SNIA Power Meter Workshop

SNIA Emerald™ Training

SNIA Emerald Power Efficiency Measurement Specification, for use in EPA ENERGY STAR®

July 14-17, 2014

SNIA™ Green Storage Initiative

SNIA Emerald™

SNIA Hands-On Power Meter Workshop

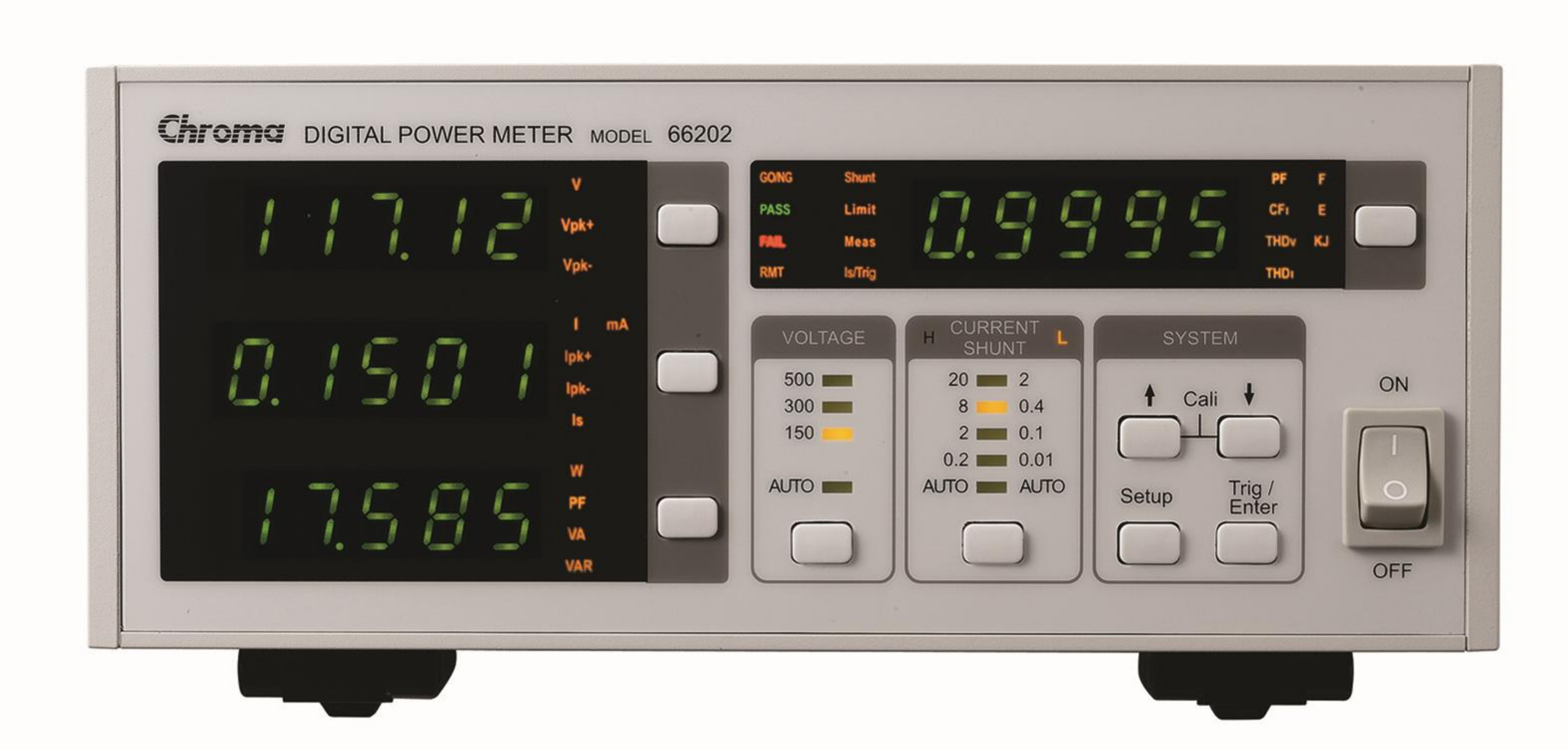
presented by

Chroma System Solutions, Inc.

Work Shop Overview

- Power Meter Basic’s
- Manual Operation of Power Meter
- Remote Interface and Software operation of Power Meter
- External Current Sensors (Shunts & Current Transformers)
- AC Source requirements for consistent and compatible measurements.
- Q & A

Power Meter Basic's



Power Meter Workshop

Power Meter Types:

- Analog Power Meter

  - Measured only Voltage, Current, Frequency, Power, Energy
  - Good for a Sine wave voltage and current
  - Limited to a specific power, voltage and freq. range.

- Digital Power Meter

  - Extended measurements to include, Voltage, Current, Frequency, Power (W, VA,VAR), Surge Current, Energy (Joules, Whr), Harmonic Distortion, Power Factor, Crest Factor.
  - Improved accuracy for Non Sine wave voltage and current.

- Power Analyzer

  - Includes DPM plus high speed waveform analysis for Phase Angle and distortion and higher frequency measurements.

Power Meter Workshop

Power Meter applications:

- Power Measurements for Energy Consumption (Joules, Whr)
  - Accurate measurements for manufacturers products to meet various energy standards. Note: a printer left on in standby mode can consume 408Kwr per year. A refrigerator 20CF can consume as much as 1700Kwhr per year. (1Whr = 3600 Joules)

- Power Measurements to determine Efficiency
  - New Standards and Guidelines have increased the need for Power Meters, due to power conservation
  - Energy Guidelines for improved efficiency, from NREL, DOE, IEC, ISO, CEC, Energy Star

- Measurements for Harmonic Distortion (THDv & THDi)
  - Utilities concern that distortion causing stress on the grid's hardware.
  - Concerns of Consumers equipment affected by Noise and Harmonics generated by devices connected to the grid including EMI.

Power Meter Workshop

Power Meter Measurements:

Power Meters should have the ability to measure or extract the following:

- Voltage RMS, Voltage Peak + and – (continuous)
- Current RMS, Current Peak + and -- (continuous),
  Surge Current (Instantaneous)
- Power Factor
- Crest Factor
- Watts, VA, VAR
- Energy (Whrs, Joules)
- THDi, THDv

And all measurements should have Accuracy better than 1%
With Sample rates greater than 100Khz

Power Meter Requirements
per Energy Star 6.0 for Computers

Power Meter: Power meters shall have the following attributes:

1. Current Crest Factor:
   - a.) An available crest factor of 3 or more at its rated range value; and
   - b.) A current range of 10 milliamperes .or less
2. Minimum Frequency Response: 3.0Khz
3. Minimum Resolution:
   - a.) 0.01W for measurement values less than 10W;
   - b.) 0.1W for measurement values from 10W to 100W; and
   - c.) 1.0W for measurement values greater than 100W
4. Measurement Accuracy:
   - a.) Power measurements with a value greater than or equal to 0.5W shall be made with an accuracy of less than 2%
   - b.) Power measurements with a value of less than 0.5W shall be made with an accuracy of less than +/- 0.01W (2% at 0.5W)

Power Source Requirements

per Energy Star 6.0 for Computers

Table 1: Input Power Requirements for Products with Nameplate Rated Power Less Than or Equal to 1500 watts (W)

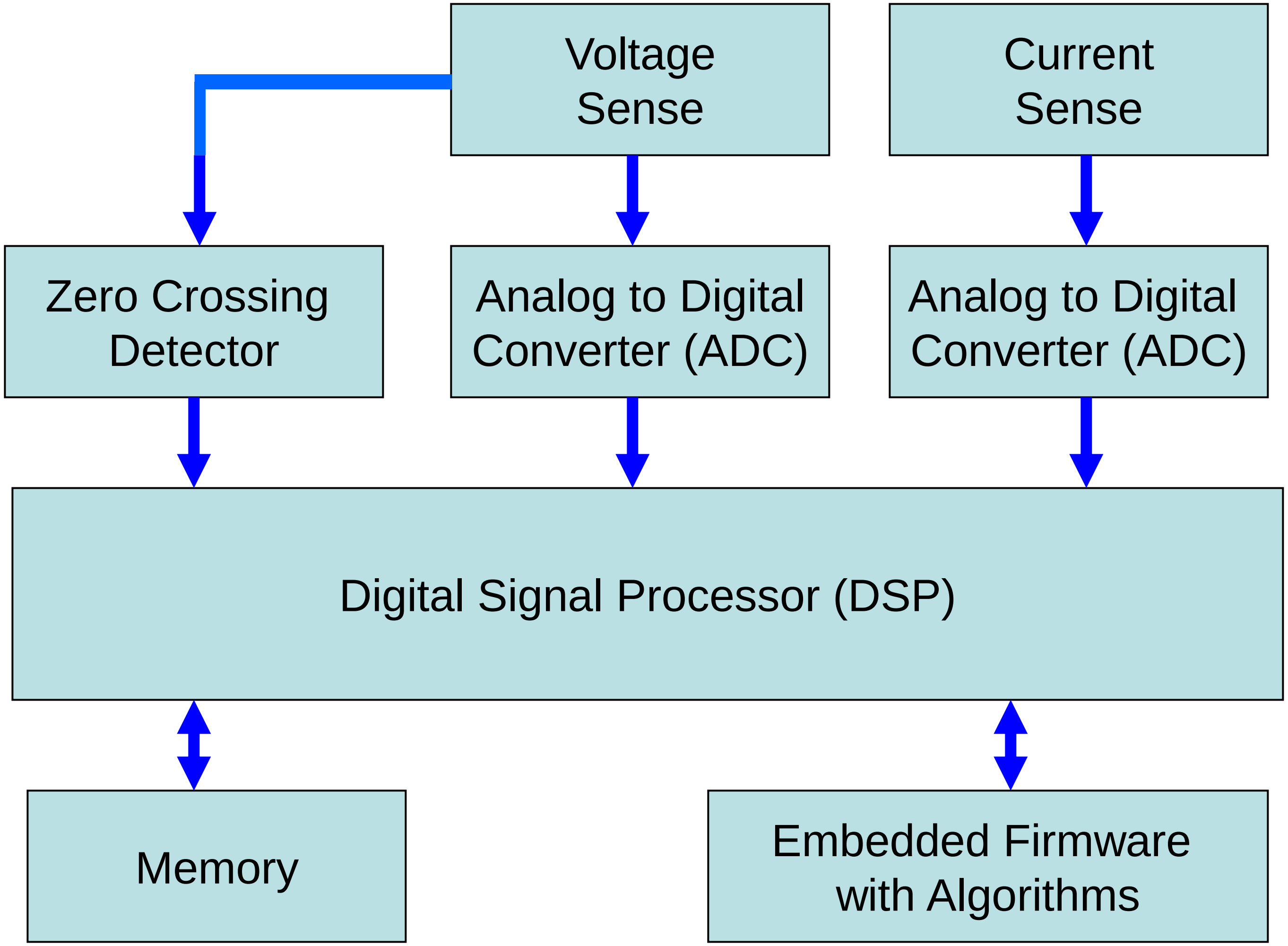
Market	Voltage	Voltage Tolerance	Maximum Total Harmonic Distortion	Frequency	Frequency Tolerance
North America, Taiwan	115 volts (V) ac	+/- 1.0 %	2.0 %	60 hertz (Hz)	+/- 1.0 %
Europe, Australia, New Zealand	230 V ac	+/- 1.0 %	2.0 %	50 Hz	+/- 1.0 %
Japan	100 V ac	+/- 1.0 %	2.0 %	50 Hz or 60 Hz	+/- 1.0 %

Table 2: Input Power Requirements for Products with Nameplate Rated Power Greater Than 1500 W

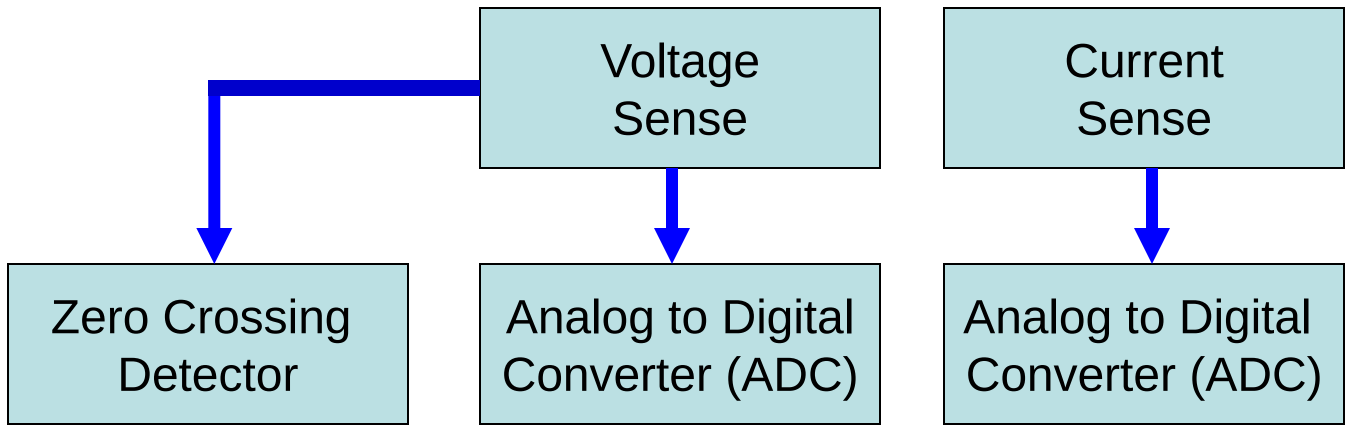
Market	Voltage	Voltage Tolerance	Maximum Total Harmonic Distortion	Frequency	Frequency Tolerance
North America, Taiwan	115 V ac	+/- 4.0 %	5.0 %	60 Hz	+/- 1.0 %
Europe, Australia, New Zealand	230 V ac	+/- 4.0 %	5.0 %	50 Hz	+/- 1.0 %
Japan	100 V ac	+/- 4.0 %	5.0 %	50 Hz or 60 Hz	+/- 1.0 %

Power Meter Workshop

Digital Power Meter:



Power Meter Workshop

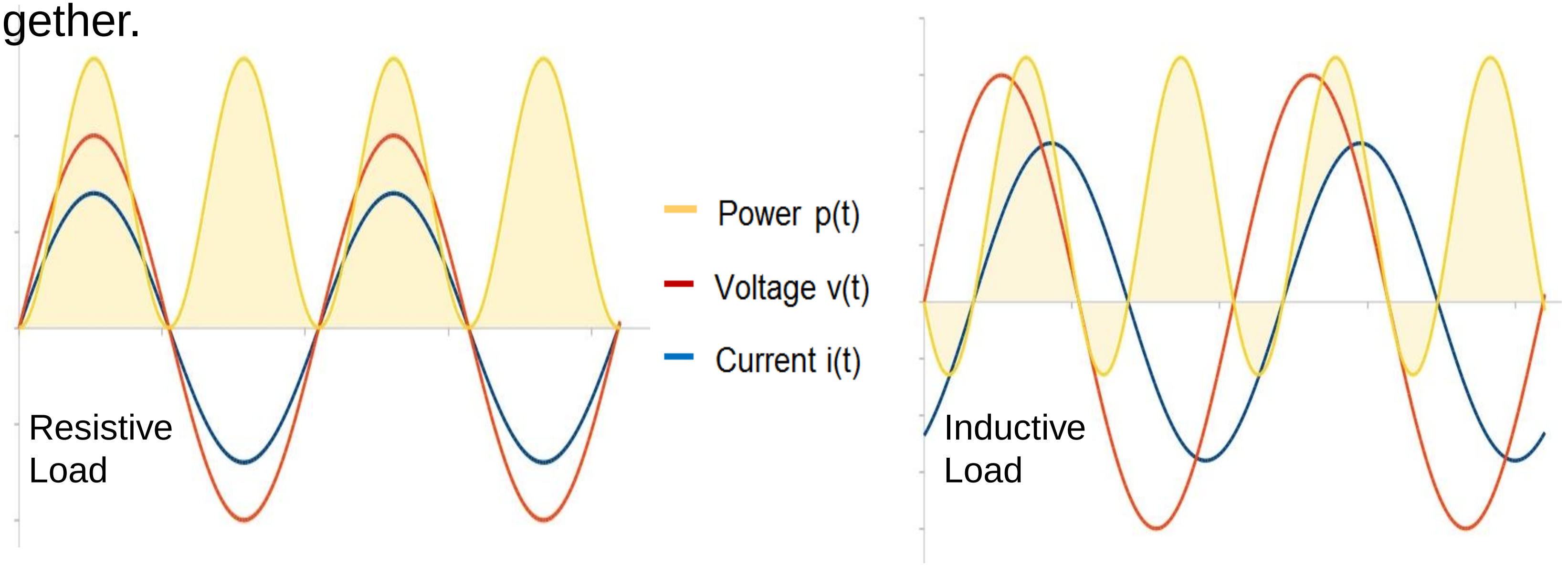


Analog to Digital Converter (ADC) Bit resolution:

- The Higher the Bit count the greater the Voltage and Current measurement resolution.
- 8 Bit ADC = 256 increments at 300V range = 1.172V resolution
- 10 Bit ADC = 1024 increments at 300V range = 0.293V resolution
- 12 Bit ADC = 4096 increments at 300V range = 0.073V resolution
- 16 Bit ADC = 65536 increments at 300V range = 0.00458V resolution

Power Meter Basics

If Voltage and Current Waveforms were pure sinewaves and loads were pure resistive the power measurements could be simply taking the Peak voltage and peak current x 0.707 to create the Vrms and Irms and the multiply the 2 together.



True Power or Watts = Vrms x Irms x cos θ

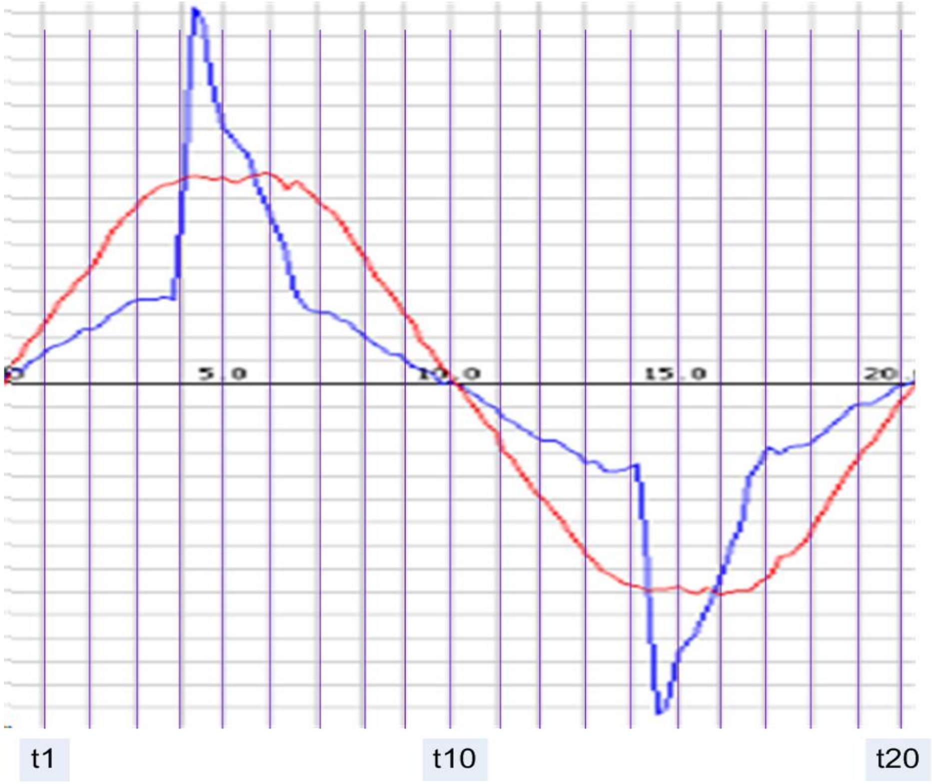
Vrms = Vpk x 0.707 Irms = Ipk x 0.707

cos θ or PF = W/(Vrms x Irms)

Ex. 120Vrms x 10Arms x 0.9PF = 1080W

Power Meter Basics (Sample Rates)

Real world voltage and current waveforms are seldom sinusoidal
Digital Power Meters Sample Rates are critical to accuracy .



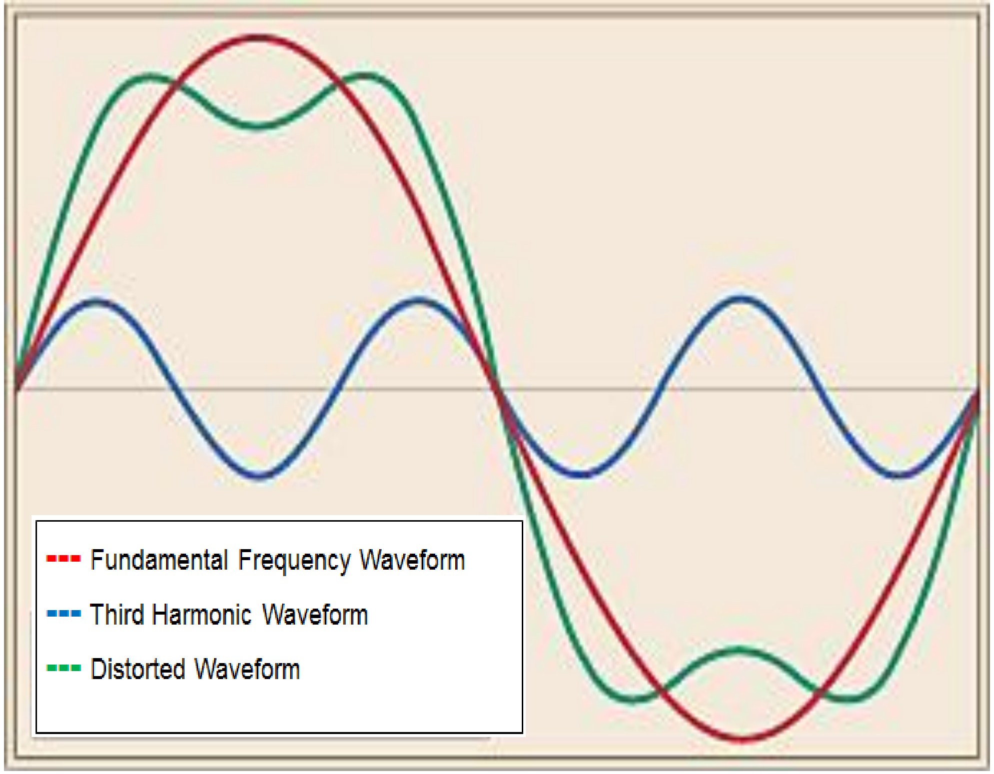
Sample rate of approx 1024 samples per second equates to approx one measurement every millisecond and only 20 measurements per cycle at 50hz. At 800Hz it equates to 1.25 measurements per cycle. In the example waveform the Peak current would be missed.

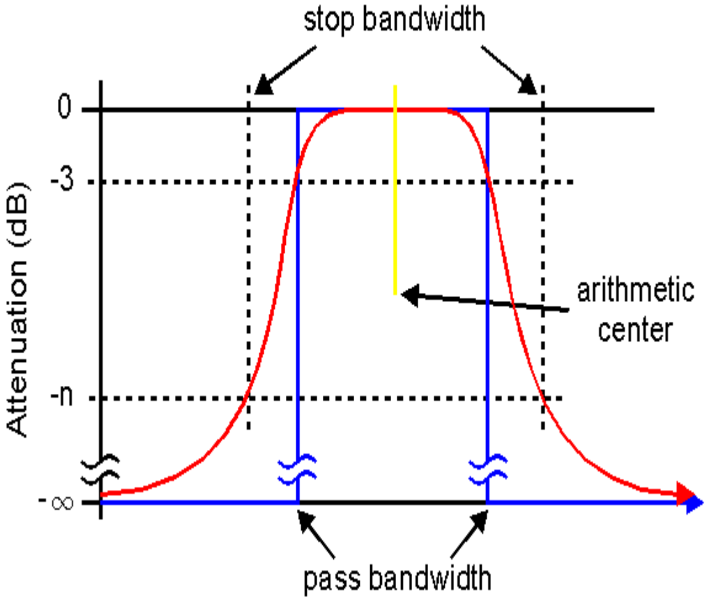
Chroma 66202 Sample rate is 240K Samples/Sec

$$V_{RMS} = \sqrt{\frac{V_1^2 + V_2^2 + V_3^2 + V_4^2 \cdots + V_{11}^2 + V_n^2}{n}}$$

Power Meter Basics

Harmonic Distortion Measurements for a specific harmonic:
Digital Power Meters use DSP's for a digital equivalent of a Digital Bandpass Filter to extract the voltage and current at a specific harmonic. Then measured using the RMS measurement algorithms for RMS Voltage and RMS Current at each Harmonic.

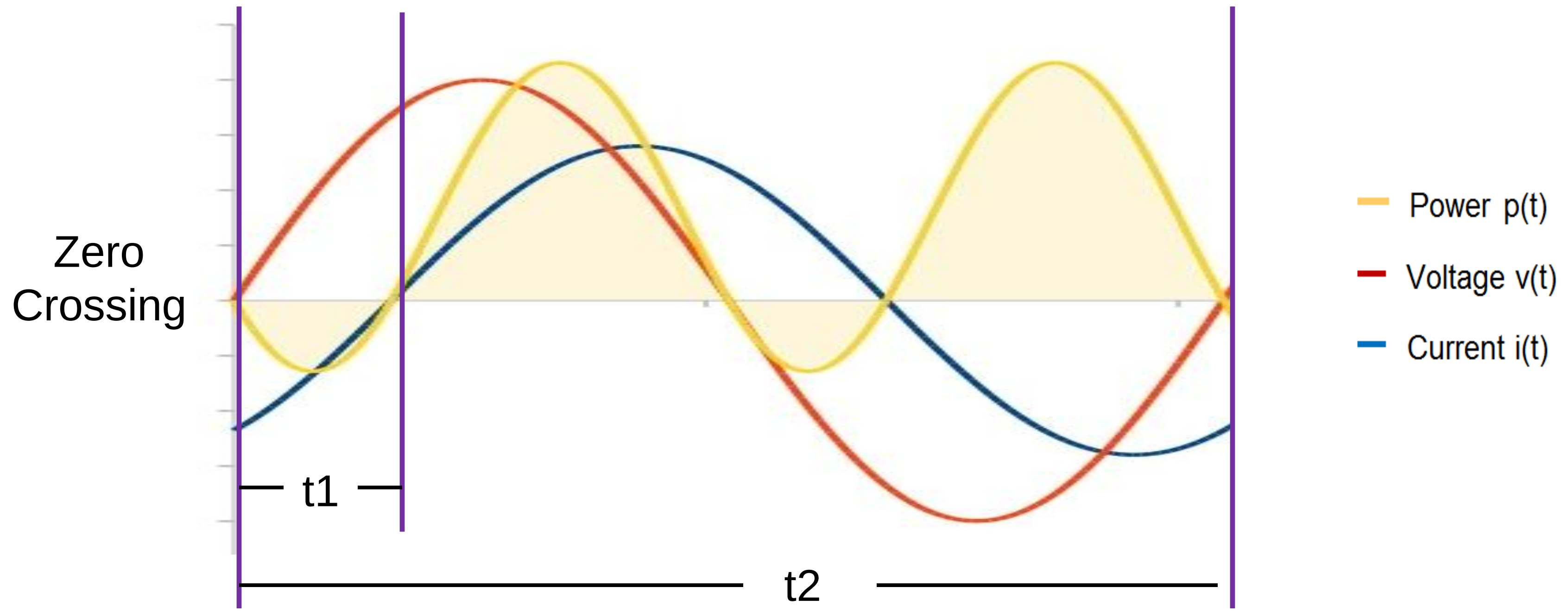




BandPass Filter Graph

Power Meter Basics

Cosine θ or Power Factor Measurements



Power Factor = the Cosine of the Phase angle of the current versus voltage waveforms.

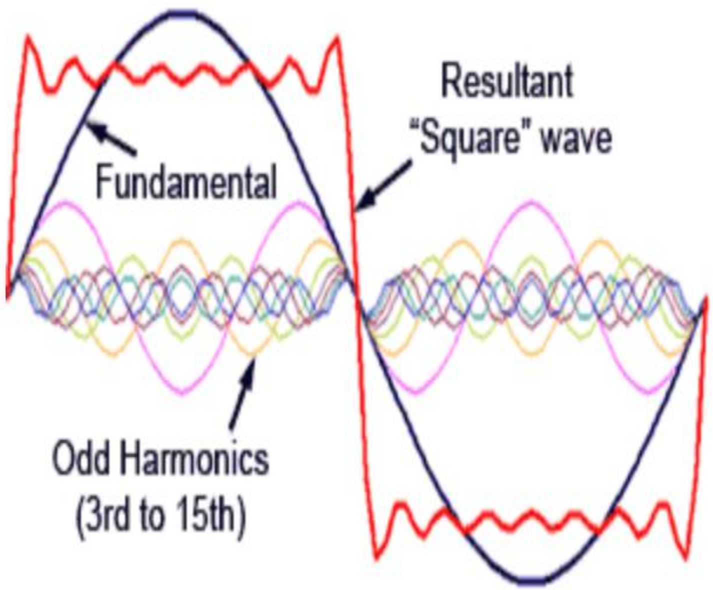
PF or cos θ = Cosine of ((t1 / t2) x 360˚)

Ex. Cosine (0.002Sec/ 0.0166Sec) x 360 = 0.726

Power Meter Basic's

- <u>Harmonic Distortion</u>

- Current distortion affects the power system and distribution equipment. It may directly or indirectly cause the destruction of loads or loss of product. From the direct perspective, current distortion may cause transformers to overheat and fail even if they are not fully loaded. Conductors and conduit systems can also overheat leading to open circuits and downtime.



Power Meter Basic's

With Digital Signal Processors many other parameters can be calculated using internal embedded Firmware and Algorithms based on Voltage, Current and time measurements.

Single Phase Measurement Parameter

Measurement Parameter	Computing Equation
True rms value	
V_{rms}	$\sqrt{\frac{1}{T}\int_0^T v^2(t)dt}$
I_{rms}	$\sqrt{\frac{1}{T}\int_0^T i^2(t)dt}$
W	$\frac{1}{T}\int_0^T v(t)\,i(t)\,dt$
VAR	$\sqrt{VA^2 - W^2}$
VA	$V_{rms} \times I_{rms}$
PF	$\frac{W}{VA}$

Power Meter Basic's

Algorithms like these use the Voltage, Current and Time measurements to determine more complex values

Mean value	
V_{dc}	$\frac{1}{T}\int_0^T v(t)dt$
I_{dc}	$\frac{1}{T}\int_0^T i(t)dt$
W_{dc}	$V_{dc} \times I_{dc}$
Integration	
Energy (Wh or Joule)	$\frac{1}{T}\int_0^T v(t)\, i(t)\, dt$ T is a setting integration time by user.
Integration(W)	$\int_0^T v(t)\, i(t)\, dt$ T is a setting integration time by user.
Frequency	
F	Zero crossing detection

Power Meter Basic's

Algorithms like these use the Voltage, Current and Time measurements to determine more complex values

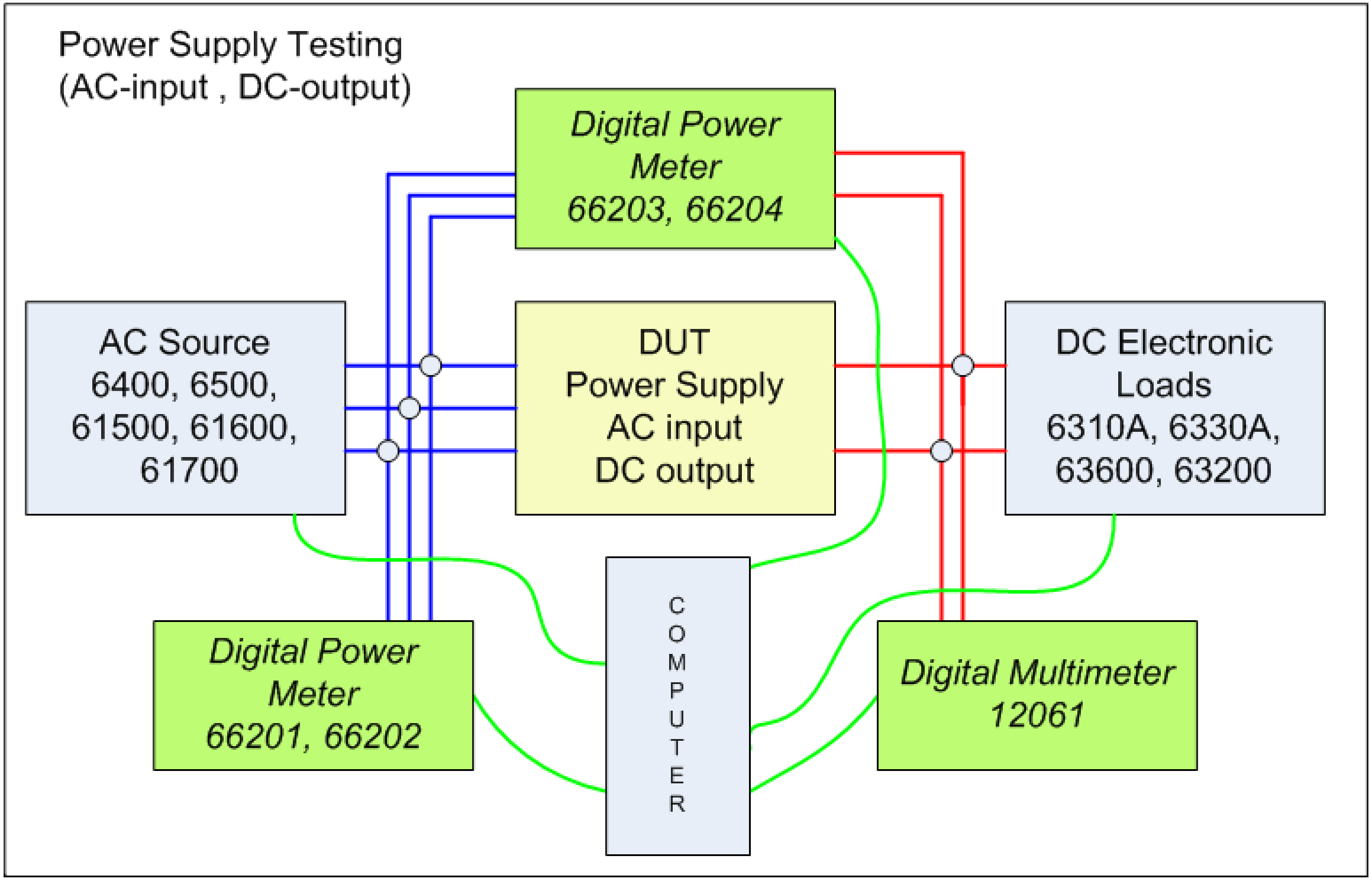
Peak value	
V_{PK+}	The maximum sampling value of the positive half wave of $v(t)$ during two continuous cycles.
V_{PK-}	Absolute value of the maximum sampling value of the negative half wave of $v(t)$ during two continuous cycles.
I_{PK+}	The maximum sampling value of the positive half wave of $i(t)$ during two continuous cycles.
I_{PK-}	Absolute value of the maximum value of the negative half wave of $i(t)$ during two continuous cycles.

Power Meter Basic's

Algorithms like these use the Voltage, Current and Time measurements to determine more complex values

Crest Factor	
CFi	$\dfrac{\max imum\ of\ (I_{pk+}, I_{pk-})}{I_{rms}}$
THD & Harmonic value	
THD_v	$\dfrac{\sqrt{V_2^2 + V_3^2 + V_4^2 + V_5^2 + \ldots\ldots V_n^2}}{V_1} \times 100\%$ I_n^2 the subscript *n* indicates the range of harmonic which is 2.3.4….100.
THD_i	$\dfrac{\sqrt{I_2^2 + I_3^2 + I_4^2 + I_5^2 + \ldots\ldots I_n^2}}{I_1} \times 100\%$ V_n^2 the subscript *n* indicates the range of harmonic which is 2.3.4….100.

Typical use of a Power Meter for Power Supply Efficiency testing



Typical use of a Power Meter for Power Supply Efficiency testing

Efficiency % = (Pout / Pin) x 100

Pin = Vrms x Irms x cosø

Pout = Vdc x Idc

Ex.

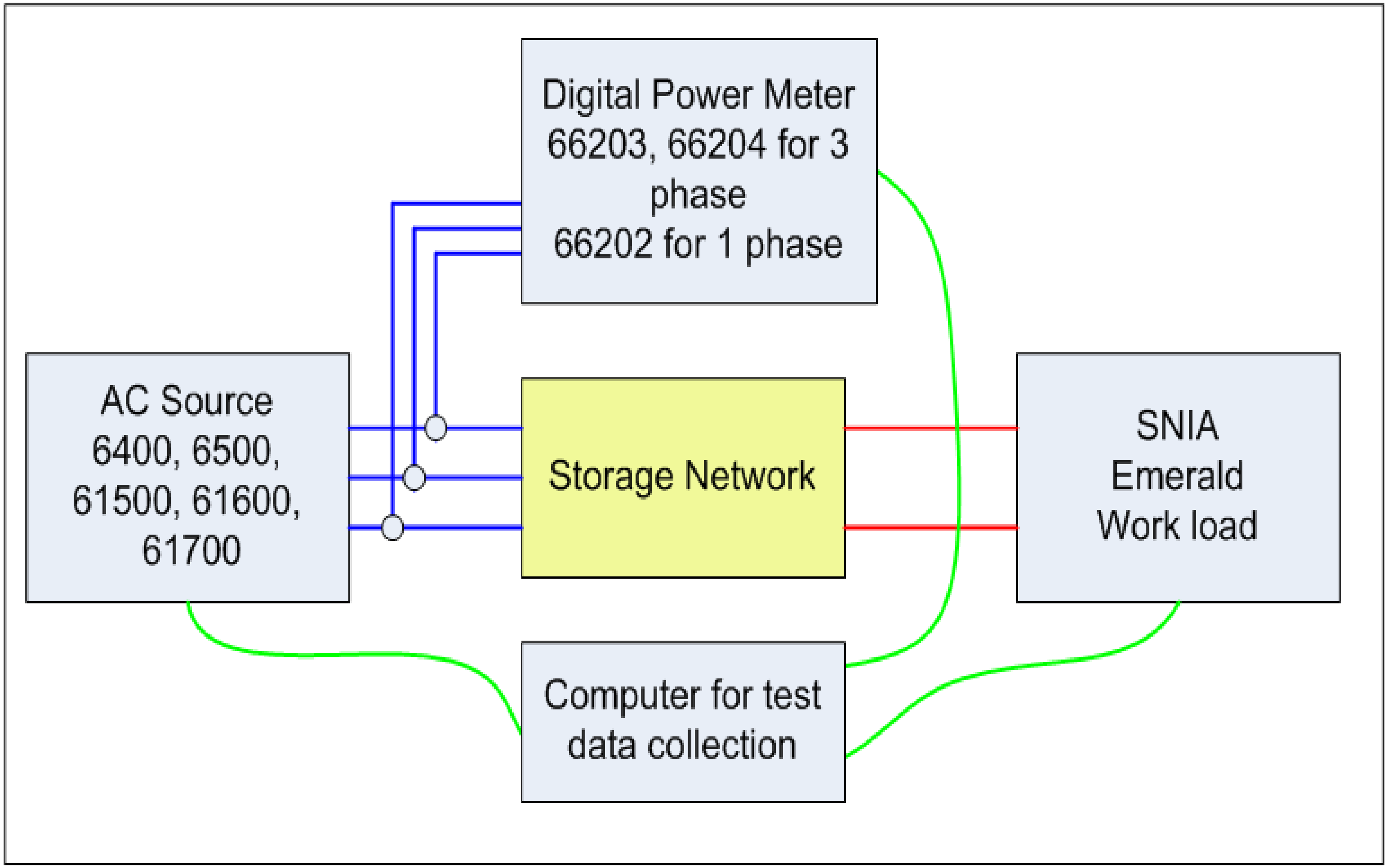
Output Power (Pout) = 100W

Vrms = 115V, Irms = 1A, PF = 0.87

Input Power (Pin) = 120W

Eff% = (100/120) x 100 = 83%

SNIA Emerald test Block Diagram



Manual Operation of Power Meter (Chroma 66202)

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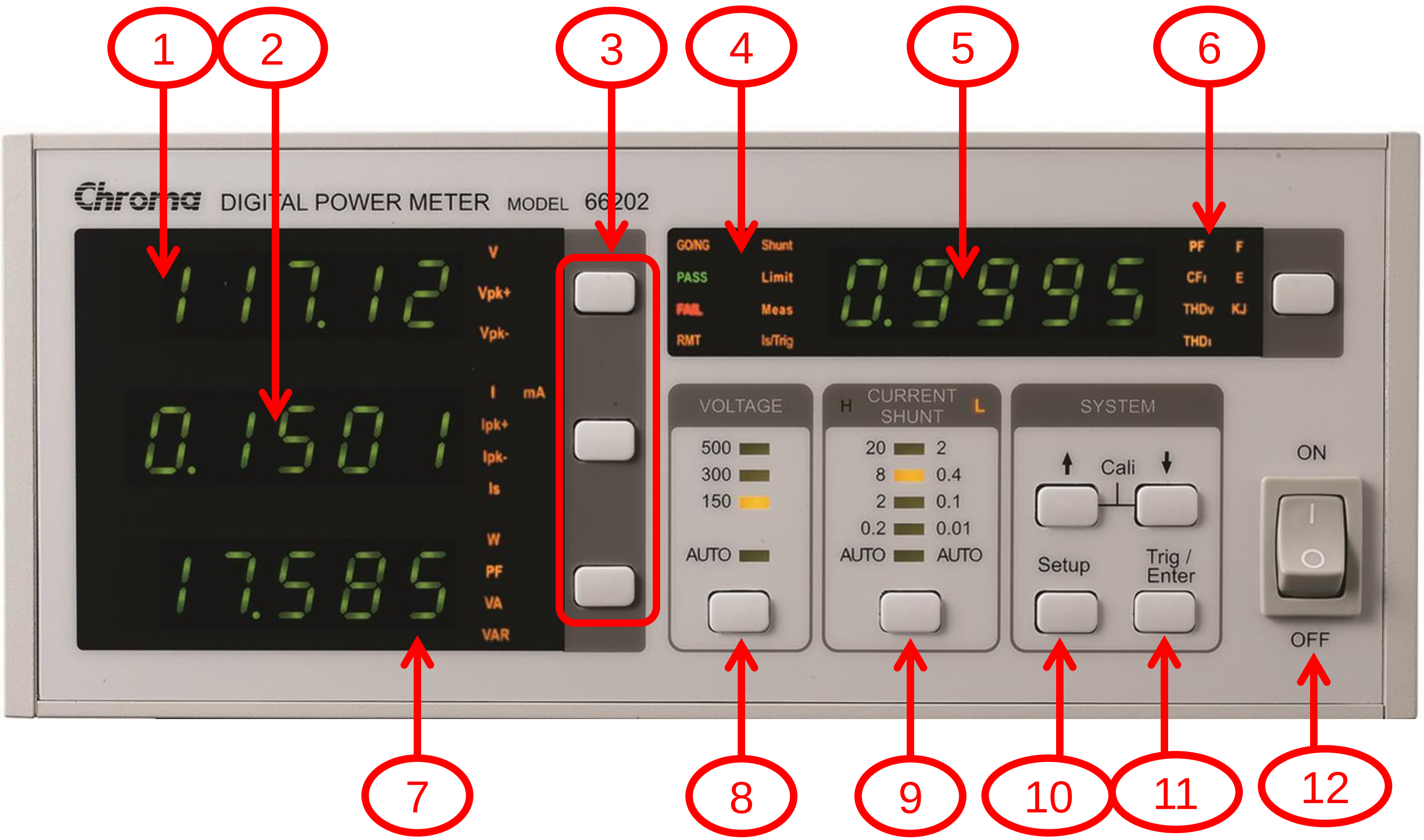
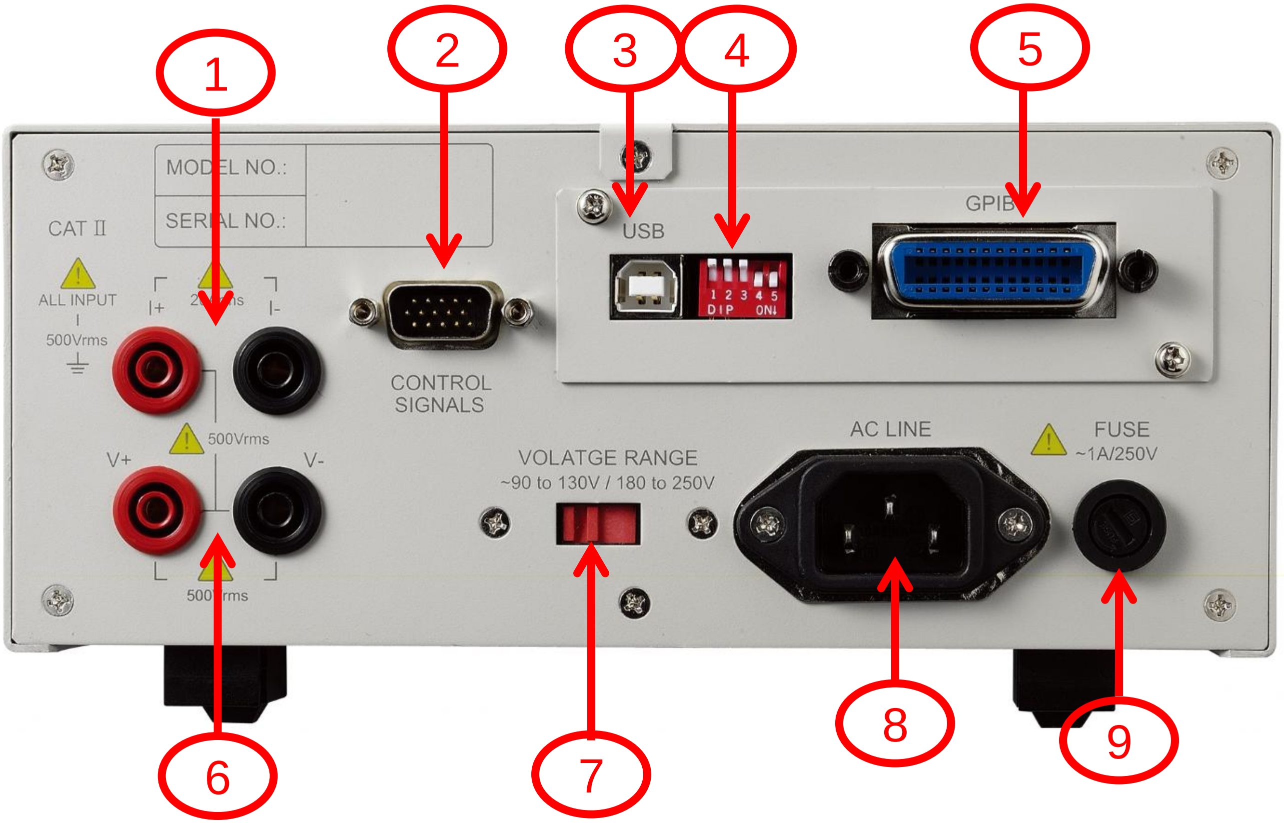


Manual Operation of Power Meter (Chroma 66202)

1. Display 1 for Vrms, Vpk+, Vpk- measurements
2. Display 2 for Current, Irms, Ipk+, Ipk-
3. Function Key for Display 1,2,and 3
4. Indicators for GO/NG, Pass, Fail, Rmt, Shunt, Limit, Meas, IS-trg
5. Display 4 for PF, CFi, THDv, THDi, Freq, Energy
6. Indicators for Key for Display 4, PF, Cfi, THDv, THDi, F, E, KJ.
7. Display 3 for Watts, PF, VA, and VAR
8. Voltage Range selection button
9. Current Range selection button
10. Setup Button
11. Trig Enter
12. Power ON/OFF

Manual Operation of Power Meter (Chroma 66202)

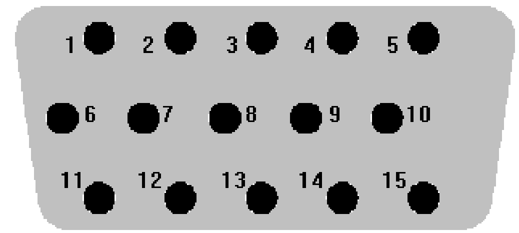


Manual Operation of Power Meter (Chroma 66202)

1. Current Sense Connections
2. Control Signals Connector
3. USB Connector
4. GPIB Address Select switch
5. GPIB
6. Voltage Sense Connectors
7. Input Voltage Select Switch 120/240
8. Input Power connection (IEC 60320-1)
9. Input Power Fuse

Chroma 66202 Power Meter

Control Signal Connector



Pin	Definition	Pin	Definition	Pin	Definition
1	+5V	6	GND	11	Fail -
2	Is Trigger	~~7~~	~~Reserve_TTL3~~	12	Fail +
~~3~~	~~Reserve_TTL1~~	8	Limit Trigger	~~13~~	~~Reserve_TTL5~~
4	GND	9	GND	14	Pass -
~~5~~	~~Reserve_TTL2~~	~~10~~	~~Reserve_TTL4~~	15	Pass +

Limit Trigger Connection

Figure A-1 shows the connection of Limit Trigger. **66201/66202** Power Meter defines the Limit Trigger as falling edge trigger. Ground the 8th pin can trigger it. The trigger is same as pressing **Trig/Enter** on the front panel.

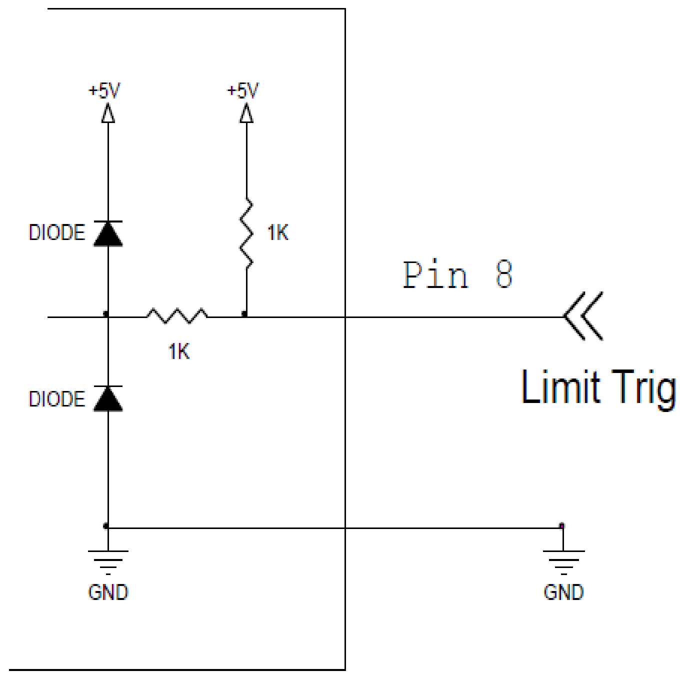
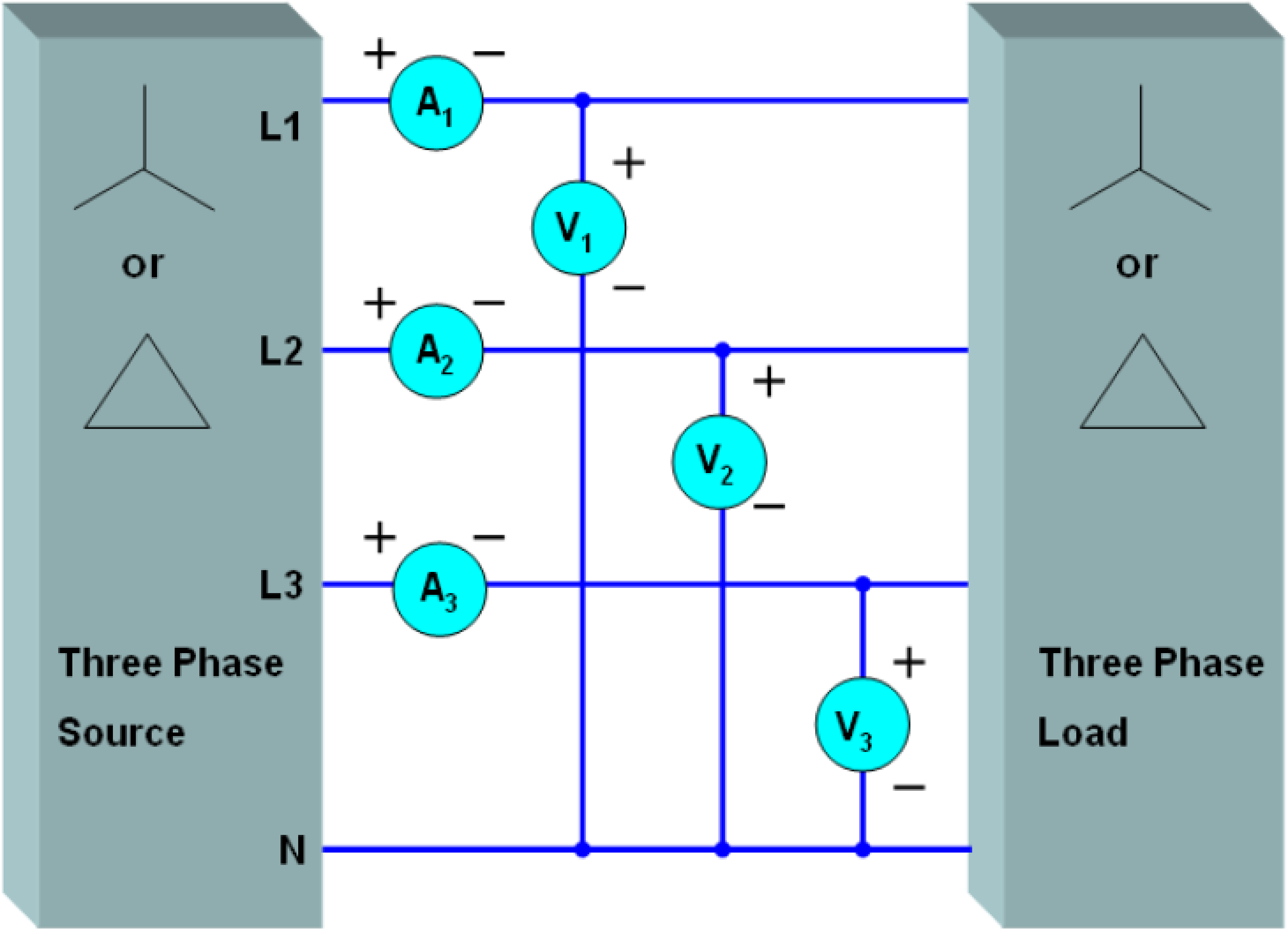
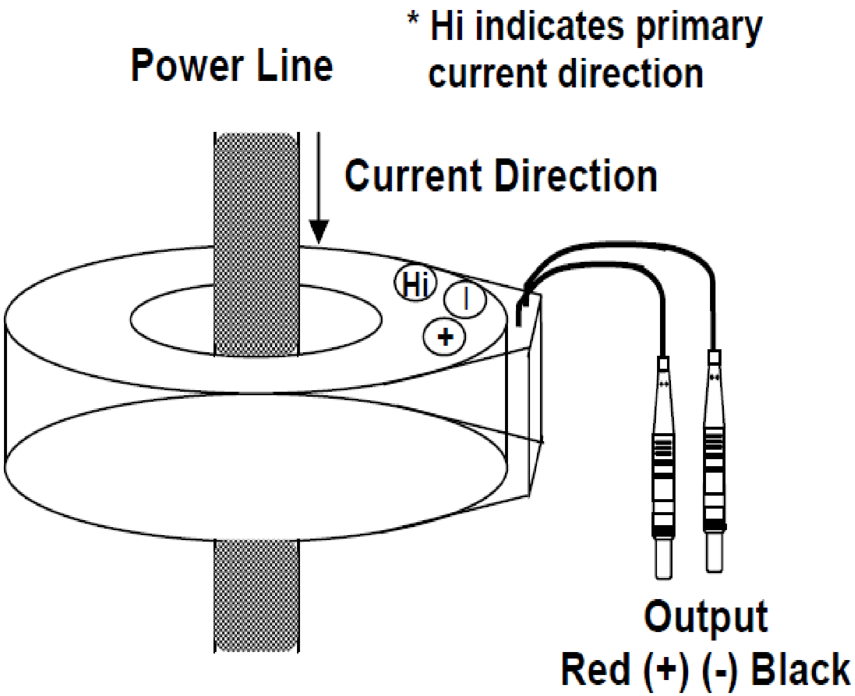


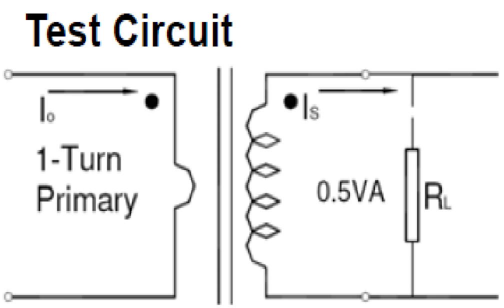
Figure A-1 Connection of Limit Trigger

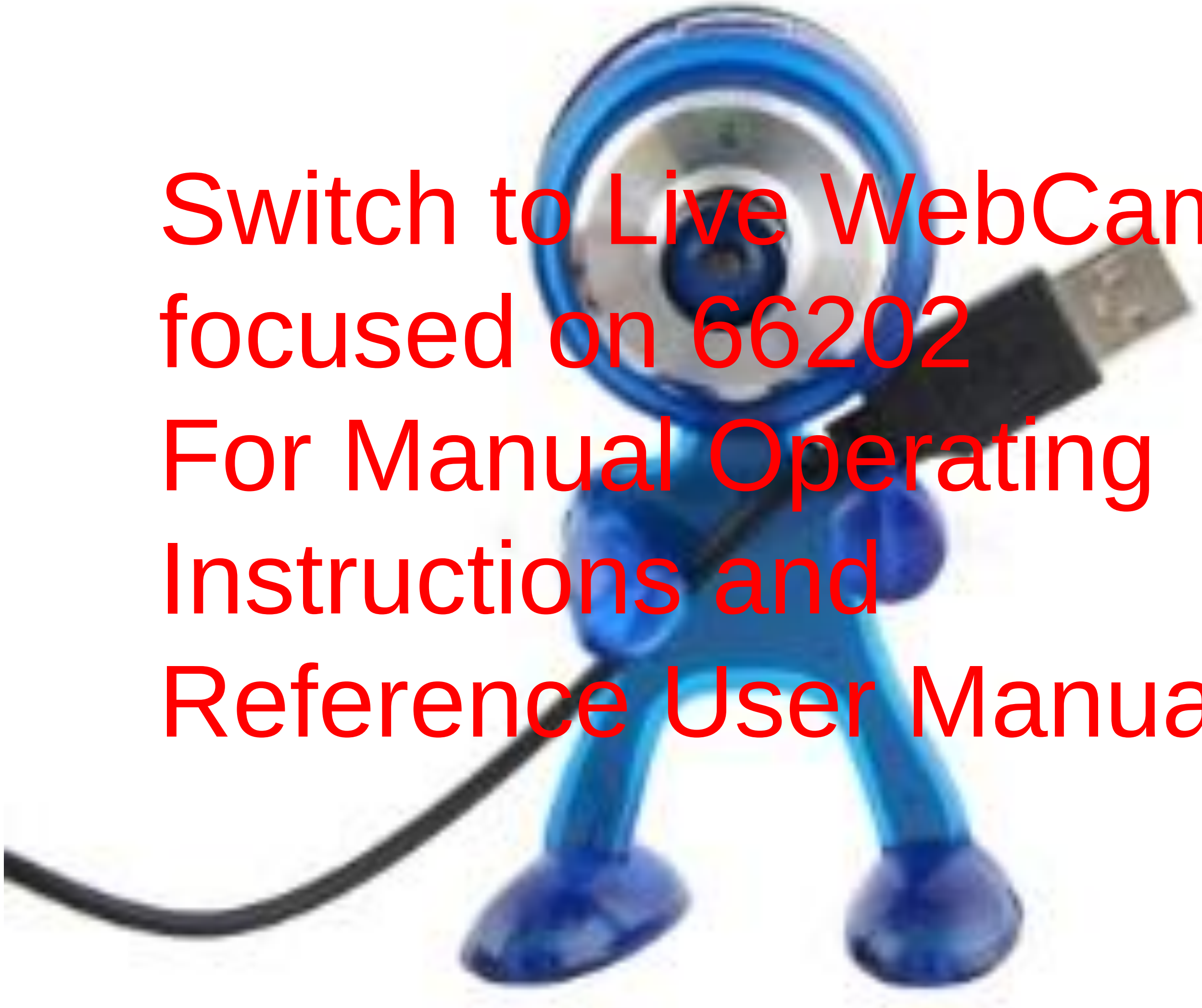
Three Phase Wye Connections



External Current Transformer & Current Shunt



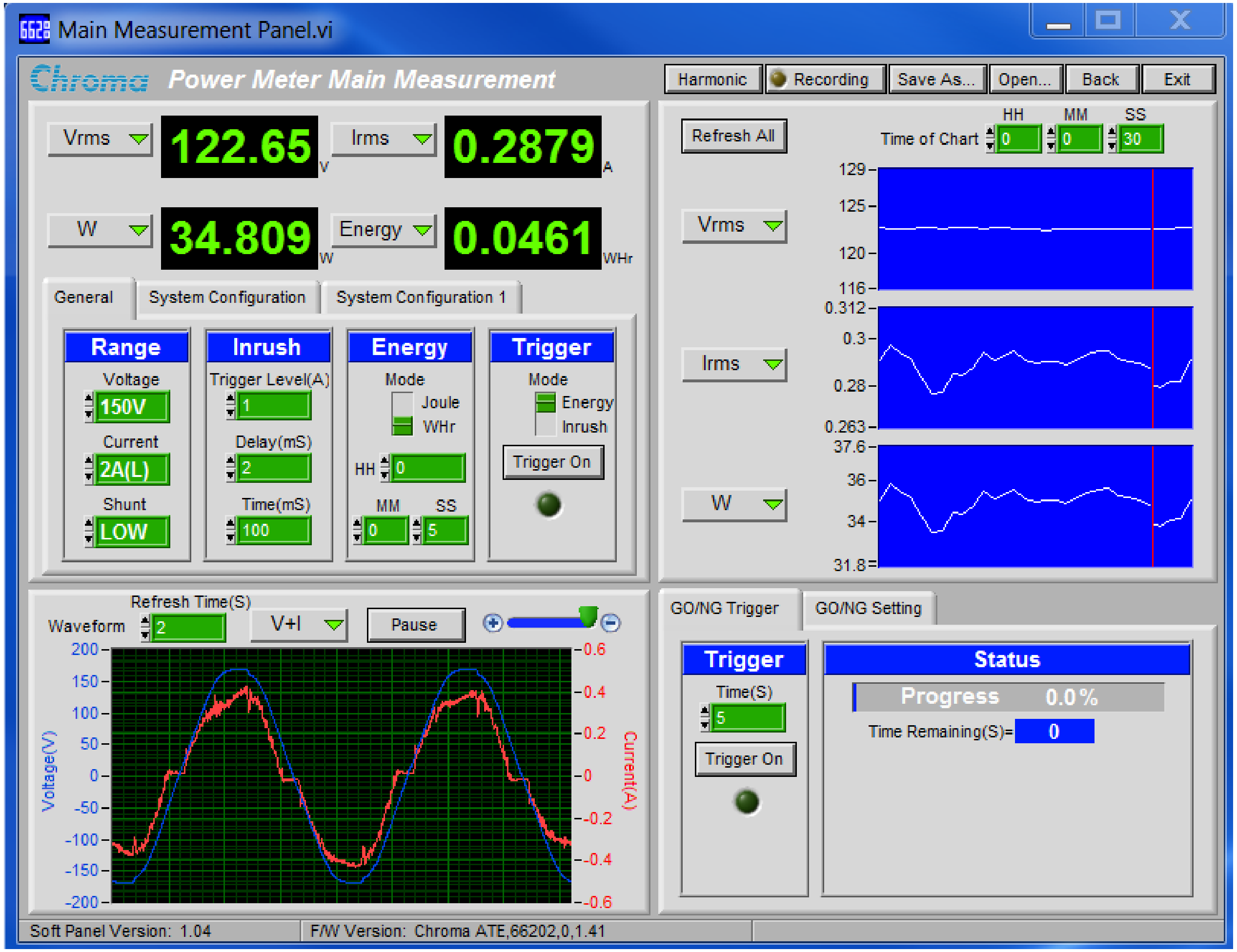




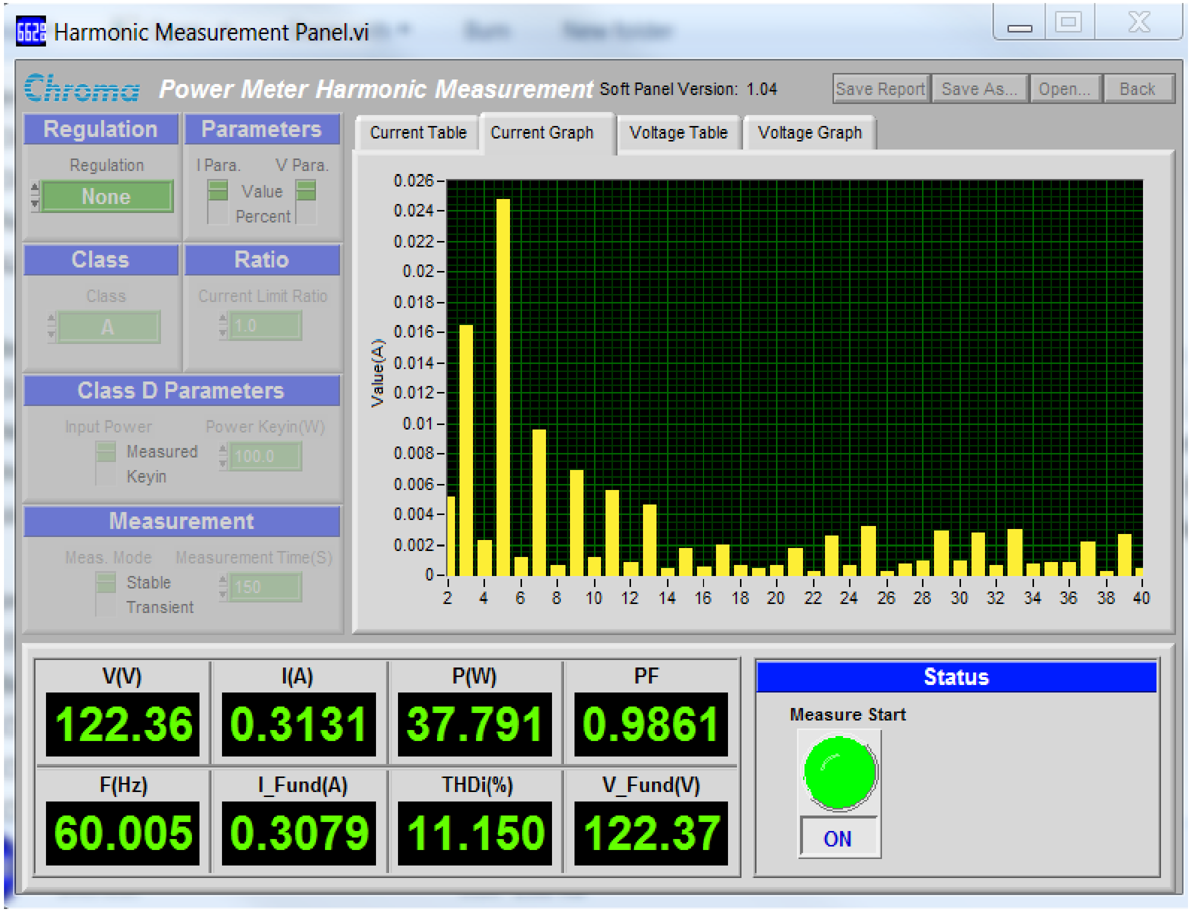
Switch to Live WebCam focused on 66202

For Manual Operating Instructions and Reference User Manual

Software for Power Meter (Chroma 66202)



Software for Power Meter (Chroma 66202)

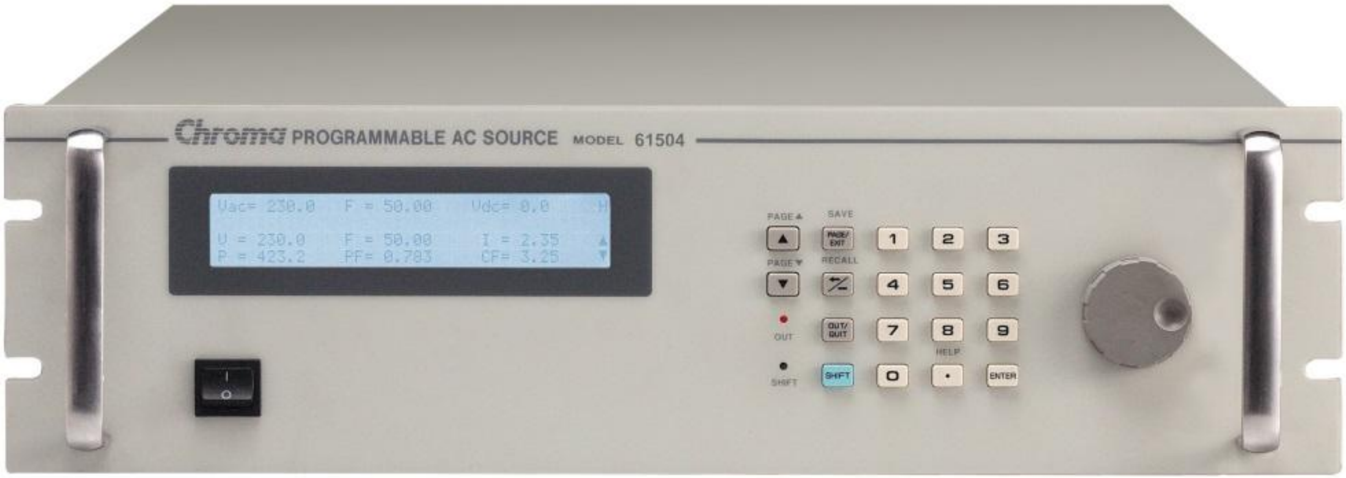


Chroma Digital Power Meters

Digital Power Meter Multi-Channel

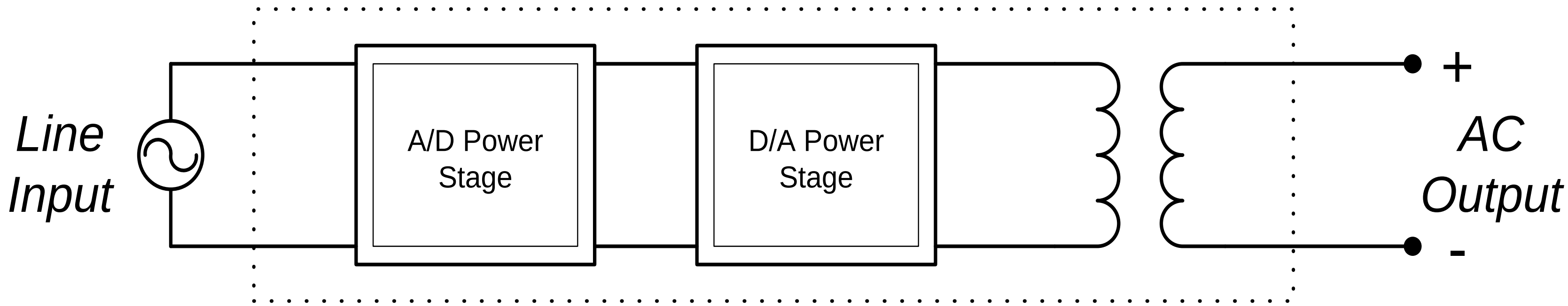
- Voltage Range : 15/30/60/150/300/600 Vrms
- Current Range : 0.005/0.02/0.05/0.2/0.5/2/5/20 Arms
- Frequency Range : DC, 15Hz~10kHz
- Support different wiring configuration power measurement (1P2W/1P3W/3P3W/3P4W)
- Support external shunt and CT for higher current measurement application
- 5 mA minimum current range & 0.1mW power resolution
- Meets ENERGY STAR / IEC 62301 measurement requirements
- Inrush current and energy measurement
- Voltage/ Current harmonics measurement up to 50 orders

AC Power Supply or Source

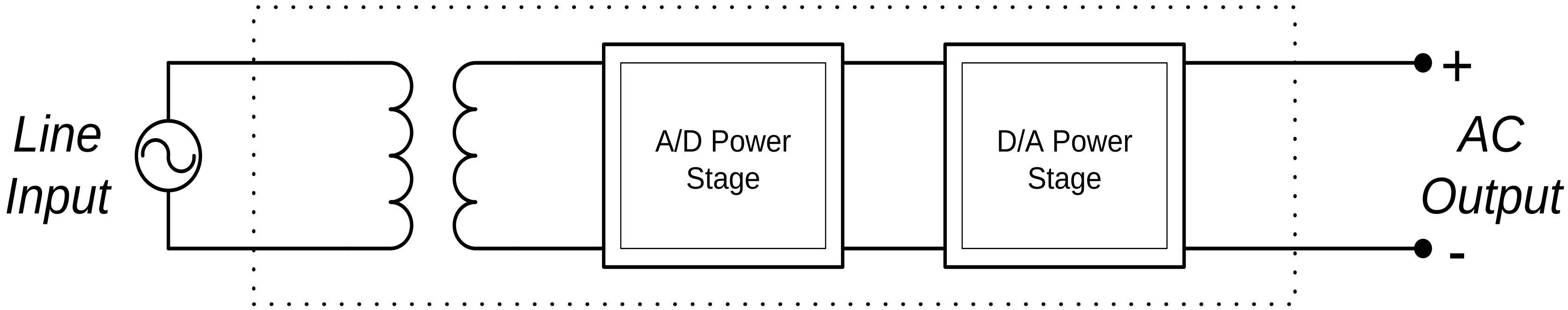


AC Source Power Stages

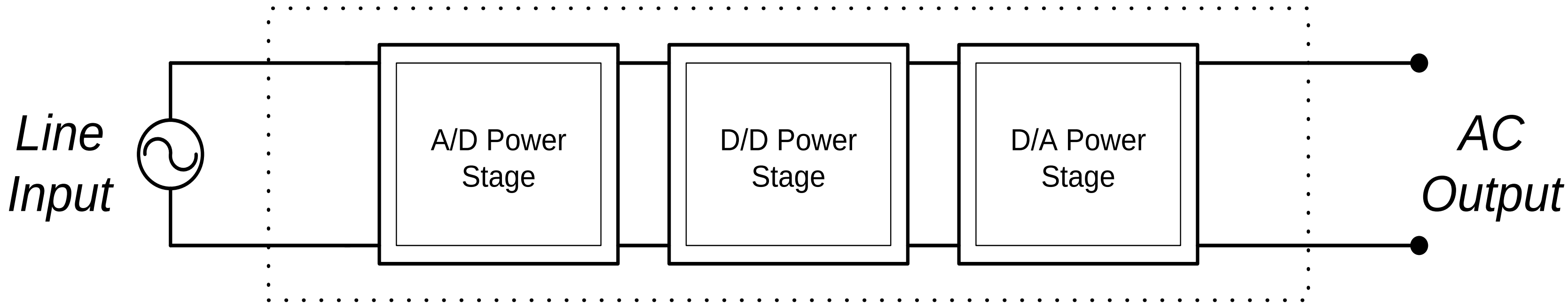
Linear type, a transformer on output, high impedance



A transformer on input, weight is heavy



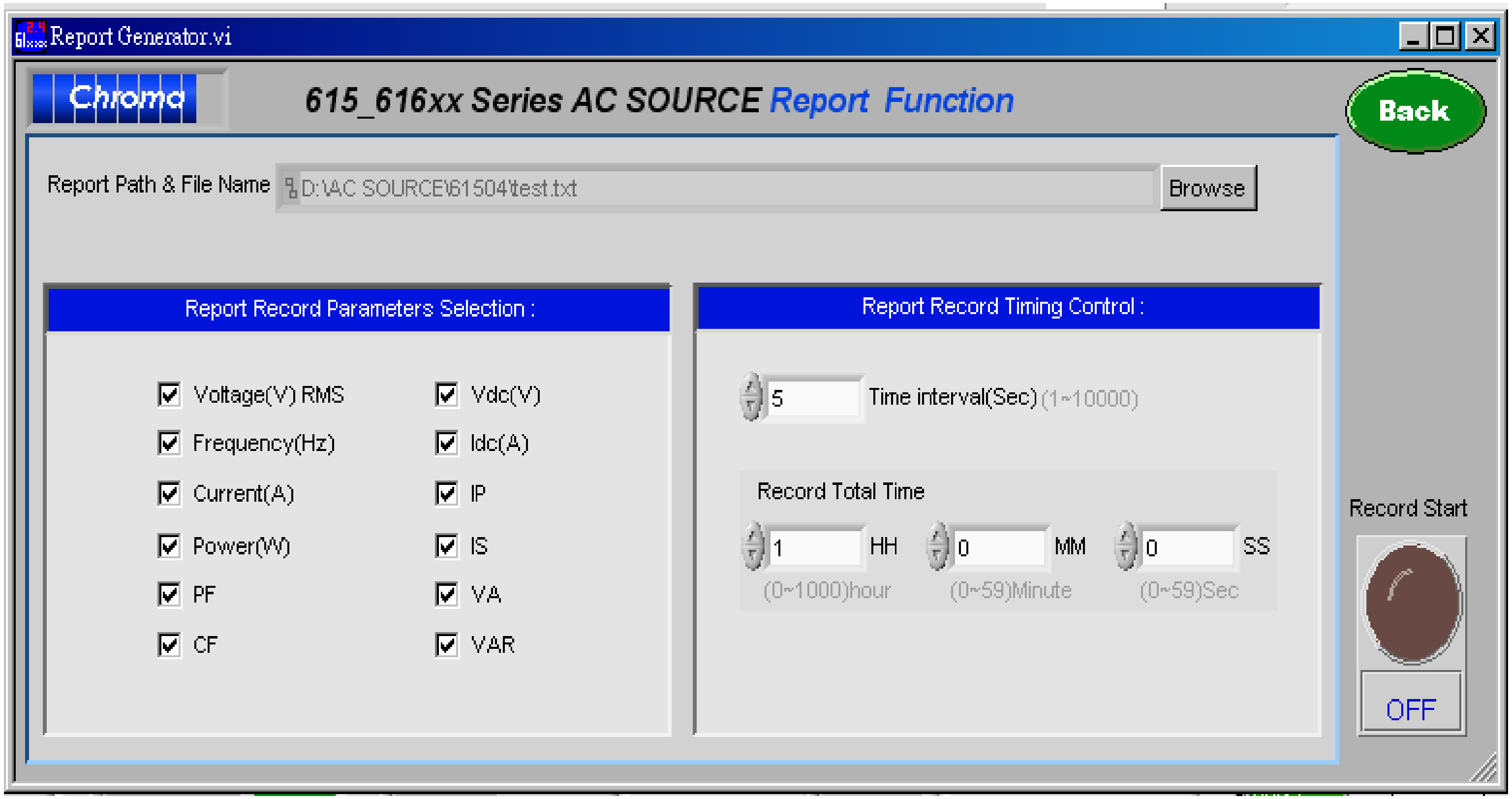
Chroma's AC Source Advantages



1. No low-frequency transformer, lighter than others
2. Standard PFC input, save power and less interference to main
3. No transformer on output, low impedance

61500/61600 Softpanel Function

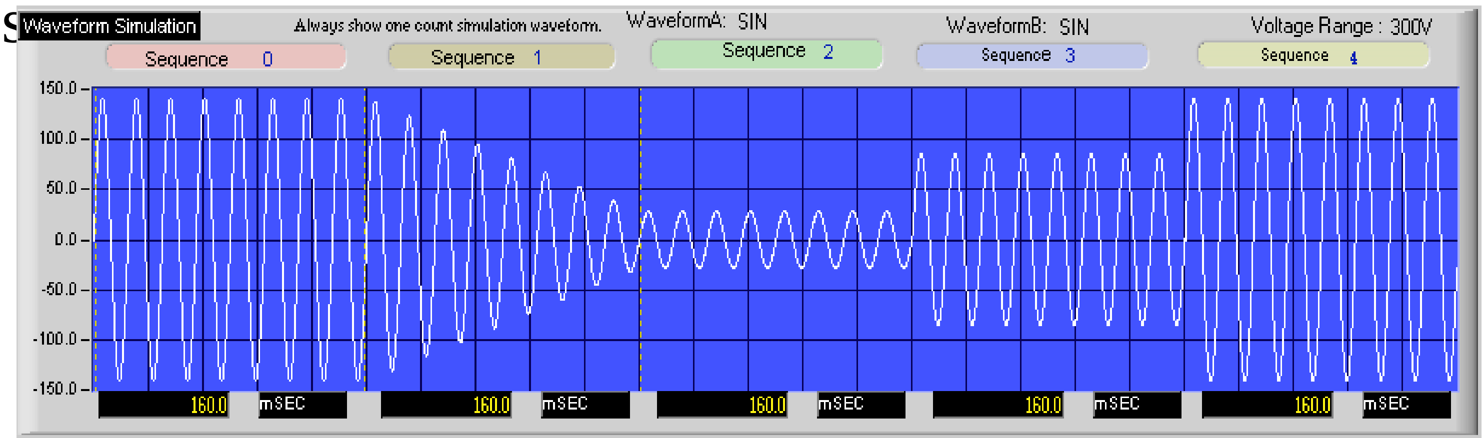
Report Function : Data Recording stored in a File

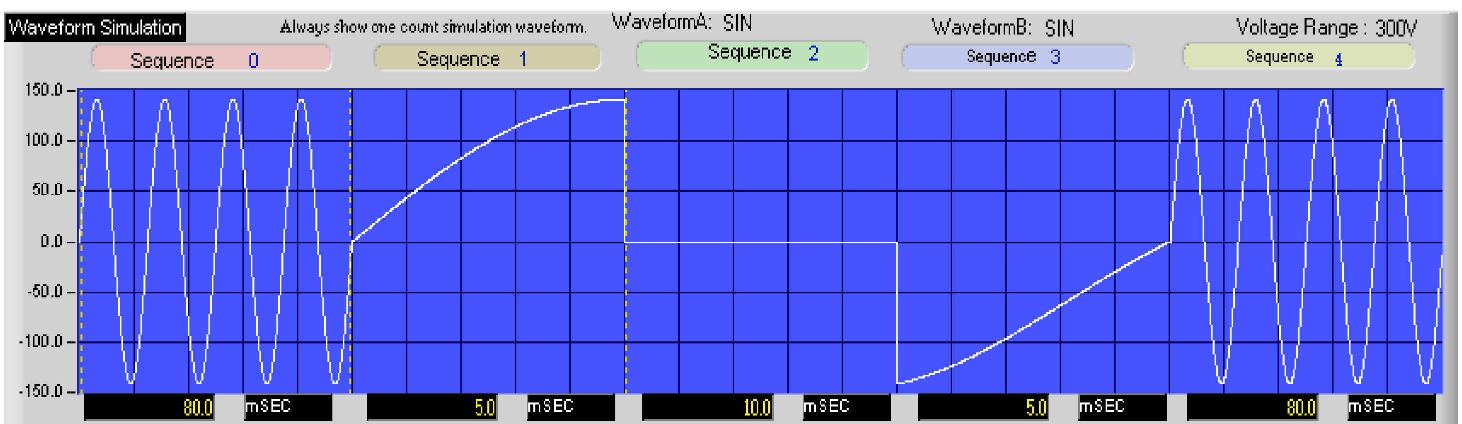


61500 AC Source Functions for Transient Output

LIST Mode: Program output waveform sequence by

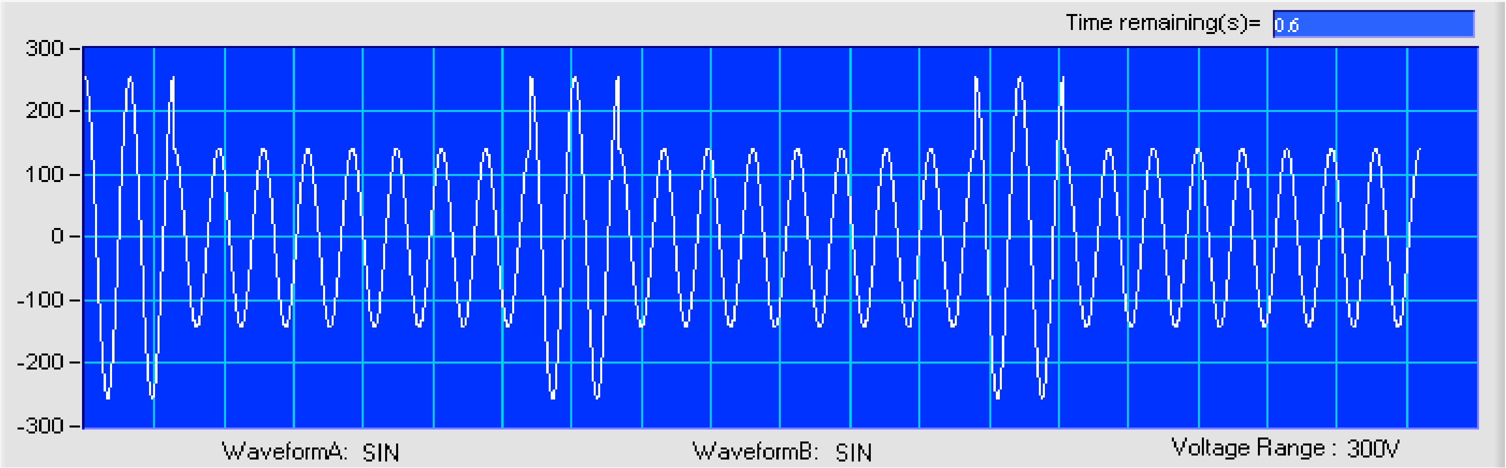
S

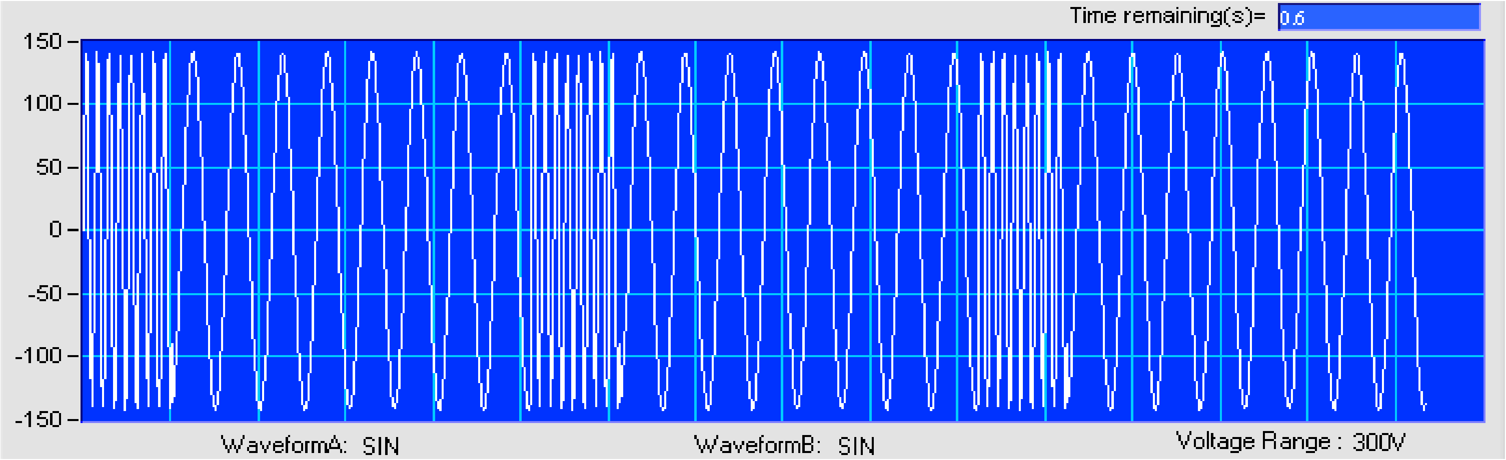




61500 AC Source Functions for Transient Output

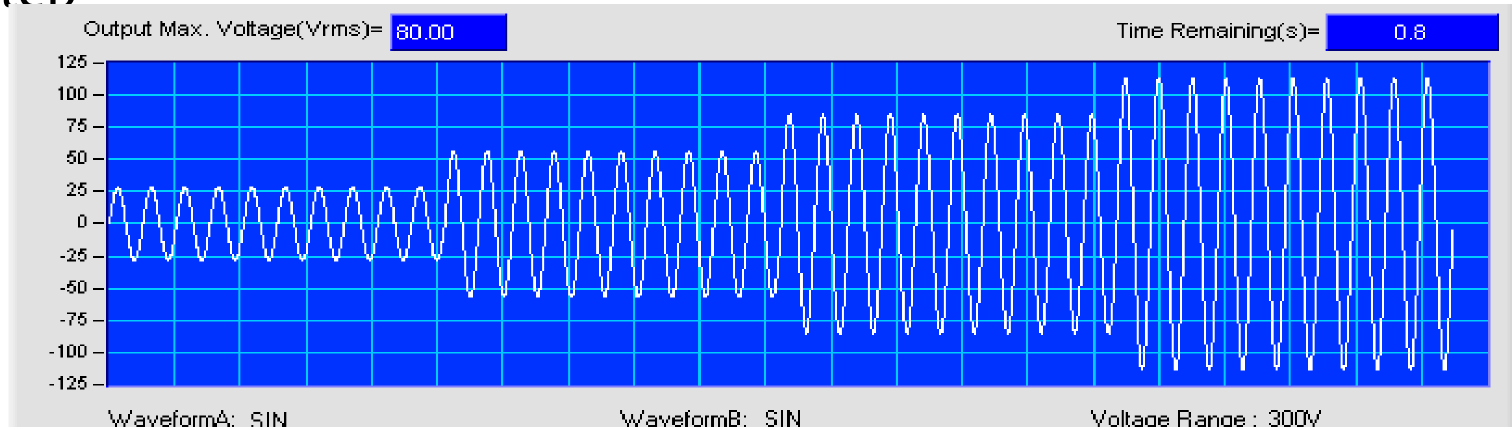
PULSE Mode: Insert a waveform into normal voltage

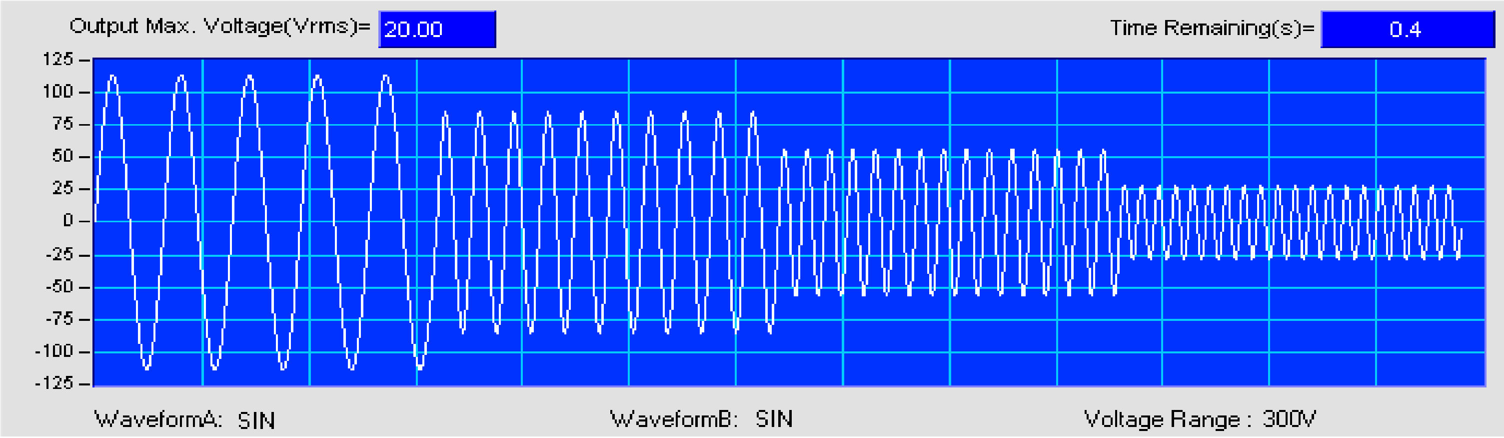




61500 AC Source Functions for Transient Output

STEP Mode : Change from an initial voltage to destination step by step





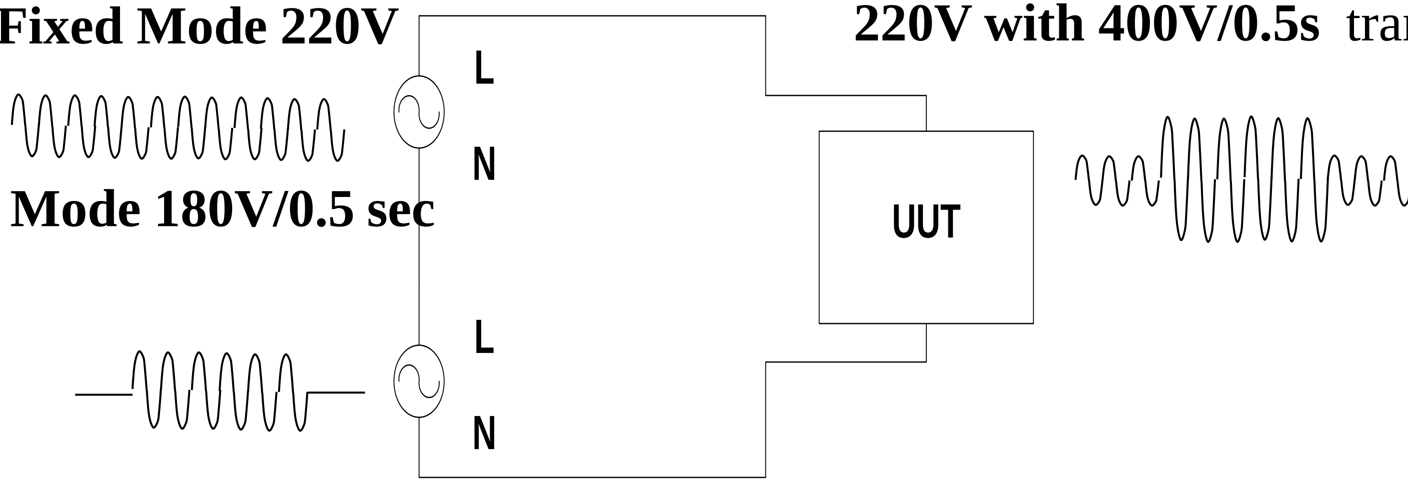
Transient Output with High Voltage

2 units of AC Source with synchronizing signal:

Use 3-phase Mode, 61500/61600 as the Master, 61500 as the Slave.

Master: Fixed Mode 220V

220V with 400V/0.5s transient

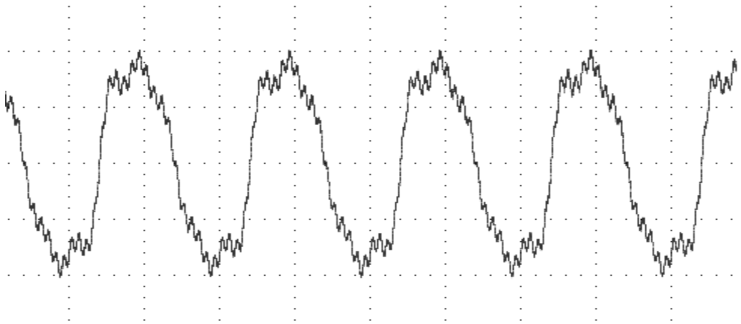


Slave: List Mode 180V/0.5 sec

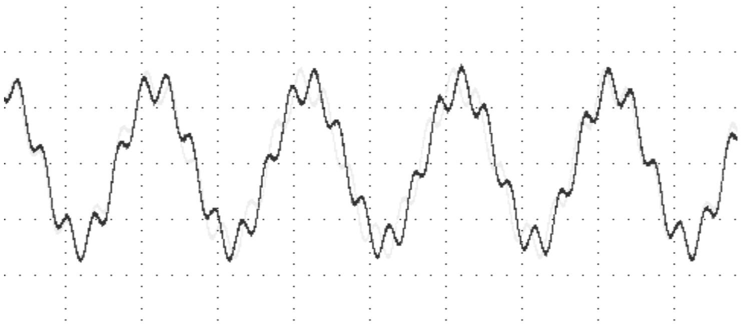
Distorted Waveform

Different kind of distorted waveform:

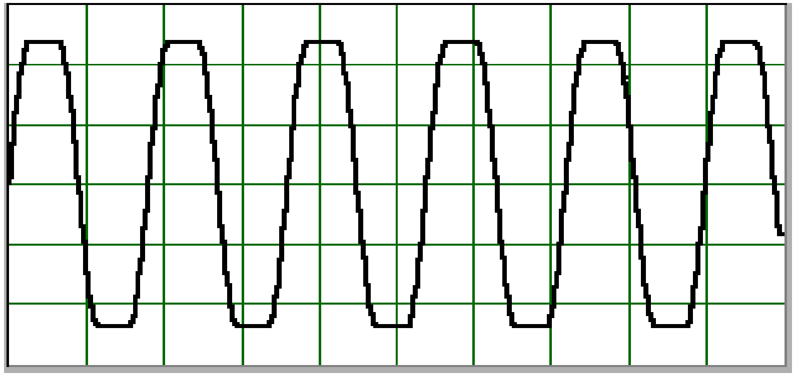
Harmonic Distortion



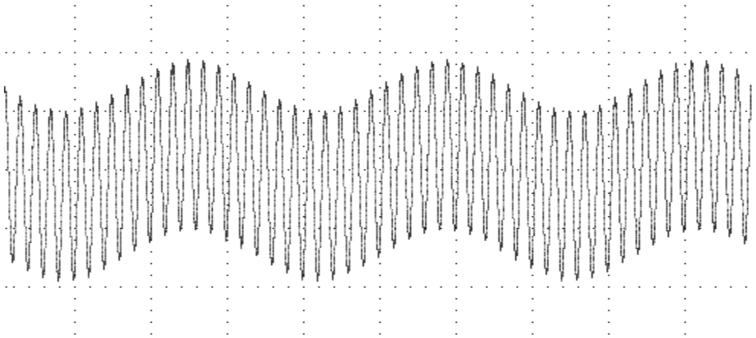
Interharmonic Distortion



Clipped Sine Waveform

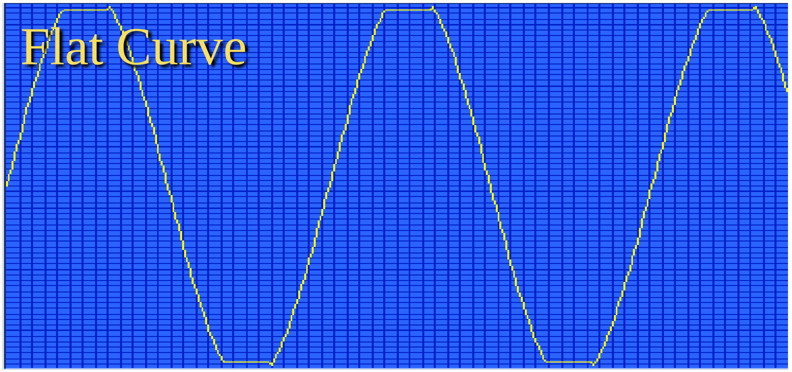


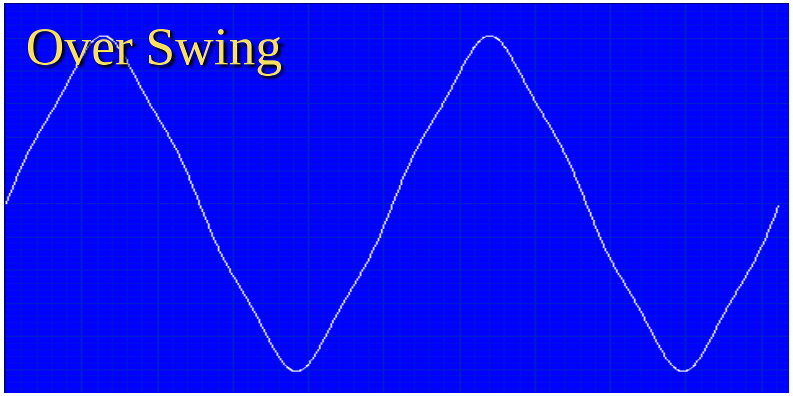
Low frequency drift

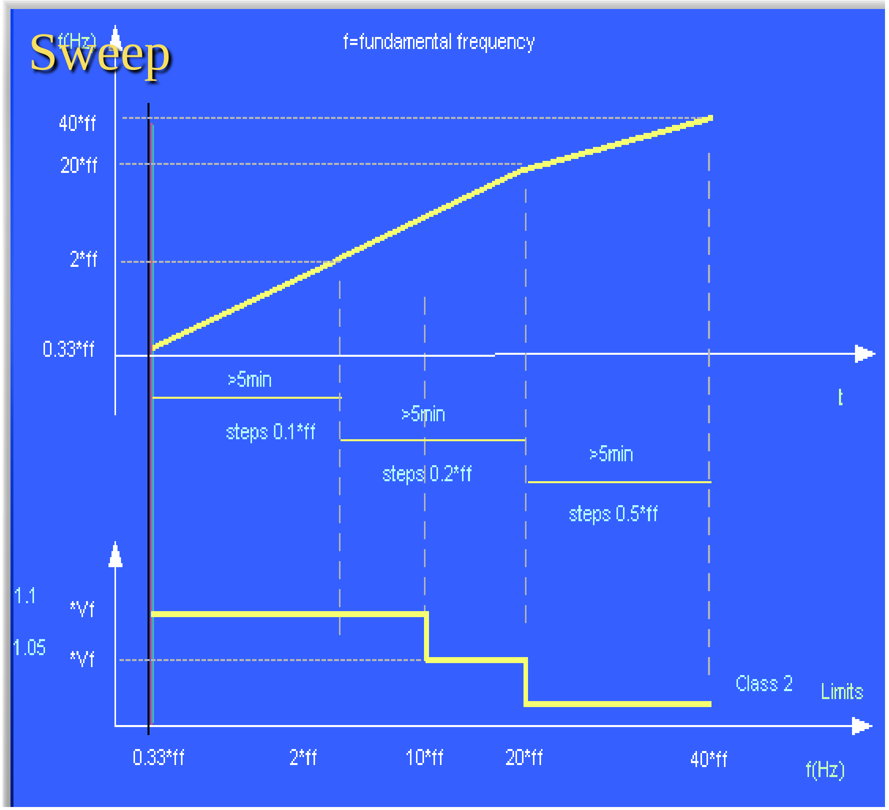


Regulation for Distorted Waveform

IEC 61000-4-13 : Harmonics, Interharmonics including mains signaling at AC power port immunity tests

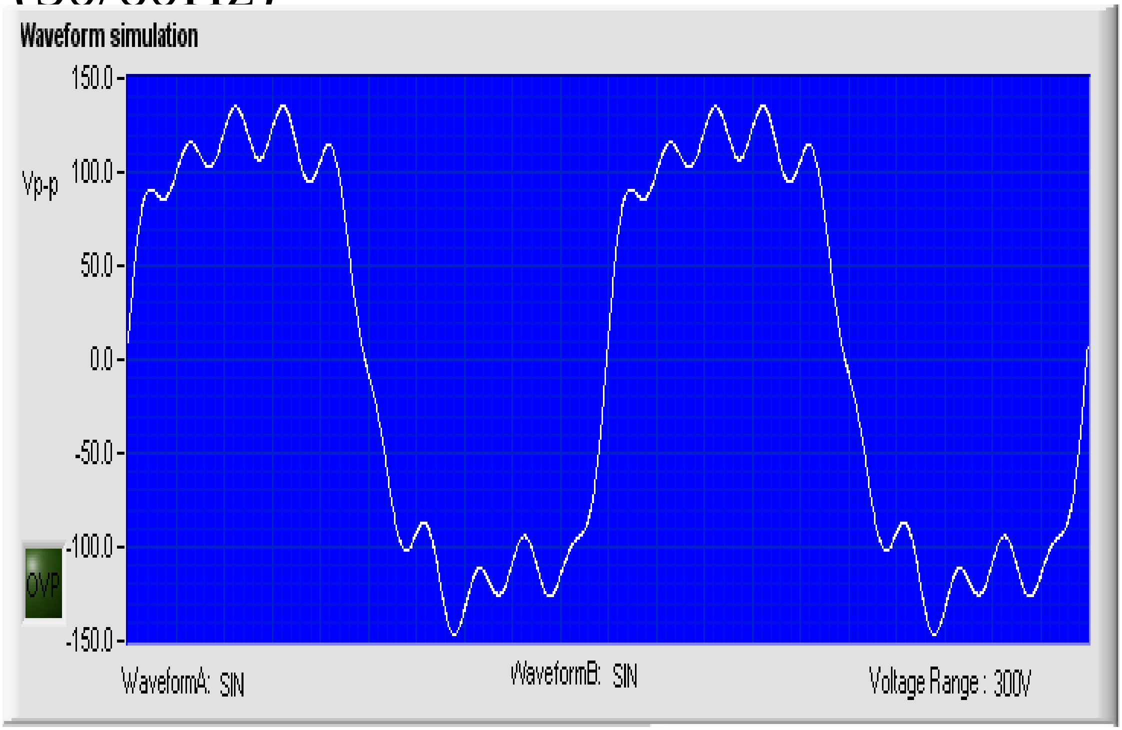


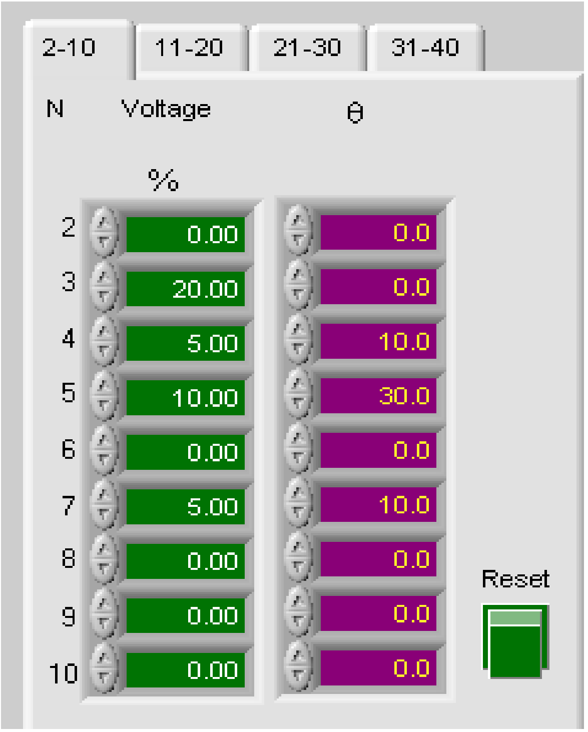




61500's Functions for Distorted Waveform

SYNTHESIS : Edit harmonic components (Amplitude & Phase) of 40 orders to synthesize a new waveform. (50/60Hz)

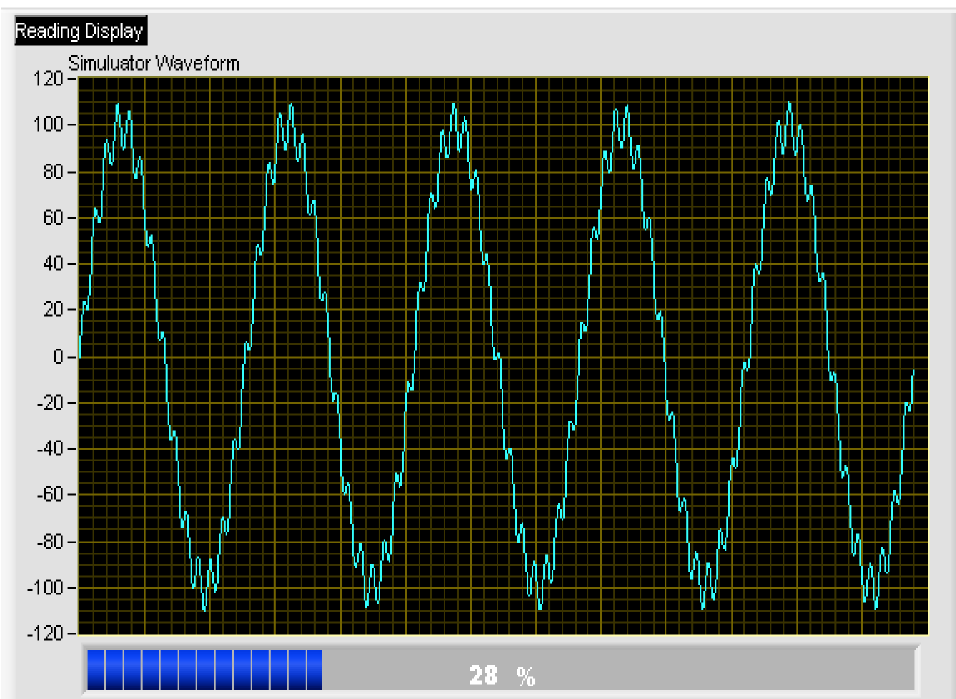


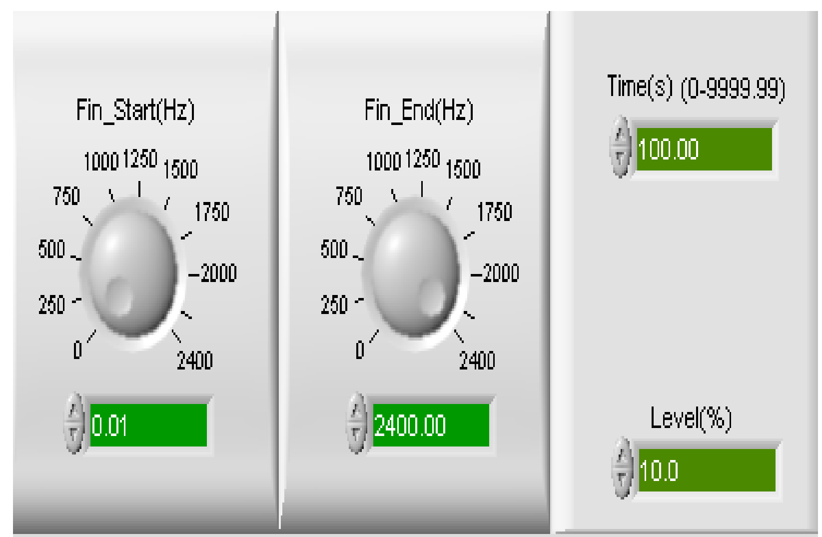


61500's Functions for Distorted Waveform

INTERHARMONICS : Add a sweeping frequency component (0.01Hz – 2400 Hz) on a normal voltage.

It helps to find the resonance point, or the weak point of the UUT.

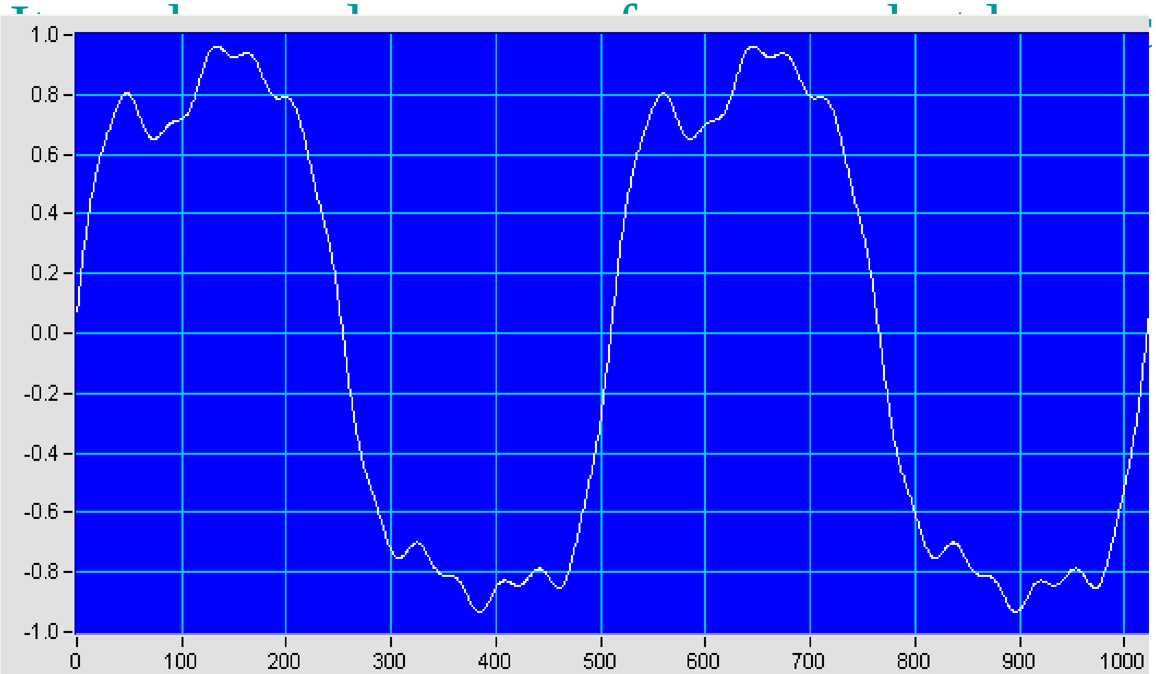


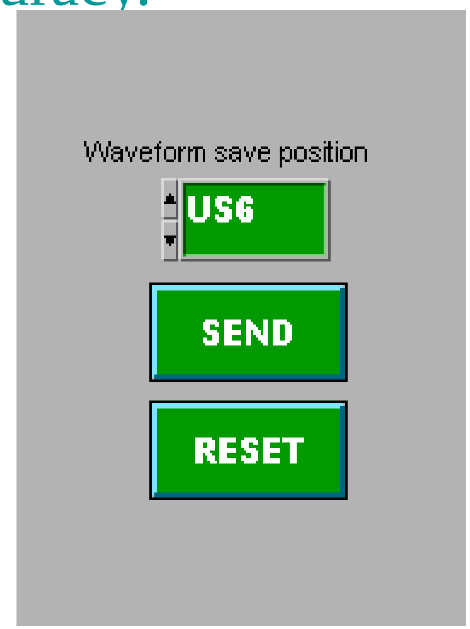


61500‘s Functions for Distorted Waveform

WAVEFORM EDITOR : Edit waveform by harmonic orders on softpanel, send the data and save to User Waveform of AC Source.

curacy.





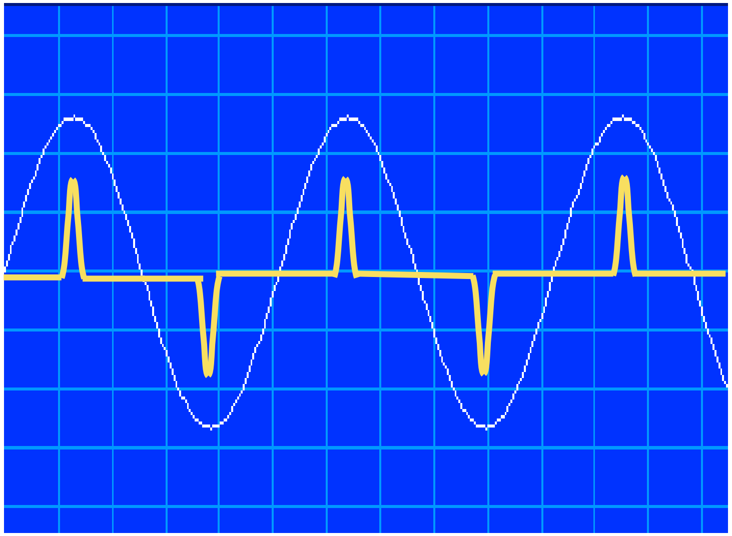
DC Component of AC Power

It contains DC component on some AC power sources, like UPS.

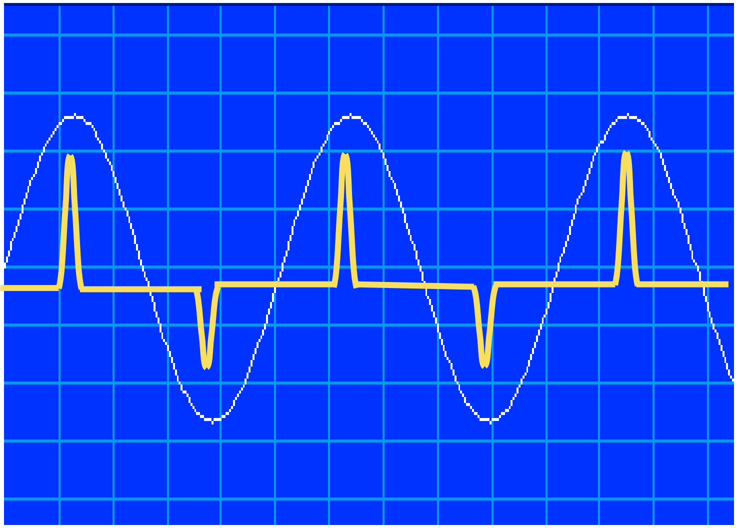
1. Current unbalance. Input rectifier may be damaged.
2. Input transformer saturation (DC current)

Using AC Source AC+DC mode to simulate.

Without DC component



With DC component



Thank You,

Chroma System Solutions

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