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Electronic Noise and Low Noise Design

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To Kathryn and Marianne

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Series Editor's Foreword

The rapid development of electronics and its engineering applications ensures that new topics are always competing for a place in university and polytechnic courses. But it is often difficult to find suitable books for recommendation to students, particularly when a topic is covered by a short lecture module, or as an 'option'.

This Series offers introductions to advanced topics. The level is generally that of second and subsequent years of undergraduate courses in electronic and electrical engineering, computer science and physics. Some of the authors will paint with a broad brush; others will concentrate on a narrower topic, and cover it in greater detail. But in all cases the titles in the Series will provide a sound basis for further reading of the specialist literature, and an up-to-date appreciation of practical applications and likely trends.

The level, scope and approach of the Series should also appeal to practising engineers and scientists encountering an area of electronics for the first time, or needing a rapid and authoritative update.

Paul A. Lynn

Preface

Noise is a problem in many electronic circuits and systems. Arising from the random movement of electrons in circuit elements (intrinsic noise) or from spuriously coupled signals from other circuits and systems (interference), it corrupts the signal of interest and introduces an uncertainty into the information it contains.

Intrinsic noise and interference are usually treated separately. The latter is normally the subject of books on electromagnetic compatibility (EMC). However the problems caused by both types of noise are similar and there is good reason for treating them together. Indeed it is often important for the design engineer to keep both types of noise in mind even when concentrating on one. For example, there is usually little point in incorporating shielding in a design in order to reduce interference well below the noise level determined by intrinsic noise.

This book covers both types of noise, and, within the category of interference, in addition to noise introduced by electric and magnetic fields, noise arising from the transduction of mechanical and thermal disturbances is described. In all cases the means of reducing noise to acceptable or minimum achievable levels are described.

The book aims to provide an introduction to the problem of noise from the viewpoint of a circuit designer, covering the theory of intrinsic noise, electromagnetic compatibility and the basis of low noise design. It will be of value to final year and postgraduate electronic engineering students taking courses on electronic noise or EMC, to postgraduate research students whose projects include low noise design and to practising engineers whose qualifying courses covered the subject inadequately or who need to refresh or improve their knowledge of this area of electronic engineering.

The author's interest in this subject arises from a 24-year involvement in medical instrumentation, dealing with low level signals in circuits with a wide range of impedance levels and from sub-audio to radio frequencies. The book, it is hoped, reflects this range, and all readers, whether concerned with signals from chemical sensors with time constants measured in seconds or with telemetry signals with bandwidths measured in megahertz, should find something of value.

A major group of noise signals is random in nature and, since these signals are often poorly understood, a chapter on the properties and the

characterisation of random signals is included – providing theoretical background to the following chapters and to further reading. The various types of interference, both of electrical and non-electrical origin, and which are influenced strongly by the physical design of equipment, are described in chapter 3. Intrinsic noise, determined by circuit design, is covered in chapter 4. The methods of noise circuit analysis and noise models of common circuit elements are described in chapters 5 and 6 respectively. Chapter 7 covers the techniques of noise measurement and chapter 8 the use of industry-standard circuit-simulation software SPICE in intrinsic noise analysis. The lessons of the previous chapters, particularly 3 to 6, are brought together in chapter 9 which describes the methods of low noise design – covering the basic theory and techniques of electromagnetic compatibility and the methods of minimising intrinsic noise.

SI units are used throughout. In particular it should be noted that distances are in metres unless otherwise stated. The term *power-line* rather than *mains* is used and power-line frequencies of 50 and 60 Hz are used in examples and exercises. Negative exponents rather than ‘/’ are used in most units. For example, intrinsic noise levels are expressed in $\text{VHz}^{-1/2}$ rather than $\text{V}/\sqrt{\text{Hz}}$.

Some of the exercises at the end of the book are adapted from my final year BEng Electronic Engineering exam questions. The permission of the University of Wales to use these questions is gratefully acknowledged.

My thanks are due also to many friends and colleagues who, often without realising it, imparted their enthusiasm for this Cinderella area of electronic engineering or gave me the opportunity to study it. I am particularly indebted to Dr Keith Battye who introduced me to the problem and challenge of noise in electromyography and who enabled me to study it in other areas of medical instrumentation, and to Professor John O'Reilly and Dr Peter Smith for giving me the opportunity to extend my interest, in teaching and production of this book. I should also like to thank Katie Parry for cheerfully typing much of the manuscript, Tony Griffiths for his artistic expertise and my final year students who, without knowing it, encouraged my production of this book in the hope that it might improve their exam grades! Special thanks are due to my family who tolerated my absence from normal family activities over a considerable period of time.