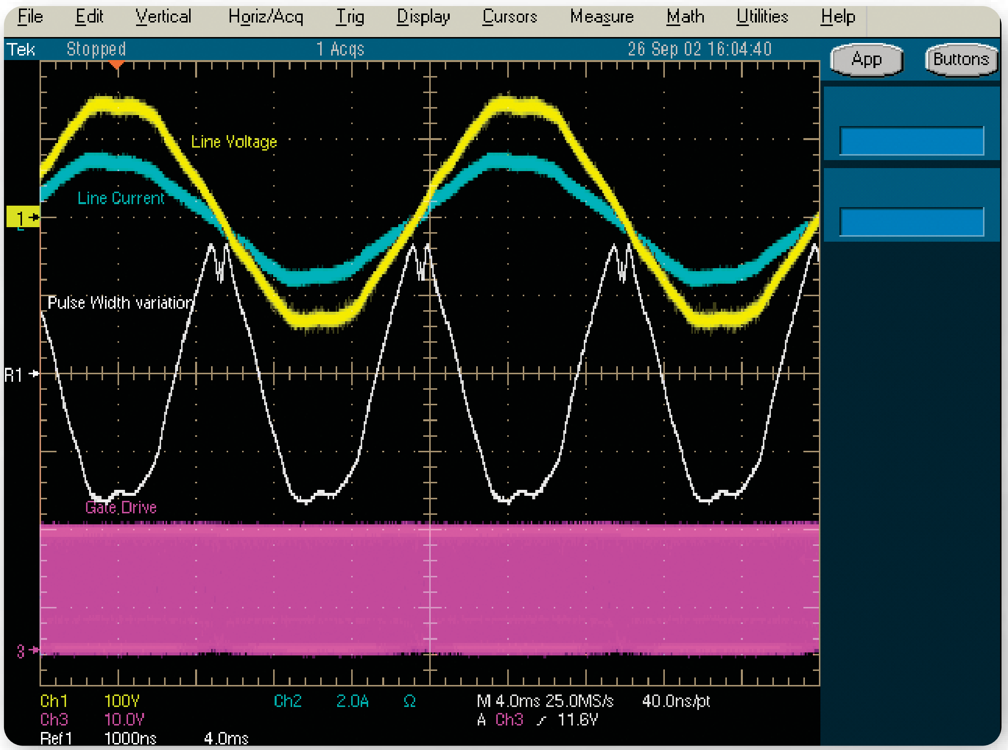
Debug Power Factor Correction Circuits With A Digital Phosphor Oscilloscope



Quickly and easily analyze waveforms in switch mode power supplies with active power factor correction.

Most switching power supply designs incorporate active power factor correction circuits to achieve a unity power factor. While this maximizes efficiency, it has also made waveform analysis with a digital oscilloscope cumbersome. Now, however, you can dramatically speed design and debug tasks by using a TDS5000B Series, TDS7054 or TDS7104 digital phosphor oscilloscope (DPO) with TDSPWR3 power measurement and analysis software.

Power factor (PF), technically the ratio of real power consumed to apparent power, is expressed in a decimal fraction of 0 to 1. PF is traditionally known as the phase difference between sinusoidal voltage and current waveforms. When the AC load is capacitive or inductive, the current waveform is out of phase with the voltage, which causes additional AC current to be generated and not consumed by the load. This additional current creates I2R losses in power cables.

A switch mode power supply, when viewed as an AC load is nonlinear. It is neither inductive nor capacitive. A switch mode power supply conducts current in short pulses that are in phase with the line voltage. The product of V_{RMS} and I_{RMS} is considerably higher than the real power consumed, and thus the PF is less than 1. The typical line voltage and line current waveforms are shown in Figure 1.

Ideally, every designer prefers to have a unity power factor to ensure maximum efficiency. To achieve this, designers use either passive or active power factor correction. Most designs incorporate an active power factor correction circuit.

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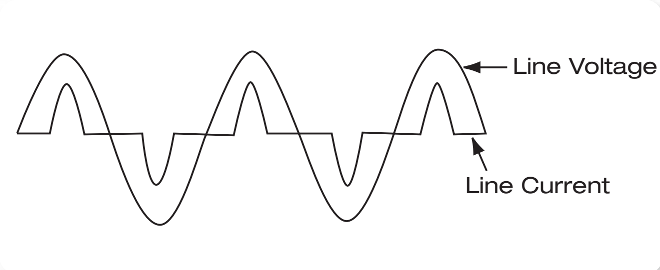
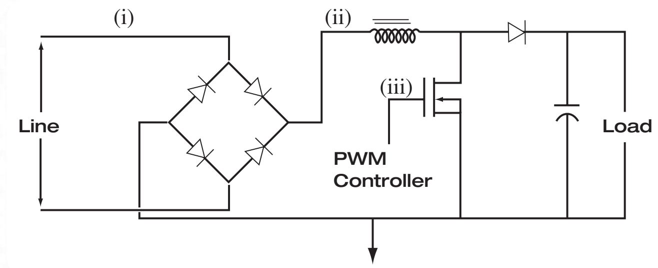


▶ **Figure 1.** *Typical line voltage and line current waveforms of a switch mode power supply.*



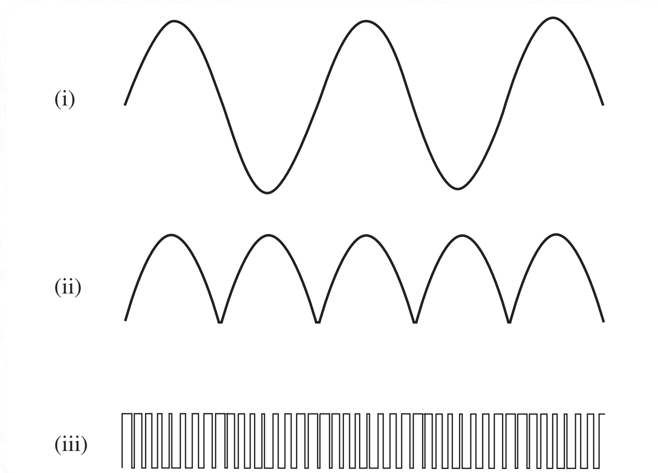
▶ **Figure 2.** *Typical boost PFC circuit. The waveforms at point i, ii, iii are shown below.*

Using a digital oscilloscope to analyze waveforms while designing a switch mode power supply with active power factor correction has historically been very cumbersome. In these circuits, a boost converter is typically put in place after an input rectifier bridge. Observe that the switching circuit runs at a much higher frequency than the mains frequency. A variable boost ratio is required to keep the output voltage constant as the input voltage varies. Therefore, the switch duty cycle must vary with the input voltage. The duty cycle is high when the input voltage is low. Conversely, the duty cycle is low when the line voltage is high. To analyze this behavior, designers view each pulse of the boost

converter in detail as it changes during each half cycle of the power line. This becomes more important as designers need to know the stress on the field effect transistor (FET) and diodes while the load and/or line voltage is changing.

Active power factor correction smooths the current flow at the front end of the rectifier. A switch mode converter regulates the pulse width or duty cycle of a transistor switch to match the line current and line voltage waveforms. The control information is embedded in the variations in transistor timing.

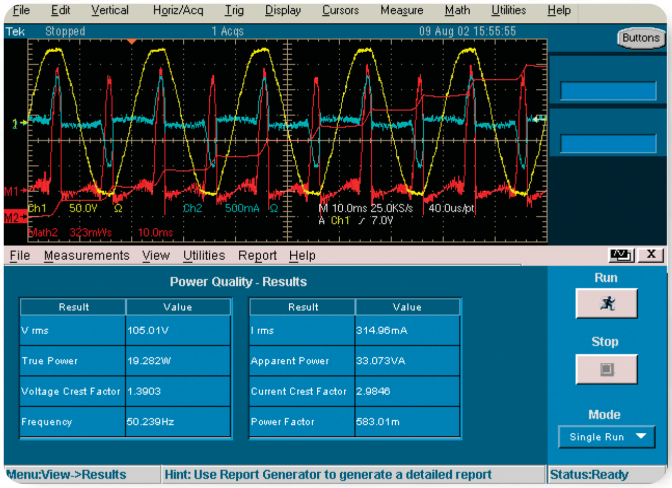
Traditionally, designers have used analog oscilloscopes to analyze and debug 50/60 Hz mains signals and fast switching signals at hundreds of kHz. Designers compiled this bit-by-bit information to determine the overall Pulse Width Modulator (PWM) signal behavior.



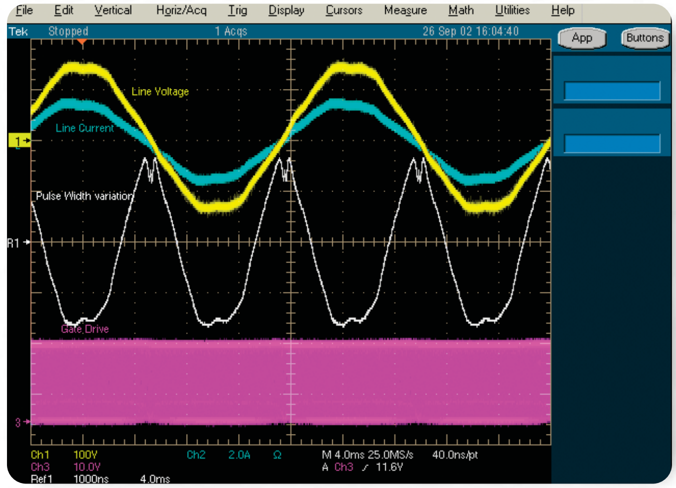
▶ **Figure 3.** *Typical waveforms at (i) are sinusoidal typically at 50 Hz or 60 Hz. Waveforms at (ii) appear at the output of rectifier and (iii) the waveform at gate drive of boost FET.*

Then, they began relying on digital storage oscilloscopes with the requisite performance to capture low-frequency signals along with fast transitioning switching signals. These signals demand:

1. High sample rate to capture embedded information on timing signals of a switching device
2. Deep record length, allowing designers to view the low frequency mains signal along with the switching signal



▶ **Figure 4.** *Power quality measurements using TDSPWR3.*



▶ **Figure 5.** *TDSPWR3 modulation analysis types.*

Even with this information, designers still struggled to get pulse or duty cycle variations in a switching signal, as that information had to be manually calculated. In addition, the user could not automatically measure power factor in a regular digital storage oscilloscope.

TDSPWR3 power measurement analysis application software makes these tasks much simpler by providing:

– Power quality measurements

– Modulation analysis capability

By running power quality measurements in TDSPWR3, designers can instantaneously make important power quality measurements, as shown in Figure 4. The alternative is to depend upon dedicated power analyzers.

Once the power factor value is determined, further debugging of the PWM signal can easily be done using TDSPWR3's modulation analysis capability.

TDSPWR3 can analyze a PWM signal using the following methods.

– Pulse width versus time plot

– Duty cycle versus time plot

– Period versus time plot

– Frequency versus time plot

With this modulation analysis feature of TDSPWR3 and the TDS5000B/7000/7000B Series oscilloscope's high sampling rate of 5 GS/sec and deep record length, two to three cycles of the mains signal along with the fast transitioning switching signal with high horizontal resolution can be comfortably captured. TDSPWR3 automatically computes pulse width variation versus time. (Figure 5 shows the line voltage, current signal and plot pulse width, versus time plot.) You can view the PWM signal's pulse width variation with time along with line voltage and line current. This provides a complete view of the PWM signal's behavior, which is required to maintain the desired PF when load and line voltage is varying. Any undesirable transitions in PWM signals can be captured instantaneously.

Conclusion

The power quality measurement and modulation analysis capabilities of TDSPWR3 significantly reduce the time it takes to design and debug tasks. When combined with the sample rate and memory depth of the TDS5000B and TDS7000/7000B Series digital phosphor oscilloscopes, switching power supplies with active power correction is easy to achieve with maximum efficiency.

TDS5000B Series DPO

The TDS5000B Series oscilloscope's fast waveform capture rate, live analog-like display, dedicated video triggers, and long record length make it the ideal solution for video design and development.

The P5205 Probe

The P5205 is a 100 MHz active differential probe capable of measuring fast rise times of signals in floating circuits.

The TCP202 DC Coupled Current Probe

The TCP202 is used for displaying and measuring current in electronic circuits. It is ideal for power supply and motor drive design and device testing.

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