

Electronic Amplifier Circuits

Theory and Design

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Preface

The amplification of weak signals into stronger signals is of fundamental importance in almost any electronic system. Sometimes this is obvious, as in a radio receiver, where the objective is to select and amplify the weak signal from the antenna and to present the detected signal via a loud-speaker. Sometimes the need for amplification is more subtle, as in an electronic computer where no “circuit” labeled “amplifier” usually exists. Even here amplification is present and important; it may occur in each logic element or in only a few, but gain is necessary to ensure that the signal information is not lost in noise.

Because of the importance of amplifiers in the electronic art, we have tried to produce a work which will be of use to both students and engineers who have a need for a second look at amplifier theory from a more advanced point of view. We do not cover all types of amplifiers in complete or even partial detail. Rather, we review the fundamental principles underlying amplifier design and show several methods of design and synthesis which have proved useful in the past. Hence, we do not teach “all about amplifiers” but, rather, show some applicable modern methods and help the student extend these for himself.

The first part of the book is a review of the active elements—vacuum tubes and transistors—and their use in simple situations. Because one of the more valuable benefits of such discussion is appreciation of the relative merits and limitations of the two devices, they are considered together—e.g., the discussion of high-frequency cutoff includes both tube and transistor equivalent circuits, to show what elements in each are important in determining the high-frequency behavior as well as useful approximations to the complete equivalent circuits. Such approximations are particularly important in that with a simpler circuit the student can think more clearly

about the logic and validity of what he is doing and at the same time develop maturity in approximating to an extent justified by the required accuracy of his result.

The number of equivalent circuits for transistors is kept to a minimum, and an effort is made to feature those which have the most physical meaning. It is felt that there are a sufficient number of transistor texts which cover multitudes of equivalent circuits exhaustively. Also, no attempt is made to cover thoroughly either vacuum-tube or transistor internal electronics, although some physical reasoning is used to show the reasonableness of an equivalent circuit.

The second major part of the book deals with the problems of making "fast" lowpass amplifiers, e.g., video amplifiers. In this section, the fundamental limitations governing the attainment of high-speed high-gain amplifiers are discussed. Since the majority of such amplifiers amplify transient signals, the bulk of the discussion concerns transient response. The effect of multiple stages on rise time and sag, the relations between bandwidth and rise time, etc., are discussed in both a theoretical and a practical manner. The introduction to the distributed amplifier is sufficient to enable one to understand the operation and limitations of such amplifiers.

The third major section, covering bandpass amplification, includes the analysis and synthesis of wideband amplifiers from the pole-zero viewpoint, and various analogies to gain functions. Although particular stress is laid upon the wideband situation, the results are generally applicable to narrow bands since the situation is actually simpler in the latter case.

Chapter 13 on Noise in Amplifier Circuits is intended to furnish the student with a reasonable physical picture of the sources of amplifier noise and especially to give him some useful equivalent circuits for the calculation of amplifier noise. These circuits are used to calculate the noise factor of amplifier input circuits and multistage amplifiers. An example of optimization of an input circuit is also given.

The final major section, on amplifier measurements, is included to clear up some of the problems common to amplifier design and to the necessary testing of the resulting amplifier. Very high-gain amplifiers, in particular, have some special problems which make accurate testing impossible if the proper precautions are not observed. Some methods of measuring the parameters of the common active and passive elements are also discussed, since these measurements are often difficult at the frequencies or signal levels that must be employed.

Consideration must be given by the instructor who will use this book as a classroom text to two possible aspects which can be emphasized in varying degree. The one, which is also the aspect likely to be most useful to the practicing engineer, is that of a presentation of the present "state of the art." Thus the book does provide substantial coverage of useful, high-

performance amplifier designs, which represent the best that one can do with presently available tubes and transistors.

On the other hand, knowledge of the state of the art is a perishable commodity and indeed is being challenged as a proper ingredient in a curriculum for engineers who are to solve problems in the distant future more than in the immediate future. Such a goal is better met by providing a good foundation in mathematics and physics, together with experience in the methodology of applying these sciences to engineering problems. While this book does not cover the science, it does contain the methodology. It includes a record of the successful application of advanced knowledge of the physical behavior of electron devices (tubes and transistors) and of the mathematics of complex variables and transform theory. The authors of the journal papers referred to in the footnotes are the engineers who have successfully applied the theory since 1940 or 1950 and who thus are the exemplars for the young engineers now in training. The journal papers are milestones along an unending road. Their authors possessed the superior mathematical ability and the physical understanding, and it is instructive to study the manner of application.

Nevertheless it is important in studying the application to notice that it is possible—and indeed an engineering necessity—to carry the application of sophisticated concepts and mathematical analysis far enough so that design formulas, charts, etc., are provided which do not require sophisticated knowledge but rather can be employed by the larger number of design engineers possessing more modest training. The results of this complete application process can be found throughout the book.

In short, the subject matter of the book can be studied for the useful, practical design data, or instead the book may be regarded as a collection of examples of the engineering method whereby mathematics and physics have been applied to the solution of new and difficult problems.

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