Use op-amp injection for Bode analysis

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Bode analysis is an excellent way to measure small-signal stability and loop response in power-supply designs. Bode analysis monitors gain and phase of a control loop. It performs this monitoring by breaking the feedback loop and injecting a signal into the feedback node and then comparing the injected signal with the output signal of the control loop. The method requires a network analyzer to sweep the frequency and compare the injected signal with the output signal. The most common method of injection is the use of transformer. **Figure 1** demonstrates how a transformer injects a signal into the feedback network. A 50Ω resistor affords impedance matching to the network-analyzer source. This method allows the dc loop to maintain regulation and allows the network analyzer to insert an ac signal on the dc voltage. The network analyzer then sweeps the source while monitoring A (voltage channel) and R (reference channel) for an A/R-ratio measurement. Although this method is

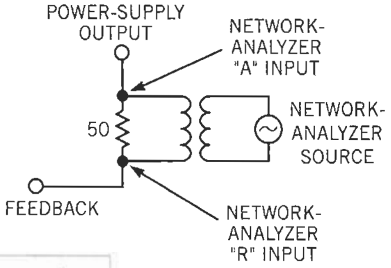

Figure 1

Bode analysis using transformer injection yields gain and phase information in a control loop.

the most common for measuring the gain and phase of a power supply, it has significant limitations. First, to measure low-frequency gain and phase, the transformer needs high inductance. Frequencies lower than 100 Hz, therefore, require a large and expensive transformer.

Also, the transformer must be able to inject high frequencies. Transformers with these wide frequency ranges generally are custom-made and usually cost several hundred dollars. By using an op amp, you can avoid the cost and frequency limitations of an injection transformer. **Figure 2** demonstrates the use of an op amp in a summing-amplifier configuration for signal injection. R_1 and R_2 reduce the dc voltage from the output to the noninverting input by half. The network analyzer is generally a 50Ω source. R_1 and R_2 also divide the ac signal from the network analyzer by half. These two signals "sum" together at half their original input. The output then gains up by a factor of two by R_3 and R_4 and goes to the feedback output. (The 50Ω resistor balances the network analyzer's source impedance.) This action essentially breaks the loop and injects the ac signal on top of the dc output voltage and sends it to the feedback terminal. By monitoring the feedback terminal (R) and output terminal (A), the analyzer measures gain and phase. This method has no minimum frequency. Make sure that the bandwidth of the op amp is much greater than the expected bandwidth of the power supply's control loop. An op amp with at least 100-MHz bandwidth is more than adequate for most linear and switching power supplies.□

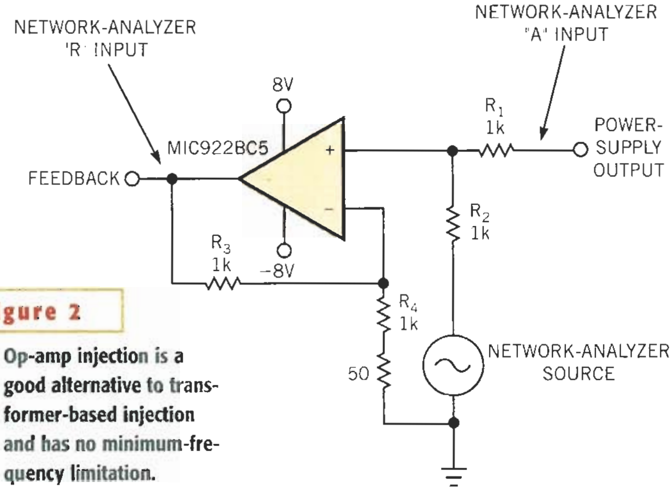

Figure 2

Op-amp injection is a good alternative to transformer-based injection and has no minimum-frequency limitation.