Inverters & Motor Drive Analysis

CN Rood/Tektronix

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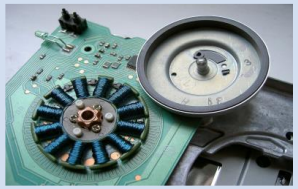
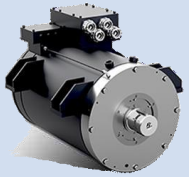
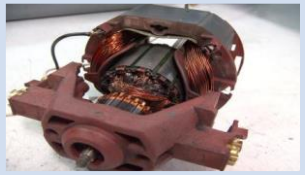
Types of Motors

Classified by design technology

BLDC Motor (Brushless DC)	Induction Motor	PMSM Motor (Permanent Magnet Synchronous Motor)	Universal Motor	Stepper Motor
				
• Computer hard drives • Consumer electronics • HVAC • Electric Cars • Industrial Engineering	• Industrial Applications • HVAC • Electric Cars	• Fans, Blowers • DC Generators • Centrifugal Pumps • Paper Mills	• 'White goods' (washing machines, kitchen appliances, ...) • Traction Motors (Railways) • Starter Motors in Cars	• Hard Disk Drives • Robotics • Antennas • Telescopes • Toys
• Better speed vs torque • High dynamic response • High efficiency • Long operating life • Noiseless operation • Higher speed ranges	• Simple, robust & mechanicaly strong • Relative lower cost • Can work in hazardous conditions • High efficiency (85%-95%)	• High performance in both low and high speed operation • Low rotor inertia, easy to control • Higher torque	• Efficiency 70%-75% • Torque vs speed • Speed cotrol	• Low cost • High reliability • High torque at low speed • Simple and rugged • Operates in almost any environment

Types of Drives

AC Drives	DC Drives	Variable Frequency Drives	Servo Drives
			
• Constant speed motors e.g. Process industry • HVAC (fans, pumps, compressors)	• Crane and hoists • Elevators • Spindle drives • Winders • Paper production machines	Controls speed of AC motors • Conveyor systems • Blower speeds • Pump speeds • Machine tool speeds	• Robotics • CNC machines • Solar tracking systems • Antenna positioning • Camera auto focus
• Low start-up current allow for smaller components and redusc mechanical shock at start-stop • Lower speed results in lower noise levels	• Adjustable speed • Good speed regulation • Frequent starting, breaking, reversing	• Reducing speed will reduce Amps drawn by motor, provides energy efficiency • Reduces in-rush and mechanical issues associated with starting	• High output power relative to motor size and weight • High torque to inertia ratio • More continuous power and torque for short periods

Segmentation per use case

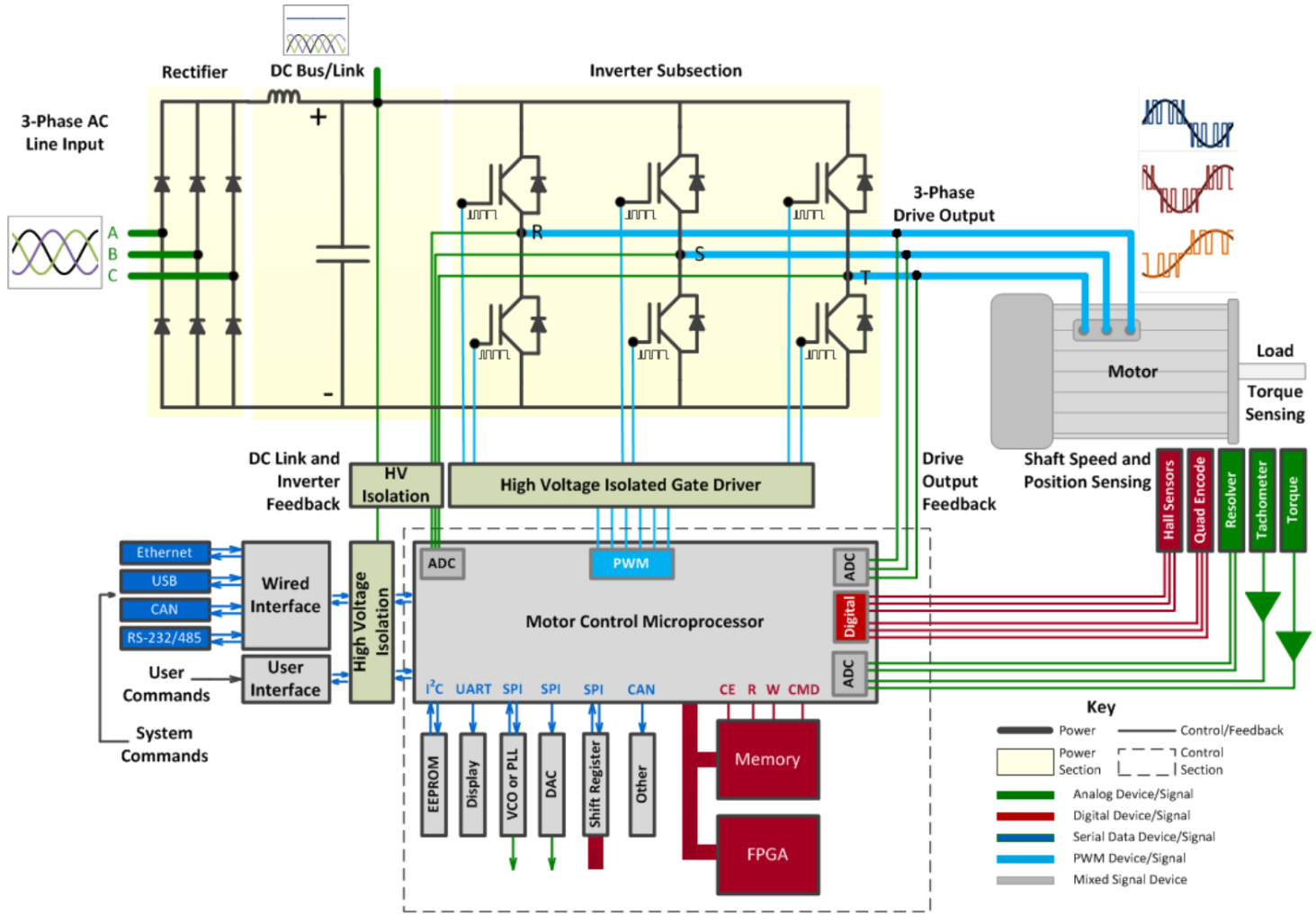
Automotive	Industrial	Consumer	MilGov/Defence/Aero
			
• EV/PHEV Power train	• Power tools • Robotics	• Washing machines • Vacuum cleaners	• Planes • Rovers • Drones
Focus on • Efficiency • Weight	Focus on • Low noise and vibration	Focus on • Energy savings / efficiency • Cost	Focus on • Precision motion control • Efficiency (drone fly time)

Questions regarding Inverter & Motor Drive Analysis

- How am I testing my Motor Drive Systems and what testing challenges do I have?
- What measurements do I need to make?
- How many channels do I need to monitor/analyze?
- How do I measure the dynamic response of my motor drive circuit?
- What mechanical measurements do I need to make?
- How do I measure magnetic components in my circuit?
- What characteristics of the semiconductor devices used in my circuit do I need to measure?
- How do I characterise the semiconductor devices used in my circuit?
- Do I need to perform Double Pulse measurements? How do I do that?
- How do I measure control loop response of my circuit?
- Which serial buses do I need to decode or measure in the control logic block of my design?
- How do I measure DC power rails in the control logic block of my design?
- Am I using WBG devices in my design? What measurement challenges do I face?
- Do I need to perform Direct Quadrature Zero (DQ0) analysis on my design?
- …

Motor Drive

- Converter
- DC Bus
- Inverter
- Control Logic
- Motor



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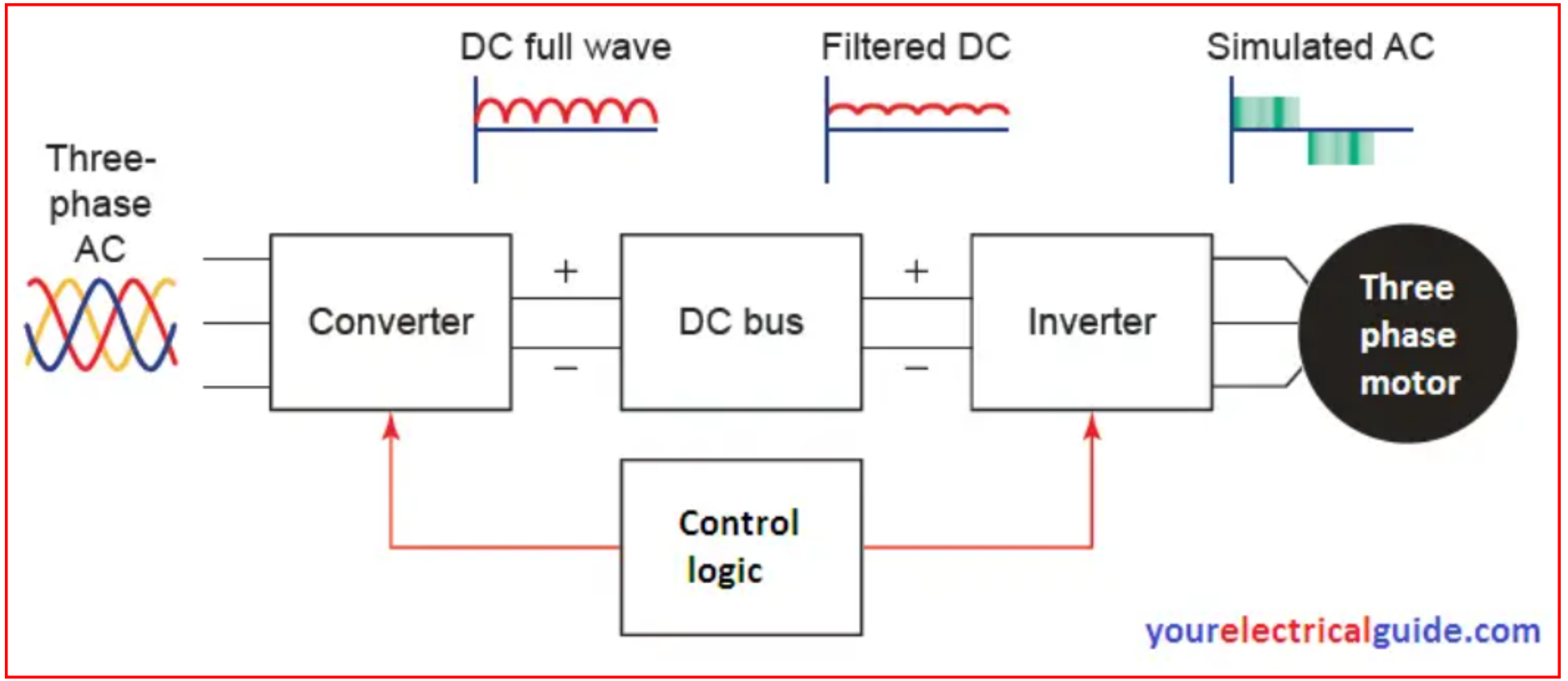
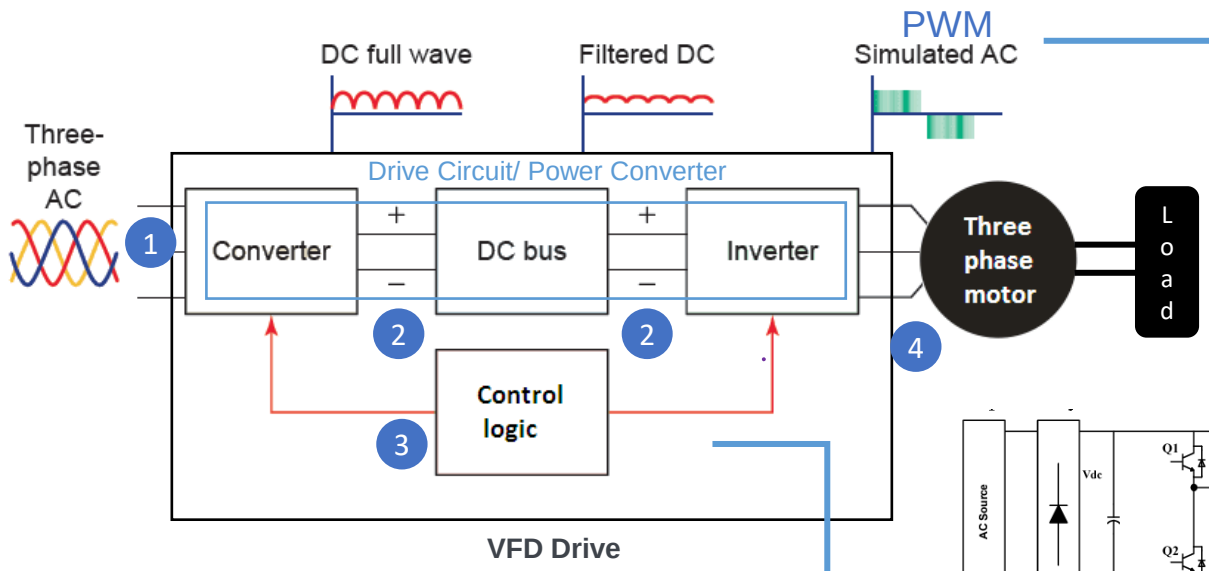
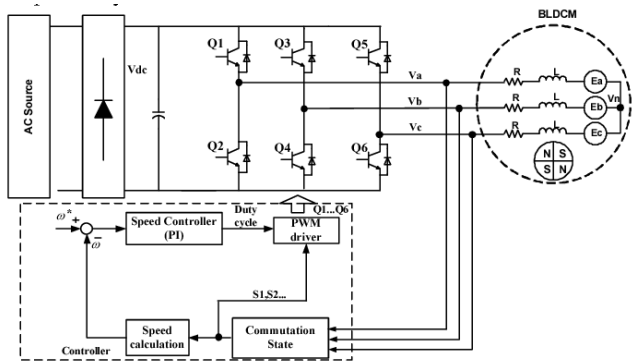
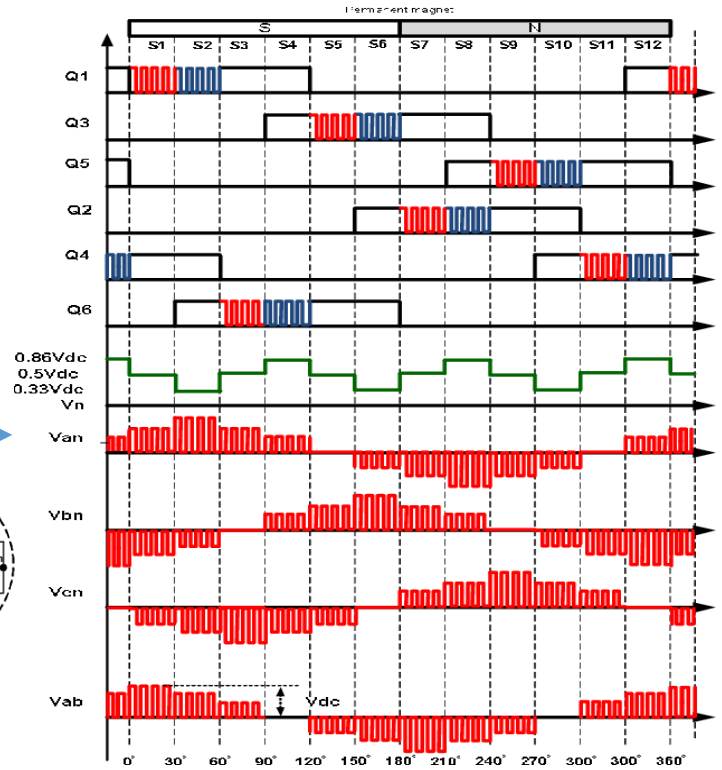


A typical 3-Phase Motor diagram







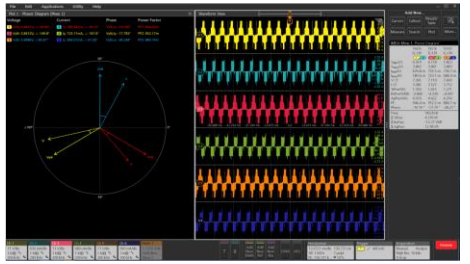
Typical Measurements of Interest

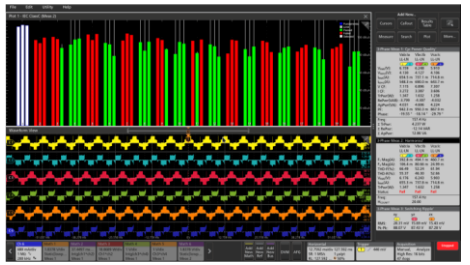
- Power Quality, Phasors 1
- Ripple 2
- Standard 5 Series measurements for control and user interface 3
- Power Quality, Phasors 4
- Efficiency 1 4

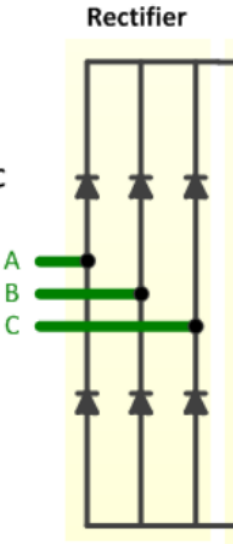
Testing that needs to be done – by building block

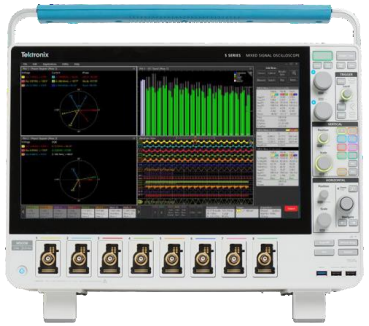
Converter

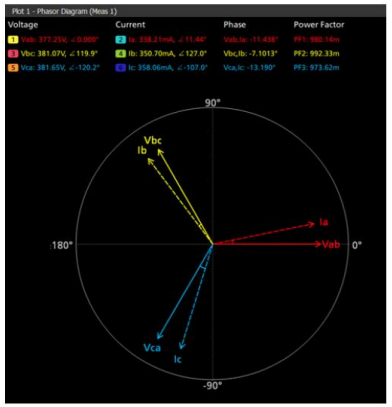
- 3-Phase Power Quality
  - Frequency, RMS values, Crest Factors, PWM frequency
- 3-Phase Harmonics analysis
- Phasor Diagram
  - Magnitude and phase angle between voltage and current
  - Power Factor for all voltages and currents







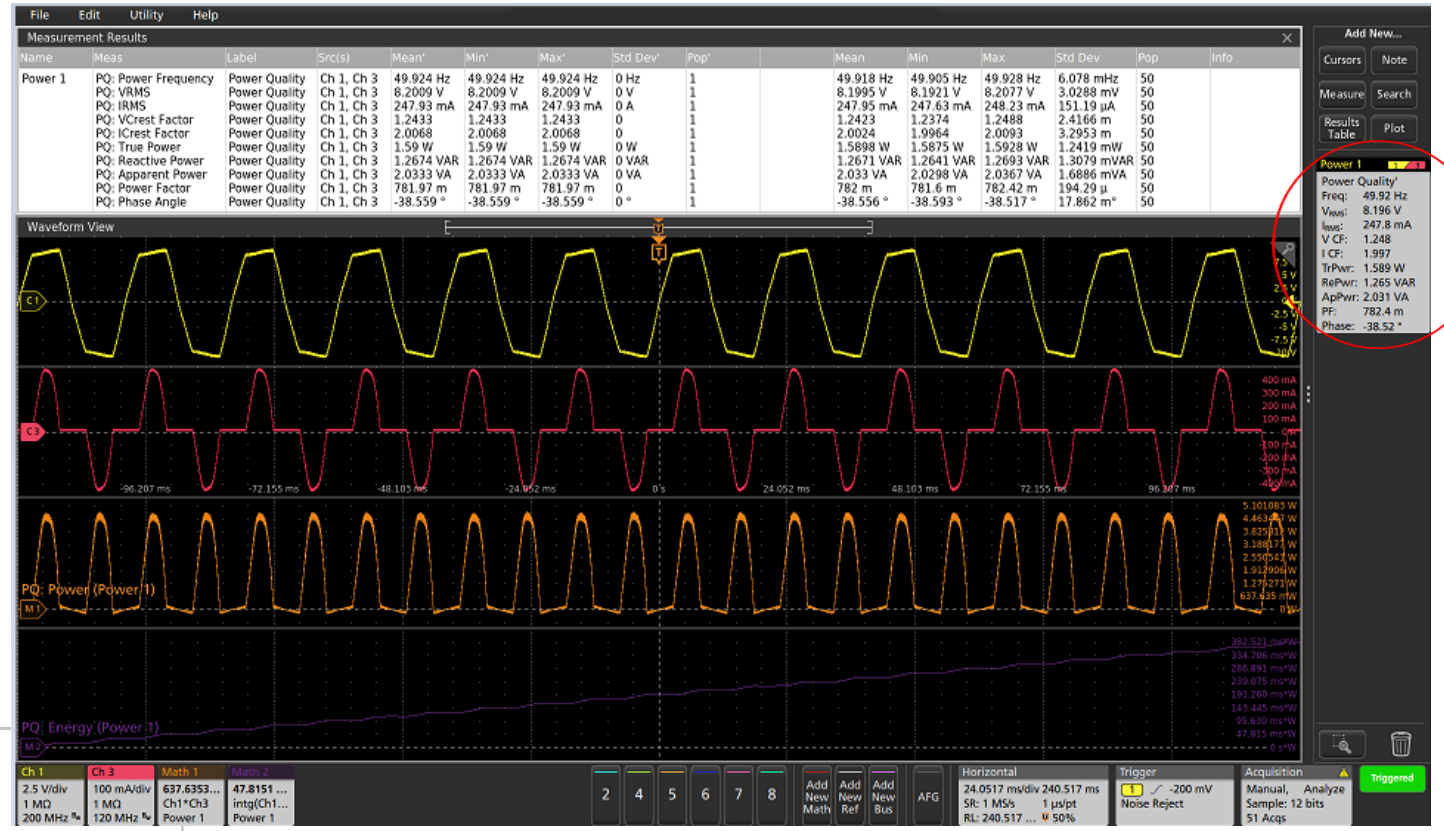


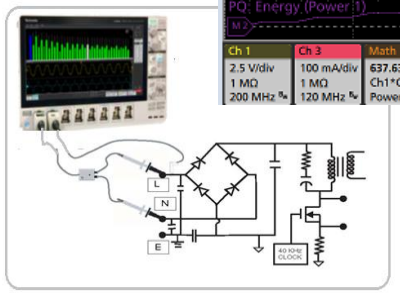


Testing that needs to be done – by building block

Converter - Significance of Power Quality

- Reduce losses
  - hence lower energy bills
- Improve Power Factor
  - avoid penalty for low power factor
- Prevent malfunctioning equipment
- Reduce losses in equipment
- Increase power equipment life span

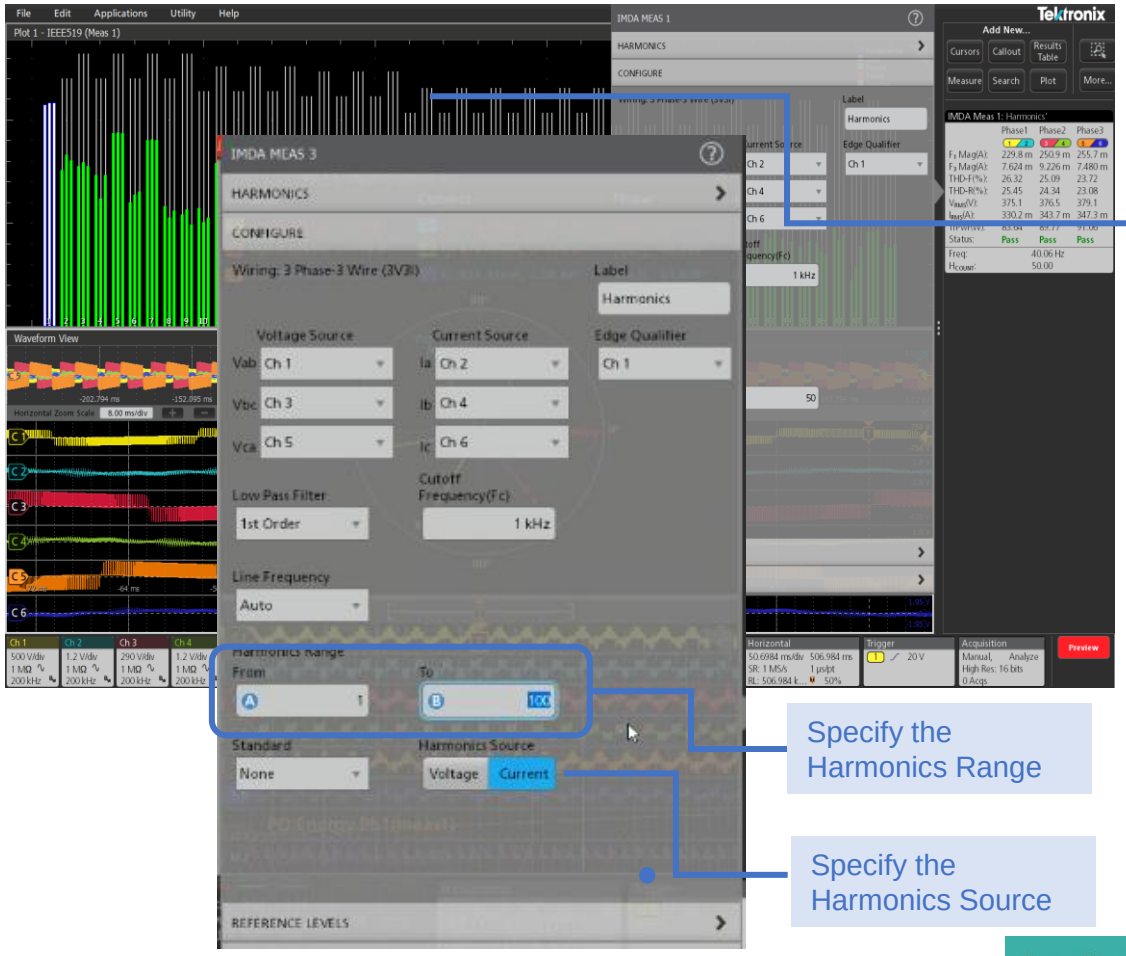




Testing that needs to be done – by building block

Converter - Significance of harmonics analysis

- Harmonics can impact efficiency
  - Can result in heating of coils, misfiring of VFDs, etc
  - Frequent cause of Power Quality Problems
- important sub-measurements such as THD-F, THD-R
- up to 200th order
  - supports range filter for visibility
- Support pass/fail status

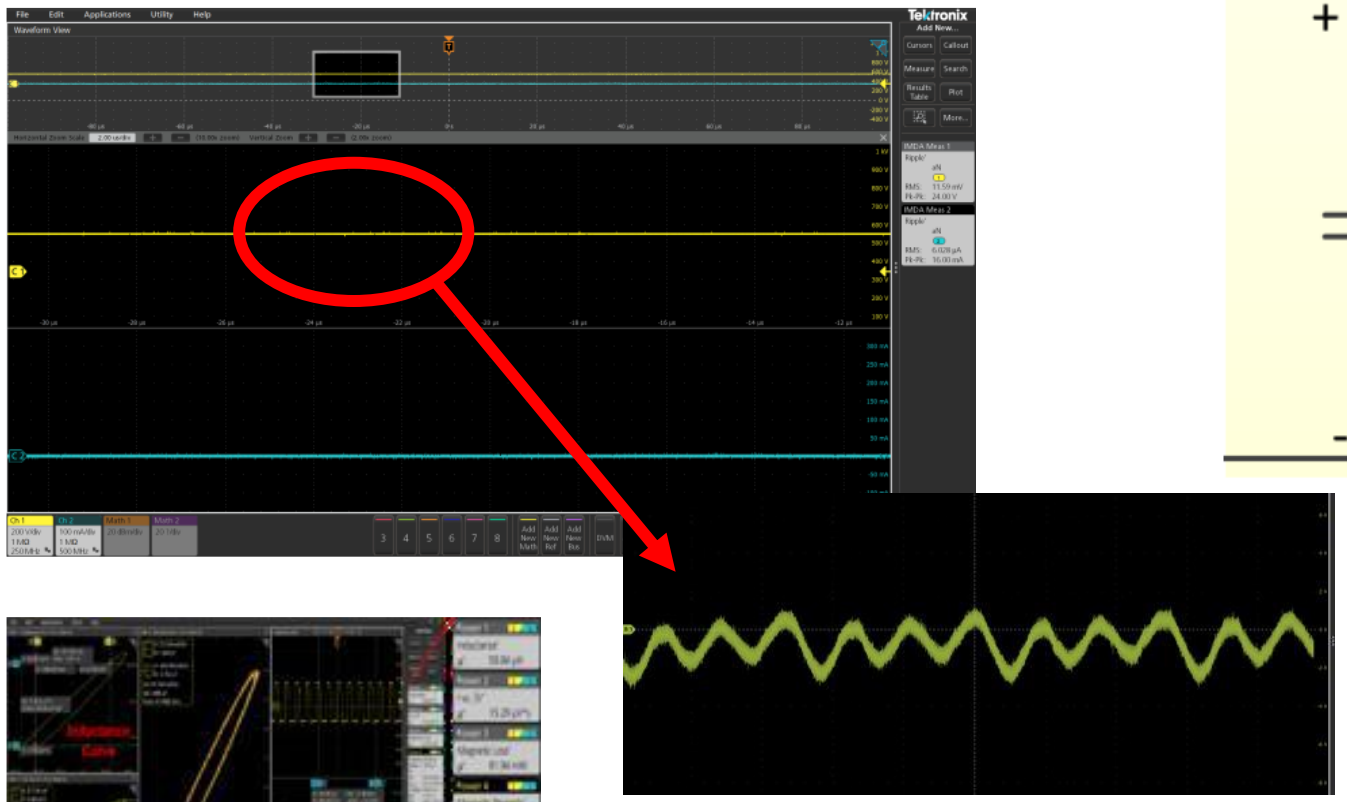


VFD : Variable Frequency Drive
THD-R : Relative to Total Signal (0 < THD-R < 1)
THD-F : Relative to Fundamental component (IEC61000-2-2)

Testing that needs to be done – by building block

DC Bus

- AC ripple analysis
  - Residual AC voltage on a DC component
  - Can be measured at input or output configuration
- Magnetic analysis



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THD-R : Relative to Total Signal (0 < THD-R < 1)
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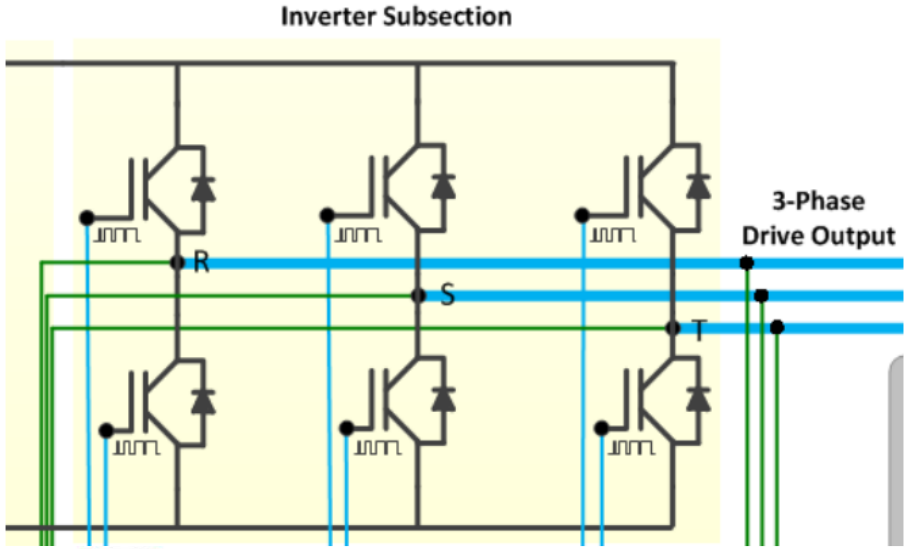
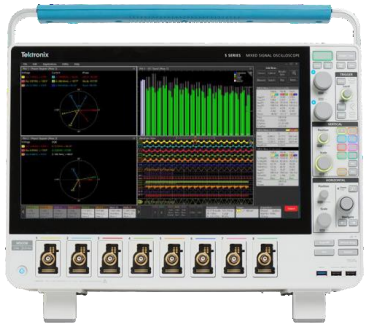
Testing that needs to be done – by building block

Inverter

- 3-phase Power Quality
- 3-phase Harmonics analysis
- Semiconductor device switching analysis
- Semiconductor device characterisation
- Safe Operating Area (SOA)
- Amplitude and timing analysis
- Turn on/turn off time analysis
- WBG Double Pulse Testing and switching analysis

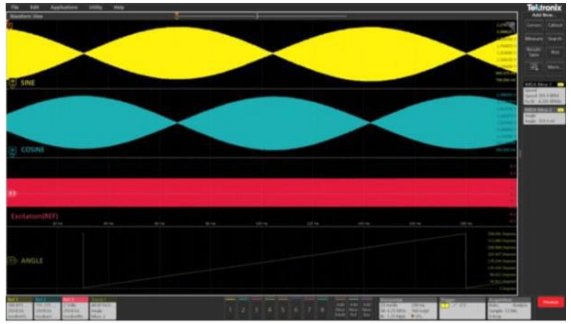


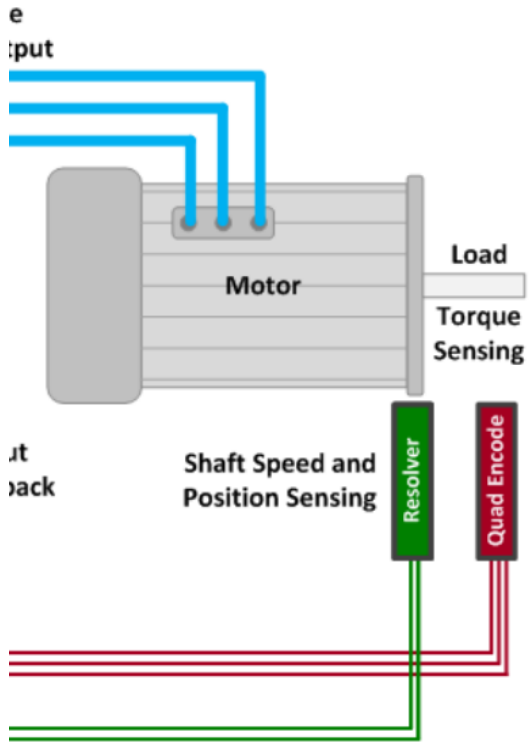


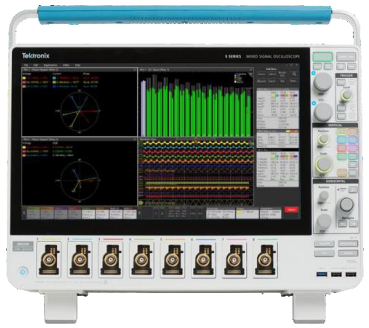
Testing that needs to be done – by building block

Motor

- Mechanical analysis
  - Speed
  - Acceleration
  - Angle
  - Direction
  - Torque
  - Mechanical power
  - System efficiency



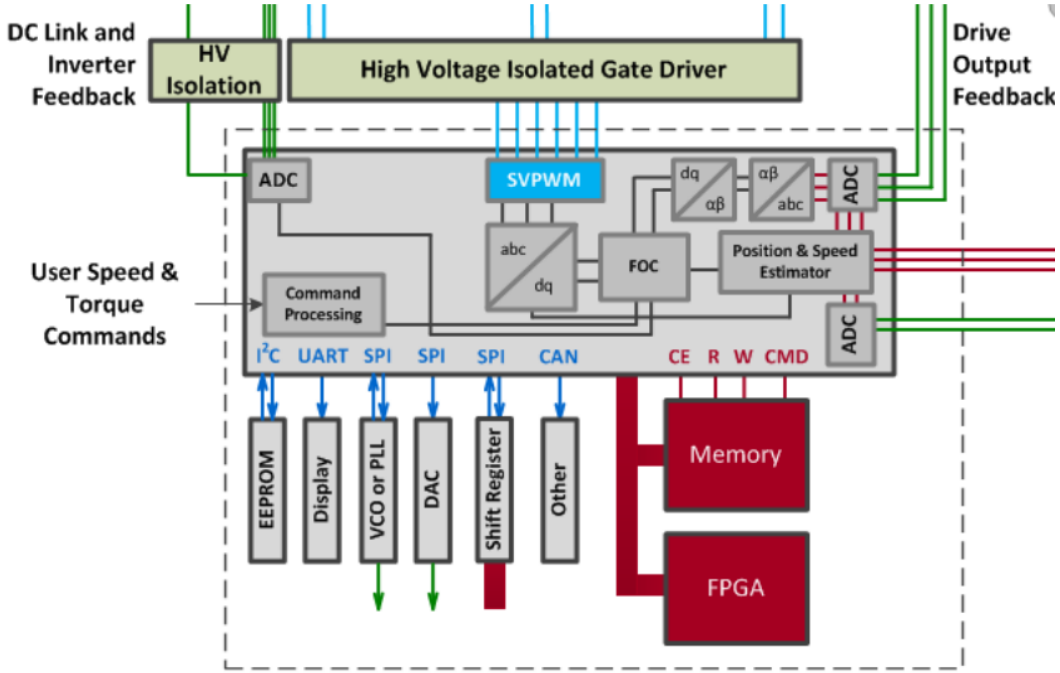


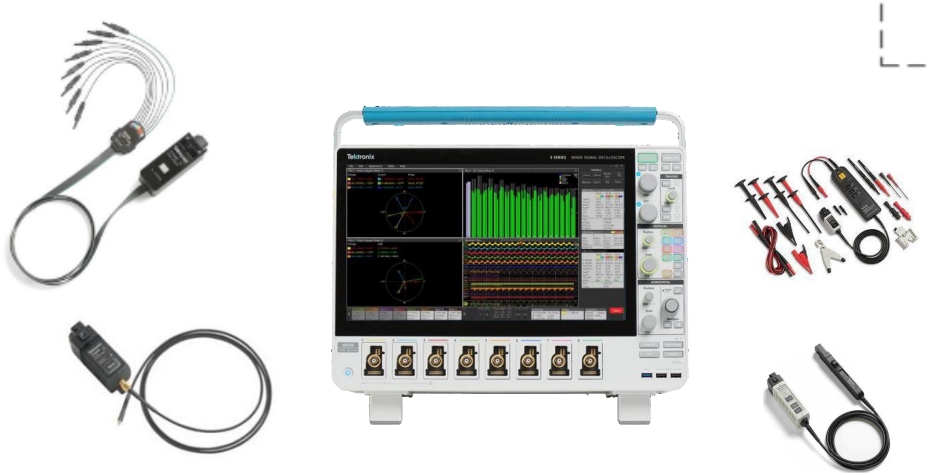


Testing that needs to be done – by building block

Control Logic

- Direct Quadrature Zero (DQ0) analysis
- Control Loop Analysis
- Serial decoding (CAN, I²C, SPI, ...)
- Mixed Signal analysis
- DC Power Rail analysis





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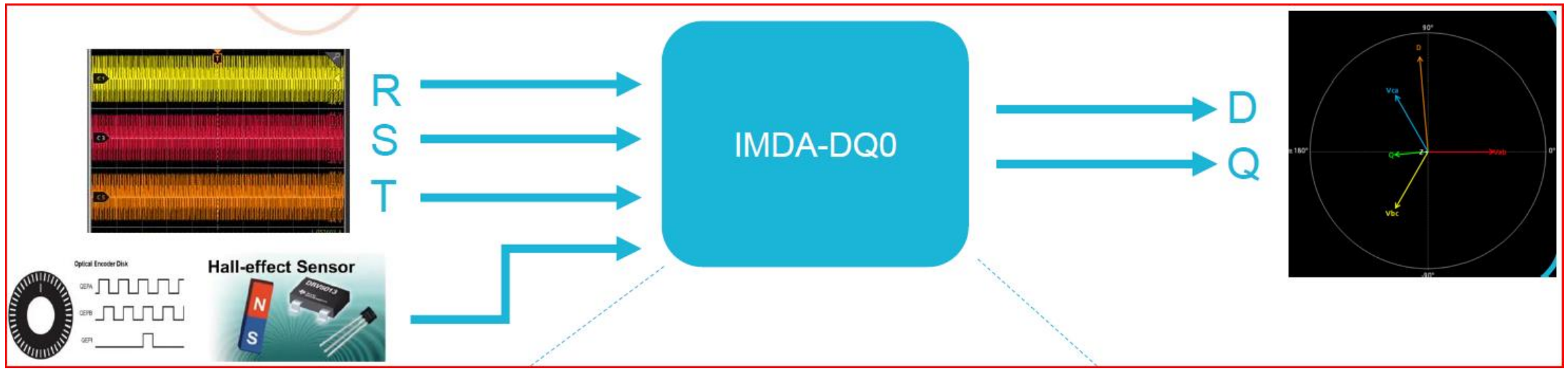
Control Logic

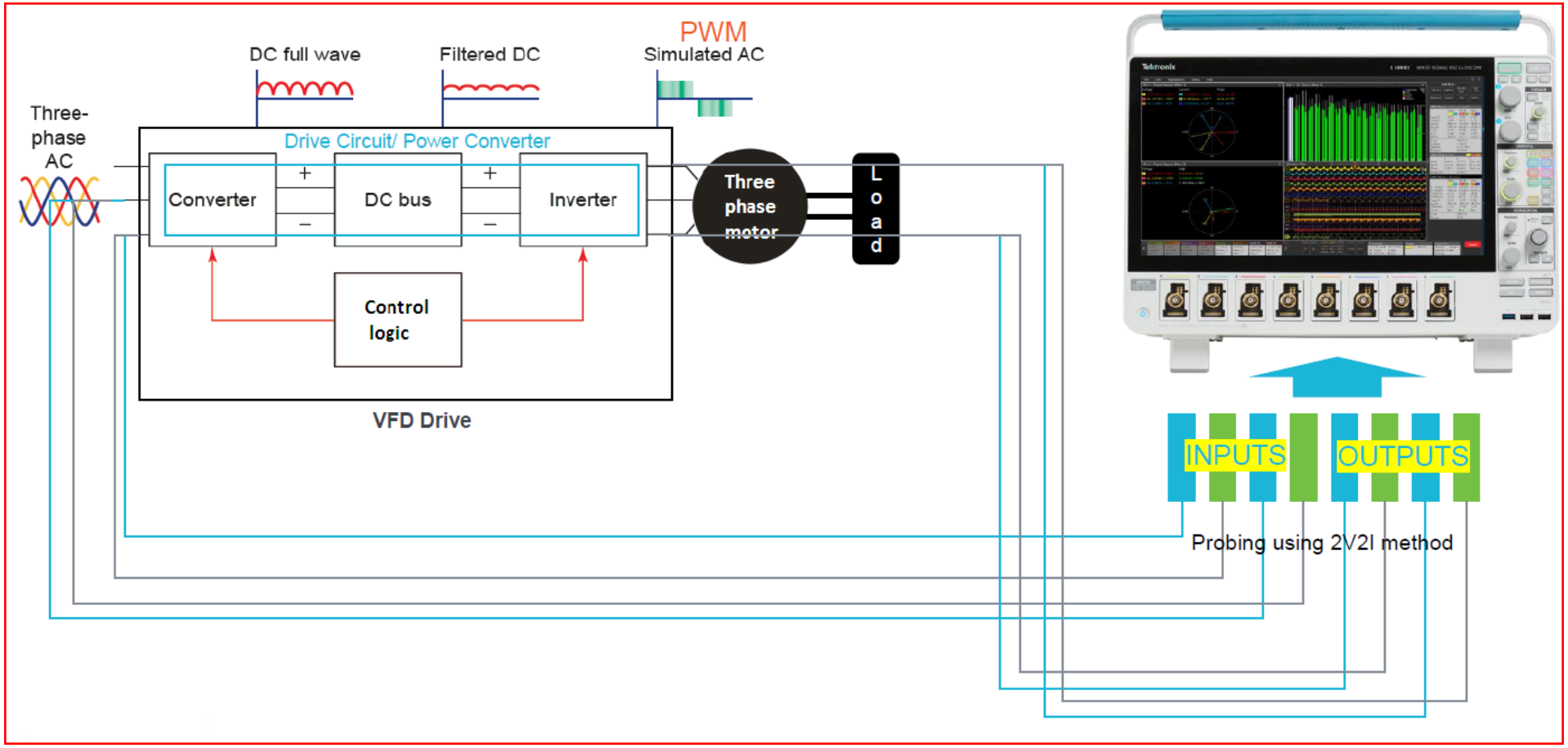
- Direct Quadrature Zero (DQ0) analysis



  - Hard to analyze – need three phases to analyze
  - Park's Transformation converts raw 3 Phase voltage or current signals into DQ0 components for simplified analysis

Testing that needs to be done – by building block

Efficiency



Thank you!

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