Preface

This book is intended to be useful to engineers concerned with the design of systems that involve frequency control or selection, or, in short, *frequency management*. Bulk wave quartz crystal resonators and associated devices are key components of such systems and yet basic information about quartz crystal products is not easily available.

There are three reasons for this situation. First, the principles of operation of crystal devices do not generally form part of the curriculum of electronic engineering courses. Second, the major texts in the field, those of Cady, Mason, Vigoreux and Booth, and Heising, are either out of print or not readily available, and in any case are generally aimed at the specialist in the field rather than the general user. Third, many of the more modern developments in the crystal field are scattered throughout a wide variety of learned journals, symposia and conference proceedings, and technical reports, and are quite simply difficult to find.

The recent books by Bottom (1982), Frerking (1978), Matthys (1983), and Parzen (1983) have all contributed towards closing this 'information gap', while the recent two-volume work edited by Gerber and Ballato (Gerber and Ballato, 1985) covers the whole field of precision frequency control including devices such as atomic and laser frequency standards on a 'state-of-the-art' level. The emphasis of the present work is very much tutorial, the main objective being to provide enough background material on both the design and manufacture of quartz devices to give an understanding of the practical and theoretical limitations on the performance of commercially available products. In some cases, theoretical considerations predominate but in many instances the practical limitations due to the complexities of the manufacturing process are the determining factors. Hence some fairly detailed descriptions of manufacturing processes are included.

Following an Introduction giving a broad view of the field, the book is organized in four main parts. Part 1 deals with the crystal resonator as a physical device. A survey of the wide range of different types of resonator is followed by a more detailed review of thickness mode resonators with particular emphasis on the AT-cut crystal which is the most widely used in modern practice. Part 1 provides the physical basis for understanding the operation of a resonator in terms of the normal modes of vibration of a piezoelectric solid. To avoid obscuring the main points of the text, the more theoretical aspects of the topics covered are restricted to a number of

appendices. Part 2 moves on to discuss the manufacture of crystal resonators, with the emphasis on the AT type. Low frequency crystal cuts are only briefly discussed in connection with modern photolithographic manufacturing methods.

Part 3 considers the crystal as a circuit component in terms of its equivalent circuit. The elements of the equivalent circuit are related to the physical characteristics of the device discussed in Part 1. The resonant frequencies and impedance and admittance characteristics of the crystal as represented by its equivalent circuit are discussed in detail, and the available measurement techniques are reviewed.

In Part 4 the key characteristics of bulk wave crystal oscillators and crystal filters are discussed. After a description of elementary oscillator circuits of the Pierce type, the main factors affecting the frequency stability of crystal oscillators are reviewed. This is followed by a survey of the main categories of packaged oscillator currently available. In the final chapter, the basic circuit configurations of narrow, intermediate and wideband crystal filters are explained, followed by a discussion of the practical limitations on crystal filter performance.

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David Salt