

# The ARRL Handbook FOR RADIO COMMUNICATIONS 2023

One-Hundredth Edition

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# Foreword

ARRL is proud to present to you the very latest in a line of technical books we have called *The ARRL Handbook for Radio Communications*, now in its one-hundredth edition. This book is the culmination of nearly a century of learning and technological advancements. It represents the cumulative works of literally hundreds of people and countless hours of dedication. How different amateur radio would be today without this stalwart volume of knowledge we have all come to rely upon through our pursuit of radio.

I fondly remember my first *Handbook*, the 54th edition back in 1977. I was a teenager and a young Novice licensee without much guidance in progressing as a radio amateur. Receiving the book as a Christmas gift made the *Handbook* something special right from the start, but oh, how it opened doors into the hobby for me. As I read through the book, chapter by chapter, my vocabulary for describing everything from antennas to operating techniques expanded. I also quickly developed a hunger to grow my simple station into something grander by building projects found within the *Handbook*.

The passing of time and of *Handbook* editions is something most amateurs just take for granted. And then there are those who want to feel and read from every *Handbook* across the decades. These collectors cherish and respect the evolution of the *Handbook's* window into the ever-changing technologies that drive radio amateurs. They smile reading how, in the early *Handbooks*, readers were directed to find nearby stations to the north, south, east, and west to keep regular schedules for passing messages. And today, how advanced our understanding of propagation has become, yet how simplistic our ability to forecast space weather is. We celebrate our *Handbook* collectors by featuring one, James “Skip” Youngberg, K1NKR, in this *Handbook*.

The one-hundredth edition of the *Handbook* is a gift that we give and share — to all of us. These pages, these words, represent so much more than the fantastic and herculean job that its editors and contributing authors have provided. This *Handbook* represents lifetimes of learning, of sharing discoveries, of displaying passion, and a commitment to practice the art of radio technology, never being satisfied that what we’ve done today will be the best option for tomorrow.

I hope you will share with me the excitement of this one-hundredth edition and will share your thoughts, discoveries, and dreams with those around you. Among us are its future authors and editors!

David A. Minster, NA2AA  
ARRL CEO  
August 2022

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## The Amateur’s Code

### The Radio Amateur is:

**Considerate**...never knowingly operates in such a way as to lessen the pleasure of others.

**Loyal**...offers loyalty, encouragement and support to other amateurs, local clubs, and the American Radio Relay League, through which Amateur Radio in the United States is represented nationally and internationally.

**Progressive**...with knowledge abreast of science, a well-built and efficient station and operation above reproach.

**Friendly**...slow and patient operating when requested; friendly advice and counsel to the beginner; kindly assistance, cooperation and consideration for the interests of others. These are the hallmarks of the amateur spirit.

**Balanced**...radio is an avocation, never interfering with duties owed to family, job, school or community.

**Patriotic**...station and skill always ready for service to country and community.

— *The original Amateur’s Code was written by Paul M. Segal, W9EEA, in 1928.*



# Preface

Here we are — the one-hundredth edition of “the *Handbook*.” First printed in 1926, *The Radio Amateur’s Handbook* was created by F.E. Handy, 1BDI and its initial edition, like the 100th, included chapters on “What Is an Amateur,” “Fundamentals,” “How Radio Signals Are Sent and Received,” and “Building a Station.” The Appendix was filled with charts, graphs, tables, and projects that are recognizable today. It was 176 pages long.

My relationship with the *Handbook* was similar to a lot of other young, new hams: I checked out copies from the library and read and read and read, learning more on each pass with the help of a well-thumbed copy of ARRL’s *Understanding Amateur Radio*. I marveled at the complex symmetry of the reactance versus frequency chart from Terman’s *Radio Engineers’ Handbook*, which appears in the Radio Fundamentals chapter of the book you are now reading. I never for a minute imagined that one day I would become its Lead Editor.

There are innumerable details in the production of the *ARRL Handbook* and those demand the careful eye of a production editor who insures everything is handled correctly. My thanks to Mark Wilson, K1RO who worked closely with me in that role from my inaugural 87th through last year’s 99th edition. The book is so much better because of his support. I appreciate the efforts of his successor, Mark Derks, to fill those shoes. Their work is key to the quality of this one-hundredth edition.

As the *Handbook*’s Lead Editor, I try never to forget the *Handbook*’s audience — motivated to become better, more capable amateurs — but I am just the editor. It is the authors and reviewers who give the book its content and the ARRL HQ staff who lay out the pages and create its classic graphics. The one-hundredth edition’s contributor list is the longest ever, updating almost every chapter with new techniques, technology, and tools. It has been a privilege to have the responsibility and it is now time for me to hand over the editorial reins.

Wither goes the *Handbook*? The *Handbook* is somewhat unique as a very large technical reference text — a dwindling breed. Even as the fundamentals remain, the means of explaining amateur radio technology are changing quickly. Its text and graphics are now complemented by videos, podcasts, websites, and all manner of social media. Our new portal with so much supplemental content extends what is in the *Handbook* itself. Whether the text is printed on paper or electronically, will it continue to be read by young hams long into the night? Will there be a copy near the workbench, open to a circuit or table? I’ll close with the ending of *200 Meters and Down* by Clinton DeSoto in 1936, “There are always new goals, new horizons. May it fall to amateur radio to march many steps toward the goal of complete knowledge ere its footprints are lost in the sands of time!”

73, Ward Silver, NØAX  
Lead Editor, *ARRL Handbook*



# ARRL Handbook Online Content

(print edition only)

A wealth of additional material for this *Handbook* is available in the online content. As a purchaser of the print edition, you are entitled to download this material. If you purchased the book directly from ARRL through **arrrl.org** you should have received an email with directions for downloading the content and a link. If you purchased the *Handbook* from another retailer, lost, or never received the email with the link to the online content, go to **arrrl.org/handbookdownload**. You must log in to the ARRL website or register an account with **arrrl.org/shop** to access the content.

## Searchable Edition of the *Handbook*

The online content includes a PDF version of the one-hundredth edition of *The ARRL Handbook*, including text, drawings, tables, illustrations, and photographs. Using *Adobe Reader*, you can view, print, or search the entire book.

## Supplemental Files for Each Chapter

The online content contains supplemental information for most chapters of this book. This includes articles from *QST*, *QEX*, and other sources; material from previous editions of *The ARRL Handbook*; tables and figures in support of the chapter material; and files that contain information to build and test the projects provided in the chapters. The online information is arranged in folders for each chapter.

## Companion Software

The following software is included with the online content:

**TubeCalculator** — A Windows application by Bentley Chan and John Stanley, K4ERO, accompanies the tube type RF power amplifier discussion in the **RF Power Amplifiers** chapter.

The following *Windows* programs by Tonne Software (**www.tonnesoftware.com**) are provided by Jim Tonne, W4ENE.

**ClassE** — Designs single-ended Class E RF amplifiers.

**Diplexer** — Designs both high-pass/low-pass and band-pass/band-stop types of diplexer circuits.

**Helical** — Designs and analyzes helical-resonator bandpass filters for the VHF and UHF frequency ranges.

**JJSmith** — A graphics-intensive transmission-line calculator based on the Smith chart.

**Elsie** — The free student edition of Elsie, a lumped-element filter design and analysis program.

**MeterBasic** — Designs and prints professional-quality analog meter scales on your printer. The full featured version of *Meter* is available from Tonne Software.

**OptLowpass** — Designs and analyzes very efficient transmitter output low-pass filters.

**PI-EL** — Designs and analyzes pi-L networks for transmitter output.

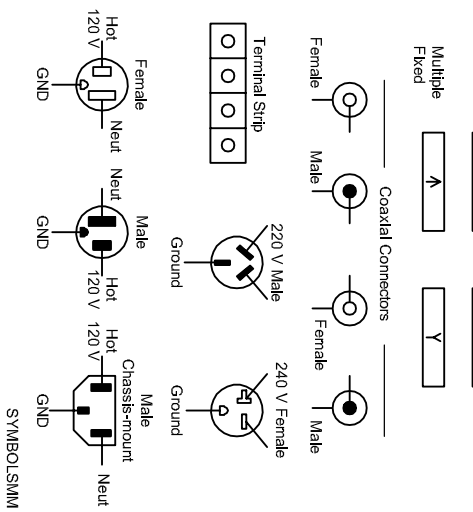
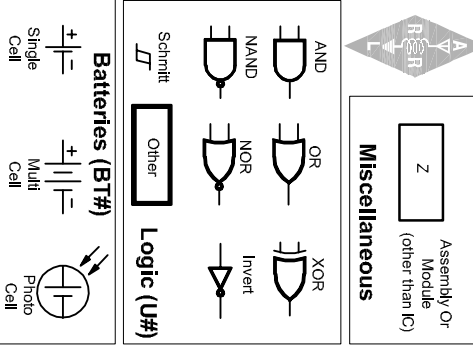
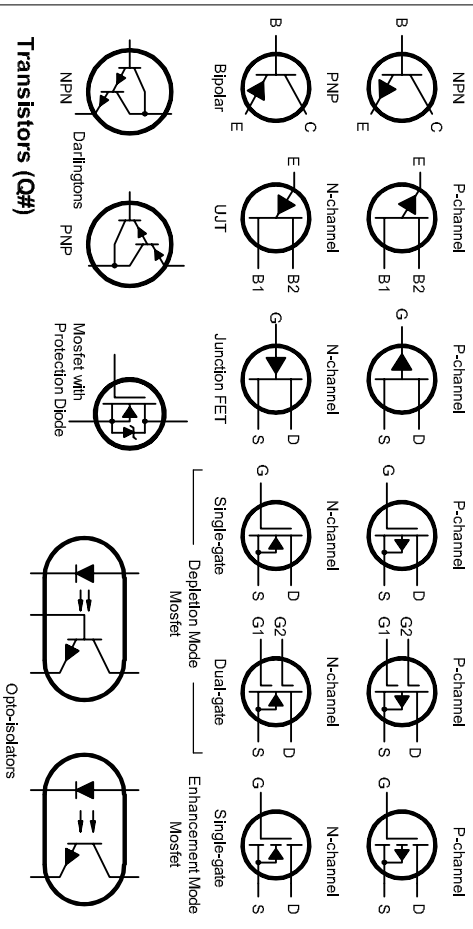
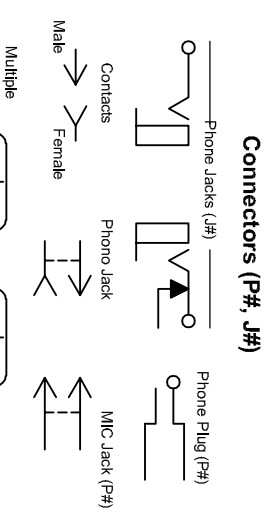
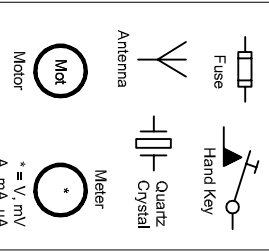
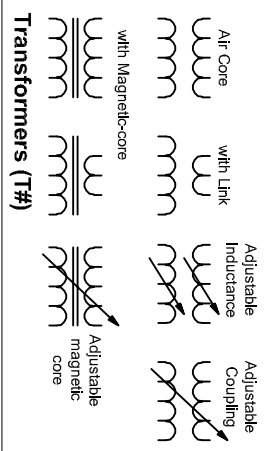
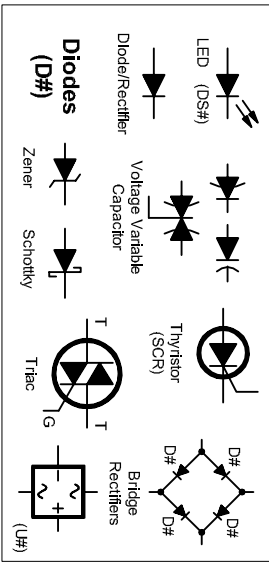
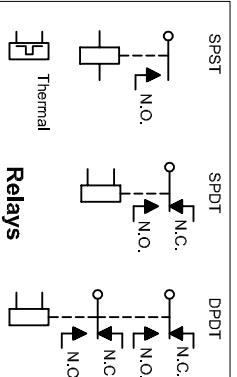
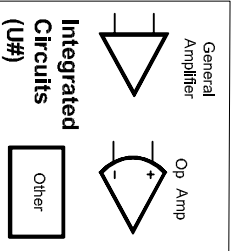
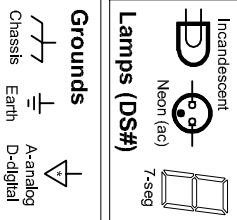
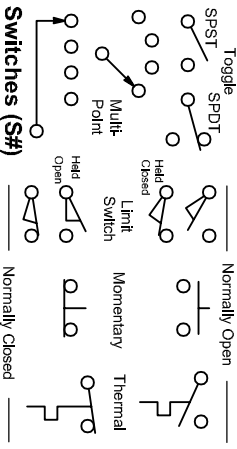
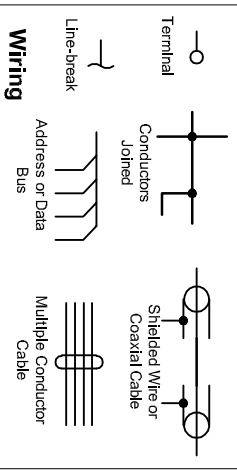
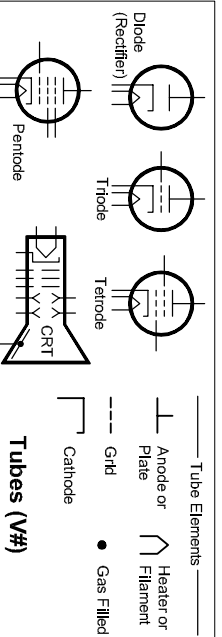
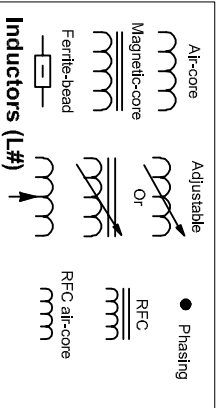
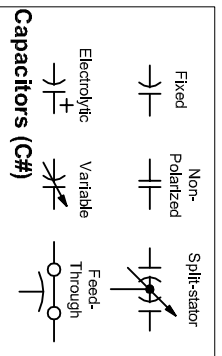
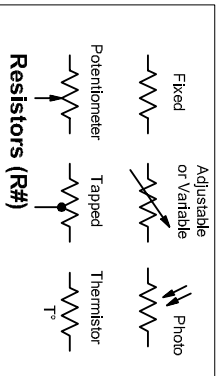
**Pizza** — A mapping program that generates printable azimuth-equidistant or rectangular maps showing the great-circle path and the sunrise-sunset terminator between your location and selectable locations.

**QuadNet** — Designs and analyzes active quadrature (“90-degree”) networks for use in SSB transmitters and receivers.

**SVCfilter** — Standard-value component routine to design low-pass and high-pass filters and delivers exact-values as well as nearest-5% values.

**Tower** — Analyzes vertical antennas. Plots resistance, reactance, and impedance at the base as a function of frequency.

# Common Schematic Symbols Used in Circuit Diagrams



# WHAT DO YOU WANT TO DO WITH AMATEUR RADIO?



ARRL is the national association for amateur radio in the US. We provide opportunities to discover radio, develop skills, and serve your local community.

## Membership in ARRL can help you:

### Discover New Interests

Whether you're interested in radiosport, new technologies, project building, emergency preparedness, or public service, ARRL has resources to help you learn, get active, and get on the air.

Your membership provides digital access to all four ARRL publications, with offerings for beginners as well as advanced hams. They include *QST*, the membership journal of ARRL; *On the Air*, an introduction to the world of amateur radio; *QEX*, covering topics related to radio communications experimentation; and *National Contest Journal (NCJ)*, covering radio contesting.

### Build & Share Your Knowledge

With online learning courses, members-only web content, and leadership opportunities, you can grow your skills and interest in amateur radio through the many ARRL programs available to members.

### Shape the Future

Your membership dollars help to preserve and protect access to frequencies allocated to the Amateur Radio Service.

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Anyone who is active in amateur radio or who wishes to get more involved to pursue technological interests, public service, or personal enjoyment will benefit from ARRL Membership.

## Benefits To get you involved and keep you up to date with all that amateur radio has to offer!



#### INFORMATION

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## About ARRL

We're the American Radio Relay League, Inc. — better known as ARRL. We're the largest membership association for the amateur radio hobby and service in the US. For over 100 years, we have been the primary source of information about amateur radio, offering a variety of benefits and services to our members, as well as the larger amateur radio community. We publish books on amateur radio, as well as four magazines covering a variety of radio communication interests. In addition, we provide technical advice and assistance to amateur radio enthusiasts, support several education programs, and sponsor a variety of operating events.

One of the primary benefits we offer to the ham radio community is in representing the interests of amateur radio operators before federal regulatory bodies advocating for meaningful access to the radio spectrum. ARRL also serves as the international secretariat of the International Amateur Radio Union, which performs a similar role internationally, advocating for amateur radio interests before the International Telecommunication Union and the World Radiocommunication Conference.

Today, we proudly serve nearly 160,000 members, both in the US and internationally, through our national headquarters and flagship amateur radio station, W1AW, in Newington, Connecticut. Every year we welcome thousands of new licensees to our membership, and we hope you will join us. Let us be a part of your amateur radio journey. Visit [www.arrl.org/join](http://www.arrl.org/join) for more information.



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# US Amateur Radio Bands

## US AMATEUR POWER LIMITS

FCC 97.313 An amateur station must use the minimum transmitter power necessary to carry out the desired communications.

(b) No station may transmit with a transmitter power exceeding 1.5 kW PEP.

Amateurs wishing to operate on either 2,200 or 630 meters must first register with the Utilities Technology Council online at <https://utc.org/pic-database-amateur-notification-process/>. You need only register once for each band.

### 2,200 Meters (135 kHz)



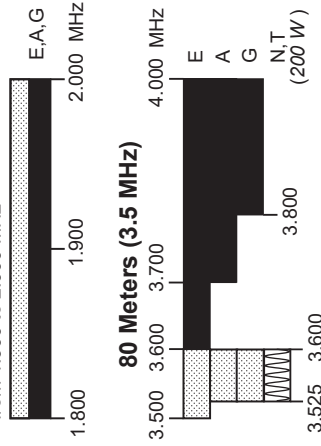
### 630 Meters (472 kHz)

5 W EIRP maximum, except in Alaska within 496 miles of Russia where the power limit is 1 W EIRP.



### 160 Meters (1.8 MHz)

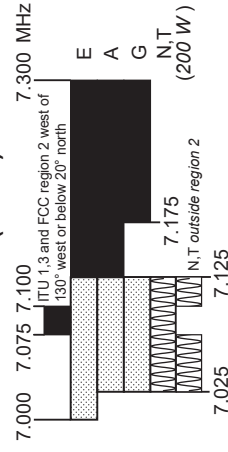
Avoid interference to radiolocation operations from 1,900 to 2,000 MHz



### 60 Meters (5.3 MHz)

CW, 5332 5348 5358.5 5373 5405 kHz  
Dig 2.8 kHz  
USB 5330.5 5346.5 5357.0 5371.5 5403.5 kHz  
General, Advanced, and Amateur Extra licensees may operate on these five channels on a secondary basis with a maximum effective radiated power (ERP) of 100 W PEP relative to a half-wave dipole. Permitted operating modes include upper sideband voice (USB), CW, RTTY, PSK31 and other digital modes such as PACTOR III. Only one signal at a time is permitted on any channel.

### 40 Meters (7 MHz)

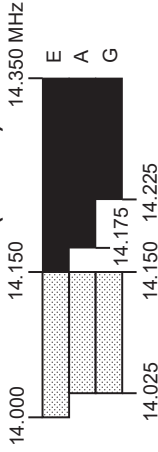


See Sections 97.305(c), 97.307(f)(11) and 97.301(e). These exemptions do not apply to stations in the continental US.

### 30 Meters (10.1 MHz)



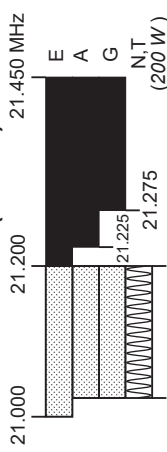
### 20 Meters (14 MHz)



### 17 Meters (18 MHz)



### 15 Meters (21 MHz)



### 12 Meters (24 MHz)



### 10 Meters (28 MHz)



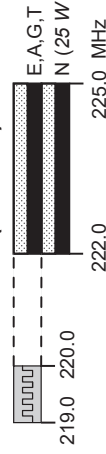
### 6 Meters (50 MHz)



### 2 Meters (144 MHz)



### 1.25 Meters (222 MHz)



\* Geographical and power restrictions may apply to all bands above 420 MHz. See FCC Part 97.303 for information about your area.

### 70 cm (420 MHz)\*



### 33 cm (902 MHz)\*



### 23 cm (1240 MHz)\*



All licensees except Novices are authorized all modes on the following frequencies:

2300-2310 MHz	10.0-10.5 GHz ‡	122.25-123.0 GHz
2390-2450 MHz	24.0-24.25 GHz	134-141 GHz
3300-3500 MHz	47.0-47.2 GHz	241-250 GHz
5650-5925 MHz	76.0-81.0 GHz	All above 275 GHz

‡ No pulse emissions



## KEY

### Note:

CW operation is permitted throughout all amateur bands.

MCW is authorized above 50.1 MHz, except for 144.0-144.1 and 219-220 MHz.

Test transmissions are authorized above 51 MHz, except for 219-220 MHz



E = Amateur Extra  
A = Advanced  
G = General  
T = Technician  
N = Novice

See [www.arrl.org](http://www.arrl.org) for detailed band plans.

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