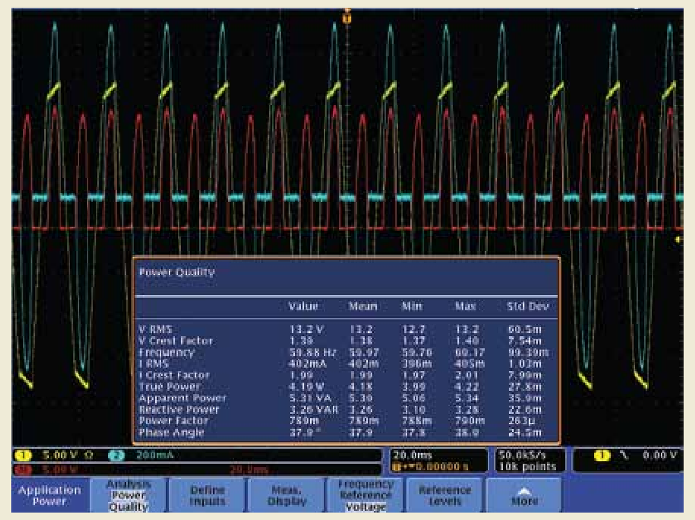
Fundamentals of Switch-Mode Power Supply Testing

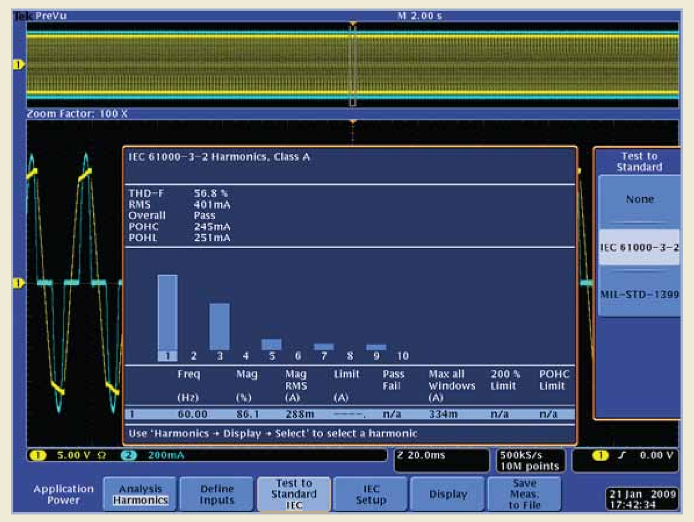
Practical Tips & Techniques

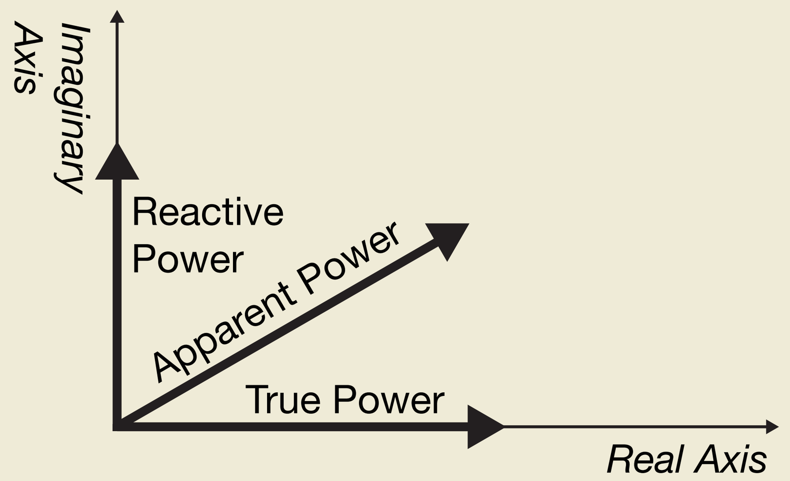
Power supplies are driving to a level of efficiency never seen before, requiring design engineers to perform numerous specialized power measurements that are time-consuming and complex. With the right oscilloscope and the tips outlined in this poster, learn how to better ensure the reliability, stability, compliance, and safety of your switch-mode power supply (SMPS) design.

Power Quality

- Power Quality Issues
  - To determine the effect of the insertion of a power supply, voltage and current parameters must be measured directly on the input power line.
  - Power quality measurements include:
    - True, Apparent or Reactive Power
    - Power Factor/Crest Factor
    - Pre-compliance Testing to EN61000-3-2 Standards
    - Total Harmonic Distortion (THD)
- Apparent Power = I_{rms} * V_{rms}



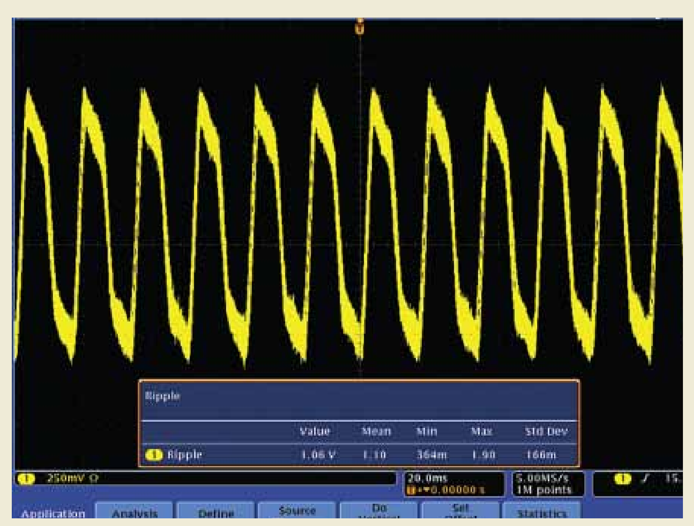


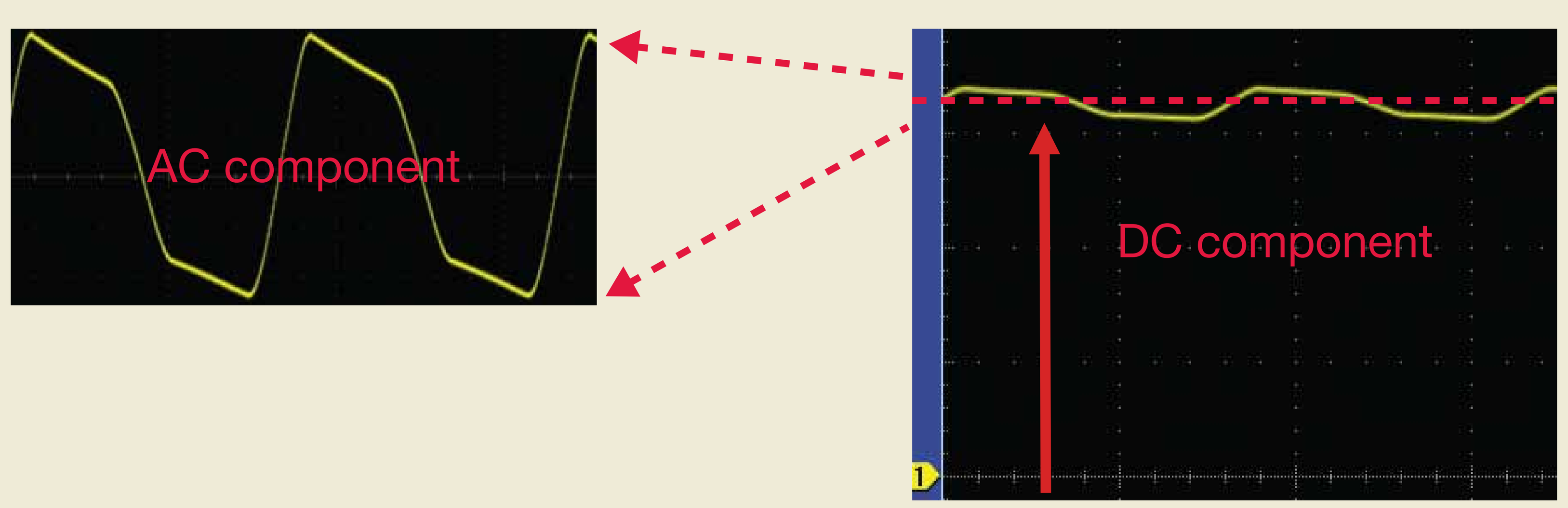


- Power Factor = $\frac{\text{True Power}}{\text{Apparent Power}}$
- Crest Factor = $\frac{V_{peak}}{V_{rms}}$

Output Analysis

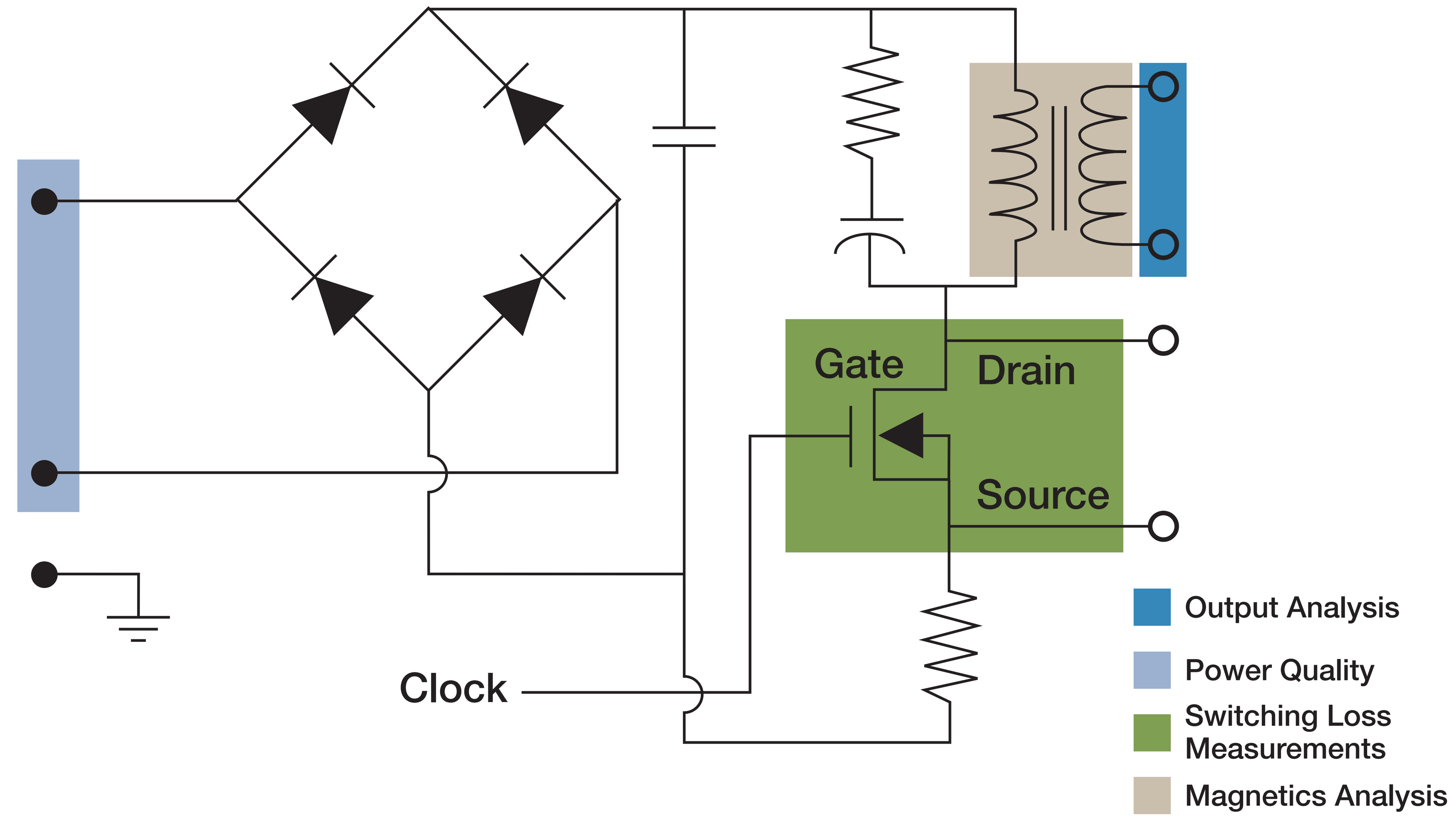
- Ripple is the periodic AC component
  - On top of the DC voltage output
- Ripple frequency is related to
  - Line frequency
    - ~120 Hz in countries with 60 Hz power
    - ~100 Hz in countries with 50 Hz power
  - Switching frequency
    - Typically > 100 kHz





Learn more about Tektronix power measurement and analysis solutions at:

www.tektronix.com/power



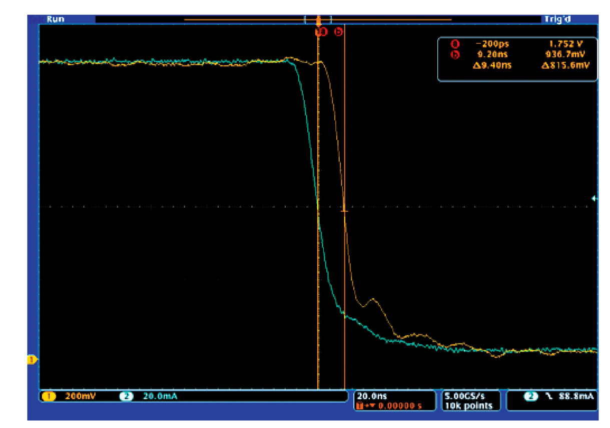
Probing Considerations

Probes and probing techniques affect the quality of a measurement. Loading and skew between probes can introduce error and distortion in power measurements.

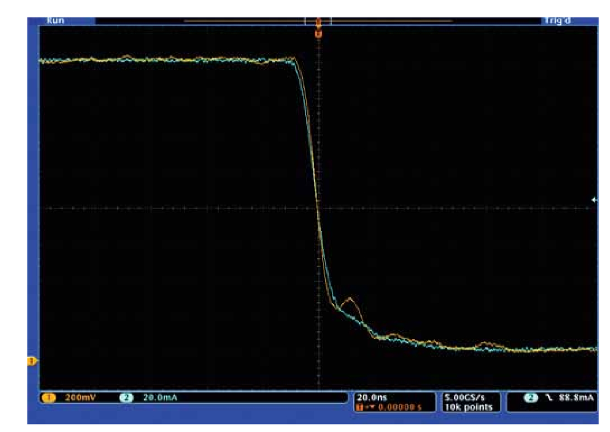
Tip: Eliminate skew between current and voltage probes. Since power is the product of voltage and current accurate measurements are made with time-aligned voltage and current waveforms. Tektronix oscilloscopes with the TekVPI interface simplify measurement setup with automated deskew.

Tip: Remove voltage offset by using the built-in DC offset adjustment controls on differential probe. Additionally run the oscilloscope self-calibration routine as often as necessary to ensure accurate voltage measurements.

Tip: A TekVPI current probe has a Degauss/AutoZero button on the probe body. Depressing the AutoZero button will remove any DC offset error present in the measurement system as a result of any residual magnetic field.



Before Deskew



After Deskew

Tektronix Oscilloscopes

- 100 MHz to 3.5 GHz models
- Up to 4 analog and 16 digital channels
- Comprehensive Probing Solutions
  - TekVPI™ interface for easy probe connectivity
  - AC/DC current probes
  - Differential probes to make floating measurements
  - High voltage with high bandwidth for accurate characterization of fast edges
- Integrated Power Analysis Software
  - Automated power measurements including switching loss, ripple, power quality, current harmonics and modulation analysis
  - Measure core loss and BH curves on magnetic components
  - Quickly deskew voltage/current probes with built-in automation
  - Generate customized reports

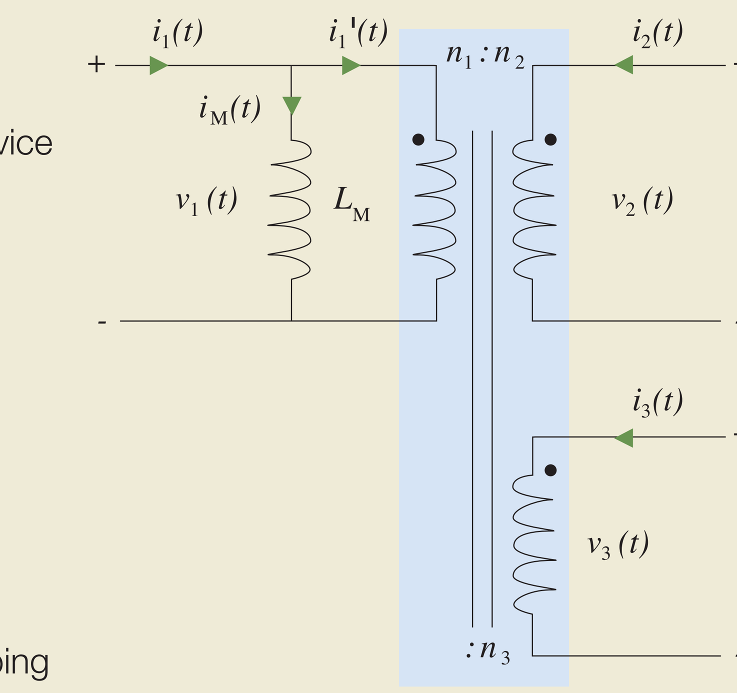
Magnetics Analysis

- Inductors
  - Used in power supplies as a filter or energy storage device

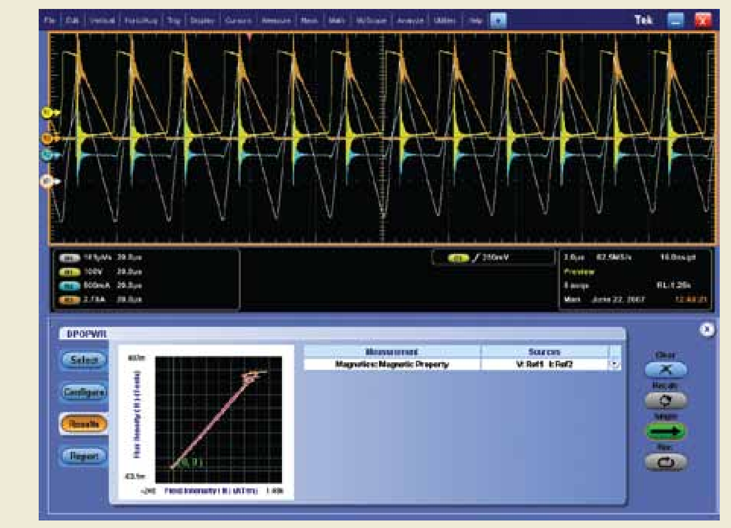
$$L = \frac{\int -Vdt}{I}$$

Where:

- L is the inductance (Henry).
- V is the voltage across the inductor.
- I is the current though the inductor.
- dt is the rate of change in a signal; the slew rate.
- Transformers
  - Multiple-winding inductor or transformer used for stepping voltages up or down with the same net power level
  - Two types of power losses are associated with magnetic elements:
    - **Core Loss:** Composed of hysteresis loss and eddy current loss. The hysteresis loss is a function of the frequency of operation and the AC flux swing.
    - **Copper Loss:** Due to the resistance of the copper winding wire.



Ideal Transformer

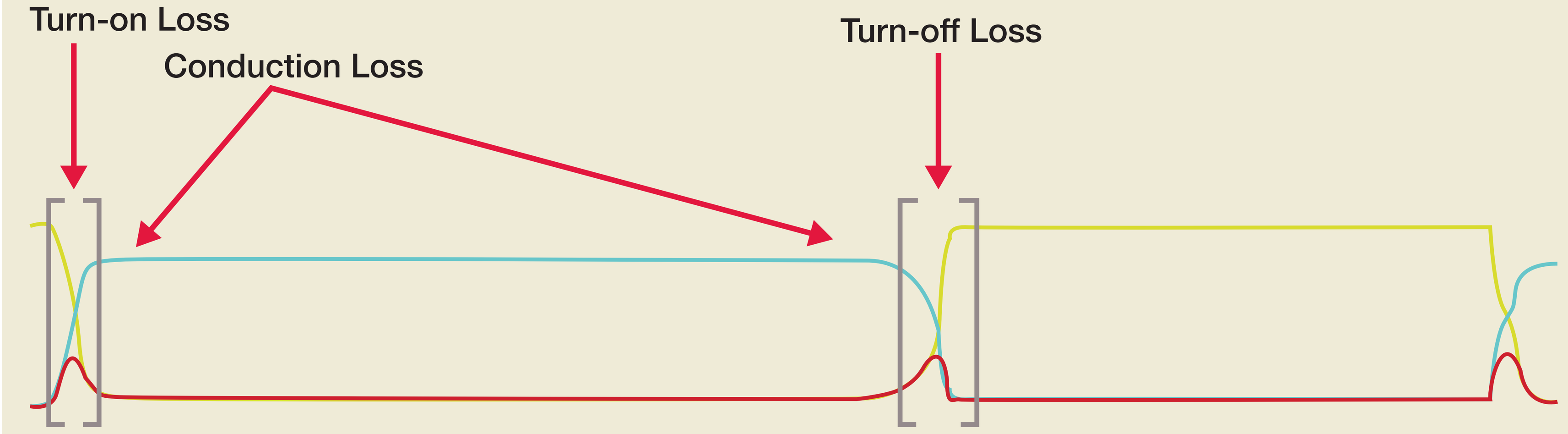


Switching Loss Measurements

- Switched-Mode Device
  - Compared to resistors and linear-mode devices, transistors dissipate very little power in either the On or Off states, achieving high efficiency with low heat dissipation.
  - Transistor switch circuits often dissipate the most energy during transitions because circuit parasitics prevent the devices from switching instantaneously.
  - For the most part, the switching device determines the overall performance of an SMPS.

Power Loss Overview

- Turn-on Loss
  - Energy losses when the switching device changes from its non-conducting state to its conducting state
- Conduction Loss
  - Losses in the switching device when it is in saturation
- Turn-off Loss
  - Energy losses when the switching device changes from its conducting state to its non-conducting state.



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