DESIGNING TRANSISTOR I.F. AMPLIFIERS

W. Th. H. HETTERSCHEID

DESIGNING TRANSISTOR I.F. AMPLIFIERS

W. Th. H. HETTERSCHEID

PHILIPS TECHNICAL LIBRARY

This book contains xiv + 330 pages and 138 illustrations and 96 pages two-coloured design charts, 3 folding-out tables.
Other editions of this book in Philips Technical Library in the German and French languages.
U.D.C. nr. 621.375.121 : 621.382.3

Printed in The Netherlands.

PREFACE

In most cases the design of I.F. amplifiers for radio, television and radar receivers involves a large amount of computational effort. This is due to the numerous requirements imposed on such an amplifier which, in most cases, are contradictory. As a consequence, a compromise must usually be found which will result in an optimum performance of the amplifier with regard to the most important specification points.

The above comments are applicable to all types of I.F. amplifier, irrespective of whether they are equipped with electron tubes or transistors. The design of transistor I.F. amplifiers, however, imposes even more problems than that of the tube counterpart. This is due to the internal feedback of the transistors, which is not negligibly small.

A transistor I.F. amplifier can, therefore, not be treated on a stage-by-stage basis as in the case of amplifiers equipped with modern penthode tubes, operating at a not too high frequency. The stage-by-stage design of a transistor I.F. amplifier is not possible because the internal feedback of the transistor in each stage affects the performance of all the other stages.

This implies that an I.F. amplifier equipped with transistors must be treated as a whole. A new parameter is therefore added to the variety of parameters which already exists with tube equipped amplifiers: this new parameter being the amount of feedback present in each stage. In this book, a method is presented which facilitates that the design of transistor I.F. amplifiers can be carried out with great ease and accuracy. The key of this design method is formed by a large number of computed "design charts" which are used in connection with a step-by-step design procedure.

These design charts contain amplitude response, envelope delay and gain characteristics, taking into account a certain set of parameters. One of these parameters is related to the amount of feedback of the transistors in the various amplifier stages. The step-by-step method of design leads to the choice of a particular set of design charts. Consultations of this set enables an accurate determination of the performance of the amplifier to be made. The design charts present moreover the information necessary for constructing the bandpass filters used as interstage networks.

The subject-matter contained in this book is based on work carried out in the Philips Semiconductor Application Laboratory at Nijmegen, The Netherlands.

The computed design charts are based on the analytical approach to amplifier design presented in the author's book "Transistor Bandpass Amplifiers".

The author wishes to express his gratitude towards his colleagues for the many discussions and the helpful suggestions. In this respect he especially wishes to mention Mr. E. J. Hoefgeest and Mr. A. H. J. Nieveen van Dijkum. For correcting the manuscript the author is indebted to Mr. W. H. Cazaly, Ilford, England.

March, 1966 The Author

CONTENTS

CHAPTER 1

INTRODUCTION

An intermediate-frequency amplifier as used in radio, television and radar receivers provides the greater part of the high-frequency gain of the whole system and almost entirely determines the amplitude and phase response characteristics. The I.F. amplifier therefore largely governs the total performance. For these reasons a great deal of attention is usually given to the design of such an amplifier.

Often the design of an I.F. amplifier is laborious because of the large number of requirements and conditions that must be taken into account. This applies especially to amplifiers in which transistors are used as amplifying elements, when problems arise associated with the internal feedback of the transistors. (In amplifiers equipped with modern electron tubes, interelectrode feedback offers few difficulties provided that no extra feedback is introduced by the arrangement of components and wiring.)

In this book a systematic method is developed which facilitates the design of transistor I.F. amplifiers by making use of a large number of computed amplifier design charts.

The heart of the design method lies in the determination of proper values of the *regeneration coefficients* of the transistors in the various stages of the amplifier. The "regeneration coefficient" is a quantity dependent on the admittance parameters of a transistor and on the admittances of tuned circuits at its input and output terminals. The relative values of the regeneration coefficients of the transistors in the various stages largely affect the performance of the amplifier.

The various phases of the design procedure are schematically illustrated in the block diagram in Fig. 1.1. From the specification of performance requirements of the amplifier and data concerning the transistors to be employed, a choice is made of the amplifier configuration (arrangement of transistors and single-tuned and/or double-tuned bandpass filters) and the number of stages needed.

With the amplifier configuration and the number of stages known, use can be made of a series of *design charts*. From these design charts amplitude response and envelope delay characteristics can be derived. Taking into account the relevant items of the design specification a certain group of curves

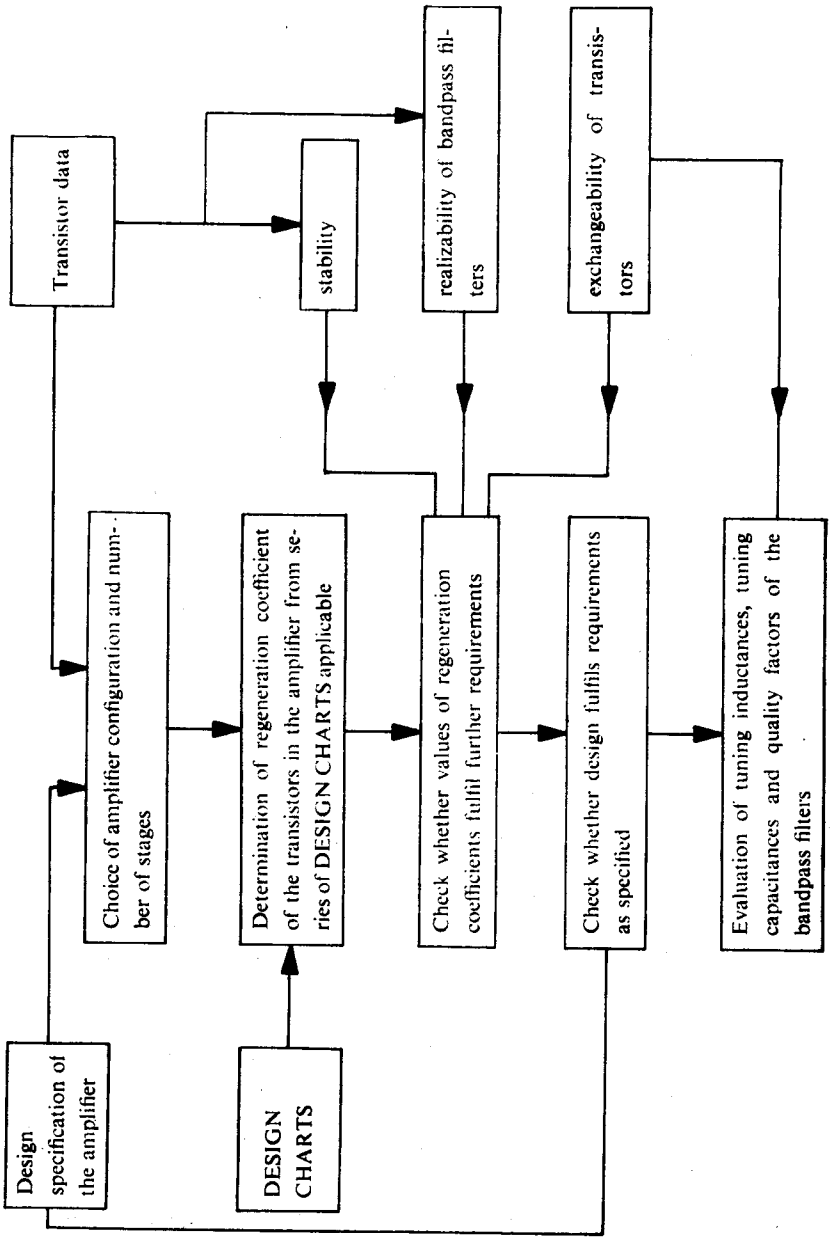

Fig. 1.1. Block diagram indicating various stages of the step-by-step method of designing I.F. amplifiers.

can be selected, valid for a particular value of the regeneration coefficient in the amplifier.

The value of the regeneration coefficient obtained from the design charts fulfils most of the requirements for designing the amplifier. Further checks, however, must be made regarding stability, interchangeability of transistors of the type chosen, and realizability of the bandpass filters to be used. A value of regeneration coefficient should be chosen which meets all requirements.

When the final values of the regeneration coefficient of the various transistors of the amplifier are arrived at, the most important part of the design procedure will have been completed, provided all specified design requirements are fulfilled. Whether this is the case or not can now be checked in detail.

The last part of the design procedure consists of the practical design of the various bandpass filters of the amplifier.

The design procedure described has been fully set out in Chapter 13, which contains a step-by-step method for designing I.F. amplifiers. To facilitate design, the results of the various steps can be entered in a systematically arranged form, as shown on a fold-out page at the end of the book.

The step-by-step method shown includes in condensed form the considerations on various aspects of amplifier design dealt with in Chapters 2 to 8 inclusive.

In Chapter 2 design specifications of gain, amplitude response, and envelope delay characteristics for various types of I.F. amplifier are considered. It is argued that specifications should comprise not only nominal values of items but also acceptable spreads of values.

Spreads in performance that occur in a series of practical amplifiers arise from the use of active and passive components, the parameters of which are subject to production spreads.

The spreads in the admittance parameters of the transistors (or other active devices) as well as in the values of the components are usually specified by the manufacturer.

In Chapter 3 is discussed how the various spreads are taken into account to obtain a true picture of actual performance spreads.

In Chapter 4 are considered the small-signal admittance parameters of the transistors required and their dependence on biasing point, operating frequency, and ambient temperature.

The design of biasing circuits is not included in this book, since the subject is adequately treated in several works on transistor circuits.

The method of design of I.F. amplifiers presented here is based on the

theoretical considerations set out in the book "Transistor Bandpass Amplifiers", which is in the present work referred to as Book I.*

In Chapter 5 (of the present work) a survey is given, for ease of reference and to facilitate its use, of the theory of I.F. amplifier design, which contains sundry references to relevant sections in the first-mentioned Book I.

In Chapter 6 a short account is given of neutralization of the internal feedback of transistors. In some instances neutralizing networks may considerably improve the performance of the amplifier.

In Chapter 7 are discussed problems of gain control in I.F. amplifiers.

Chapter 8 presents further considerations related to the development of the step-by-step method of designing practical I.F. amplifiers.

Chapters 9, 10, 11 and 12 give examples of the design of I.F. amplifiers.

In Chapter 9 examples of the design of I.F. amplifiers for radio receivers for A.M. and F.M. signals are presented.

In Chapter 10 examples of the design of I.F. amplifiers for television receivers are given.

In Chapter 11 the spreads in performance of the amplifiers designed in Chapter 10 are evaluated as they affect the choice of an A.G.C. system.

Chapter 12 presents an example of a theoretical method of calculating the spreads in performance that may occur in a vision I.F. amplifier due to spreads in the admittance parameters of the transistors.

Chapters 11 and 12 show how individual spreads of transistors and components should be evaluated and combined in order to obtain a realistic picture of the overall spread in the performance of an amplifier.

Chapter 13 shows a further example of the design of a vision I.F. amplifier.

Chapter 14 presents the step-by-step method of I.F. amplifier design and Chapter 15 contains the design charts referred to above.

*) W. Th. H. HETTERSCHEID, *Transistor Bandpass Amplifiers*, Philips Technical Library, Eindhoven, 1964.