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IEEE Trial-Use Standard
Guide on Solid-State Devices:
Varactor Measurements
Part I — Small Signal Measurements

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Foreword

The purpose of this Guide is to promote the use of uniform and reliable measurement techniques for the characterization of varactors. The techniques described in Part I of this Guide are appropriate primarily for varactors used in small-signal applications, such as parametric amplifiers. Part II, which will be published later in 1971, discusses modifications, limitations, and extensions of these techniques, as well as other measurements, which are more appropriate for certain large-signal varactors, such as some harmonic generator diodes. The design of varactors is advancing at a pace which sometimes outstrips the progress in evaluation techniques. Both diode design and measurement methods are evolving at a rate which exceeds that at which characterization guides can be written. This Guide is not intended to discourage such innovation but will provide a basis for uniform evaluation of the large class of varactors to which it is applicable.

Acknowledgment

The Institute wishes to acknowledge its indebtedness to those who have so freely given of their time and knowledge and have conducted experimental work on which many of the IEEE publications are based.

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Contents

SECTION	PAGE
1 General	5
1.1 Scope	5
1.2 Equivalent Circuits	5
1.3 Glossary	6
2 Measurements of Equivalent Circuit Elements	7
2.1 General Remarks	7
2.2 Low Frequency	8
2.2.1 Introduction and General Considerations	8
2.2.2 Total Capacitance Measurement	9
2.2.3 Inductance Measurement	9
2.2.4 Measurement of Quality Factor	9
2.3 High Frequency	9
2.3.1 General Considerations	9
2.3.2 Constant Transformation Method	10
2.3.2.1 General	10
2.3.2.2 Procedure	12
2.3.2.3 Precautions	13
2.3.3 Matching Method	14
2.3.3.1 General	14
2.3.3.2 Procedure	16
2.3.3.3 Precautions	16
2.3.4 Transmission Method	17
2.3.4.1 General	18
2.3.4.2 Procedure	18
2.3.4.3 Precautions	19
References	19
Figures	
Fig. 1 Conventional Separation of Varactor Elements	5
Fig. 2 Configuration for Immittance Measurements on Varactor	5
Fig. 3 Nonlinear Element Small-Signal Equivalent Circuit	5
Fig. 4 High Frequency Equivalent Circuit	6
Fig. 5 Low Frequency Equivalent Circuit	6
Fig. 6 Variation of Capacitance with Voltage	6
Fig. 7 Equivalent Circuit of Transformation from the Nonlinear Element to the Uniform Transmission Line	11
Fig. 8 Typical Impedance Plot of GaAs Abrupt Junction Varactor	12
Fig. 9 Setup for the Q Measurement	13
Fig. 10 Simplified Equivalent Circuit for Matching to Transmission Line	14
Fig. 11 Typical Impedance Plot of Silicon Graded Junction Varactor	11
Fig. 12 Equivalent Circuits for Transmission Method Measurements	12
Fig. 13 Test Set-Up for Transmission Method Measurements	19

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Guide on Solid-State Devices: Varactor Measurements

Part I — Small Signal Measurements

1 General

1.1 Scope. This guide describes several methods of measurement for the small signal characterization of varactors. For the purpose of this guide, a varactor is defined as a two-terminal device used as a voltage-dependent capacitance. Such devices can be used from dc to microwave frequencies. Examples include low noise parametric amplifiers from audio to microwave frequencies, tuning elements, choppers, and phase shifters.

A small-signal equivalent circuit is presented and its validity discussed. Methods for determining the elements of this circuit by means of ac measurements are described in general terms, and restrictions are discussed. The use of dc measurement techniques is discussed in Test Procedure for Semiconductor Diodes IEEE 256. For a consideration of noise measurements, see Part 9: Noise in Linear Twoports, Methods of Testing Electron Tubes - IEEE 158.

1.2 Equivalent Circuits. All of the nonlinear characteristics and most of the losses of typical varactors are localized in a minute semiconductor element, hereafter called the nonlinear element. As long as the size of this element is a small fraction of the wavelength of the electromagnetic radiation with which the varactor is to interact, it is valid and useful to treat the element as a two-terminal

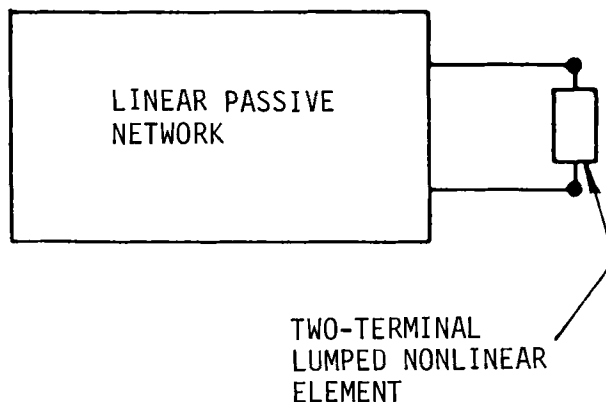


Fig. 1 Conventional Separation of Varactor Elements

lumped nonlinear circuit element embedded in a linear network, as shown in Fig. 1. The linear network, with one or more ports, may be representable by lumped and/or distributed elements.

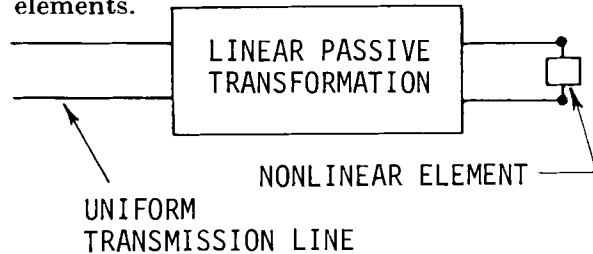


Fig. 2 Configuration for Immittance Measurements on Varactor

For measurement of varactor impedances or for the use of some varactor mountings, the circuit of Fig. 2 is important. A waveguide operating in a single mode is essential in order that the uniform transmission line shown in Fig. 2 be valid at the measurement frequency. Immittances may then be measured in the fashion appropriate to the transmission line.

A useful equivalent circuit for the nonlinear element of a varactor is given in Fig. 3. This

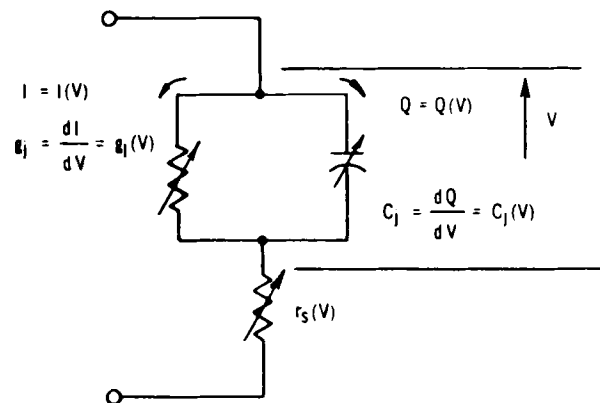


Fig. 3 Nonlinear Element, Small-Signal Equivalent Circuit

equivalent circuit includes three elements, C_j , g_j , and r_s which are both voltage-dependent and frequency-dependent. In some circumstances, more complicated equivalent circuits may be necessary.

At sufficiently high frequencies in the absence of conductive currents, this circuit re-