

Measuring Phase Margin

Measure The Phase Margin Of Power Supply Control Loops

Phase margin is a critical figure of merit which serves to indicate the stability of a closed loop control system. It is one of the most common design verification measurements made in power systems.

Phase margin is the phase difference between the input and output of an open circuit control loop at a frequency where the loop has unity gain. While this measurement characterizes the open loop characteristics of the feedback control loop, it is most often measured in a closed loop configuration. The block diagram in figure 1 shows a common technique for measuring open loop characteristics, such as phase and gain margin, while maintaining a closed loop configuration. A small spreading resistor, 20 Ω in this example, is inserted into the control loop at a point where it will not disturb the normal operation of the circuit. A small sinusoidal signal is injected via a transformer and as the frequency is varied the gain and phase difference around the loop can be determined by measuring the voltages and phase difference using an oscilloscope or frequency response analyzer. The loop gain is the ratio of the loop output measured on channel 2 divided by the loop input measured on channel 1. The phase difference is also measured between the loop input and output directly. Figure 2 shows a typical measurement of the loop phase margin. The frequency of the sine wave generator is varied until the input and output waveforms are equal in ampli-

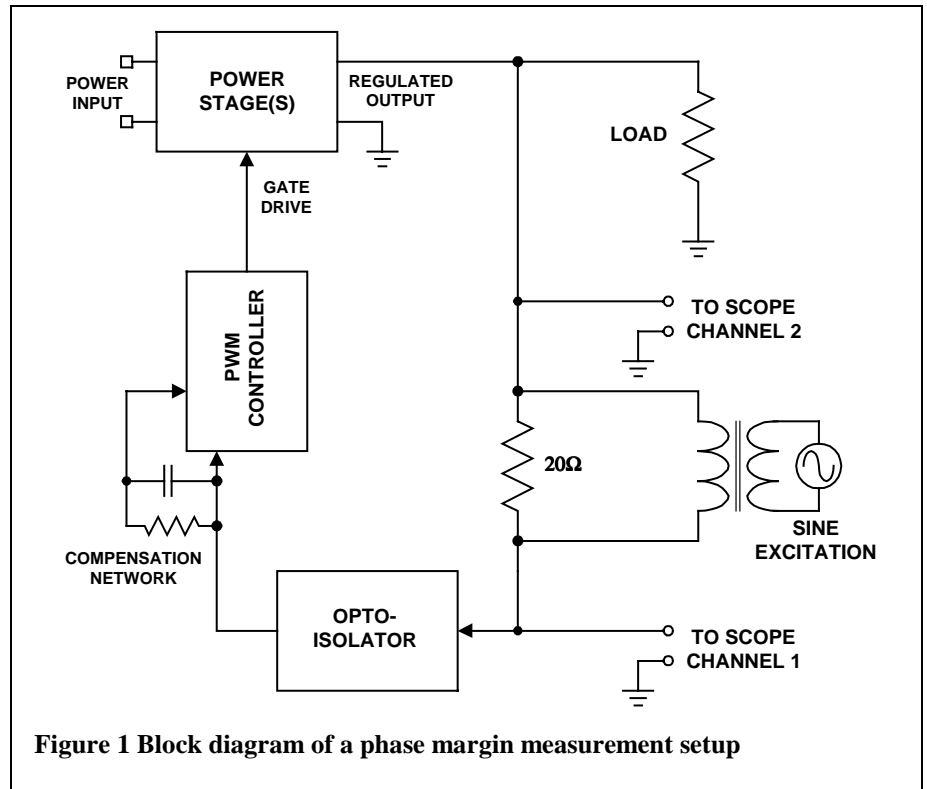


Figure 1 Block diagram of a phase margin measurement setup

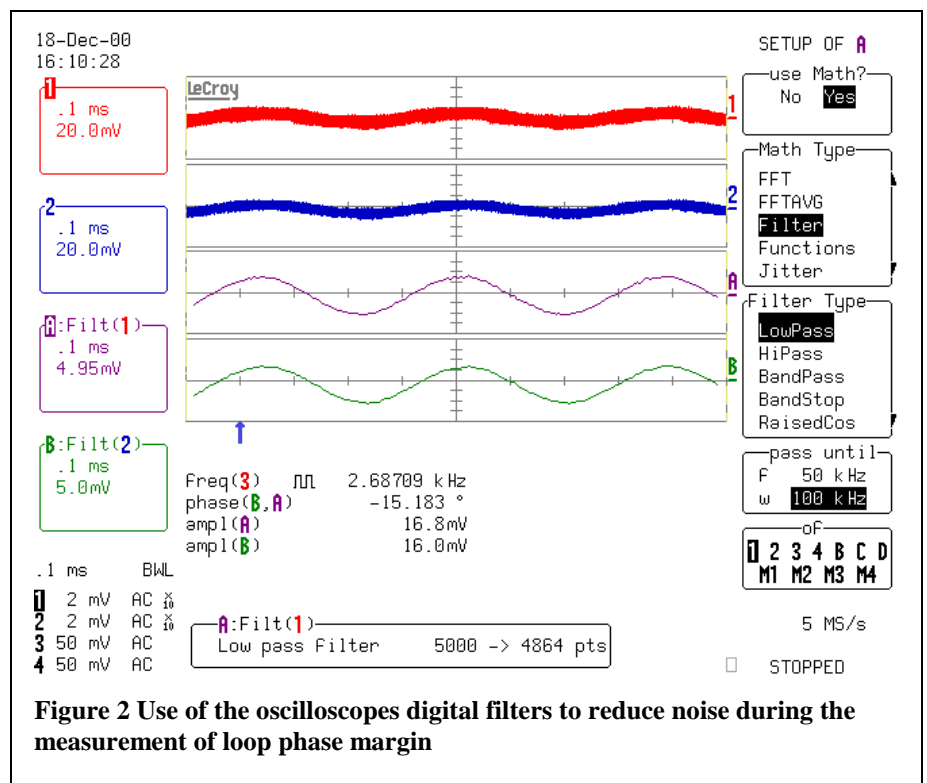


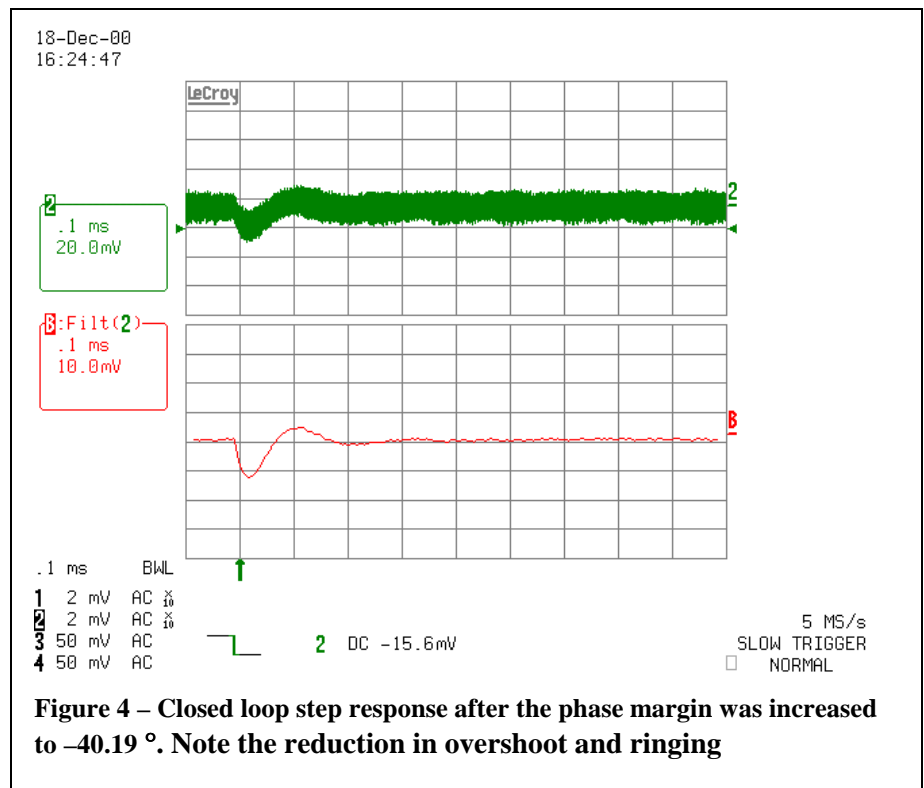
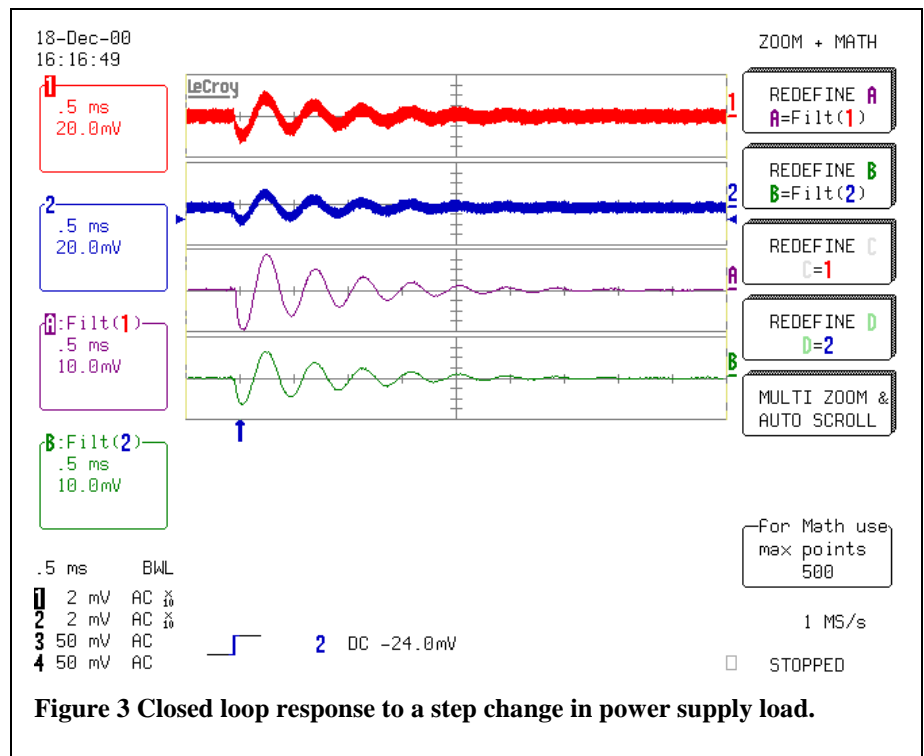
Figure 2 Use of the oscilloscopes digital filters to reduce noise during the measurement of loop phase margin

tude (unity gain). The phase difference at this frequency is the loop's phase margin. Note that the greatest difficulty encountered with this measurement is the accurate determination of the small voltages encountered in the presence of the switching noise of the power supply. The effect of the noise can be reduced significantly by averaging synchronously with the sine wave excitation or by filtering the signal. In this example, LeCroy's digital filter package (DFP) option is used to low pass filter the signals before measurement. The switching frequency of this supply, 400 kHz, is almost completely eliminated by applying a 50 kHz low pass filter. The breakpoint of the low pass filter is still high enough so as not to add any additional phase shift to the measurement.

The sine amplitudes and phase are read directly using the oscilloscope's amplitude and phase measurement parameters. Note also that the shape of the input and output waveforms is a good indication that the loop is not being overdriven by the sine excitation. Overdrive would show as non sinusoidal waveshape.

The measured phase margin, -15.18° , is critically low. This was further verified by looking at the supplies response to a step change in the load. A 100% change in load current resulted in a highly under damped response shown in figure 3.

The phase margin was increased to -40.19° by adjusting the compensation network on the PWM controller. This provided much greater stability in the system and a more controlled transient response without ringing as shown in figure 4.



Note that all these measurements were performed using a LeCroy Waverunner series oscilloscope equipped with the digital filter and power measurement options.

Many thanks to Bob Buono of Buono Consulting (bbengg@aol.com) for refining this technique and for his help in setting up and making these measurements.