November 29, 2004

4400/PX5 Data Acquisition and Sampling Techniques

The Dranetz-BMI PowerGuide 4400 and PowerXplorer PX5 are the first in a new class of instruments that fully comply with the latest international and US standards on power quality. These instruments are fully compliant with:

- **IEC61000-4-30** Class A, *Electromagnetic Compatibility (Emc) Part 4-30: Testing And Measurement Techniques - Power Quality Measurement Methods*
    - **IEC61000-4-7 Second Edition** Class I, *Basic Standard On Harmonics And Interharmonics Measurements And Instrumentation, For Power Supply Systems And Equipment Connected Thereto*
    - **IEC61000-4-15**, *Flickermeter – Functional and design specifications*
- **EN50160**, *Voltage Characteristics Of Electricity Supplied By Public Distribution Systems*
- **IEEE1159**, *Guide for Recorder and Data Acquisition Requirements for Characterization of Power Quality Events*
- **IEEE1453,** *Recommended Practice for Measurement and Limits of Voltage Flicker on AC Power Systems*
- **IEEE519***, IEEE Standard Practices and Requirements for Harmonic Control in Electrical Power Systems*
- **IEEE1459**, *Trial-Use Standard for the Measurement of Electric Power Quantities Under Sinusoidal, Nonsinusoidal, Balanced, or Unbalanced Conditions* (PX5 only).

In order to comply with these standards this new breed of instruments introduce some new data acquisition and sampling techniques to Dranetz-BMI products. This application guide describes how the 4400 and PX5 sample and acquire data but it is important to note that these products go well beyond the requirements of these standards and provide all of the features and capabilities expected from Dranetz-BMI products. This guide breaks down the data acquisition into the building blocks used by the instrument including digitization, PQ detection, IEC measurement time intervals, power updates, journal entries. Note that this guide is intended to supplement and not replace the instruments operators' manual.

Except where noted this guide applies to the 4400, PX5 and PX5-400. Also all references to the PX5 imply PX5-400 also except where noted.

Digitization

RMS Cycle by Cycle Measurements:
The 4400 and PX5 sample each cycle on all 8 channels 256 times which represents a 2x improvement over former Dranetz-BMI products such as the PP1, 4300, 658. Sampling is gapless which means each voltage and current cycle is continuously sampled without gaps between cycles. Sampling is controlled by a Phase Locked Loop (PLL) circuit that is referenced to voltage channel A. The PLL automatically adjusts the sampling rate to the power line frequency to insure the instrument always acquires 256 samples per cycle on every channel. Therefore, any variation in the power line frequency adjusts the sampling rate accordingly. This translates into a sampling rate of 15.36KHz at 60Hz and 12.8KHz at 50Hz (256 and 60/50).

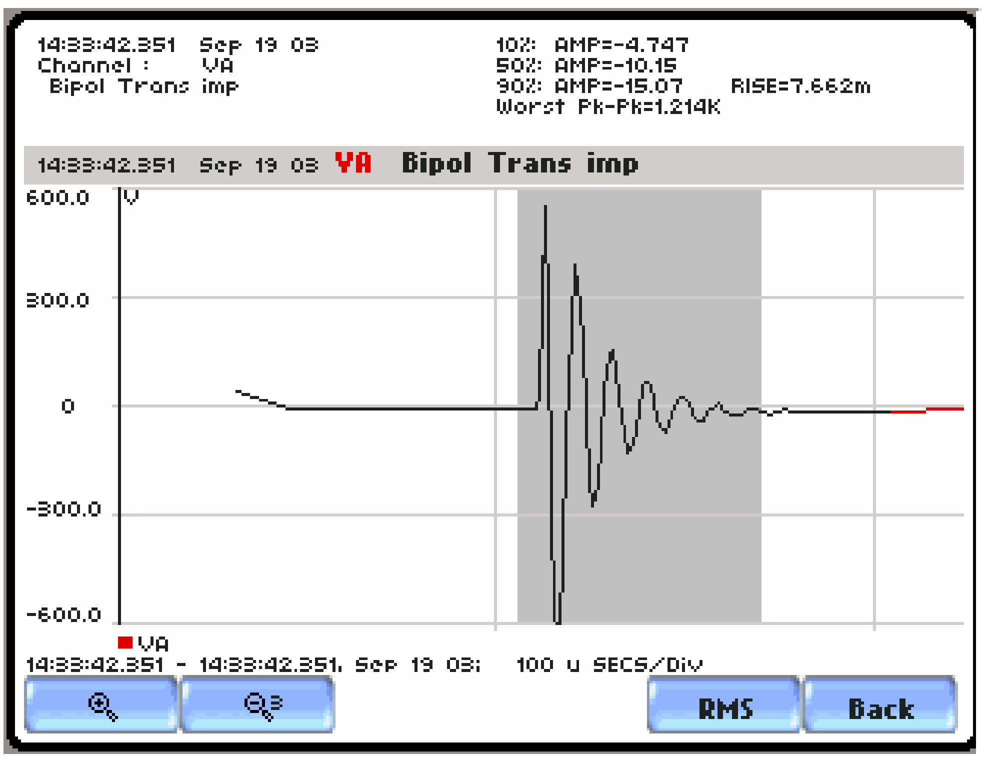
The data acquired by the above process is digitized by a 16 bit Analog to Digital (A/D) converter and is used as the foundation for all measurements and computations except for high speed transients which are available in the PX5 only.

This technique of data acquisition is appropriate for low and medium frequency transients (as defined by IEEE1159) but is not adequate for high frequency transients. At 256 samples per cycle the time between samples is about 65us at 60Hz and 78us at 50Hz. This is not fast enough to accurately detect, measure and record damaging high speed transients which can be much shorter in duration. In order to greatly improve the transient capabilities beyond 256 samples per cycle the PX5 adds high speed transient measurements that are described below. Being a lower cost instrument the 4400 does not have high speed transient capabilities and is appropriate for the measurement of low and medium frequency transients only.

High Speed Transient Measurements (PX5 only):
Dranetz-BMI has a long standing reputation as the industry leader in Power Quality measurement instruments. The PX5 represents the next generation of these instruments and unlike its predecessor, the Power Platform 4300, the PX5 has high speed digitization of transients. Like the Dranetz-BMI 658 and 8800 this technology not only detects the transient but digitizes the waveform in a manner similar to a digital oscilloscope allowing for detailed analysis of the transient waveshape. As a point of comparison the 4300 used a technology called peak detection that provides the transient magnitude and point on wave information only but digitization is far superior as it records the actual shape of the high speed waveform. Again, this is a feature of the PX5 only and is not available in the 4400.

The PX5 high speed transients are sampled at a rate of 1Mhz for voltage and 0.5Mhz for current. Both voltage and current are digitized using a 14 bit Analog to Digital (A/D) converter. Therefore, the PX5 can detect and record virtually any high speed transient in a power system.

High speed (HS) transient data is stored in 80us windows with a minimum of 4 windows (320us) of data being recorded on any HS transient event. The 4 windows are comprised of 1 fault, 1 pre, and 2 post windows of data. HS triggers are detected using an energy/area under the curve method. Each 80us window is compared to the previous window for a change in area under the curve relative to the users settings. If a change exists that exceeds the thresholds the data is stored to memory. Data is continuously recorded until an 80us window goes below the threshold or reaches a total duration of 16/20ms (60/50Hz), whichever comes first. The PX5 HS transient circuitry always works in a worst case mode continually recording the information with data stored to memory only if thresholds are exceeded.

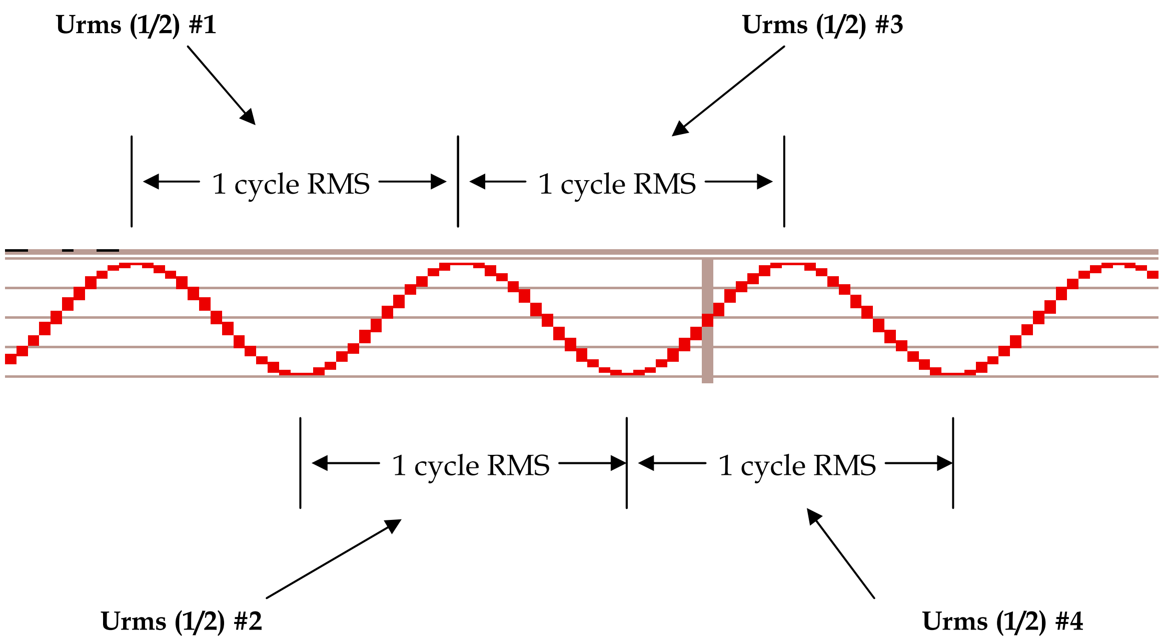


Power Quality Triggers

PQ disturbances can affect the power line waveform in different ways. Therefore, different events may require different triggering mechanisms. The most common method of triggering, RMS sampling will not capture every type of disturbance even if the sampling rate is greatly increased. As a result, Dranetz-BMI has developed advanced methods to capture the various types of events. This section describes the various triggering methods available in the 4400 and PX5 and their application.

RMS Triggers

RMS measurements are made over one AC cycle. In accordance with IEC standards RMS measurements are over once cycle but incremented in ½ cycle steps. The IEC standards refer to this as *Urms(1/2)*. As a point of comparison, with the exception of the Signature System EPQ DataNode all prior Dranetz-BMI products increment in 1 cycle steps. It's important to note that the measurement window for PQ triggers is still always 1 cycle but the ½ cycle increment allows for more detailed event detection. Any one cycle exceeding the instruments limits will trigger an RMS event, regardless if it's detected on a ½ cycle boundary.



If a trigger occurs data is stored to memory in accordance with the RMS Summary and Waveform (# of cycles recorded) settings entered during setup. This tells the instrument how many cycles of data to record if an even occurs. Please see the instruments users guide for further details.

Like other Dranetz-BMI products, the 4400 and PX5 detect and record *current* RMS events in the same manner as voltage.

In addition to PQ triggers the *Urms(1/2)* data is used as the basis for all voltage and current min, max and average measurements which therefore have a 1 cycle resolution with ½ cycle steps.

Transient Triggers

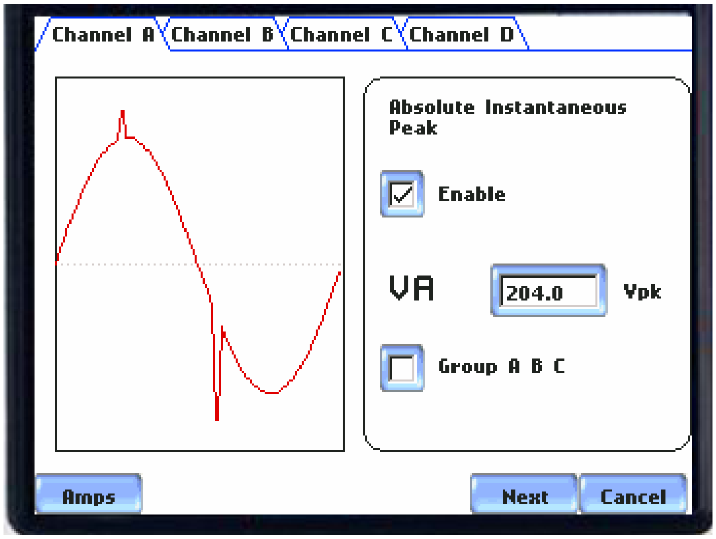
As per IEEE1159, transients are divided into 3 categories;

- Low frequency (<5Khz)
- Medium frequency (5 – 500Khz)
- High frequency (500Khz – 5Mhz)

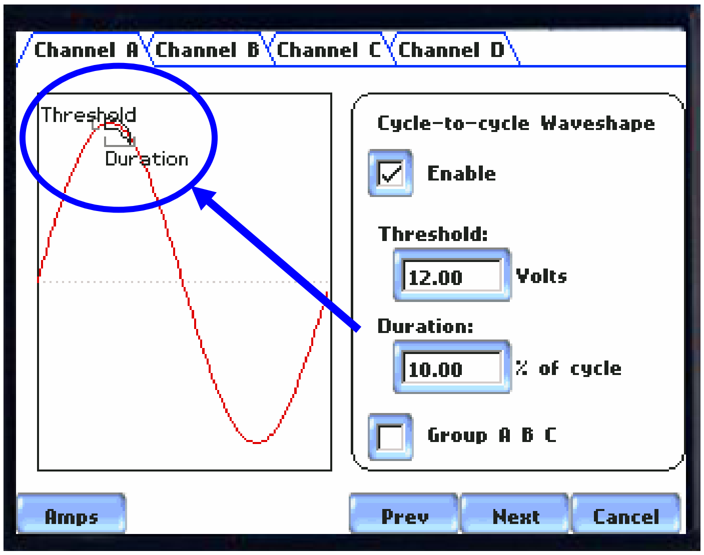
Both the 4400 and PX5 can capture low and medium frequency transients. With its high speed transient capabilities the PX5 can also detect and record high frequency transients. It is important to note that the 4400 and PX5 go well beyond the requirements of IEC61000-4-30 as it does not specify transient capture and is limited to dips (sags) and swell measurements.

The 4400 has 2 transient capture trigger methods with the PX5 adding a 3rd for high speed capture.

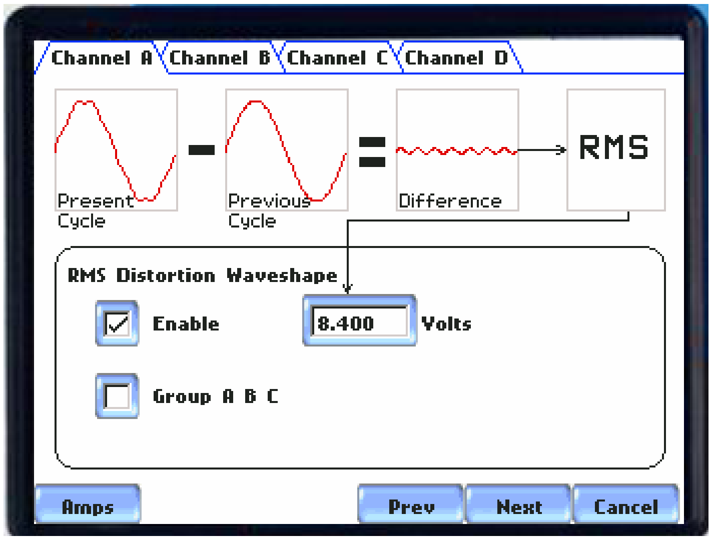
- Instantaneous Peak (Low/Medium Frequency - 4400, PX5): This trigger uses the RMS sampled data and looks for any one of the 256 samples to exceed the Instantaneous Peak limit. If at least one sample exceeds the limit data is recorded to memory based upon the users pre/post waveform settings. Applications for this trigger are events such as peak over voltage (or current), lightning strikes, etc…



- Waveshape Triggers (Low/Medium Frequency - 4400, PX5): Waveshape triggers look for changes in the waveform on a cycle by cycle basis. These are important triggers as many types of transients do not affect the waveform enough to change the RMS significantly. Therefore, traditional RMS triggers will not detect these events. There are two waveform trigger methods available; cycle to cycle waveshape and RMS distortion (or difference) waveshape. Both methods look for changes to the waveshape by comparing the present AC cycle to the previous AC cycle. If the difference exceeds the user's limits an event is recorded. Both methods have been available in prior Dranetz-BMI products. Even though these are similar trigger methods both remain available since some customers prefer one over the other. Also, both methods are available for voltage and current triggers:
    - Cycle to cycle Waveshape: This method breaks down the present AC waveform being measured into user defined windows of time (shown below in the circle) that represents a percentage of the overall waveform. Each window is compared to the same window of time in the previous waveform and if the difference exceeds the user's limits an event is recorded. In the picture below the duration (width of the window) is 10% (1.67ms @60Hz) which means the waveform is broken down into 10 consecutive windows with each representing 10% of the overall waveform. If the duration were 50% the waveform would be broken down into 2 windows with each representing 50% (8.3ms) of the overall waveform.



    - RMS distortion (or difference) waveshape: This method does a (sample) point by point subtraction of the previous waveform from the present waveform. If the waveforms are the same the difference will be zero, otherwise the difference will be the change in waveshape from the previous to present waveform. If the difference exceeds the customers limits an event is recorded.



- High Speed Transient (High Frequency - PX5): The PX5 adds high speed transient detection and recording circuitry. Details are described in the Digitization section above. This additional circuitry works in addition to and in parallel with the other triggering methods described above to capture high speed events that cannot be detected using transitional RMS (256 samples per cycle) triggering methods.
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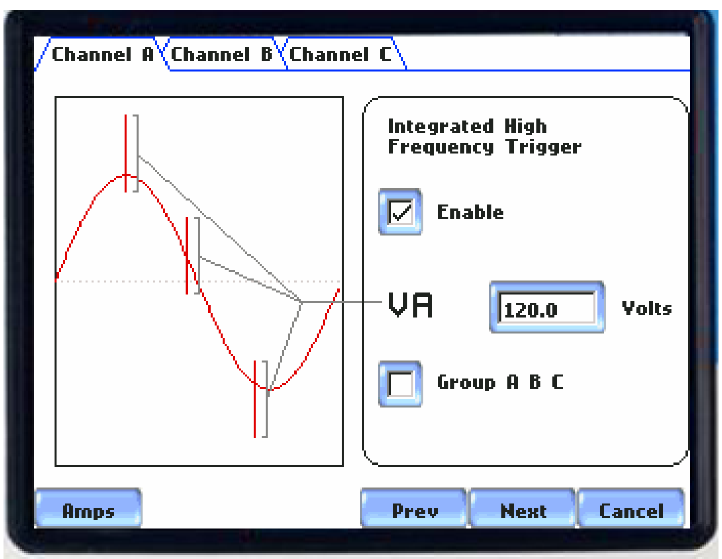
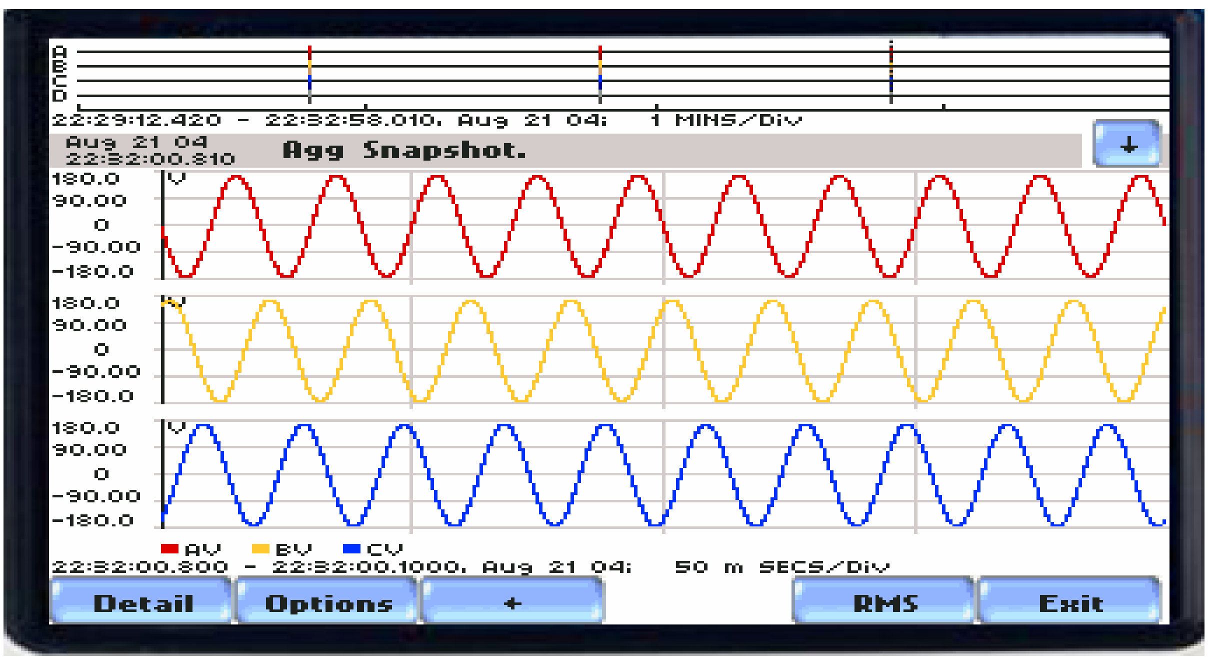


Magnitude of Supply 200ms Window

IEC 61000-4-30 and IEC61000-4-7 require data be acquired over a 200ms window for use in certain measurements such as magnitude of supply, harmonics and interharmonics. The 200ms window equates to 12 cycles at 60Hz and 10 cycles at 50hz. A 10 cycle 50Hz example is shown below. In addition, class A compliance requires the 200ms windows to be gapless meaning that any processing by the instrument must be completed in time to process the next 200ms window without any gaps between windows. Being class A, the 4400 and PX5 fully complies with these requirements.

Harmonic computations include all 10/12 cycles in this 200ms window using a Discrete Fourier Transform (DFT). The results are used for all harmonic parameters and triggers. Therefore, 200ms is the smallest unit of time for harmonic type parameters and is the basis for all associated min, max and average measurements.

The above is a departure from former instruments. As an example, the 4300 computes harmonics by taking one cycle, processing it for about a second then taking another cycle. These new IEC standards are much more stringent and require significantly more processing power, especially for class A instruments.



Power Measurements – One second

Power measurements for parameters such as Watts, VA, VAR, PF, etc are computed over a one second interval. Each cycle measured over this one second interval is included in the measurement. This is opposed to the composite and snapshot methods used by prior instruments such as the 4300 and PP1. The interval is adjusted to the nearest complete cycle to compensate for any frequency differences from the ideal 50/60Hz that are integer multiples of one second.

The one second time unit is the basis for all associated min, max and average measurements.

Journals

Journals are measurements and computations recorded to memory based upon a timer. Journals are analogous to timed readings in former instruments such as the 4300 and PP1. The 4400 and PX5 support four independent journal categories each with a separate time base. These categories are described below along with a description of the type of data included:

Power Values:
Power values include V, I, W, VA, VAR, PF, etc. The user has the choice of the timer interval and whether to record waveforms (waveform snapshot) with the computed parameters recorded to memory. If the waveform snapshot is enabled a 200ms window is recorded as described above. Therefore, the user will see 10 cycles at 50Hz and 12 cycles at 60Hz. This is a departure from former instruments which recorded only one cycle.

Min, max and average values are based upon the data acquisition method used for the specific parameter. Therefore, V and I are measured on a cyclic basis (½ cycle increments) while power parameters such as W, VA, VAR, PF are based upon the one second power update rate.

Demand and Energy

Allows for an independent timer for demand and energy. Also supports a demand sub-interval timer. Min, max and average is based upon the one second power measurement update rate.

Harmonics

Allows for an impendent timer for harmonics. Min, max and average are based upon the 200ms window required by the IEC for harmonic measurements.

Flicker

Allows for an independent timer for the Flicker parameters Pst and Plt. The default is based upon the IEC requirements of 10 minutes for Pst and 2 hours for Plt. Min, max and average is based upon these times.