Errata

**Document Title:** Impedance Characterization of Resonators Using the 4194A Impedance / Gain-Phase Analyzer (AN 339-1)

**Part Number:** 5950-2882

**Revision Date:** October 1985

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**HP References in this Application Note**

This application note may contain references to HP or Hewlett-Packard. Please note that Hewlett-Packard's former test and measurement, semiconductor products and chemical analysis businesses are now part of Agilent Technologies. We have made no changes to this application note copy. The HP XXXX referred to in this document is now the Agilent XXXX. For example, model number HP8648A is now model number Agilent 8648A.

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Impedance Characterization of Resonators
Using the HP 4194A
Impedance/Gain-Phase Analyzer

1. Resonator Evaluation

A wide variety of resonators are now used in an ever-increasing spectrum of products such as microprocessor clock oscillators, tone generators, TV IF filters, etc. The types of resonators used include crystal, ceramic, polymer, mechanical and ferrite.

Until the HP 4194A became available, serious analysis and testing of resonators, and determining the device parameters from measured frequency characteristics required an external computer/controller to perform complex calculations and control functions. The HP 4194A is a single instrument solution for obtaining frequency characteristics and computing parameters. Frequency characteristics are displayed on a color CRT and markers are used to define an area to be analyzed and extract data from the point indicated by the marker. Data analysis is carried out using the HP 4194A's computational, programmability and equivalent circuit analysis functions. We will discuss an efficient method to evaluate ceramic resonators as the example. The single instrument solution to complex problems!
2. Resonator Characterization Using the HP 4194A

(1) Resonant/Antiresonant Frequency

The resonant/antiresonant frequencies (series and parallel resonance modes) are the principle parameters of interest when analyzing resonators. The 4194A’s markers are used to zoom in on an area of the displayed frequency characteristics to quickly find the points of resonance.

Markers are used to read frequency, impedance and phase anywhere on the displayed trace. Measurement resolution of 1mHz enables you to easily detect abrupt changes in frequency characteristics such as found in crystal resonators.

(2) Electro Mechanical Coupling Coefficient

This parameter indicates the efficiency of electrical to mechanical energy conversion. The coupling coefficient is calculated from the resonant/antiresonant frequency data using the following equation.

$$K_t = \left(\frac{\pi}{2} \cdot \frac{f_r}{f_a} \tan \left(\frac{\pi}{2} \cdot \frac{f_a - f_r}{f_a}\right)\right)^{1/2}$$

where $K_t$ is the electro-mechanical coupling coefficient, $f_r$ is the resonant frequency, and $f_a$ is the antiresonant frequency.

Arithmetic operations such as used in the above equation are possible from the HP 4194A’s front panel, and the marker function can be used to specify the values for $f_r$ and $f_a$ from the displayed measurement data.
(3) Equivalent Circuit Analysis

The equivalent circuit model for a resonator is shown in Figure 3-1. The components used in this model, L, C, R and Cb, are the basic elements needed to accurately model a resonator over the 4194A's frequency range. The 4194A computes the values of the equivalent circuit components from the measured data. The equivalent circuit analysis function is a powerful tool, unique to the 4194A, that designers can use to vary circuit constants when simulating possible changes in design, processing tolerances, and temperature. In a matter of minutes an engineer can measure the response of a resonator, compute the values of the equivalent circuit components, and display the response of the hypothetical resonator simultaneously with the resonator's measured response (Figure 3-2).

(4) Circle Diagram of Admittance

The circle diagram of admittance is a quick and convenient method of evaluating resonators. The diameter of the admittance circle represents the Q of the resonator, and the closer the admittance circle comes to forming a perfect circle, the better the stability of the resonator.

Previously obtaining an admittance circle diagram required the use of an X-Y recorder or an external computer. You can obtain an admittance circle diagram directly without other instruments or a computer. You can use the 4194A's marker function to read the resonant frequency or other information from the admittance diagram.
3. Automatic Evaluation of Resonators

The HP 4194A's internal programming function, Auto Sequence Program (ASP), gives you the ability to perform automatic evaluation without the need of an external computer.

ASP can control all of the HP 4194A's operations: measurement, display, and analysis. ASP can automate any of the foregoing resonator evaluations, for quick and efficient evaluation using only a single instrument. Figure 3 shows a sample program to perform quick automated resonator evaluation by measuring the following items.

(1) Resonant/antiresonant frequency
(2) Electro mechanical coupling coefficient
(3) Equivalent circuit analysis
(4) Circle diagram of admittance

4. Ordering Information

All of the functions and evaluations we have described can be performed using the HP 4194A Impedance/Gain-Phase Analyzer and the HP 16047D Test Fixture furnished with the 4194A.

When you order the HP 4194A, you must indicate which test port impedance option you want. Option 350 is for a test port impedance of 50 ohm, and Option 375 is for a test port impedance of 75 ohm. Other test fixtures are available. Contact the nearest HP Sales Office for details.