FREQUENCY RESPONSE ANALYSIS

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INTRODUCTION

Frequency response is the quantitative measure of the output spectrum of a system or device in response to a stimulus, and is used to characterise the dynamics of the system. It is a measure of magnitude and phase of the output as a function of frequency, in comparison to the input. In simplest terms, if a sine wave is injected into a system at a given frequency, a linear system will respond at that same frequency with a certain magnitude and a certain phase angle relative to the input. Also for a linear system, doubling the amplitude of the input will double the amplitude of the output. In addition, if the system is time-invariant, then the frequency response also will not vary with time.

Two applications of frequency response analysis are related but have different objectives. For an audio system, the objective may be to reproduce the input signal with no distortion. That would require a uniform (flat) magnitude of response up to the bandwidth limitation of the system, with the signal delayed by precisely the same amount of time at all frequencies. That amount of time could be seconds, or weeks or months in the case of recorded media. In contrast, for a feedback apparatus used to control a dynamic system, the objective is to give the closed-loop system improved response as compared to the uncompensated system. The feedback generally needs to respond to system dynamics within a very small number of cycles of oscillation (usually less than one full cycle), and with a definite phase angle relative to the commanded control input. For feedback of sufficient amplification, getting the phase angle wrong can lead to instability for an open-loop stable system, or failure to stabilize a system that is open-loop unstable. Digital filters may be used for both audio systems and feedback control systems, but since the objectives are different, generally the phase characteristics of the filters will be significantly different for the two applications.

The frequency response of a device or a circuit describes its operation over a specified range of signal frequencies by showing how its gain, or the amount of signal it lets through changes with frequency.

Bode plots are graphical representations of the circuits frequency response characteristics and as such can be used in solving design problems. Generally, the circuits gain magnitude and phase functions are shown on separate graphs using logarithmic frequency scale along the x-axis.

Bandwidth is the range of frequencies that a circuit operates at in between its upper and lower cut-off frequency points. These cut-off or corner frequency points indicate the frequencies at which the power associated with the output falls to half its maximum value. These half power points corresponds to a fall in gain of 3dB (0.7071) relative to its maximum dB value.

Most amplifiers and filters have a flat frequency response characteristic in which the bandwidth or passband section of the circuit is flat and constant over a wide range of frequencies. Resonant circuits are designed to pass a range of frequencies and block others. They are constructed using resistors, inductors, and capacitors whose reactances vary with the frequency, their frequency response curves can look like a sharp rise or point as their bandwidth is affected by resonance which depends on the Q of the circuit, as a higher Q provides a narrower bandwidth.

Frequency Response of an electric or electronics circuit allows us to see exactly how the output gain (known as the *magnitude response*) and the phase (known as the *phase response*) changes at a particular single frequency, or over a whole range of different frequencies from 0Hz, (d.c.) to many thousands of mega-hertz, (MHz) depending upon the design characteristics of the circuit.

Generally, the frequency response analysis of a circuit or system is shown by plotting its gain, that is the size of its output signal to its input signal, Output/Input against a frequency scale over which the circuit or system is expected to operate. Then by knowing the circuits gain, (or loss) at each frequency point helps us to understand how well (or badly) the circuit can distinguish between signals of different frequencies.

The frequency response of a given frequency dependent circuit can be displayed as a graphical sketch of magnitude (gain) against frequency (f). The horizontal frequency axis is usually plotted on a logarithmic scale while the vertical axis representing the voltage output or gain, is usually drawn as a linear scale in decimal divisions. Since a systems gain can be both positive or negative, the y-axis can therefore have both positive and negative values.

NONLINEAR FREQUENCY RESPONSE ANALYSIS

Nonlinear frequency response of a multistage clutch damper system in the framework of the harmonic balance method. For the numerical analysis, a multistage clutch damper with multiple nonlinearities is modeled as a single degree-of-freedom torsional system subjected to sinusoidal excitations. The nonlinearities include piecewise-linear stiffness, hysteresis, and preload all with asymmetric transition angles. Then, the nonlinear frequency response of the system is numerically obtained by applying the Newton–Raphson method to a system equation formulated by using the harmonic balance method. The resulting nonlinear frequency response is then compared with that obtained by direct numerical simulation of the system in the time domain.

FREQUENCY RESPONSE CURVE

To get the most enjoyment from your stereo speakers, your amplifier and your microphone, they must accurately reproduce sound frequency. The manufacturer of your stereo components will often use a frequency response curve to determine bandwidth and the upper and lower frequency limits of specific components to assure the quality of sound reproduction based on the visual results of a system's response to frequency input.

The frequency response curve is a visual representation of the quality of amplitude over frequency generated by specific components. The graph depicting such curve will have a vertical axis and a horizontal axis. The vertical axis is usually labeled as the level of sound, also called amplitude, in decibels (dB), while the horizontal axis is labeled as the frequency, the vibration that is captured by your ear and is measured in hertz (Hz).
Bandwidth is the boundary or band marking the highest frequency signal output to the lowest demonstrated by a particular component. The *fo* in a frequency response curve is the peak of the curve, where the actual bandwidth is noted and compared to the designed bandwidth of the component. Should the actual bandwidth not measure up to the design, the frequency response of the component can be improved using a digital or analog filter.
A hi-fidelity amplifier usually has a frequency response of 20 Hz to 20,000 Hz within approximately one dB. The human ear can normally detect audio frequencies encompassed by that specific range with a dB being the loudness or

amplitudeThe specific numbers indicated by the frequency response curve are not as important as the variation of response from frequency to frequency (e.g. high frequency to low frequency and vice versa).This response indicates to the tester that the component will accept an input signal and generate a response. The frequency response curve will not, however, define the actual audio quality.

FREQUENCY RESPONSE FUNCTION

This basic theory will then be used to calculate the frequency response function between two points on a structure using an accelerometer to measure the response and a force gauge hammer to measure the excitation. Fundamentally a frequency response function is a mathematical representation of the relationship between the input and the output of a system.

So for example the frequency response function between two points on a structure. It would be possible to attach an accelerometer at a particular point and excite the structure at another point with a force gauge instrumented hammer. Then by measuring the excitation force and the response acceleration the resulting frequency response function would describe as a function of frequency the relationship between those two points on the structure.
The basic formula for a frequency response function is
$H(f)=Y(f)X(f)$
Where $H(f)$is the frequency response function.
And $Y(f)$is the output of the system in the frequency domain.
And where $X(f)$is the input to the system in the frequency domain.

APPLICATION OF FRA

The Frequency Response Analysis (FRA) test is recognized in the electricity industry as one of the best techniques available for detecting mechanical changes inside a power transformer. FRA measures the complex frequency response of a transformer that defines the dynamic characteristics as a RLC network. The frequency-dependent behavior of complex distributive RLC networks helps to describe the internal components of a transformer.

The FRA test was developed at Kinectrics Inc. using a network analyzer in 1978, when the company was known as the Research Division of Ontario Hydro. FRA testing has been used more extensively in the last 10 years by taking advantage of digital automatic measurement software and hardware.

Application of FRA:

- Assurance of proper shipping, especially overseas transportation
- Creating a baseline for any future comparison
- Mechanical integrity and health of active-parts
- Detecting mechanical faults

Kinectrics offers a full range of routine, type, and advanced tests for power transformers and has over 30 years experience in providing FRA testing services. Our capabilities include: performing FRA testing analysis, interpreting test results, and assisting utilities with decision making based on the results.

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