Errata

Document Title: Input-output Impedance and Reflection Coefficient Measurements (AN 339-10)

Part Number: 5950-2925

Revision Date: May 1987

HP References in this Application Note

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Introduction

Designing electronic circuits involves interconnecting basic circuit building blocks (amplifiers, filters, etc.), and a network circuit is formed at the interface (connection point), of the circuit building blocks. The impedance of each circuit component and the circuit impedance/transmission characteristics of these interface network circuits must be evaluated if the intended circuit characteristics are to be obtained. These characteristics must be measured quickly and precisely in order to minimize development time and cost. Especially, the input/output impedance or reflection coefficients of grounded circuits should be measured when evaluating impedance matching characteristics.

The HP 4194A has the ability to measure the impedance of components and the transmission characteristics of circuits, making evaluating impedance matching characteristics a snap. The HP 4194A when combined with the HP 41941A/B Impedance Probe Kit can measure the impedance of grounded circuits over a frequency range of 10kHz to 100MHz with an accuracy of ±1.5%. The reflection coefficient and return loss can be derived using the HP 4194A's internal programming function (ASP).

As an example, the technique for measuring the Input/Output impedance and reflection coefficient of a negative feedback configuration amplifier will be described.
Measurement Requirements and
the HP 4194A's Solutions

* Precise Measurement of Circuit Impedance

Evaluating circuit impedance requires making ground referenced measurements, which in the past have been performed using network analyzers with directional bridges. The problem has been that it is difficult to precisely measure the impedance of grounded devices.

With its powerful calibration capability using 0Ω, OS, 50Ω standards, the HP 4194A combined with the HP 41941A/B features a superior measurement accuracy of ±1.5% for grounded measurements over a frequency range of 10kHz to 100MHz.

* Reflection Coefficient, Return Loss Calculation, and Automatic Evaluation

The reflection coefficient and return loss can also be obtained, using the HP 4194A's internal math function, from the measured impedance measurement data. The measurement data and the calculated data can be displayed in three formats on the HP 4194A's color display as you choose, e.g., impedance vs. frequency, reflection coefficient vs. frequency, $\Gamma_r$ vs. $\Gamma_r$ characteristics by using the Auto Sequence Program (ASP) function. In addition, the HP 4194A gives you automatic evaluation capabilities of circuit impedance through impedance measurement, reflection coefficient calculation, and plotting without an external computer.

Thus, you can evaluate circuits by measuring and calculating input/output impedance, reflection coefficient and return loss.

Input/Output Impedance Measurements

Input/Output impedance measurements are useful for evaluating circuit performance as a function of frequency and signal level when two circuits are interfaced.

After calibration, you can probe devices directly using the impedance probe as shown in Figure 1.

A typical example of an input impedance measurement of a negative feedback amplifier using the HP 4194A with the HP 41941A/B is shown in Figure 2 (the output impedance characteristics are shown in Figure 3). Hard copies are easily obtained by performing a direct dump to a plotter or printer. The input impedance of this circuit is approximately 50Ω. Therefore the test circuit should be designed for 50Ω matching so as not to cause reflections.

The HP 4194A can quickly measure circuit impedances and display the measurement data to improve efficiency of measurements and analysis.
Reflection Coefficient and Return Loss Derivation Using ASP

The reflection coefficient and return loss are computed using the following equations:

\[ \Gamma = \frac{e_r}{e_i} = \frac{Z_2 - Z_1}{Z_2 + Z_1} = \Gamma_x + j\Gamma_y \]

Return Loss = \(-20\log|\Gamma|\)

Where:

- \(\Gamma\) = Voltage reflection coefficient
- \(e_r\) = Reflected wave
- \(e_i\) = Incident wave
- \(Z_1\) = Output impedance (characteristics) of transmitting side
- \(Z_2\) = Input impedance of receiving side
- \(\Gamma_x\) = Real part of \(\Gamma_y\)
- \(\Gamma_y\) = Imaginary part of \(\Gamma_y\)

ASP was used to compute the reflection coefficient shown in Figure 4. The \(\Gamma_x, \Gamma_y\) characteristics of a negative feedback amplifier obtained using the HP 4194A’s ASP function are shown in Figure 5. The \(|\Gamma|\)-f characteristics are shown in Figure 6, and the return loss characteristics are shown in Figure 7, and these can also be automatically displayed. The ASP subroutine shown in Figure 4 sets the impedance to 50Ω. The reflection coefficient in Figure 6 indicates a value close to zero, or very little reflection.

The HP 4194A’s Marker function is used to read values at a specific frequency when analyzing these characteristics.

![Figure 4. ASP Reflection Coefficient Program](image-url)

![Figure 5. \(\Gamma_x, \Gamma_y\) Characteristics](image-url)

![Figure 6. \(|\Gamma|\)-f Characteristics](image-url)
Conclusion

Reflection coefficient measurements are made possible by combining the HP 8721A Directional bridge with the HP 4194A and making Gain-Phase measurements (See Figure 8). The impedance probe function with 0Ω/0S/50Ω compensation is available to reduce the error due to the directional bridge.

You can select the evaluation method appropriate for measuring and calculating the impedance characteristics, reflection coefficient, and return loss. The high measurement accuracy, the wide measurement capabilities, and the ASP programming function of the HP 4194A and 41941A/B combination will reduce the development time and cost, and the investment needed for making complex Input/Output impedance & reflection coefficient measurements and calculations.