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VACUUM TUBE ELECTRONICS
REVIEWS OF THE MAJOR TEXTS

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If the current tube renaissance continues, future designers will want to know about the following texts, as replacements are not forthcoming. In order to show historical precedence, books are listed chronologically by first edition. The most recent edition is nonetheless considered to be definitive.

This survey is by no means intended to be exhaustive—on the contrary, only the most widely quoted texts are considered for inclusion here (widely quoted texts are considered to be both authoritative and influential.) Books marked with a "☞" will be of greatest interest to the audio designer (although each book listed provides a different slant on the subject, and is thereby useful in its own right.)

It is the author's intention to expand this list as books are discovered that may equal in quality of content the high standards set by those listed below. The interested reader is hereby encouraged to contribute title suggestions for inclusion in future editions of this survey.

Part I of this series includes books of a general nature that are particularly clear about at least one aspect of tube amplifier design. Part II covers books on electric circuit theory, Part III covers books on electromagnetics and tube theory, while books of a more specialized nature, such as those on transformer design, tube manufacturing, etc., are included in Part IV of this series Books of a supplementary nature, such as acoustics, bibliographies, tube manuals, etc., will appear in Part III. Books of an incidental nature, such as biographies, histories, music appreciation, etc., will appear in Part IV.

The entire survey, subject to updates, appears as a permanent feature of the PEARL Audio Notes and the PEARL Vacuum-Tube Technology Archive. Compiled by Bill Perkins, the 'Archive consists of approximately 1000 technical articles related to tube amplifier design. To obtain a copy of the latest revision of the Audio Notes, which contains an 'Archive index, contact PEARL, INC. at: Ph. 403 244 4434; Fx. 403 240 2851; email: custserv@pearl-hifi.com. Or visit PEARL's website: http://www.pearl-hifi.com, where you can download the entire set of Audio Note articles along with many other items of interest.

PART I
THE CLASSIC TEXTS

1920
Theory of the Thermionic Tube and Its Applications
H.J. van der Bijl
(McGraw-Hill Book Co., Inc., NY.)

Hendrik Johannes van der Bijl is the father of electron tube theory.[1—6] In 1913, van der Bijl deduced the fundamental functional relationships of triodes; and from these, derived the tube constants and gain equations.[7] These feats won for him a post at the Western Electric Company where he functioned as Senior Research Physicist until the publication of his seminal book in 1920. Many believe that Irving Langmuir, a research chemist for the General Electric Company, deserves the patriarch's mantle; but Langmuir's research focused on thermionic emission. Langmuir's landmark theory, published in 1913,[8] capped a materials research phase begun by Richardson[9] and Child.[10] Langmuir's paper refuted the long held belief that electric current could flow through a vacuum only by means of ionization (the infamous "blue glow".) Harold Arnold, head of the Western Electric research division for tube development, echoed Langmuir's belief in pure thermionic emission.[11] But until the advent of the molecular vacuum pump† in 1912, no one could prove otherwise. Van der Bijl's book guided designers, teachers, and researchers throughout the 1920s. Today, it remains useful as a broad source of information with respect to the earliest contributors to the vacuum tube art.

1932
Radio Engineering,
Frederick Emmons Terman
(McGraw-Hill Book Co., Inc., NY.)

Terman was for many years Dean of Engineering at Stanford. Terman published the 4th edition of his book in 1955 which he then renamed *Electronic and Radio Engineering* to emphasize "the general techniques of electronics, without regard to the extent of their use in radio systems." While useful

† By means of this device, very low gas pressures could be achieved within vacuum tubes. The consequent low density of gas-molecules was then demonstrated to be insufficient to support, by ionization alone, the electron flow that could be drawn through a thermionic emitter to an adjacent anode. *bp.*

mainly as a compendium of the radio arts, Terman's book nonetheless contains a very clear description of push-pull operation and of distortion theory, among other topics relevant to the audio arts.

1933

Theory of Thermionic Vacuum Tubes

E. Leon Chaffee,
(McGraw-Hill Book Co., Inc., NY)

Chaffee was Professor of Applied Physics at Harvard; and, for many years, Director of the Cruft Laboratory there (Chaffee was, in many ways, Terman's counterpart on the East Coast.) This authoritative book was among the first to formalize—by the use of equivalent circuits—the functional relationships, tube constants, and gain equations as deduced by van der Bijl, Miller, Hazeltine, and others.[4] In addition to triodes, Chaffee applies his modeling technique to the multi-grid tubes. Most interesting is the manner in which Chaffee exhaustively explores the various ways in which pentodes can be externally wired to behave as triodes. Meticulously illustrated.

1934

☞ ***Radiotron Designer's Handbook*** ☜

F. Langford-Smith, ed.
(Amalgamated Wireless Valve
Company Pty., Ltd., Australia)

This book was distributed by RCA in the U.S., and is clearly the most comprehensive collection of hands-on audio information ever compiled in a single volume. It is essentially a collection of technical essays by authorities in each branch of the audio field. This indispensable book combines technical expertise with an audiophile's sensibility for good sound. Highly sought after, unquestionably authoritative, it reached its 4th edition in 1953.

1937

Fundamentals of Engineering Electronics

William G. Dow
(John Wiley & Sons, Inc., NY)

Dow was Professor of Electrical Engineering at the University of Michigan. Dow's approach was essentially that of a physicist; hence, the operative word in the title of his book is *Fundamentals*. Dow's special contribution was a more exact method of relating tube geometry and potential distribution to cathode current. Dow's method utilized conformal transformations of equivalent electrostatic circuits. A widely quoted reference; firmly grounded in physics. The 2nd edition appeared in 1952.

1937

☞ ***Fundamentals of Vacuum Tubes*** ☜

Austin V. Eastman
(McGraw-Hill Book Co., Inc., NY)

Eastman was Head of the Department of Electrical Engineering at the University of Washington. Despite its title, Eastman's book emphasizes applications. Contains a thorough discussion of distortion in amplifiers with special emphasis on intermodulation distortion. Very strong in transmitting and modulation theory. In addition, Eastman was one of the few authors who could clearly explain the theory of push-pull operation. The definitive explanation would have to wait, however, for Melehay.[12] The 3rd edition of Eastman's book appeared in 1949.

1939

Theory and Application of Electron Tubes

Herbert J. Reich
(McGraw-Hill Book Co., Inc., NY)

Reich was Professor of Electrical Engineering at Yale. This book contains a thorough survey of the basic engineering problems encountered in the design of power amplifiers. Contains many useful references to early papers on push-pull amplifiers (although Barton is conspicuously absent.[13]) The 2nd edition appeared in 1944.

1943

☞ ***Graphical Constructions for Vacuum Tube Circuits*** ☜

Albert Preisman
(McGraw-Hill Book Co., Inc., NY)

Preisman was Director of Engineering Texts at the Capitol Radio Engineering Institute when he wrote this book. He was previously a teacher at RCA Institutes. The author argues, convincingly, that non-linear circuit analysis is best performed by graphical methods. Many important methods are shown and the solutions are verified by rigorous mathematical analysis. A very in-depth look at the complexities of amplifier design. Recommended for anyone interested in an advanced understanding of push-pull theory or distortion theory. Elegantly explains the most obscure points of amplifier design.

1943

☞ ***Applied Electronics*** ☜

The Staff at MIT
(John Wiley & Sons, Inc., NY)

This book comprehensively summarizes the subject of electronics in the first half of the twentieth century. It includes work done by physicists, chemists, materials scientists and electronics engineers. The 2nd edition, re-edited by Truman S. Gray—an Associate Professor of Engineering Electronics at MIT—

appeared in 1954. Push-pull power amplifier design is extensively covered in this book, as is distortion theory. Chapter XII, Article 7, gives a complete exposition of the power series representation of nonlinear functions, leading to the Taylor-series representation of triode characteristics in Article 9. In addition, the book contains copious footnote references to early source materials, such as to original papers and patents by Edison, Fleming, Child, Richardson, Langmuir, Schottky, etc. Rivals van der Bijl's book in this regard.

1948

Vacuum-Tube Circuits

Lawrence Baker Arguimbeau

(John Wiley & Sons, Inc., NY)

Arguimbeau was associate professor of electrical communications at MIT. In later years he worked at the McIntosh Laboratories. One of the few engineering books that manages to poke fun at itself. The fifth printing, entitled *Vacuum-Tube Circuits and Transistors*, appeared in 1963. A very modern treatment of tube circuits is given in this book (i.e., general analytic methods are emphasized.)

1948

Vacuum Tube Amplifiers

George E. Valley and Henry Wallman, editors

(McGraw-Hill Book Co., Inc., NY)

This fabled book is the centerpiece of a 28-volume set, edited by Louis N. Ridenour (MIT's radar systems expert at the time.) This series, compiled at the MIT Radiation Laboratory, was commissioned by the National Defense Research Committee; and includes work done at many laboratories—Army, Navy, university, and industrial—in America, England, Canada, and elsewhere. *Vacuum Tube Amplifiers* explains in detail a number of esoteric amplifier techniques—including direct-coupled amplifiers; differential amplifiers; cascodes; and active loads. These techniques are discussed in detail in Chapter 11. In addition, a rigorous theoretical treatment of noise in tubes and tube amplifiers is given in chapters 12 and 13. The entire first half of the book is given over to the subject of transients and pulse amplifiers. Chapter 11, in particular, makes *Vacuum Tube Amplifiers* an indispensable reference for the designer looking to go beyond the ordinary.

1953

Engineering Electronics

by George E. Happell and Wilfred M. Hesselberth

(McGraw-Hill Book Co., Inc., NY)

Both authors were Associate Professors of Electrical Engineering at Purdue University. These two authors bring electronics theory down to earth using simple descriptions and familiar analogies. The basic subject of tube theory is nonetheless presented about as completely as one will find anywhere. In many instances where math is used, the authors restate the equations in plain English. In cases of non-linear analysis, as in power amps, graphical methods are shown. Wherever possible, a combination of analytical, interpretive, and graphical methods is used. By this means, the reader is led into an understanding of tubes and circuits by discrete stages, wherein each stage is plainly yet thoroughly described in its essential features. Whatever subject they treat, the author's follow these same basic precepts. They make understanding the basic action of the tube about as easy to digest as is possible, given the complexity of the subject. All aspects of voltage and power amplification are treated in like manner: plainly, clearly, simply, yet thoroughly. A marvel of exposition.

1954

Electronics

by George F. Corcoran and Henry W. Price

(John Wiley & Sons, Inc., NY)

Corcoran was Chairman of the Dept. of Electrical Engineering at the University of Maryland; Price was an Assistant Professor there. This diminutive little book covers the basics of audio engineering about as well as any book here listed; and it does so with uncommon clarity and thoroughness. Contains an excellent discussion of tube loss vs. DC load loss relative to AC power output. Gives a chart showing 2nd harmonic plus 4th harmonic distortion vs. power output for a single-ended amplifier. Another chart shows the grid no. 2 current and plate current vs. power output. Yet another chart shows the shift in operating point with output stage rectification due to 2nd order distortion. Thoroughly explains this effect. One of the few books to show the composite curves for a pentode push-pull amplifier. Clearly and thoroughly explains push-pull operation, including AB_2 operation. Thoroughly explains the various effects of negative feedback, including the effect on gain stability; noise reduction; input impedance; gain-bandwidth product; etc. One of the very few electronics texts to show the complete polar plot of a Nyquist stability curve. A tremendously well thought-out text.

1956

Principles of Electronics and Electronic Systems

J. L. Daley, ed.

(United States Naval Institute, Annapolis, MD)

A very accessible introduction to electronics design principles. Although not widely quoted in the literature, this book nonetheless provides insight that the others do not; particularly with regard to

the basics of load-line construction. For example, it shows the step-by-step procedure for setting up DC and AC load lines for bypassed and unbypassed voltage amplifiers. Clearly explains the classes of power amplifier operation from class-A through class-C.

1957

Engineering Electronics

John D. Ryder

(McGraw-Hill Book Co., Inc., NY)

Ryder was Dean of Engineering at Michigan State University. This meticulous book contains a step-by-step procedure for the design of a class-B or AB amplifier output stage, as well as a thorough presentation of general distortion theory. There is a very clear discussion of feedback theory, as well. In addition, the action of a tube voltage regulator is thoroughly described and mathematically analyzed. The design procedure for a cathode follower is also uncommonly thorough. An unmatched how-to handbook, grounded on solid engineering principles. This book, together with the other emphasized titles, will provide unerring guidance for the aspiring designer.

1959

Electronic Circuit Theory

by Henry Zimmermann and Samuel J. Mason

(John Wiley & Sons, Inc., NY)

The authors were both Professors of Electrical Engineering at MIT. This is the first book among those listed that can be said to have broken through to a purely modern didactic approach; which is to say that a new philosophy of teaching electronics at length established itself as the standard method. Because the field of electronics had by this time become so diverse, a method was needed whereby any particular branch of electronics could be approached, having once learned the general principles involved. In this approach, largely pioneered at MIT, experimentation is the basis for theoretical model-making in the solution of general engineering problems. In all cases the stress is laid on basic principles and methods of analysis. The fact that tubes are used in the examples makes this book a unique resource.

1965

Principles of Vacuum Tubes

J. W. Gewartowski and H. A. Watson

(D. Van Nostrand, Princeton, NJ)

One of the last of the large-scale textbooks to be published on the subject of vacuum tubes, this book was originally used as the basis for a training course at Bell Labs for newly recruited engineers and physicists. Emphasizes physics to explain the fundamentals of industrial-type amplifiers, such as microwave amplifiers and traveling-wave amplifiers. Although oriented toward industry, much of the material presented in this book was derived from Bell Labs' research archives; and is thus valuable from that standpoint. Bell Labs did a monumental amount of research on vacuum tubes and tube amplifier design (beginning at Western Electric, a precursor of Bell Labs.) Of particular interest is the excellent chapter on noise that includes a rare discussion of partition noise in pentodes.

1965

Analysis and Design of Electronic Circuits

Paul M. Chirlian

(McGraw-Hill Book Co., Inc., NY)

Chirlian, was Associate Professor of Electrical Engineering at Stevens Institute of Technology. His book contains many practical design examples and discussions. Particularly strong in the transient behavior of small-signal circuits. Covers the design principals for push-pull amplifiers for both tubes and transistors. Excellent treatment of feedback stabilization techniques.

1966

Amplifier Handbook

Richard F. Shea, Editor-in-Chief,

(McGraw-Hill Book Co., Inc., NY)

A huge book written purely about amplifiers. Covers mainly industrial-type amplifiers, both tube-type and solid-state. As big as it is, this book lacks detail on key subjects such as the push-pull amplifier, the cathode follower, and the regulated power supply. There is nonetheless an excellent section on tubes that covers many of the last innovations in tube design, such as frame grids and specialized beam formers. Factors governing tube life are thoroughly discussed.[14] There is also an excellent discussion of noise in tubes. Various kinds of unusual electrode currents are discussed in much more detail than is usually encountered; including contact potential bias and grid leakage currents. In addition, there are charts that show the variation in tube parameters for lots of 100 raw tubes (as the manufacturer might encounter them.) A unique reference manual; although, generally speaking, more theoretical than practical.

1967

Electronic Devices and Circuits

Jacob Millman and Christos C. Halkias,

(McGraw-Hill Book Co., Inc., NY)

By 1967 the McGraw-Hill Electrical and Electronic Engineering Series (edited by Terman) had swollen to 100 volumes. This book does an excellent job of discussing both tube and transistor circuits;

and draws many useful parallels between the two. Gives a detailed analysis of the operation of voltage regulators. Shows a step-by-step procedure for the design of a solid-state voltage regulator; including four ways in which the basic regulator can be improved. Compares the completed solid-state voltage regulator to a similar tube-type regulator.

1968

☞ *Amplifying Devices and Low-Pass Amplifier Design* ☜

E. M. Cherry and D. E. Hooper,
(John Wiley & Sons, Inc., NY)

This book caps a long and distinguished tradition of "hands-on" audio research in Australia (as inaugurated by the great F. Langford-Smith.) Cherry and Hooper's book is among the very few written specifically about audio amplifiers; and it is surely one of the largest. Weighing in at just over 1000 pages, this book is a paragon of formalized, yet accessible, design theory. It addresses solid-state as well as tube circuits. Unquestionably strong on feedback theory; practical compensation techniques; noise theory; and distortion theory. There is also an extensive treatment of differential amplifiers. The final section of the book shows construction techniques for hand-wired prototypes. Provides a thorough theoretical base while emphasizing "proven rules for circuit design of immediate use to practicing engineers." Cherry was later to formalize the theory of TIM.[15]

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PART II
ELECTRIC CIRCUIT THEORY

Preface

Ampère defined electric current as charge in motion. The rate of movement increases as the electromotive force (voltage) is increased. Thus, to increase current flow, the voltage must be made great enough to overcome whatever resistance may be present in the current path. This relationship can be stated by the formula: I = V/R. This is Ohm's law for current (1827.)

Generalizing this law for resistive networks, Kirchhoff was enabled to define the equilibrium equations (1845) for both voltage and current. Kirchhoff's laws laid the foundation for electric circuit theory. Since that time, network theory, as it is often called, has evolved into a standardized system of analysis and synthesis.

Since I came at network theory after college, I was interested in finding books that clearly summarize the fundamental concepts; and which, preferably, use tubes in the examples. I felt that, in this way, I would be enabled to learn the concepts with a minimum of tutoring. To reinforce the concepts, I recommend Paul Tuinenga's book, *Spice: A Guide to Circuit Simulation & Analysis Using PSpice* (available from Old Colony), along with the accompanying software.

I next began to look for books that explained the concepts in a more rigorous and thorough manner (but not necessarily in a way that I found easy to understand.) In so doing, I discovered many excellent books on circuit theory—far too many to discuss in an article of this kind. One seminal book only will be presented here (the first book listed.) To bridge the gap, a book covering the history of circuit theory is also listed (the last book listed.)

The books included here, then, were selected based upon their ability to clearly communicate the techniques most directly bearing on the needs of the tube circuit designer. A great many of the standard texts were surveyed with this aim in mind. In spite of that, some worthy candidates have probably been overlooked. I would appreciate knowing about such books (provided you feel they surpass those shown below, for the criteria stated above.)

The Basics of Electric Circuit Theory

The body of work that deals with circuit analysis is known as network theory or electric circuit theory. Network theory is based upon the fundamental Kirchhoff voltage and current laws. Circuit analysis involves converting the active devices in a network to equivalent voltage or current sources; then calculating the voltage drops across the passive elements within the network. Reactive elements will of course cause signal currents to vary with frequency. At the same time, there is phase shift between the voltage and current waveforms. Recourse is had to calculus to evaluate these time-varying relationships. Differential equations are needed to freeze moments in time such that the instantaneous voltage-current relationships can be made known in any given branch of the network.

Due to the division of current through the various branches, audio circuits typically contain simultaneous currents. Network analysis tries to account for each one. Branch currents can be distinguished, however, only within linear systems. That is because non- linearity creates harmonic distortion which then allows intermodulation among the currents (see Eastman [op. cit.]); destroying their isolation (see Cheng, [op. cit.].) Ordinary methods of network analysis are thus limited to the domain of linear systems; although there are other methods (see Preisman [op. cit.]) that can be used to identify the distortion products in non-linear circuits.

In linear circuit analysis, each current must be expressed by its own integro-differential equation. These equations can be cumbersome, given complex networks. Fortunately there are transforms. Transforms convert integro-differential equations into concise algebraic expressions; enabling the rapid solution of a number of common network problems.

The ultimate aim of circuit analysis is to predict the response of any given network to an arbitrary input, based on its response to an impulse. The function that describes this response is called the input-output relation; sometimes known as the transfer function.

Introduction

I. In essence, network analysis reveals how a particular circuit alters the complex frequency response of a given input signal. The complex response includes phase as well as frequency. This alteration to the input signal is known as the filter function or transfer function. The network response is characterized either by its transient response or by its steady-state response, which are transformable, one into the other.

The response in either case is due purely to R-L-C factors and neglects non-linear distortion due to the active elements. For this reason such analysis is known as linear analysis. Other branches of circuit theory study active devices in their non-linear aspects. One such branch is known as device theory and is addressed in Parts IIIA & B of this survey under the headings "Electromagnetics" and "Tube Physics" respectively.

A network is defined as a closed circuit consisting of resistive, reactive, and active devices; just as in any real amplifier. Circuit analysis involves, e.g., converting the active devices into voltage sources; separating the various branches into current loops; extracting the redundant loops; then calculating the voltage drop across each impedance within the network. The individual voltage drops are then summed as a single equation for each branch. These are the Kirchhoff equilibrium equations.

The equilibrium equations are solved simultaneously by means of matrix arrays or determinants. The resulting operations can be cumbersome, given complex networks. Fortunately there are transforms that are used to convert the differential form of an equation into an equivalent algebraic expression, which is easier to manipulate. Once solved, the algebraic form is then inverse transformed to obtain the network response. A table of transform pairs is used for the most common network functions—such as sine waves or exponentially increasing or decreasing waveforms.

The fact that computers now do most of the work of analyzing and synthesizing networks is in some ways a double-edged sword: while it does tend to make engineers more productive, it also tends to widen the gap between engineer and mathematician; not such a good thing if understanding is what is wanted.

II. The ultimate aim of circuit analysis is to find the natural response of a given network to an arbitrary input, based upon that network's response to a pulse. The natural response is simply the effect upon the pulse of the reactive elements within the circuit. Since all real circuits contain reactive elements, any circuit can be expected to filter or otherwise alter an input pulse. The most typical effects are roll-off, delay and ringing.

These effects are related to the number of poles and zeros in the network and by their position in the complex plane. A pole-zero pair may be thought of as the mathematical consequence of the reactive impedance of a capacitor and/or an inductor, wherein the opposing reactances interact to one degree or another depending upon the signal frequency. The extreme cases are resonance (wherein X_L cancels X_C) and antiresonance (wherein I_L cancels I_C.)

The relative position of poles and zeros on the complex plane also indicates the degree of damping imparted by R, and thus, the tendency of the circuit toward either oscillation or stability. These concepts are analogous to the mass, compliance and friction seen in vibrating systems of a mechanical nature. Indeed, the same equations describe both systems (see Cheng, below.)

It goes without saying that network analysis requires mathematical tools—in particular algebra (to organize basic operations); trigonometry (to mark time); differential and integral calculus (to freeze and sum quantities which are functions of time); the theory of functions and graphs (to plot waveforms or functions of time); complex number theory (to evaluate the phase shift between voltage and current waveforms across reactive networks); and, ideally, operational calculus such as the Laplace transform (to simplify operations and to convert frequency domain quantities into time domain quantities.)

The drudgery of learning math without concrete problems to solve is largely overcome by the study of network theory, which not only employs all of the tools shown above, but does so in a manner that links them together into a coherent system; wherein each branch serves to reflect and illuminate the others.

III. It's no wonder then, that mathematicians so often feel compelled to study network theory: e.g., Heaviside; Campbell; Zobel; Carson; Black; Nyquist; Bode; etc. Indeed, the rapid progress in network theory achieved in the period before World War II is due in large part to telephone company mathematicians responding to the pent-up demand for improved long distance communications.

It is interesting to note that all of the great theorists listed above (with the exception of Heaviside, whose work stemmed from telegraphic research) worked in the research departments at the American Telephone and Telegraph Company (AT&T) or at one of its subsidiaries—Western Electric and Bell Labs. These theorists functioned primarily as advisors to AT&T's physicists and engineers, e.g., Arnold; Crandall; Wegel; Wente; etc., who had been working to create the basic elements of communications systems: including microphones, tubes, amplifiers, loudspeakers, filters and transmission lines.

One of the most difficult problems was the development of low distortion amplifiers. Such amplifiers were used first to transmit speech and with subsequent advancements, to transmit music via long lines. Low distortion was critical due to the fact that a number of amplifiers in series were used along the lines. It is readily seen that frequent boosting of the signal is needed to overcome the conductor resistance. Under such conditions, speech becomes unintelligible unless distortion can be reduced throughout the chain.

A related problem was the development of loading networks to improve the efficiency of the long lines. These large-scale projects, at first subject to the hits and misses of trial and error engineering, were ultimately made predictable by the systematic knowledge developed by circuit theorists.

While basic circuit theory was unified by Kelvin in 1855, the following list includes only those books written after World War II—since by then, theorists had come to understand transients in feedback systems. Ironically, the same theory that ensured the automatic control of machinery in peacetime, pre-War industry, was raised to a fine art during the war; increasing enormously the lethal potential of weapons systems.

One book that appeared at the beginning of the war must be mentioned first, by way of preface, since this book is in many ways seminal to those that followed in its wake:

∞ 1942 ∞

Transients in Linear Systems

Murray F. Gardner and John L. Barnes,
(John Wiley & Sons, Inc., NY)

Gardner was a professor of electrical engineering at MIT; Barnes was a professor of engineering at UCLA. This is among the most influential of all books on electric circuit theory. The book stems from the graduate lectures of Vannevar Bush at MIT. (Bush became famous for his invention of the differential analyzer, which is widely acknowledged to have ushered in the modern computer age circa 1930.) In addition to its didactic function, this book is also intended to serve as a reference for practicing engineers. The authors show how to use an extensive table of transform pairs to solve many common engineering problems. This book was among the first to replace the older operational calculus of Heaviside with the Laplace-transform notation (see also Valley and Wallman [Section 1.4] reviewed in Part 1.) To buttress this radical notion, a thorough review of the mathematical literature relating to engineering problems is given in Appendix C. Finally, the bibliography comprises fifteen pages of tightly compacted references.

1955

☞ *Network Analysis* ☜

M. E. Van Valkenburg

(Prentice-Hall, Inc., Englewood Cliffs, NJ)

Van Valkenburg was Professor of Electrical Engineering at the University of Illinois. The author emphasizes the pole and zero approach to network analysis. In so doing, he clearly explains the complex-frequency plane and its use in determining the damping ratio of overshoots; indispensable for predicting the transient response of feedback amplifiers. In addition, this book provides a thorough explanation of the Fourier transform and clearly shows its relation to the Laplace transform. Chapter 14 covers tuned amplifier networks using a pentode tube as a current source. The final chapter is an extensive treatment of stability in feedback amplifiers. This book, while not considered seminal, was for many years one of the standard texts on the subject. Its reputation is well deserved as it teaches the basics in a way that none of the other books on this list quite approach. The 8th printing appeared in 1962.

1956

Pulse and Digital Circuits

Jacob Millman and Herbert Taub,

(McGraw-Hill Book Co., Inc., NY)

Millman was Professor of Electrical Engineering at Columbia University; Taub was Associate Professor Electrical Engineering at The City College of New York. In the preface to their book the authors, being teachers by profession, present strong views concerning what constitutes a proper curriculum in electrical engineering. They state that the sequence "should begin with physical electronics, continue with what might now be called classical (radio) circuits, and should conclude with pulse and digital circuitry." The authors emphasize that the best way to understand a circuit is to analyze it on a physical basis first, and then to follow up with the analytic solution. All of Millman's many books on electronics follow these precepts, and each book is uniformly excellent. Although this particular book stresses waveshaping techniques, there are a few sections that will be found useful to amplifier designers. These are mainly found in the chapter covering linear pulse amplifiers. These sections discuss, e.g., the transient response of an RC-coupled amplifier; shunt compensation to achieve critical damping of transient response; the cathode follower at high frequencies; and the "totem-pole" or active-load amplifier. This last section is especially valuable in that it shows how to set up a totem-pole and to adjust R so as to balance the out-of-phase currents for lowest distortion (see also Valley and Wallman in Part I.) There is also an informative section covering cathode-interface resistance (such as can occur with standby circuits.)

1957

Engineering Electronics

John D. Ryder

(McGraw-Hill Book Co., Inc., NY)

Reviewed in Part I. As usual, Ryder has a way of cutting to the essential elements of a subject and making them immediately accessible. See chapter 7 for a concise summary of pole-zero theory as it relates to stability considerations in feedback amplifiers.

1957

☞ *Electrical Engineering Circuits* ☜

Hugh Hildreth Skilling,

(John Wiley & Sons, Inc., NY)

Skilling was a professor of electrical engineering at Stanford. This book was developed as a new approach to classroom teaching at Stanford. Thus, it does not present the rudiments of its subject in the usual way, as by allotting equal space to each element of the discussion; rather, the most fundamental concepts are allotted the most space, and are the most thoroughly developed, especially with regard to graphical illustration. Indeed, this book excels in the area of graphical presentation. Many key concepts, with which other authors often assume familiarity, are illustrated by means of a series of cunningly contrived graphical representations. This becomes evident in the chapter on complex algebra, and in the chapters on network analysis and resonance that follow. There is even a chapter dedicated to explaining the three basic types of diagrams (chapter 8), which also tells how to map simple functions on the complex impedance plane. Another notable chapter is dedicated to nonlinear elements (chapter 13), a subject that is conspicuously absent from most other elementary texts on network analysis.

The waveforms of certain nonlinear passives are depicted (i.e., a resistor, an inductor, a detector, and a transistor), and the method known as the power series is used to evaluate each waveform. An example is then given of the application of Taylor's method for approximating a function out to three terms. The terms are plotted graphically to show the approximation to the actual function.This is a rare presentation of a valuable method of analysis that can be applied to, e.g., the transfer curve of a triode or pentode. There are further chapters on Fourier analysis, on transient analysis (Laplace transform), and on the complex frequency plane. This book is almost uniquely valuable in its ability to present many key aspects of basic circuit theory with a "beginner's mind". Rivals Van Valkenburg's book in this regard, while providing many new insights of its own.

1959

☞ ***Analysis of Electric Circuits*** ☜

Egon Brenner and Mansour Javid,
(McGraw-Hill Book Co., Inc., NY)

Both authors were Assistant Professors of Electrical Engineering at the City College of New York. This book represents a breakthrough to the modern approach to network analysis. The authors argue their points persuasively in the preface. The idea is to tie-in transient concepts early on in the student's career and to defer the use of transforms for later study. This places the emphasis on simple, fundamental problems. Such problems can be readily solved by classical means—i.e., by means of graphical analysis or by differential equations. The method culminates in the study of pole-zero configurations. The foundation is thus laid for a later study of transformation methods and of servo-mechanisms. In addition, there is an entire chapter covering magnetic coupling, and a final chapter that clearly explains the Fourier series.

1959

Analysis of Linear Systems

David K. Cheng,
(Addison-Wesley Publishing Co., Inc., Reading, MA)

Cheng worked in the Department of Electrical Engineering at Syracuse University. His book emphasizes the block diagram approach to network analysis, in which complex systems are reduced to block diagrams by means of transfer functions. Depicts the common transfer functions that appear, for example, in most of the classic TIM articles. Many illustrations and examples are provided. In preparation for this study, there are chapters on solving differential equations and another on analogous systems. For those familiar with mechanical physics these two chapters will make the electrical analogies immediately clear. The 2nd printing appeared in 1961.

1960

Electronic Circuits, Signals, and Systems

Samuel J. Mason and Henry J. Zimmermann,
(John Wiley & Sons, Inc., NY)

This book is a companion volume to Electronic Circuit Theory, reviewed in Part 1. Section 3.7 analyzes the triode circuit. Section 3.8 expands this analysis to derive the voltage gain of a triode feedback amplifier. Section 6.22 shows how to make successive differentiations in order to simplify the Fourier transformation. This allows one to quickly jump from the time domain to the complex-frequency domain, where network problems are more easily solved. The spectra of many common waveforms are then analyzed by means of the Fourier transform. Profusely illustrated and annotated.

1966

Electric Networks: Functions, Filters, Analysis

Henry Ruston and Joseph Bordogna,
(McGraw-Hill Book Co., Inc., NY)

Ruston was Associate Professor of Electrical Engineering at Brooklyn's Polytechnic Institute; Bordogna was Winterstein Assistant Professor of Engineering at The Moore School of Electrical Engineering, UOP. This relatively large book (550+ pages) covers the subject of network theory about as thoroughly as one could reasonably expect—and it does so without bogging down in abstruse detail. Abbreviations and symbols are given immediately at the front of the book, where they belong. As the book moves from basic network concepts to complex frequencies to network synthesis to network analysis, the authors take pains to explain the concepts in minute detail. In spite of this, or perhaps because of it, the presentation of network fundamentals is not always as accessible as in Skilling's book (above.) After the introduction of the concept of complex-frequency, the tie-in is made immediately to the representation of frequency-dependent impedances (i.e., reactive elements) as mathematical poles and zeroes on the complex plane. The mechanics of finding poles and zeroes is treated more thoroughly than in any book known to me. For example, tables are given that show the polynomial, the trigonometric form, and the phase plot of each pole or zero configuration. Each configuration is shown on the complex plane and is then correlated to a number of common filter functions. This method of parallel analysis provides a physical insight into the nature of filters not often encountered. An enormously successful book that is almost uniquely clear on this difficult subject.

1967

Introductory Signals and Circuits,

M. E. Van Valkenberg & Jose B. Cruz, Jr. and
M.E. Van Valkenburg
(Ginn & Co., Waltham, Ma.)

Cruz was a professor at the University of Illinois. By this time, Van Valkenburg had moved on to Princeton. This book presents an introductory approach to circuit analysis by means of signals and waveforms in simple networks. In other words, it explains in a straightforward manner what happens to a particular waveform when it passes through a particular circuit. This fundamental knowledge then allows the designer to predict the response of any given circuit to an arbitrary waveform. The authors stress differential equations as the preferred tools for evaluating the concepts. Transforms are deferred for the later study of transients in linear systems. Contains an extensive bibliography, conveniently organized into the various branches of circuit theory.

1974

Circuit Theory: Foundations and Classical Contributions

M.E. Van Valkenburg, ed.,
(Dowden, Hutchinson & Ross, Inc.,
Stroudsburg, PA)

This book is a collection of twenty-five seminal articles on electric circuit theory. It is Volume 8 in a series entitled *Benchmark Papers in Electrical Engineering and Computer Science* (by the same publisher.) The intent of this collection is to trace the development of circuit theory since its inception. Two of the articles are themselves histories of circuit theory. The editor introduces each chapter with a short essay in which he describes the significance of each paper. A recurring theme in these essays is that familiarity with the original contributors "frequently offer[s] insight and clarity not found in textbook treatments." Perhaps that is because, in so many cases, the originator of an idea best understands what it takes to grasp the theory behind it; being the only one who approached the idea from a blank slate.

1988

Spice: A Guide to Circuit Simulation & Analysis Using PSpice.

Paul W. Tuinenga
Companion software is also available.
Review in process.

PART IIIA
ELECTROMAGNETICS

Introduction

Nothing is more fundamental to the study of electronics than electromagnetic theory. Long before there were active—or even passive devices—there was electromagnetic theory. According to Loeb, the development of electromagnetic theory begins circa 1600 with the publication of Gilbert's book on magnetism, *De Magnete*. Loeb cites Newton's *Principia*, published in 1687, as the next great stepping stone in the development of electromagnetic theory. Newton's three laws of motion laid the foundation for the study of physics as a unified whole. Indeed, Coloumb's equations describing the behavior of electric charges are directly analogous to Newton's laws of force and motion.

Newton's laws enabled what Loeb calls "the great systematic period of scientific development." This was the period in which the various pieces of the electromagnetic puzzle were systematically investigated, and the basic laws of Ohm, Gauss, Coulomb, Ampère, and Kirchhoff were formulated. The period culminated in 1865, upon the publication of Maxwell's *Treatise on Electricity and Magnetism*. Maxwell's equations are the nearest thing to a scientific epiphany. Seemingly deduced from thin air, they are actually based rather firmly upon the 19th century electrical experiments of Faraday.

It is sufficient to state that Maxwell's equations unify all other observed electrical laws; including those of Ohm, Gauss, Coulomb, Ampère and Kirchhoff. Maxwell's book later inspired the theories of Lorentz on the electron and Einstein on relativity. Einstein himself has said that "The formulation of [Maxwell's] equations is the most important event in physics since Newton's time." *(The Evolution of Physics)*

1931

Fundamentals of Electricity and Magnetism

Leonard B. Loeb
(John Wiley & Sons, Inc., NY)

Loeb was Professor of Physics at the University of California at Berkeley. His book is an established classic in its field. Very clearly written and yet comprehensive in its scope, the book begins with a wonderfully concise history of electromagnetic science. The body of the book explores the various auxiliary laws that lead up to Maxwell's wave equations. Partial differential equations—rather than the more arcane vector calculus—are used to derive Maxwell's equations. Loeb's book is less used now because Loeb chose to employ the now outdated CGS system of physical units in his equations. Since these units are less familiar to modern readers it is inevitable that this book will ultimately fall into disuse, which is a shame. Nonetheless, the book remains a valueable source of detailed historical information. It reached its 3rd edition in 1947.

1951

Ferromagnetism

Richard M. Bozorth
(D. Van Nostrand Co., Inc., NY)

This enormous volume reveal's the secrets of Bell Labs' fabled ferromagnetic research. Chapter 1 introduces the basic concepts of ferromagnetism. There is a section in Chapter 2 that depicts the manufacturing steps in producing magnetic materials on a large scale. Chapter 11 explains the three parts of the magnetization curve according to domain theory. Appendix 4 gives the magnetic properties of a large number of magnetic materials. Like the book itself, the bibliography is enormous, containing as it does more than 70 pages of related references. See also Bozorth's earlier summary of the subject in the *Bell System Technical Journal*.[1]

∞ 1954 ∞

Introduction to Electric Fields

Walter E. Rogers

(McGraw-Hill Book Co., Inc., NY)

Rogers was Associate Professor of Electrical Engineering at the University of Washington. Includes an especially thorough discussion of Gauss's law, which is fundamental to the understanding of Maxwell's equations. Shows the complete derivation of Child's ⅔ power law as derived from Poisson's equation, and explains the effect of space charge on potential distribution in vacuum tubes (see also Dow under TUBE PHYSICS, below.) Uses vector calculus to derive Maxwell's equations. This book excels as an introduction to the field by virtue of its evocative illustrations and its numerous backlit rubber sheet models. Professor A.D. Moore at the University of Michigan made the fluid-flow maps.[2]

∞ 1958 ∞

☞ ***Engineering Electromagnetics*** ☜

William H. Hayt, Jr.

(McGraw-Hill Book Co., Inc., NY)

Hayt was Associate Professor of Electrical Engineering at Purdue University. More theoretical than the title implies, this book is nonetheless one of the clearest books I've seen on this complex subject. As Hayt himself says in the preface to his book: "This book has been written with the goal of making it as easy as possible for the student to teach himself." In keeping with this philosophy of self-teaching, the book contains an introductory chapter on vector analysis that succinctly summarizes the subject in less than 25 pages (essential for proceeding further in the book.) The book proper begins by thoroughly explaining the relation of electric field intensity to electron motion in free space. Hayt introduces Maxwell's equations early on by linking them to the more fundamental theories, such as Gauss's law. In so doing, he thoroughly explains and derives the basic principles of electrical theory without skipping any steps, allowing the reader to experience for himself the discoveries of Coloumb; Gauss; Poisson; and Maxwell. Having established the basic laws of electrical forces, Hayt then explains the forces acting within steady magnetic fields. This is followed by a discussion of time-varying fields. Maxwell's equations are then applied to representative electrical problems—such as wave motion; skin effect; radiation; and basic circuit theory. Hayt completes his exposition by applying all four of Maxwell's equations simultaneously to the familiar example of the space charge in vacuum tubes. The exercise ends with the derivation of the Child-Langmuir law, or 3/2 power law, which is the fundamental law of tube conduction. Hayt's lucid, easy-going style and unerring organizational logic encourages the reader at every turn to explore the various theories, while his droll humor adds pungency to the task of learning. The 5th edition appeared in 1989, evidence of its sustained influence within academic circles.

∞ 1966 ∞

☞ ***The Physics of Electricity and Magnetism*** ☜

William Taussig Scott,

(John Wiley & Sons, Inc., NY)

Scott was Professor of Physics at Smith College. This book ties together electric circuit theory and electromagnetics in a way that no other book in this survey quite approaches (see Part II of this series for books on electric circuit theory.) Scott's book begins, as all such books must, with a discussion of Coulomb's law for electric field strength. The author shows how Coulomb's wonderfully simple law is merely a special case of the more powerful and encompassing law formulated by Gauss. He next explains how the motion of charge in vacuum tubes gives rise to variations of electric field. The relation between potential difference and field strength is then discussed. This leads to the concept of potential gradient. Having established the basics, Poisson's equation is then applied to a vacuum tube in order to show that the sum of the kinetic and potential energies of each electron is constant. This is equivalent to stating that the charge density will be inversely proportional to electron speed. An equation is then derived that makes it possible to find the way in which field strength, charge density, and potential each vary with distance x from the cathode. These relatively advanced concepts are all introduced in the first chapter as being fundamental to what follows. They are more fully developed in later chapters, after a number of related concepts are first clarified. Among these concepts are electric conduction within metals; the shielding of fields by metals; lines of force within triodes; and dielectric effects. Chapter 5 culminates in a discussion of electric circuit theory based on Kirchhoff's method and the theory of determinants. A thorough discussion of magnetic field theory follows. Chapter 8 discusses magnetic materials and shows the magnetization curves for a large number of transformer core materials. The hysteresis loop is analyzed in fine detail. Various core geometries are shown including one with an air gap (section 8.7.) Alternating current theory is next discussed, including complex waveforms and transients. The book ends with a discussion of electromagnetic radiation and its relation to the special theory of relativity. Tensor analysis is used to combine Maxwell's equations and to illustrate the Lorentz transformation. An appendix

explains vector calculus by means of Maxwell's shorthand operators. Throughout the book, the history of each topic is always touched upon, and supporting references appear frequently. A very thorough and yet eminently readable textbook.

1966

Electromagnetics

Robert S. Elliot,

(McGraw-Hill Book Co., Inc., NY)

Elliot was Professor of Engineering at UCLA. This book stands as a pillar of pedagogy among science books, in my humble opinion. Its organization and intent should be studied by all aspiring authors of technical subjects. Not only is the entire subject matter developed out of a single experimental postulate based on Couloumb's law, but each topic grows out of the historical backdrop of its subject matter. The author explains his purpose in the preface:

> "Without the historical background, the reader of a technical exposition often is left with a bland reaction to his first encounter with a new physical concept. Yet, more often than not, there is behind this concept a rich heritage of thought, as outstanding human minds have struggled to identify the concept and clarify it. Awareness of this heritage instills added respect for each new principle and reveals an important lesson which all scientific history teaches—that complete understanding is rarely attained and that the struggle for clarity is still going on… The reader will also note that extensive use has been made of direct quotations from the writings of scientific discoverers. It is hoped that this adds to the sense of reality in the reconstruction of the event and gives some insight to the character of the discoverer."

What's new about Elliot's treatment is the featured role of the historical aspects of his topics, including original illustrations in most cases. The author also has a knack for presenting his material in a manner that emphasizes key concepts; thereby clarifying fundamental principles. Poisson's equation, for example, is almost never explained clearly even when it is fully developed by other authors. Elliot makes Poisson's intent clear with one or two illustrations and then relates the concept to the inner workings of the vacuum tube. Such penetrating insight permeates the entire book.

PART IIIB
TUBE PHYSICS

Introduction

Tube physics properly begins with Richardson's equation, first announced in 1901 In 1907 Lee De Forest patented the triode. De Forest described his invention as a "Device for Amplifying Feeble Electrical Currents" (US patent #841,387.) In 1912, De Forest invented the world's first triode amplifier. Technically speaking, it was a 3-stage, single-ended voltage amplifier. The amplifier barely worked, however, due to excess gas in the tubes. Like most scientists of his day, De Forest believed that gas molecules aided amplification. It was later proved that this is true only for operation at impractically low plate voltages. At higher voltages the positive ions interfere with normal tube operation.

The most obvious commercial application for amplifiers at that time was the telephone repeater. Thus, De Forest soon brought his amplifier to AT&T. The telephone people were intrigued by this new invention, but didn't quite know what to make of it. Harold Arnold was recruited from the University of Chicago to see if the triode could be developed into something practical.

From his work with theoretical physicists (such as Nobel Laureate Robert Millikan) Arnold believed that a pure electron discharge could produce current flow in the *absence* of gaseous ions (the infamous "blue glow".) Irving Langmuir, a research chemist at the General Electric Company, echoed Arnold's belief in pure thermionic emission; but until 1912, and the advent of the molecular vacuum pump, no one could prove otherwise.

Armed only with his belief, Arnold pioneered the hard-vacuum tube at Western Electric (WE.) Arnold's persistence culminated in the breakthrough 101B type triode in 1915. This breakthrough triode had an average lifespan of 4000 hours—ten times greater than any of its predecessors. Since the majority of tubes developed at WE were intended for demanding applications—such as transoceanic telephone systems—WE tubes were built to the highest possible standards as to both performance and reliability.

The materials used for these tubes were often exotic, such as platinum and iridium for filaments. These directly-heated filamentary cathodes were then coated with the oxides of barium and strontium applied alternately in successive layers. Like a fine Samurai sword, the filament is methodically heated to 1000˚C after each oxide application. In what became known as the WE standard filament, sixteen such layers were applied. Tubes containing WE standard filaments were found to last more than 20,000 hours under laboratory conditions.

In America, most of the big breakthroughs in tube development occurred at either Western Electric or at General Electric. The initial problem was simply to evacuate the bulb—once the "guts" were installed—and to ensure a hard vacuum. The second problem was to produce rugged, highly emissive cathodes. The third problem was to analyze the general characteristics of triodes in order to develop tubes for diverse applications.

The work of formulating the functional relationships of grid, plate, and cathode was delegated to H.J. van der Bijl, the senior research physicist at WE. In deducing the tube constants and gain equations, Van der Bijl became the father of tube theory. His book, *Theory of the Thermionic Tube and Its Applications* (reviewed in Part 1 of this series), was the first major textbook on vacuum tubes (see also, below.)

1920

Theory of the Thermionic Tube and Its Applications

H.J. van der Bijl,
(McGraw-Hill Book Co., Inc., NY)

Reviewed in Part I. In addition to its applications coverage, this book also stands as one of the preeminent books covering the physics of tube operation. Van der Bijl made a number of brilliant fundamental discoveries regarding tube physics, which helps to explain his utter clarity of exposition on this subject. In this regard, van der Bijl's writing style ranks with that of Langmuir (see, for example, Langmuir's paper on the pure electron discharge[4].)

1933

Theory of Thermionic Vacuum Tubes

E. Leon Chaffee,
(McGraw-Hill Book Co., Inc., NY)

Reviewed in Part I. Chaffee was, like van der Bijl, a physicist by training. Chaffee's main contribution consists in an expansion or extension of the pioneering work done by van der Bijl in defining the tube coefficients—especially as regards circuit modeling at high frequencies. His book also serves, like van der Bijl's, as an authoritative source of references toearly research in the field.

1934

☞ ***The Physics of Electron Tubes*** ☜

L.R. Koller,
(McGraw-Hill Book Co., Inc., NY)

Koller was a research physicist at the General Electric Company (where Langmuir worked.) This diminutive little book shines as a beacon of insight into the intricacies of tube physics. Koller's ability is second to none in clearly explaining the central concepts with a bare minimum of distracting details. Rivals the lucid narrative of van der Bijl in this regard. Thoroughly explains the theory of emission as pioneered by Richardson and Schottky. Also provides a rare insight into how "getters" work. Indeed, everything about this book displays rare insight. The 2nd edition appeared in 1937.

1937

☞ ***Fundamentals of Engineering Electronics*** ☜

William G. Dow
(John Wiley & Sons, Inc., NY)

Reviewed in Part I. Goes into greater detail than any other book known to me about tube physics, other than Spangenberg's below. Provides information not found in Spangenberg's book, however, especially as regards the influence of space charge on potential distribution; and of the influence of electrode geometry on high frequency response. The 2nd edition appeared in 1952.

1941

Electronics

Jacob Millman and Samuel Seely,
(McGraw-Hill Book Co., Inc., NY)

Millman was Professor of Electrical Engineering at Columbia University; Seely was Professor and Chairman of the Department of Electrical Engineering at Syracuse University. This book provides over 250 pages of tube physics. The authors feel so strongly about fundamentals that the entire first half of the book is given over to physics as opposed to applications. The applications section that follows tends to emphasize basic engineering problems such as load-line construction. The book is thus valuable mainly as regards physics. What is treated in more depth than in any of the other books here listed is the statistical theory of emission (as distinguished from the classical or kinetic theory.) Richardson first modeled electron emission on kinetic principles, probably because hot gas was the closest known analogy to this new (at the time) phenomenon. The statistical theory arose from a somewhat more precise approach pioneered by Fermi and Dirac. This latter theory is thoroughly summarized by Nottingham in the *Handbuch der Physic*.[5] It is yet more concisely summarized by Hemenway, Henry, and Caulton in their book *Physical Electronics* (chapter 3.)[6] Millman and Seely throw particular light on the potential-energy system of metal-to-metal contacts (pp.143–159.) The 2nd edition appeared in 1951.

1943

Applied Electronics

MIT Staff,
(John Wiley & Sons, Inc., NY)

Reviewed in Part I. The 1954 edition by Truman S. Gray is an attempt to provide every known fact of any significance about the field of electronics. This includes, of course, tube physics; upon which subject this book excels. There is ample detail and exceptional clarity at every turn. The derivation of the 3/2 power law is about as thorough as can be found anywhere. In addition, many footnote references point toward further reading.

1948

☞ *Vacuum Tubes* ☜

Karl R. Spangenberg,
(McGraw-Hill Book Co., Inc., NY)

Spangenberg was Professor of Electrical Engineering at Stanford. This book formalizes much of the research done by tube manufacturers,[7, 8, 9] and is one of the most important books on tube physics published in America. Derives the amplification factor of pentodes from electrostatic fields (as pioneered by Dow for triodes.)[10] This was the second book to appear in the monumental McGraw-Hill Electrical and Electronic Engineering Series (after Terman's *Radio Engineering.*) This book, along with boss Terman's, established Stanford as the center for tube research on the West Coast. On the East Coast (due to Chaffee and the Cruft Laboratory) Harvard reigned supreme—until MIT cranked out its monumental Radiation Lab Series in response to the wartime crisis (see Valley and Wallman, *op. cit.*, in Part I of this series.) Thereafter MIT gained the ascendancy. It is only fair to say, however, that throughout the 40s, a tremendous amount of productive research was accomplished on all sides to try to make oxide-coated cathodes stable, quiet, and reliable.[11] Indeed, it was in 1948 that RCA released its famous "Red Base" series of tubes,[12] the same year that Spangenberg's book appeared.

1951

Basic Electron Tubes

Donovan V. Geppert,
(McGraw-Hill Book Co., Inc., NY)

Geppert worked at the Motorola Research Laboratory. Provides a useful summary of the influence of tube geometry upon the tube coefficients, μ, g_m, and r_p for both triodes and pentodes. Clearly shows how to graphically derive these coefficients from the plate characteristics. Uses rubber sheet models to show the potential distribution in triodes, tetrodes, and pentodes. Thoroughly explains the behavior of beam power tubes by means of a variety of illustrations and field diagrams.

1953

Engineering Electronics

George E. Happell and Wilfred M. Hesselberth,
(McGraw-Hill Book Co., Inc., NY)

Reviewed in Part I. Contains a very concise overview of tube physics. The explanation of the space-charge equation (Child-Langmuir equation or 3/2 power law) is especially clear. The steps in the derivation from Poisson's equation are explained about as well as by anyone on this list.

1953

Fundamentals of Electronic Motion

Willis W. Harman,
(McGraw-Hill Book Co., Inc., NY)

Harman was Associate Professor of Electrical Engineering at Stanford. His book is in many ways a simplified summary of colleague Spangenberg's, although it provides insights not found elsewhere. One of its most significant features is its preface. The author's pedagogical insight is every bit as great as his physical insight. Explains the basics of electron ballistics within electric, magnetic, and electromagnetic fields for both static and time-varying fields.

1957

Engineering Electronics

John D. Ryder,
(McGraw-Hill Book Co., Inc., NY)

Reviewed in Part I. Ryder's insights into tube physics are well worth pondering. His analysis of the trajectory of a single electron within a vacuum tube is fascinating (pp. 5–7); as is the whole of Chapter 2, "Physical Phenomena in Electron Tubes."

1967

Electronic Devices and Circuits

Jacob Millman and Christos C. Halkias,
(McGraw-Hill Book Co., Inc., NY)

Reviewed in Part I. This book presents the essentials of Millman's earlier book, *Electronics* (reviewed above), in a more concise and easily digested form.

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PART IV
SPECIALIZED TITLES

This section includes books that tend to focus on one particular aspect of tube amplifier design: such as grounding and shielding; transformer design; or power supplies. The books in this section are arranged alphabetically according to subject matter, and then chronologically under each subject heading. Those books marked with a "☞" will be of greatest interest to the audio designer

AMPLIFIER CIRCUITS

1959
☞ *Mullard Tube Circuits for Audio Amplifiers* ☜
Mullard Staff
(Mullard Ltd., London)

Contains sheet metal diagrams, part lists, and schematics for building a number of tube power amps and preamps. Also provides performance data as well as extensive guidance on general design and construction principles. A new edition appeared in 1993 from Old Colony Sound Lab (Peterborough, NH.)

1979
☞ *Audio Amplifiers* ☜
M.O. Valve Co., Ltd.,
(M.O. Valve Co., Ltd., London)

This booklet is essentially a compilation of M. O. Valve technical bulletins. Also contains design data for "kinkless tetrode" tube types KT77 and 88. In addition, gives curves and data for ultra-linear amplifiers not to be found elsewhere. There is, for example, a curve for the variation in IM distortion vs. power output for different UL taps using KT88s (in the appendix to "Application Report No. 3.") There is also a rare specification for tube life in the KT77 section. In addition to power amps, there are schematics for complete preamps, including tables and graphs for setting the playback EQ to a wide variety of disc and tape standards.

1986
Rorforstarkare
Jean Hiraga,
(publisher unknown)

Hiraga, the newly appointed editor of France's oldest hi-fi magazine, *La Nouvelle Revue du Son*, is an acknowledged authority on the history of the single-ended amplifier. Written in Swedish, this book consists mainly of photos, schematics, and spec sheets of vintage tube equipment. Reviewed in the Old Colony Catalog.

1986
The Tube Amp Book
Aspen Pitman
(Groove Tubes, Sylmar, CA)

An encyclopedia of guitar amp circuits. Perhaps the most interesting aspect of this book from the audiophile's point of view are the sonic descriptions of many common audio tubes. The sound of a tube in a guitar amp generally correlates well to its "sonic signature" in an audio amp. The 4th edition appeared in 1993.

1990
The Williamson Amplifier
D. T. N. Williamson
(Audio Amateur Publications Inc.,
Peterborough, NH)

This little booklet comprises a collection of articles written by Williamson in the late 40s. Accompanied by more than 40 illustrations, it gives the construction details for an established classic. It is not widely known outside England, but this design stems from an august history. In 1938, an editorial in *Wireless World* showed how to adapt W.T. Cocking's original "high quality" amplifier[1] for use in a receiver.[2] Cocking's amplifier was essentially a push-pull pair of triodes fronted by a balanced driver stage. The adaptation by the *Wireless World* editors incorporates a unity-gain phase-splitter at the input. In a 1946 follow-up article, the editors added negative feedback[3] to the design. One year later, D.T.N. Williamson's landmark article appeared, "Design for a High Quality Amplifier." [4]

Williamson advocated adding, not just a phase-splitter, but an additional gain stage to the circuit. The gain stage recovered some of the input sensitivity lost to negative feedback. It also allowed more conservative operating parameters for the front end stages. Williamson was particularly concerned with changes in effective gain that occur near cut-off that might then affect the "accurate reproduction of transient waveforms." Williamson's gain stage was direct-coupled to the input phase-splitter so did little harm in point of phase shift.

In his article, Williamson echoed the words of Cocking when he summed up his analysis of the requirements for high quality amplification: "It appears then that the design of an amplifier for sound reproduction to give the highest possible fidelity should centre round a push-pull triode output stage and should incorporate negative feedback." Williamson takes particular care to defend his findings. Some of the more salient are outlined below:

(1) Output impedance of the amplifier to be "much lower" than the loudspeaker impedance. "In order to avoid a high bass-resonance frequency, the suspension stiffness in a high-grade loudspeaker is kept low, and obviously the power loss in such a suspension cannot be large. Electro-magnetic damping is therefore important in controlling the motion of the cone." Williamson suggested that a damping factor of 20-30 was required for moving-coil loudspeakers.
(2) Negative feedback is optimized at 20dB. Williamson stated that "there will be little if any audible improvement to be gained with this amplifier by increasing the amount of feedback beyond 20dB."
(3) Frequency response to be –3dB @ 3.3Hz & 60kHz in order to minimize phase shift.
(4) Phase shift to be less than 20° within the audible range in order to optimize transient response.
(5) Adequate power reserve to accommodate large dynamic peaks.
(6) Output transformer to be designed along specific lines (as shown in the appendix.) Thus, the evolution of the "*Wireless World* Push-Pull Quality Amplifier", as begun in 1934 by Cocking, culminated in the famous Williamson amplifier of 1947. The distinguishing feature of this amplifier, in each of its incarnations, is triode tubes in push-pull (although Williamson's amplifier used KT66 beam tubes converted to triode.) Triodes were preferred over pentodes because, in spite of their reduced output, the triode distortion products were found to be less objectionable.[5]

☞ ***Sam's Photofacts*** ☜
(Howard W. Sams & Co., Inc., NY)
The ultimate source for schematics of vintage tube components.

Audio Anthology:
When Audio was Young, Vols. 1—5
Various Authors,
(Audio Amateur Publications, Inc.,
Peterborough, NH)
Reprints of classic articles that appeared in *Audio Engineering* magazine, one of America's best sources of technical articles from the golden era of high fidelity. Reviewed in the Old Colony Catalog.

Communication Engineering

1932
Communication Engineering
William Littell Everitt
(McGraw-Hill Book Co., Inc., NY)
Everitt was Dean of the College of Engineering at the University of Illinois. This is one of the most widely quoted texts whenever the subject of radio transmission or modulation is discussed by later authors. Provides a broad theoretical base for radio communication. The chapter on modulation is exceptionally complete. One of the rarest of technical books in that droll humor bubbles up from time to time. The 3rd edition appeared in 1956.

Construction Techniques

1958
Mullard Tube Circuits for Audio Amplifiers.
Mullard Staff,
Reviewed under **Amplifier Circuits**, above.

1966
Electronics Construction Techniques
George L. Ritchie
(Holt, Rinehart and Winston, Inc., NY)
Ritchie was an instructor at San Jose City College; a school known for its DIY approach to electronics. He has produced a first-rate guide to building prototype electronics projects. Ritchie's book tells how to draw the chassis from flat sheetmetal to exploded pictorial view showing all part locations. Explains what machine shops expect to see in a fab drawing—or, do it yourself using manual sheetmetal tools such as the punch, the brake, and the squaring shear. Explains the proper use of hand tools used in marking and scribing sheetmetal; including the sharpening of bits and twist drills. Explains how to lay out front panel markings and how to make your own silkscreen. Explains in detail how to solder and how to tie and lace cables. Every

aspect of printed circuit board design and fab is discussed. Summarizes the entire prototype development process.

∽ 1968 ∽

Amplifier Devices and Low-Pass Amplifier Design

E.M. Cherry and D.E. Hooper,
(John Wiley & Sons, Inc., NY)
See review in Part I.

∽ 1980 ∽

How to Make Printed Circuit Boards

Joel Goldberg,
(publisher unknown)
Reviewed by Old Colony.

∽ 1991 ∽

Electronic Techniques: Shop Practices and Construction

Robert S. Villanucci, et al,
(publisher unknown)
Reviewed by Old Colony

∽ 1991 ∽

Electronic Techniques: Shop Practices and Construction

Robert S. Villanucci, et al.
Review in process.

DRAFTING

∽ 1958 ∽

Graphic Science

Thomas E. French and Charles J. Vierck,
(McGraw-Hill Book Co., Inc., NY)

Both authors taught engineering drawing at Ohio State University. This book explains the use of all the common drafting implements. Thoroughly reviews geometric principles and explains the theory of orthographic projection. Contains thousands of fully drafted illustrations. Explains how to make working drawings for fab shops—from title blocks to tolerances. The final chapter shows how to draw curves by means of graphic calculus. In addition, there is a 7-page glossary and a 9-page bibliography that includes standards publications by national societies. Also provides complete dimensions for standard fasteners. As a how-to manual, this 750+ page book is easily the best I have yet seen on this subject.

FEEDBACK THEORY

∽ 1945 ∽

Network Analysis and Feedback Amplifier Design

H.W. Bode
(D. Van Nostrand Co., Inc., Princeton, NJ)

Bode, who followed T.C. Fry as head of the Mathematics Department at Bell Labs, developed the relation between amplitude and phase shift, and established the minimum phase requirement for feedback amplifiers.[6] Although more succinctly explained by others,[7] Bode's method remains the simplest means of predicting the stability margin of a feedback amplifier.

∽ 1951 ∽

Servomechanisms and Regulating System Design, Volume 1

Harold Chestnut and Robert W. Mayer
(John Wiley & Sons, Inc., NY)

Both authors worked at the General Electric Company in the Aeronautics and Ordnance Systems Division. This book, the first of two volumes, provides a very clear presentation of control theory. Gives many practical examples. Picks up where books on network theory leave off regarding transients in feedback systems. Very clearly explains Nyquist's stability criteria for feedback amplifiers in terms of transfer functions. Thoroughly explains the relationship of damping ratio to phase margin (see also Van Valkenburg under ELECTRIC CIRCUIT THEORY— in Part II.) These concepts relate directly to transient distortion in feedback amplifiers. Thus, TIM theory,[8] as developed during the 1970s, leaned heavily on control theory for many of its key concepts. Assumes a working familiarity with the Laplace transformation. The 2nd edition appeared in 1961.

∽ 1982 ∽

Feedback

Fred D. Waldhauer
(John Wiley & Sons, Inc., NY)

The material in this book arose from a course Waldhauer taught at Bell Labs. Waldhauer adopts "a basic change in outlook that greatly simplifies feedback analysis and design." This approach had been popular at Bell Labs ever since Bode published his book (above) purporting to simplify the prior work of Black and Nyquist. Waldhauer deliberately avoids getting bogged down in mathematical detail and attempts to provide a clear mental picture of how feedback systems operate. One of the key objectives of this book is to provide practical tools for engineers who seek to design feedback systems. Provides

programs, for example, for manipulating polynomial roots on the HP 41C calculator. Such roots help to define the poles and zeroes of a network, essential for computing the damping ratio of transients and of establishing critical damping at the amplifier output. Explains why the *delay* in signal paths is the "fundamental limitation on the application of feedback." This delay factor was rigorously analyzed by Cherry in 1981. Cherry explicitly defined the delay function (see Cherry's paper in ref. 8) and later showed how to unconditionally overcome delay to avoid transient distortion in feedback amplifiers.[9]

GROUNDING, SHIELDING AND NOISE

∞ 1967 ∞

Grounding and Shielding Techniques in Instrumentation

Ralph Morrison

(John Wiley & Sons, Inc., NY)

Covers mainly externally induced sources of noise; such as RFI, EMI, and common-mode noise. Employs field theory to provide one of the best theoretical treatments of the principles of shielding yet seen. Section 6.18 shows how to terminate a ground system in either a series (bus) or a star (single-point) configuration. Although this section is brief, it at least gives the main clues to enable low-noise grounding in complex systems. The 2nd edition appeared in 1977.

∞ 1976 ∞

☞ ***Noise Reduction Techniques in Electronic Systems*** ☜

Henry W. Ott,

(John Wiley & Sons, Inc., NY)

Ott's book grew out of a lecture series given at Bell Labs for in-house engineers. His book provides immediate solutions to the most common noise problems in electronic equipment. For the most part, the book takes a pragmatic approach, with mathematics brought in only as needed. No book here listed is anywhere near as comprehensive in its approach: there is an entire chapter on grounding; another on shielding; and another on decoupling and filtering. There are also chapters covering the noise arising from passive components and active devices. The author is typically concise yet methodical in his treatment of the subject matter. The chapter on grounding, for example, illustrates numerous systems, e.g., single-point; multi-point; hybrid; low-frequency; high frequency; analog-plus-digital; and multiple chassis systems. Each grounding system is then briefly discussed in terms of its pros and cons. The chapter on shielding shows eleven methods for grounding a shield. The attenuation factor for each variation is then tabulated and compared. An indispensable resource for understanding noise sources and their effective suppression. The 2nd edition appeared in 1988.

∞ 1979 ∞

Handbook of Electrical Noise: Measurement and Technology

Charles A. Vergers

(TAB Books Inc., Blue Ridge Summit, PA)

Covers mainly the internal noise sources in amplifiers; such as circuit elements and active devices. Good theoretical treatment (see also Valley and Wallman; Gewartowski and Watson; and Shea—all reviewed in Part I of this series.)

∞ 1992 ∞

Noise and Other Interfering Signals

Ralph Morrison

Review in process.

HIGH FIDELITY TECHNIQUES

∞ 1953 ∞

High Fidelity Techniques

John H. Newitt,

(Rinehart & Co., Inc., NY)

A window on the subject of high fidelity in its heyday. Newitt, like Lawrence Baker Arguimbeau, was an MIT professor with a strong interest in audio. Excellent coverage of the leading tube amps of the day; including the Brook Model 10 and the McIntosh 50W-1.

∞ 1957 ∞

☞ ***Understanding Hi-Fi Circuits*** ☜

Norman Crowhurst,

(Gernsback Library, Inc., NY)

Crowhurst's definitive statement on high fidelity techniques. A prolific author of audio-related articles, Crowhurst was formerly Senior Mathematics Lecturer at London S.E. Technical College. This book explains Crowhurst's unique perspective on a number of specialized design problems, more or less in laymen's terms. Contains an extensive chapter on phase splitters that compares the most commonly employed circuits.[10] Also includes an extensive comparison of output circuits; including the Unity-Coupled, the Ultralinear, and the Circlotron. Contains an excellent, simplified method for predicting the stability of feedback amplifiers. Contains a thorough chapter on noise and another on

RIAA preamplifiers. A unique book, one of the best on high fidelity techniques.

∞ 1959 ∞

Mullard Tube Circuits for Audio Amplifiers.

Mullard Staff,

Reviewed under AMPLIFIER CIRCUITS, above.

∞ 1990 ∞

The Williamson Amplifier.

D. T. N. Williamson,

Reviewed under AMPLIFIER CIRCUITS, above.

MEASUREMENTS

∞ 1935 ∞

Electronic Measurements in Radio Engineering

Frederick Emmons Terman

and Joseph Mayo Pettit,

(McGraw-Hill Book Co., Inc., NY)

Terman was Dean of the School of Engineering at Stanford; Pettit was Associate Professor of Electrical Engineering at Stanford. The second edition appeared in 1952. The title was at that time changed to *Electronic Measurements* to indicate that the scope of the book had been extended to encompass fields of electronics beyond that of radio. The aim of the new book, in typical Termanian fashion, was to provide "a comprehensive engineering discussion of the measuring problems commonly encountered by radio or electronic engineers." The book was meant to be a companion volume to Terman's equally comprehensive *Radio Engineering* (to be reviewed under RADIO ELECTRONICS in Part V.) As such, the book is intended to be used as both a textbook and as a reference for practicing engineers. In addition, there are more than 1000 references to related books and articles in the literature. Chapter 7 shows how to obtain the characteristic curves of tubes and how to measure the basic tube parameters. Chapter 8 shows how to perform a variety of amplifier tests, including: voltage gain; phase shift; transient and frequency response using square waves; harmonic distortion (including the individual harmonic products); and intermodulation distortion.

∞ 1935 ∞

☞ ***Audio Measurements*** ☜

Norman Crowhurst,

(Gernsback Library, Inc., NY)

Explains the common measurements for all types of audio components. Includes numerous tips on how to detect borderline instability in amplifiers that otherwise meet conventional standards. An excellent companion to the author's *Understanding Hi-Fi Circuits* (reviewed under HIGH FIDELITY TECHNIQUES, above.)

∞ 1995 ∞

EIA, JEDEC, and TIA Standards and Engineering Publications

Electronic Industries Association (EIA)

(Global Engineering Documents, Englewood, CO)

Global is the authorized distributor for the EIA's engineering standards publications. EIA-490 provides the *Standard Test Methods of Measurement for Audio Amplifiers*. EIA-295 provides *Disc Recording Characteristics*. EIA-518 gives the *Tape Recorder Measurement Standard*.

POWER SUPPLIES

∞ 1971 ∞

☞ ***Regulated Power Supplies*** ☜

Irving M. Gottlieb,

(Howard W. Sams & Co., Inc., Indianapolis, IN)

Highly recommended for anyone seeking to understand active regulators. Gottlieb is about as objective toward his subject as one could reasonably imagine. He constantly questions his assumptions and qualifies his conclusions. The theory of regulation is explained in the first chapter, pro and con. Chapter 3 is perhaps the most essential, as it contains an exhaustive look at the dynamic behavior of voltage and current regulators. In this chapter, the regulated supply is modeled after a working amplifier circuit. All of the typical problems that apply to amplifiers are then shown to apply equally to regulators. The concluding chapters contain extensive implementation examples. Gottlieb's approach to regulator design is about as enlightened as one will find anywhere. The 4th edition appeared in 1992.

TRANSFORMER DESIGN

1934

Radiotron Designer's Handbook

F. Langford-Smith, ed.,
(Amalgamated Wireless Valve
Company Pty., Ltd., Australia)

Reviewed in Part I. A treasure-trove of transformer lore, both power and audio. Tells how to make many useful calculations for audio transformers but lacks practical examples and winding data.

1943

☞ ***Magnetic Circuits and Transformers*** ☜

MIT Electrical Engineering Staff
(John Wiley & Sons, Inc., NY)

This book marks a turning point in MIT's heuristic philosophy in that many different specialists are brought together to provide both a more extensive and a deeper coverage of the subject than is otherwise possible from a single author. At Stanford, Terman disagreed vehemently with this approach, citing the lack of continuity of this approach believing that it would impair continuity. Within a few years however, he too relented and adopted this approach; as by then the field had become too unwieldy for a single author to survey with complete authority. A number of other highly successful electronics texts have been produced in this manner: e.g., *Radiotron Designer's Handbook; Vacuum Tube Amplifiers; and Applied Electronics* (all reviewed in Part I.) The book here reviewed thus provides the combined insight of the MIT electronics staff on the theory of transformers. Covers all the common types of transformers and chokes, including audio transformers. Not a how-to book, but explains how to make magnetic-circuit computations in minute detail by means of equations, graphs, and data tables. Gives extensive consideration to core saturation and to gapping procedures. Thoroughly explains core losses and transformer-related distortions. Analyzes the frequency and phase characteristics of both output and interstage transformers, and explains the tradeoffs involving interleaved windings. The 12th printing appeared in 1958.

1947

☞ ***Transformers and Circuits*** ☜

Reuben Lee Electric
(John Wiley & Sons, Inc., NY)

A how-to book that is also strong on theory. Full of tricks and insights into the woolly world of transformer design. Virtually every aspect of transformer design is covered for a wide variety of transformer types, including audio transformers (although information concerning specific winding techniques is skimpy); high-voltage transformers; and pulse transformers. There is a detailed design example for both a filament and a plate transformer. Shows how to set up a calculation sheet for keeping track of the turns. Thoroughly covers inductor design. Tells how to perform all the standard transformer tests. The 3rd edition appeared in 1988.

1964

Electronic Transformers

Harold H. Nordenburg
(Reinhold Publishing Corp., NY)
Review in process.

1967

Transformers for Electronic Circuits

Nathan R. Grossner
(McGraw-Hill Book Co., Inc., NY)
The 2nd edition appeared in 1983.
Review in process.

1969

Computer-Aided Design of Magnetic Circuits

Alexander Kusko and Theodore Wroblewski
(MIT Press, Cambridge, MA)
Review in process.

1978

Transformer and Inductor Design Handbook

Colonel William T. McLyman
(M. Dekker, NY)
The 2nd edition appeared in 1988.
Review in process.

1980

☞ ***Practical Transformer Design Handbook*** ☜

Eric Lowdon
(TAB Books Inc., Blue Ridge Summit, PA)

A how-to book that is also strong on theory. Mainly useful for power transformer and choke design, there is nonetheless a brief but informative chapter on how to minimize stray capacitance and leakage inductance in audio transformers (and the various tradeoffs involved—see pp. 154–160.) Explains the pros and cons of sectionalizing; bifilar winding; and balanced windings. Gives a design example for a power transformer wherein five different parameters are alternately optimized. There is also a thorough treatment of the effect of various rectifiers on power transformer performance. Also covers autotransformers. Tells how to perform all the standard transformer tests. Includes numerous design charts and extensive materials data. So far as basic power transformers are concerned, this 389 page book is both comprehensive and immediately practical. The 2nd edition appeared in 1989.

1984

Transformer Design and Manufacturing Manual

Robert G. Wolpert

(Transformer Design Services, Irvine, CA)

Covers power transformers and chokes. This self-published book gives the life-long secrets of a veteran transformer engineer. Shows how to wind transformers from start to finish, and gives the actual charts used by a going concern. Among these charts is a bill of materials; a lamination table; a wire table; a winding sheet; a lead finishing chart; a stacking and assembly chart; and test instructions. Not nearly as extensive as Lowdon's book (above), but nonetheless useful as a straightforward guide to rolling your own tranny.

1989

☞ ***Audio Transformer Design Manual*** ☜

Robert G. Wolpert,

(Transformer Design Services, Irvine, CA)

Here we have one of the few books specializing in audio transformer design. Like his book on power transformers (above), this book is self-published. The book assumes that the reader has already learned how to wind power transformers, and so jumps into its subject with both feet. The main consideration, frequency response, is explained to be a function of wire turns vs. the winding configuration. The relation between flux density (also a function of wire turns) and core saturation is then discussed. In addition, due consideration is given to insertion loss and to harmonic distortion. The complete design procedure is then given for an ultra-linear output transformer. This particular transformer is designed to deliver 100W into 4, 8, or 16 ohms. The selected winding configuration is a 4-to-5 interleave. The primary is accordingly divided into 4 sections in series and the secondary into 5 sections in parallel. A chart shows the position of each interleave. Numerous tips and tricks are given along the way. A formula is then given for calculating the leakage inductance of the finished transformer. The high frequency response is then calculated for the finished transformer and is found to be 95kHz. The measured response is found to be 90kHz. A close correspondence and a better-than-average result overall.

1986

Handbook of Transformer Applications

William M. Flanagan

(McGraw-Hill Book Co., Inc., NY)

The 2nd edition appeared in 1992.

Review in process.

1990

The Williamson Amplifier.

D. T. N. Williamson,

Reviewed under AMPLIFIER CIRCUITS, above. This booklet contains winding data for a wideband, sectionalized output transformer.

TUBE DESIGN AND MANUFACTURING

see also ref. 11

1948

Karl R. Spangenberg

Vacuum Tubes

(McGraw-Hill Book Co., Inc., NY)

Spangenberg was Professor of Electrical Engineering at Stanford. This book formalizes much of the research done by tube manufacturers, [12, 13] and is one of the most important books on tube physics published in America. Derives the amplification factor of pentodes from electrostatic fields (as pioneered by Dow for triodes. [14]) Published after Terman's Radio Engineering, this was the second book to appear in the monumental McGraw-Hill Electrical and Electronic Engineering Series. Along with boss Terman's book, Spangenberg's text established Stanford as the center for tube theory on the West Coast. Harvard remained the East Coast center, due to Chaffee and the Cruft Laboratory, until MIT cranked out its monumental *Radiation Lab Series* in response to the wartime crisis (see Valley and Wallman listed in Part I of this series.)

1949

Fundamentals of Radio-Valve Technique

J. Deketh (translated by F.G. Garratt)

(N.V. Philips' Gloeilampenfabrieken Eindhoven, Netherlands)

The first of a series of seven books on tubes and tube applications; excellently translated. This remarkable book contains 384 photographs and illustrations; many of which show the working parts of tubes and of tubes in the process of manufacture. Notable for the insight it gives into the arcane process of tube manufacturing. Covers the physical fundamentals of tubes and gives basic tube applications. The remaining books in the series give tube data; show representative circuits; discuss power amplifier design and provide transmitting tube data.

1951

The Oxide-Coated Cathode
Ing. G. Herrmann and Dr. P. S. Wagener
(Chapman & Hall Ltd., London)

Originally published in Germany in 1944, this book was later excellently translated by Dr. Wagener, one of the authors. Published in two volumes: Volume 1 covers the manufacture of oxide-coated cathodes. Copious illustrations give insight into cathode failures and tube life. The physical description of cathode emission, as given in Volume 2, provides a foundation for the further study of tube physics.

TUBE MANUALS

Tube manuals give tube specifications and design data. Such manuals have been available since the earliest days of tube manufacturing. We therefore list the later editions; so as to include newer tubes.

1964

☞ ***Essential Characteristics*** ☜
General Electric Co.
(Owensboro, KY)

1973

☞ ***Tube Substitution Handbook*** ☜
The Howard W. Sams Engineering Staff
(Indianapolis, IN)

1975

☞ ***RCA Receiving Tube Manual*** ☜
RCA Corp.
(Camden, NJ)

1975

☞ ***Sylvania Technical Manual*** ☜
GTE Sylvania Inc.
(Waltham, MA)

1979

☞ ***Audio Amplifiers*** ☜
M. O. Valve Co., Ltd.
(London, England)

1979

Tube Substitution Handbook
William Smith and Barry Buchanan
(***)

1993

The Audio Designer's Tube Register, Volume I
Tom Mitchell
(***)

Gives complete data for a number of popular tube types. Includes ratings; characteristic curves; transfer curves; tables; pin-outs; etc. A comprehensive resource for designers.

General Specification for Electron Tubes
Military Specification MIL-E-1.

Sampling Procedures and Tables, for Inspection by Attributes
MIL-STD-105 Military Standard.

REFERENCES - PART IV

1 W.T. Cocking, "High Quality Amplification," *WW*, May 4, 1934, pp. 302–304; "Push–Pull Quality Amplifier," May 11, 1934, pp. 320–323; cont. May 18, 1934, pp. 336–339.
2 Editorial: "Communication Receiver", *WW*, Aug 18, 1938, pp. 135–137.
3 Editorial: "Quality Amplifiers", *WW*, Jan 1946, pp. 2–6.
4 D.T.N. Williamson, "Design for a High Quality Amplifier," *WW*, Apr 1947 (Part 1), pp. 118–121; May 1947 (Part 2), pp. 161–163.
5 See also: H.F. Olson, *Elements of Acoustical Engineering*, D. Van Nostrand Co., Inc., NY, 2nd ed., 1947.
6 Bode's work was based on Nyquist's stability criteria. See: H. Nyquist, "Regeneration Theory," *BSTJ*, **11**, Jan 1932, pp. 126–147. See also: H.S. Black, "Stabilized Feedback Amplifiers," *BSTJ*, Jan 1934, pp. 1–18 (also published in *Elec. Eng.*, 53, 1934.) Nyquist, Black, and Bode, all of Bell Labs, pioneered feedback theory.
7 F.E. Terman, "Network Theory, Filters and Equalizers", *Proc. IRE*, May 1943.
8 See the bibliography in E.M. Cherry's, "Transient Intermodulation Distortion–Part 1: Hard Nonlinearity," *IEEE Trans. on Acous., Speech, and Sig. Proc.*, 29:2, Apr 1981.
9 Cherry, E.M. and Dabke, K.P., "Transient Intermodulation Distortion—Part 2: Soft Nonlinearity," *J. Aud. Eng. Soc*, 34:1/2, Jan/Feb 1986, pp. 19–35.
10 See also: W.T. Cocking, "Push–Pull Input Circuits," *WW*, 1948, Jan, pp. 7–10; Feb, pp. 62–66; Mar, pp. 85–87; Apr, pp. 126–130; May, pp. 183–186.
11 "Tube Manufacturing at Western Electric: The WE 300B," by A.R. Balaton, *Journal of the Audio Engineering Society*, 37**:**11, Nov. 1989, pgs. 950–958.
12 O.H. Schade (of RCA), "Beam Power Tubes," *Proc. IRE* , 26:2, Feb 1938, pgs. 162–176.
13 Saul Dushman (of GE), "Thermionic Emission," *Review of Modern Physics*, 2:4, Oct 1930.
14 W.G. Dow, "Equivalent Electrostatic Circuits for Vacuum Tubes," *Proc. IRE*, Dec. 1940, pgs. 548–556.

PART V
INCIDENTAL AND SUPPLEMENTAL TITLES

The following selections include a wide variety of books relevant to the subjects of audio design—such as biographies, histories, music & recordings;

and to tube amplifier design—such as acoustics; bibliographies; tube manuals; etc.

Books on music and records are included because it is felt that audio has a critical aesthetic dimension that is best approached through an appreciation of music. Indeed, the compleat designer will study the arts as much as the sciences.

ACOUSTICS AND PSYCHOACOUSTICS

∞ 1862 ∞

On the Sensations of Tone as a Physiological Basis for the Theory of Music

Hermann L.F. Helmholtz

(Dover Pubs., Inc., NY)

Originally published in Germany. The Dover, English language edition appeared in 1954. Review in process.

∞ 1938 ∞

Hearing, Its Psychology and Physiology

Stanley Smith Stevens and Hallowell Davis

(John Wiley & Sons, Inc., NY)

A classic in the psychophysiology of hearing. Stevens was Director of the Psychophysics Laboratory at Harvard. Davis was a physiologist at the Harvard Medical School. In 1932, Davis discovered the pulse-code mechanism of high frequency hearing. Contains an excellent discussion of masking as well as a very cogent summary of the history of sound and hearing.

∞ 1973 ∞

☞ ***Sound and Hearing*** ☜

S. S. Stevens, Fred Warshofsky, and the Editors of LIFE magazine.

(Time Inc., NY)

Provides an illustrated tour of the hearing mechanism right up to the auditory cortex. Beautifully illustrated and unquestionable authoritative.

∞ 1967 ∞

☞ ***Music, Physics, and Engineering*** ☜

Olson, H.F.

(Dover Pubs., Inc., NY, 2nd ed.)

Olson was Staff Vice President of the RCA Acoustical Research Laboratory during the "golden era" of sound recording. Similar in content to Winckel's book (below), but includes outstanding discussions of waveform synthesis, the audibility of distortion and acoustical phenomena in both halls and instruments.

∞ 1967 ∞

☞ ***Music, Sound, and Sensation*** ☜

Fritz Winckel

(Dover Pubs., Inc., NY)

A classic in psychoacoustics. Excels in its analysis of "onset transients" in musical instruments. Contains a thorough discussion of the psychological and physiological limits of human hearing, plus chapters on the effect of music on the listener; the subjective character of intervals; unclarity in musical structures; and many more topics that throw light on subjective sonic preferences. Indispensable.

∞ 1988 ∞

Acoustics Source Book

Parker, Sybil P., ed.

(McGraw-Hill Book Co., Inc., NY)

A collection of essays by leading authorities in the field. All aspects of acoustics are touched upon in encyclopedic fashion. Some of the essays, such as that on hearing by Karl U. Smith, are outstanding. This book, together with *Sound and Hearing* (above) and *Sound and Hearing, A Conceptual Introduction* (below), will provide a very clear conception of the physiological basis of hearing.

∞ 1990 ∞

The Science of Sound

Thomas D. Rossing

(***)

Review in process.

∞ 1993 ∞

☞ ***Sound and Hearing, A Conceptual Introduction*** ☜

R. Duncan Luce

(L. Erlbaum Assoc., Hillsdale, NJ)

Excellent update on the hearing mechanism. Explains frequency coding, intensity coding, firing rates, and internal tuning curves in light of current research. Explains masking as "the inevitable consequence of the somewhat odd way in which the neurons encode information." About music perception Luce has this to say: "Complex matters of music perception—for example, one's ability to single out individual instruments—and of speech perception are far beyond any physiological explanation at this time. To a degree, the behavioral results establish a challenge to neural scientists, telling them what to look for in the brain."

The publisher's name and the date of original publication will be provided as the following reviews are completed.

∞ XXX ∞

The Master Handbook of Acoustics
F. Alton Everest
(***)
The 3rd edition appeared in 1994.
Review in process.

∞ XXX ∞

The Theory of Sound
Lord Rayleigh (John William Strutt)
(Dover Pubs., Inc., NY)
Review in process.

∞ XXX ∞

Structural Hearing:
Tonal Coherence in Music
Felix Salzer
(Dover Pubs., Inc., NY)
Review in process

∞ XXX ∞

Rayleigh's Principle and Its Applications to
Engineering, The Theory of Sound
G.F. Temple and W.G. Bickley
(Dover Pubs., Inc., NY)
Review in process.

∞ XXX ∞

The Dynamical Theory of Sound
H. Lamb
(Dover Pubs., Inc., NY)
Review in process.

∞ XXX ∞

Antonio Stradivari: His Life and Work
William H. Hill, Arthur F. Hill, and Alfred E. Hill
(Dover Pubs., Inc., NY)
Review in process.

∞ XXX ∞

A Guide to Musical Acoustics
H. Lowery
(Dover Pubs., Inc., NY)
Review in process.

∞ XXX ∞

On Studying Singing
Sergius Kagen
(Dover Pubs., Inc., NY)
Review in process.

∞ XXX ∞

Textbook of Sound
Alexander Wood
(Dover Pubs., Inc., NY)
Review in process.

∞ XXX ∞

The Essence of Music and Other Papers
Feruccio Busoni
(Dover Pubs., Inc., NY)
Review in process.

∞ XXX ∞

Acoustical Engineering
Harry F. Olson
(***)
Review in process.

∞ XXX ∞

Experiments in Hearing
Georg von Békésy
(***)
Review in process.

∞ XXX ∞

Listening: An Introduction to
the Perception of Auditory Events
Stephen Handel
(***)
Review in process.

∞ XXX ∞

Auditory Scene Analysis:
The Perceptual Organization of Sound
Albert S. Bregman
(***)
Review in process.

∞ XXX ∞

Auditory Perception
F. Alton Everest
(***)
Review in process.

∞ XXX ∞

Perception of Reproduced Sound
Soren Bech, O. Juhl Pedersen, eds.,
(***)
Review in process

∞ XXX ∞

Loudspeakers, Volume I
Raymond E. Cook, ed.,
(***)
Review in process

XXX

Loudspeakers, Volume 2
Raymond E. Cook, ed.,
(***)
Review in process

XXX

Measured Tones:
The Interplay of Physics and Music
Ian Johnston
(***)
Review in process

XXX

Fundamentals of Musical Acoustics
Arthur H. Benade
(***)
Review in process

XXX

Psychology of Music
Carl E. Seashore
(***)
Review in process

XXX

From Music to the Self
Author not currently known
(***)
Review in process

XXX

Science and Music
Sir James Jeans
(***)
Review in process

XXX

Physics and the Sound of Music
John S. Rigden
(***)
Review in process

AUDIO

1990

The Audio Glossary
J. Gordon Holt
(***)
Review in process.

1992

The New Stereo Soundbook
F. Alton Everest and Ron Streicher
(***)
Review in process.

1995

The Complete Guide to High-End Audio
Robert Harley
(Acapella Publishing, Albequerque, NM)
Review in process.

BASIC ELECTRONICS

1943

Basic Electricity for Communications
William H. Timbie
(John Wiley & Sons, Inc., NY)

Timbie was Professor of Electrical Engineering and Industrial Practice at MIT. This book emphasizes industrial electronics applications; such as motors and electromagnetics. In the process, the basics of electricity and magnetism are revealed.

1946

Inside the Vacuum Tube
John F. Rider
(John F. Rider Publisher, Inc., NY)

A unique book. Contains several drawings in 3-D; some of which show the internal action of the tube. A set of 3-D glasses is included in a sleeve inside the back cover. Review in process.

1959

☞ ***Basic Electronics*** ☜
Bernard Grob
(McGraw-Hill Book Co., Inc., NY)

Grob was an instructor at the RCA Institutes. One of the few books that plainly explains the physics of the basic circuit elements. Grob, treats capacitive reactance as the "inverse" of inductive reactance, and draws many instructive parallels between the two. An easy to read book that nonetheless manages to penetrate to the deepest layers of its subject.

Covers a great mass of material in relatively few pages by sticking to fundamentals. A classic.

1987

The Homebuilt Dynamo
Alfred T. Forbes
(***)
Review in process

BIBLIOGRAPHIES

1906
The Engineering Index
(Engineering Index Inc., NY)
Published monthly with annual cumulations. One of the best indexes to early periodicals. Gives a brief abstract for each article. Look under "Radio Amplifiers" for relevant references. Still published.

1931
A Bibliography of Bibliographies in Electrical Engineering, 1918—1929
K. Maynard
(Special Libraries Assoc., NY)
Lists 2,250 references.

1961
Electronics: A Bibliographical Guide
C.K.Moore and K.J. Spencer
(MacDonald and Co., Ltd., London)
A comprehensive look at the entire electronics literature; including guides to the world's patent literature. Also lists the world's major electronics periodicals.

1972
Bibliography of the History of Electronics
George Shiers
(Scarecrow Press, Inc., Metuchen, NJ)
Contains 1,820 listings of books and articles dating back to 1860. Relevant listings can be found on pgs. 160-169.

1987
A Guide to the Literature of Electrical and Electronics Engineering
Susan B. Ardis,
(Libraries Unlimited, Inc., Littleton, CO)
A comprehensive sourcebook that lists other bibliographies, abstracts and indexes, databases, encyclopedias, dictionaries, handbooks, trade journals, standards literature, newsletters, product catalogs, trade directories, buyer's guides, document search services, patent literature, and more. Most entries are annotated. Indexed.

BIOGRAPHIES & AUTOBIOGRAPHIES

1930
A Conqueror of Space
Georgette Carneal
(H. Liveright, NY)
The most widely quoted biography of Lee De Forest. Authorized by De Forest. Review in process.

1973
☞ ***My Young Years*** ☜
Artur Rubinstein
(Knopf, NY)
Perhaps the last word we shall hear from a living descendent of the great "lost" Romantic tradition of the nineteenth century. Rubinstein was not just a musician's musician, he was a composer's musician. His book tells us everything we need to know about the inner life of an itinerant concert pianist.
The joyful soul of a consummate artist is revealed within its pages.

1959
Edison
Matthew Josephson
(McGraw-Hill Book Co., Inc., NY)
Review in process.

CIRCUITS: FILTER

1975
Active Filter Cookbook
Don Lancaster
(***)
Companion software is also available
Review in process.

1991
Practical Electronic Filters
Owen Bishop
(***)
Review in process

1991
Preamp and Filter Circuits
R.A. Penfold,
(***)
Review in process

XXX
IC OP-Amp Cookbook
Walter G. Jung
(***)
Review in process.

CIRCUITS: MISC.

1968

Sourcebook of Electronic Circuits

John Markus

(McGraw-Hill, Book Co. Inc., NY)

Contains more than 3000 circuits, tube and transistor. Includes circuits for preamplifiers, amplifiers and tape recorders.

1974

TTL Cookbook

Don Lancaster

(***)

Review in process

1977

IC Timer Cookbook

Walter G. Jung

(***)

Review in process

The 2nd edition appeared in 1983.

1985

The Encyclopedia of Electronic Circuits

Rudolf F. Graf,

(TAB Books Inc., Blue Ridge Summit, PA)

Contains 1,300 representative circuits for everything from timers to tone controls. Most are op-amp based. Mainly useful for supplementary circuits.

1988

Linear Databook

(National Semiconductor Corp., Santa Clara, CA)

An excellent source of ideas for supplementary circuits utilizing ICs. Volume 1 contains circuits for voltage regulators, operational amplifiers, buffers, voltage comparators, and instrumentation amplifiers. Volume 2 includes active filters, analog switches & multiplexers, AD converters, DA converters, sample and hold, temperature sensors, and voltage references. Volume 3 includes audio circuits, radio circuits, video circuits, motion control and special functions.

HISTORY OF ELECTRONICS

1926

History of Radio Telegraphy and Telephony

G.G. Blake

(Radio Press Ltd., London)

Contains an extensive bibliography of early radio communication; including references to original sources of fundamental data and patents. More than 1100 references are given in the bibliography (pgs. 353-403.)

1949

☞ ***Invention and Innovation in the Radio Industry*** ☜

W. Rupert MacLaurin and R. Joyce Harman

(MacMillan Co., NY)

Part of the MIT *Studies of Innovation* series. A book impeccably written by two multi-faceted individuals, this model of scholarship gives the central facts of every important inventor and scientist involved in the development of the vacuum tube and of wireless telegraphy.

Looks deeply at the economic factors that led to technological change at the turn of the century and the protracted litigation that often followed ensuing struggles to control the technology. Provides a very clear picture of the emergence of the vacuum tube as the central force of electronics technology in the early days of radio. An indispensable historical resource.

1964

The Discovery of the Electron

David L. Anderson

(Van Nostrand Reinhold Co., NY)

Traces the long search for the electron charge. Tells the role physicists (other than Child and Richardson) played in our understanding of thermionic emission. Gives extensive references.

1971

History of Radio to 1926

Gleason L. Archer

(Arno Press and The New York Times, NY)

Review in process.

1975

☞ ***A History of Engineering and Science in the Bell System, The Early Years (1875-1925)*** ☜

M.D. Fagen, ed.,

(Bell Telephone Laboratories, Inc.,

Murray Hill, NJ)

This marvel of modern scholarship is part of a series that details the growth of the Bell System; particularly the research arms at AT&T—Western Electric and Bell Labs. Traces Western Electric's pioneering development of the vacuum tube under Harold Arnold; equaled in significance only by that of Irving Langmuir at General Electric.

Provides organizational charts showing the make-up of the various research departments during the seminal days of tube development at WE.

Discusses every aspect of tube development and gives extensive footnote references. Contains many photographs of the earliest WE tube types. Sponsored by the phone company, this book is—not surprisingly—somewhat biased in favor of its own inventors in its interpretation of large-scale historical developments such as the vacuum tube. Nonetheless, it is the best window on Western Electric available and a monument of historical research in its own right.

1975

The Story of Radio (in three volumes)
W.M. Dalton
(Adam Hilger Ltd., Bristol, England)
Review in process

1981

Electrical and Electronic Technologies: A Chronology of Events and Inventors to 1900
Henry B.O. Davis
(Scarecrow Press, Inc., Metuchen, NJ)

This first volume of a 3-volume set begins with Thales of Miletus, circa 640 B.C., and works its way up to the turn of the 20th century. Places virtually every significant electrical event in between in crisp, chronological order.

1982

70 Years of Radio Tubes and Valves
John W. Stokes
(***)

A gorgeous gallery of tube photography and lore. An indispensable resource for tube collectors. The 2nd edition appeared in l992.

1983

Electrical and Electronic Technologies: A Chronology of Events and Inventors from 1900 to 1940
Henry B.O. Davis
(Scarecrow Press, Inc., Metuchen, NJ)

A continuation of Vol. 1. In addition, contains an extensive appendix showing the year of introduction of a large number of tube types.

1985

Electrical and Electronic Technologies: A Chronology of Events and Inventors from 1940 to 1980
Henry B.O. Davis
(Scarecrow Press, Inc., Metuchen, NJ)
A continuation of Vol. 2.

1992

History of the British Radio Valve to 1940
Keith R. Thrower
(***)
Review in process.

XXX

Philosophies of Music History
Warren D. Allen
(Dover Pubs., Inc., NY)
Review in process.

MATHEMATICS

Mathematics are the "hand tools" of engineers.

Algebra is used extensively in circuit modeling; especially as regards gain equations. Vector algebra is used extensively wherever voltage and current waveforms diverge in phase.

Trigonometry is used in all aspects of AC power and circuit analysis whenever it is desired to mark a time-varying signal.

Calculus provides tools to freeze moments in time and to quantify time-varying events. Differential equations are chains of instantaneous quantities and are the primary tool in circuit analysis. Operational calculus is a form of mathematical shorthand that simplifies otherwise cumbersome differential equations. Vector calculus is a branch of operational calculus widely used in electromagnetic studies.

Transforms are another branch of operational calculus and are used to convert differential equations into algebraic expressions and back again. Transforms are used extensively in control theory and in circuit analysis.

Complex number theory teaches how to compute amplitude as a function of frequency vs. phase; and thus to verify stability in feedback systems.

Engineers use all of these tools as an integrated system.

1958

Calculus for Electronics
A.E. Richmond
(McGraw-Hill Book Co., Inc., NY)

Richmond was a Training Supervisor at Tektronix. In this text, he puts standard calculus equations into familiar electrical contexts. He goes on to demonstrate the use of graphical methods to explain even and odd functions and shows those functions' effects on waveform symmetry. Gives the basic tools necessary to visually inspect waveforms and distinguish distortion components. Chapter 24 contains an excellent discussion of the Fourier series. The 2nd edition appeared in 1972. A long-established standard

1961

☞ ***Basic Mathematics*** ☜

Norman H. Crowhurst

(John F. Rider Publisher, Inc., NY)

Before turning to audio writing as a career, Crowhurst was Senior Mathematics Lecturer at London S.E. Technical College. This 4-volume set expertly summarizes arithmetic through calculus. Crowhurst, was a believer in integrating the various branches of math and showing their relations from the start. He also eschewed memorization of formulas and instead emphasized learning the proofs of a theorem. Working backwards from the proof then allows one to reconstruct the formula. Later abbreviated and renamed *Mastering Technical Mathematics* (TAB Books Inc., Blue RidgeSummit, PA, 1992.) Shows numerous shortcuts and mathematician's tricks.

1966

☞ ***Technical Mathematics With Calculus*** ☜

Harold S. Rice and Raymond M. Knight

(McGraw-Hill Book Co., Inc., NY)

Written specifically for engineering students. Each author was a mathematics-department head. The book covers all branches of math needed to approach the final two chapters on the differential and integral calculus—including algebra, trig and trig functions. Takes a graphical as well as analytical approach. Chapter 23 contains an excellent discussion of complex number theory needed to solve network problems involving reactive elements. Chapter 8 gives one of the clearest explanations of the *j* operator ever seen.

1966

About Vectors

Banesh Hoffmann

(Prentice-Hall, Inc., Englewood Cliffs, NJ;
reprinted in 1975 by Dover Publications, Inc., NY)

Written as a supplement and corrective to textbooks, yet comprehensive enough in scope to stand on its own as a general introduction to the subject.

XXXX

Introduction to Linear Algebra

Marvin Marcus and Henryk Minc

(Dover Pubs., Inc., NY)

Review in process.

MODIFICATION MANUALS

1976

Tu-be or Not Tu-be

H.L. Eisenson

(Audio Dimensions, San Diego, CA)

This DIY manual focuses on vintage tube equipment from the 50s and 60s. H.L. "Ike" Eisenson was among the earliest writers to pick up the tube "torch" after the transistor revolution had all but snuffed the flame. Ike's book explains how to spot a suitable mod candidate and provides details for dozens of models. Although chock full of interesting ideas, this book essentially chronicles the ongoing experiments of an amateur enthusiast. Care must be taken, therefore, not to interpret its contents too literally. Nonetheless, this book (and the newsletters that accompanied it) had a tremendous impact on amateur hobbyists; briefly recreating a kind of 50s DIY atmosphere among disenfranchised audiophiles who missed it the first time around. That, and the success of The Abso!ute Sound magazine,[1] proved that an interest in tube sound was deeply ingrained within the soul of audio's true believers. The 4th edition appeared in 1978.

MUSIC APPRECIATION

1955

The Enjoyment of Music

Joseph Machlis

(McGraw-Hill Book Co., Inc., NY)

Machlis was Professor of Music at Queen's College, City University of NY. This book has become something of an icon in its field. Provides the basics of music theory. Covers the major periods of Westem music—including Medieval; Renaissance; Baroque; Classical; Romantic and Modern. Compares these movements with the major themes of Western painting and art during the same periods. Machlis evidently started a tradition that was taken up by his junior colleague at Queen's College, Roger Kamien (see below.) The 5th edition appeared in 1984.

1976

☞ ***Music, An Appreciation*** ☜

Roger Kamien

(McGraw-Hill Book Co., Inc., NY)

Similar to Machlis's book but better organized. Includes chapters on rock; jazz; African; Indian, and Japanese music. The 4th edition appeared in 1988.

∞ 1977 ∞

☞ *Jazz, A History* ☜

Frank Tirro

(W. W. Norton & Co., Inc., NY)

Review in process.

∞ 1983 ∞

☞ *The Harmony Illustrated Encyclopedia of Rock, 4th Edition* ☜

Mike Clifford, consultant

(Harmony Books, NY)

Review in process.

∞ 1992 ∞

☞ *The Rolling Stone Album Guide* ☜

Anthony DeCurtis and James Henke, with Holly George-Warren, editors

(Random House, Inc., NY)

Review in process.

∞ 1990 ∞

☞ *Full Frequency Stereophonic Sound* ☜

Robert Moon and Michael Gray

Evaluates the London "blueback" catalog from the golden era. Gives performance and sound ratings for 231 records. The top 50 receive full reviews. Gives the history of the catalog and the engineering philosophy behind it. Also contains a number of ancillary essays.

∞ 1993 ∞

☞ *The RCA Bible* ☜

Jonathan Valin

(Music Lovers, Cincinnati, OH)

This book has been aptly named. It contains comparison reviews and ratings of virtually every record issued in the *Living Stereo* catalog. Includes shaded dogs, white dogs, and Victrola's. Evaluates the stamper variations of the more important shaded dogs and shows how to read the dead-wax hieroglyphics. Includes informative charts of the microphone set-ups on several of the most important golden era recordings. Also contains essays on collecting these, and related labels, by noted authorities in the collecting community. An indispensable resource for collectors and music lovers alike.

∞ XXX ∞

☞ *Audiophile Record Collector's Handbook* ☜

Phil Rees

Review in process.

PARTS DIRECTORIES

Electronic Design's Gold Book

(Hayden Publishing Co., Inc., Dalton, MA)

Review in process.

☞ *Electronic Engineers Master Catalog* ☜

(Hearst Business Communications, Inc., NY)

This may be the ultimate sourcebook for electronic parts. Volume A lists sources for electronic components; Volume B for electromechanical and electro-optical components; Volume C for interconnections, packaging and hardware; and Volume D for power sources, instrumentation, computer products, and equipment. Gives complete specifications on many components, including characteristics and dimensional drawings. Extensively cross-referenced. Includes technical glossaries; color codes; abbreviations; international symbols; definitions of units; etc. Lists manufacturers as well as sales offices. Updated annually. Comes free when you subscribe to *Electronic Products* magazine.

☞ *World Tube Directory* ☜

(Glass Audio, Peterborough, NH)

This authoritative directory lists manufacturers of tube equipment; kits; parts; transformers; et al. A comprehensive source to the world of tubes.

RECORDING

∞ 1986 ∞

☞ *Handbook of Recording Engineering* ☜

John Eargle

(Van Nostrand Reinhold Co., NY)

Eargle was past president of the AES. He also worked for both RCA and Mercury as a recording engineer. This book provides a good introduction to both analog and digital recording theory. Thoroughly explains basic stereophonic imaging techniques.

∞ 1988 ∞

Magnetic Recording Handbook

Martin Camras

(Van Nostrand Reinhold Co., NY)

Excellent coverage of heads, head biasing, and tape. Shows electron micrographs of various tape formulations. Appendix A gives the highlights of magnetic recording development. Includes many photos of vintage machines going back to the earliest days. Gives a photo gallery of the great contributors to the art. Extensive bibliography.

1988

The Complete Handbook of Magnetic Recording

Finn Jorgensen

(TAB Books Inc., Blue Ridge Summit, PA)

Similar to Camras' book (above) but less historical and more technical.

REFERENCE BOOKS

1884

American Standard Definitions of Electrical Terms

(American Institute of Electrical Engineers, NY)

One of the earliest dictionaries of electrical terms.

1912

Dictionary of Electronic Terms

Institute of Radio Engineers

(***)

Updated in 1961.

The IRE was the most important affiliation of engineers in the early days of radio

1933

Handbook of Radio Engineering

Keith Henny, editor

(McGraw-Hill Book Co., Inc., NY)

Henny was for many years editor of *Electronics* magazine. Chapter 13 is of particular interest. It was written by G. D. O'Neill of the Sylvania research department. Section 9 of this chapter covers the preparation of cathodes; section 10 covers coating suspensions; section 11 covers the exhaust and aging of coated cathodes; section 12 covers base materials; section 13 covers thermionic emission.

The 4th edition appeared in 1950.

1943

Radio Engineer's Handbook

F.E. Terman

(McGraw-Hill, Book Co., Inc., NY)

Stresses radio engineering; tuned circuits, and communications theory; but attempts to cover all aspects of the electronics art.

Outstanding as a sourcebook, as approximately 1500 footnote references are included.

1943

Reference Data for Radio Engineers

H.P. Westman, editor

(Federal Telephone and Radio Corp., NY)

Over 1000 pages of formulas; tables; charts; and graphs. The concluding chapters provide a thorough review of the Fourier transform and of Maxwell's equations (electromagnetic wave theory.)

The 4th edition appeared in 1956.

1957

Electronic Designers' Handbook

R.W. Landee, D.C. Davis and A.P. Albrecht

(McGraw- Hill Book Co., Inc., NY)

Provides extensive reference data.

1959

Audio Cyclopedia

Howard M. Tremaine

(Howard W. Sams & Co., Inc., NY)

Published in 1969, the 2nd edition is the definitive version. Unsurpassed as a labor of one man's love for audio; this book contains numerous nuggets of arcane information useful to the tube-audio aficionado.

Arranged under common subject headings, the book is formatted as a series of questions. Due to its unusual format however, it is sometimes difficult to find information. In spite of the extensive index, it often reads more like a bedazzling kaleidoscope of facts than a reference text. In 1987 the book was resurrected into a new format by a new writing team—see below.

1962

☞ ***Dictionary of Electronics*** ☜

Rudolf F. Graf

(Howard W. Sams & Co., Inc., NY)

More than 18,000 terms are authoritatively defined. The 6th edition appeared in 1990.

1972

Standard Dictionary of Electrical and Electronic Terms

EKE

(Institute of Electrical and Electronics Engineers, NY)

Perhaps the most authoritative book of its kind. More than 1000 pages of definitions. The 4th edition appeared in 1988.

1984

☞ ***Barnes & Noble Thesaurus of Physics*** ☜

Teresa Rickards

(Barnes & Noble Books, NY)

Meticulous, colorful illustrations are the hallmark of this very engrossing book. The authors make it easy to envision the underlying physical concepts whether they involve electron physics; electromagnetism; harmonic motion or sound vibration.

∞ 1987 ∞

Handbook for Sound Engineers: The New Audio Cyclopedia

Glen Ballou, editor

(Howard W. Sams & Co., Indianapolis, IN)

A virtual encyclopedia in one volume. Profusely illustrated. Contains outstanding chapters on microphones and disc recording; including design requirements for recording studios. 1247 pages.

∞ 1989 ∞

Audio Electronics Reference Book

Alan R. Sinclair, ed.

(***)

Review in process.

REFERENCES - PART V

1 *The Abso!ute Sound* (Sea Cliff, NY), began publishing in 1973. It's discovery of tube equipment began in earnest in Volume I, Issue 3 with the Audio Research SP–3 preamp. TAS has been a champion of tubes ever since. Audio Research was the first tube company to compete in the new transistor era. The tube renaissance that followed in the wake of Audio Research is due largely to TAS's encouragement of the vacuum tube.