Article Series on 3PEAK Power Frequency Response: Is Your Power Frequency Response Testing Method Correct?

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Power frequency response testing is typically performed using a network analyzer or a frequency response analyzer. The test results are usually presented in the form of a logarithmic frequency response curve, known as a Bode plot, as shown in Figure 1-1 below.

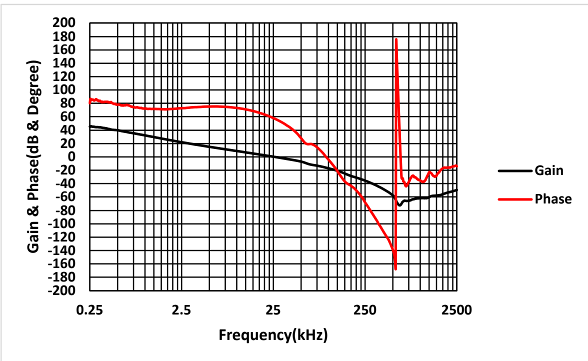

Figure 1-1

As shown in Figure 1-1 , the Bode plot consists of two curves known as the gain curve and the phase curve (or amplitude-frequency response curve and phase-frequency response curve). These curves reflect the response of the power supply to different frequencies of sinusoidal disturbances; hence they are referred to as frequency response. Power engineers may often wonder why their power supply's Bode plot test results do not match their expectations, while the load step response of the power supply tested with an oscilloscope is as expected. To answer this question, we need to understand the basic principles of power frequency response testing. Figure 1-2 showcases the scene of 3PEAK's laboratory testing of the Bode plot for their switch-mode power supply product, TPP60508. TPP60508 is an asynchronous buck converter product currently being mass-produced by 3PEAK. It operates in peak current control mode, supports a wide input voltage range from 4.5 V to 60 V, and has a current rating of 5 A.

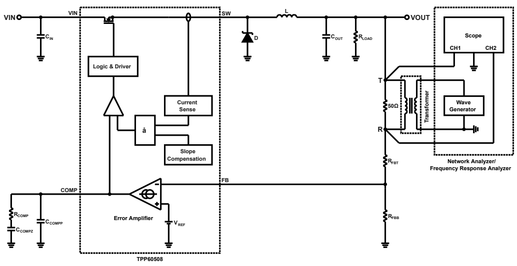

Figure 1-2

As shown in Figure 1-2 , the basic principle of power Bode plot testing is to disconnect the loop from the output and connect a 50-Ω resistor. A network analyzer or frequency response analyzer with a built-in function generator is used to generate sinusoidal disturbances at different frequencies. After passing through the transformer for electrical isolation, the disturbances are injected into the 50-Ω resistor. The response signal at the 50-Ω resistor is then fed back to the network analyzer or frequency response analyzer's built-in oscilloscope for amplitude and phase analysis. Finally, the test results (i.e., the Bode plot) are presented to the user.

We know that the stability analysis of a system is based on a certain steady-state operating point. Therefore, during Bode plot testing, the sinusoidal disturbances injected into the power supply system from the 50-Ω resistor should not disrupt its linear response operating state. This means that the error amplifier and pulse width modulator in Figure 1-2 should operate in their linear regions.

To determine if the disturbances injected into the loop from the 50-Ω resistor are correct in practical testing, a simple method is to observe the current waveform flowing through the inductor using an oscilloscope throughout the entire Bode plot test process. The envelope waveform shape and frequency of the peak value of the inductor current should match the sinusoidal disturbances injected into the 50-Ω resistor. Only the amplitude and phase should differ, which are the aspects of frequency response that power engineers are concerned about. If the envelope signal of the inductor current does not exhibit the characteristics described above and shows distortion, it can be determined that the disturbances injected into the 50-Ω resistor are inappropriate, and the resulting Bode plot will be incorrect.

Looking at the Bode plot shown in Figure 1-1 , the power supply system has high gain at low frequencies. Therefore, the amplitude of the sinusoidal disturbances injected into the 50-Ω resistor can be appropriately amplified to improve the accuracy of the test. As the frequency increases, the gain of the power supply system gradually decreases. Therefore, the amplitude of the sinusoidal disturbances injected into the 50-Ω resistor needs to be appropriately reduced to ensure that the power supply system operates in a linear state. This is commonly referred to as the "segmented injection method" often mentioned in power Bode plot testing.

Based on the above analysis, I believe you can quickly make judgments about the Bode plot testing process corresponding to Figure 1-3 and Figure 1-4.

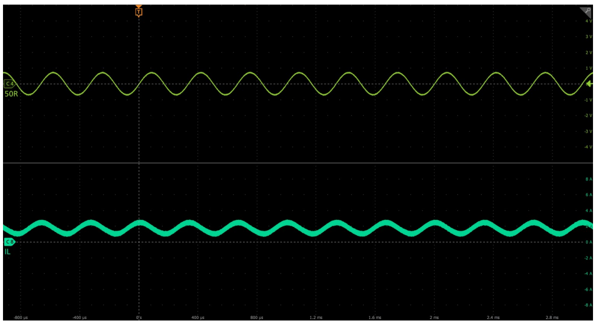

Figure 1-3

Figure 1-4

The signal injection in Figure 1-3 is appropriate, while the signal injection in Figure 1-4 is too large, resulting in system instability.

The basic principle of power Bode plot testing, as illustrated in Figure 1-2 can be succinctly explained using the following equation:

$G = \frac{V_T}{V_R}$, where

$V_{50\Omega} = V_T - V_R$

Finally, it should be noted that:

1. The sinusoidal disturbance generated by the function generator in Figure 1-2 needs to pass through a transformer for electrical isolation before being injected into the 50-Ω resistor. This is to prevent a short circuit because the function generator's output and the oscilloscope's input are typically referenced to the same ground. Without electrical isolation using a transformer, it can lead to incorrect Bode plot test results and may damage the power supply under test or the testing equipment.
2. Can the 50-Ω resistor in Figure 1-2 be replaced with a different value? The answer is yes. As long as the introduction of the resistor does not affect the static operating point of the power supply system and can handle the power dissipation caused by the sinusoidal disturbance injected across it, other values can be used. Generally, selecting a nominal value within the range of 10-50Ω is common, with 50 Ω being the most frequently used.
3. How should the amplitude of the sinusoidal disturbance injected across the 50-Ω resistor be selected in practical operation? 3PEAK recommends reducing the amplitude as much as possible while ensuring test accuracy to improve the stability of the power supply system's static operating point. In other words, during power Bode plot testing, the ripple voltage of the output should be much smaller than the steady-state output voltage.
4. In Figure 1-2, a resistor is used as the load at the power supply output for illustrative purposes. In practical power

engineering, an electronic load is often used. In such cases, it is important to set the electronic load to constant current mode and avoid using dynamic load mode to obtain accurate test results. Particularly, when testing the Bode plot of a power supply system on a complete board, it is crucial to ensure that the load after the power supply is a stable and constant static load.

The Bode plot testing principle showcased in Figure 1-2 highlights how power engineers can perform power supply frequency response testing and evaluation using only an oscilloscope, function generator, and transformer when they do not have access to a network analyzer or frequency response analyzer.