

The
Microphone
Handbook

John Eargle

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The Microphone Handbook

John Eargle
First Edition



E8360268

Elar Publishing
Plainview, New York

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Eargle, John

The microphone handbook.

Plainview, NY: Elar Publishing Co.

256 p.

8112

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Illustrations by Hal Keith

Page layout by K&S Graphics, Island Park, N.Y.

The Microphone Handbook

Foreword

I first met John Eargle in 1965, at the old RCA studios on 24th Street in New York City. I had just joined RCA as Musical Director in the classical Red Seal division. John was director of Quality Control at the time. As it happened, we both were engaged in special projects which required night-work. It didn't take long to establish a series of nightly "bull-sessions" (in which we quite naturally solved all of the problems in audio, as well as those that beset the world in general). Those "bull-sessions" were also a very revealing insight into this multi-talented, very complex man that is John Eargle.

John Eargle is one of those rare individuals—some call them "renaissance men"—who combine a profound knowledge of the theoretical and practical aspects of physics, acoustics, electronics and audio engineering, along with the intellectual capacities and disciplines which are manifested in artistic expression. John has a lifelong commitment to music. He is an accomplished pianist and particularly enjoys playing his recently acquired Bösendorfer grand piano.

In addition to holding a Master's Degree in Music from the University of Michigan, John also has obtained a Master's Degree in Engineering from Cooper Union.

This book is about microphones and their use. Is it necessary to have degrees in music to understand microphones? Probably not. But certainly in the area of applications and the primary use of microphones—the recording of music—a knowledge of the music, and the physics of music, can be invaluable. John Eargle combines this knowledge with his experience as former Chief Engineer of Mercury Records. John quite rightly eschews the common practice of choosing microphones by some sort of esoteric subjective "mumbo-jumbo." John Eargle believes in a thorough, meticulous, scientific explanation of the operating principles of the various types of microphones. After establishing these facts, John offers a scientific rationale for his selection of microphones which will provide optimum results in a specific application.

Those looking for a "cookbook" approach to microphone usage will not find it here. Recording engineers, and all others who require an accurate

and comprehensive reference guide to microphones and their applications, will find this book invaluable.

Bert Whyte
Recording Engineer
Associate Editor Audio Magazine
New York

Author's Preface

The microphone is one of the most important tools in the disciplines of recording, broadcasting and sound reinforcement, and a thorough understanding of its operation and use is essential for a student or apprentice aspiring to a career in one of these fields. Not too many years ago, the beginning engineer had to learn his craft on the job. It was easiest for him simply to emulate an experienced engineer without taking the time required to learn the physical principles of how microphones really work. A person who learns his trade in this way may become a competent, but not flexible, engineer, and come to rely too heavily on certain microphone models, and much of his problem solving may be by rote.

It is the author's conviction that the student who learns principles also acquires analytical skills. With the principles in place, the particulars of a given problem can easily be solved. The student who knows "why," as well as "how," obviously can progress rapidly in his chosen field. This is the premise for *The Microphone Handbook*. It teaches fundamental principles; problems are solved through analysis, and the student is encouraged to think of basic microphone types rather than specific models.

The last ten years have seen many colleges develop four-year programs in the recording arts and sciences. Other schools offer summer workshops in this field, and many competent recording engineers have set up their own studio-oriented educational activities. This book is intended for use at both the collegiate level and the more informal workshop level. The treatment is essentially non-mathematical, and the emphasis is on graphic methods of presentation. It is desirable, but not essential, that the student using this book have a familiarity with acoustics and a broad knowledge of electro-acoustical systems.

The book is broadly divided into four sections. The first presents fundamentals of how microphones operate and covers the following:

1. Basic Transducer Theory
2. Directional Characteristics: The Basic Patterns
3. Microphone Sensitivity Ratings
4. Remote Powering of Capacitor Microphones
5. Microphone Care and Maintenance

The next section deals with the microphone in its physical environment and covers:

6. Using Patterns Effectively
7. Proximity and Distance Effects
8. Reflections from Nearby Surfaces
9. Multi-microphone Interference Problems

The third section treats the microphone in its various aesthetic environments:

10. Stereo Microphone Techniques
11. Speech and Music Reinforcement
12. Studio Microphone Techniques

The last section deals with two practical topics which are not always given the attention they deserve:

13. Electrical Interface Problems
14. Microphone Accessories

A bibliography is included for those students who wish to broaden their knowledge in the allied arts as well as delve more deeply into the technology of microphone design.

The author is grateful to the following manufacturers who have supplied photographs and drawings for use in the book: Altec Corporation, Atlas Sound, Audio-Technica, Bruel & Kjaer, Crown International, Edcor, Electro-Voice, Gotham Audio Corporation, Journal of the Audio Engineering Society, JVC, G. Neumann GMBH, Sennheiser, Schoeps, and Shure Brothers.

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Basic Transducer Theory

INTRODUCTION

A transducer is a device which transfers energy from one system to another, usually in a different form. The microphone is one of the earliest *electro-acoustical* transducers. Its origins go back about a century, to the introduction of telephony. But it was not until the late twenties that the microphone was to be used for sound recording. During the preceding decade, the microphone had been introduced to the emerging fields of sound reinforcement and radio broadcasting.

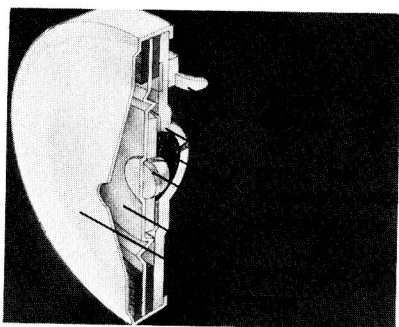
In the United States, Western Electric and RCA played major roles in the early development of microphones, followed in later years by Electro-Voice and Shure Brothers. In Europe, Neumann in Germany and AKG in Austria have been important contributors.

While just about every known means of acoustical-to-electrical transduction has been used in microphone design, the present art has settled on magnetic and capacitor types, which are inherently capable of flat frequency response. The carbon-granule microphone was developed for telephony, and is still used for that purpose. Crystal microphones, using the piezo-electric principle of operation, were at one time used extensively for paging applications, but they have been largely replaced by moving-coil types.

Microphones have improved dramatically and become lower in price over the years, and many specialized types have been developed for particular applications and use under unusual environmental conditions. In this chapter, we will examine the four basic types of transduction listed above.

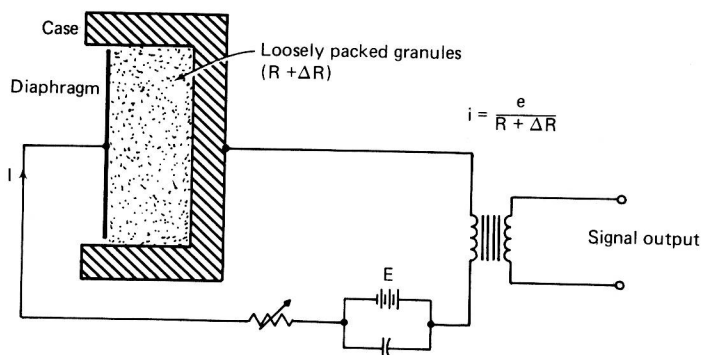
THE CARBON MICROPHONE

The carbon microphone operates on the principle of varying the resistance of loosely-packed carbon granules as they react under the varying pressure of sound waves. The basic design is shown in Figure 1-1.

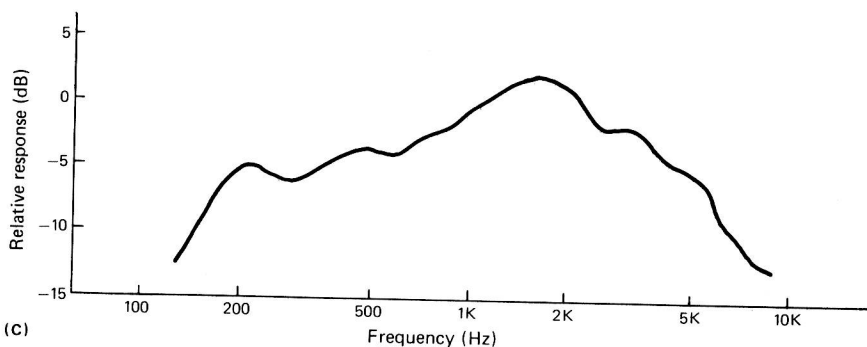


(A)

Figure 1-1. Details of a carbon microphone. **(A)** Cutaway view; **(B)** circuit diagram; **(C)** typical response.



(B)



(C)

When no signal is present, the resistance, R , of the carbon microphone is constant. When sound waves impinge on the diaphragm, the resulting vibrations cause a corresponding alternating change in R . As the diaphragm moves inward, compressing the carbon granules, R decreases; as the diaphragm moves outward, R increases. The change in R , symbolized as ΔR , causes a corresponding change in the current flowing through the carbon element. The Greek letter, Δ ("Delta"), represents a small change in a quantity. The change can be either

positive or negative, and—in the case of audio signals—will vary with time. The varying current can modulate an earphone directly, as in early telephony, or it can be amplified as required.

The carbon microphone is very limited in dynamic range and frequency response, and it exhibits high distortion. It is rarely used outside of telephony, where its performance characteristics and low cost work to its advantage.

THE PIEZO-ELECTRIC MICROPHONE

Some crystalline substances, if bent or twisted along certain of their axes, will generate an electrical potential between opposite faces. The effect is known as *piezo-electricity* (from the Greek *piezein* meaning, “to press”). The crystal can be coupled to a diaphragm and the device used as a microphone. While the performance characteristics of the crystal are better than those of the carbon microphone, they are fairly limited, relegating crystal microphones to no more than paging applications. Details of the crystal microphone are shown in Figure 1-2.

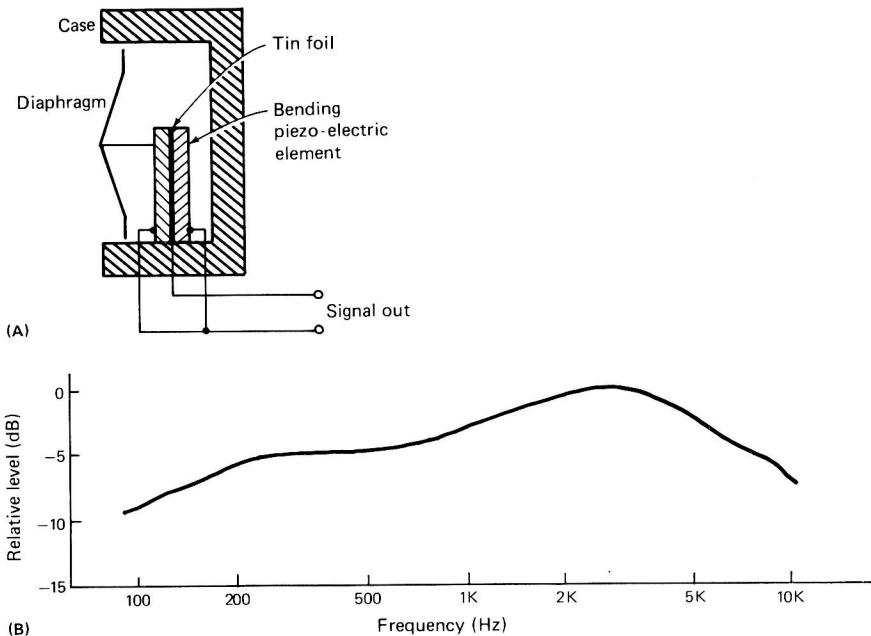


Figure 1-2. Details of a piezo-electric microphone. **(A)** Circuit diagram; **(B)** typical response.

DYNAMIC MICROPHONES

The Moving-coil Microphone

The principle of magnetic induction underlies the operation of the dynamic microphone: if a conductor is moved within a magnetic field, a voltage is induced across the conductor, as shown in the equation

$$e = Blv$$

where:

e = the induced potential, in volts;

B = the magnetic flux density, in teslas;

l = the conductor length, in meters;

v = the velocity of movement, in meters-per-second.

In its simplest form, the dynamic moving-coil microphone consists of a fine coil of wire, suspended in a magnetic gap. The coil is attached to a dome-shaped diaphragm which acts as a receiver for sound waves. Details are shown in Figure 1-3.

Modern dynamic moving-coil microphones are quite small, and some may have diaphragms no more than 1.5 cm (0.6 in) in diameter. Coils of very fine wire with many turns acting in high-energy magnetic gaps result in relatively high output levels. Attention to diaphragm suspension design results in linear, low-distortion output, and careful damping of cavities in the neighborhood of the diaphragm results in smooth, peak-free response. Current models are extremely rugged.

For flat output over a wide frequency range, the diaphragm of a dynamic microphone must execute constant velocity with respect to frequency when it is placed in a sound field of constant pressure with respect to frequency. In order to ensure this, the diaphragm must be well damped, so that it is *resistance-controlled*. This will be discussed in considerable detail in Chapter 2.

The Ribbon Microphone

The ribbon microphone also operates on the principle of magnetic induction. A corrugated ribbon, suspended in a magnetic gap, develops a signal voltage as it moves in response to sound waves. Because of the relatively-short conductor length (as compared with the multi-

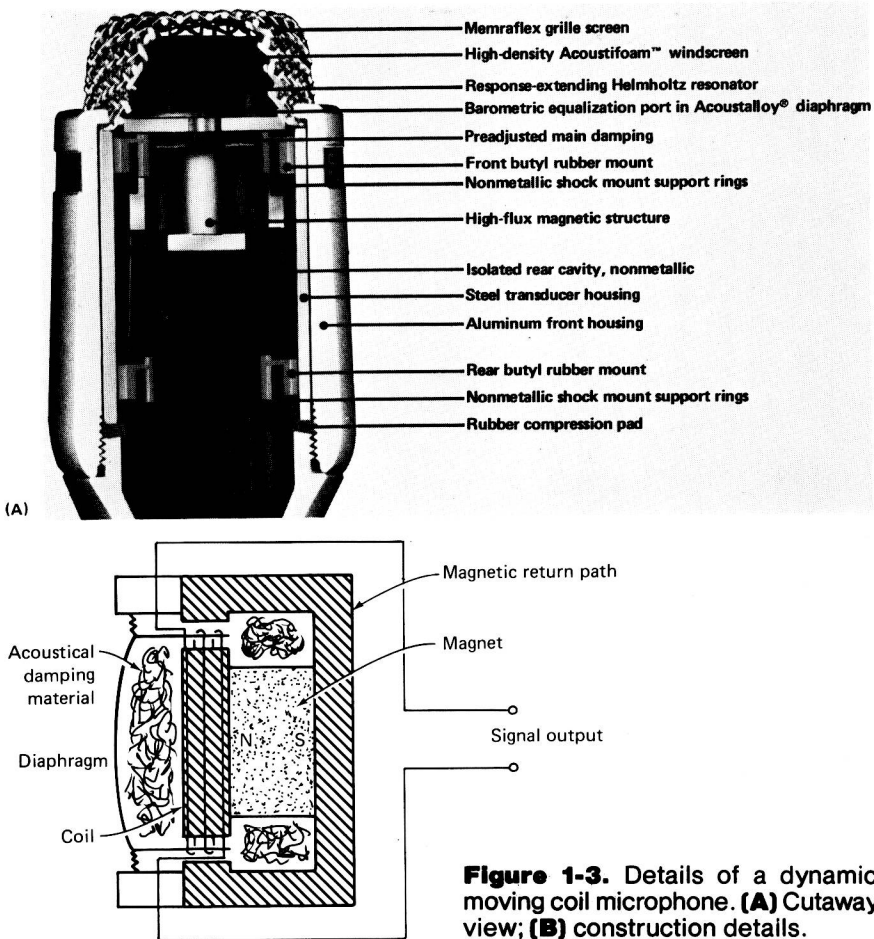


Figure 1-3. Details of a dynamic moving coil microphone. **(A)** Cutaway view; **(B)** construction details.

turn coil described above), and the large magnetic gap with its relatively low magnetic field strength, the output of the ribbon is very low. It is customary to use a step-up transformer in the design of the microphone to attain a useful output level. Details of the ribbon microphone are shown in Figure 1-4.

The ribbon microphone is also known as a *velocity*, or *pressure gradient*, microphone; that is, it responds to the air particle velocity which is developed by the pressure gradient (i.e., difference) between the two sides of the ribbon. Side- and top-view details are given in Figure 1-4. In the top view, note the difference in path lengths, P_1 and P_2 , for a sound arriving at an angle perpendicular to the ribbon. For