings for the specific command.

15.9.1. ACCUM=string

This command either initiates the accumulation mode of operation (*ACCUM=ON*) or terminates the accumulation mode of operation (*ACCUM=OFF*). The = character is not optional in this command. As for the manual command, the *ACCUM=ON* command clears the accumulation results prior to initiating the accumulation, and the *ACCUM=OFF* command holds the results for later interrogation. Final results are available following a delay of at least one measurement period following the termination of the accumulation.

15.9.2. ANALOG[n]=DEFAULT and ANALOG[n]=numeric

These commands are only effective if option **AN** is fitted. These commands either force the specified (***n***, between 0 and 7 inclusive) analog output to the specified output level (***numeric***, -1.0 to +1.0 yielding an output level of between -5.0 and +5.0V respectively), or returns the analog output (***n***) to the parameter, channel, zero offset and span specified by means of the front panel controlled configuration (*ANALOG[n]=DEFAULT*).

It should be noted that, following a power-on reset (or a device clear via the IE interface), all analog outputs are returned to their respective front panel configured parameters, channels, zero offsets and spans.

These commands allow the user to either override an analog output used to drive a plotter or alarm output, or allow the user to control another instrument or power supply via this analog level.

The *[,]* and = characters are optional.

15.9.3. ANALYSE or ANALYZE

This command is only effective in the **2501H**, **2502H** and **2503H** versions of these instruments. There are several different syntax variations allowable for this command, all of which control the type of spectrum analysis performed by the instrument. The instrument normally performs spectrum analysis of the applied signals only when requested by the user. This command gives the user the capability of controlling this via the interface. For full details regarding the use of the frequency step data, refer to the earlier chapter regarding FFT spectrum and harmonic analysis.

The allowable syntax variations are as follows, the user should note that either spelling of the command is effective :

ANALYSE[c]	Selects that an analysis is always performed (for the specified channel) using the automatically selected frequency step. This is the preferred option when THD or individual harmonic data is required.
ANALYSE[c]=AUTO	Same as above.
ANALYSE[c]=0	Same as above.
ANALYSE[c]=1	Selects that an analysis is always performed (for the specified channel) using a frequency step of 2.4Hz. This selects that the ***SPECTRUM*** results (see the ***READ***= command) will have data between 2.4Hz and 2.46KHz (approximately).
ANALYSE[c]=2	As the ***ANALYSE[c]=1*** command above, except the frequency step is 4.8Hz and the frequency span is 4.8Hz to 4.92KHz.
ANALYSE[c]=3	As the ***ANALYSE[c]=1*** command above, except the frequency step is 9.6Hz and the frequency span is 9.6Hz to 9.84KHz.
ANALYSE[c]=4	As the ***ANALYSE[c]=1*** command above, except the frequency step is 19Hz and the frequency span is 19Hz to 19.7KHz.
ANALYSE[c]=5	As the ***ANALYSE[c]=1*** command above, except the frequency step is 38Hz and the frequency span is 38Hz to 39.4KHz.
ANALYSE[c]=6	As the ***ANALYSE[c]=1*** command above, except the frequency step is 77Hz and the frequency span is 77Hz to 78.7KHz.
ANALYSE[c]=7	As the ***ANALYSE[c]=1*** command above, except the frequency step is 154Hz and the frequency span is 154Hz to 157KHz.

ANALYSE[c]=OFF	Returns the decision whether an analysis is performed (for the specified channel) to be dependent on the display data selection. Any previously selected frequency step remains unchanged.

In all of the above variations, the *[c]* portion is optional (defaulting to channel A if not present), and the = character is optional.

15.9.4. CIT[c]=numeric

This command specifies that the selected channel (channel A if the optional *[c]* portion is not present) is using a current output CT on its input that has an input to output ratio given in the numeric portion of the command. The = character is optional.

15.9.5. CONNECT=n

This command selects that all following commands will be transparently transferred through, using the multi-instrument network, to the instrument having the Configuration (MIB) Code given in the numeric portion of this command. Commands will be decoded locally when this command is received with this particular units' Configuration Code. In this manner, the code of the instrument that has the interface fitted need not be known by the controller. All commands received after power on reset (or a commanded reset) are decoded locally by default.

15.9.6. CVT[c]=numeric

This command specifies that the selected channel (channel A if the optional *[c]* portion is not present) is using a voltage output CT on its current input that has an input (amps) to output (volts) ratio given in the numeric portion of the command. The = character is optional.

15.9.7. DISP[n]=chl/parameter

This command specifies that the selected display line (*n*, 0 through 3 inclusive) should display the specified parameter from the specified channel. If the optional [n] portion is not specified then the lowest line ($n = 3$) is affected. The = character is optional. See the list at the end of this section for the available channel and parameter descriptors.

15.9.8. EXTCAL, EXTSKIP and EXTUSE

These commands allow the user to perform an automated external calibration of the instrument. The *EXTCAL* command initiates an external calibration sequence, the *EXTSKIP* command selects the next external calibration point without affecting the data for the point being measured (if any) and the *EXTUSE* command shows that the instrument should compute the calibration data using the actual input level present and then select the next calibration point. The nominal input level required may be obtained by finding the current/voltage range in use for each channel using the *STATUS* command (described later in this chapter).

15.9.9. FILT[c]=n

This command specifies that the selected channel (or channel A if the optional *[c]* portion is not specified) is to use a digital filter. The = character is optional. The available filters are as follows :

FILT[c]=0	No filtering.
FILT[c]=1	20KHz Low Pass Filter
FILT[c]=2	10KHz Low Pass Filter
FILT[c]=3	5KHz Low Pass Filter
FILT[c]=4	2KHz Low Pass Filter
FILT[c]=5	1KHz Low Pass Filter
FILT[c]=6	120Hz to 5KHz Band Pass Filter
FILT[c]=7	800Hz to 10KHz Band Pass Filter
FILT[c]=8	50Hz Low Pass Filter

15.9.10. HOLD

This command specifies that the instrument is to enter the HOLD state. All database parameters are maintained at the values present at the time this command is received. These parameters may be subsequently released by the *RUN* command.

15.9.11. INTCAL

This command specifies that the instrument is to perform an automatically sequenced internal calibration sequence. If possible, the input terminal pairs should each be shorted together prior to issuing this command.

15.9.12. IRNG[c]=string

This command specifies that the instrument is to select the specified range for use on the specified channel. If the channel is not specified (i.e., the *[c]* portion is not included) then channel A is affected by this command. The = character is optional. The available strings are as shown below :

IRNG[c]=20A	Selects the 20A range.
IRNG[c]=10A	Selects the 10A range
IRNG[c]=5A	Selects the 5A range.
IRNG[c]=2A	Selects the 2A range.
IRNG[c]=1A	Selects the 1A range.
IRNG[c]=0.5A	Selects the 0.5A range.

IRNG[c]=0.2A	Selects the 0.2A range.
IRNG[c]=0.1A	Selects the 0.1A range.
IRNG[c]=0.05A	Selects the 0.05A range.
IRNG[c]=IAUTO	Selects the current input, using internal current shunts, in autorange.
IRNG[c]=1V	Selects a 1V range on the current inputs.
IRNG[c]=0.5V	Selects the 0.5V range on the current inputs.
IRNG[c]=0.25V	Selects the 0.25V range on the current inputs.
IRNG[c]=VAUTO	Selects the current input, not using internal shunts, in autorange.

15.9.13. LOCK[c]=string

This command specifies that the selected channel (only channels B and C are valid for this command) is either locked to channel A (*LOCK[c]=ON*) or unlocked from channel A (*LOCK[c]=OFF*). The = character is optional. The *[c]* portion of the command must be included and may be either *[B]* (in the **2502, 2502H, 2503** or **2503H** only) or *[C]* (in the **2503** or **2503H** only). The user is referred to the previous chapter regarding locking and unlocking channels from channel A.

15.9.14. MEAS[c]=numeric

This command specifies that the selected channel should use the specified measurement period (in seconds). If the channel is not specified (i.e., the *[c]* portion is not included) then channel A is affected. The user should note that these commands will only affect channel B or C if they are unlocked from channel A. Changing the measurement period of channel A will automatically change the measurement periods of any channels locked to channel A. The numeric portion may be between 0.05 and 6.5 inclusive, values outside this range will leave the measurement period unchanged.

15.9.15. NOCT[c]

This command specifies that the selected channel does not have a CT connected on its current input. If the *[c]* portion is not present, then channel A is affected by this command.

15.9.16. NOPT[c]

This command specifies that the selected channel does not have a PT connected on its voltage input. If the *[c]* portion is not present, then channel A is affected by this command.

15.9.17. PRINT=string

This command initiates a printout from the RS232 interface. The commands are as follows :

PRINT=CHA/PRESENT	This initiates a printout of the present data for channel A only. Data from channels B or C may also be selected by changing the *CHA* portion of the command to *CHB* or *CHC* respectively. Accumulated data for the selected data may also be included in the printout by changing the *PRESENT* portion of the command to ***ACCUM***.
PRINT=INPUT/PRESENT	This initiates a printout for the present total data for the channels configured as monitoring input wire groups. The totals for the channels monitoring the output wire groups may be selected by changing the *INPUT* portion of the command to ***OUTPUT***. Accumulated data for the selected data may also be included in the printout by changing the *PRESENT* portion of the command to ***ACCUM***.
PRINT=IO	This initiates a printout of the total data for both channels configured as monitoring the input wire groups and for channels configured as monitoring output wire groups. This data is only available for a **2502** or **2503** instrument that has channel A configured as monitoring an input wire group and channel B configured as monitoring an output wire group.
PRINT=TOTAL/PRESENT	This initiates a printout for the present total data for the channels configured as monitoring the same wire group as monitored by channel A. Accumulated data for the selected data may also be included in the printout by changing the *PRESENT* portion of the command to ***ACCUM***.
PRINT=CHA/AHARMnnn	This initiates a printout of the absolute harmonic data for the selected channel (channel A as shown here, change the *CHA* portion of the command to *CHB* or *CHC* to printout data for channel B or C respectively). The number of harmonics included in the printout is commanded by the numerics found in the position indicated by the ***nnn*** portion of the command (e.g. *PRINT=CHA/AHARM49* prints the harmonic data up to and including the

49th harmonic). The relative data for each harmonic may be printed by replacing the *AHARM* portion of the command with *RHARM*.

15.9.18. PT[c]=numeric

This command specifies that the selected channel (channel A if the optional *[c]* portion is not present) is using a PT on its input that has an input to output ratio given in the numeric portion of the command. The = character is optional.

15.9.19. QUICK

This command specifies that the instrument is to be configured as defined by the factory default "quick start" settings. The settings configured by this command are as follows :

Measurement Period	0.5s
Synchronization	Voltage on channel A
Lock	Channels B and C locked to channel A
Ranging	Autorange on all inputs (channels B and C are locked to channel A)
Configuration	2502 : 3-phase, 3-wire
	2503 : 3-phase, 4-wire or 3-phase 3-wire
Filters	20KHz low pass

For further details regarding these settings the user is referred to previous chapters of this manual.

15.9.20. READ=chl/parameter

This command determines which parameter (and from which channel) the instrument will next transmit to the controller. For the **RS** interface the requested data will be transmitted automatically following decode of this command, whereas the **IE** will simply store this request until the instrument is next interrogated by the controller (i.e. addressed as a talker).

Several parameters may be specified to be read simultaneously, if desired. Here, each ***chl/parameter*** string should be separated by the ***:*** (colon) character. If this is commanded, then each data item read will be separated by the ***,*** (comma) character in the received data string.

Besides the standard ***chl/parameter*** strings listed at the end of this section, there are "special" strings that allow the user to access certain specialized data. These strings are listed below :

READ=STATUS — This string requests that the present status of the instrument is transmitted to the controller. The format of this data is listed under the STATUS command later in this chapter. This command string performs the same task as the STATUS command, but enables the user to read several data items (using the *:* separator described above).

READ=SPECTRUM[c]un This string requests that the results of the last spectrum analysis are transmitted to the controller. It the channel designator *[c]* is omitted, then the results from channel A are transmitted. The portion of the string designated *u* designates whether the voltage (*V*), current (*I*) or power (*W*) spectrum is to be interrogated. The integer portion of this command must be present, and may be between 0 and 1021 inclusive. This number represents the offset in the spectrum analysis that is to be transmitted, the frequency of this point is approximately the frequency step size (in Hz) multiplied by (*n*+1). The string transmitted from the instrument contains the real portion of the amplitude, imaginary portion of the amplitude and the actual frequency of the selected point. The transmitted data are separated by *,* (comma) characters.

READ=HARMONIC[c]un This string requests that the results of the last harmonic analysis are transmitted to the controller. It the channel designator *[c]* is omitted, then the results from channel A are transmitted. The portion of the string designated *u* designates whether the voltage (*V*), current (*I*) or power (*W*) harmonics are to be interrogated. The integer portion of this command must be present, and may be between 1 and 255 inclusive. This number represents the harmonic which is to be transmitted. The string transmitted from the instrument contains the amplitude (in V, A or W units, as applicable), phase (in degrees, relative to the fundamental voltage waveform for V and I data, true phase for W data) and the actual frequency of the selected point. The transmitted data are separated by *,* (comma) characters.

15.9.21. RECALL=n

This command specifies that the instrument configuration is to be set according to that previous stored in the location specified by the number *n*. This number should be either *0, 1* or 2.

15.9.22. RUN

This command releases a previously received *HOLD* command. If the instrument is not presently in the HOLD state then this command has no effect.

15.9.23. SAVE=n

This command specifies that the instrument should save the present configuration in the specified storage location. The number ***n*** should be either ***0, 1*** or ***2.***

15.9.24. STATUS

This command is similar to the ***READ=STATUS*** string. This commands the instrument to transmit the present status of the instrument to the controller. The format of the string returned to the controller is as follows :

1st character	Space character. This character is only present if this was the first requested string as part of a ***READ=STATUS*** command.
2nd character	The voltage range presently in use on channel A (1=600V, 2=300V, 3=150V, 4=60V, 5=30V, 6=15V)
3rd & 4th characters	The current range presently in use on channel A (01=1V, 02=0.5V, 03=0.25V, 05=20A, 06=10A, 07=5A, 08=2A, 09=1A, 10=0.5A, 11=0.2A, 12=0.1A, 13=0.05A)
5th character	The voltage overload status of channel A (0=Not in overload, 1=In overload)
6th character	The current overload status of channel A (0=Not in overload, 1=In overload)
7th thru 11th characters	Same as 2nd thru 6th, but for channel B (not **2501** or **2501H**)
12th thru 16th characters	Same as 2nd thru 6th, but for channel C (only **2503** or **2503H**)

15.9.25. SYNC[c]=string

This command specifies that the selected channel should synchronize its' measurements to the item selected by the ***string*** portion of the command. If the ***[c]*** portion of the command is omitted, then channel A is affected. The ***string*** portion is of the following formats :

SYNC[c]=OFF	Specifies that the selected channel does not synchronize its' measurement period. If the specified channel is locked to channel A, then this selection is ignored until the channel is subsequently unlocked.
SYNC[c]=ON	Specifies that the selected channel synchronizes its' measurement period to that channels' voltage input. If the specified channel is locked to channel A, then this selection is ignored until the channel is subsequently unlocked.

SYNC[c]=A | Specifies that the selected channel synchronizes its' measurement period to that of channel A. This command is only applicable for channels B and C.

SYNC[c]=I | Specifies that the selected channel synchronizes its' measurement period to that channels' current input. If the specified channel is locked to channel A, then this selection is ignored until the channel is subsequently unlocked.

15.9.26. VRNG[c]=string

This command specifies that the selected channel (channel A if the *[c]* portion is omitted) sets its' voltage range to that specified by the ***string*** portion of the command. The available options for the ***string*** portion are as follows :

VRNG[c]=600V	Selects the 600V range.
VRNG[c]=300V	Selects the 300V range.
VRNG[c]=150V	Selects the 150V range.
VRNG[c]=60V	Selects the 60V range
VRNG[c]=30V	Selects the 30V range.
VRNG[c]=15V	Selects the 15V range.
VRNG[c]=AUTO	Selects autorange.

15.9.27. Available *chl/parameter* strings

The ***DISP*** and ***READ*** commands accept any of these strings as defining the source of the data to be interrogated by these commands. The ***chl/*** portion of the string is optional, and specifies the source of the parameter. If this portion is omitted then channel A is used as the source. The available options for this portion of the string are as follows :

CHA/	Channel A data is the source.
CHB/	Channel B data is the source. This option is not available in the **2501** and **2501H**, if specified then channel A is used.
CHC/	Channel C data is the source. This option is not available in the **2501**, **2501H**, **2502** and **2502H**, if specified then channel A is used.
GROUP/	The total of all instruments having the same group code as channel A is the source.
INPUT/	The total of all instruments having group codes of 0 through 4 is the source.
OUTPUT/	The total of all instruments having group codes of 5 through 9 is the source.

The available ***parameter*** selections are as follows :

ACAHR	The AC coupled Ampere-Hour accumulated data. Only channels A, B or C are valid sources for this parameter.
ACEPA	The AC coupled computed Effective Phase Angle data (i.e., $\cos^{-1}$ (*ACPF*)).
ACI	The AC coupled current data. Only channels A, B or C are valid sources for this parameter.
ACPF	The AC coupled Power Factor data.
ACVAHR	The AC coupled VA-Hour accumulated data.
ACVA	The AC coupled VA data.
ACV	The AC coupled voltage data. Only channels A, B or C are valid sources for this parameter.
ACWHR	The AC coupled Watt-Hour accumulated data.
ACW	The AC coupled power data.
AHR	The AC+DC coupled Ampere-Hour accumulated data. Only channels A, B or C are valid sources for this parameter.
ALTI	The computed "remnant" current data for the group to which channel A belongs. If this group is configured as a 3-phase 3-wire group, then this is the unmeasured phase current. If this group is configured as another multi-phase (e.g., 3-phase 4-wire) group, then this is the neutral current. *GROUP/* is the only valid source for this parameter, and must be specified.
ATHD	**2501H, 2502H** and **2503H** only. The computed current total harmonic distortion. Only channels A, B or C are valid sources for this parameter.
DCAHR	The DC coupled Ampere-Hour accumulated data. Only channels A, B or C are valid sources for this parameter.
DCI	The DC coupled current data. Only channels A, B or C are valid sources for this parameter.
DCVAHR	The DC coupled VA-Hour accumulated data.
DCVA	The DC coupled VA data.
DCV	The DC coupled voltage data. Only channels A, B or C are valid sources for this parameter.
DCWHR	The DC coupled Watt-Hour accumulated data. It should be noted that this is the same as the *DCVAHR* parameter.
DCW	The DC coupled power data. Is should be noted that this is the same as the *DCVA* parameter.

EFF	The Efficiency data. This data is the ratio of the *OUTPUT/PWR* and *INPUT/PWR* parameters expressed as a percentage. If a source is specified it will be ignored, as this parameter has no specific data source.
EPA	The AC+DC coupled computed Effective Phase Angle data (i.e., $\cos^{-1}$ (*PF*)).
FREQ	The fundamental frequency of the voltage input (in Hz). Only channels A, B or C are valid sources for this parameter.
ICF	The Current Crest Factor data. Only channels A, B or C are valid sources for this parameter.
LOSS	The Power Loss data. This data is the result of subtracting the *OUTPUT/PWR* data from the *INPUT/PWR* data. If a source is specified it will be ignored, as this parameter has no specific data source.
PF	The AC+DC coupled Power Factor data.
PKI	The Peak current data. Only channels A, B or C are valid sources for this parameter.
PKV	The Peak voltage data. Only channels A, B or C are valid sources for this parameter.
PKW	The Peak power data. Only channels A, B or C are valid sources for this parameter.
PWR	The AC+DC coupled power data.
RMSI	The AC+DC coupled current data. Only channels A, B or C are valid sources for this parameter.
RMSV	The AC+DC coupled voltage data. Only channels A, B or C are valid sources for this parameter.
VAHR	The AC+DC coupled VA-Hour accumulated data.
VARHR	The VAR-Hour accumulated data.
VAR	The VAR data.
VA	The AC+DC coupled VA data.
VCF	The Voltage Crest Factor data. Only channels A, B or C are valid sources for this parameter.
VTHD	**2501H, 2502H** and **2503H** only. The computed voltage total harmonic distortion. Only channels A, B or C are valid sources for this parameter.
WHR	The AC+DC coupled Watt-Hour accumulated data.

^*ACI*	The highest recorded AC coupled current data during an accumulation. Only channels A, B or C are valid sources for this parameter.
^*ACVA*	The highest recorded AC coupled VA data during an accumulation.
^*ACV*	The highest recorded AC coupled voltage data during an accumulation. Only channels A, B or C are valid sources for this parameter.
^*ACW*	The highest recorded AC coupled power data during an accumulation.
^*DCI*	The highest recorded DC coupled current data during an accumulation. Only channels A, B or C are valid sources for this parameter.
^*DCVA*	The highest recorded DC coupled VA data during an accumulation.
^*DCV*	The highest recorded DC coupled voltage data during an accumulation. Only channels A, B or C are valid sources for this parameter.
^*DCW*	The highest recorded DC coupled power data during an accumulation. Is should be noted that this is the same as the ^*DCVA* parameter.
^*PKI*	The highest recorded Peak current data during an accumulation. Only channels A, B or C are valid sources for this parameter.
^*PKV*	The highest recorded Peak voltage data during an accumulation. Only channels A, B or C are valid sources for this parameter.
^*PKW*	The highest recorded Peak power data during an accumulation. Only channels A, B or C are valid sources for this parameter.
^*PWR*	The highest recorded AC+DC coupled power data during an accumulation.
^*RMSI*	The highest recorded AC+DC coupled current data during an accumulation. Only channels A, B or C are valid sources for this parameter.
^*RMSV*	The highest recorded AC+DC coupled voltage data during an accumulation. Only channels A, B or C are valid sources for this parameter.
^*VAR*	The highest recorded VAR data during an accumulation.
^*VA*	The highest recorded AC+DC coupled VA data during an accumulation.