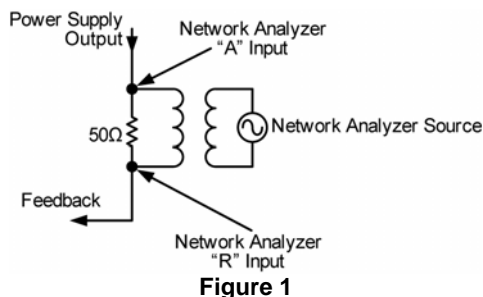


### General Description

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. This is done by breaking the feedback loop and injecting a signal into the feedback node and comparing the injected signal to the output signal of the control loop. This will require a network analyzer to sweep the frequency and compare the injected signal to the output signal. The most common method of injection is the use of transformer. Figure 1 demonstrates how a transformer is used to inject a signal into the feedback network.



A 50 ohm resistor allows impedance matching from the network analyzer source. This method allows the DC loop to maintain regulation and allow the network analyzer to insert an AC signal on top of the DC voltage. The network analyzer will then sweep the source while monitoring A and R for an A/R measurement. While this is the most common method for measuring the gain and phase of a power supply, it does have significant limitations. First, to

measure low frequency gain and phase, the transformer needs to be high in inductance. This makes frequencies <100Hz require an extremely large transformer and expensive transformer. Conversely, it must be able to inject high frequencies. Transformers with these wide frequency ranges generally need to be custom made and are extremely expensive (usually in the tune of several hundred dollars!). By using an op-amp, cost and frequency limitations used by an injection transformer are completely eliminated. Figure 2 demonstrates using an op-amp in a summing amplifier configuration for signal injection. R1 and R2 reduce the DC voltage from the output to the non-inverting input by half. The network analyzer is generally a 50 Ohm source. R1 and R2 also divide the AC signal sourced by the network analyzer by half. These two signals are "summed" together at half of their original input. The output is then gained up by 2 by R3 and R4 (the 50 Ohm is to balance the network analyzer's source impedance) and sent to the feedback signal. This essentially breaks the loop and injects the AC signal on top of the DC output voltage and sends it to the feedback. By monitoring the feedback "R" and output "A", gain and phase are measured. This method has no minimum frequency. Ensure that the bandwidth of the op-amp being used is much greater than the expected bandwidth of the power supplies control loop. An op-amp with >100MHz bandwidth is more than sufficient for most power supplies (which includes both linear and switching) and are more common and significantly cheaper than the injection transformers previously mentioned.

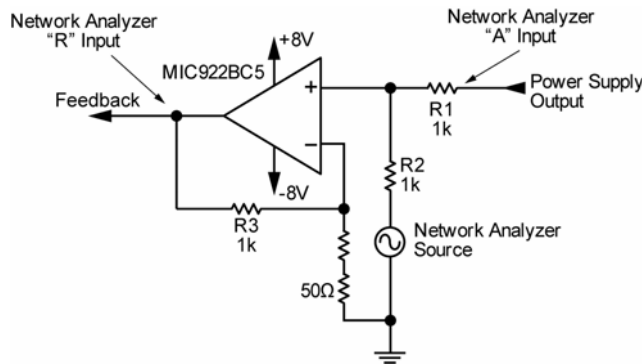


Figure 2

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