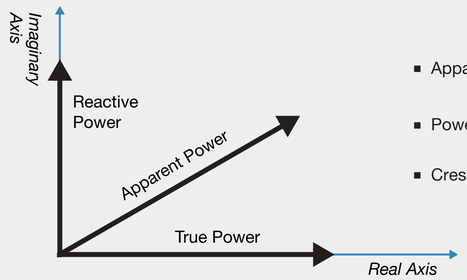
Fundamentals of Switch-Mode Power Supply Testing

Practical Tips & Techniques

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

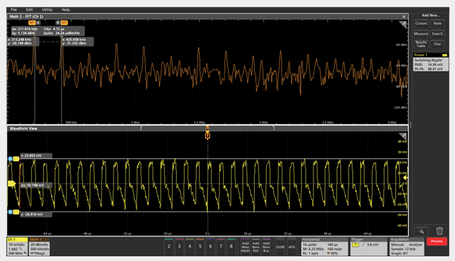
- Power Quality Issues
  - To determine the effect of the insertion of a power supply, voltage and current parameters must be measured directly on the input power line.
  - Power quality measurements include:
    - True, Apparent or Reactive Power
    - Power Factor/Crest Factor
    - Pre-compliance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

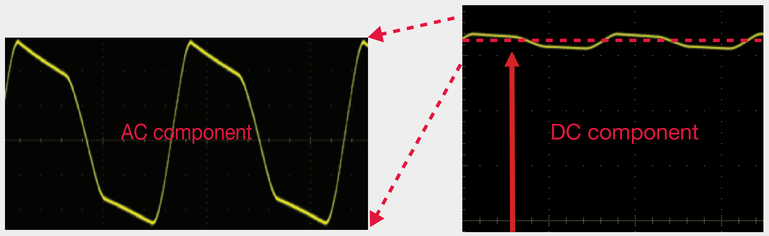


- Apparent Power = $I_{rms} * V_{rms}$
- Power Factor = $\frac{\text{True Power}}{\text{Apparent Power}}$
- Crest Factor = $\frac{V_{peak}}{V_{rms}}$

Output Analysis

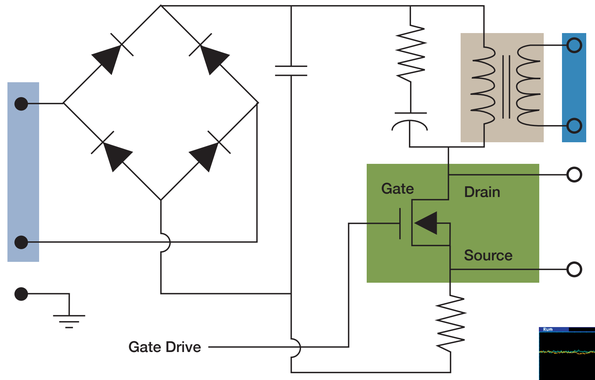
- Ripple is the periodic AC component on the top of the DC voltage output
- Ripple frequency is related to
  - Line frequency
    - ~120 Hz in countries with 60 Hz power
    - ~100 Hz in countries with 50 Hz power
  - Switching frequency
    - Typically > 100 kHz





Learn more about Tektronix power measurement and analysis solutions at:

www.tektronix.com/power-efficiency



Output Analysis
Power Quality
Switching Loss Measurements
Magnetics Analysis

Probing Considerations

Loading and skew between probes can introduce error and distortion in power measurements.

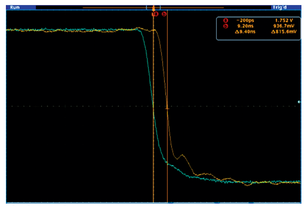
Tip: Eliminate skew between current and voltage probes. Since power is the product of voltage and current accurate measurements are made with time-aligned voltage and current waveforms. Tektronix oscilloscopes with the TekVPI interface simplify measurement setup with automated deskew.

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

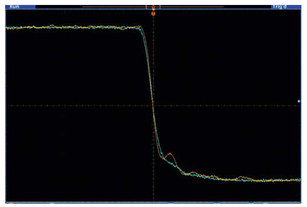
Tip: A TekVPI current probe has a Degauss/AutoZero button on the probe body. Depressing the AutoZero button will remove any DC offset error present in the measurement system as a result of any residual magnetic field.

Tektronix 4 and 5 Series MSO

- 200 MHz – 1.5 GHz (4 Series)
  350 MHz – 2 GHz (5 Series)
- Up to 6 analog and 48 digital channels (4 series)
  Up to 8 analog and 64 digital channels (5 Series)
- Comprehensive probing solutions
  - Differential probes to make floating measurements
  - IsoVu® isolated probes with high bandwidth for accurate characterization of fast edges
  - Power rail probes with low noise and high DC offset specifically for power integrity measurements
- 12 bit ADC vertical resolution
- Repeatable, automated power measurement software — key to ensuring designs are reliable, safe and compliant.



Before Deskew



After Deskew

Overcoming Common Mode Voltage

Many power supply topologies require measurements of small differential voltages in the presence of high common mode signals. For example, VGS and VDS on the high side of a half-bridge switching stage often move up and down 100s or 1000s of volts relative to ground. IsoVu® Isolated Measurement Systems offer extremely high common mode rejection.

Magnetics Analysis

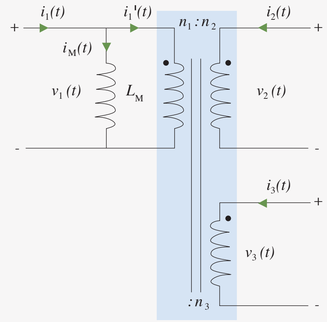
- Inductors
  - Used in power supplies as a filter or energy storage device

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

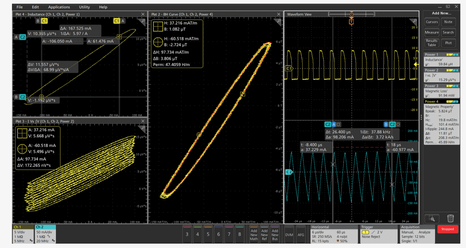
Where:
- L is the inductance
- V is the voltage across the inductor
- I is the current though the inductor
- dt is the rate of change in a signal; the slew rate

- 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.

Note: Magnetics analysis software only available on the 5 and 6 Series scopes.



Ideal Transformer

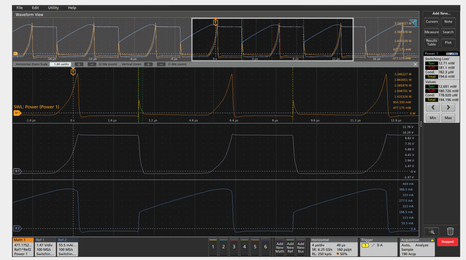


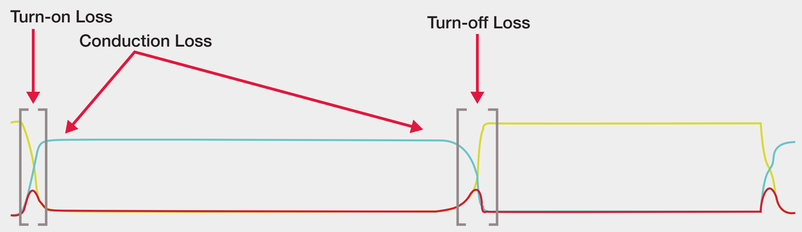
Switching Loss Measurements

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

Switching 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 conducting (on)
- Turn-off Loss
  - Energy losses when the switching device changes from its conducting state to its non-conducting state.





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