

ARCHITECTURAL ACOUSTICS



MARSHALL LONG

SECOND EDITION



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Second Edition

by Marshall Long



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The preparation of this book, which spanned more than ten years, took place in snatches of time – a few hours every evening and several more each weekend. It was time that was taken from commitments to family, home maintenance projects, teaching, and other activities forgone, of a pleasurable and useful nature. During that time our two older sons grew through their teens and went off to college. Our youngest son cannot remember a time when his father did not go upstairs to work every evening. So it is to my wife Marilyn and our sons Jamie, Scott, and Kevin that I dedicate this work. I am grateful for the time. I hope it was worth it. And to my environmentally conscious children, I hope it is worth the trees.

PREFACE

Architectural acoustics has been described as something of a black art or perhaps more charitably, an arcane science. While not purely an art, at its best it results in structures that are beautiful as well as functional. To produce art, however, the practitioner must first master the science of the craft before useful creativity is possible, just as a potter must learn clay or a painter his oils.

Prior to Sabine's work at the beginning of the 20th century there was little to go on. Jean Louis Charles Garnier (1825–1898), designer of the Paris Opera House, expressed his frustration at the time:

I gave myself pains to master this bizarre science [of acoustics] but . . . nowhere did I find a positive rule to guide me; on the contrary, nothing but contradictory statements . . . I must explain that I have adopted no principle, that my plan has been based on no theory, and that I leave success or failure to chance alone . . . like an acrobat who closes his eyes and clings to the ropes of an ascending balloon.

(Garnier, 1880)

Since Sabine's contributions in the early 1900's, there has been a century of technical advances. Studies funded by the EPA and HUD in the 1970's were particularly useful. Work in Canada, Europe, and Japan has also contributed greatly to the advancement of the field.

When Dick Stern first suggested this work, like Garnier one-hundred years earlier, I found, at first, few guides. There were many fine books for architects that graphically illustrated acoustic principles. There were also excellent books on noise and vibration control, theoretical acoustics, and others that were more narrowly focused on concert halls, room acoustics, and sound transmission. Many of these went deeper into aspects of the field than there is room for here, and many have been useful in the preparation of this material. Several good books are, unfortunately, out of print so where possible I have tried to include examples from them.

The goal is to present a technical overview of architectural acoustics at a level suitable for an upper division undergraduate or an introductory graduate course. The book is organized as a step-by-step progression through acoustic interactions. I have tried to include

practical applications where it seemed appropriate. The algorithms are useful not only for problem solving, but also for understanding the fundamentals. I have included treatments of certain areas of audio engineering that are encountered in real-life design problems that are not normally found in texts on acoustics. There is also some material on computer modeling of loudspeakers and ray tracing. Too often designers accept the conclusions obtained from software models without knowing the underlying basis of the computations. Above all I hope the book will provide an intellectual framework for thinking about the subject in a logical way and be helpful to those working in the field.

FIRST EDITION ACKNOWLEDGMENTS

Many people have contributed directly and indirectly to the preparation of this book. Various authors have been generous in granting permission to quote figures from their publications and in supplying helpful comments and suggestions. Among these were Mark Alcalde, Don Allen, Michael Barron, Leo Beranek, John Bradley, Jerry Brigham, Bob Bronsdon, Howard Castrup, Bob Chanaud, John Eargle, Angelo Farina, Jean Francois Hamet, George Hessler, Russ Johnson, David Klepper, Zyun-iti Maekawa, Nelson Meacham, Shawn Murphy, Chris Peck, Jens Rindel, Thomas Rossing, Ben Sharp, Chip Smith, Dick Stern, Will and Regina Thackara, and Floyd Toole. Jean Claude Lesaca and Richard Lent prepared several of the original drawings. My secretary Pat Behne scanned in many of the quoted drawings and traced over them in AutoCAD before I did the final versions. She also reviewed and helped correct the various drafts.

The staff of Academic Press including Zvi Ruder, Joel Stein, Shoshanna Grossman, Angela Dooley, and Simon Crump were helpful in shepherding me through the process. Dick Stern was present at the beginning and his steady hand and wise counsel were most appreciated. My wife Marilyn McAmis and our family showed great patience with the long hours required, for which I am very grateful.

Although I have tried to purge the document of errors, there are undoubtedly some that I have missed. Errors in earlier printings were pointed out by Michael Haberman at the University of Texas, Austin, Herb Kuntz, and Bob Celmer, at the University of Hartford. I hope that those that remain are few and do not cause undue confusion.

SECOND EDITION ACKNOWLEDGMENTS

Since the initial publication many people have made suggestions and contributions for the next edition. Where possible I have tried to accommodate these but due to time and other constraints not all could be included.

It is with great sadness that I remember Prof. Richard Stern, my friend and mentor, who introduced me to acoustics and whose patient guidance led me through my post graduate studies. Unfortunately his recent, untimely death prevented him from seeing this result of his original idea. I cherish our friendship and regular conversations over the years, and will miss his wisdom and unflagging good humor.

My assistant of twenty-four years, Pat Behne, also died last year. She was a steady hand and a good helper. Candyce Francis has ably assumed her duties and also acted as a proofreader and editor.

Contributions from Nick Antonio, Leo Beranek, Bob Bravermaan, Howard Castrup, Bob Celmer, Elzo Gernhart, Mike Haberman, Jean-Francois Hamet, Russ Johnson, David Klepper, Kevin Long, Neil Miller, Garry Ritchie, Istvan Ver, and others have helped me with a number of sections.

Gentle prodding by the Elsevier editorial staff: Hayley Gray, Lisa Jones, and Charlotte (Charlie) Kent, has kept this edition on track.

Again I regret any lingering errors, which are my sole responsibility.

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