Application of the **Tektronix Power Analyzer PA4000** for an investigation of the selected problems in the power electronics

Adrian Drzazga
Application Engineer

TESPOL® Sp. z o.o.

Tektronix®

Agenda

- Some problems with the Power Quality (PQ)
- Power Electronics – PQ Point of View
- What does Power Analyzer PA4000 do?
- Power Electronics / Applications
- Conclusions

Tektronix®

Some problems connected with the Power Quality

Why should we focus on the Power Conversion?

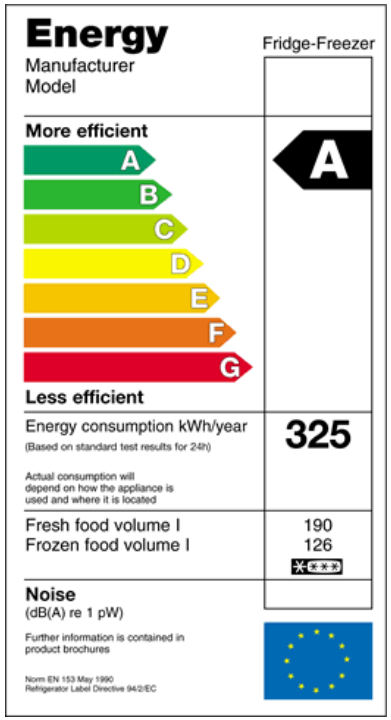
Global energy consumption
will grow 53% between now and 2035

- **Trend #1:** Government regulations to reduce power draw
  - Energy Star -- European Directive 2005/32/EC
  - California Energy Commission -- Clean Energy Act
- **Trend #2:** Increasing popularity in battery-driven devices (chargers) and **power conversion units (inverters, rectifiers, filters)**
- **Impact:** increase **efficiency in power conversion**, driving change in design techniques and test requirements

Tektronix®

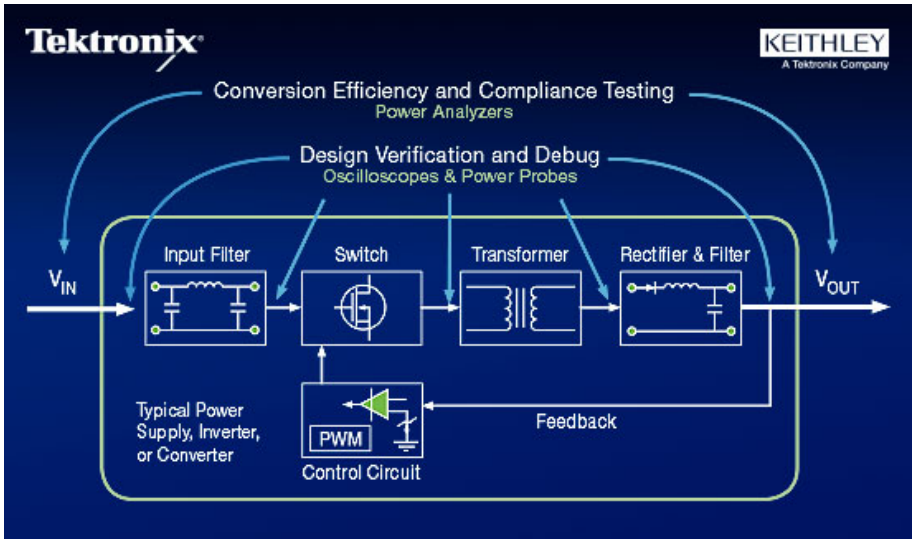
Some problems connected with the Power Quality

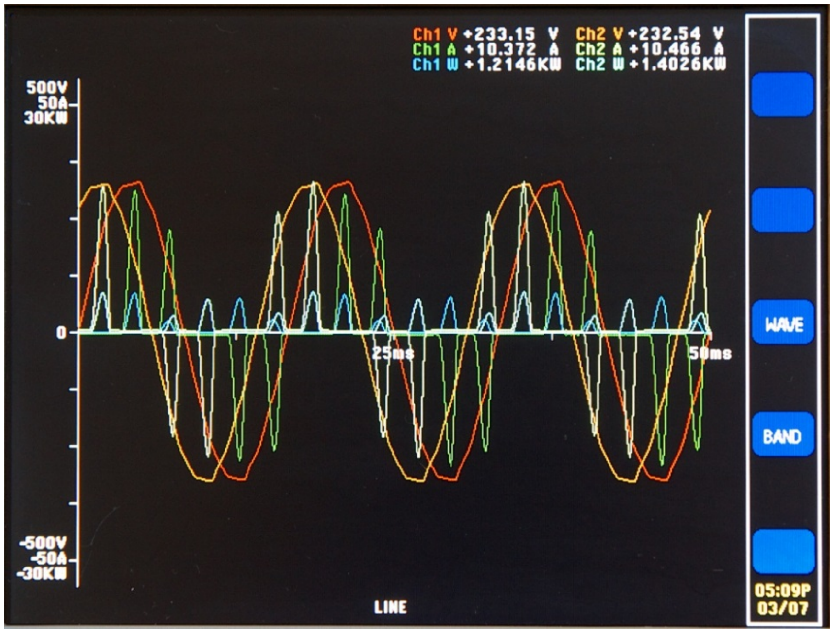
- Input power rating (Watts).
  - Over the range of load and AC line conditions.
- Electrical Energy over time (W-hrs)
- Efficiency and losses
  - Especially of a power supply
- Input Power Factor
  - Especially for lighting
- Input current distortion
  - THD and individual harmonics
- Standby Power and Energy
  - **EcoDesign**, **EnergyStar**, **IEC62301**, **IEC5056**



Tektronix®

Power Electronics – PQ Point of View

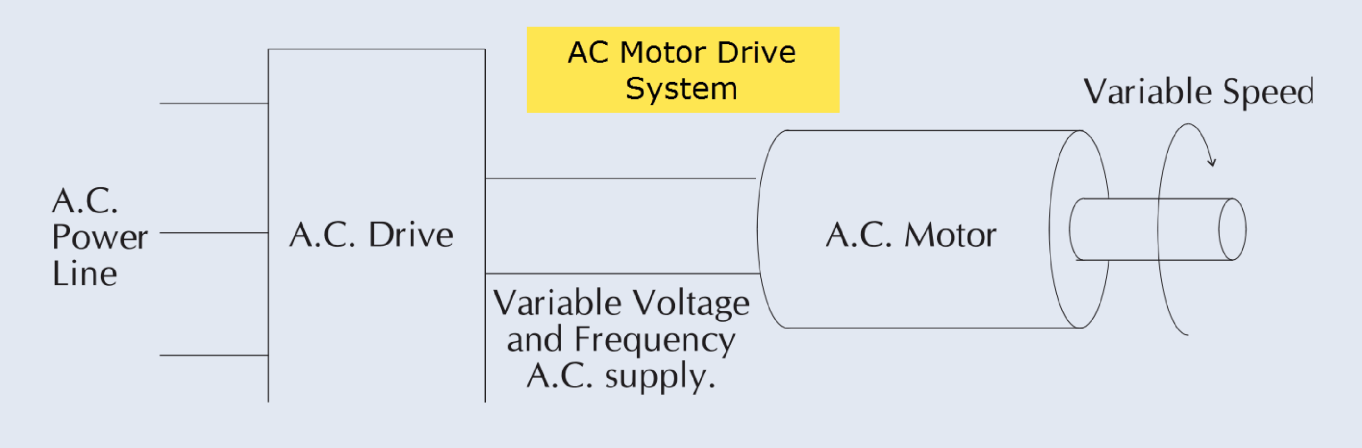


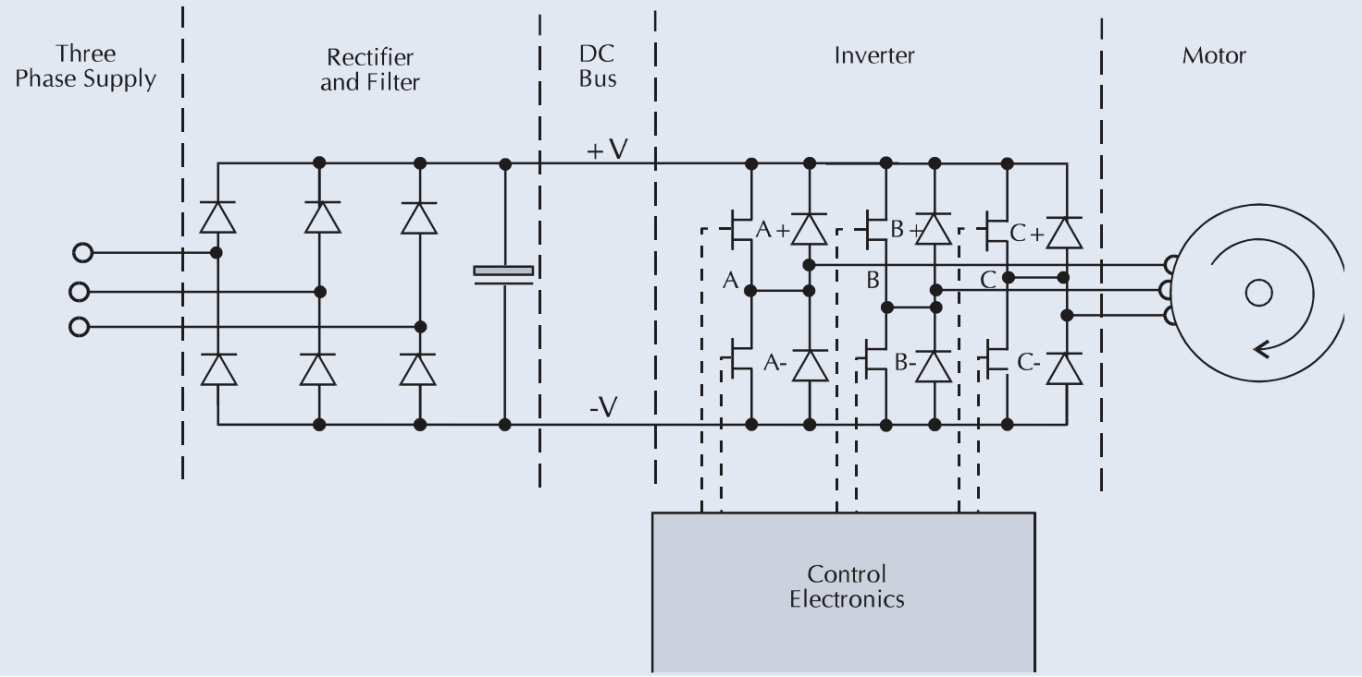


- Complex, PWM waveforms can make setup very time-consuming
- Fast slew rates create common-mode coupling & noise problems
- Changing drive speed requires dynamic synchronization to fundamental frequency
- High current crest factor can affect measurement accuracy
- High-current external transducers may require external power supply
- Multi-parameter testing results in large amounts of data to collect and analyze

Tektronix®

Power Electronics Applications / PWM Motor Drive

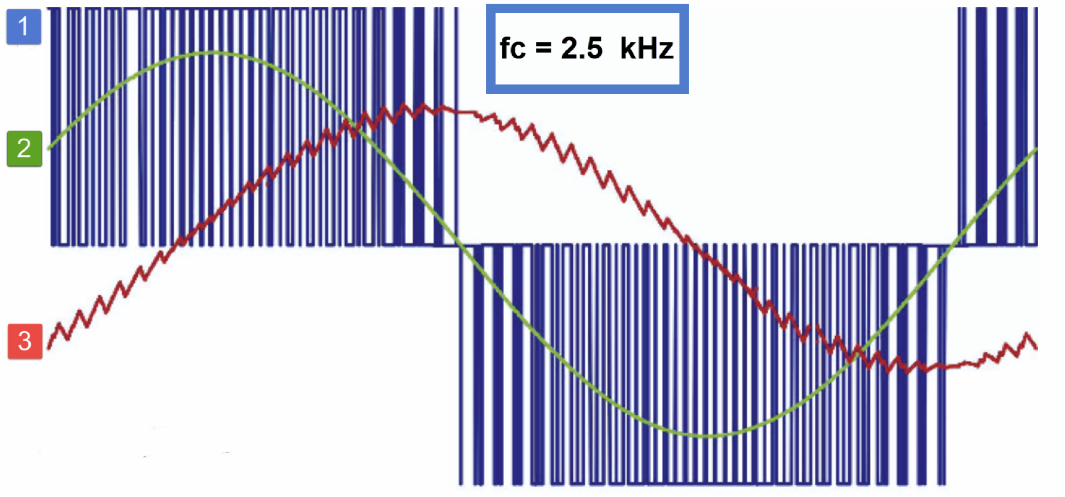


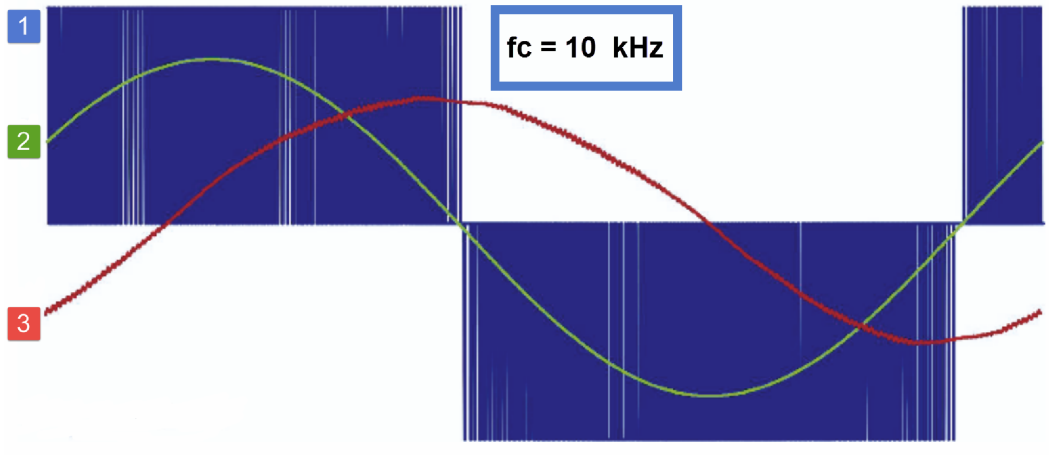


AC Motor Drive System

Tektronix®

Power Electronics Applications / PWM Motor Drive





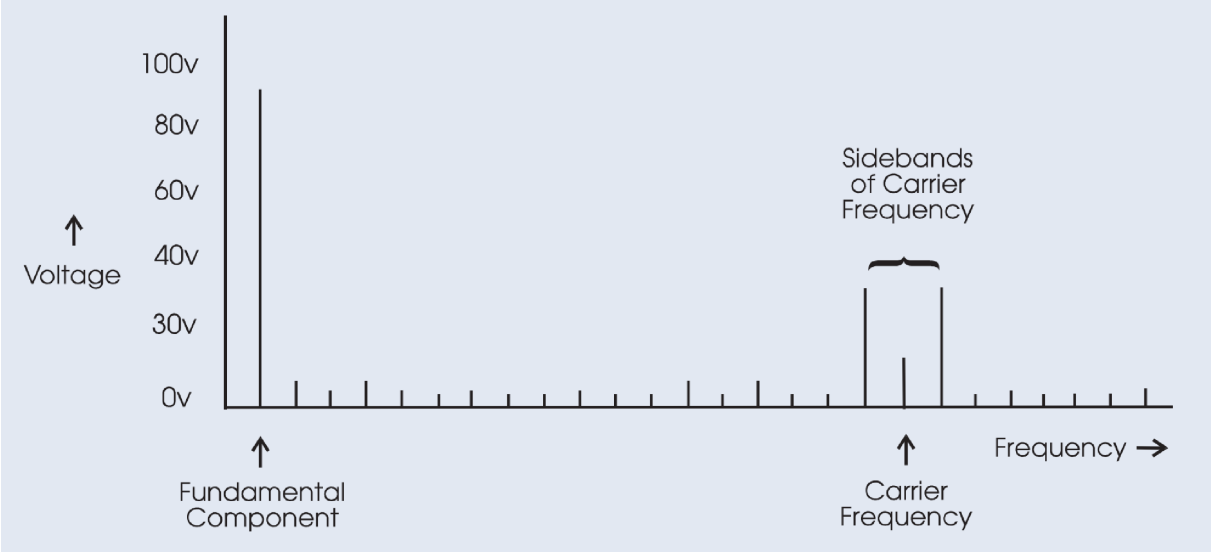
Pulsed frequency and the influence on the stator voltage the stator current.

Industrial drives operate from a few Hertz up to about 100 Hz with carrier in the range of 2 kHz up to about 10 kHz

1. Pulsed phase-to-phase voltage
2. Fundamental wave of the voltage
3. Current

Tektronix®

Power Electronics Applications / PWM Motor Drive



High Carrier Frequencies

Advantages	Disadvantages
Lower losses in motor (current more sinusoidal)	Higher switching losses in inverter
No audible noise due to carrier	Potential for more radiated radio frequency noise.

How to find a compromise for a carrier ?

Tektronix®

Power Electronics Applications / PWM Motor Drive

Drive Section	Parameters
Motor Output Measurements	Speed, Torque, Shaft Power
Drive Output Measurements	Total Output Power & Power Factor Fundamental Output Power & PF RMS Output Voltage and Current Fundamental Output Voltage and Current Harmonic voltages, currents & powers Output Frequency
Drive DC Bus Measurements	DC Bus Voltage, Current and Power
Drive Input Measurements	Input Voltage and Current Input Power and Power Factor Input VA and VARs Input Harmonic Currents (including checking to harmonic specifications such as IEC61000-3-2)
Efficiency Measurements	Efficiency of each section of PWM drive, motor efficiency and overall efficiency
Measurements Under Dynamic Load Conditions	Real-time analog outputs representing voltage, current, watts and power factor of drive output

How to find a compromise for a carrier ?

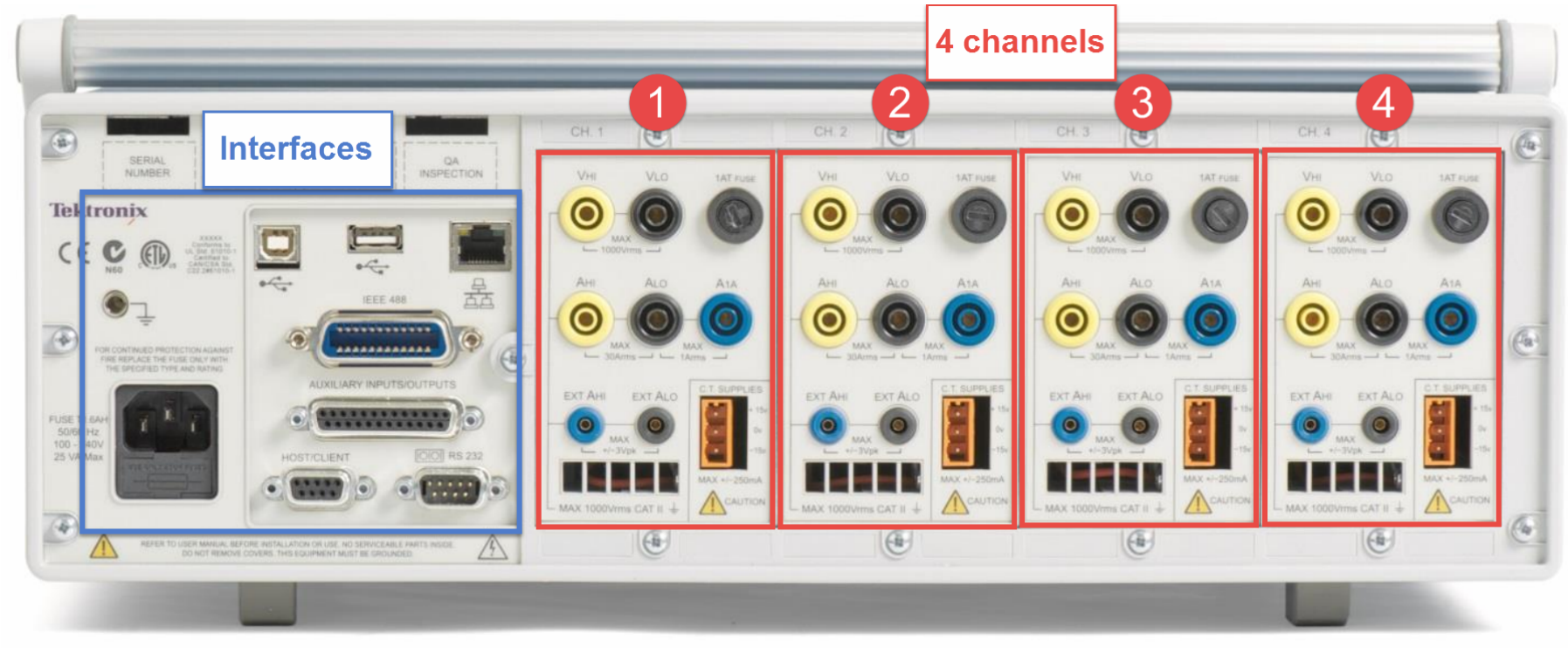
Tektronix®

PA4000 – What does it do?

- Measures **electrical power** (Watts). Provides many other measurements as standard, but this is the prime. The PA4000 is a “wattmeter”.
- Measures **apparent power** (VA), **power factor** (PF), **reactive power** (VAr), **volts** RMS, **amps** RMS, **crest factors**, **peaks**, **frequency, total harmonic distortion (THD)**

Tektronix®

PA4000 – What does it do?



- Measures **harmonics** of voltage, current and power.
- Measures electrical **energy consumption** over time (W-h), the rate at which power is consumed.
- Measures **standby power** in full compliance to standards.

Tektronix®

PA4000 – What does it do?

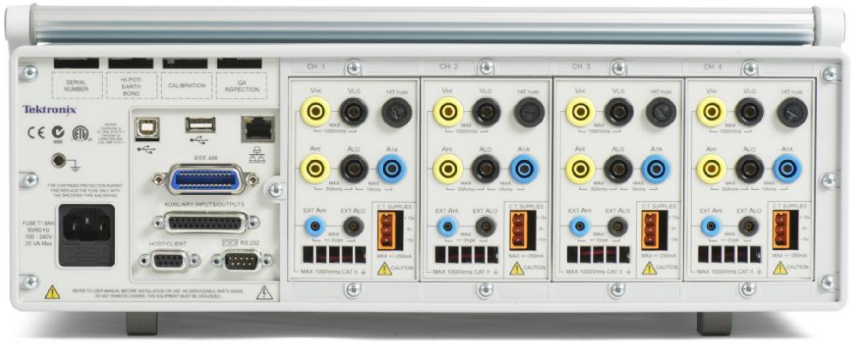
- **Precision Matched Voltage/Current Pairs**
  - High Resolution 14-bit ADC's
  - **Bandwidth up to 1 MHz** // **Sampling 1 MS/s**
- **Up to 100th harmonics can be calculated**
- **Industry's first Spiral Shunt™ technology** (patent application submitted)
  - Maximizes stability over changes in temperature, current level, frequency and other factors
- **Unique DSP algorithm**
  - For reliably locking onto frequency of the signal-under-test, even in the presence of transients and noise
- **High Crest Factor (CF=10)**
  - Inputs, measurement circuitry & algorithms are tolerant of the high crest factor commonly seen in today's power electronic devices
- **High Measurement Accuracy: 0.04% basic accuracy**

Uncompromised Measurement Accuracy

Tektronix®

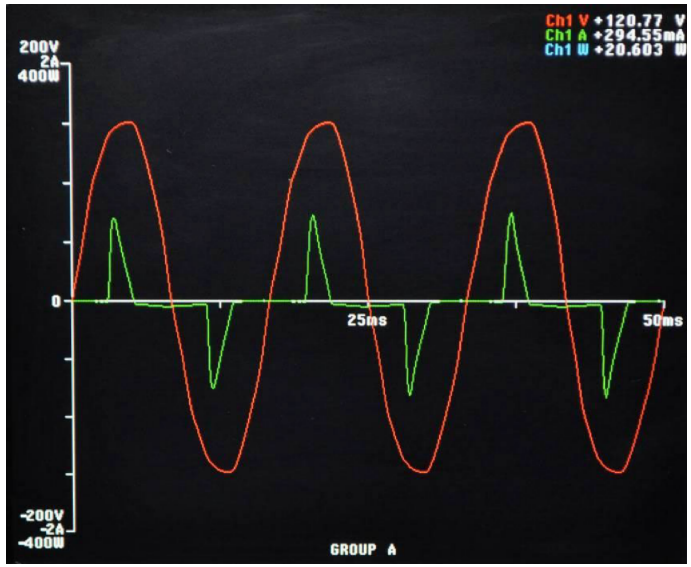
PA4000 – What does it do?

- **Voltage up to 1000 V_{RMS} , 2000V $_{peak}$**
- **Dual internal Spiral Shunt current shunts**
  - 30 A_{RMS} Shunts for current up to 30 A_{RMS}, 200 A_{Peak}
  - 1 A_{RMS} Shunts for optimal resolution on low-current devices
  - Broad range of external current transducers available
    - High-accuracy fixed core CT's up to 1000 Amps
- **Fast Autoranging**
  - Quickly adapts to changing signals with no gaps in data

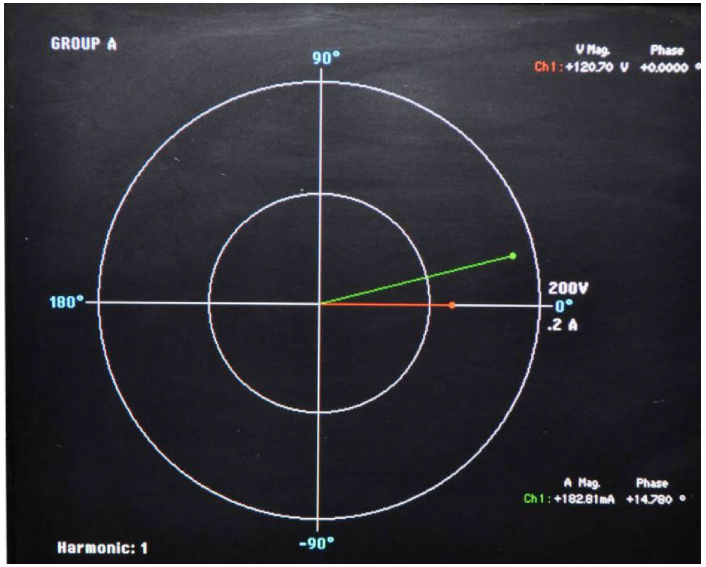


Tektronix®

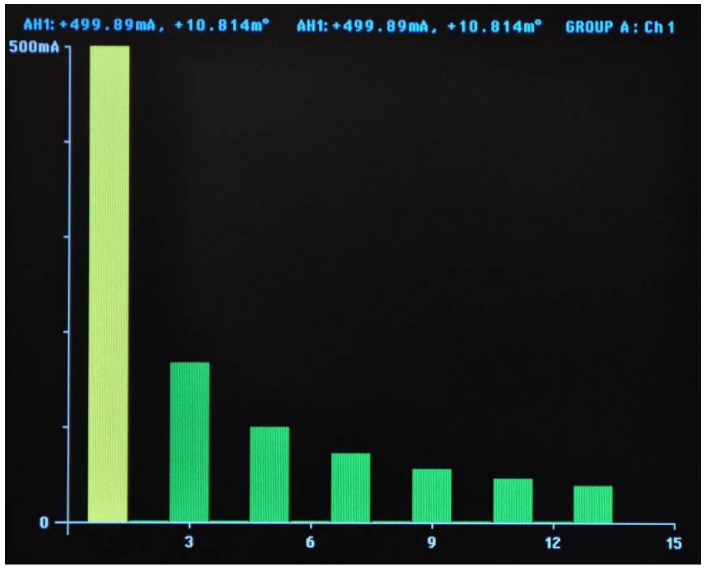
PA4000 – What does it do?



Waveforms



Polar Plot



Harmonics

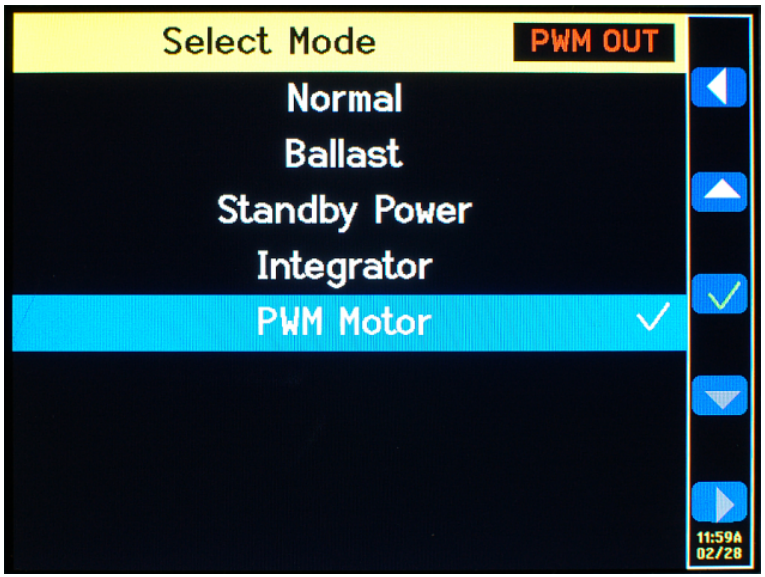
	Ch1		PWM OUT Ch2		Sum		AC INPUT Ch3	
Watt	22.755	W	3.5988	W	26.354	W	Vrms 255.96	V
Vrms	138.85	V	139.03	V	138.94	V	Arms 169.39	mA
Arms	241.63	mA	241.03	mA	371.33	mA	Watt 23.853	W
VA	33.551	VA	33.569	VA	89.364	VA	WHr 18.417	Wh
VAr	24.654	VA	33.375	VA	85.389	VA	Hr 774.53	mh
Freq	26.449	Hz	26.449	Hz	-----		VA 43.356	VA
PF	0.6782		0.1072		0.2949		VAr 36.205	VA
Vcf	2.2337		2.2066		-----		Freq 60.011	Hz
Acf	1.3584		1.4328		-----		PF 0.5502	
Vthd	1.9678	%	1.8139	%	-----		A1m 95.403	mA
Athd	3.3732	%	2.9895	%	-----		A1p -7.7309	°
							A2m 1.1083	mA

12:58P
02/28

Results

Tektronix®

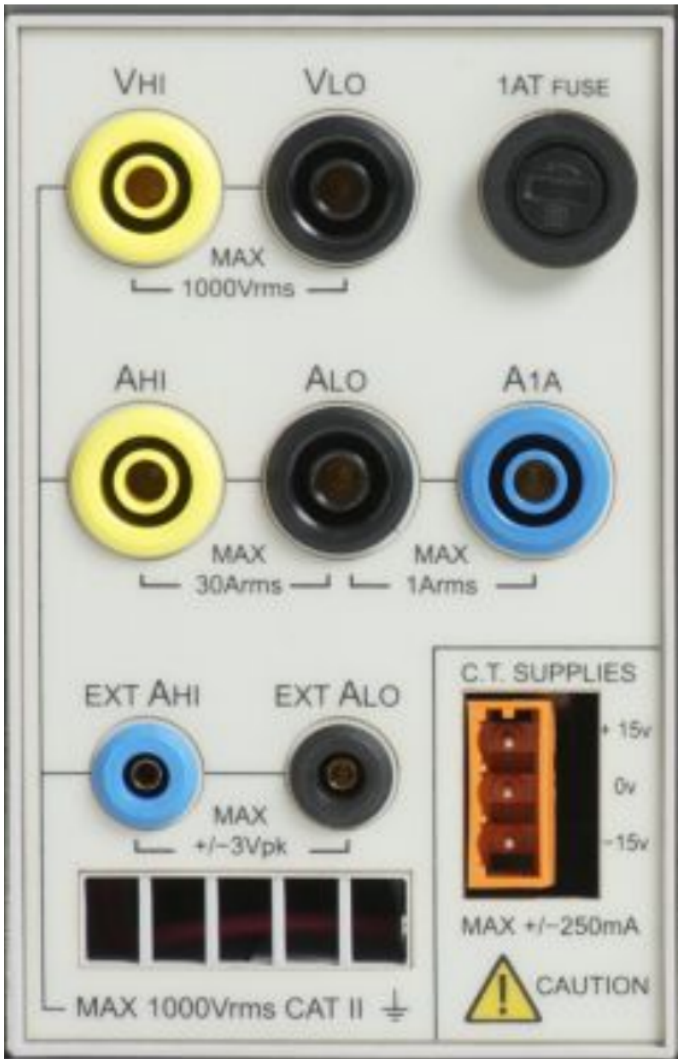
PA4000 – What does it do?

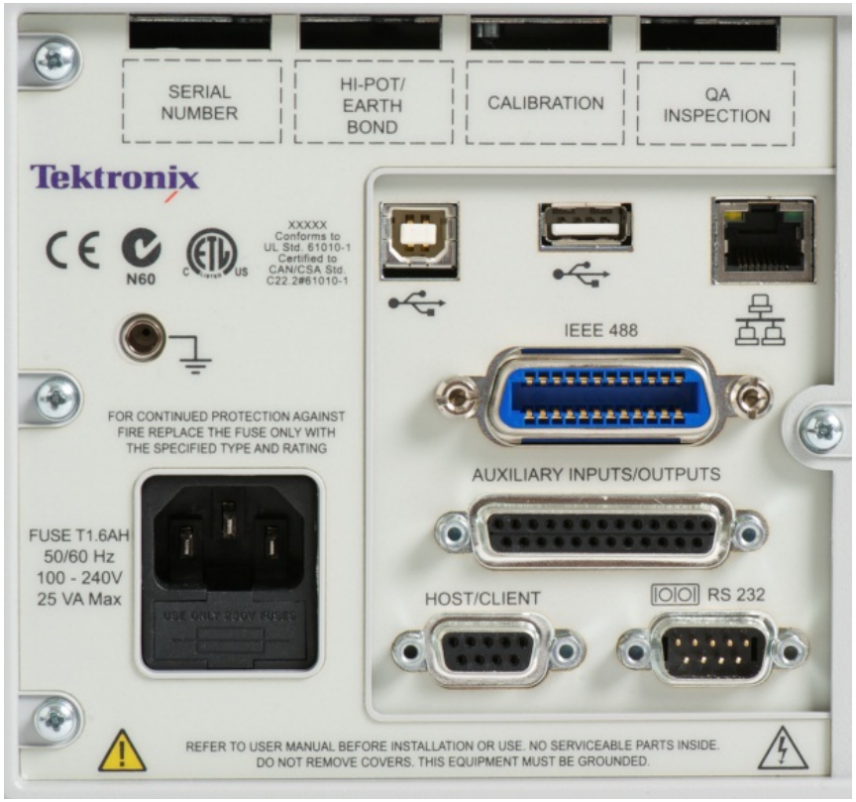


- **Normal** – standard settings
- **Ballast** – electronic lighting ballasts, HF waveforms modulated by the power frequency
- **Standby Power –** power consumption of products while they are in standby mode (**Energy Star**, **IEC 62301**)
- **Integrator** – measurements for determining energy consumption (**Watt-hours**, Ampere-hours)
- **PWM Motor** – making measurements on the complex waveforms commonly found on the motor drives (high frequency signals, rejecting the carrier)

Tektronix®

PA4000 – What does it do?

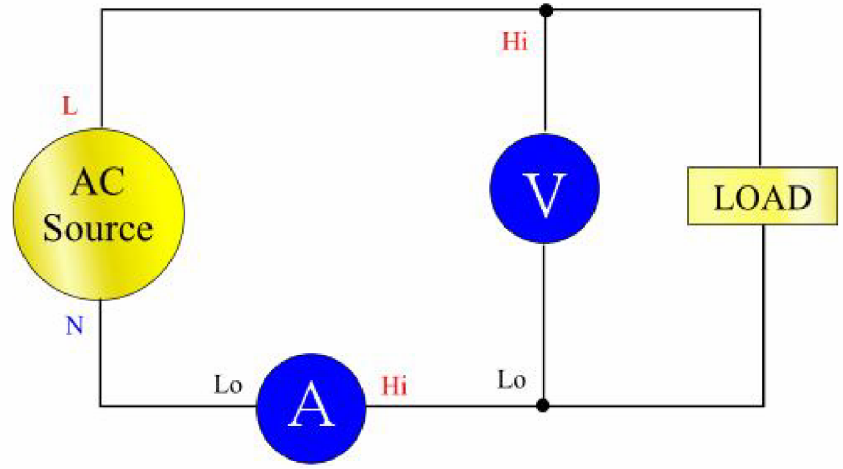




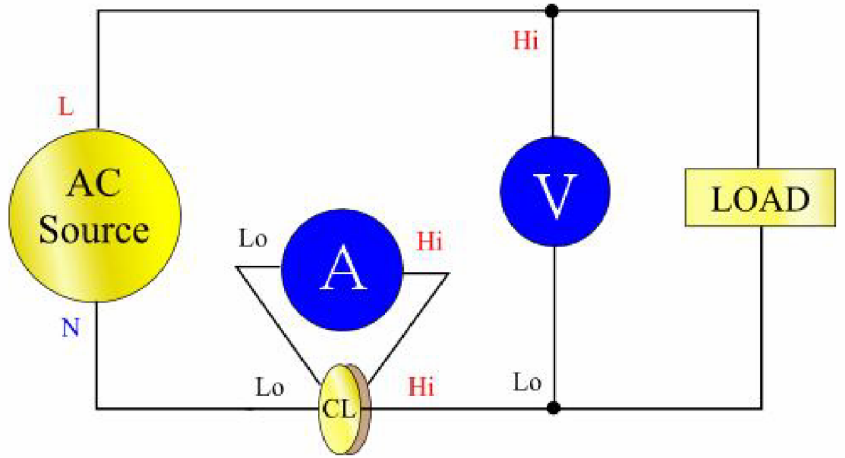
- Rear Panel single Input Module & Interfaces

Tektronix®

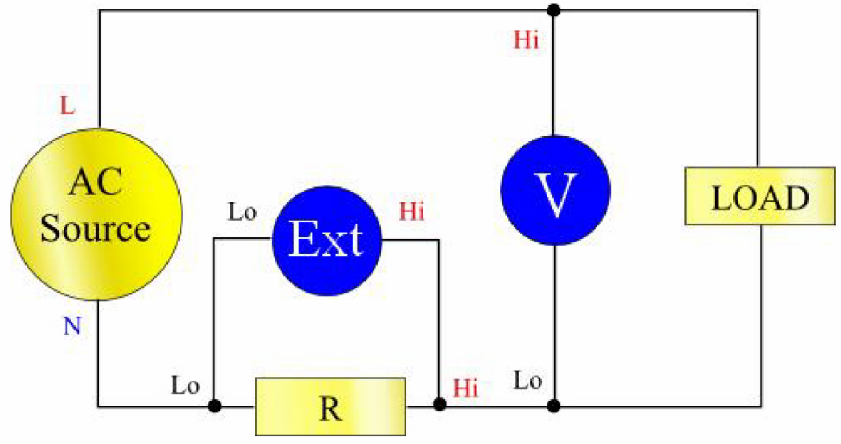
PA4000 – What does it do?



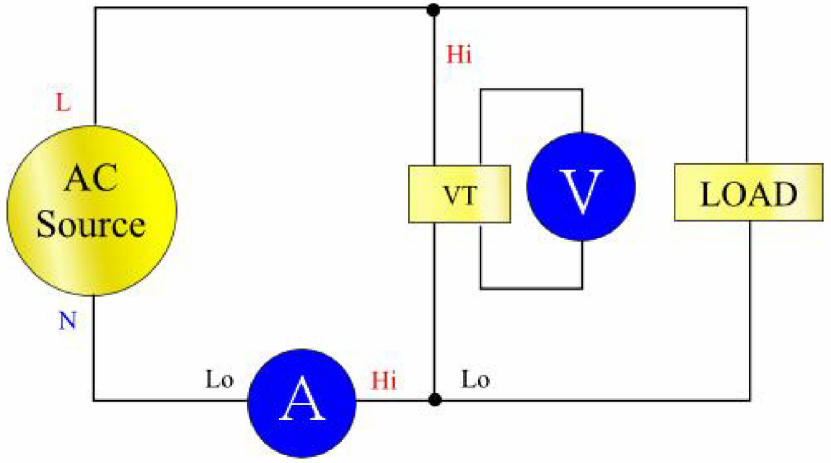
Standard Circuit



Current Transducers



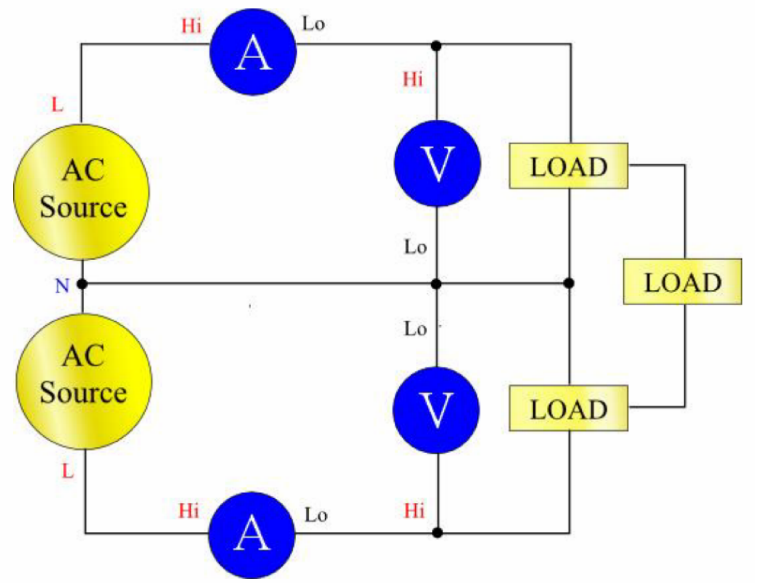
External Shunt



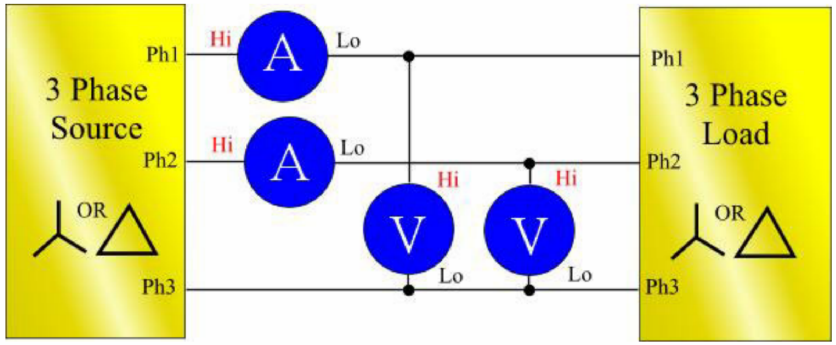
Volage Transducer

Tektronix®

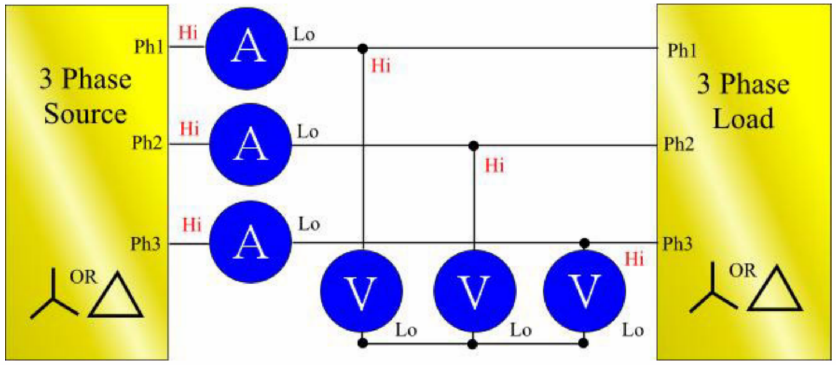
PA4000 – What does it do?



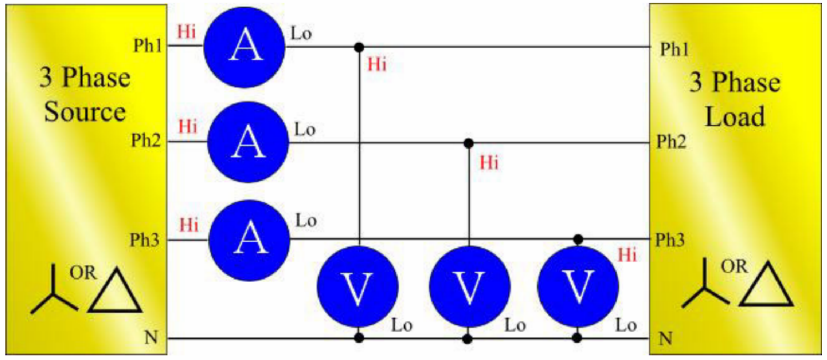
Single-phase, three-wire



Three-phase, three-wire



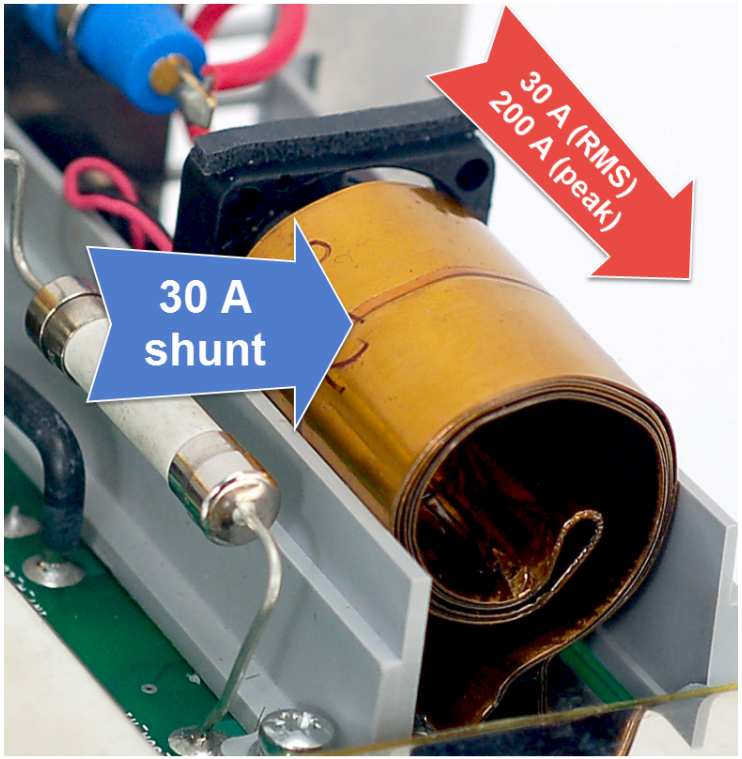
Three-phase, three-wire
(3 Wattmeter method)



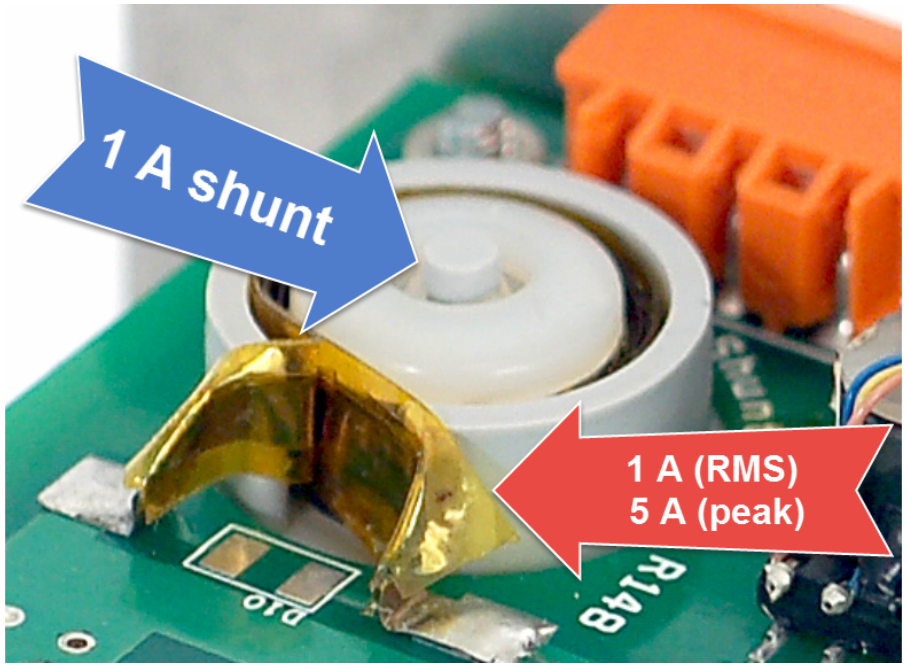
Three-phase, four-wire
(3 Wattmeter method)

Tektronix®

PA4000 – What does it do?



- The PA4000 employs an innovative **Spiral Shunt** design that ensures **stable**, **linear response** over a wide range of input current levels, ambient temperatures, crest factors, and other variables.



- The spiral construction not only **minimizes stray inductance** but also provides for high **overload capability** and improved **thermal stability**.

Tektronix®

PA4000 – What does it do?

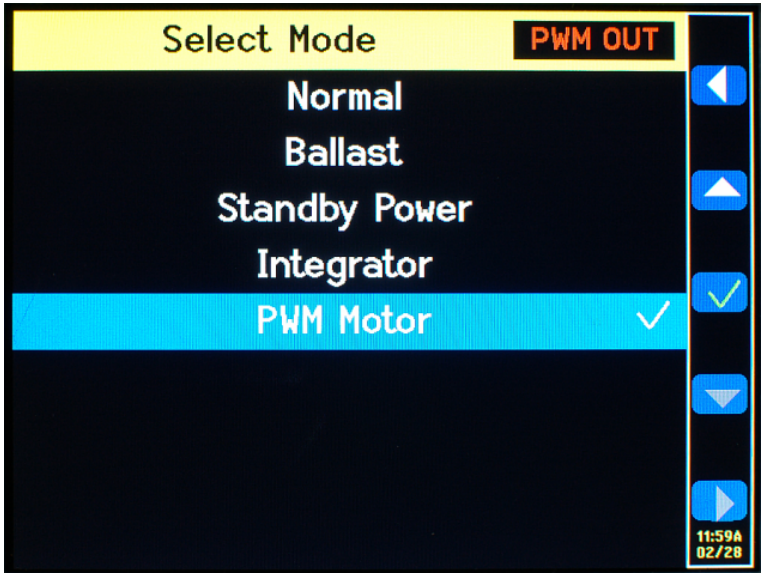
- Very high accuracy (<0.035%)
- Excellent linearity (< 20 ppm)
- Extremely (< 2.5 ppm/K)
- Wide frequency bandwidth (from DC to 100 kHz)
- Closed loop (compensated) current transducer using an extremely accurate zero flux detector

- No insertion losses
- High immunity to external electrostatic and magnetic fields interference
- Low noise on output signal
- Ideal for the precision and high stability inverters & energy measurement

Fixed Core Hall-effect Transducers

Tektronix®

Power Electronics Applications / PWM Motor Drive



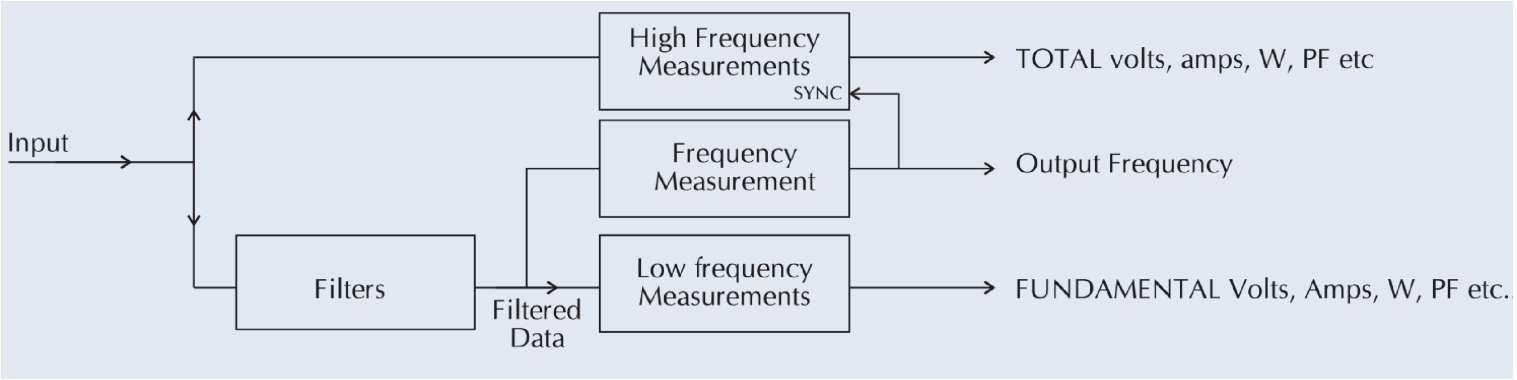
- One-Button PWM Setup
- PWM Mode automatically optimizes filters and timing for testing pulse-width modulated motor drive outputs
- PA4000 includes analog inputs to integrate speed and torque sensors for overall efficiency measurements
- High crest factor (up to 10) for accurate current measurements

Dynamic Frequency Synchronization

- Precise detection of frequency is critical
  - PWM carrier frequency and noise make frequency detection challenging
  - If the frequency is wrong, the measurements are wrong
- PA4000's unique algorithms quickly detect PWM **fundamental frequency**
  - Unlike traditional zero-crossing methods, the PA4000 reliably locks onto fundamental frequency
  - Saves you time by quickly adapting to drive / motor speed changes

Tektronix®

Power Electronics Applications / PWM Motor Drive



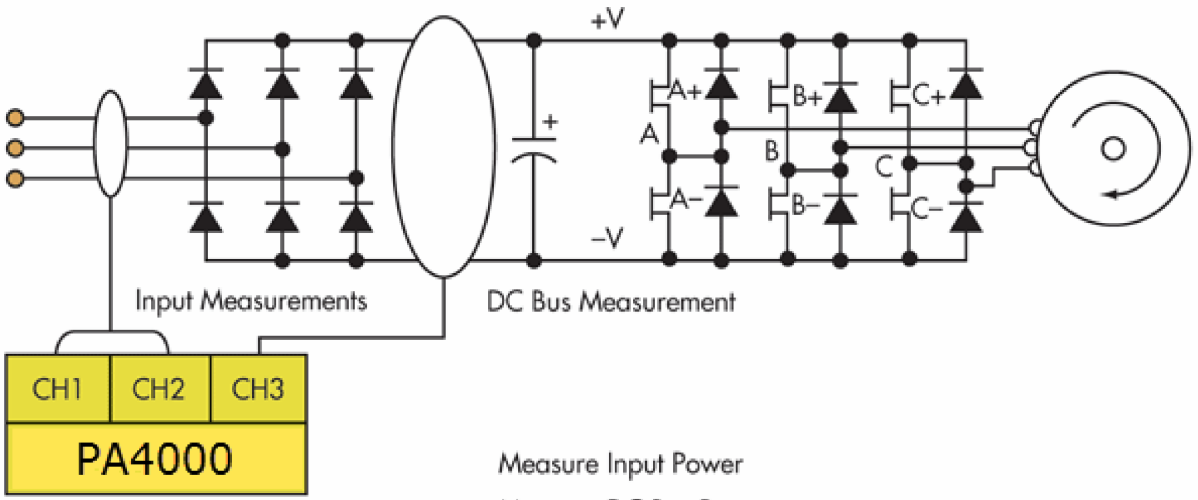
- Application filter for each frequency range within the PWM motor drive system

Filter	Application
5Hz to 500Hz	PWM Drives down to 5Hz output
0.5Hz to 25Hz	Low speed measurement down to 0.5Hz
0.1Hz to 25Hz	Very low speed measurement down to 0.1Hz

Dynamic Frequency Synchronization / Filtering

Tektronix®

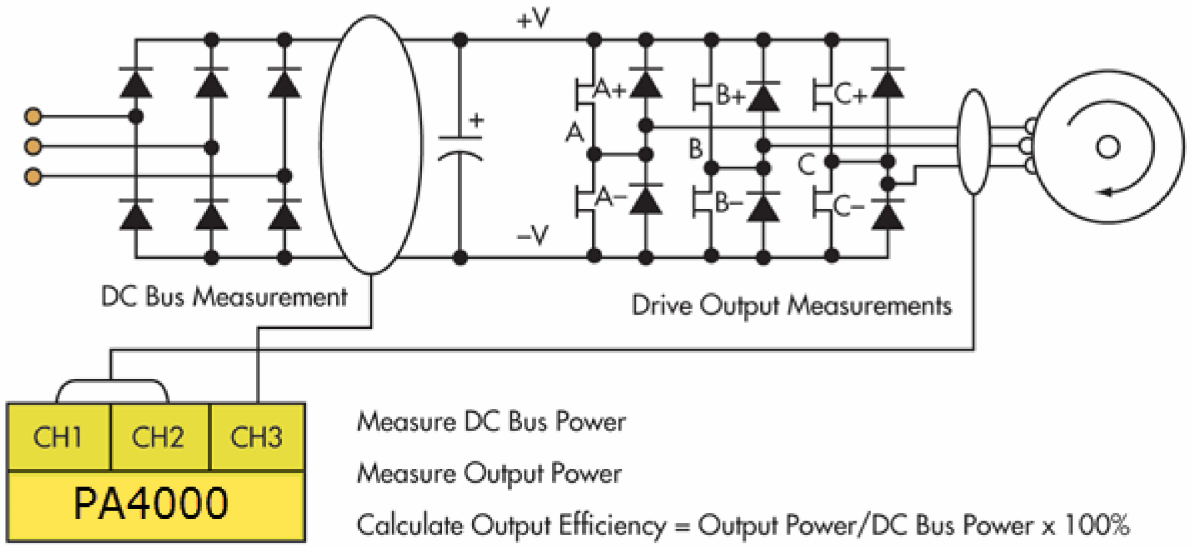
Power Electronics Applications / PWM Motor Drive



Measure Input Power

Measure DC Bus Power

Calculate Input Efficiency = DC Bus Power/Input Power x 100%



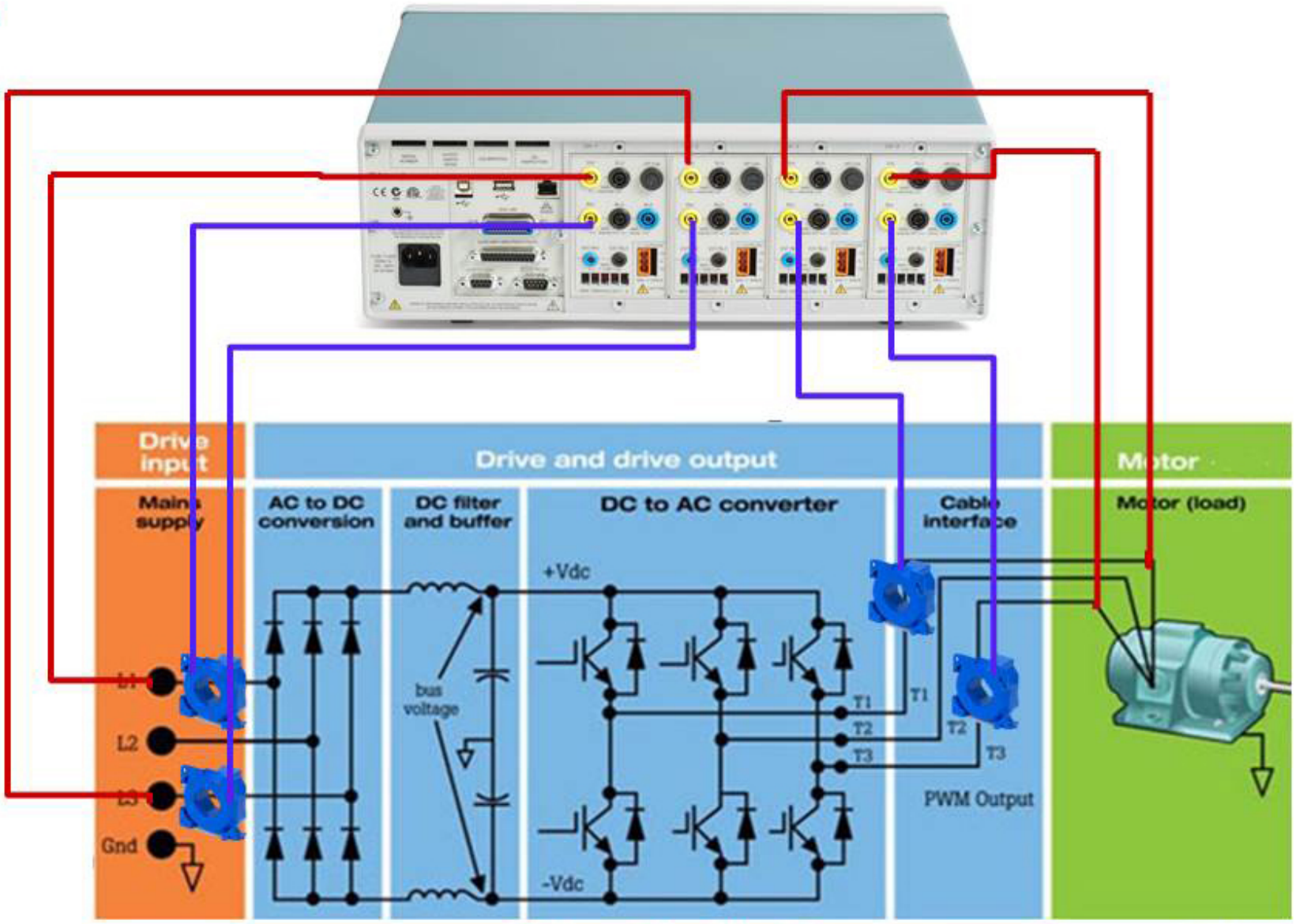
Measure DC Bus Power

Measure Output Power

Calculate Output Efficiency = Output Power/DC Bus Power x 100%

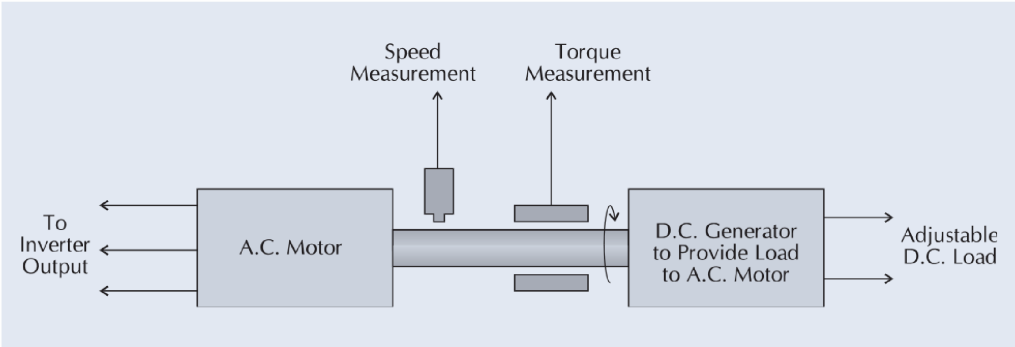
Tektronix®

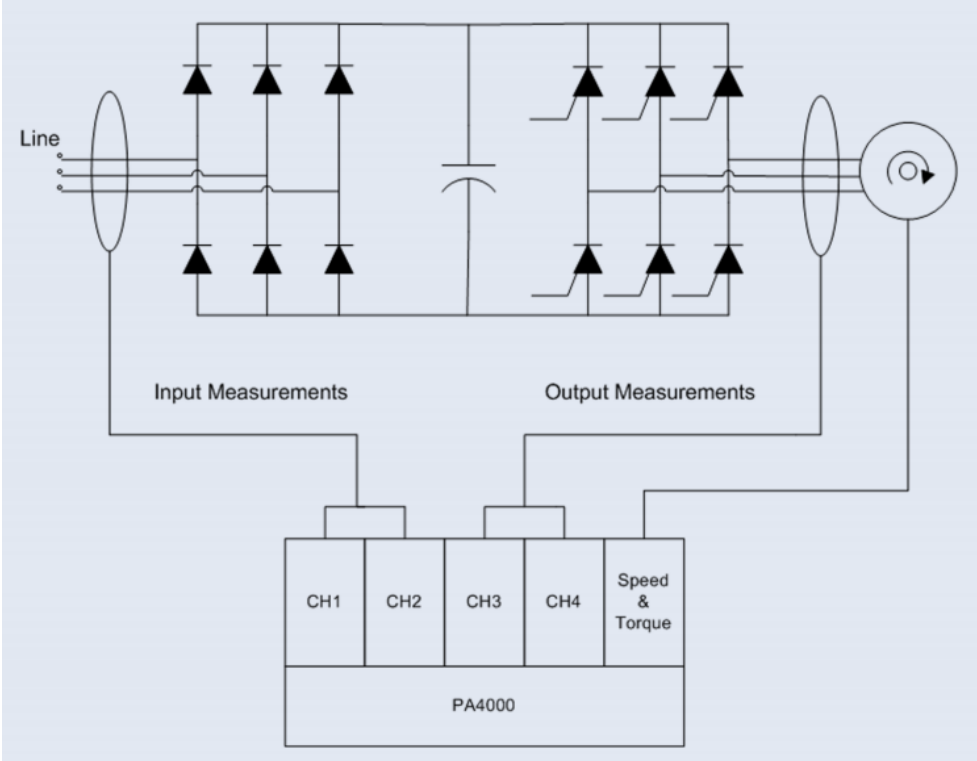
Power Electronics Applications / PWM Motor Drive



Tektronix®

Power Electronics Applications / PWM Motor Drive



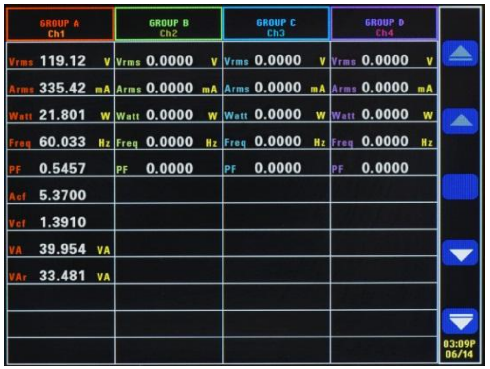


Speed & Torque Measurements

Tektronix®

Conclusions

PWM Performance

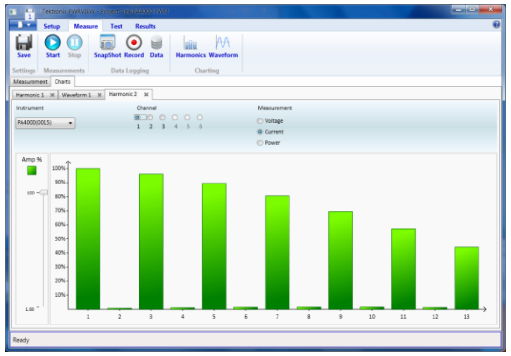


- Dynamic frequency synchronization
- Accurate with crest factors up to 10
- Peak ranging for high crest factor
- Spiral Shunt technology for improved stability
- DFT algorithm for accuracy

Versatility

- Available with 1 to 4 inputs
- 30A and 1A shunts
- Standard torque and speed sensor inputs
- Harmonic measurements are standard
- USB, LAN, and RS-232 are standard (GPIB opt.)

Setup & Analysis



- One-button PWM Setup
- Integrated current transducer supply
- PWRVIEW PC Software is included
- Easy logging to flash drive

Tektronix®

Thank You!

Tektronix®