

Control Loop Analysis

Measuring Feedback Loop Response In Power Systems

TECHNICAL BRIEF

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Summary

Every power supply has a feed-back loop that monitors the output voltage or current and keeps the output within acceptable limits. Control Loop Analysis allows close study of this feedback loop.

Feedback Loop Analysis of Power Supply Control Loops

Every power supply has a feed-back loop that monitors the output voltage or current and keeps the device's output level constant despite changes in the load. This means that the power device conducts longer if the output voltage is too low. Most switched mode power supplies use pulse width (PWM) or frequency modulation (FM) in their control loops. Analysis of the loop dynamics requires the ability to demodulate these signals. Power Analysis software, available in Teledyne LeCroy oscilloscopes, includes easy-to-use modulation analysis capabilities.

Modulation analysis functions produce a time domain display that represents the modulated parameter in a time vs. time graphical plot. They are convenient tools for intuitively viewing the time domain response of the entire control loop, including any time constants added by the pulse width modulator. Modulation analysis can be performed for duty cycle, period, frequency, or pulse width.

An example is shown in Figure 1, where the response to a step load change of a PWM-based control loop is shown.



Figure 1: Measuring the step load response in a switched mode power supply using Teledyne LeCroy's Power Analysis option software

The upper trace, C1, is the gate-to-source drive signal to a MOSFET. This PWM signal is demodulated using a track function of width shown in the lower Control Loop trace. The Control Loop function displays the duty cycle of the gate drive signal as a function of time, which is time synchronous with the source waveform. The user can use the zoom features and see the width of each individual cycle and the corresponding value of the track plot so each point in the track function can be related to the source waveform. It is easy to see that the control loop initially overshoots and then recovers in about 800 μ s. The time scale of this acquisition is 200 μ s per division and the vertical scaling of the track of width is 2% per division. The pulse duty cycle before the load change is approximately 4.8%. After the change, it increases to 15% and then quickly recovers to 9%.

Note that the use of a moderate acquisition memory length of 200 kilo Samples allows the measured waveforms to be digitized at 100 MS/s for a time resolution of 10 ns. This particular oscilloscope offers a maximum of 250MS memory length. Since the switching frequency of this supply is only 68 kHz, the 100 MS/s sample rate is more than adequate to provide ample time resolution in the measurement.

A related study is shown in Figure 2. In this example, Power Analysis software running on an HDO 6000 oscilloscope acquires a 20 ms record including every gate drive pulse from the time the power supply is turned on until it reaches steady state.



Figure 2: A control loop study showing the startup of the power supply

The modulation analysis display shows the pulse width of every cycle of the gate drive signal as it occurs. The soft start circuit's performance is readily observed. The minimum and maximum parameters read the range of pulse width variations as 220 ns to 5.08 μ s.

The Power Analysis option simplifies power analysis by automating the setup of even these relatively complex functions. Modulation analysis can be used to characterize power supply stability under load changes, line changes, soft-starts, dropouts, hot swap, and short circuits. It allows us to see, on a cycle-by-cycle basis, the behavior of the control loop.