How PMUs get and process time signals from GPS antenna

"A Virtual Instrumentation Approach"

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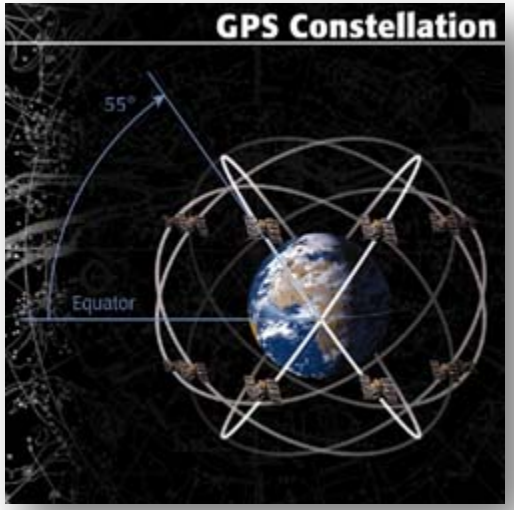
GPS Basics

- **GPS = Global Positioning System**
  - *Worldwide radio-navigation and timing system*
  - *Constellation of 24 satellites with atomic clocks*
  - *Calculates position utilizing the "Triangulation" concept*
    - *Measures signals from three satellites, and uses a forth one to compensate for errors*
    - *Signals are corrected for any delays as it travels through the atmosphere*

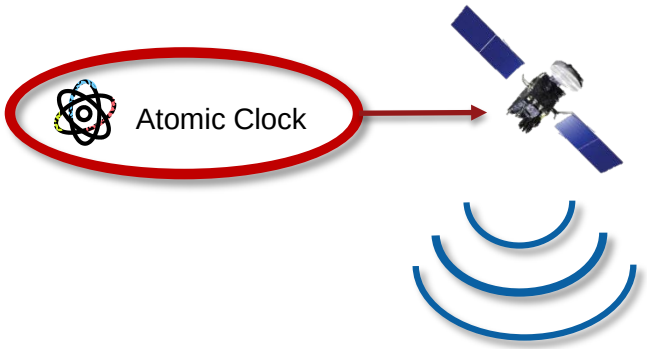
- **Accuracy**
  - *Position*
    - *Within meters for most applications*
    - *Within centimeters for advanced applications (i.e. Military)*
  - *Timing*
    - *10 – 100 ns*



- **GPS Receivers**
  - *Available in multiple form factors including integrated circuits*

- **Applications**
  - *Wide range of applications (scientific, financial, military, social networks, navigation, etc.)*

Making Every Receiver a “Virtual” Atomic Clock

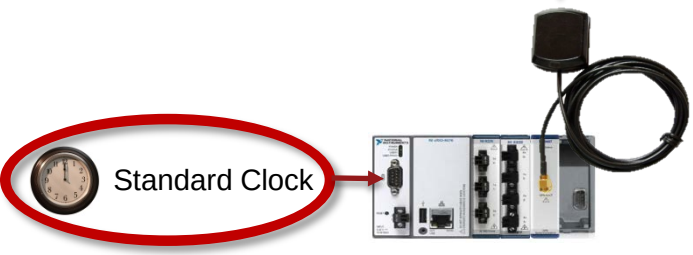


12:00 AM

10101000110101100100 1
Pseudo-Random code

Because GPS Receiver clock is inaccurate, distance to satellite is also very inaccurate!

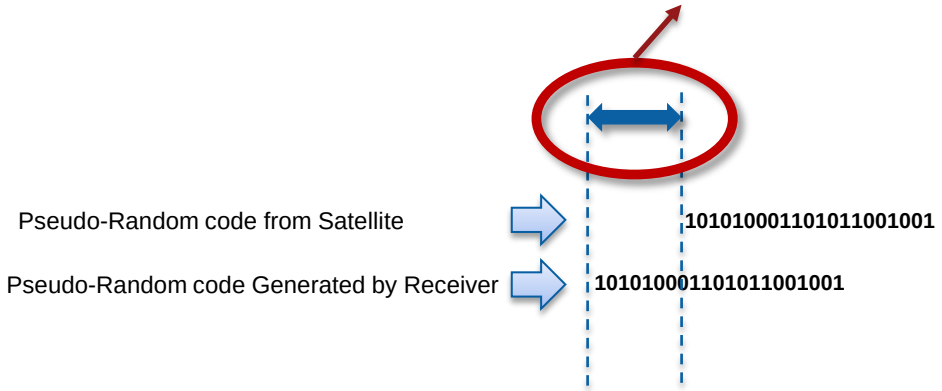
Misalignment X Speed of Light = Distance to Satellite



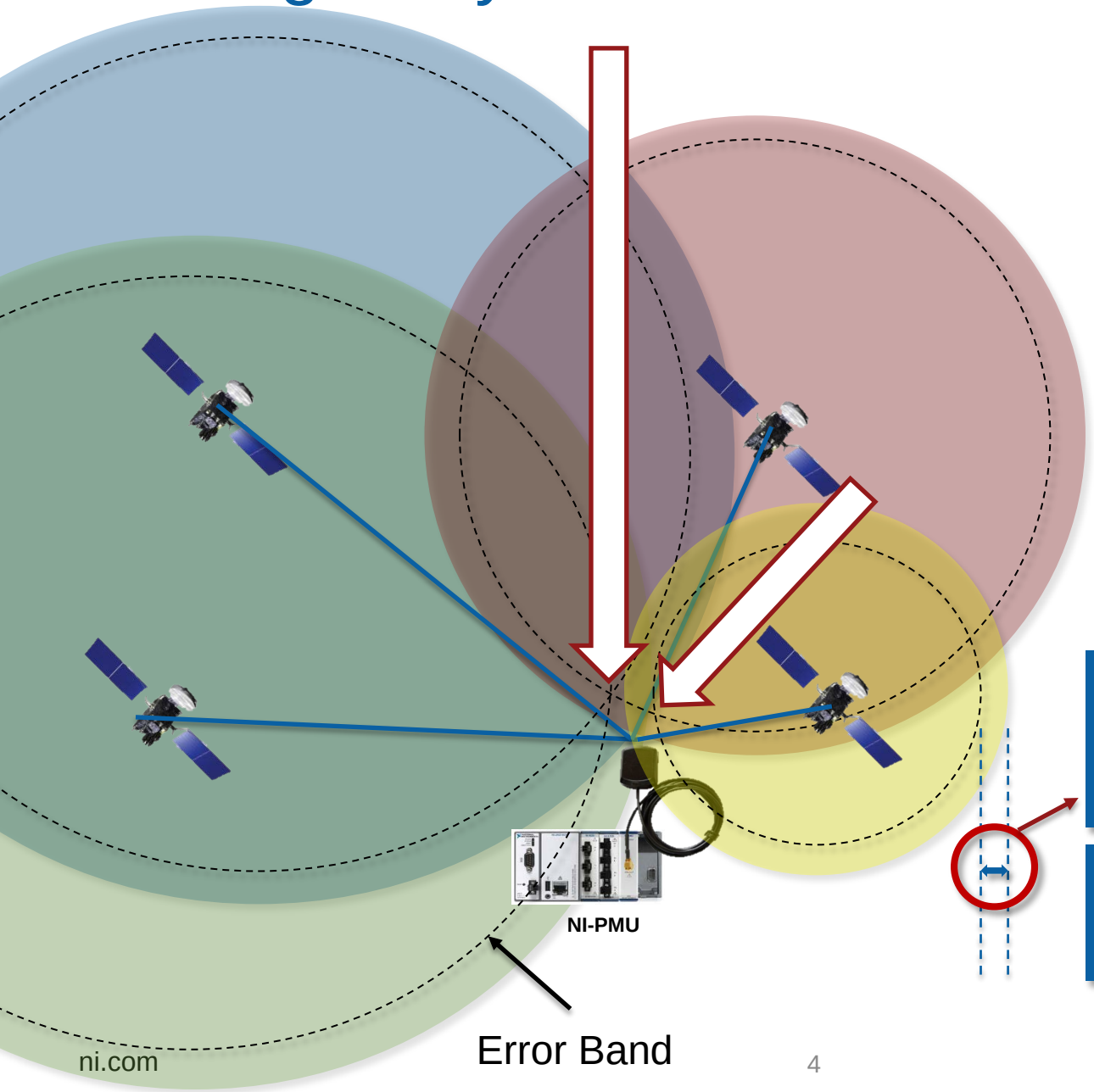
NI-PMU

12:00 AM

10101000110101100100 1
Pseudo-Random code



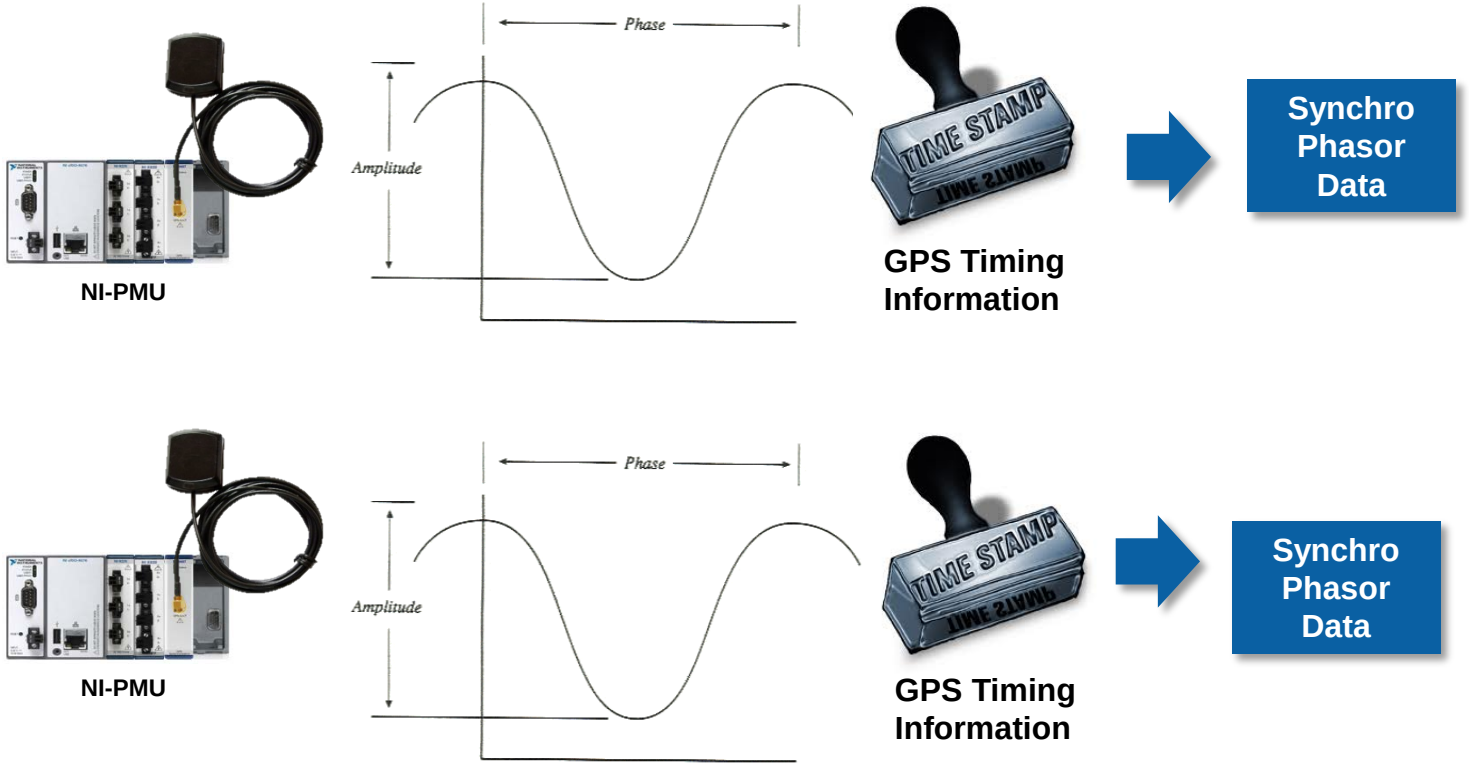
Making Every Receiver a “Virtual” Atomic Clock



Receiver calculates single correction factor that when applied to all four measurements make the spheres meet on the same point

This correction factor is then applied to the receiver clock, and at this point receiver and satellite are in lock mode.

How PMU's utilize GPS Timing



- **Two types of PMUs**
  - External GPS Source: Depends on external device to monitor and take action in the event of GPS signal issues
  - Built-in GPS: Has more flexibility to monitor and take action in the event of GPS signal issues

Potential GPS Issues

- **Natural or intrinsic issues**
  - Atmospheric effect
  - Multipath effects
  - Artificial degradation of the satellite signal
- **Malicious attacks**
  - Broadcasting noise on the same frequency as the satellites
  - Broadcasting signal with false information
  - Etc…
- **Counter measures**
  - Amplitude discrimination
  - Time-of-arrival discrimination
  - Navigation inertial measurement unit (IMU) cross-check
  - Polarization discrimination
  - Angle-of-arrival discrimination
  - Cryptographic authentication
  - Etc…

Likely to continue to evolve!

Smart Grid-Ready Instrumentation

Computers

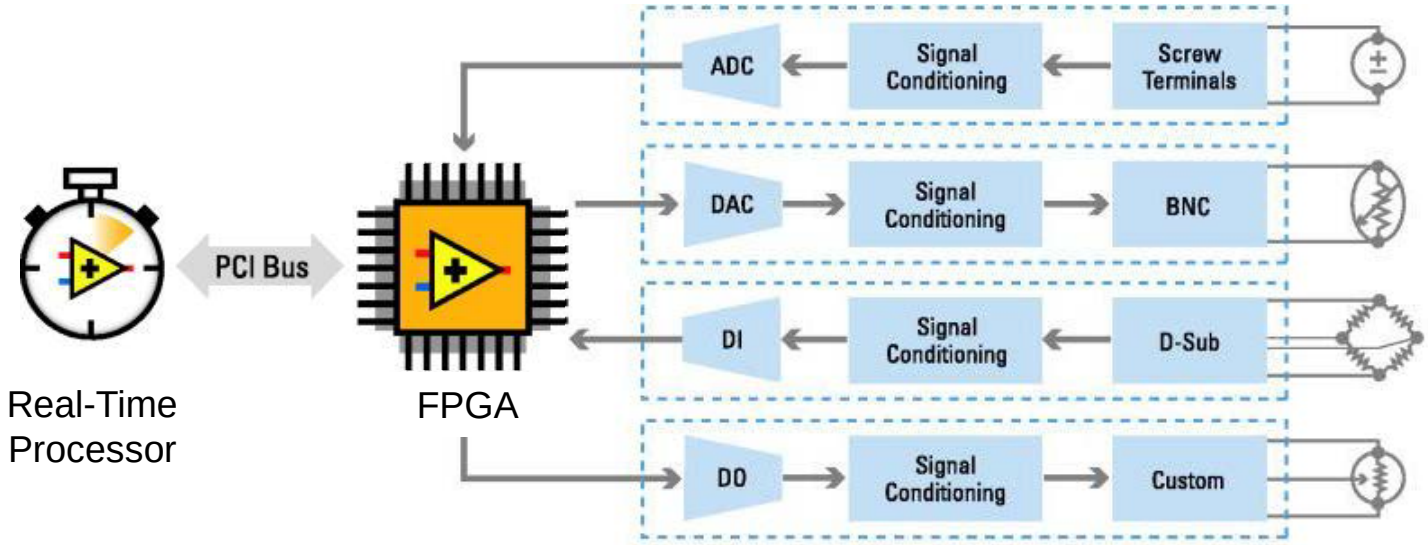
- Processing Power
- Open Source
- I/O Expandable
- Programmable
- Software-Defined

- Measurement Quality
- Embedded Processing Power
- Reliable and Robust
- Open source and Programmable
- I/O Expandable and Standards-Based
- Software-defined

T&D Instrumentation

- Measurement Quality
- Embedded
- Reliable and Robust
- Standards-based
- Vendor-Defined

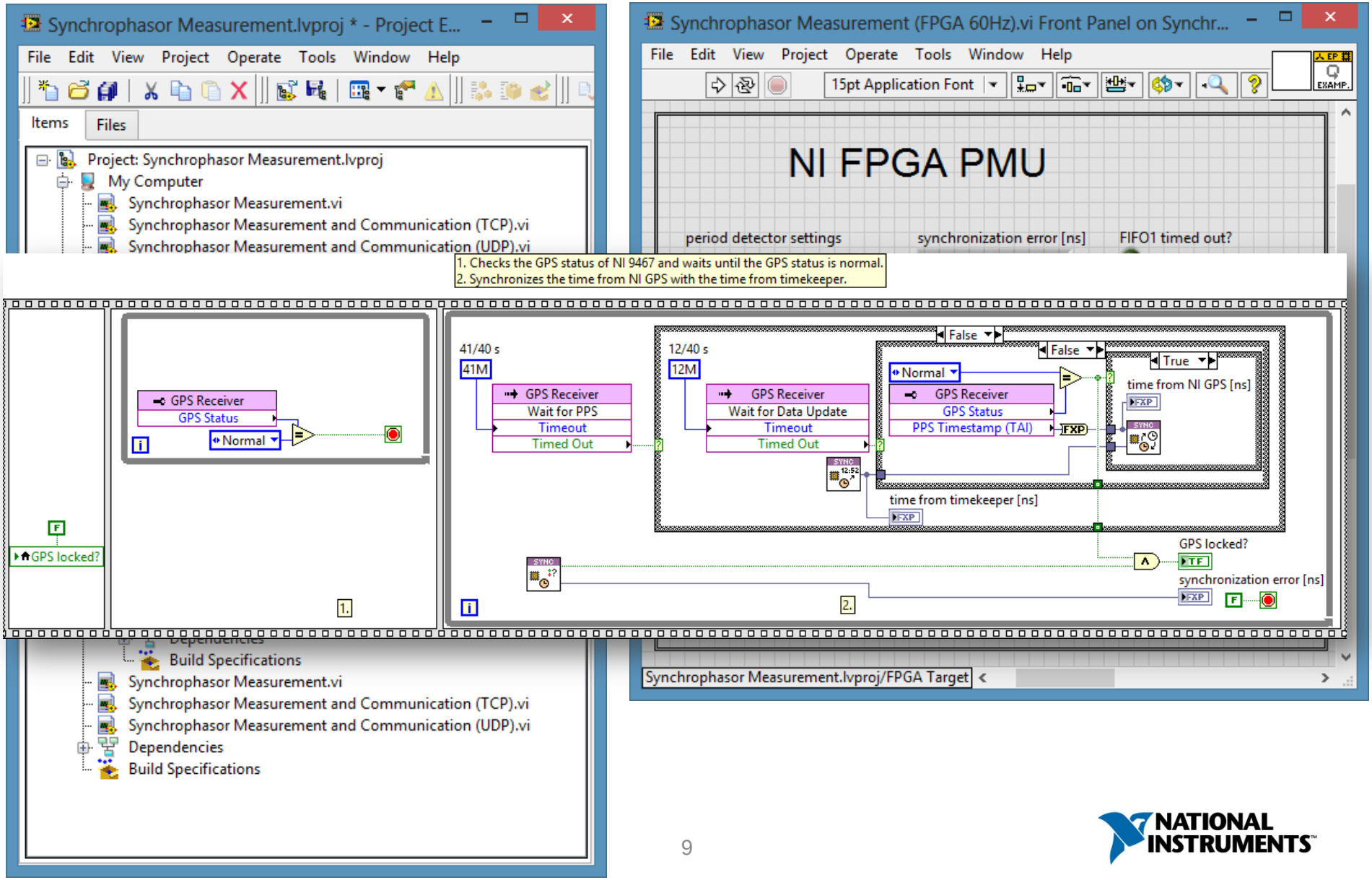
Smart Grid Ready Instrumentation an FPGA-based Platform



- **Reconfigurable FPGA** for high-speed and custom I/O timing, triggering, and control
- **I/O modules** with built-in signal conditioning for connection to sensors/actuators
- **Real-time processor** for reliable measurement, analysis, connectivity, and control

BOTTOM LINE: FPGA-Based platform provides flexible instrumentation that adapts to changing requirements and allows custom algorithms to check and monitor abnormal GPS variations

Virtual Instrumentation: PMU Example



NATIONAL INSTRUMENTS

Summary

- **There is no silver bullet to defend from GPS issues**
  - *Malicious vs. Nature related causes*
  - *Most likely a continuous effort (Anti-virus analogy)*

- Time-Keepers constantly **monitors the "Quality" of various time sources** and selects the one that is most appropriate at any given time.

- **Smart-Grid Ready Instrumentation** that adapts as needs evolves, without asset replacement, **is key for future-proofing our infrastructure**