

2013

The ARRL Handbook

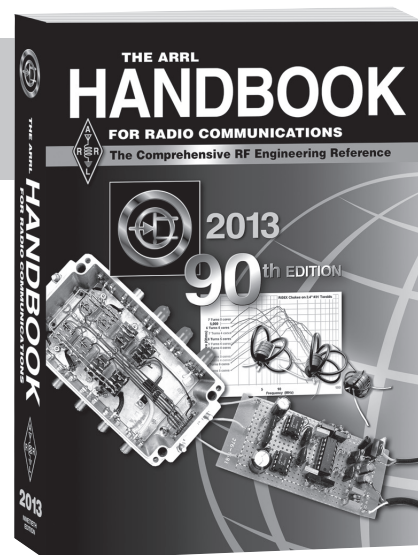
For Radio Communications



Ninetieth Edition

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the national association for Amateur Radio™
Newington, CT 06111 USA



Cover Info: Clockwise from left, from Chapter 24, an external automatic antenna switch by Joe Carcia, NJ1Q; from Chapter 20, a collection of common-mode chokes and a graph of their performance in terms of impedance vs frequency; and, from Chapter 24, an audio intelligibility enhancer by Hal Kennedy, N4GG.

Editor

H. Ward Silver, N0AX

Contributing Editors

Steven R. Ford, WB8IMY

Mark J. Wilson, K1RO

Editorial Assistant

Maty Weinberg, KB1EIB

Technical Consultants

Bob Allison, WB1GCM

Michael E. Gruber, W1MG

Edward F. Hare, Jr, W1RFI

Zachary H.J. Lau, W1VT

Cover Design

Sue Fagan, KB1OKW

Bob Inderbitzen, NQ1R

Production

Michelle Bloom, WB1ENT

Nancy G. Hallas, W1NCY

Carol Michaud, KB1QAW

Jodi Morin, KA1JPA

David F. Pingree, N1NAS

Additional Contributors to the 2013 Edition

George Dobbs, G3RJV

Terry Fletcher, WA0ITP

Joel R. Hallas, W1ZR

Carl Leutzelschwab, K9LA

Jim Tonne, W4ENE

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Ninetieth Edition

Contents

A more detailed Table of Contents is included at the beginning of each chapter.

1	INTRODUCTION What is Amateur (Ham) Radio? 1.1 Do-It-Yourself Wireless 1.2 Joining the Ham Radio Community 1.3 Assembling Your Station 1.4 <i>Hello, World!</i> — Getting on the Air 1.5 Your Ham Radio “Lifestyle” 1.6 Public Service 1.7 Ham Radio in the Classroom 1.8 Resources 1.9 Glossary	4	Digital Basics 4.1 Digital vs Analog 4.2 Number Systems 4.3 Physical Representation of Binary States 4.4 Combinational Logic 4.5 Sequential Logic 4.6 Digital Integrated Circuits 4.7 Microcontrollers 4.8 Personal Computer Interfacing 4.9 Glossary of Digital Electronics Terms 4.10 References and Bibliography
2	FUNDAMENTAL THEORY Electrical Fundamentals 2.1 Introduction to Electricity 2.2 Resistance and Conductance 2.3 Basic Circuit Principles 2.4 Power and Energy 2.5 Circuit Control Components 2.6 AC Theory and Waveforms 2.7 Capacitance and Capacitors 2.8 Inductance and Inductors 2.9 Working with Reactance 2.10 Impedance 2.11 Quality Factor (Q) of Components 2.12 Practical Inductors 2.13 Resonant Circuits 2.14 Transformers 2.15 Heat Management 2.16 Radio Mathematics 2.17 References and Bibliography	5	PRACTICAL DESIGN AND PRINCIPLES RF Techniques 5.1 Introduction 5.2 Lumped-Element versus Distributed Characteristics 5.3 Effects of Parasitic Characteristics 5.4 Ferrite Materials 5.5 Semiconductor Circuits at RF 5.6 Impedance Matching Networks 5.7 RF Transformers 5.8 Noise 5.9 Two-Port Networks 5.10 RF Techniques Glossary 5.11 References and Bibliography
3	Analog Basics 3.1 Analog Signal Processing 3.2 Analog Devices 3.3 Practical Semiconductors 3.4 Analog Systems 3.5 Amplifiers 3.6 Operational Amplifiers 3.7 Analog-Digital Conversion 3.8 Miscellaneous Analog ICs 3.9 Analog Glossary 3.10 References and Bibliography	6	Computer-Aided Circuit Design 6.1 Circuit Simulation Overview 6.2 Computer-Aided Design Examples 6.3 Limitations of Simulation at RF 6.4 CAD for PCB Design 6.5 References and Bibliography

7	Power Supplies		
	7.1 The Need for Power Processing		11.8 Transmission Line Filters
	7.2 AC-AC Power Conversion		11.9 Helical Resonators
	7.3 Power Transformers		11.10 Use of Filters at VHF and UHF
	7.4 AC-DC Power Conversion		11.11 Filter Projects
	7.5 Voltage Multipliers		11.12 Filter Glossary
	7.6 Current Multipliers		11.13 References and Bibliography
	7.7 Rectifier Types	12	Receivers
	7.8 Power Filtering		12.1 Introduction
	7.9 Power Supply Regulation		12.2 Basics of Heterodyne Receivers
	7.10 “Crowbar” Protective Circuits		12.3 The Superheterodyne Receiver
	7.11 DC-DC Switchmode Power Conversion		12.4 Superhet Receiver Design Details
	7.12 High-Voltage Techniques		12.5 Control and Processing Outside the Primary Signal Path
	7.13 Batteries		12.6 Pulse Noise Reduction
	7.14 Glossary of Power Supply Terms		12.7 VHF and UHF Receivers
	7.15 Reference and Bibliography		12.8 UHF Techniques
	7.16 Power Supply Projects		12.9 References and Bibliography
8	Modulation	13	Transmitters
	8.1 Introduction		13.1 Introduction
	8.2 Analog Modulation		13.2 Early Transmitter Architectures
	8.3 Digital Modulation		13.3 Modulation Types and Methods Applied to Transmitter Design
	8.4 Image Modulation		13.4 Modern Baseband Processing
	8.5 Modulation Impairments		13.5 Increasing Transmitter Power
	8.6 Modulation Glossary		13.6 References and Bibliography
	8.7 References and Bibliography	14	Transceivers
9	Oscillators and Synthesizers		14.1 The Transceiver Appears
	9.1 How Oscillators Work		14.2 Early SSB Transceiver Architectures
	9.2 Phase Noise		14.3 Modern Transceiver Architecture and Capabilities
	9.3 Oscillator Circuits and Construction		14.4 Transceiver Control and Interconnection
	9.4 Designing an Oscillator		14.5 Transceiver Projects
	9.5 Quartz Crystals in Oscillators		14.6 References
	9.6 Oscillators at UHF and Above	15	DSP and Software Radio Design
	9.7 Frequency Synthesizers		15.1 Introduction
	9.8 Present and Future Trends in Oscillator Application		15.2 Typical DSP System Block Diagram
	9.9 Glossary of Oscillator and Synthesizer Terms		15.3 Digital Signals
	9.10 References and Bibliography		15.4 Digital Filters
10	Mixers, Modulators and Demodulators		15.5 Miscellaneous DSP Algorithms
	10.1 The Mechanism of Mixers and Mixing		15.6 Analytic Signals and Modulation
	10.2 Mixers and Amplitude Modulation		15.7 Software-Defined Radios (SDR)
	10.3 Mixers and Angle Modulation		15.8 Glossary
	10.4 Putting Mixers, Modulators and Demodulators to Work		15.9 References and Bibliography
	10.5 A Survey of Common Mixer Types	16	Digital Modes
	10.6 References and Bibliography		16.1 Digital “Modes”
11	RF and AF Filters		16.2 Unstructured Digital Modes
	11.1 Introduction		16.3 Fuzzy Modes
	11.2 Filter Basics		16.4 Structured Digital Modes
	11.3 Lumped-Element Filters		16.5 Networking Modes
	11.4 Filter Design Examples		16.6 Glossary
	11.5 Active Audio Filters		16.7 References and Bibliography
	11.6 Quartz Crystal Filters		
	11.7 SAW Filters		

17 RF Power Amplifiers

- 17.1 High Power, Who Needs It?
- 17.2 Types of Power Amplifiers
- 17.3 Vacuum Tube Basics
- 17.4 Tank Circuits
- 17.5 Transmitting Device Ratings
- 17.6 Sources of Operating Voltages
- 17.7 Tube Amplifier Cooling
- 17.8 Amplifier Stabilization
- 17.9 Design Example: A High Power Vacuum Tube HF Amplifier
- 17.10 Solid-State Amplifiers
- 17.11 A New 250-W Broadband Linear Amplifier
- 17.12 Tube Amplifier Projects
- 17.13 References and Bibliography

18 Repeaters

- 18.1 A Brief History
- 18.2 Repeater Overview
- 18.3 FM Voice Repeaters
- 18.4 D-STAR Repeater Systems
- 18.5 Glossary of FM and Repeater Terminology
- 18.6 References and Bibliography

ANTENNA SYSTEMS AND RADIO PROPAGATION

19 Propagation of Radio Signals

- 19.1 Fundamentals of Radio Waves
- 19.2 Sky-Wave Propagation and the Sun
- 19.3 MUF Predictions
- 19.4 Propagation in the Troposphere
- 19.5 VHF/UHF Mobile Propagation
- 19.6 Propagation for Space Communications
- 19.7 Noise and Propagation
- 19.8 Glossary of Radio Propagation Terms
- 19.9 References and Bibliography

20 Transmission Lines

- 20.1 Transmission Line Basics
- 20.2 Choosing a Transmission Line
- 20.3 The Transmission Line as Impedance Transformer
- 20.4 Matching Impedances in the Antenna System
- 20.5 Baluns and Transmission-Line Transformers
- 20.6 Using Transmission Lines in Digital Circuits
- 20.7 Waveguides
- 20.8 Glossary of Transmission Line Terms
- 20.9 References and Bibliography

21 Antennas

- 21.1 Antenna Basics
- 21.2 Dipoles and the Half-Wave Antenna
- 21.3 Vertical (Ground-Plane) Antennas

- 21.4 T and Inverted-L Antennas
- 21.5 Slopers and Vertical Dipoles
- 21.6 Yagi Antennas
- 21.7 Quad and Loop Antennas
- 21.8 HF Mobile Antennas
- 21.9 VHF/UHF Mobile Antennas
- 21.10 VHF/UHF Antennas
- 21.11 VHF/UHF Yagis
- 21.12 Radio Direction Finding Antennas
- 21.13 Glossary
- 21.14 References and Bibliography

EQUIPMENT CONSTRUCTION AND MAINTENANCE

22 Component Data and References

- 22.1 Component Data
- 22.2 Resistors
- 22.3 Capacitors
- 22.4 Inductors
- 22.5 Transformers
- 22.6 Semiconductors
- 22.7 Tubes, Wire, Materials, Attenuators,
Miscellaneous
- 22.8 Computer Connectors
- 22.9 RF Connectors and Transmission Lines
- 22.10 Reference Tables

23 Construction Techniques

- 23.1 Electronic Shop Safety
- 23.2 Tools and Their Use
- 23.3 Soldering Tools and Techniques
- 23.4 Surface Mount Technology (SMT)
- 23.5 Electronic Circuits
- 23.6 Mechanical Fabrication

24 Station Accessories

- 24.1 A 100-W Compact Z-Match Antenna Tuner
- 24.2 A Microprocessor Controlled SWR Monitor
- 24.3 A 160- and 80-M Matching Network for Your 43-Foot Vertical
- 24.4 Switching the Matching Network for Your 43-Foot Vertical
- 24.5 An External Automatic Antenna Switch for Use With Yaesu or ICOM Radios
- 24.6 A Low-Cost Remote Antenna Switch
- 24.7 Audible Antenna Bridge
- 24.8 A Trio of Transceiver/Computer Interfaces
- 24.9 A Simple Serial Interface
- 24.10 USB Interfaces For Your Ham Gear
- 24.11 The Universal Keying Adapter
- 24.12 The TiCK-4 — A Tiny CMOS Keyer
- 24.13 Adapting Aviation Headsets to Ham Radio
- 24.14 An Audio Intelligibility Enhancer
- 24.15 An Audio Interface Unit for Field Day and Contesting

25 Test Equipment and Measurements

- 25.1 Introduction
- 25.2 DC Measurements
- 25.3 AC Measurements
- 25.4 RF Measurements
- 25.5 Receiver Measurements
- 25.6 Transmitter Measurements
- 25.7 Miscellaneous Measurements
- 25.8 Construction Projects
- 25.9 References and Further Reading
- 25.10 Test and Measurement Glossary

26 Troubleshooting and Maintenance

- 26.1 Test Equipment
- 26.2 Where to Begin
- 26.3 Testing Within a Stage
- 26.4 Typical Symptoms and Faults
- 26.5 Troubleshooting Hints
- 26.6 Components
- 26.7 After the Repairs
- 26.8 Professional Repairs
- 26.9 Repair and Restoration of Vintage Equipment
- 26.10 References and Bibliography

27 RF Interference

- 27.1 Managing Radio Frequency Interference
- 27.2 FCC Rules and Regulations
- 27.3 Elements of RFI
- 27.4 Identifying the Type of RFI Source
- 27.5 Locating Sources of RFI
- 27.6 Power-line Noise
- 27.7 Elements of RFI Control
- 27.8 Troubleshooting RFI
- 27.9 Automotive RFI
- 27.10 RFI Projects
- 27.11 RFI Glossary
- 27.12 References and Bibliography

STATION ASSEMBLY AND MANAGEMENT

28 Safety

- 28.1 Electrical Safety
- 28.2 Antenna and Tower Safety
- 28.3 RF Safety

29 Assembling a Station

- 29.1 Fixed Stations
- 29.2 Mobile Installations
- 29.3 Portable Installations
- 29.4 Remote Stations
- 29.5 References and Bibliography

Operating Supplement (CD-ROM only)

- Space Communications
- Digital Communications
- Image Communications
- 2013 HF Transceiver Survey

Advertiser's Index

Index

Project Index

Author Index

Foreword

In its fourth year of the current cycle of renewal and updates, the *2013 ARRL Handbook* reaches out to draw on the expertise of the amateur community around the world. Along with new projects from here at home, others have been added to this edition from the Radio Society of Great Britain (RSGB). These represent the international face of amateur self-teaching and training — expect more projects from our many friends around the world in future editions.

The new projects include several useful antenna designs. Coverage is expanded for quad and delta loop antennas which find so many applications on the lower HF bands. A sturdy and practical design for VHF and UHF coaxial dipole construction has been added. A single-support HF antenna design from “across the pond,” the skeleton slot antenna for 14 to 30 MHz is a new addition, as well.

Elsewhere in the book, more projects have been added in support of how today’s amateurs are operating and what they are building today. A set of practical polarity protection circuits collected by Terry Fletcher, WAØITP, are included in the **Power Supply** chapter. Another contribution from the RSGB is a 2 meter band-pass filter that should be very helpful in rejecting strong out-of-band signals from paging and public safety stations. The **Transmitter** chapter updates the venerable W1FB “Pebble Crusher” QRP CW transmitter by one of the QRP community’s leading proponents, Rev. George Dobbs, G3RJV. In the **Station Accessories** chapter you’ll learn how to adapt aviation headsets to amateur gear and Carl Leutzelschwab, K9LA, updates the **Propagation** chapter to review the status and future of on-again-off-again Cycle 24.

The editors are expanding the use of electronic media as well, supplementing the printed material and developing new means of providing information to the reader. With each new edition, we are adding more material on the book’s accompanying CD-ROM. For example, the operating supplement includes three complete chapters of material: **Space Communications**, **Digital Communications**, and **Image Communications**. Projects that are no longer available in the current edition have been converted to PDF files that are included on the CD-ROM that is an ever-more-important element of the *ARRL Handbook*. If a project references a *QST* article, you’ll find that on the CD-ROM, too. Be sure to install the book’s content on your computer!

One of the most important items on the CD-ROM is the set of design software packages from Tonne Software. Jim Tonne, W4ENE’s professional-quality *ELSIE* filter-design software, has received significant updates to its data entry screen and the circuit editor. The Smith chart plotting page has also been improved. Jim’s *Pi-El Circuit Design* software also received a major upgrade. We are very fortunate to have such high-quality software tools included with the *ARRL Handbook*.

The CD-ROM also includes the yearly update of transceiver models and specifications by the 2012 Dayton Hamvention Technical Achievement award-winner, Joel Hallas, W1ZR. Joel has organized the material by type and frequency coverage which is very useful to the ham considering making a radio purchase.

The ARRL Handbook — now in its ninetieth edition — continues to excel in its mission of providing a reference for all hams as they continue in their endeavors. Whether they choose to pursue public service communications, engage in technical experimentation, hone their operating skills, or enjoy their ability to communicate, “the Handbook” has a place in their library and at their workbench.

David Sumner, K1ZZ
Chief Executive Officer
Newington, Connecticut
September 2012



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.

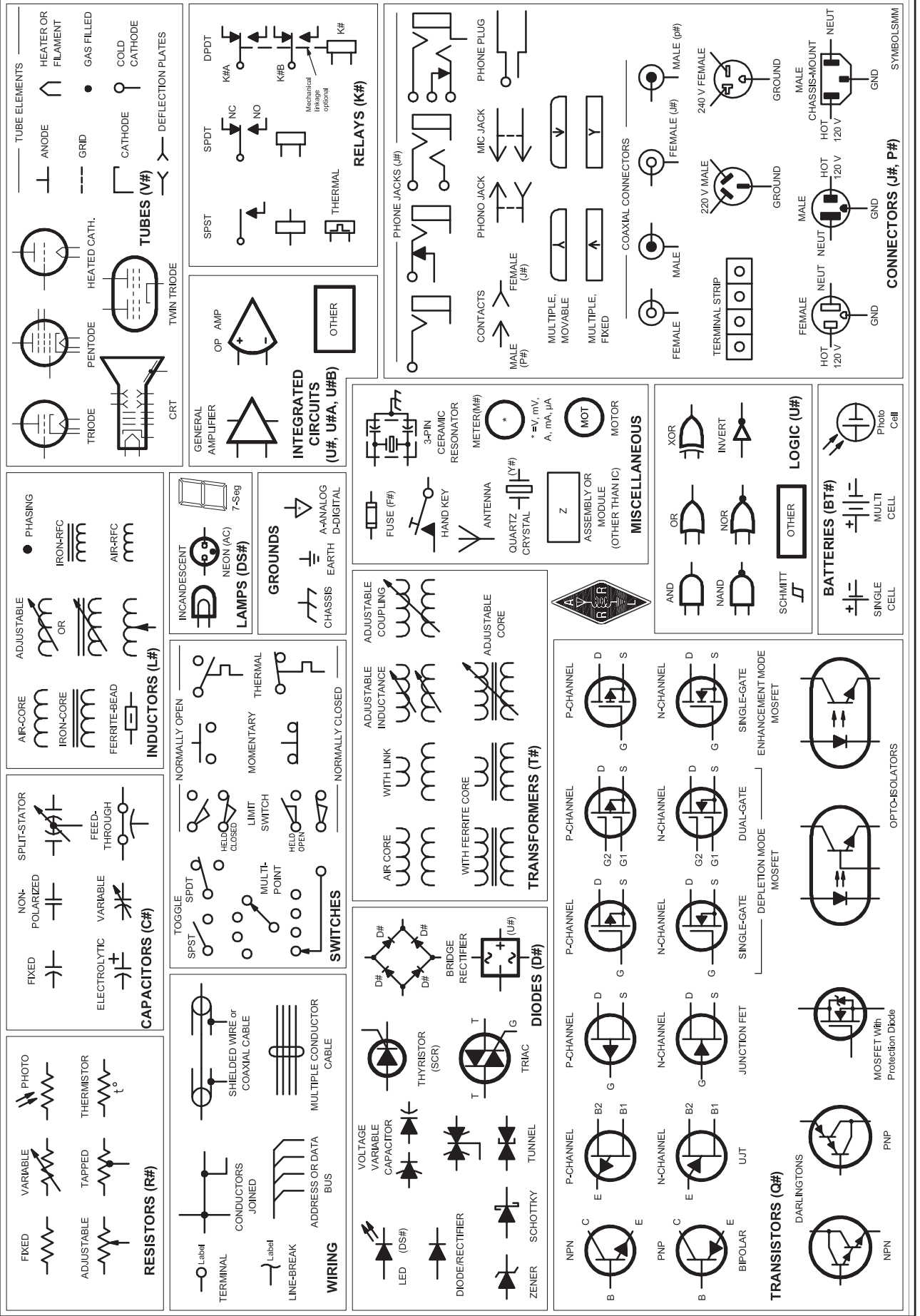
FRIENDLY...slow and patient operating when requested; friendly advice and counsel to the beginner; kindly assistance, cooperation and consideration for the interests of others. These are the hallmarks of the amateur spirit.

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.

Common Schematic Symbols Used in Circuit Diagrams



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- **Customized ARRL.org home page**
Customize your home page to see local ham radio events, clubs and news.
- **ARRL Member Directory**
Connect with other ARRL members via a searchable online Member Directory. Share profiles, photos and more with members who have similar interests.

ARRL Technical Information Service — www.arrl.org/tis

Get answers on a variety of technical and operating topics through ARRL's Technical Information Service. ARRL Lab experts and technical volunteers can help you overcome hurdles and answer all your questions.

ARRL as an Advocate — www.arrl.org/regulatory-advocacy

ARRL supports legislation and regulatory measures that preserve and protect access to Amateur Radio Service frequencies. Members may contact the **ARRL Regulatory Information Branch** for information on FCC rules; problems with antenna, tower and zoning restrictions; and reciprocal licensing procedures for international travelers.

ARRL Group Benefit Programs* — www.arrl.org/benefits

- **ARRL "Special Risk" Ham Radio Equipment Insurance Plan**
Insurance is available to protect you from loss or damage to your station, antennas and mobile equipment by lightning, theft, accident, fire, flood, tornado, and other natural disasters.
- **The ARRL Visa Signature® Card**
Every purchase supports ARRL programs and services.
- **MetLife® Auto, Home, Renters, Boaters, Fire Insurance and Banking Products**
ARRL members may qualify for up to a 10% discount on home or auto insurance.

* ARRL Group Benefit Programs are offered by third parties through contractual arrangements with ARRL. The programs and coverage are available in the US only. Other restrictions may apply.

Programs

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Contests — www.arrl.org/contests
QSL Service — www.arrl.org/qs1
Logbook of the World — www.arrl.org/lotw

Community

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Hamfests and Conventions — www.arrl.org/hamfests
ARRL Field Organization — www.arrl.org/field-organization

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ARRL Continuing Education Program — www.arrl.org/courses-training
Books, Software and Operating Resources — www.arrl.org/shop

Quick Links and Resources

QST — ARRL members' journal — www.arrl.org/qst
QEX — A Forum for Communications Experimenters — www.arrl.org/qex
NCJ — National Contest Journal — www.arrl.org/ncj
Support for Instructors — www.arrl.org/instructors
Support for Teachers — www.arrl.org/teachers
ARRL Volunteer Examiner Coordinator (ARRL VEC) — www.arrl.org/vec
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www.arrl.org/newham

e-mail newham@arrl.org
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Contact Us

ARRL, the national association for Amateur Radio®

225 Main Street, Newington, CT 06111-1494 USA
Tel 1-860-594-0200, Mon-Fri 8 AM to 5 PM ET (except holidays)
FAX 1-860-594-0259, e-mail hqinfo@arrl.org, website — www.arrl.org



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www.youtube.com/ARRLHQ

The American Radio Relay League, Inc.

The American Radio Relay League, Inc. is a noncommercial association of radio amateurs, organized for the promotion of interest in Amateur Radio communication and experimentation, for the establishment of networks to provide communication in the event of disasters or other emergencies, for the advancement of the radio art and of the public welfare, for the representation of the radio amateur in legislative matters, and for the maintenance of fraternalism and a high standard of conduct.

ARRL is an incorporated association without capital stock chartered under the laws of the State of Connecticut, and is an exempt organization under Section 501(c)(3) of the Internal Revenue Code of 1986. Its affairs are governed by a Board of Directors, whose voting members are elected every three years by the general membership. The officers are elected or appointed by the directors. The League is noncommercial, and no one

with a pervasive and continuing conflict of interest is eligible for membership on its Board.

"Of, by, and for the radio amateur," the ARRL numbers within its ranks the vast majority of active amateurs in the nation and has a proud history of achievement as the standard-bearer in amateur affairs.

A *bona fide* interest in Amateur Radio is the only essential qualification of membership; an Amateur Radio license is not a prerequisite, although full voting membership is granted only to licensed amateurs in the US.

Membership inquiries and general correspondence should be addressed to the administrative headquarters: ARRL, 225 Main Street, Newington, Connecticut 06111-1494.

About the ARRL

The seed for Amateur Radio was planted in the 1890s, when Guglielmo Marconi began his experiments in wireless telegraphy. Soon he was joined by dozens, then hundreds, of others who were enthusiastic about sending and receiving messages through the air—some with a commercial interest, but others solely out of a love for this new communications medium. The United States government began licensing Amateur Radio operators in 1912.

By 1914, there were thousands of Amateur Radio operators—hams—in the United States. Hiram Percy Maxim, a leading Hartford, Connecticut inventor and industrialist, saw the need for an organization to band together this fledgling group of radio experimenters. In May 1914 he founded the American Radio Relay League (ARRL) to meet that need.

Today ARRL, with approximately 155,000 members, is the largest organization of radio amateurs in the United States. The ARRL is a not-for-profit organization that:

- promotes interest in Amateur Radio communications and experimentation
- represents US radio amateurs in legislative matters, and
- maintains fraternalism and a high standard of conduct among Amateur Radio operators.

At ARRL headquarters in the Hartford suburb of Newington, the staff helps serve the needs of members. ARRL is also International Secretariat for the International Amateur Radio Union, which is made up of similar societies in 150 countries around the world.

ARRL publishes the monthly journal *QST* and an interactive digital version of *QST*, as well as newsletters and many publications covering all aspects of Amateur Radio. Its headquarters station, W1AW, transmits bulletins of interest to radio amateurs and Morse code practice sessions. The ARRL also coordinates an extensive field organization, which includes volunteers who provide technical information and other support services for radio amateurs as well as communications for public-service activities. In addition, ARRL represents US amateurs with the Federal Communications Commission and other government agencies in the US and abroad.

Membership in ARRL means much more than receiving *QST* each month. In addition to the services already described, ARRL offers membership services on a personal level, such as the Technical Information Service—where members can get answers by phone, email or the ARRL website, to all their technical and operating questions.

Full ARRL membership (available only to licensed radio amateurs) gives you a voice in how the affairs of the organization are governed. ARRL policy is set by a Board of Directors (one from each of 15 Divisions). Each year, one-third of the ARRL Board of Directors stands for election by the full members they represent. The day-to-day operation of ARRL HQ is managed by an Executive Vice President and his staff.

No matter what aspect of Amateur Radio attracts you, ARRL membership is relevant and important. There would be no Amateur Radio as we know it today were it not for the ARRL. We would be happy to welcome you as a member! (An Amateur Radio license is not required for Associate Membership.) For more information about ARRL and answers to any questions you may have about Amateur Radio, write or call:

ARRL—the national association for Amateur Radio®

225 Main Street

Newington CT 06111-1494

Voice: 860-594-0200

Fax: 860-594-0259

E-mail: hq@arrl.org

Internet: www.arrl.org

Prospective new amateurs call (toll-free):

800-32-NEW HAM (800-326-3942)

You can also contact us via e-mail at newham@arrl.org

or check out the ARRL website at www.arrl.org

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.

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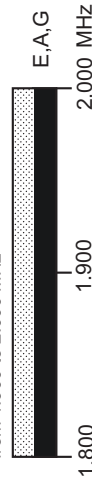


The national association for
ARRL AMATEUR RADIO®
www.arrl.org

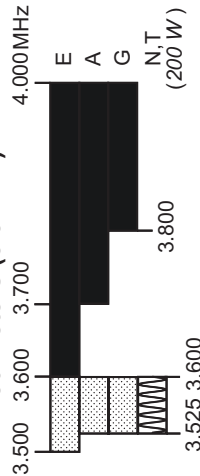
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160 Meters (1.8 MHz)

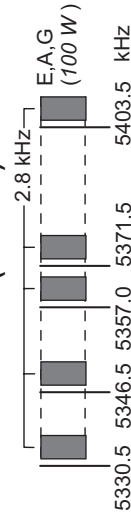
Avoid interference to radiolocation operations from 1,900 to 2,000 MHz



80 Meters (3.5 MHz)



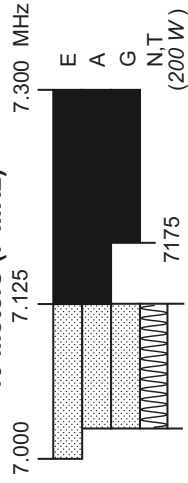
60 Meters (5.3 MHz)



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 output of 100 W PEP. Permitted operating modes include upper sideband voice (USB), CW, RTTY, PSK31 and other digital modes such as PACTOR III as defined by the FCC Report and Order of November 18, 2011. USB is limited to 2.8 kHz centered on 5332, 5348, 5358.5, 5373 and 5405 kHz. CW and digital emissions must be centered 1.5 kHz above the channel frequencies indicated above. Only one signal at a time is permitted on any channel.

40 Meters (7 MHz)



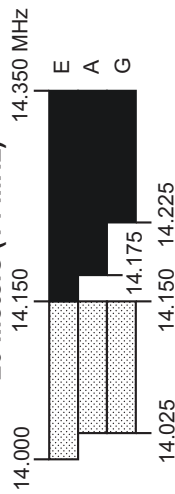
Phone and Image modes are permitted between 7,075 and 7,100 MHz for FCC licensed stations in ITU Regions 1 and 3 and by FCC licensed stations in ITU Region 2 West of 130 degrees West longitude or South of 20 degrees North latitude. See Sections 97.305(c) and 97.307(f)(11). Novice and Technician licensees outside ITU Region 2 may use CW only between 7,025 and 7,075 MHz and between 7,100 and 7,125 MHz. 7,200 to 7,300 MHz is not available outside ITU Region 2. See Section 97.301(e). These exemptions do not apply to stations in the continental US.

30 Meters (10.1 MHz)

Avoid interference to fixed services outside the US.



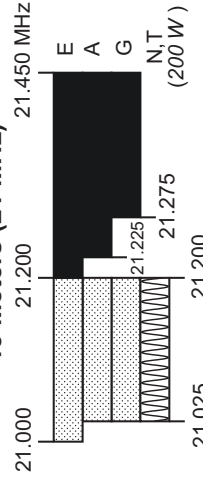
20 Meters (14 MHz)



17 Meters (18 MHz)



15 Meters (21 MHz)



12 Meters (24 MHz)



10 Meters (28 MHz)



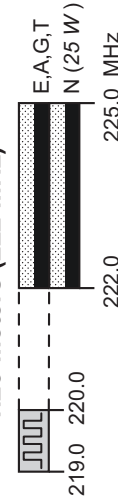
6 Meters (50 MHz)



2 Meters (144 MHz)



1.25 Meters (222 MHz)



* Geographical and power restrictions may apply to all bands above 420 MHz. See *The ARRL Operating Manual* 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

- = RTTY and data
- = phone and image
- = CW only
- = SSB phone
- = USB phone, CW, RTTY, and data.
- = Fixed digital message forwarding systems only

E = Amateur Extra

A = Advanced

G = General

T = Technician

N = Novice

See *ARRLWeb* at www.arrl.org for detailed band plans.

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ARRL Handbook

CD-ROM Contents

On the CD-ROM included with this book you'll find this entire edition of the *Handbook*, including text, drawings, tables, illustrations and photographs — many in color. Using Adobe *Reader*, you can view and print the text of the book, zoom in and out on pages, and copy selected parts of pages to the clipboard. A powerful search engine — *Reader Search* — helps you find topics of interest. Also included is supplemental information and articles, PC board template packages for many projects, and companion software mentioned throughout. A README file is included on the CD-ROM for more information. The CD-ROM is included in a protective envelope attached inside the back cover of the book.

Supplemental Files for Each Chapter

The CD-ROM provides supplemental information for most chapters of this book. This includes articles from *QST* and other sources, material from previous editions of the *ARRL Handbook*, tables and figures in support of the chapter material, and files that contain PC board layout and other design information to build and test the projects provided in the chapters.

New Supplemental Files for the 90th Edition

Chapter 7, Power Supplies: Micro-M+ PV Charge Controller (from previous editions)

Chapter 11, AF and RF Filters: High Performance Low Cost 1.8 to 54 MHz Low Pass Filter by K8CU
(*QST* article)

Chapter 13, Transmitters: The Tuna Tin 2 Today by W1RFI (*QST* article)

Chapter 14, Transceivers: 2013 HF Transceiver Survey by W1ZR

Chapter 17, RF Power Amplifiers: Updated design files by K4XU

Chapter 21, Antennas:

Wire Quad for 40 Meters (from previous editions)

A Vertical Loop for 28 MHz (from previous editions)

Dual-Band Antenna for 146/446 MHz (from previous editions)

Chapter 24, Station Accessories:

Multiband Tuning Circuits by W6MUR (*QST* article)

The ID-O-Matic Station Identification Timer (from previous editions)

Chapter 25, Test Equipment and Measurements: updated Dip Oscillator design files from N1AL

Companion Software

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.

ClassEinstall204.exe — Designs single-ended Class E RF amplifiers.

DiplexerInstall209.exe — Designs both high-pass/low-pass and band-pass/band-stop types of diplexer circuits.

HelicalInstall205.exe — Designs and analyzes helical-resonator bandpass filters for the VHF and UHF frequency ranges.

LCinstall250.exe — The free student edition of *Elsie*, a lumped-element filter design and analysis program.

MeterBasicInstall303.exe — Designs and prints professional-quality analog meter scales on your printer. The full-featured version of *Meter* is available from Tonne Software.

OptLowpassInstall203.exe — Designs and analyzes very efficient transmitter output low-pass filters.

PIELinstall215.exe — Designs and analyzes pi-L networks for transmitter output.

QuadNetInstall203.exe — Designs and analyzes active quadrature ("90-degree") networks for use in SSB transmitters and receivers.

SVCFilterInstall212.exe — Standard-value component routine to design low-pass and high-pass filters and delivers exact-values as well as nearest-5% values.