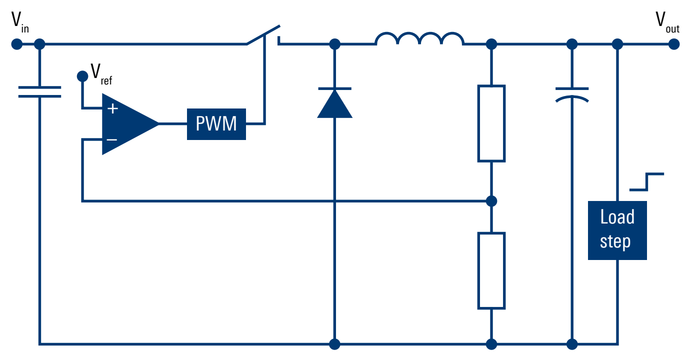
LOAD TRANSIENT RESPONSE – ENHANCING LOOP STABILITY TESTING

Validating switching converter stability is vital for any power supply design. Frequency loop and load transient responses are often used to ensure switching converter stability. Even as frequency loop response becomes more important to design validation, load transient response is still commonly used. Load transient response can also be enhanced by visualizing the positive duty cycle for pulse width modulation (PWM) signals over time. A modern oscilloscope can do this, while also helping identify unknown converter effects.

MXO 5 series oscilloscope

Fig. 1: Load transient setup of a step-down converter



Your task

Power supply designs must be validated for loop stability to ensure proper and stable operation. Today, frequency loop response is the first choice for measuring converter loop stability. Frequency loop response uses small-signal AC analysis, where a small sinusoidal signal is injected into the loop to measure gain and phase over a wide frequency range in an open loop.

Measured gain and phase values are plotted against the frequency in a Bode plot diagram to directly obtain gain margin, phase margin and crossover frequency. In load step response testing, a large current step is applied and then the voltage response needs to be measured and analyzed. Large signal measurements are performed in a closed loop, which are very different from open loop systems. Output voltage needs to be analyzed in the time domain to estimate and determine converter stability. The example in Fig. 1 uses a step-down converter to test load transient response.

Having the load step generator connected to a converter output terminal is vital when rapidly changing the load current. Since PWM signals control the power plant in control loops, measuring the positive duty cycle during the load step can enhance load transient response when visualizing unknown effects.

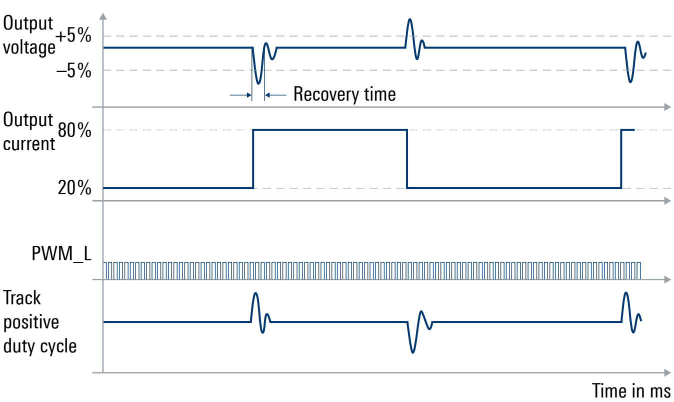
This measurement requires an instrument where the positive duty cycle can be measured with high sample rates over the complete recording period. The cycle-by-cycle measurement must be displayed as a waveform over time.

Rohde & Schwarz solution

The MXO series oscilloscopes are ideal for this challenging task, because they can measure the positive duty cycle over a long recording period even at higher PWM switching frequencies. Sufficient bandwidth, a high sampling rate and a large amount of memory are all needed. All positive duty cycles in an acquisition can be used to visualize variations over an entire acquisition in a track. The tracks for each measurement in a single cycle can be displayed over time. A typical load transient waveform included in the track waveform is illustrated in Fig. 2.

Fig. 2 shows the standard output voltage and current waveforms for three consecutive load steps. The positive duty cycles for the controller output are also displayed and used to create a track. In theory, the track waveform mirrors the output voltage waveform, since the duty cycle regulates the power plant to maintain constant output voltage.

Fig. 2: Load transient response



Application

A DC/DC switching converter in a full bridge topology with synchronous rectification showcases the track function. The isolated converter operates at a switching frequency of 100 kHz and converts 48 V input voltage to 12 V output voltage. The output current is set to 8 A maximum and the output load step is generated with an electronic load.

Device setup

Before applying the load steps at the converter output, several tasks need to be completed beforehand to visualize the positive duty cycle as a track waveform:

- A channel setup with a probe selection
- Definition of a trigger to catch load step events at the controller output
- Activation of the positive duty cycle measurement function and definition of reference voltage percentage levels (e.g. 20%, 50%, 80%)
- A sufficient sampling rate ≥100 Msample/s must be defined to accurately measure a PWM signal with sharp edges
- A recording length sufficient to catch a whole sequence (at least one current step from low-to-high and another form high-to-low)
- Activation of track function within the measurement sub menu and optimization of vertical scaling

Measuring the transient load

After completing the setup, configure the electronic load to apply a load step between a low current value (20% of maximum load) and a high current value (80% of maximum load). As soon as the trigger detects a valid trigger condition, the waveforms will appear on the screen (see Fig. 3). The top window shows the acquisition of two load steps in either direction. The output voltage is measured on channel 1 and the output current is measured on channel 2. The PWM control signal (channel 3) and the track waveform for the positive duty cycle are also displayed.

Fig. 3: Load transient setup of a step-down converter

The zoom window shows that output voltage drops only for approximately 300 µs before reentering steady state operations. The deviation between the 20% and 80% loads in a steady state is only 2.4 mV as measured by the cursor function. The track waveform shows a different level (26% instead of 24%) after the converter enters a steady state. The deviation reveals an effect, which does not meet the expectations described in Fig. 2. According to the definition and theory, the duty cycle should be independent of the load current.

Reviewing control theory shows the 2% deviation comes from higher conduction losses caused by higher output current. The higher losses are mainly generated in the transformer and output rectifier. The additional losses need to be equalized by increasing the positive duty cycle and the track function allows this complex measurement task to be performed.

Summary

The MXO series oscilloscopes are ideal for verifying load transients for any power converters with PWM control, where deeper analysis is required to reveal system behavior details. Outstanding capabilities such as large memory storage and the track functions help users find and understand details of the converter operation.

See also

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