Reprinted with permission from the December 2005 *issue of ...* ***US-Tech***

The Network Analyzer: Simplifying Frequency Response Measurements

By John Iannuzzi, VP Design and Consulting, Core Technology Group, Inc., Willow Grove, PA

In an amplifier or filter system, a frequency response plot gives a complete picture of the system's gain flatness, linearity, phase and bandwidth. Control system designers use frequency response analysis for optimizing the speed and precision of feedback control systems. Frequency response analysis is used to determine points of resonance in mechanical systems, as well as the presence of cracks or fatigue in materials. Power systems designers study the parasitic effects of components such as capacitors and inductors to optimize efficiency. In electro-chemical systems like batteries and fuel cells, frequency response analysis is used to measure impedance as a function of frequency. Impedance measurements are also used to detect early signs of corrosion in materials. Additional applications include acoustics, ultrasonics, and oil exploration. Only a frequency response/network analyzer can completely characterize a system's performance over the required frequency range.

A network analyzer measures the frequency response of a system by injecting a known signal, and then measuring the system's response to that signal. A measurement is taken at each specified frequency point over the required bandwidth and it then plots a curve based on those measurements.

A network analyzer is comprised of a precision sine wave signal source and at least two input channels, A and B. Channel (A) is used as the reference signal and is connected to the input of the system to be measured. The remaining channel (B) is connected to the output of the system. The user chooses a frequency band over which the test is to be performed, and as the test progresses, the ratio of the output to the input (B/A) is measured at each frequency. Since the receivers are synchronized to the signal source, the analyzer will detect and measure the system's response to the test signal. The narrow bandwidth of the receivers in the Circuit Sleuth allows the detection of very small signals (into the microvolt region) even in the presence of noise. The Circuit Sleuth SA Series frequency response analyzer from Core Technology , is a newly patented, portable, powerful and low cost frequency response analyzer .

Spectrum vs. Network Analysis

A network analyzer stimulates a system with a test signal and then measures the response of the system to the stimulus. A spectrum analyzer, on the other hand, is essentially a wide bandwidth receiver designed to detect all frequencies that exist over a bandwidth specified by the user. It does not, however, stimulate the system with a test signal to make the measurement.

Why not just use an oscilloscope and a signal generator? Oscilloscopes and signal generators are workhorses of the test and measurement industry, and provide a wealth of information about the operation of a circuit or system in the time domain. A network analyzer is a frequency domain device, which measures precise magnitude, phase, transfer functions and low-level signals mixed with noise, which are difficult, if not impossible, to measure with an oscilloscope.

There are a number of industries and professions where a network analyzer is especially useful. The Circuit Sleuth can be used in a number of areas that include:

- Electro-chemical - corrosion, chemical impedance, battery/fuel cell.
- Electrical and Mechanical Engineering - switching power supplies, amplifiers, filters, impedance, mechanical resonance and vibration analysis.
- Material Science/Nano Technologies - non-destructive testing, resonance, vibration analysis.
- Robotics and Feedback Control Systems - stability analysis, electro-mechanical resonance.
- LASERS and Optics - LASER power stability, optical communications, modulation, optical receivers.
- Ultrasonics - fluid composition, crack detection.

Vibration Analyses

Used for vibration analysis, a network analyzer can be used to detect the points of resonance in a mechanical system under vibration.

A vibration table provides the mechanical force needed to shake the device under test (DUT). The DUT is rigidly secured to the vibration table and a system of accelerometers is used to measure the magnitude and frequency of the vibration. The Circuit Sleuth SA-Ol, with its bandwidth of 10Hz to lMHz, is especially suited for this type of measurement. The output signal from the SA-Ol is used to provide the sine wave reference signal for the power amplifier that drives the vibration table. Channel A is the reference accelerometer attached to the surface of the vibration table and Channel B is the accelerometer that is attached to the DUT. The network analyzer is programmed to sweep over the specified frequency range. As the test progresses, a measurement is taken and plotted at each frequency point. If there is a tendency for the DUT to resonate at a particular frequency, a peak will show up on the plot.

Electro-chemical impedance

The SA-l0, with its bandwidth of 1Hz to 10MHz, can be used to measure the series impedance of a battery or fuel cell. As a battery ages, its internal impedance increases to a point where the battery is no longer useful. Techniques can be used to continuously monitor the battery and predict how much life remains. It can be a valuable aid in scheduling the right time to replace a battery system before it fails unexpectedly. The SA-l0 injects a swept frequency signal into the battery , with channel A measuring current and channel B measuring voltage, and then measures the voltage across the battery and the current flowing through it. The voltage and current measured are used to calculate and plot the impedance at each frequency point. In a production environment, the impedance curve can be used to ensure that the final product is within specifications. The electro-chemical impedance of a solution can also be measured with a network analyzer. This can be accomplished by connecting channels A and B to two electrodes submerged in the solution, and the impedance measured as described above.

Electro-mechanical control systems

The SA-l0 can also be used to analyze feedback control systems ranging from switching power supplies to robotic positioning systems. In robotic systems, such as those used in manufacturing, packaging, inspection and assembly, the controlled parameter could be the position of a robot arm. The robot arm must be quickly and precisely located (controlled) in order to perform, for example, a welding operation. If this control system is not optimally designed, throughput and product quality will suffer. In many cases, the mechanical structure of the system is the limiting factor and may experience resonance at certain frequencies. This type of resonance may limit the speed of the robot arm system. The control system designer can use a network analyzer to measure the open loop response of the entire electromechanical control system, and reveal frequencies of resonance and instability. This information is then used to optimize the system for speed, stability and precision.

Switching power supply designers use a similar technique to measure open loop response, to determine the stability of the power supply. In this case, the controlled parameter is the output voltage. The network analyzer output provides the stimulus signal for the loop. The signal is injected into the loop using an isolation transformer or an op amp summing circuit. In some cases, a DC offset is present inside the control loop. This does not affect the SA Series analyzer because AC coupling removes any DC offset concerns. Channel A is connected to the relative input to the loop and channel B is connected to the relative output of the loop. At low frequencies, the gain of the loop will be relatively high. As the frequency increases, the relative gain of the loop will decrease indicating that the loop is losing its ability to keep up with the disturbance. Control system designers use the analyzer's simultaneous display of magnitude and phase to determine system stability, and places where modifications are necessary to optimize the system.

The advantage of using a network analyzer for this measurement is that the loop can be measured with the feedback path unbroken and under real-world conditions.

Parasitic effects in inductors, transformers and capacitors

In many cases, switching power supply designers must design custom magnetic). components such as inductors and transformers in order to get high efficiency or to meet strict performance requirements. Additionally, the effective series resistance (ESR) of capacitors must be characterized to insure stable feedback control. In inductors, parasitic effects include DC resistance, resonance and inter-winding capacitance. Transformers are measured to characterize magnetizing inductance, leakage inductance, turns ratio and resonance. These parasitic effects are frequency dependent, and show up at higher frequencies. Typically, parasitic effects can be seen in the 5MHz-20Mhz region. The 40Mhz bandwidth of the Circuit Sleuth allows characterizing components and insuring that parasitic effects do not adversely affect the design.

Probes

Probes provide a means to get the signal to the instrument, and keep in mind that probes are actually part of the test setup. Some network analyzers have low input impedances (typically 50 ohms) that require buffer amplifiers to isolate the test signal from the input stage. The input impedance of the SA series analyzers (1megohm/20pf) eliminates the need for buffer amplifiers and allows the use of standard lx or l0x probes to perform measurements.

If required, passive probes and injection transformers are also available as accessories.

For more information, contact:
Core Technology Group, Inc.
2425 Maryland Road, Willow Grove, PA 19090.
Phone: 215-830-9826 ext. 21
E- mail: sales@coretechgroup.com
Web: www.coretechgroup.com