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Chapter 22

Component Data and References

Radio amateurs are known for electronic experimentation and homebrew building. Using the wide variety of components available, they design and build impressive radio equipment. With the industry growth of components for wireless communications and surface mount technology (SMT), the choices available seem endless and selecting the proper component can seem a daunting task.

Fortunately, most amateurs tend to use a limited number of component types that have "passed the test of time," making component selection in many cases easy and safe. Others are learning to design and build using the vast array of SMT parts.

Paul Harden, NA5N, updated this chapter for the 2010 edition and Dick Frey, K4XU, updated the power MOSFET tables for the 2015 edition.

Chapter 22 — CD-ROM Content

Supplemental Files

- BNC Crimp Installation Instructions
- N Crimp Installation Instructions
- Miniature Lamp Guide
- Thermoplastics Properties
- TV Deflection Tube Guide
- Obsolete RF Power Semiconductor Tables

22.1 Component Data

This section provides reference information on the old and new components most often used by the Amateur Radio experimenter and homebrewer, and information for those wishing to learn more about component performance and selection.

22.1.1 EIA and Industry Standards

The American National Standards Institute (ANSI), the Electronic Industries Alliance (EIA), and the Electronic Components Association (ECA) establish the US standards for most electronic components, connectors, wire and cables. These standards establish component sizes, wattages, "standard values," tolerances and other performance characteristics. A branch of the EIA sets the standards for Mil-spec (standard military specification) and special electronic components used by defense and government agencies. The Joint Electron Devices Engineering Council (JEDEC), another branch of the EIA, develops the standards for the semiconductor industry. The EIA cooperates with other standards agencies such as the International Electrotechnical Commission (IEC), a worldwide standards agency. You can often find published EIA standards in the engineering library of a college or university.

And finally, the International Organization of Standardization (ISO), headquartered in Geneva, Switzerland, sets the global standards for nearly everything from paper sizes to photographic film speeds. ANSI is the US representative to the ISO.

These organizations, or their acronyms, are familiar to most of us. They are much more than a label on a component. EIA and other industry standards are what mark components for identification, establishes the "preferred standard values" and ensures their reliable performance from one unit to the next, regardless of their source. Standards require that a 1.2 kΩ 5% resistor from Ohmite Corp. has the same performance as a 1.2 kΩ 5% resistor from Vishay-Dale, or a 2N3904 to have the same performance characteristics and physical packaging whether from ON Semi or Gold Star.

Much of the component data in this chapter is devoted to presenting these component standards, physical dimensions and the various methods of component identification and marking. By selecting components manufactured under these industry standards, building a project from the *Handbook* or other source will ensure nearly identical performance to the original design.

22.1.2 Other Sources of Component Data

There are many sources you can consult for detailed component data but the best source of component information and data sheets is the Internet. Most manufacturers maintain extensive Web sites with information and data on their products. Often, the quickest route to detailed product information is to enter "data sheet" and the part number into an Internet search engine. Distributors such as Digi-Key and Mouser include links to useful information in their online catalogs as well. Some manufacturers still publish data books for the components they make, and parts catalogs themselves are often good sources of component data and application notes and bulletins.

Some of the tables printed in previous editions of this book have been moved to the accompanying CD-ROM to make room for new material. If a table or figure you need is missing, check the CD-ROM!

22.1.3 The ARRL Technical Information Service (TIS)

The ARRL Technical Information Service on the ARRL Web site (**www.arrl.org/technical-information-service**) provides technical assistance to members and nonmembers, including information about components and useful references. The TIS includes links to detailed, commonly needed information in many technical areas. Questions may also be submitted via email (**tis@arrl.org**); fax (860-594-0259); or mail (TIS, ARRL, 225 Main St, Newington, CT 06111).

22.1.4 Definitions

Electronic components such as resistors, capacitors, and inductors are manufactured with a *nominal* value — the value with which they are labeled. The component's *actual* value is what is measured with a suitable measuring instrument. If the nominal value is given as text characters, an "R" in the value (for example "4R7") stands for *radix* and is read as a decimal point, thus "4.7".

Tolerance refers to a range of acceptable values above and below the nominal component value. For example, a 4700-Ω resistor rated for ±20% tolerance can have an actual value anywhere between 3760 Ω and 5640 Ω. You may always substitute a closer-tolerance device for one with a wider tolerance. For most Amateur Radio projects, assume a 10% tolerance if none is specified.

The *temperature coefficient* or *tempco* of a component describes its change in value with temperature. Tempco may be expressed as a change in unit value per degree (ohms per degree Celsius) or as a relative change per degree (parts per million per degree). Except for temperature sensing components that may use Fahrenheit or Kelvin, Celsius is almost always used for the temperature scale. Temperature coefficients may not be linear, such as those for capacitors, thermistors, or quartz crystals. In such cases, tempco is specified by an identifier such as Z5U or C0G and an equation or graph of the change with temperature provided by the manufacturer.

22.1.5 Surface-Mount Technology (SMT)

"SMT" is used throughout this book to refer to components, printed-circuit boards or assembly techniques that involve surface-mount technology. SMT components are often referred to by the abbreviations "SMD" and "SMC," but all three abbreviations are considered to be effectively equivalent. *Through-hole* or *leaded* components are those with wire leads intended to be inserted into holes in printed-circuit boards or used in point-to-point wiring.

Many different types of electronic components, both active and passive, are now available in surface-mount packages. Each package is identified by a code, such as 1802 or SOT. Resistors in SMT packages are referred to by package code and not by power dissipation, as through-hole resistors are. The very small size of these components leaves little space for marking with conventional codes, so brief alphanumeric codes are used to convey the most information in the smallest possible space. You will need a magnifying glass to read the markings on the bodies of SMT components.

In many cases, vendors will deliver SMT components packaged in tape from master reels and the components will not be marked. This is often the case with SMT resistors and small capacitors. However, the tape will be marked or the components are delivered in a plastic bag with a label. Take care to keep the components separated and labeled or you'll have to measure their values one by one!

HAMCALC Calculators

The *HAMCALC* package of software calculators by George Murphy, VE3ERP, is very handy. Covering dozens of topics from antenna lengths to impedance matching, the package can be downloaded free of charge from **www.cq-amateur-radio.com**. *HAMCALC* utilities were written in GWBASIC. *Windows 7* and later users may not be able to run *HAMCALC* software depending on the version and configuration of their operating system.

22.2 Resistors

Most resistors are manufactured using EIA standards to establish common ratings for wattage, resistor values and tolerance regardless of the manufacturer. EIA marking methods for resistors utilize either an alphanumeric scheme or a color code to denote the value and tolerance.

In the earlier days of electronics, 10% and 20% tolerance resistors were the common and inexpensive varieties used by most amateurs. 1% tolerance resistors were considered the "precision resistors" and seldom used by the amateur due to their significantly higher cost.

Today, with improved manufacturing techniques, both 5% and 1% tolerance resistors are commonly available *and* inexpensive, with precision resistors to 0.1% not uncommon.

22.2.1 Resistor Types

The major resistor types are carbon composition, carbon film, metalized film and wire-wound, as described below. (For additional discussion of the characteristics of the different types of resistors, see the **Electrical Fundamentals** chapter.)

Carbon composition resistors are made from a slurry of carbon and binder material formulated to achieve the desired resistance when compressed into a cylinder and encapsulated. This yields a resistor with tolerances in the 5% to 20% range. "Carbon comp" resistors have a tendency to absorb moisture over time and to change value, but can withstand temporary "pulse" overloads that would damage or destroy a film-type resistor.

Carbon film resistors are made from a layer of carbon deposited on a dielectric film or substrate. The thickness of the carbon film is controlled to form the desired resistance with greater accuracy than for carbon composition. They are low cost alternatives to carbon composition resistors and are available with 1% to 5% tolerances.

Metalized film resistors replace carbon films with metal films deposited onto the dielectric using sputtering techniques to achieve very accurate resistances to 0.1% tolerances. Metal film resistors also generate less thermal noise than carbon resistors.

All three of these resistor types are normally available with power ratings from 1/10 W to 2 W. **Fig 22.1** and **Tables 22.1** and **22.2** provide the body sizes and lead or pad spacing for through-hole and SMT resistors.

For new designs, carbon film and metalized film resistors should be used for their improved characteristics and lower cost compared to the older carbon composition resistors. Metalized films have lower residual inductance and often preferred at VHF. Most surface mount resistors (shown in **Fig 22.2**) are metalized films.

Wire-wound resistors, as the name implies, are made from lengths of wire wound around an insulating form to achieve the desired resistance for power ratings above 2 W. Wire-wound resistors have high parasitic inductance, caused by the wire wrapped around a form similar to a coil, and thus should not be used at RF frequencies. **Fig 22.3** (A, B and D) show three types of wire-wound resistors with wattage ranges in **Table 22.3**.

An alternative to wire-wound resistors is the new generation of resistors known as *thick-film power resistors*. They are rated up to 100 W and packaged in a TO-220 or similar case which makes it easy to mount them on heat sinks and printed-circuit boards. Most varieties are non-inductive and suitable for RF use. Metal-oxide ("cement") resistors are also available in packages similar to that of Fig 22.3B. Similar to carbon composition resistors, metal-oxide resistors are non-inductive and useful at RF.

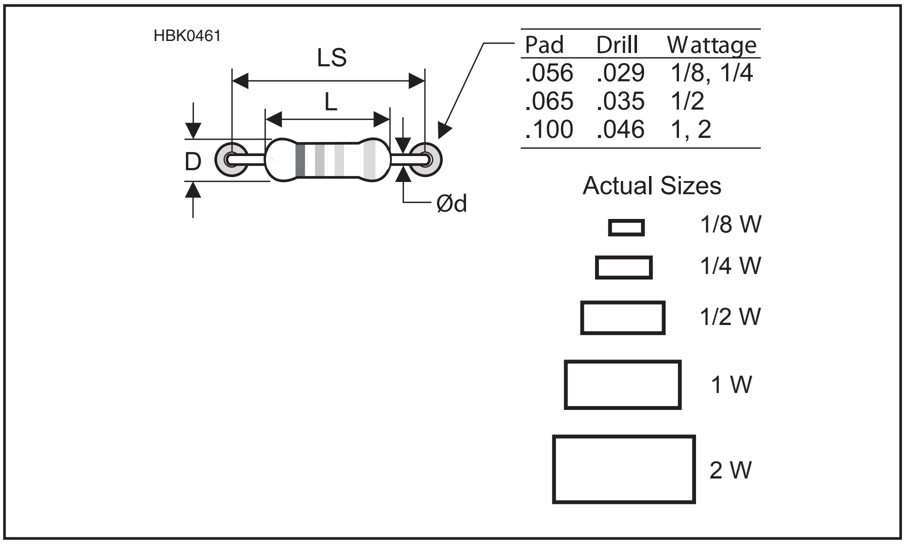


Fig 22.1 — Resistor wattages and sizes.

Table 22.1
Resistor Wattages and Sizes

Size	*L*	*D*	*LS**	*Ød*	*PCB Pad Size and Drill*
1/8 W	0.165	0.079	0.25	0.020	0.056 round, 0.029 hole
1/4 W	0.268	0.098	0.35	0.024	0.056 round, 0.029 hole
1/2 W	0.394	0.138	0.60	0.029	0.065 round, 0.035 hole
1 W	0.472	0.197	0.70	0.032	0.100 round, 0.046 hole
2 W	0.687	0.300	0.90	0.032	0.100 round, 0.046 hole

Dimensions in inches.
*LS = Recommended PCB lead bend

22.2.2 Resistor Identification

Resistors are identified by the EIA numerical or color code standard as shown in **Fig 22.4**. The EIA numerical code for resistor identification is widely used in industry. The nominal resistance, expressed in ohms, is identified by three digits for 2% (and greater) tolerance devices. The first two digits represent the significant figures; the last digit specifies the multiplier as the exponent of 10. (The multiplier is simply the number of zeros following the significant numerals.) For values less than 100 Ω, the letter R is substituted for one of the significant digits and represents a decimal point. An alphabetic character indicates the tolerance as shown in Table 22.2

For example, a resistor marked with "122J" would be a 1200 Ω, or a 1.2 kΩ 5% resistor. A resistor containing four digits, such as "1211," would be a 1210 Ω, or a 1.21 kΩ 1% precision resistor.

If the tolerance of the unit is narrower than ±2%, the code used is a four-digit code where the first three digits are the significant figures and the last is the multiplier. The letter R is used in the same way to represent

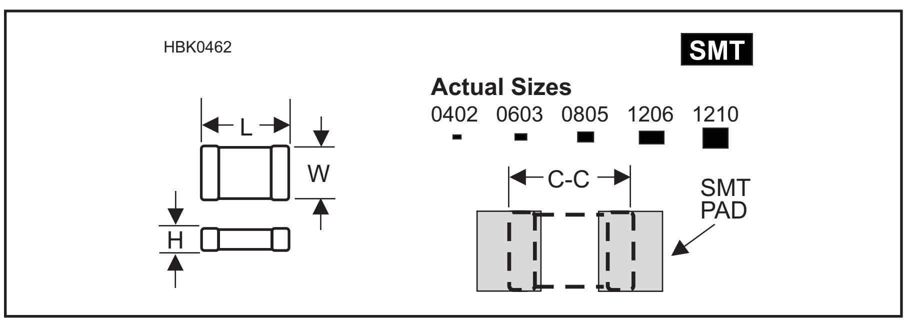


Fig 22.2 — Surface mount resistors.

Table 22.2
SMT Resistor Wattages and Sizes

Body Size	*L*	*W*	*H*	*SMT Pad*	*C-C**
0402	0.039	0.020	0.014	0.025 × 0.035	0.050
0603	0.063	0.031	0.018	0.030 × 0.030	0.055
0805	0.079	0.049	0.020	0.040 × 0.050	0.075
1206	0.126	0.063	0.024	0.064 × 0.064	0.125
1210	0.126	0.102	0.024	0.070 × 0.100	0.150

Dimensions in inches.
*C-C is SMT pad center-to-center spacing

SMT Resistor Tolerance Codes

Letter	*Tolerance*
D	±0.5%
F	±1.0%
G	±2.0%
J	±5.0%

a decimal point. For example, 1001 indicates a 1000-Ω unit, and 22R0 indicates a 22-Ω unit.

Here are some additional examples of resistor value markings:

Code	*Value*
101	10 and 1 zero = 100 Ω
224	22 and 4 zeros = 220,000 Ω
1R0	1.0 and no zeros = 1 Ω
22R	22.0 and no zeros = 22 Ω
R10	0.1 and no zeros = 0.1 Ω

The resistor color code, used only with through-hole components, assigns colors to the numerals one through nine and zero, as shown in **Table 22.4**, to represent the significant numerals, the multiplier and the tolerance. The color code is often memorized with a mnemonic such as "Big boys race our young girls, but Violet generally wins" to represent the colors black (0), brown (1), red (2), orange (3), yellow (4), green (5), blue (6), violet (7), gray (8) and white (9). You will no doubt discover other versions of this memory aid made popular over the years.

For example, a resistor with color bands black (1), red (2), red (2) and gold would be a 1200 Ω, or 1.2 kΩ 5% resistor, with the gold band signifying 5% tolerance.

The resistor color code should be memorized as it is also used for identifying capacitors, and inductors. It is also handy to use when connecting multi-conductor or ribbon cables.

Resistors are also identified by an "E" series classification, such as E12 or E48. The number following the letter E signifies the number of logarithmic steps per decade. The more steps per decade, the more choices of resistor values and tighter the tolerances can be. For example, in the E12 series, there are twelve resistor values between 1 kΩ and 10 kΩ with 10% tolerance; E48 provides 48 values between 1 kΩ and 10 kΩ at 1% tolerance. This system is often used with online circuit calculators to indicate the resistor accuracy and tolerance desired. The standard resistor values of the E12 (±10%), E24 (±5%), E48 (±2%) and E96 (±1%) series are listed in **Table 22.5**.

Resistors used in military electronics (Mil-spec) use the type identifiers listed in **Table 22.6**. In addition, Mil-spec resistors with paint-stripe value bands have an extra band indicating the reliability level to which they are certified.

Surface-mount resistors are labeled with an alphanumeric code. There are several identification conventions, including the three-digit and four-digit value-and-exponent and an EIA-96 labeling standard described at **www.hobby-hour.com/electronics/smd-calc.php**.

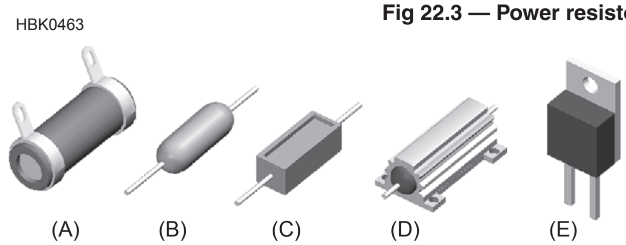


Fig 22.3 — Power resistors.

Table 22.3
Power Resistors

Fig 22.3	*Power Resistor Type*	*Wattage Range*
A	Wire-wound, ceramic core	10-300 W
B	Wire-wound, axial	3-10 W
C	Metal-oxide	5-25 W
D	Wire-wound, aluminum housing	3-50 W
E	Thick-film resistors*	15-100 W

*Wire-wound resistors are inductive, though seldom noted as such on the data sheets, and are not recommended for RF. Thick-film and metal-oxide power resistors are low inductance or noninductive.

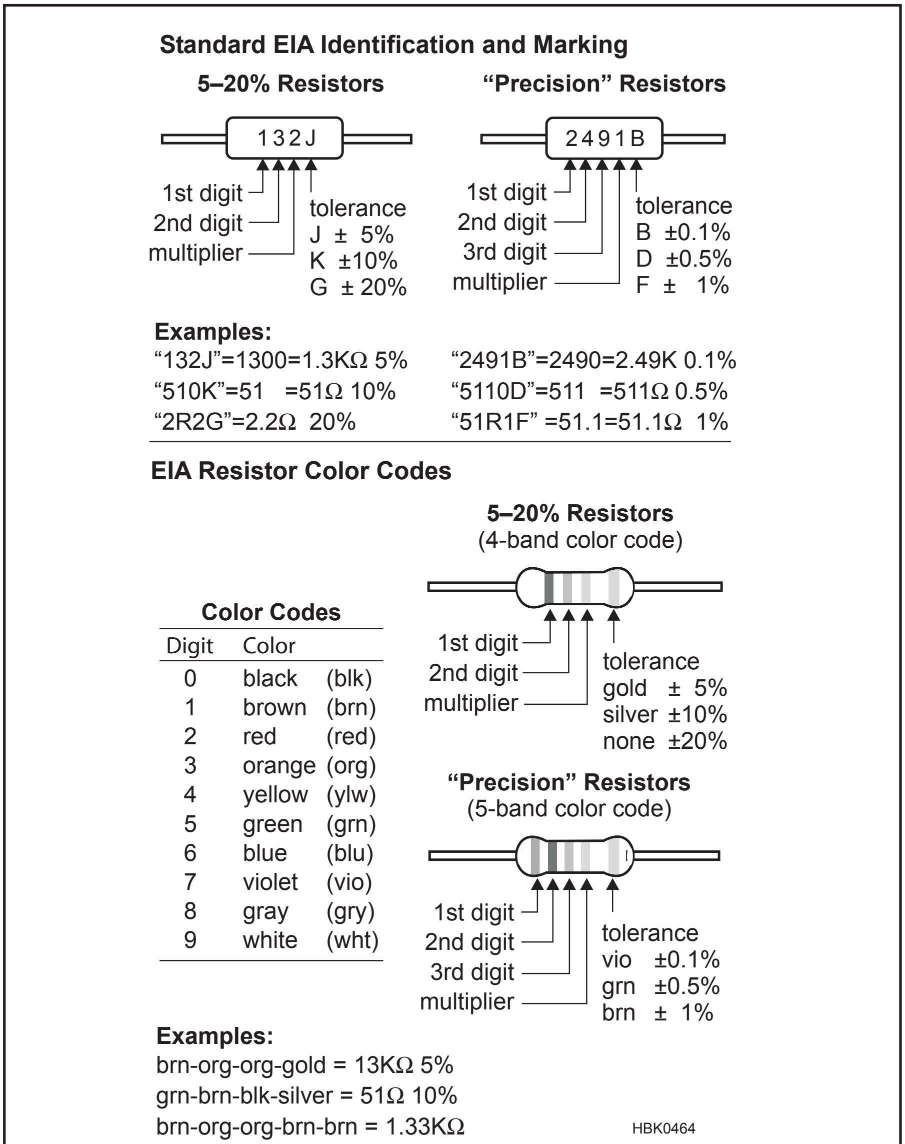


Fig 22.4 — Resistor value identification.

Table 22.4
Resistor Color Codes

Color	*Significant Figure*	*Decimal Multiplier*	*Tolerance (%)*
Black	0	1	
Brown	1	10	1
Red	2	100	2
Orange	3	1,000	
Yellow	4	10,000	
Green	5	100,000	0.5
Blue	6	1,000,000	0.25
Violet	7	10,000,000	0.1
Gray	8	100,000,000	0.05
White	9	1,000,000,000	
Gold		0.1	5
Silver		0.01	10
No color			20

Table 22.5
EIA Standard Resistor Values

±10% (E12)	*±5% (E24)*	*±2% (E48)*		*±1% (E96)*			
100	100	100	316	100	178	316	562
120	110	105	332	102	182	323	576
150	120	110	348	105	187	332	590
180	130	115	365	107	191	340	604
220	150	121	383	110	196	348	619
270	160	127	402	113	200	357	634
330	180	133	422	115	205	365	649
390	200	140	442	118	210	374	665
470	220	147	464	121	215	383	681
560	240	154	487	124	221	392	698
680	270	162	511	127	226	402	715
820	300	169	536	130	232	412	732
	330	178	562	133	237	422	750
	360	187	590	137	243	432	768
	390	196	619	140	249	442	787
	430	205	649	143	255	453	806
	470	215	681	147	261	464	825
	510	226	715	150	267	475	845
	560	237	750	154	274	487	866
	620	249	787	158	280	499	887
	680	261	825	162	287	511	909
	750	274	866	165	294	523	931
	820	287	909	169	301	536	953
	910	301	953	174	309	549	976

Use Table 22.5 values for each decade.
Example: 133 = 13.3 Ω, 133 Ω, 1.33 kΩ, 13.3 Ω, 133 kΩ, 1.33MΩ

Table 22.6
Mil-Spec Resistors

Wattage	*Metal Film Types*	*Fixed Film Types*	*Composition Types*	
1⁄10 W	RN50			
1⁄8 W	RN55	RL05	RLR05	RCR05
1⁄4 W	RN60	RL07	RLR07	RCR07
1⁄2 W	RN65	RL20	RLR20	RCR20
1 W	RN75	RL32	RLR32	RCR32
2 W	RN80	RL42	RLR62	RCR42

Tolerance Codes

B	±0.1%
C	±0.25%
D	±0.5%
F	±1%
G	±2%
J	±5%
K	±10%

Examples:
RN60D-2202F = 22 kΩ 1%
RL07S-471J = 470 Ω ±5%
RLR07C-471J = 470 Ω ±5%

Note: The RN Mil-Spec was discontinued in 1996 Still used by some manufacturers such as Vishay-Dale.

22.3 Capacitors

Capacitors exhibit the largest variety of electronic components. So many varieties and types are available that selecting the proper capacitor for a particular application can be overwhelming. Ceramic and film capacitors are the two most common types used by the amateur. (For additional information on the characteristics of the different types of capacitors, see the **Electrical Fundamentals** chapter.)

Though capacitors are classified by dozens of characteristics, the EIA has simplified the selection process by organizing ceramic capacitors into four categories called Class 1, 2, 3 and 4. Class 1 capacitors are the most stable and Class 4 the least preferred. Many catalogs now list ceramic capacitors by their class, greatly simplifying component selection.

For capacitors used in frequency-sensitive circuits, such as the frequency determining capacitors in oscillators or tuned circuits, select a Class 1 capacitor (C0G or NP0). For other applications, such as interstage coupling or bypass capacitors, components from Class 2 or Class 3 (X7R or Z5U) are usually sufficient. With modern manufacturing techniques, it is rare to find a Class 4 capacitor today.

Like resistors, capacitors are available in EIA standard series of values, E6 and E12, shown in **Table 22.7**. Most capacitors have a tolerance of 5% or greater. High-value capacitors used for filtering may have asymmetric tolerances, such as –5% and +10%, since the primary concern is for a guaranteed minimum value of capacitance.

Table 22.7
EIA Standard Capacitor Values

±20% Capacitors (E6)

pF	*pF*	*pF*	*µF*	*µF*	*µF*	*µF*
1.0	10	100	0.001	0.01	0.1	1
1.5	15	150	0.0015	0.015	0.15	1.5
2.2	22	220	0.0022	0.022	0.22	2.2
3.3	33	330	0.0033	0.033	0.33	3.3
4.7	47	470	0.0047	0.047	0.47	4.7
6.8	68	680	0.0068	0.068	0.68	6.8

±10%, ±5% Capacitors (E12)

pF	*pF*	*pF*	*µF*	*µF*	*µF*	*µF*
1.0	10	100	0.001	0.01	0.1	1
1.2	12	120	0.0012	0.012	0.12	
1.5	15	150	0.0015	0.015	0.15	
1.8	18	180	0.0018	0.018	0.18	
2.2	22	220	0.0022	0.022	0.22	2.2
2.7	27	270	0.0027	0.027	0.27	
3.3	33	330	0.0033	0.033	0.33	3.3
3.9	39	390	0.0039	0.039	0.39	
4.7	47	470	0.0047	0.047	0.47	4.7
5.6	56	560	0.0056	0.056	0.56	
6.8	68	680	0.0068	0.068	0.68	
8.2	82	820	0.0082	0.082	0.82	

22.3.1 Capacitor Types

Capacitor types can be grouped into ceramic dielectrics, film dielectrics and electrolytics. The type of capacitor can often be determined by their appearance, as shown in **Figs 22.5** and **22.6**. Capacitors with wire leads have two lead styles: *axial* and *radial*. Axial leads are aligned in opposite directions along a common axis, usually the largest dimension of the capacitor. Radial leads leave the capacitor body in the same direction and are usually arranged radially about the center of the capacitor body.

*Disc (*or *disk) ceramic* capacitors consist of two metal plates separated by a ceramic dielectric that establishes the desired capacitance. Due to their low cost, they are the most common capacitor type. The main disadvantage is their sensitivity to temperature changes (that is, a high temperature coefficient).

Monolithic ceramic capacitors are made by sandwiching layers of metal electrodes and ceramic layers to form the desired capacitance. "Monolithics" are physically smaller than disc ceramics for the same value of capacitance and cost, but exhibit the same high temperature coefficients.

Polyester film capacitors use layers of metal and polyester (Mylar) to make a wide

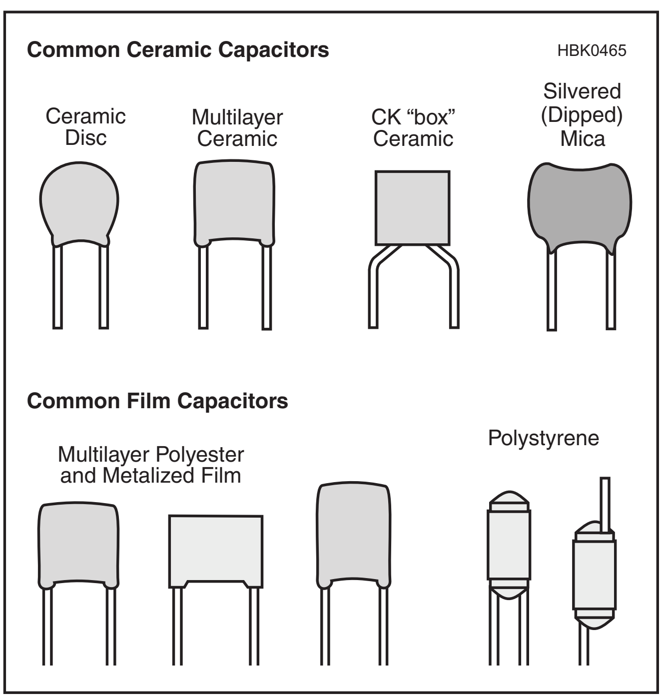


Fig 22.5 — Common capacitor types and package styles.

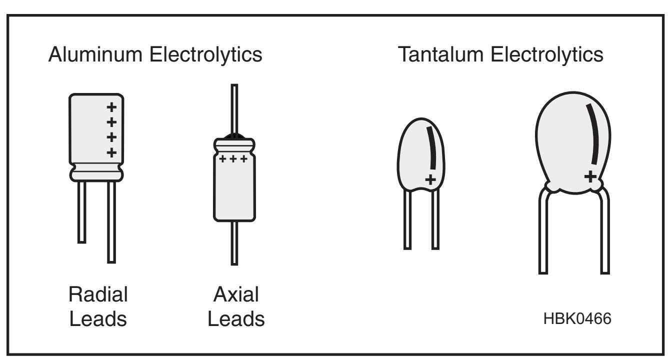


Fig 22.6 — Aluminum and tantalum electrolytic capacitors.

range of capacitances. They have poor temperature coefficients and are not recommended for high frequency use, but are suitable for low frequency and audio circuits.

To improve the performance of film capacitors, other dielectrics are used, such as polypropylene, polystyrene or polycarbonate film, or silvered-mica. These are very stable capacitors developed for RF use. Their main disadvantages are higher cost and lower working voltages than other varieties.

Capacitors are particularly sensitive to temperature changes because the physical dimensions of the capacitor determine its value. Standard temperature coefficient codes are shown in **Table 22.8**. Each code is made up of one character from each column in the table. For example, a capacitor marked Z5U is suitable for use between +10 and +85°C, with a maximum change in capacitance of –56% or +22%.

Capacitors with highly predictable temperature coefficients of capacitance are sometimes used in circuits whose performance must remain stable with temperature. If an application called for a temperature coefficient of –750 ppm/°C (N750), a capacitor marked U2J would be suitable. The older industry code for these ratings is being replaced with the EIA code shown in Table 22.8. NP0 (that is, N-P-zero) means “negative, positive, zero.” It is a characteristic often specified for RF circuits requiring temperature stability, such as VFOs. A capacitor of the proper value marked C0G is a suitable replacement for an NP0 unit.

Table 22.8
Ceramic Temperature Characteristics

Common EIA Types:

EIA Class	*EIA Code*	*Characteristics*	*Temp. Range**
1	C0G	0 ± 30 ppm/°C	–55 °C to +125 °C
2	Y5P	±10%	–30 °C to + 85 °C
2	X7R	±15%	–55 °C to +125 °C
2	Y5U	±20%	–10 °C to + 85 °C
2	Z5U	±20%	+10 °C to + 85 °C
2	Z5V	+80%, –20%	–30 °C to + 85 °C
3	Y5V	+80%, –20%	–10 °C to + 85 °C

Common Industry Types:

EIA Class	*EIA Code*	*Characteristics*	*Temp. Range**
1	NP0	0 ± 30 ppm/°C	–55 °C to +125 °C
2	CK05	±10%	–55 °C to +125 °C

*Temp. range for which characteristics are specified and may vary slightly between different manufacturers

Temperature Coefficient Codes

Minimum Temperature	*Maximum Temperature*	*Maximum capacitance change over temp range*
X –55 °C	2 +45°C	A ±1.0%
Y –30 °C	4 +65°C	B ±1.5%
Z +10 °C	5 +85°C	C ±2.2%
6 +105 °C		D ±3.3%
7 +125 °C		E ±4.7%
		F ±7.5%
		P ±10%
		R ±15%
		S ±22%
		T –33%, +22%
		U –56%, +22%
		V –82%, +22%

Table 22.9
Aluminum Electrolytic Capacitors Standard Sizes (Radial Leads)

H	*Dia*	*LS*	*Pad Size and Drill**
0.44	0.20	0.08	0.056 round, 0.029 hole
0.44	0.25	0.10	0.056 round, 0.029 hole
0.44	0.32	0.14	0.065 round, 0.029 hole
0.52	0.40	0.20	0.080 round, 0.035 hole
0.78	0.50	0.20	0.080 round, 0.035 hole
1.00	0.63	0.30	0.100 round, 0.035 hole
1.42	0.72	0.30	0.100 round, 0.035 hole
1.60	0.88	0.40	0.100 round, 0.035 hole

Dimensions in inches.
*Customary to make “+” lead square pad on PCB

HBK0467

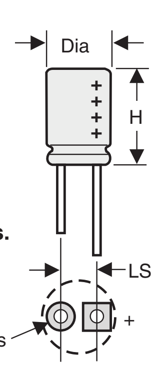


Fig 22.7 — Aluminum electrolytic capacitor dimensions.

22.3.2 Electrolytic Capacitors

Aluminum electrolytic capacitors use aluminum foil “wetted” with a chemical agent and formed into layers to increase the effective area, and therefore the capacitance. Aluminum electrolytics provide high capacitance in small packages at low cost. Most varieties are polarized, that is, voltage should only be applied in one “direction.” Polarized capacitors have a negative (–) and positive (+) lead. Standard dimensions of aluminum electrolytics are shown in **Fig 22.7** and **Table 22.9**. EIA standard values for aluminum electrolytics are given in **Table 22.10**.

Very old electrolytic capacitors should be used with care or, preferably, replaced. The wet dielectric agent can dry out during prolonged periods of non-use, causing the internal capacitor plates to form a short circuit when energized. Applying low voltage and gradually increasing it over a period of time may restore the capacitor to operation, but if the dielectric agent has dried out, the capacitor will have lost some or most of its value and will likely be lossy and prone to failure.

Tantalum electrolytic capacitors consist of a tantalum pentoxide powder mixed with a wet or dry electrolyte, then formed into a pellet or slug for a large effective area. Tantalums also provide high capacitance values in very small packages. Tantalums tend to be more expensive than aluminum electrolytic capacitors. Like the aluminum electrolytic capacitor, tantalum capacitors are also polarized for which care should be exercised. Some varieties of tantalums can literally explode or burst open if voltage is applied with reverse polarity or the voltage rating is exceeded. Tantalum electrolytics are used almost exclusively as high-value SMT components due to their small sizes. Capacitance values up to 1000 µF at 4 V are available with body sizes about a quarter-inch square.

Identifying the polarity markings of aluminum and tantalum electrolytics (shown in Fig 22.6) can be confusing. Most tantalum electrolytics are marked with a solid band indicating the positive lead. Aluminum electrolytics are available with bands or symbols marking

Table 22.10
Aluminum Electrolytic Capacitors EIA ±20%Standard Values

µF	*µF*	*µF*	*µF*	*µF*
0.1	1.0	10	100	1000
0.22	2.2	22	220	2200
0.33	3.3	33	330	3300
0.47	4.7	47	470	4700
0.68	6.8	68	680	6800
0.82	8.2	82	820	8200

either the negative or positive lead. The positive lead of axial-lead electrolytic capacitors is usually manufactured to be longer than the negative lead and often enters the capacitor through fiber or plastic insulating material while the negative lead is connected directly to the metallic case of the capacitor. Misidentifying the polarity of capacitors is a common error during assembly or repair.

22.3.3 Surface Mount Capacitors

SMT capacitors are generally film, ceramic or tantalum electrolytics. Body sizes are shown in **Fig 22.8** and **22.9**. Although the EIA scheme is the standard method of labeling capacitor value, you may encounter a two-character alphanumeric code (see **Table 22.11**) consisting of a letter indicating the significant digits and a number indicating the multiplier. The code represents the capacitance in picofarads. For example, a chip capacitor marked "A4" would have a capacitance of 10,000 pF, or 0.01 µF. A unit marked "N1" would be a 33-pF capacitor. If there is sufficient space on the device package, a tolerance code may be included. The standard SMT body sizes and pad spacing are provided in **Table 22.12**.

Table 22.11
SMT Capacitor Two-Character Labeling

Significant Figure Codes

Character	*Significant Figures*	*Character*	*Significant Figures*
A	1.0	T	5.1
B	1.1	U	5.6
C	1.2	V	6.2
D	1.3	W	6.8
E	1.5	X	7.5
F	1.6	Y	8.2
G	1.8	Z	9.1
H	2.0	a	2.5
J	2.2	b	3.5
K	2.4	d	4.0
L	2.7	e	4.5
M	3.0	f	5.0
N	3.3	m	6.0
P	3.6	n	7.0
Q	3.9	t	8.0
R	4.3	y	9.0
S	4.7		

Multiplier Codes

Numeric Character	*Decimal Multiplier*
0	1
1	10
2	100
3	1,000
4	10,000
5	100,000
6	1,000,000
7	10,000,000
8	100,000,000
9	0.1

Table 22.12
Surface Mount Capacitors — EIA Standard Sizes

Size	*Length*	*Width*	*Height*	*C*	*SMT Pad*	*C-C**
0402	0.039	0.020	0.014	0.010	0.025 × 0.035	0.050
0603	0.063	0.031	0.018	0.014	0.030 × 0.030	0.055
0805	0.079	0.049	0.020	0.016	0.040 × 0.050	0.075
1206	0.126	0.063	0.024	0.020	0.064 × 0.064	0.125
1210	0.126	0.102	0.024	0.020	0.070 × 0.100	0.150

Surface Mount Electrolytic Capacitors — EIA Standard Sizes

Size	*Length*	*Width*	*Height*	*C-C**	*SMT Pad*
A (1206)	0.126	0.063	0.063	0.110	0.055 × 0.060
B (1411)	0.138	0.110	0.075	0.136	0.075 × 0.090
C (2412)	0.236	0.126	0.098	0.265	0.090 × 0.120
D (2916)	0.287	0.169	0.110	0.250	0.100 × 0.100
E (2924)	0.287	0.236	0.142	0.250	0.100 × 0.100

Dimensions in inches.
*C-C is SMT pad center-to-center spacing

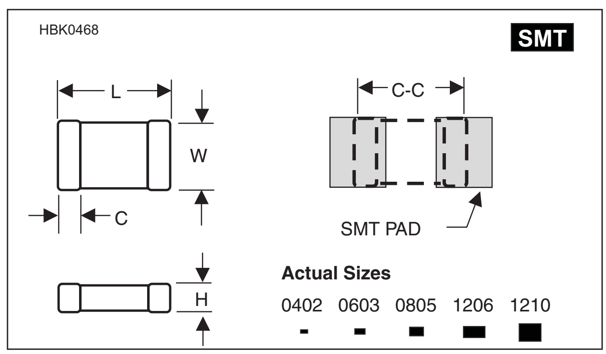


Fig 22.8 — Surface-mount capacitor packages.

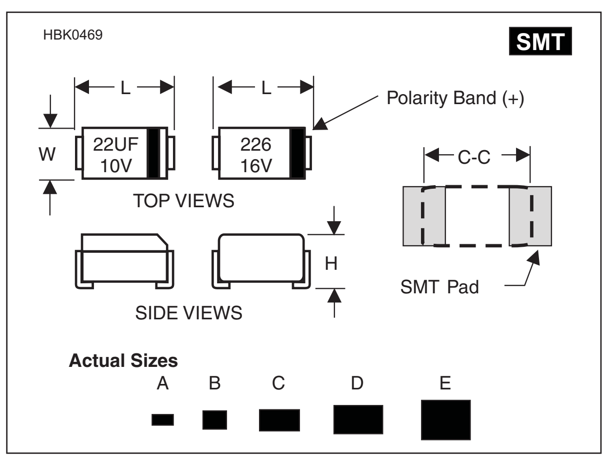


Fig 22.9 — Surface-mount electrolytic packages.

22.3.4 Capacitor Voltage Ratings

Capacitors are also rated by their maximum operating voltage. The importance of selecting a capacitor with the proper voltage rating is often overlooked. Exceeding the voltage rating, even momentarily, can cause excessive heating, a permanent shift of the capacitance value, a short circuit, or outright destruction. As a result, the voltage rating should be at least 25% higher than the working voltage across the capacitor; many designers use 50-100%.

Following the 25% guideline, filter capacitors for a 12-V system should have at least a 15-V rating (12 V × 1.25). However, 12-V systems such as 12-V power supplies and automotive 12-V electrical systems actually operate near 13.8 V and in the case of automotive systems, as high as 15 V. In such cases, capacitors rated for 15 V would be an insufficient margin of safety; 20 to 25-V capacitors should be used in such cases.

In large signal ac circuits, the maximum voltage rating of the capacitor should be based on the peak-to-peak voltages present. For example, the output of a 5-W QRP transmitter is 16 V_{RMS}, or about 45 V_{P-P}. Capacitors exposed to the 5 W RF power, such as in the output low-pass filter, should be rated well above 50 V for the 25% rule. A 100 W transmitter produces RF voltages of about 200 V_{P-P}.

Capacitors that are to be connected to primary ac circuits (directly to the ac line) for filtering or coupling *must* be rated for ac line use. These capacitors are listed as such in catalogs and are designed to minimize fire and other hazards in case of failure. Remember, too, that ac line voltage is given as RMS, with peak-to-peak voltage 2.83 times higher: 120 V_{RMS} = 339 V_{P-P}.

Applying peak-to-peak voltages approaching the maximum voltage rating will cause excessive heating of the capacitor. This, in turn, will cause a permanent shift in the capacitance value. This could be undesirable in the output low pass filter example cited above in trying to maintain the proper impedance match between transmitter and antenna.

Exceeding the maximum voltage rating can also cause a breakdown of the dielectric material in the capacitor. The voltage can jump between the plates causing momentary or permanent electrical shorts between the capacitor plates.

In electrolytic and tantalum capacitors, exceeding the voltage rating can produce extreme heating of the oil or wetting agent used as the dielectric material. The expanding gases can cause the capacitor to burst or explode.

These over-voltage problems are easily avoided by selecting a capacitor with a voltage rating 25-50% above the normal peak-to-peak

Table 22.13
Capacitor Standard Working Voltages

Ceramic	*Polyester*	*Electrolytic*	*Tantalum*
		6.3 V	6.3 V
		10 V	10 V
16 V		16 V	16 V
			20 V
25 V		25 V	25 V
		35 V	35 V
50 V	50 V	50 V	50 V
		63 V	63 V
100 V	100 V	100 V	
	150 V	150 V	
200 V	200 V		
	250 V	250 V	

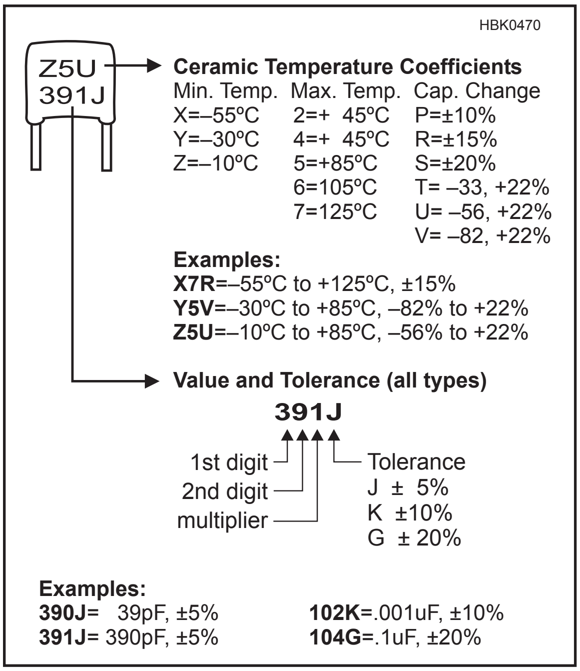
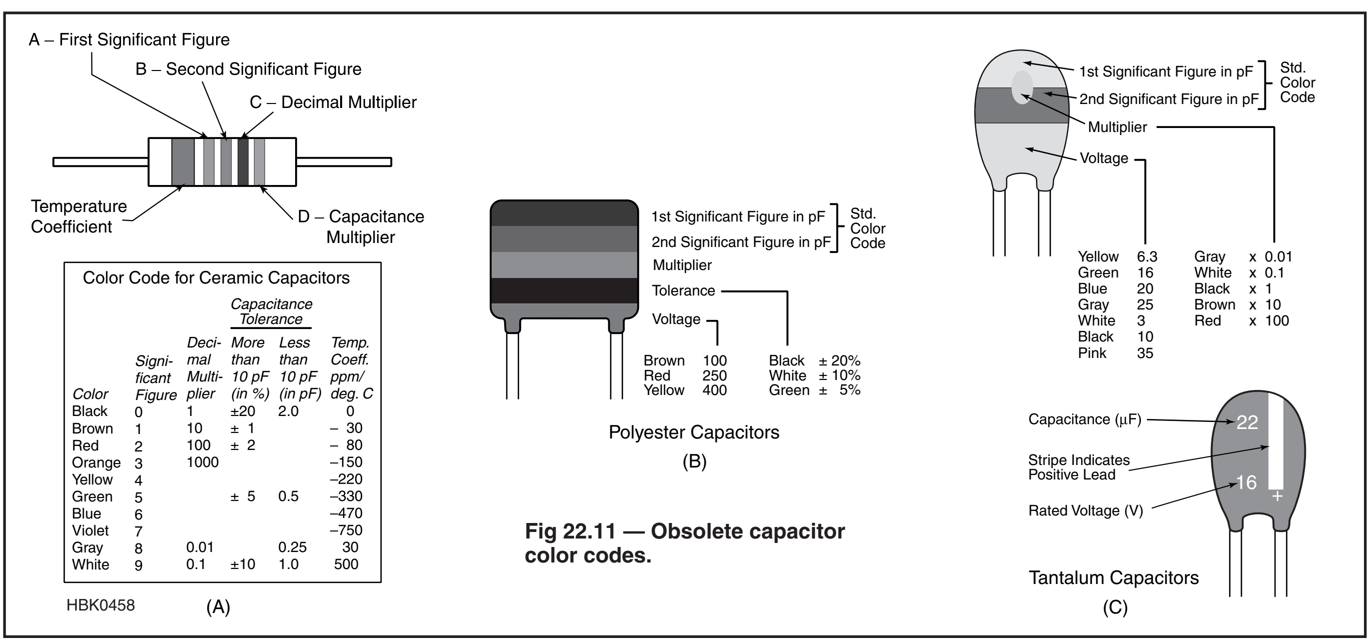


Fig 22.10 — Abbreviated EIA capacitor identification. This method is used on SMT capacitors. An "R" in the numeric field stands for "radix" and represents a decimal point, so that "4R7" indicates "4.7" for example.



Color Code for Ceramic Capacitors

Color	Significant Figure	Decimal Multiplier	Capacitance Tolerance: More than 10 pF (in %)	Capacitance Tolerance: Less than 10 pF (in pF)	Temp. Coeff. ppm/deg. C
Black	0	1	±20	2.0	0
Brown	1	10	± 1		– 30
Red	2	100	± 2		– 80
Orange	3	1000			–150
Yellow	4				–220
Green	5		± 5	0.5	–330
Blue	6				–470
Violet	7				–750
Gray	8	0.01		0.25	30
White	9	0.1	±10	1.0	500

Fig 22.11 — Obsolete capacitor color codes.

operating voltage. **Table 22.13** lists standard working voltages for common capacitor types.

22.3.5 Capacitor Identification

Capacitors are identified by the EIA numerical or color code standard as shown in **Fig 22.10**. Since 2000, the EIA numerical code is the most dominant form of capacitor identification and is used on all capacitor types and body styles. Color coding schemes are becoming rare, used only by a few non-US manufacturers. Some thru-hole "gum drop" tantalum capacitors also still use the color codes of **Fig 22.11**. Electrolytic and tantalum capacitors are often labeled with capacitance and working voltage in µF and V as in Fig 22.11C.

Similar to the resistor EIA code, numerals are used to indicate the significant numerals and the multiplier, followed by an alphabetic character to indicate the tolerance. The multiplier is simply the number of zeros following the significant numerals. For example, a capacitor marked with "122K" would be a 1200 pF 10% capacitor. The use of R to denote a decimal point in a value can be confusing if pF or µF are not specified. Generally, an inspection of the capacitor will determine which is correct but a capacitance meter may be required. Additional digits and codes may be encountered as shown in **Fig 22.12**.

Military-surplus equipment using the obsolete "postage stamp" capacitors is still encountered in Amateur Radio. These capacitors used the colored dot method of value identification shown in **Fig 22.13**.

European manufacturers often use nanofarads or nF, such that 10 nF, or simply 10N, indicates 10 nanofarads. This is equivalent to 10,000 pF or 0.01 µF. This notational scheme, shown in **Table 22.14**, is more commonly found on schematic diagrams than actual part markings.

Table 22.14
European Marking Standards for Capacitors

Marking	*Value*
1p	1 pF
2p2	2.2 pF
10p	10 pF
100p	100 pF
1n	1 nF (= 0.001 µF)
2n2	2.2 nF (= 0.0022 µF)
10n	10 nF (= 0.01 µF)
100n	100 nF (= 0.1 µF)
1u	1 µF
5u6	5.6 µF
10u	10 µF
100u	100 µF

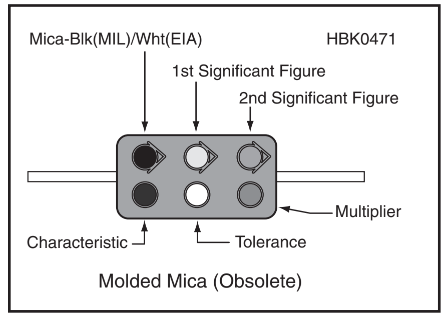
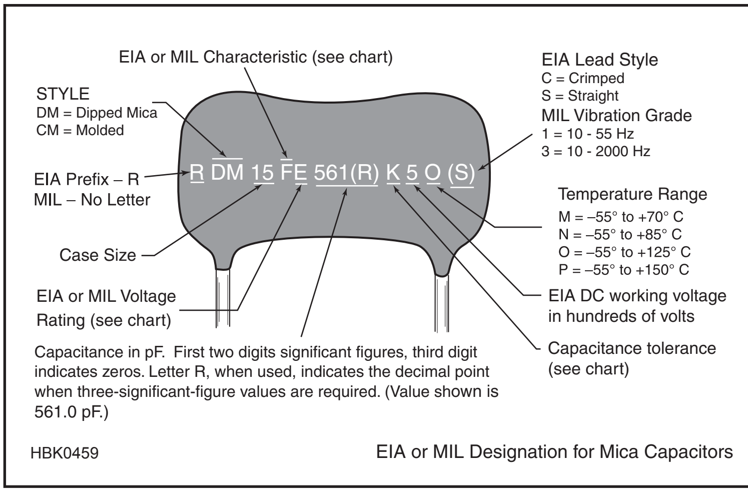


Fig 22.13 — Obsolete JAN "postage stamp" capacitor labeling.



Letter Designator	*"Characteristic" Max Capacitance Drift*	*"Characteristic" Max Range of Temp Coeff (ppm / deg. C)*	*MIL Voltage Rating (V)*	*Capactitance Tolerance (Percent)*
A	-	-	100	-
B	Not Specified	Not Specified	250	-
C	±(0.5% + 0.1 pF)	±200	300	-
D	±(0.3% + 0.1 pF)	±100	500	-
E	±(0.1% + 0.1 pF)	–20 to +100	600	-
F	±(0.05% + 0.1 pF)	0 to +70	1000	±1
G	-	-	1200	±2
H	-	-	1500	-
J	-	-	2000	±5
K	-	-	2500	±10
L	-	-	3000	-
M	-	-	4000	±20

MIL voltage ratings for other letter designators: N=5000 V, P=6000 V, Q=8000 V, R=10,000 V, S-12,000 V, T=15,000 V, U=20,000 V, V=25,000 V, W=30,000 V, X=35,000 V.

Fig 22.12 — Complete EIA capacitor labeling scheme.

22.4 Inductors

Inductors, both fixed and variable are available in a wide variety of types and packages, and many offer few clues as to their values. Some coils and chokes are marked with the EIA color code shown in Table 22.4. See **Fig 22.14** for another marking system for cylindrical encapsulated RF chokes. The body of these components is often green to identify them as inductors and not resistors. Measure the resistance of the component with an ohmmeter if there is any doubt as to the identity of the component. **Table 22.15** is a list of the EIA standard inductor values.

Table 22.16 lists the properties of common powdered-iron cores. Formulas are given for calculating the number of required turns based on a given inductance and for calculating the inductance given a specific number of turns. Most powdered-iron toroid cores that amateurs use are manufactured by Micrometals (**www.micrometals.com**). Paint is used to identify the material used in the core. The Micrometals color code is part of Table 22.16. **Table 22.17** gives the physical dimensions of powdered-iron toroids.

An excellent design resource for ferrite-based components is the Fair-Rite Materials Corp on-line catalog at **www.fair-rite.com**. The Fair-Rite Web site's Technical section also has free papers on the use of ferrites for EMI suppression and broadband transformers. The

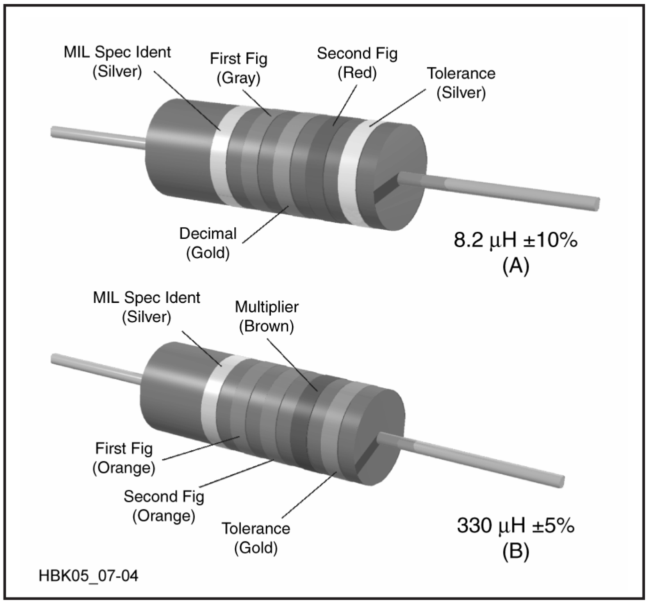


Fig 22.14 — Color coding for cylindrical encapsulated RF chokes. At A, an example of the coding for an 8.2-µH choke is given. At B, the color bands for a 330-µH inductor are illustrated. The color code is given in Table 22.4.

Table 22.15
EIA Standard Inductor Values

µH	*µH*	*µH*	*mH*	*mH*	*mH*
1.0	10	100	1.0	10	100
1.2	12	120	1.2	12	120
1.5	15	150	1.5	15	150
2.2	22	220	2.2	22	220
2.7	27	270	2.7	27	270
3.3	33	330	3.3	33	330
3.9	39	390	3.9	39	390
4.7	47	470	4.7	47	470
5.6	56	560	5.6	56	560
6.8	68	680	6.8	68	680
8.2	82	820	8.2	82	820

following list presents the general characteristics (material and composition and intended application) of Fair-Rite's ferrite materials:

- Type 31 (MnZn) — EMI suppression applications from 1 MHz up to 500 MHz.
- Type 43 (NiZn) — Suppression of conducted EMI, inductors and HF common-mode chokes from 20 MHz to 250 MHz.
- Type 44 (NiZn) — EMI suppression from 30 MHz to 500 MHz.
- Type 61 (NiZn) — Inductors up to 25 MHz and EMI suppression above 200 MHz.
- Type 67 (NiZn) — Broadband transformers, antennas and high-Q inductors up to 50 MHz.
- Type 73 (MnZn) — Suppression of conducted EMI below 50 MHz.
- Type 75 (MnZn) — Broadband and pulse transformers.

See **Table 22.18** for information about the magnetic properties of ferrite cores. Ferrite cores are not typically painted, so identification is often difficult. More information about the use of ferrites at RF is provided in the **RF Techniques** chapter.

Table 22.16

Powdered-Iron Toroidal Cores: Magnetic Properties

There are differing conventions for referring to the type of core material: #, mix and type are all used. For example, all of the following designate the same material: #12, Mix 12, 12-Mix, Type 12 and 12-Type.

Inductance and Turns Formula

The turns required for a given inductance or inductance for a given number of turns can be calculated from:

$$N = 100\sqrt{\frac{L}{A_L}} \qquad L = A_L\left(\frac{N^2}{10{,}000}\right)$$

where N = number of turns; L = desired inductance (μH); A_L = inductance index (μH per 100 turns).

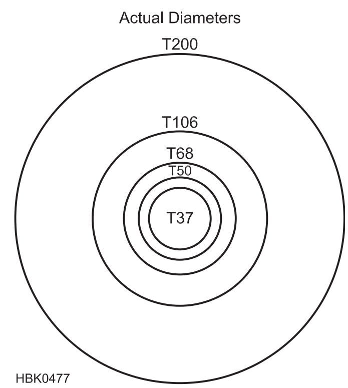
The industry standard is to provide values of A_L in units of inductance per number of turns squared as in the preceding formulas. Amidon Associates gives the A_L value in units of inductance per turn. The units of inductance are generally in nH but may also be mH. Make sure you understand which units apply and use the A_L value and formula provided by the manufacturer of the core to calculate number of turns or inductance.

Toroid diameter is indicated by the number following "T" — T-200 is 2.00 in. dia; T-68 is 0.68 in. diameter, etc.

AL Values

	Mix										
Size	*26**	*3*	*15*	*1*	*2*	*7*	*6*	*10*	*12*	*17*	*0*
T-12	na	60	50	48	20	18	17	12	7.5	7.5	3.0
T-16	145	61	55	44	22	na	19	13	8.0	8.0	3.0
T-20	180	76	65	52	27	24	22	16	10.0	10.0	3.5
T-25	235	100	85	70	34	29	27	19	12.0	12.0	4.5
T-30	325	140	93	85	43	37	36	25	16.0	16.0	6.0
T-37	275	120	90	80	40	32	30	25	15.0	15.0	4.9
T-44	360	180	160	105	52	46	42	33	18.5	18.5	6.5
T-50	320	175	135	100	49	43	40	31	18.0	18.0	6.4
T-68	420	195	180	115	57	52	47	32	21.0	21.0	7.5
T-80	450	180	170	115	55	50	45	32	22.0	22.0	8.5
T-94	590	248	200	160	84	na	70	58	32.0	na	10.6
T-106	900	450	345	325	135	133	116	na	na	na	19.0
T-130	785	350	250	200	110	103	96	na	na	na	15.0
T-157	870	420	360	320	140	na	115	na	na	na	na
T-184	1640	720	na	500	240	na	195	na	na	na	na
T-200	895	425	na	250	120	105	100	na	na	na	na

*Mix-26 is similar to the older Mix-41, but can provide an extended frequency range.



Magnetic Properties Iron Powder Cores

Mix	*Color*	*Material*	μ	*Temp stability (ppm/°C)*	*f (MHz)*	*Notes*
26	Yellow/white	Hydrogen reduced	75	825	dc - 1	Used for EMI filters and dc chokes
3	Gray	Carbonyl HP	35	370	0.05 - 0.50	Excellent stability, good Q for lower frequencies
15	Red/white	Carbonyl GS6	25	190	0.10 - 2	Excellent stability, good Q
1	Blue	Carbonyl C	20	280	0.50 - 5	Similar to Mix-3, but better stability
2	Red	Carbonyl E	10	95	2 - 30	High Q material
7	White	Carbonyl TH	9	30	3 - 35	Similar to Mix-2 and Mix-6, but better temperature stability
6	Yellow	Carbonyl SF	8	35	10 - 50	Very good Q and temperature stability for 20-50 MHz
10	Black	Powdered iron W	6	150	30 - 100	Good Q and stability for 40 - 100 MHz
12	Green/white	Synthetic oxide	4	170	50 - 200	Good Q, moderate temperature stability
17	Blue/yellow	Carbonyl	4	50	40 - 180	Similar to Mix-12, better temperature stability, Q drops about 10% above 50 MHz, 20% above 100 MHz
0	Tan	phenolic	1	0	100 - 300	Inductance may vary greatly with winding technique

Courtesy of Amidon Assoc and Micrometals
Note: Color codes hold only for cores manufactured by Micrometals, which makes the cores sold by most Amateur Radio distributors.

Table 22.17

Powdered-Iron Toroidal Cores: Dimensions

Toroid diameter is indicated by the number following "T" — T-200 is 2.00 in. dia; T-68 is 0.68 in. diameter, etc.
See Table 22.16 for a core sizing guide.

Red E Cores—500 kHz to 30 MHz (μ = 10)

No.	*OD (in)*	*ID (in)*	*H (in)*
T-200-2	2.00	1.25	0.55
T-94-2	0.94	0.56	0.31
T-80-2	0.80	0.50	0.25
T-68-2	0.68	0.37	0.19
T-50-2	0.50	0.30	0.19
T-37-2	0.37	0.21	0.12
T-25-2	0.25	0.12	0.09
T-12-2	0.125	0.06	0.05

Black W Cores—30 MHz to 200 MHz (μ=6)

No.	*OD (In)*	*ID (In)*	*H (In)*
T-50-10	0.50	0.30	0.19
T-37-10	0.37	0.21	0.12
T-25-10	0.25	0.12	0.09
T-12-10	0.125	0.06	0.05

Yellow SF Cores—10 MHz to 90 MHz (μ=8)

No.	*OD (In)*	*ID (In)*	*H (In)*
T-94-6	0.94	0.56	0.31
T-80-6	0.80	0.50	0.25
T-68-6	0.68	0.37	0.19
T-50-6	0.50	0.30	0.19
T-26-6	0.25	0.12	0.09
T-12-6	0.125	0.06	0.05

Number of Turns vs Wire Size and Core Size

Approximate maximum number of turns—single layer wound—enameled wire.

Wire Size	*T-200*	*T-130*	*T-106*	*T-94*	*T-80*	*T-68*	*T-50*	*T-37*	*T-25*	*T-12*
10	33	20	12	12	10	6	4	1		
12	43	25	16	16	14	9	6	3		
14	54	32	21	21	18	13	8	5	1	
16	69	41	28	28	24	17	13	7	2	
18	88	53	37	37	32	23	18	10	4	1
20	111	67	47	47	41	29	23	14	6	1
22	140	86	60	60	53	38	30	19	9	2
24	177	109	77	77	67	49	39	25	13	4
26	223	137	97	97	85	63	50	33	17	7
28	281	173	123	123	108	80	64	42	23	9
30	355	217	154	154	136	101	81	54	29	13
32	439	272	194	194	171	127	103	68	38	17
34	557	346	247	247	218	162	132	88	49	23
36	683	424	304	304	268	199	162	108	62	30
38	875	544	389	389	344	256	209	140	80	39
40	1103	687	492	492	434	324	264	178	102	51

Actual number of turns may differ from above figures according to winding techniques, especially when using the larger size wires. Chart prepared by Michel J. Gordon, Jr, WB9FHC.
Courtesy of Amidon Assoc.

Table 22.18
Ferrite Toroids: A_L Chart (mH per 1000 turns) Enameled Wire

There are differing conventions for referring to the type of ferrite material: #, mix and type are all used. For example, all of the following designate the same ferrite material: #43, Mix 43, 43-Mix, Type 43, and 43-Type.

Fair-Rite Corporation (**www.fair-rite.com**) and Amidon (**www.amidoncorp.com**) ferrite toroids can be cross-referenced as follows:

For Amidon toroids, "FT-XXX-YY" indicates a ferrite toroid, with XXX as the OD in hundredths of an inch and YY the mix. For example, an FT-23-43 core has an OD of 0.23 inch and is made of type 43 material. Additional letters (usually "C") are added to indicate special coatings or different thicknesses.

For Fair-Rite toroids, digits 1 and 2 of the part number indicate product type (59 indicates a part for inductive uses), digits 3 and 4 indicate the material type, digits 5 through 9 indicate core size, and the final digit indicates coating (1 for Paralene and 2 for thermo-set). For example, Fair-Rite part number 5943000101 is equivalent to the Amidon FT-23-43 core.

Ferrite Toroids: A_L Chart (mH per 1000 turns)

Toroid diameter is specified as the outside diameter of the core. See Table 22.16 for a core sizing guide.

Core Size (in)	*63/67-Mix μ = 40*	*61-Mix μ = 125*	*43-Mix μ = 850*	*77 (72)-Mix μ = 2000*	*J (75)-Mix μ = 5000*
0.23	7.9	24.8	188	396	980
0.37	19.7	55.3	420	884	2196
0.50	22.0	68.0	523	1100	2715
0.82	22.4	73.3	557	1170	NA
1.14	25.4	79.3	603	1270	3170
1.40	45	140	885	2400	5500
2.40	55	170	1075	2950	6850

31-Mix is an EMI suppression material and not recommended for inductive use.

Inductance and Turns Formula

The turns required for a given inductance or inductance for a given number of turns can be calculated from:

$$N = 1000\sqrt{\frac{L}{A_L}} \qquad L = A_L\left(\frac{N^2}{1{,}000{,}000}\right)$$

where N = number of turns; L = desired inductance (mH); A_L = inductance index (mH per 1000 turns).

Ferrite Magnetic Properties

Property	*Unit*	*63/67-Mix*	*61-Mix*	*43-Mix*	*77 (72)-Mix*	*J (75)-Mix*	*31-Mix*
Initial perm.	(μ_i)	40	125	850	2000	5000	1500
Max. perm.		125	450	3000	6000	8000	Not spec.
Saturation flux density @ 10 oe	gauss	1850	2350	2750	4600	3900	3400
Residual flux density	gauss	750	1200	1200	1150	1250	2500
Curie temp.	°C	450	350	130	200	140	>130
Vol. resistivity	ohm/cm	1×10^8	1×10^8	1×10^5	1×10^2	5×10^2	3×10^3
Resonant circuit frequency	MHz	15-25	0.2-10	0.01-1	0.001-1	0.001-1	*
Specific gravity		4.7	4.7	4.5	4.8	4.8	4.7
Loss factor	$\frac{1}{\mu_i Q}$	110×10^{-6} @25 MHz	32×10^{-6} @2.5 MHz	120×10^{-6} @1 MHz	4.5×10^{-6} @0.1 MHz	15×10^{-6} @0.1 MHz	20×10^{-6} @0.1 MHz
Coercive force	Oe	2.40	1.60	0.30	0.22	0.16	0.35
Temp. Coef. of initial perm.	%/°C (20°-70°)	0.10	0.15	1.0	0.60	0.90	1.6

*31-Mix is an EMI suppression material and not recommended for inductive uses.

Ferrite Toroids—Physical Properties

All physical dimensions in inches.

OD (in)	*ID (in)*	*Height (in)*	A_e	ℓ_e	V_e
0.230	0.120	0.060	0.00330	0.529	0.00174
0.375	0.187	0.125	0.01175	0.846	0.00994
0.500	0.281	0.188	0.02060	1.190	0.02450
0.825	0.520	0.250	0.03810	2.070	0.07890
1.142	0.750	0.295	0.05810	2.920	0.16950
1.400	0.900	0.500	0.12245	3.504	0.42700
2.400	1.400	0.500	0.24490	5.709	1.39080

Different height cores may be available for each core size.
A_e — Effective magnetic cross-sectional area $(in)^2$
ℓ_e — Effective magnetic path length (inches)
V_e — Effective magnetic volume $(in)^3$
To convert from $(in)^2$ to $(cm)^2$, divide by 0.155
To convert from $(in)^3$ to $(cm)^3$, divide by 0.0610
Courtesy of Amidon Assoc. and Fair-Rite Corp.

22.5 Transformers

Many transformers, including power transformers, IF transformers, and audio transformers, are made to be installed on PC boards, and have terminals designed for that purpose. Some transformers are manufactured with wire leads that are color-coded to identify each connection. When colored wire leads are present, the color codes in **Tables 22.19**, **22.20** and **22.21** usually apply. In addition, many miniature IF transformers are tuned with slugs, color-coded to signify their application. **Table 22.22** lists application versus slug color.

Table 22.20
IF Transformer Wiring Color Codes

Plate lead:	Blue
B+ lead:	Red
Grid (or diode) lead:	Green
Grid (or diode) return:	Black

Note: If the secondary of the IF transformer is center-tapped, the second diode plate lead is green-and-black striped, and black is used for the center-tap lead.

Table 22.21
IF Transformer Slug Color Codes

Frequency	*Application*	*Slug color*
455 kHz	1st IF	Yellow
	2nd IF	White
	3rd IF	Black
	Osc tuning	Red
10.7 MHz	1st IF	Green
	2nd or 3rd IF	Orange, Brown or Black

Table 22.19
Power-Transformer Wiring Color Codes

Non-tapped primary leads:	Black
Tapped primary leads:	Common: Black Tap: Black/yellow striped Finish: Black/red striped
High-voltage plate winding:	Red
Center tap:	Red/yellow striped
Rectifier filament winding:	Yellow
Center tap:	Yellow/blue striped
Filament winding 1:	Green
Center tap:	Green/yellow striped
Filament winding 2:	Brown
Center tap:	Brown/yellow striped
Filament winding 3:	Slate
Center tap:	Slate/yellow striped

Table 22.22
Audio Transformer Wiring Color Codes

Plate lead of primary	Blue
B+ lead (plain or center-tapped)	Red
Plate (start) lead on center-tapped primaries	Brown (or blue if polarity is not important)
Grid (finish) lead to secondary	Green
Grid return (plain or center tapped)	Black
Grid (start) lead on center tapped secondaries	Yellow (or green if polarity not important)

Note: These markings also apply to line-to-grid and tube-to-line transformers.

22.6 Semiconductors

Most semiconductors are labeled with industry standard part numbers, such as 1N4148 or 2N3904, and possibly a date or batch code. You will also encounter numerous manufacturer-specific part numbers and the so-called "house numbers" (marked with codes used by an equipment manufacturer instead of the standard part numbers). In such cases, it is often possible to find the standard equivalent or a suitable replacement by using one of the semiconductor cross-reference directories available from various replacement-parts distributors. If you look up the house number and find the recommended replacement part, you can often find other standard parts that are replaced by that same part.

Information on the use of semiconductors, common design practices, and the necessary circuit design equations can be found in the chapters on **Analog Basics** and **Digital Basics**. Manufacturer Web sites are often a rich source of information on applying semiconductors, both in general and the specific devices they offer.

22.6.1 Diodes

The diode parameters of most importance are maximum forward current or power handling capacity, reverse leakage current, maximum peak inverse voltage (PIV), maximum reverse voltage and the forward voltage. (See **Table 22.23**) For switching or high-speed rectification applications, the time response parameters are also important.

Power dissipation in a diode is equal to the diode's forward voltage drop multiplied by the average forward current. Although fixed voltages are often used for diodes in small-signal applications (0.6 V for silicon PN-junction diodes, 0.3 V for germanium, for example), the actual forward voltage at higher currents can be significantly higher and must be taken into account for high-current applications, such as power supplies.

Most diodes are marked with a part number and some means of identifying the anode or cathode. A thick band or stripe is commonly used to identify the cathode lead or terminal. Stud-mount diodes are usually labeled with a small diode symbol to indicate anode and cathode. Diodes in axial lead packages are sometimes identified with a color scheme as shown in **Fig 22.15**. The common diode packaging standards are illustrated in **Fig 22.16** and the dimensions listed in **Table 22.24**. Many surface mount diodes are packaged in the same SMT packages as resistors.

Packages containing multiple diodes and rectifier bridge configurations are also

Table 22.23
Semiconductor Diode Specifications†

Listed numerically by device

Device	*Type*	*Material*	*Peak Inverse Voltage, PIV (V)*	*Average Rectified Current Forward (Reverse) $I_O(A)(I_R(A))$*	*Peak Surge Current, I_{FSM} 1 s @ 25°C (A)*	*Average Forward Voltage, VF (V)*
1N34	Signal	Ge	60	8.5 m (15.0 μ)		1.0
1N34A	Signal	Ge	60	5.0 m (30.0 μ)		1.0
1N67A	Signal	Ge	100	4.0 m (5.0 μ)		1.0
1N191	Signal	Ge	90	15.0 m		1.0
1N270	Signal	Ge	80	0.2 (100 μ)		1.0
1N914	Fast Switch	Si	75	75.0 m (25.0 n)	0.5	1.0
1N1183	RFR	Si	50	40 (5 m)	800	1.1
1N1184	RFR	Si	100	40 (5 m)	800	1.1
1N2071	RFR	Si	600	0.75 (10.0 μ)		0.6
1N3666	Signal	Ge	80	0.2 (25.0 μ)		1.0
1N4001	RFR	Si	50	1.0 (0.03 m)		1.1
1N4002	RFR	Si	100	1.0 (0.03 m)		1.1
1N4003	RFR	Si	200	1.0 (0.03 m)		1.1
1N4004	RFR	Si	400	1.0 (0.03 m)		1.1
1N4005	RFR	Si	600	1.0 (0.03 m)		1.1
1N4006	RFR	Si	800	1.0 (0.03 m)		1.1
1N4007	RFR	Si	1000	1.0 (0.03 m)		1.1
1N4148	Signal	Si	75	10.0 m (25.0 n)		1.0
1N4149	Signal	Si	75	10.0 m (25.0 n)		1.0
1N4152	Fast Switch	Si	40	20.0 m (0.05 μ)		0.8
1N4445	Signal	Si	100	0.1 (50.0 n)		1.0
1N5400	RFR	Si	50	3.0 (500 μ)	200	
1N5401	RFR	Si	100	3.0 (500 μ)	200	
1N5402	RFR	Si	200	3.0 (500 μ)	200	
1N5403	RFR	Si	300	3.0 (500 μ)	200	
1N5404	RFR	Si	400	3.0 (500 μ)	200	
1N5405	RFR	Si	500	3.0 (500 μ)	200	
1N5406	RFR	Si	600	3.0 (500 μ)	200	
1N5408	RFR	Si	1000	3.0 (500 μ)	200	
1N5711	Schottky	Si	70	1 m (200 n)	15 m	0.41 @ 1 mA
1N5767	Signal	Si		0.1 (1.0 μ)		1.0
1N5817	Schottky	Si	20	1.0 (1 m)	25	0.75
1N5819	Schottky	Si	40	1.0 (1 m)	25	0.9
1N5821	Schottky	Si	30	3.0		
ECG5863	RFR	Si	600	6	150	0.9
1N6263	Schottky	Si	70	15 m	50 m	0.41 @ 1 mA
5082-2835	Schottky	Si	8	1 m (100 n)	10 m	0.34 @ 1 mA

Si = Silicon; Ge = Germanium; RFR = rectifier, fast recovery.

†For package shape, size and pin-connection information see manufacturers' data sheets. Many retail suppliers offer data sheets to buyers free of charge on request. Data books are available from many manufacturers and retailers.

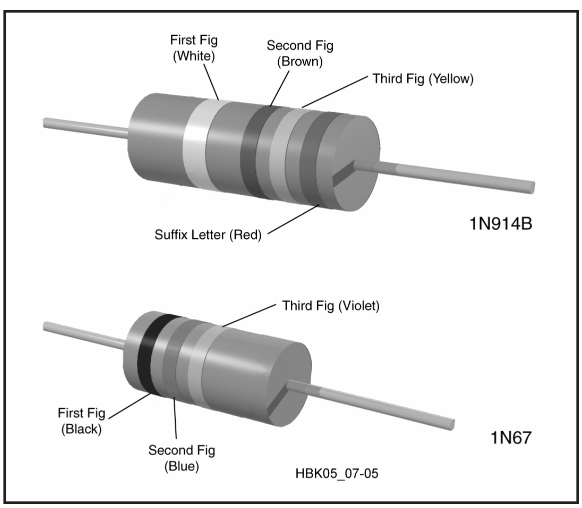


Fig 22.15 — Color-coding for semiconductor diodes. At A, the cathode is identified by the double-width first band. At B, the bands are grouped toward the cathode. Two-Fig designations are signified by a black first band. The color code is given in Table 22.4. The suffix-letter code is A-Brown, B-red, C-orange, D-yellow, E-green, F-blue. The 1N prefix is assumed.

Table 22.24
Package Dimensions for Small Signal, Rectifier and Zener diodes

Case	*L*	*D*	*Ød*	*LS*	*PCB Pads**	*Hole*	*Example*
DO-35	0.166	0.080	0.020	0.30	0.056 dia	0.029	1N4148
DO-41	0.205	0.107	0.034	0.40	0.074 dia	0.040	1N4001
DO-201	0.283	0.189	0.048	0.65	0.150 dia	0.079	1N5401
DO-204	0.205	0.106	0.034	0.40	0.074 dia	0.040	1N4001

Dimensions in inches.
*Customary to make cathode lead square.

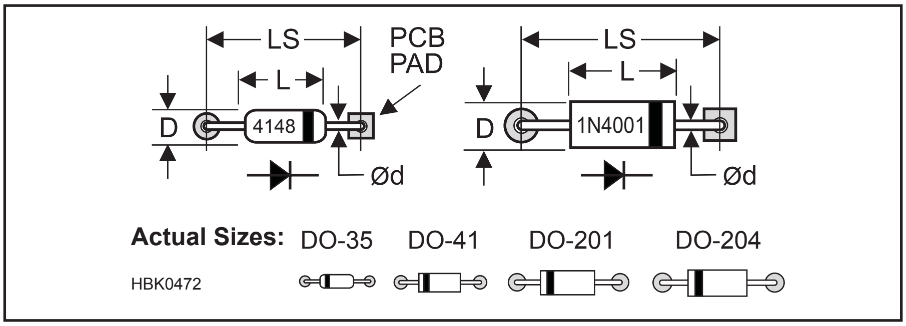


Fig 22.16 — Axial-leaded diode packages and pad dimensions.

commonly available. Full-wave bridge packages are labeled with tildes (~) for the ac inputs and + and – symbols for the rectifier outputs. High-power diodes are often packaged in TO-220 packages with two leads. The package may be labeled with a diode symbol, but if not you will have to obtain the manufacturer's data sheet to identify the anode and cathode leads.

The common 1N914, 1N4148, and 1N5767 switching diodes are suitable for most all small signal applications. The 1N4000 family is commonly used for ac voltage rectification up to 1000 volts PIV. Schottky diodes are used when low forward voltages are required, particularly at high-currents, and exhibit voltages of 0.1-0.2 V at low currents.

Zener diodes, used as voltage references, are manufactured in a wide range of voltages and power handling capacities. Power dissipation in a Zener diode is equal to the Zener voltage multiplied by the average reverse current. The Zener voltage has a significant temperature coefficient and also varies with reverse current. To avoid excessive variations in Zener voltage, limit the diode's power dissipation to no more than ½ of the rated value and for precision uses, ⅕ to ⅒ of the rated power dissipation is recommended. Common varieties of Zener diodes are listed in **Table 22.25**.

Voltage-variable capacitance diodes, also called Varicaps, varactors or tuning diodes, are used in oscillator and tuned circuits where a variable capacitor is needed. Operated with reverse bias, the depletion region forms a capacitor of variable width with a fairly linear voltage vs. capacitance function. Standard tuning diodes produce capacitances in the range of 5 to 40 pF. Hyper-abrupt tuning diodes produce variable capacitances to 100 pF or more for low frequency or wide tuning range applications. Some of the common voltage variable capacitance diodes are listed in **Table 22.26**.

Maximum capacitance occurs with minimum reverse voltage. As the reverse voltage is increased, the capacitance decreases. Tuning diodes are specified by the capacitance produced at two reverse voltages, usually 2 and 30 V. This is called the capacitance ratio and is specified in units of pF per volt. Beyond this range, capacitance change with voltage can become non-linear and may cause signal distortion.

All diodes exhibit some capacitance when reversed biased. Amateurs have learned to use reverse biased Zener and rectifier diodes to form tuning diodes with 20-30 pF maximum capacitance. These "poor man's" tuning diodes are widely used in homebrew projects. However, because the capacitance ratio varies widely from one diode to the next, requiring experimentation to find a suitable diode, they are seldom used in published construction articles.

Light emitting diodes (LED) are another common type of diode. The primary application is that of an illuminated visual indicator when forward biased. LEDs have virtually replaced miniature lamp bulbs for indicators and illumination. LED's are specified primarily by their color, size, shape and output light intensity.

The "standard" size LED is the T-1¾; 5 mm or 0.20 in. diameter. The "miniature" size is the T-1; 3 mm or 0.125 in. diameter. Today, the "standard" and "miniature" size is a bit of a misnomer due to the wide variety of LED sizes and shapes, including SMT varieties. However, the T-1 and T-1¾ remain the most common for homebrew projects due to their inexpensive availability and ease of mounting with a simple panel hole. Their long leads are ideal for prototyping.

22.6.2 Transistors

The information in the tables of transistor data includes the most important parameters for typical applications of transistors of that type. The meaning of the parameters and their relationship to circuit design is covered in the **Analog Basics** chapter or in the references listed at the end of that chapter.

The tables are organized by application; small-signal, general-purpose, RF power, and so on. Some obsolete parts are listed in these tables for reference in repair and maintenance of older equipment. Before using a device in a new design, it is recommended that you check the manufacturer's Web site to be sure that the device has not been replaced by a more capable part and that it is available for future orders.

22.6.3 Voltage Regulators

For establishing a well-regulated fixed voltage reference, the linear voltage regular ICs are often preferred over the Zener diode. Three-terminal voltage regulators require no external components and most have internal current limiting and thermal shutdown circuitry, making them virtually indestructible. (Three-terminal regulators are described in the **Analog Basics** chapter.) The specifications and packages for common voltage regulators are listed in **Table 22.27**.

For fixed-voltage positive regulators, the 7800 family in the TO-220 package is the most common and reasonably priced. They are available in a variety of voltages and supply up to 1 A of current or more, depending on the input voltage. The part number identifies the voltage. For example, a 7805 is a 5-V regulator and a 7812 is a 12-V regulator. The 78L00 low-power versions in the TO-98 package or SOT-89 surface-mount package provide load currents up to 100 mA. The 317 and 340 are the most common adjustable-voltage regulators. Integrated voltage regulators can be used with a pass transistor to extend their load current capability as described in the device data sheets.

Three-terminal regulators are selected primarily for output voltage and maximum load

Table 22.25
Common Zener Diodes

Power dissipation and (package style)

Voltage (V)	*¼ W (DO-35)*	*0.35 W (SOT-23)*	*½ W (SOD-123)*	*½ W (DO-35)*	*1 W (D041)*
2.7	1N4618	MMBZ5223B	MMSZ5223B	1N5223B	—
3.3	1N4620	MMBZ5226B	MMSZ5226B	1N5226B	1N4728A
3.6	1N4621	MMBZ5227B	MMSZ5227B	1N5227B	1N4729A
3.9	1N4622	MMBZ5228B	MMSZ5228B	1N5228B	1N4730A
4.3	1N4623	MMBZ5229B	MMSZ5229B	1N5229B	1N4731A
4.7	1N4624	MMBZ5230B	MMSZ5230B	1N5230B	1N4732A
5.1	1N4625	MMBZ5231B	MMSZ5231B	1N5231B	1N4733A
5.6	1N4626	MMBZ5232B	MMSZ5232B	1N5232B	1N4734A
6.0	— –	MMBZ5233B	MMSZ5233B	1N5233B	—
6.2	1N4627	MMBZ5234B	MMSZ5234B	1N5234B	1N4735A
6.8	1N4099	MMBZ5235B	MMSZ5235B	1N5235B	1N4736A
7.5	1N4100	MMBZ5236B	MMSZ5236B	1N5236B	1N4737A
8.2	1N4101	MMBZ5237B	MMSZ5237B	1N5237B	1N4738A
9.1	1N4103	MMBZ5239B	MMSZ5239B	1N5239B	1N4739A
10	1N4104	MMBZ5240B	MMSZ5240B	1N5240B	1N4740A
11	1N4105	MMBZ5241B	MMSZ5241B	1N5241B	1N4741A
12	— –	MMBZ5242B	MMSZ5242B	1N5242B	1N4742A
13	1N4107	MMBZ5243B	MMSZ5243B	1N5243B	1N4743A
15	1N4109	MMBZ5245B	MMSZ5245B	1N5245B	1N4744A
18	1N4112	MMBZ5248B	MMSZ5248B	1N5248B	1N4746A
20	1N4114	MMBZ5250B	MMSZ5250B	1N5250B	1N4747A
22	1N4115	MMBZ5251B	MMSZ5251B	1N5251B	1N4748A
24	1N4116	MMBZ5252B	MMSZ5252B	1N5252B	1N4749A
27	1N4118	MMBZ5254B	MMSZ5254B	1N5254B	1N4750A
28	1N4119	MMBZ5255B	MMSZ5255B	1N5255B	—
30	1N4120	MMBZ5256B	MMSZ5256B	1N5256B	1N4751A
33	1N4121	MMBZ5257B	MMSZ5257B	1N5257B	1N4752A
36	1N4122	MMBZ5258B	MMSZ5258B	1N5258B	1N4753A
39	1N4123			1N5259B	1N4754A
43	—			1N5260B	1N4755A
47	1N4125			1N5261B	1N4756A
51	1N4126			1N5262B	1N4757A
56				1N5263B	1N4758A
60				1N5264B	—
62				1N5265B	1N4759A
68				1N5266B	1N4760A
75				1N5267B	1N4761A
82					1N4762A
91					1N4763A
100					1N4764A

current. Dropout voltage — the minimum voltage between input and output for which regulation can be maintained — is also very important. For example, the dropout voltage for the 5-V 78L05 is 1.7 V. Therefore, the input voltage must be at least 6.7 V (5 + 1.7 V) to ensure output voltage regulation. The maximum input voltage should also not be exceeded.

Make sure to check the pin assignments for all voltage regulators. While the fixed-voltage positive regulators generally share a common orientation of input, output, and ground, negative-voltage and adjustable regulators do not. Installing a regulator with the wrong connections will usually destroy it and may allow excessive voltage to be applied to the circuit it supplies.

22.6.4 Analog and Digital Integrated Circuits

Integrated circuits (ICs) come in a variety of packages, including transistor-like metal cans, dual and single in-line packages (DIPs and SIPs), flat-packs and surface-mount packages. Most are marked with a part number and a four-digit manufacturer's date code indicating the year (first two digits) and week (last two digits) that the component was made. As mentioned in the introduction to this chapter, ICs are frequently house-marked and cross-reference directories can be helpful in identification and replacement. Another very useful reference tool for working with ICs is IC Master (**www.icmaster.com**), a master selection guide that organizes ICs by type, function and certain key parameters. A part number index is included, along with application notes and manufacturer's information for millions of devices.

IC part numbers provide a complete description of the device's function and ratings. For example, a 4066 IC contains four independent CMOS SPST switches. The 4066 is a CMOS device available from a number of different manufacturers in different package styles and ratings. The two- or three-letter prefix of the part number is generally associated with the part manufacturer. Next, the part type (4066 in this case) shows the function and pin assignments or "pin outs." Following the part type is an alphabetic suffix that describes the version of the part, package code, temperature range, reliability rating and possibly other information. For

Table 22.26

Voltage-Variable Capacitance Diodes†

Listed numerically by device

Device	Nominal Capacitance pF ±10% @ V_R = 4.0 V f = 1.0 MHz	Capacitance Ratio 2-30 V Min.	Q @ 4.0 V 50 MHz Min.	Case Style
1N5441A	6.8	2.5	450	
1N5442A	8.2	2.5	450	
1N5443A	10	2.6	400	DO-7
1N5444A	12	2.6	400	
1N5445A	15	2.6	450	
1N5446A	18	2.6	350	
1N5447A	20	2.6	350	
1N5448A	22	2.6	350	DO-7
1N5449A	27	2.6	350	
1N5450A	33	2.6	350	
1N5451A	39	2.6	300	
1N5452A	47	2.6	250	
1N5453A	56	2.6	200	DO-7
1N5454A	68	2.7	175	
1N5455A	82	2.7	175	
1N5456A	100	2.7	175	
1N5461A	6.8	2.7	600	
1N5462A	8.2	2.8	600	
1N5463A	10	2.8	550	DO-7
1N5464A	12	2.8	550	
1N5465A	15	2.8	550	
1N5466A	18	2.8	500	
1N5467A	20	2.9	500	
1N5468A	22	2.9	500	DO-7
1N5469A	27	2.9	500	
1N5470A	33	2.9	500	

Device	Nominal Capacitance pF ±10% @ V_R = 4.0 V f = 1.0 MHz	Capacitance Ratio 2-30 V Min.	Q @ 4.0 V 50 MHz Min.	Case Style
1N5471A	39	2.9	450	
1N5472A	47	2.9	400	
1N5473A	56	2.9	300	DO-7
1N5474A	68	2.9	250	
1N5475A	82	2.9	225	
1N5476A	100	2.9	200	
MV2101	6.8	2.5	450	TO-92
MV2102	8.2	2.5	450	
MV2103	10	2.0	400	
MV2104	12	2.5	400	
MV2105	15	2.5	400	
MV2106	18	2.5	350	TO-92
MV2107	22	2.5	350	
MV2108	27	2.5	300	
MV2109	33	2.5	200	
MV2110	39	2.5	150	
MV2111	47	2.5	150	TO-92
MV2112	56	2.6	150	
MV2113	68	2.6	150	
MV2114	82	2.6	100	
MV2115	100	2.6	100	

†For package shape, size and pin-connection information, see manufacturers' data sheets.

complete information on the part — any or all of which may be significant to circuit function — use the Web sites of the various manufacturers or enter "data sheet" and the part number into an Internet search engine.

When choosing ICs that are not exact replacements, be wary of substituting "similar" devices, particularly in demanding applications, such as high-speed logic, sensitive receivers, precision instrumentation and similar devices. In particular, substitution of one type of logic family for another — even if the device functions and pin outs are the same — can cause a circuit to not function or function erratically, particularly at temperature extremes. For example, substituting LS TTL devices for HCMOS devices will result in mismatches between logic level thresholds. Substituting a lower-power IC may result in problems supplying enough output current. Even using a faster or higher clock-speed part can cause problems if signals change faster or propagate more quickly than the circuit was designed for. Problems of this sort can be extremely difficult to troubleshoot unless you are skilled in circuit design. When necessary, you can add interface circuits or buffer amplifiers that improve the input and output capabilities of replacement ICs, but auxiliary circuits cannot improve basic device ratings, such as speed or bandwidth. Whenever possible, substitute ICs that are guaranteed or "direct" replacements and that are listed as such by the manufacturer.

ICs are available in different operating temperature ranges. Three standard ranges are common:

- Commercial: 0 °C to 70 °C
- Industrial: –25 °C to 85 °C
- Automotive: –40 °C to 85 °C
- Military: –55°C to 125°C

In some cases, part numbers reflect the temperature ratings. For example, an LM301A op amp is rated for the commercial temperature range; an LM201A op amp for the industrial range and an LM101A for the military range. It is usually acceptable, all other things being equal, to substitute ICs rated for a wider temperature range, but there are often other performance differences associated with the devices meeting wider temperature specifications that should be evaluated before making the substitution.

Table 22.27

Three-Terminal Voltage Regulators

Listed numerically by device

Device	*Description*	*Package*	*Voltage*	*Current (A)*
317	Adj Pos	TO-205	+1.2 to +37	0.5
317	Adj Pos	TO-204,TO-220	+1.2 to +37	1.5
317L	Low Current Adj Pos	TO-205,TO-92	+1.2 to +37	0.1
317M	Med Current Adj Pos	TO-220	+1.2 to +37	0.5
338	Adj Pos	TO-3	+1.2 to +32	5.0
350	High Current Adj Pos	TO-204,TO-220	+1.2 to +33	3.0
337	Adj Neg	TO-205	–1.2 to –37	0.5
337	Adj Neg	TO-204,TO-220	–1.2 to –37	1.5
337M	Med Current Adj Neg	TO-220	–1.2 to –37	0.5
309		TO-205	+5	0.2
309		TO-204	+5	1.0
323		TO-204,TO-220	+5	3.0
140-XX	Fixed Pos	TO-204,TO-220	Note 1	1.0
340-XX		TO-204,TO-220		1.0
78XX		TO-204,TO-220		1.0
78LXX		TO-205,TO-92		0.1
78MXX		TO-220		0.5
78TXX		TO-204		3.0
79XX	Fixed Neg	TO-204,TO-220	Note 1	1.0
79LXX		TO-205,TO-92		0.1
79MXX		TO-220		0.5

Note 1—XX indicates the regulated voltage; this value may be anywhere from 1.2 V to 35 V. A 7815 is a positive 15-V regulator, and a 7924 is a negative 24-V regulator.

The regulator package may be denoted by an additional suffix, according to the following:

Package	**Suffix**
TO-204 (TO-3)	K
TO-220	T
TO-205 (TO-39)	H, G
TO-92	P, Z

For example, a 7812K is a positive 12-V regulator in a TO-204 package. An LM340T-5 is a positive 5-V regulator in a TO-220 package. In addition, different manufacturers use different prefixes. An LM7805 is equivalent to a µA7805 or MC7805.

Common Voltage Regulators — Fixed Positive Voltage

Device	*Output Voltage (V)*	*Output Current (A)*	*Load Regulation (mV)*	*Dropout Voltage (V)*	*Min. Input Voltage (V)*	*Max. Input Voltage (V)*
Surface Mount SOT-89 Case						
78L05ACPK	5.0	0.1	60	1.7	7.0	20
78L06ACPK	6.2	0.1	80	1.7	8.5	20
78L08ACPK	8.0	0.1	80	1.7	10.5	23
78L09ACPK	9.0	0.1	90	1.7	11.5	24
78L12ACPK	12	0.1	100	1.7	14.5	27
78L15ACPK	15	0.1	150	1.7	17.5	30
TO-92 Case						
78L33ACZ	3.3	0.1	60	1.7	5.0	30
78L05ACZ	5.0	0.1	60	1.7	7.0	30
78L06ACZ	6.0	0.1	60	1.7	8.5	30
78L08ACZ	8.0	0.1	80	1.7	10.5	30
78L09ACZ	9.0	0.1	80	1.7	11.5	30
78L12ACZ	12	0.1	100	1.7	14.5	35
78L15ACZ	15	0.1	150	1.7	17.5	35
TO-220 Case						
78M05CV	5.0	0.5	100	2.0	7.0	35
7805ACV	5.0	1.0	100	2.0	7.0	35
7806ACV	6.0	1.0	100	2.0	8.0	35
7808ACV	8.0	1.0	100	2.0	10.0	35
7809ACV	9.0	1.0	100	2.0	11.0	35
7812ACV	12	1.0	100	2.0	14.0	35
7815CV	15	1.0	300	2.0	17.0	35

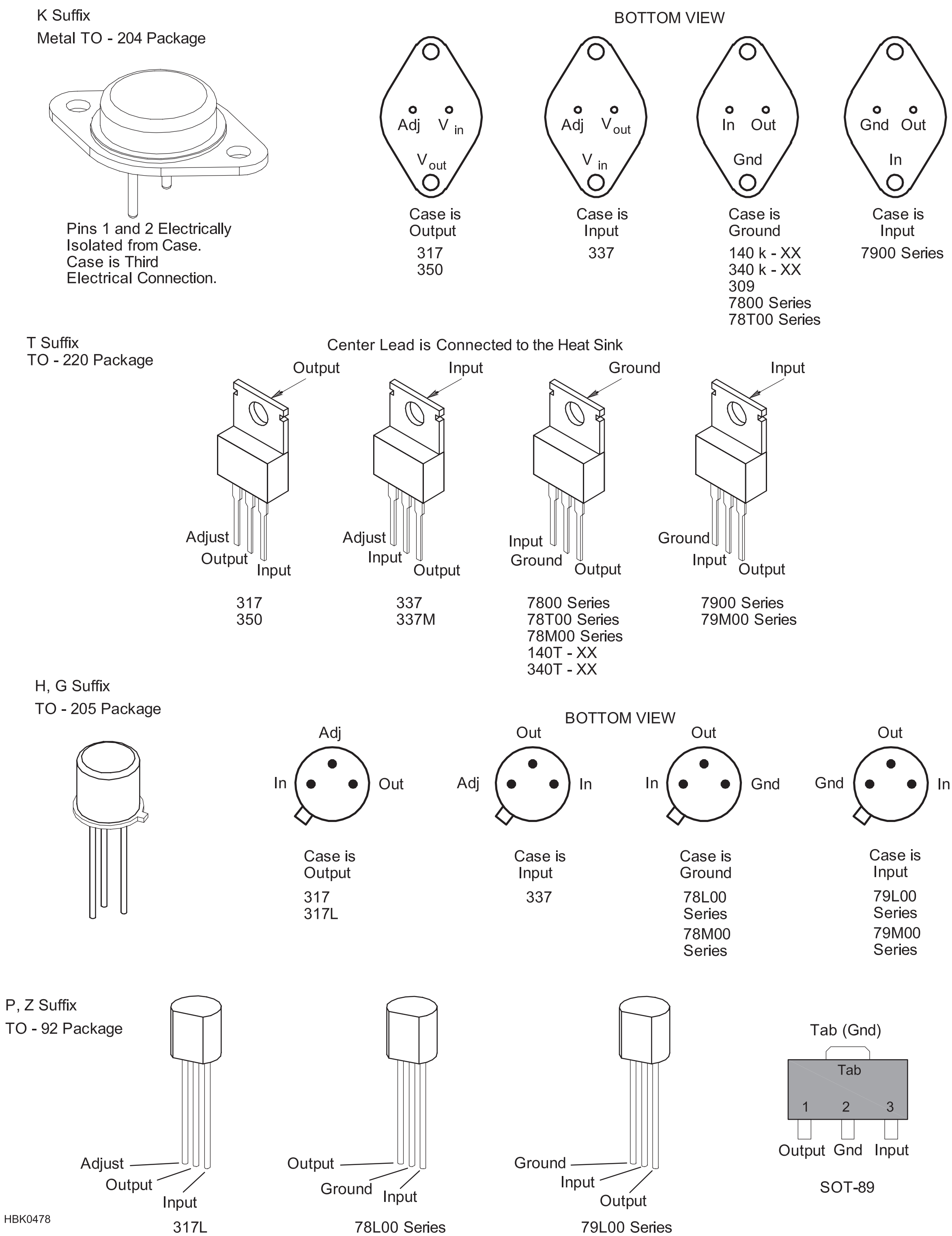

K Suffix
Metal TO - 204 Package
BOTTOM VIEW
Adj V in
V out
Adj V out
V in
In Out
Gnd
Gnd Out
In
Pins 1 and 2 Electrically
Isolated from Case.
Case is Third
Electrical Connection.
Case is
Output
317
350
Case is
Input
337
Case is
Ground
140 k - XX
340 k - XX
309
7800 Series
78T00 Series
Case is
Input
7900 Series
T Suffix
TO - 220 Package
Center Lead is Connected to the Heat Sink
Output
Input
Ground
Input
Adjust
Output
Input
Adjust
Input
Output
Input
Ground
Output
Ground
Input
Output
317
350
337
337M
7800 Series
78T00 Series
78M00 Series
140T - XX
340T - XX
7900 Series
79M00 Series
H, G Suffix
TO - 205 Package
BOTTOM VIEW
Adj
In
Out
Out
Adj
In
Out
In
Gnd
Out
Gnd
In
Case is
Output
317
317L
Case is
Input
337
Case is
Ground
78L00
Series
78M00
Series
Case is
Input
79L00
Series
79M00
Series
P, Z Suffix
TO - 92 Package
Adjust
Output
Input
317L
Output
Ground
Input
78L00 Series
Ground
Input
Output
79L00 Series
Tab (Gnd)
Tab
1 2 3
Output Gnd Input
SOT-89
HBK0478

Table 22.28
Monolithic 50-Ω Amplifiers (MMIC Gain Blocks)

Device	*Case Style*	*Freq. Range (MHz)*	*Gain at 100 MHz (dB)*	*Gain at 1000 MHz (dB)*	*Output Power P1dB (dBm)*	*IP3 (dB)*	*NF (dB)*	*DC Conditions Vb @ Ib*
Avago Technologies								
MSA-0386	B	dc-2400	12.5	11.9	+10.0	+23.0	6.0	5.0 V @ 35 mA
MSA-0486	B	dc-3200	16.4	15.9	+12.5	+25.5	6.5	5.3 V @ 50 mA
MSA-0505	A	dc-2300	7.8	7.0	+18.0	+29.0	6.5	8.4 V @ 80 mA
MSA-0611	C	dc-700	19.5	12.0	+2.0	+14.0	3.0	3.3 V @ 16 mA
MSA-0686	B	dc-800	20.0	16.0	+2.0	+14.5	3.0	3.5 V @ 16 mA
MSA-0786	B	dc-2000	13.5	12.6	+2.0	+14.5	3.0	3.5 V @ 16 mA
MSA-0886	B	dc-1000	32.5	22.4	+5.5	+19.0	5.5	4.0 V @ 22 mA
Mini-Circuits “ERA” Series								
ERA-1+	A, B	dc-8000	12.2	12.1	+11.7	+26.0	5.3	3.6 V @ 40 mA
ERA-2+	A, B	dc-6000	16.2	16.0	+12.8	+26.0	4.7	3.6 V @ 40 mA
ERA-3+	A, B	dc-3000	22.9	22.2	+12.1	+23.0	3.8	3.5 V @ 35 mA
ERA-4+	A, B	dc-4000	13.8	13.7	+17.0	+32.5	5.5	5.0 V @ 65 mA
ERA-5+	A, B	dc-4000	20.2	19.8	+18.4	+33.0	4.5	4.9 V @ 65 mA
ERA-6+	A, B	dc-4000	11.1	11.1	+18.5	+36.5	8.4	5.2 V @ 70 mA
Mini-Circuits “MAR” Series								
MAR-1SM+	A, B	dc-1000	18.5	15.5	+1.5	+14.0	5.5	5.0 V @ 17 mA
MAR-2SM+	A, B	dc-2000	12.5	12.0	+4.5	+17.0	6.5	5.0 V @ 25 mA
MAR-3SM+	A, B	dc-2000	12.5	12.0	+10.0	+23.0	6.0	5.0 V @ 35 mA
MAR-4SM+	A, B	dc-1000	8.3	8.0	+12.5	+25.5	7.0	5.3 V @ 50 mA
MAR-6SM+	A, B	dc-2000	20.0	16.0	+2.0	+14.5	3.0	3.5 V @ 16 mA
MAR-7SM+	A, B	dc-2000	13.5	12.5	+5.5	+19.0	5.0	4.0 V @ 22 mA
MAR-8SM+	A, B	dc-1000	32.5	22.5	+12.5	+27.0	3.3	7.8 V @ 36 mA
Mini-Circuits “VAM” Series								
VAM-3+	C	dc-2000	11.5	11.0	+9.0	+22.0	6.0	4.7 V @ 35 mA
VAM-6+	C	dc-2000	19.5	15.0	+2.0	+14.0	3.0	3.3 V @ 16 mA
VAM-7+	C	dc-2000	13.0	12.0	+5.5	+18.0	5.0	3.8 V @ 22 mA
Mini–Circuits “GALI” Series								
GALI-1+	D	dc-8000	12.7	12.5	+10.5	+27.0	4.5	3.4 V @ 40 mA
GALI-2+	D	dc-8000	16.2	15.8	+12.9	+27.0	4.6	3.5 V @ 40 mA
GALI–3+	D	dc-3000	22.4	21.1	+12.5	+25.0	3.5	3.3 V @ 35 mA
GALI-39+	D	dc-7000	20.8	21.1	+10.5	+22.9	2.4	3.5 V @ 35 mA
GALI-4+	D	dc-4000	14.4	14.1	+17.5	+34.0	4.0	4.6 V @ 65 mA
GALI-5+	D	dc-4000	20.6	19.4	+18.0	+35.0	3.5	4.4 V @ 65 mA
GALI-6+	D	dc-4000	12.2	12.2	+18.2	+35.5	4.5	5.0 V @ 70 mA
GALI-S66+	D	dc-3000	22.0	20.3	+2.8	+18.0	2.7	3.5 V @ 16 mA
Mini–Circuits “RAM” Series								
RAM–1+	B	dc-1000	19.0	15.5	+1.5	+14.0	5.5	5.0 V @ 17 mA
RAM–2+	B	dc-2000	12.5	11.8	+4.5	+17.0	6.5	5.0 V @ 25 mA
RAM–3+	B	dc-2000	12.5	12.0	+10.0	+23.0	6.0	5.0 V @ 35 mA
RAM–4+	B	dc-1000	8.5	8.0	+12.5	+25.5	6.5	5.3 V @ 50 mA
RAM–6+	B	dc-2000	20.0	16.0	+2.0	+14.5	2.8	3.5 V @ 16 mA
RAM–7+	B	dc-2000	13.5	12.5	+5.5	+19.0	4.5	4.0 V @ 22 mA
RAM–8+	B	dc-1000	32.5	23.0	+12.5	+27.0	3.0	7.8 V @ 36 mA

Avago — **www.avagotech.com**
Mini-Circuits Labs — **www.minicircuits.com**

22.6.5 MMIC Amplifiers

Monolithic microwave integrated circuit (MMIC) amplifiers are single-supply 50-Ω wideband gain blocks offering high dynamic range for output powers to about +15 dBm. MMIC amplifiers are becoming increasingly popular in homebrew communications circuits. With bandwidths over 1 GHz, they are well suited for HF, VHF, UHF and lower microwave frequencies.

MMIC amplifiers produce power gains from 10 dB to 30 dB. They also have a high third-order intercept point (IP3), usually in the +20 to +30 dBm range, easing the concerns about amplifier compression for most applications. They are used for RF and IF amplifiers, local oscillator amplifiers, transmitter drivers, and other medium power applications in 50-Ω systems. MMICs are especially well suited for driving 50-Ω double-balanced mixers (DBM). **Fig 22.17** shows the typical circuit arrangement for most MMIC amplifiers.

MMICs are available in a variety of packages, mostly surface mount as shown in **Fig 22.18**, requiring very few external components. Vendor data sheets and application notes, found on the manufacturer's Web sites, should be used for the proper selection of the biasing resistor, coupling capacitors, and other design criteria. Some of the popular MMIC amplifiers are listed in **Table 22.28**.

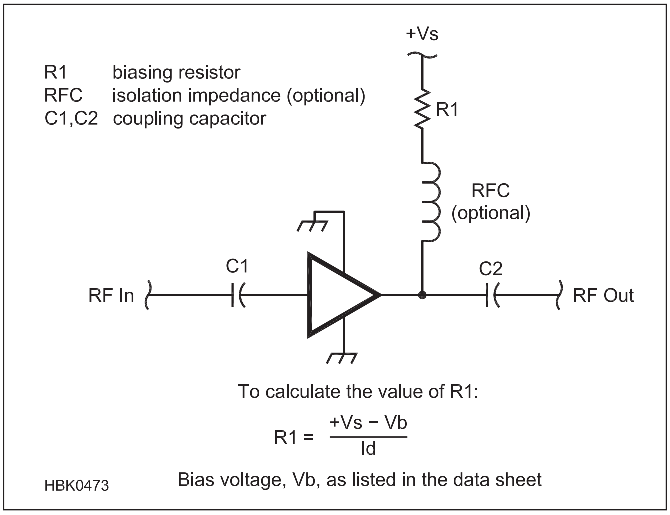


Fig 22.17 — MMIC application.

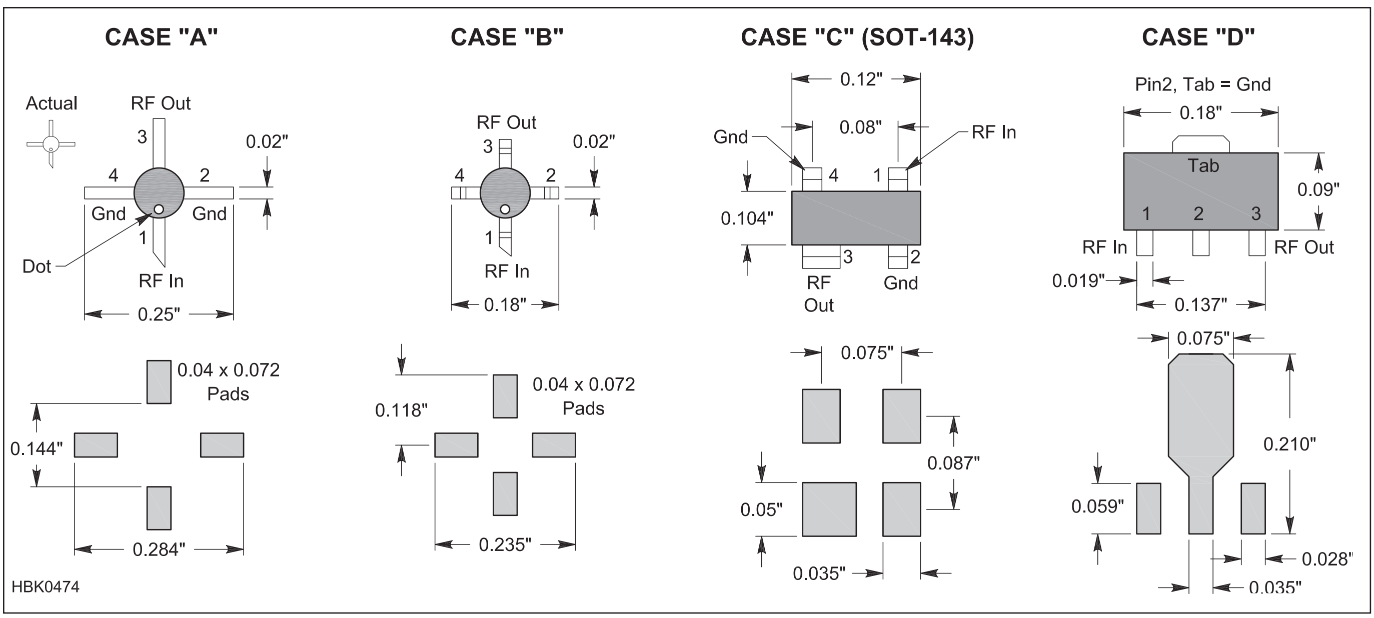


Fig 22.18 — MMIC package styles.

The main disadvantage of MMIC amplifiers is their relatively high current demands, usually in the 30 mA to 80 mA range per device, making them unsuitable for battery-powered portable equipment. On the other hand, the high current demand is what establishes their high gain and high IP3 characteristics with 50-Ω loads.

Another disadvantage is their wide gain-bandwidth. Their gain should be band-limited by input and output tuned circuits or filters to reduce the gain outside the desired ranges. For example, for an HF amplifier, 30 MHz low-pass filters can be used to reduce the gain outside the HF spectrum, or a band-pass filter used for the frequency band of interest.

Selecting the proper MMIC amplifier is fairly straightforward. First, select a device for the desired frequency bandwidth, gain, and output power. Ensure device current is compatible with the design application. Calculate the value for the bias resistor (R1 in Fig 22.17) based on the biasing voltage (V_b) listed in Table 22.28 and whatever value of supply voltage (V_s) is available.

With increasing availability and ease of use, there are many circuits where MMIC amplifiers can be used. There are many MMIC amplifiers that are relatively inexpensive for hobby use.

Table 22.29
Small-Signal FETs

Device	*Type*	*Max Diss (mW)*	*Max V_{DS} (V)*	*$V_{GS(off)}$ (V)*	*Min gfs (µS)*	*Input C (pF)*	*Max ID (mA)*[1]	*f_{max} (MHz)*	*Noise Figure (typ)*	*Case*	*Base*	*Applications*
2N4416	N-JFET	300	30	–6	4500	4	–15	450	4 dB @400 MHz	TO-72	1	VHF/UHF amp, mix, osc
2N5484	N-JFET	310	25	–3	2500	5	30	200	4 dB @200 MHz	TO-92	2	VHF/UHF amp, mix, osc
2N5485	N-JFET	310	25	–4	3500	5	30	400	4 dB @400 MHz	TO-92	2	VHF/UHF amp, mix, osc
2N5486	N-JFET	360	25	–2	5500	5	15	400	4 dB @400 MHz	TO-92	2	VHF/UHF amp. mix, osc
3N200 NTE222 SK3065	N-dual-gate MOSFET	330	20	–6	10,000	4-8.5	50	500	4.5 dB @400 MHz	TO-72	3	VHF/UHF amp, mix, osc
3N202 NTE454 SK3991	N-dual-gate MOSFET	360	25	–5	8000	6	50	200	4.5 dB @200 MHz	TO-72	3	VHF amp, mixer
MPF102 NTE451 SK9164	N-JFET	310	25	–8	2000	4.5	20	200	4 dB @400 MHz	TO-92	2	HF/VHF amp, mix, osc
MPF106 2N5484	N-JFET	310	25	–6	2500	5	30	400	4 dB @200 MHz	TO-92	2	HF/VHF/UHF amp, mix, osc
40673 NTE222 SK3050	N-dual-gate MOSFET	330	20	–4	12,000	6	50	400	6 dB @200 MHz	TO-72	3	HF/VHF/UHF amp, mix, osc
U304	P-JFET	350	–30	+10	27		–50	—	—	TO-18	4	analog switch chopper
U310	N-JFET	500 300	30 30	–6	10,000	2.5	60	450	3.2 dB @450 MHz	TO-52	5	common-gate VHF/UHF amp,
U350	N-JFET Quad	1W	25	–6	9000	5	60	100	7 dB @100 MHz	TO-99	6	matched JFET doubly bal mix
U431	N-JFET Dual	300	25	–6	10,000	5	30	100	—	TO-99	7	matched JFET cascode amp and bal mix
2N5670	N-JFET	350	25	8	3000	7	20	400	2.5 dB @100 MHz	TO-92	2	VHF/UHF osc, mix, front-end amp
2N5668	N-JFET	350	25	4	1500	7	5	400	2.5 dB @100 MHz	TO-92	2	VHF/UHF osc, mix, front-end amp
2N5669	N-JFET	350	25	6	2000	7	10	400	2.5 dB @100 MHz	TO-92	2	VHF/UHF osc, mix, front-end amp
J308	N-JFET	350	25	6.5	8000	7.5	60	1000	1.5 dB @100 MHz	TO-92	2	VHF/UHF osc, mix, front-end amp
J309	N-JFET	350	25	4	10,000	7.5	30	1000	1.5 dB @100 MHz	TO-92	2	VHF/UHF osc, mix, front-end amp
J310	N-JFET	350	25	6.5	8000	7.5	60	1000	1.5 dB @100 MHz	TO-92	2	VHF/UHF osc, mix, front-end amp
NE32684A	HJ-FET	165	2.0	–0.8	45,000	—	30	20 GHz	0.5 dB @12 GHz	84A		Low-noise amp

Notes:
[1]25°C.
For package shape, size and pin-connection information, see manufacturers' data sheets.

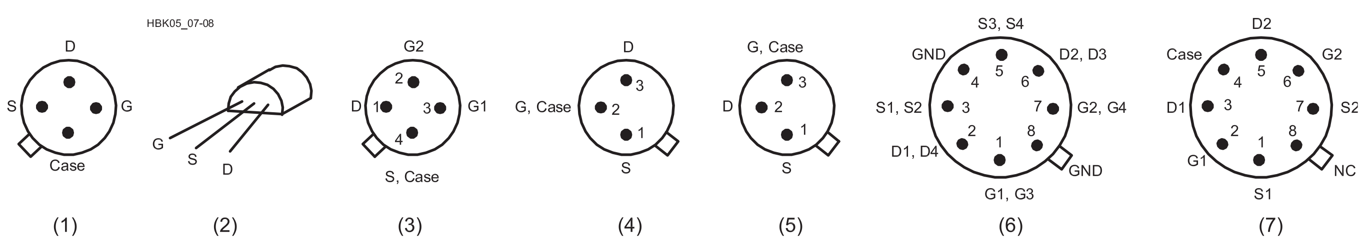


Table 22.30
Low-Noise Bipolar Transistors

Device	*NF (dB)*	*F (MHz)*	*f_T (GHz)*	*I_C (mA)*	*Gain (dB)*	*F (MHz)*	*$V_{(BR)CEO}$ (V)*	*I_C (mA)*	*P_T (mW)*	*Case*
MRF904	1.5	450	4	15	16	450	15	30	200	TO-206AF
MRF571	1.5	1000	8	50	12	1000	10	70	1000	Macro-X
MRF2369	1.5	1000	6	40	12	1000	15	70	750	Macro-X
MPS911	1.7	500	7	30	16.5	500	12	40	625	TO-226AA
MRF581A	1.8	500	5	75	15.5	500	15	200	2500	Macro-X
BFR91	1.9	500	5	30	16	500	12	35	180	Macro-T
BFR96	2	500	4.5	50	14.5	500	15	100	500	Macro-T
MPS571	2	500	6	50	14	500	10	80	625	TO-226AA
MRF581	2	500	5	75	15.5	500	18	200	2500	Macro-X
MRF901	2	1000	4.5	15	12	1000	15	30	375	Macro-X
MRF941	2.1	2000	8	15	12.5	2000	10	15	400	Macro-X
MRF951	2.1	2000	7.5	30	12.5	2000	10	100	1000	Macro-X
BFR90	2.4	500	5	14	18	500	15	30	180	Macro-T
MPS901	2.4	900	4.5	15	12	900	15	30	300	TO-226AA
MRF1001A	2.5	300	3	90	13.5	300	20	200	3000	TO-205AD
2N5031	2.5	450	1.6	5	14	450	10	20	200	TO-206AF
MRF4239A	2.5	500	5	90	14	500	12	400	3000	TO-205AD
BFW92A	2.7	500	4.5	10	16	500	15	35	180	Macro-T
MRF521*	2.8	1000	4.2	–50	11	1000	–10	–70	750	Macro-X
2N5109	3	200	1.5	50	11	216	20	400	2500	TO-205AD
2N4957*	3	450	1.6	–2	12	450	–30	–30	200	TO-206AF
MM4049*	3	500	5	–20	11.5	500	–10	–30	200	TO-206AF
2N5943	3.4	200	1.5	50	11.4	200	30	400	3500	TO-205AD
MRF586	4	500	1.5	90	9	500	17	200	2500	TO-205AD
2N5179	4.5	200	1.4	10	15	200	12	50	200	TO-206AF
2N2857	4.5	450	1.6	8	12.5	450	15	40	200	TO-206AF
2N6304	4.5	450	1.8	10	15	450	15	50	200	TO-206AF
MPS536*	4.5	500	5	–20	4.5	500	–10	–30	625	TO-226AA
MRF536*	4.5	1000	6	–20	10	1000	–10	–30	300	Macro-X

*denotes a PNP device

Complementary devices

NPN	*PNP*
2N2857	2N4957
MRF904	MM4049
MRF571	MRF521

For package shape, size and pin-connection information, see manufacturers' data sheets. Many retail suppliers and manufacturers offer data sheets on their Web sites.

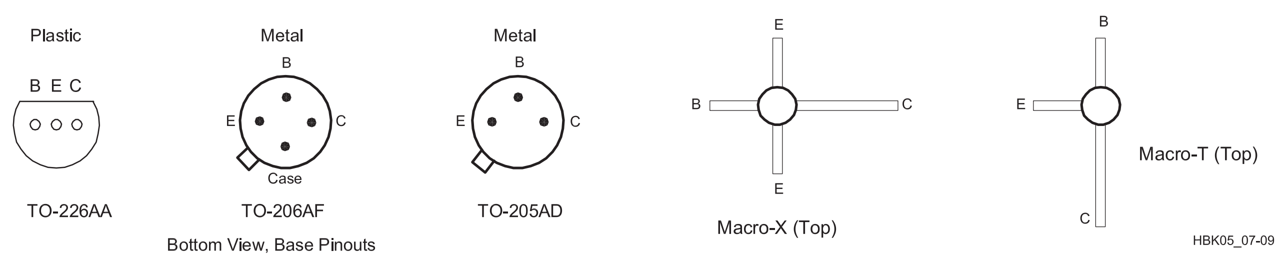
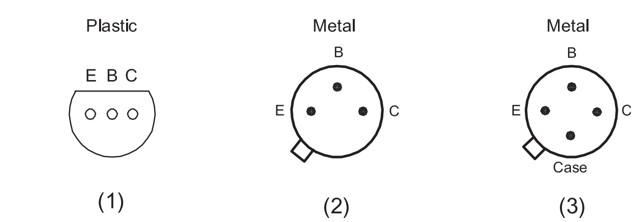


Table 22.31
General-Purpose Bipolar Transistors
Listed numerically by device

Device	*Type*	V_{CEO} *Maximum Collector Emitter Voltage (V)*	V_{CBO} *Maximum Collector Base Voltage (V)*	V_{EBO} *Maximum Emitter Base Voltage (V)*	I_C *Maximum Collector Current (mA)*	P_O *Maximum Device Dissipation (W)*	***Minimum DC Current Gain*** $I_C = 0.1$ *mA*	$I_C = 150$ *mA*	*Current-Gain Bandwidth Product* f_T *(MHz)*	*Noise Figure NF Maximum (dB)*	*Base*
2N918	NPN	15	30	3.0	50	0.2	20 (3 mA)	—	600	6.0	3
2N2102	NPN	65	120	7.0	1000	1.0	20	40	60	6.0	2
2N2218	NPN	30	60	5.0	800	0.8	20	40	250		2
2N2218A	NPN	40	75	6.0	800	0.8	20	40	250		2
2N2219	NPN	30	60	5.0	800	3.0	35	100	250		2
2N2219A	NPN	40	75	6.0	800	3.0	35	100	300	4.0	2
2N2222	NPN	30	60	5.0	800	1.2	35	100	250		2
2N2222A	NPN	40	75	6.0	800	1.2	35	100	200	4.0	2
2N2905	PNP	40	60	5.0	600	0.6	35	—	200		2
2N2905A	PNP	60	60	5.0	600	0.6	75	100	200		2
2N2907	PNP	40	60	5.0	600	0.4	35	—	200		2
2N2907A	PNP	60	60	5.0	600	0.4	75	100	200		2
2N3053	NPN	40	60	5.0	700	5.0	—	50	100		2
2N3053A	NPN	60	80	5.0	700	5.0	—	50	100		2
2N3563	NPN	15	30	2.0	50	0.6	20	—	800		1
2N3904	NPN	40	60	6.0	200	0.625	40	—	300	5.0	1
2N3906	PNP	40	40	5.0	200	0.625	60	—	250	4.0	1
2N4037	PNP	40	60	7.0	1000	5.0	—	50			2
2N4123	NPN	30	40	5.0	200	0.35	—	25 (50 mA)	250	6.0	1
2N4124	NPN	25	30	5.0	200	0.35	120 (2 mA)	60 (50 mA)	300	5.0	1
2N4125	PNP	30	30	4.0	200	0.625	50 (2 mA)	25 (50 mA)	200	5.0	1
2N4126	PNP	25	25	4.0	200	0.625	120 (2 mA)	60 (50 mA)	250	4.0	1
2N4401	NPN	40	60	6.0	600	0.625	20	100	250		1
2N4403	PNP	40	40	5.0	600	0.625	30	100	200		1
2N5320	NPN	75	100	7.0	2000	10.0	—	30 (I A)			2
2N5415	PNP	200	200	4.0	1000	10.0	—	30 (50 mA)	15		2
MM4003	PNP	250	250	4.0	500	1.0	20 (10 mA)	—			2
MPSA55	PNP	60	60	4.0	500	0.625	—	50 (0.1 A)	50		1
MPS6531	NPN	40	60	5.0	600	0.625	60 (10 mA)	90 (0.1 A)			1
MPS6547	NPN	25	35	3.0	50	0.625	20 (2 mA)	—	600		1

Test conditions: $I_C = 20$ mA dc; $V_{CE} = 20$ V; f = 100 MHz



Bottom View, Base Pinouts

Table 22.32

General Purpose Silicon Bipolar Power Transistors

TO-220 Case, Pin 1=Base, Pin 2, Case = Collector; Pin 3 = Emitter

NPN	PNP	I_C Max (A)	V_{CEO} Max (V)	h_{FE} Min	F_T (MHz)	Power Dissipation (W)
D44C8		4	60	100/220	50	30
	D45C8	4	60	40/120	50	30
TIP29		1	40	15/75	3	30
	TIP30	1	40	15/75	3	30
TIP29A		1	50	15/75	3	30
	TIP30A	1	60	15/75	3	30
TIP29B		1	80	15/75	3	30
TIP29C		1	100	15/75	3	30
	TIP30C	1	100	15/75	3	30
TIP47		1	250	30/150	10	40
TIP48		1	300	30/150	10	40
TIP49		1	350	30/150	10	40
TIP50		1	400	30/150	10	40
TIP110*		2	60	500	> 5	50
	TIP115*	2	60	500	> 5	50
TIP116		2	80	500	25	50
TIP31		3	40	25	3	40
	TIP32	3	40	25	3	40
TIP31A		3	60	25	3	40
	TIP32A	3	60	25	3	40
TIP31B		3	80	25	3	40
	TIP32B	3	80	25	3	40
TIP31C		3	100	25	3	40
	TIP32C	3	100	25	3	40
2N6124		4	45	25/100	2.5	40
2N6122		4	60	25/100	2.5	40
MJE1300		4	300	6/30	4	60
TIP120*		5	60	1000	> 5	65
	TIP125*	5	60	1000	> 10	65
	TIP42	6	40	15/75	3	65
TIP41A		6	60	15/75	3	65
TIP41B		6	80	15/75	3	65
2N6290		7	50	30/150	4	40
	2N6109		50	30/150	4	40
2N6292		7	70	30/150	4	40
	2N6107	7	70	30/150	4	40
MJE3055T		10	50	20/70	2	75
	MJE2955T	10	60	20/70	2	75
2N6486		15	40	20/150	5	75
2N6488		15	80	20/150	5	75
TIP140*		10	60	500	> 5	125
	TIP145*	10	60	600	> 10	125
2N3055A		15	60	20/70	0.8	115

Useful URLs for finding transistor/IC data sheets:

1. Line of replacement transistors and ICs: **www.nteinc.com**
2. General-purpose replacements: **www.mouser.com**, **www.digikey.com**
3. NXP Semiconductors: **www.nxp.com**
4. Mitsubishi: **www.mitsubishielectric.com/semiconductors/php/eSearch.php**
5. ON Semiconductor: **www.onsemi.com**
6. M/A-COM: **www.macomtech.com**
7. Freescale: **www.freescale.com**
8. STMicroelectronics: **www.st.com**
9. Microsemi: **www.microsemi.com**

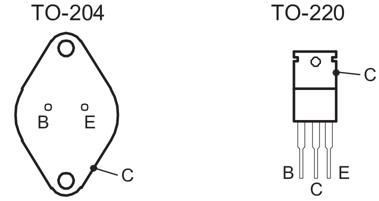
TO-204 Case (TO-3), Pin 1=Base, Pin 2 = Emitter, Case = Collector;

NPN	PNP	I_C Max (A)	V_{CEO} Max (V)	h_{FE} Min	F_T (MHz)	Power Dissipation (W)
2N3055		15	60	20/70	2.5	115
	MJ2955	15	60	20/70	2.5	115
2N6545		8	400	7/35	6	125
2N5039		20	75	20/100	—	140
2N3771		30	40	15	0.2	150
2N3789		10	60	15	4	150
2N3715		10	60	30	4	150
	2N3791	10	60	30	4	150
	2N5875	10	60	20/100	4	150
	2N3790	10	80	15	4	150
2N3716		10	80	30	4	150
	2N3792	10	80	30	4	150
2N3773		16	140	15/60	4	150
2N6284		20	100	750/18K	—	160
	2N6287	20	100	750/18K	—	160
2N5881		15	60	20/100	4	160
2N5880		15	80	20/100	4	160
2N6249		15	200	10/50	2.5	175
2N6250		15	275	8/50	2.5	175
2N6546		15	300	6/30	6-28	175
2N6251		15	350	6/50	2.5	175
2N5630		16	120	20/80	1	200
2N5301		30	40	15/60	2	200
2N5303		20	80	15/60	2	200
2N5885		25	60	20/100	4	200
2N5302		30	60	15/60	2	200
	2N4399	30	60	15/60	4	200
2N5886		25	80	20/100	4	200
	2N5884	25	80	20/100	4	200
MJ802		30	100	25/100	2	200
	MJ4502	30	100	25/100	2	200
MJ15003		20	140	25/150	2	250
	MJI5004	20	140	25/150	2	250
MJ15024		25	250	15/60	4	250

(shaded) = Complimentary pairs

* = Darlington transistor

TO-204 TO-220



Bottom View Front View

HBK05_07-11

Table 22.33
General Purpose JFETs and MOSFETs

Device	*Type*	*VDSS min (V)*	*RDS(on) max (Ω)*	*ID max (A)*	*PD max (W)*	*Case†*	*Mfr*
BS250P	P-channel	45	14	0.23	0.7	E-line	Z
IRFZ30	N-channel	50	0.050	30	75	TO-220	IR
IRFZ42	N-channel	50	0.035	50	150	TO-220	IR
2N7000	N-channel	60	5	0.20	0.4	E-line	Z
VN10LP	N-channel	60	7.5	0.27	0.625	E-line	Z
VN10KM	N-channel	60	5	0.3	1	TO-237	S
ZVN2106B	N-channel	60	2	1.2	5	TO-39	Z
IRF511	N-channel	60	0.6	2.5	20	TO-220AB	IR
IRF531	N-channel	60	0.180	14	75	TO-220AB	IR
IRF531	N-channel	80	0.160	14	79	TO-220	IR
ZVP3310A	P-channel	100	20	0.14	0.625	E-line	Z
ZVN2110B	N-channel	100	4	0.85	5	TO-39	Z
ZVP3310B	P-channel	100	20	0.3	5	TO-39	Z
IRF510	N-channel	100	0.6	2	20	TO-220AB	IR
IRF520	N-channel	100	0.27	5	40	TO-220AB	IR
IRF150	N-channel	100	0.055	40	150	TO-204AE	IR
IRFP150	N-channel	100	0.055	40	180	TO-247	IR
ZVP1320A	P-channel	200	80	0.02	0.625	E-line	Z
ZVN0120B	N-channel	200	16	0.42	5	TO-39	Z
ZVP1320B	P-channel	200	80	0.1	5	TO-39	Z
IRF620	N-channel	200	0.800	5	40	TO-220AB	IR
IRF220	N-channel	200	0.400	8	75	TO-220AB	IR
IRF640	N-channel	200	0.18	10	125	TO-220AB	IR

Manufacturers: IR = International Rectifier; M = Motorola; S = Siliconix; Z = Zetex.

†For package shape, size and pin-connection information, see manufacturers' data sheets. Many retail suppliers offer data sheets to buyers free of charge on request. Data books are available from many manufacturers and retailers.

Table 22.34
RF Power Transistors — By Part Number

Part Number	P_O *(W)*	*Type*	*Gain (dB)*	V_{DD} *(V)*	*Package*	*f(MHz)*	BV_{DSS}	P_D *max (W)*	*Mfr*
ARF1500	750	MOS	16	125	T1	40	500		MS
ARF1501	750	MOS	17	250	T1	40	1000		MS
ARF1505	750	MOS	17	300	T1	40	1200		MS
ARF460AG	150	MOS	15	125	TO-247s	65	500		MS
ARF461AG	150	MOS	15	250	TO-247s	65	1000		MS
ARF463AG	100	MOS	15	125	TO-247s	100	500		MS
ARF465AG	150	MOS	15	300	TO-247s	60	1200		MS
ARF466AG	300	MOS	16	200	TO-247s	45	1000		MS
ARF466FL	300	MOS	16	200	T3	45	1000		MS
ARF473	300	MOS	14	165	M244	150	500		MS
ARF475FL	450	MOS	14	165	T3	150	500		MS
ARF476FL	450	MOS	14	165	T3	150	500		MS
ARF477FL	400	MOS	16	165	T3a	100	500		MS
ARF521	150	MOS	15	165	M174	150	500		MS
BLF1043	10	MOS	16.5	26	SOT538A	1000			NXP
BLF1046	45	MOS	14	26	SOT467C	1000			NXP
BLF145	30	MOS	20	28	SOT123A	30			NXP
BLF147	150	MOS	14	28	SOT121B	175			NXP
BLF174XR	600	LDMOS	28.5	50	SOT1214A	128			NXP
BLF175	30	MOS	20	50	SOT123A	108			NXP
BLF177	150	MOS	19	50	SOT121B	108			NXP
BLF202	2	MOS	13	12.5	SOT409A	175			NXP
BLF242	5	MOS	16	28	SOT123A	200			NXP
BLF244	15	MOS	17	28	SOT123A	175			NXP
BLF245	30	MOS	15.5	28	SOT123A	175			NXP
BLF245B	30	MOS	18	28	SOT279A	175			NXP
BLF246	80	MOS	18	28	SOT121B	175			NXP
BLF246B	60	MOS	19	28	SOT161A	175			NXP
BLF278	300	MOS	16	50	SOT262A1	225			NXP
BLF369	500	LDMOS	18	32	SOT800-2	500			NXP
BLF571	20	LDMOS	27.5	50	SOT467C	500			NXP

Table 22.34 continued

Part Number	*P_O (W)*	*Type*	*Gain (dB)*	*V_{DD} (V)*	*Package*	*f(MHz)*	*BV_{DSS}*	*P_D max (W)*	*Mfr*
BLF573	300	LDMOS	27.2	50	SOT502A	500			NXP
BLF573S	300	LDMOS	27.2	50	SOT502B	500			NXP
BLF574	600	LDMOS	26.5	50	SOT539A	500			NXP
BLF574XR	600	LDMOS	23	50	SOT1214A	500			NXP
BLF578	300	LDMOS	26	50	SOT539A	500			NXP
BLF642	35	LDMOS	19	32	SOT467C	1400			NXP
BLF645	100	LDMOS	18	32	SOT540A	1400			NXP
BLF871	100	LDMOS	21	40	SOT467C	1000			NXP
BLF871S	100	LDMOS	21	40	SOT467B	1000			NXP
BLF881	140	LDMOS	21	50	SOT467C	1000			NXP
BLF881S	140	LDMOS	21	50	SOT467B	1000			NXP
MRF141	150	MOS	21	28	M174	175			MA
MRF141G	300	MOS	21	28	M244	175			MA
MRF148A	30	MOS	18	50	M113	175			MA
MRF150	150	MOS	20	50	M174	150			MA
MRF151	150	MOS	21	50	M177	175			MA
MRF151G	300	MOS	20	50	M244	175			MA
MRF154	600	MOS	16	50	HOG	80			MA
MRFE6VP100H	100	LDMOS	27.2	50	Flange	0 to 2000			FR
MRFE6VP5600H	600	LDMOS	24.6	50	Flange	1.8 to 600			FR
MRFE6VP61K25H	1250	LDMOS	22.9	50	Flange	1.8 to 600			FR
MRFE6VP6300H	300	LDMOS	25	50	Flange	1.8 to 600			FR
RD00HHS1	0.3	LDMOS	18.7	12.5	SOT-89	30	30	3.1	MT
RD00HVS1	0.5	LDMOS	20	12.5	SOT-89	175	30	3.1	MT
RD06HHF1	6	LDMOS	16	12.5	TO-220S	30	50	27.8	MT
RD06HVF1	6	LDMOS	16	12.5	TO-220S	175	50	27.8	MT
RD100HHF1	100	LDMOS	14	12.5	Flange large	30	50	176.5	MS
RD15HVF1	15	LDMOS	12	12.5	TO-220S	520	30	48	MT
RD16HHF1	16	LDMOS	16	12.5	TO-220S	30	50	56.8	MT
RD20HMF1	20	LDMOS	8.5	12.5	Flange small	900	30	71.4	MT
RD30HUF1	30	LDMOS	10	12.5	Flange small	520	30	75	MT
RD30HVF1	30	LDMOS	15	12.5	Flange small	175	30	75	MT
RD45HMF1	45	LDMOS	8	12.5	Flange large	900	30	125	MT
RD60HUF1	60	LDMOS	10	12.5	Flange large	520	30	150	MT
RD70HHF1	70	LDMOS	14	12.5	Flange large	30	50	150	MS
RD70HVF1	70	LDMOS	12	12.5	Flange large	175	30	150	MT
SD1274-01	30	BJT	10	13.6	M113	160			ST
SD1275-01	40	BJT	9	13.6	M113	160			ST
SD1726	150	BJT	14	50	M174	30			ST
SD1728	250	BJT	14.5	50	M177	30			ST
SD2902	15	BJT	12.5	28	M113	400			ST
SD2904	30	BJT	9.5	28	M113	400			ST
SD2918	30	MOS	18	50	M113	30			ST
SD2931-10	150	MOS	14	50	M174	175			ST
SD2932	300	MOS	15	50	M244	175			ST
SD2933	300	MOS	20	50	M177	30			ST
SD2941-10	175	MOS	15	50	M174	175			ST
SD2942	350	MOS	15	50	M244	175			ST
SD2943	350	MOS	22	50	M177	30			ST
SD3931-10	175	MOS	20	100	M174	150			ST
SD3932	350	MOS	24	100	M244	150			ST
SD3933	350	MOS	25	100	M177	30			ST
SD4931	150	MOS	14.8	50	M174	175			ST
SD4933	300	MOS	24	50	M177	30			ST
VRF141	150	MOS	13	28	M174	175	80		MS
VRF141G	300	MOS	14	28	M244	175	80		MS
VRF148A	30	MOS	16	50	M113	175	170		MS
VRF150	150	MOS	11	50	M174	150	170		MS
VRF151	150	MOS	14	50	M174	175	170		MS
VRF151E	150	MOS	14	50	M174	175	170		MS
VRF151G	300	MOS	16	50	M244	175	170		MS
VRF152	150	MOS	14	50	M174	175	170		MS
VRF154FL	600	MOS	17	50	T2	80	170		MS
VRF157FL	600	MOS	21	50	T2	80	170		MS
VRF2933	300	MOS	22	50	M177	100	170		MS

Manufacturer codes:
1. FR – Freescale: **www.freescale.com**
2. MA – M/A-COM: **www.macomtech.com**
3. MS - Microsemi: **www.microsemi.com**
4. MT – Mitsubishi: **www.mitsubishielectric.com/semiconductors/php/eSearch.php**
5. NXP – NXP Semiconductors: **www.nxp.com**
6. ST – STMicroelectronics: **www.st.com**

Table 22.35
RF Power Transistors — By Frequency and Power Output

Part Number	P_O (W)	Type	Gain (dB)	V_{DD} (V)	Package	f(MHz)	BV_{DSS}	P_D max (W)	Mfr
RD00HHS1	0.3	LDMOS	18.7	12.5	SOT-89	30	30	3.1	MT
RD06HHF1	6	LDMOS	16	12.5	TO-220S	30	50	27.8	MT
RD16HHF1	16	LDMOS	16	12.5	TO-220S	30	50	56.8	MT
BLF145	30	MOS	20	28	SOT123A	30			NXP
SD2918	30	MOS	18	50	M113	30			ST
RD70HHF1	70	LDMOS	14	12.5	Flange large	30	50	150	MS
RD100HHF1	100	LDMOS	14	12.5	Flange large	30	50	176.5	MS
SD1726	150	BJT	14	50	M174	30			ST
SD1728	250	BJT	14.5	50	M177	30			ST
SD2933	300	MOS	20	50	M177	30			ST
SD4933	300	MOS	24	50	M177	30			ST
SD2943	350	MOS	22	50	M177	30			ST
SD3933	350	MOS	25	100	M177	30			ST
ARF1500	750	MOS	16	125	T1	40	500		MS
ARF1501	750	MOS	17	250	T1	40	1000		MS
ARF1505	750	MOS	17	300	T1	40	1200		MS
ARF466AG	300	MOS	16	200	TO-247s	45	1000		MS
ARF466FL	300	MOS	16	200	T3	45	1000		MS
ARF465AG	150	MOS	15	300	TO-247s	60	1200		MS
ARF460AG	150	MOS	15	125	TO-247s	65	500		MS
ARF461AG	150	MOS	15	250	TO-247s	65	1000		MS
MRF154	600	MOS	16	50	HOG	80			MA
VRF154FL	600	MOS	17	50	T2	80	170		MS
VRF157FL	600	MOS	21	50	T2	80	170		MS
ARF463AG	100	MOS	15	125	TO-247s	100	500		MS
VRF2933	300	MOS	22	50	M177	100	170		MS
ARF477FL	400	MOS	16	165	T3a	100	500		MS
BLF175	30	MOS	20	50	SOT123A	108			NXP
BLF177	150	MOS	19	50	SOT121B	108			NXP
BLF174XR	600	LDMOS	28.5	50	SOT1214A	128			NXP
MRF150	150	MOS	20	50	M174	150			MA
ARF521	150	MOS	15	165	M174	150	500		MS
VRF150	150	MOS	11	50	M174	150	170		MS
SD3931-10	175	MOS	20	100	M174	150			ST
ARF473	300	MOS	14	165	M244	150	500		MS
SD3932	350	MOS	24	100	M244	150			ST
ARF475FL	450	MOS	14	165	T3	150	500		MS
ARF476FL	450	MOS	14	165	T3	150	500		MS
SD1274-01	30	BJT	10	13.6	M113	160			ST
SD1275-01	40	BJT	9	13.6	M113	160			ST
RD00HVS1	0.5	LDMOS	20	12.5	SOT-89	175	30	3.1	MT
BLF202	2	MOS	13	12.5	SOT409A	175			NXP
RD06HVF1	6	LDMOS	16	12.5	TO-220S	175	50	27.8	MT
BLF244	15	MOS	17	28	SOT123A	175			NXP
RD30HVF1	30	LDMOS	15	12.5	Flange small	175	30	75	MT
MRF148A	30	MOS	18	50	M113	175			MA
BLF245	30	MOS	15.5	28	SOT123A	175			NXP
BLF245B	30	MOS	18	28	SOT279A	175			NXP
VRF148A	30	MOS	16	50	M113	175	170		MS
BLF246B	60	MOS	19	28	SOT161A	175			NXP
RD70HVF1	70	LDMOS	12	12.5	Flange large	175	30	150	MT
BLF246	80	MOS	18	28	SOT121B	175			NXP
MRF141	150	MOS	21	28	M174	175			MA
MRF151	150	MOS	21	50	M177	175			MA
BLF147	150	MOS	14	28	SOT121B	175			NXP
SD2931-10	150	MOS	14	50	M174	175			ST
SD4931	150	MOS	14.8	50	M174	175			ST
VRF141	150	MOS	13	28	M174	175	80		MS
VRF151	150	MOS	14	50	M174	175	170		MS
VRF151E	150	MOS	14	50	M174	175	170		MS
VRF152	150	MOS	14	50	M174	175	170		MS
SD2941-10	175	MOS	15	50	M174	175			ST
MRF151G	300	MOS	20	50	M244	175			MA
MRF141G	300	MOS	21	28	M244	175			MA
SD2932	300	MOS	15	50	M244	175			ST
VRF141G	300	MOS	14	28	M244	175	80		MS
VRF151G	300	MOS	16	50	M244	175	170		MS
SD2942	350	MOS	15	50	M244	175			ST
BLF242	5	MOS	16	28	SOT123A	200			NXP
BLF278	300	MOS	16	50	SOT262A1	225			NXP
SD2902	15	BJT	12.5	28	M113	400			ST
SD2904	30	BJT	9.5	28	M113	400			ST
BLF571	20	LDMOS	27.5	50	SOT467C	500			NXP
BLF578	300	LDMOS	26	50	SOT539A	500			NXP
BLF573	300	LDMOS	27.2	50	SOT502A	500			NXP
BLF573S	300	LDMOS	27.2	50	SOT502B	500			NXP
BLF369	500	LDMOS	18	32	SOT800-2	500			NXP
BLF574XR	600	LDMOS	23	50	SOT1214A	500			NXP
BLF574	600	LDMOS	26.5	50	SOT539A	500			NXP
RD15HVF1	15	LDMOS	12	12.5	TO-220S	520	30	48	MT

Part Number	P_O (W)	Type	Gain (dB)	V_{DD} (V)	Package	f(MHz)	BV_{DSS}	P_D max (W)	Mfr
RD30HUF1	30	LDMOS	10	12.5	Flange small	520	30	75	MT
RD60HUF1	60	LDMOS	10	12.5	Flange large	520	30	150	MT
RD20HMF1	20	LDMOS	8.5	12.5	Flange small	900	30	71.4	MT
RD45HMF1	45	LDMOS	8	12.5	Flange large	900	30	125	MT
BLF1043	10	MOS	16.5	26	SOT538A	1000			NXP
BLF1046	45	MOS	14	26	SOT467C	1000			NXP
BLF871	100	LDMOS	21	40	SOT467C	1000			NXP
BLF871S	100	LDMOS	21	40	SOT467B	1000			NXP
BLF881	140	LDMOS	21	50	SOT467C	1000			NXP
BLF881S	140	LDMOS	21	50	SOT467B	1000			NXP
BLF642	35	LDMOS	19	32	SOT467C	1400			NXP
BLF645	100	LDMOS	18	32	SOT540A	1400			NXP
MRFE6VP100H	100	LDMOS	27.2	50	Flange	0 to 2000			FR
MRFE6VP6300H	300	LDMOS	25	50	Flange	1.8 to 600			FR
MRFE6VP5600H	600	LDMOS	24.6	50	Flange	1.8 to 600			FR
MRFE6VP61K25H	1250	LDMOS	22.9	50	Flange	1.8 to 600			FR

Manufacturer codes:
1. FR – Freescale: **www.freescale.com**
2. MA – M/A-COM: **www.macomtech.com**
3. MS - Microsemi: **www.microsemi.com**
4. MT – Mitsubishi: **www.mitsubishielectric.com/semiconductors/php/eSearch.php**
5. NXP – NXP Semiconductors: **www.nxp.com**
6. ST – STMicroelectronics: **www.st.com**

Table 22.36
RF Power Amplifier Modules

Listed by frequency

Device	Supply (V)	Frequency Range (MHz)	Output Power (W)	Power Gain (dB)	Package†	Mfr/ Notes
M57735	17	50-54	14	21	H3C	MI; SSB mobile
M57719N	17	142-163	14	18.4	H2	MI; FM mobile
S-AV17	16	144-148	60	21.7	5-53L	T, FM mobile
S-AV7	16	144-148	28	21.4	5-53H	T, FM mobile
MHW607-1	7.5	136-150	7	38.4	301K-02/3	FR; class C
BGY35	12.5	132-156	18	20.8	SOT132B	NXP
M67712	17	220-225	25	20	H3B	MI; SSB mobile
M57774	17	220-225	25	20	H2	MI; FM mobile
MHW720-1	12.5	400-440	20	21	700-04/1	FR; class C
MHW720-2	12.5	440-470	20	21	700-04/1	FR; class C
M57789	17	890-915	12	33.8	H3B	MI
MHW912	12.5	880-915	12	40.8	301R-01/1	FR; class AB
MHW820-3	12.5	870-950	18	17.1	301G-03/1	FR; class C
HMC487LP5/E	7	9-12 GHz	2	20	25 mm^2 SMT	H

Manufacturer codes: FR = Freescale; H = Hittite; MI = Mitsubishi; NXP = NXP Semiconductors; T = Toshiba.

†For package shape, size and pin-connection information, see manufacturers' data sheets. See Tables of RF Power Transistors for manufacturers and URL for data sheets.

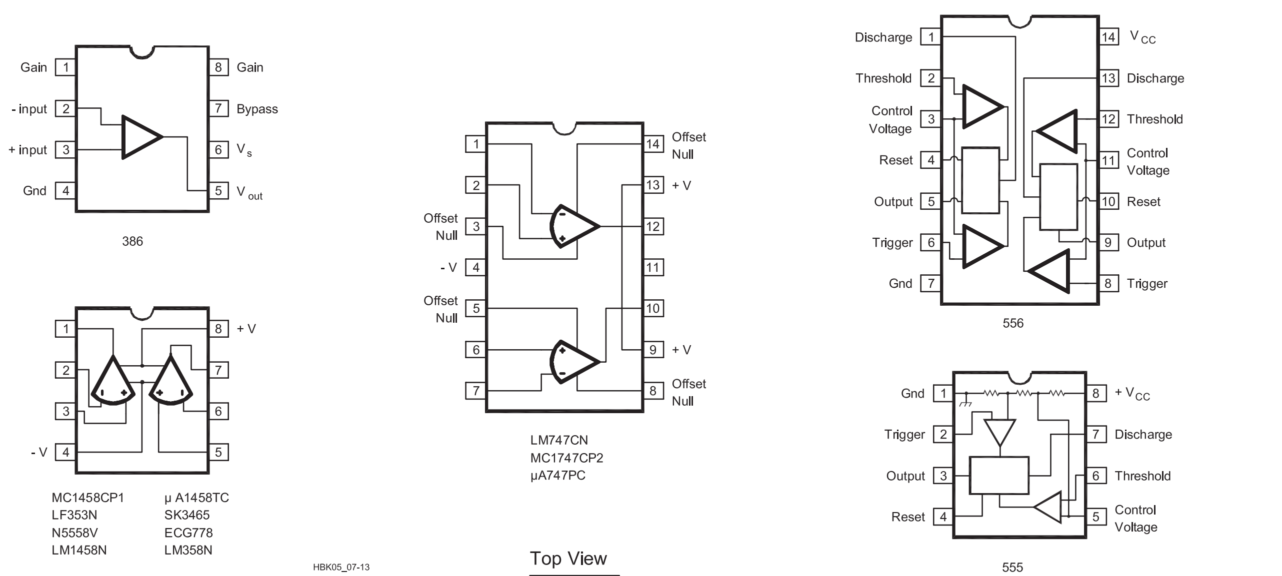
Table 22.37
Digital Logic Families

Type	Propagation Delay for CL = 50 pF (ns) Typ	Max	Max Clock Frequency (MHz)	Power Dissipation (CL = 0) @ 1 MHz (mW/gate)	Output Current @ 0.5 V max (mA)	Input Current (Max mA)	Threshold Voltage (V)	Supply Voltage (V) Min	Typ	Max
CMOS										
74AC	3	5.1	125	0.5	24	0	V+/2	2	5 or 3.3	6
74ACT	3	5.1	125	0.5	24	0	1.4	4.5	5	5.5
74HC	9	18	30	0.5	8	0	V+/2	2	5	6
74HCT	9	18	30	0.5	8	0	1.4	4.5	5	5.5
4000B/74C (10 V)	30	60	5	1.2	1.3	0	V+/2	3	5 - 15	18
4000B/74C (5V)	50	90	2	3.3	0.5	0	V+/2	3	5 - 15	18
TTL										
74AS	2	4.5	105	8	20	0.5	1.5	4.5	5	5.5
74F	3.5	5	100	5.4	20	0.6	1.6	4.75	5	5.25
74ALS	4	11	34	1.3	8	0.1	1.4	4.5	5	5.5
74LS	10	15	25	2	8	0.4	1.1	4.75	5	5.25
ECL										
ECL III	1.0	1.5	500	60	—	—	–1.3	–5.19	–5.2	–5.21
ECL 100K	0.75	1.0	350	40	—	—	–1.32	–4.2	–4.5	–5.2
ECL100KH	1.0	1.5	250	25	—	—	–1.29	–4.9	–5.2	–5.5
ECL 10K	2.0	2.9	125	25	—	—	–1.3	–5.19	–5.2	–5.21
GaAs										
10G	0.3	0.32	2700	125	—	—	–1.3	–3.3	–3.4	–3.5
10G	0.3	0.32	2700	125	—	—	–1.3	–5.1	–5.2	–5.5

Source: Horowitz (W1HFA) and Hill, *The Art of Electronics—2nd edition,* page 570. © Cambridge University Press 1980, 1989. Reprinted with the permission of Cambridge University Press.

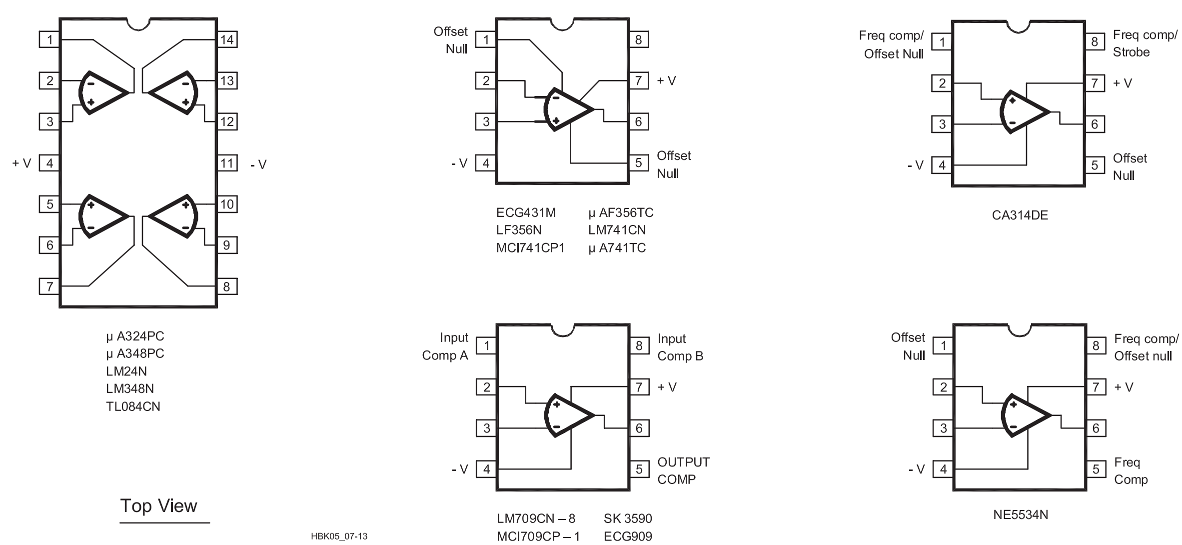
Table 22.38
Operational Amplifiers (Op Amps)
Listed by device number

Device	*Type*	*Freq Comp*	*Max Supply* (V)*	*Min Input Resistance (MΩ)*	*Max Offset Voltage (mV)*	*Min dc Open-Loop Gain (dB)*	*Min Output Current (mA)*	*Min Small-Signal Bandwidth (MHz)*	*Min Slew Rate (V/µs)*	*Notes*
101A	Bipolar	ext	44	1.5	3.0	79	15	1.0	0.5	General purpose
108	Bipolar	ext	40	30	2.0	100	5	1.0		
124	Bipolar	int	32		5.0	100	5	1.0		Quad op amp, low power
148	Bipolar	int	44	0.8	5.0	90	10	1.0	0.5	Quad 741
158	Bipolar	int	32		5.0	100	5	1.0		Dual op amp, low power
301	Bipolar	ext	36	0.5	7.5	88	5	1.0	10	Bandwidth extendable with external components
324	Bipolar	int	32		7.0	100	10	1.0		Quad op amp, single supply
347	BiFET	ext	36	106	5.0	100	30	4	13	Quad, high speed
351	BiFET	ext	36	106	5.0	100	20	4	13	
353	BiFET	ext	36	106	5.0	100	15	4	13	
355	BiFET	ext	44	106	10.0	100	25	2.5	5	
355B	BiFET	ext	44	106	5.0	100	25	2.5	5	
356A	BiFET	ext	36	106	2.0	100	25	4.5	12	
356B	BiFET	ext	44	106	5.0	100	25	5.0	12	
357	BiFET	ext	36	106	10.0	100	25	20.0	50	
357B	BiFET	ext	36	106	5.0	100	25	20.0	30	
358	Bipolar	int	32		7.0	100	10	1.0		Dual op amp, single supply
411	BiFET	ext	36	106	2.0	100	20	4.0	15	Low offset, low drift
709	Bipolar	ext	36	0.05	7.5	84	5	0.3	0.15	
741	Bipolar	int	36	0.3	6.0	88	5	0.4	0.2	
741S	Bipolar	int	36	0.3	6.0	86	5	1.0	3	Improved 741 for AF
1436	Bipolar	int	68	10	5.0	100	17	1.0	2.0	High-voltage
1437	Bipolar	ext	36	0.050	7.5	90		1.0	0.25	Matched, dual 1709
1439	Bipolar	ext	36	0.100	7.5	100		1.0	34	
1456	Bipolar	int	44	3.0	10.0	100	9.0	1.0	2.5	Dual 1741
1458	Bipolar	int	36	0.3	6.0	100	20.0	0.5	3.0	
1458S	Bipolar	int	36	0.3	6.0	86	5.0	0.5	3.0	Improved 1458 for AF
1709	Bipolar	ext	36	0.040	6.0	80	10.0	1.0		
1741	Bipolar	int	36	0.3	5.0	100	20.0	1.0	0.5	
1747	Bipolar	int	44	0.3	5.0	100	25.0	1.0	0.5	Dual 1741
1748	Bipolar	ext	44	0.3	6.0	100	25.0	1.0	0.8	Non-comp-ensated 1741
1776	Bipolar	int	36	50	5.0	110	5.0		0.35	Micro power, programmable
3140	BiFET	int	36	1.5 × 106	2.0	86	1	3.7	9	Strobable output
3403	Bipolar	int	36	0.3	10.0	80		1.0	0.6	Quad, low power
3405	Bipolar	ext	36		10.0	86	10	1.0	0.6	Dual op amp and dual comparator
3458	Bipolar	int	36	0.3	10.0	86	10	1.0	0.6	Dual, low power



Device	Type	Freq Comp	Max Supply* (V)	Min Input Resistance (MΩ)	Max Offset Voltage (mV)	Min dc Open-Loop Gain (dB)	Min Output Current (mA)	Min Small-Signal Bandwidth (MHz)	Min Slew Rate (V/µs)	Notes
3476	Bipolar	int	36	5.0	6.0	92	12		0.8	
3900	Bipolar	int	32	1.0		65	0.5	4.0	0.5	Quad, Norton single supply
4558	Bipolar	int	44	0.3	5.0	88	10	2.5	1.0	Dual, wideband
4741	Bipolar	int	44	0.3	5.0	94	20	1.0	0.5	Quad 1741
5534	Bipolar	int	44	0.030	5.0	100	38	10.0	13	Low noise, can swing 20V P-P across 600
5556	Bipolar	int	36	1.0	12.0	88	5.0	0.5	1	Equivalent to 1456
5558	Bipolar	int	36	0.15	10.0	84	4.0	0.5	0.3	Dual, equivalent to 1458
34001	BiFET	int	44	106	2.0	94		4.0	13	JFET input
AD745	BiFET	int	±18	104	0.5	63	20	20	12.5	Ultra-low noise, high speed
LT1001	Precision op amp, low offset voltage (15 µV max), low drift (0.6 µV/°C max), low noise (0.3 µV p-p)									
LT1007	Extremely low noise (0.06 µV p-p), very high gain (20 x 10^6 into 2 kΩ load)									
LT1360	High speed, very high slew rate (800 V/µs), 50 MHz gain bandwidth, ±2.5 V to ±15 V supply range									
NE5514	Bipolar	int	±16	100	1		10	3	0.6	
NE5532	Bipolar	int	±20	0.03	4	47	10	10	9	Low noise
OP-27A	Bipolar	ext	44	1.5	0.025	115		5.0	1.7	Ultra-low noise, high speed
OP-37A	Bipolar	ext	44	1.5	0.025	115		45.0	11.0	
TL-071	BiFET	int	36	10^6	6.0	91		4.0	13.0	Low noise
TL-081	BiFET	int	36	10^6	6.0	88		4.0	8.0	
TL-082	BiFET	int	36	10^6	15.0	99		4.0	8.0	Low noise
TL-084	BiFET	int	36	10^6	15.0	88		4.0	8.0	Quad, high-performance AF
TLC27M2	CMOS	int	18	10^6	10	44		0.6	0.6	Low noise
TLC27M4	CMOS	int	18	10^6	10	44		0.6	0.6	Low noise

*From –V to +V terminals



22.7 Tubes, Wire, Materials, Attenuators, Miscellaneous

Table 22.39

Triode Transmitting Tubes

The full 1988 *Handbook* table of power tube specifications and base diagrams can be viewed in pdf format on the *ARRLWeb* at www.arrl.org/hf-tube-amplifiers.

Type	*Power Diss.(W)*	*Plate (V)*	*Plate (mA)*	*Grid dc (mA)*	*Freq (MHz)*	*Ampl Factor*	*Fil (V)*	*Fil (A)*	*C_{IN} (pF)*	*C_{GP} (pF)*	*C_{OUT} (pF)*	*Base Diagram*	*Service Class[1]*	*Plate (V)*	*Grid (V)*	*Plate (mA)*	*Grid dc (mA)*	*Input (W)*	*P-P (kΩ)*	*Output (W)*
5675	5	165	30	8	3000	20	6.3	0.135	2.3	1.3	0.09	Fig 21	GG0	120	–8	25	4	¾	—	0.05
2C40	6.5	500	25	—	500	36	6.3	0.75	2.1	1.3	0.05	Fig 11	CT0	250	–5	20	0.3	¾	—	0.075
5893	8.0	400	40	13	1000	27	6.0	0.33	2.5	1.75	0.07	Fig 21	CT	350	–33	35	13	2.4	—	6.5
													CP	300	–45	30	12	2.0	—	6.5
2C43	12	500	40	—	1250	48	6.3	0.9	2.9	1.7	0.05	Fig 11	CTO	470	—	38[7]	—	¾	—	9[2]
811-A	65	1000	175	50	60	160	6.3	4.0	5.9	5.6	0.7	3G	CT	1500	–70	173	40	7.1	—	200
													CP	1250	–120	140	45	10.0	—	135
													B/CG	1250	0	21/175	28	12	—	165
													AB_1	1250	0	27/175	13	3.0	—	155
812-A	65	1500	175	35	60	29	6.3	4.0	5.4	5.5	0.77	3G	CT	1500	–120	173	30	6.5	—	190
													CP	1250	–115	140	35	7.6	—	130
													B[2]	1500	–48	28/310	270[4]	5.0	13.2	340
3CX100A5[6]	100	1000	125[5]	50	2500	100	6.0	1.05	7.0	2.15	0.035	—	AGG	800	–20	80	30	6	—	27
	70	600	100[5]										CP	600	–15	75	40	6	—	18
2C39	100	1000	60	40	500	100	6.3	1.1	6.5	1.95	0.03	—	G1C	600	–35	60	40	5.0	—	20
													CTO	900	–40	90	30	¾	—	40
													CP	600	–150	100[5]	50	¾	—	¾
AX9900,	135	2500	200	40	150	25	6.3	5.4	5.8	5.5	0.1	Fig 3	CT	2500	–200	200	40	16	—	390
5866													CP	2000	–225	127	40	16	—	204
													B[2]	2500	–90	80/330	350[4]	14[3]	15.68	560
572B	160	2750	275	—	—	170	6.3	4.0	—	—	—	3G	CT	1650	–70	165	32	6	—	205
T160L													B/GG[2]	2400	–2.0	90/500	—	100	—	600
8873	200	2200	250	—	500	160	6.3	3.2	19.5	7.0	0.03	Fig 87	AB_2	2000	—	22/500	98[3]	27[3]	—	505
8875	300	2200	250	—	500	160	6.3	3.2	19.5	7.0	0.03	—	AB_2	2000	—	22/500	98[3]	27[3]	—	505
833A	350	3300	500	100	30	35	10	10	12.3	6.3	8.5	Fig 41	CTO	2250	–125	445	85	23	—	780
													CTO	3000	–160	335	70	20	—	800
													CP	2500	–300	335	75	30	—	635
	450[6]	4000[6]	500	100	20[6]	35	10	10	12.3	6.3	8.5	Fig 41	CP	3000	–240	335	70	26	—	800
													B[2]	3000	–70	100/750	400[4]	20[4]	9.5	1650
8874	400	2200	350	—	500	160	6.3	3.2	19.5	7.0	0.03	—	AB_2	2000	—	22/500	98[3]	27[3]	—	505
3-400Z	400	3000	400	—	110	200	5	14.5	7.4	4.1	0.07	Fig 3	B/GG	3000	0	100/333	120	32	—	655
3-500Z	500	4000	400	—	110	160	5	14.5	7.4	4.1	0.07	Fig 3	B/GG	3000	—	370	115	30	5	750
3-600Z	600	4000	425	—	110	165	5	15.0	7.8	4.6	0.08	Fig 3	B/GG	3000	—	400	118	33	—	810
													B/GG	3500	—	400	110	35	—	950
3CX800A7	800	2250	600	60	350	200	13.5	1.5	26	—	6.1	Fig 87	AB_2GG[7]	2200	–8.2	500	36	16	—	750
3-1000Z	1000	3000	800	—	110	200	7.5	21.3	17	6.9	0.12	Fig 3	B/GG	3000	0	180/670	300	65	—	1360
3CX1200A7	1200	5000	800	—	110	200	7.5	21.0	20	12	0.2	Fig 3	AB_2GG	3600	–10	700	230	85	—	1500
8877	1500	4000	1000	—	250	200	5.0	10	42	10	0.1	—	AB_2	2500	–8.2	1000	—	57	—	1520

Table 22-40

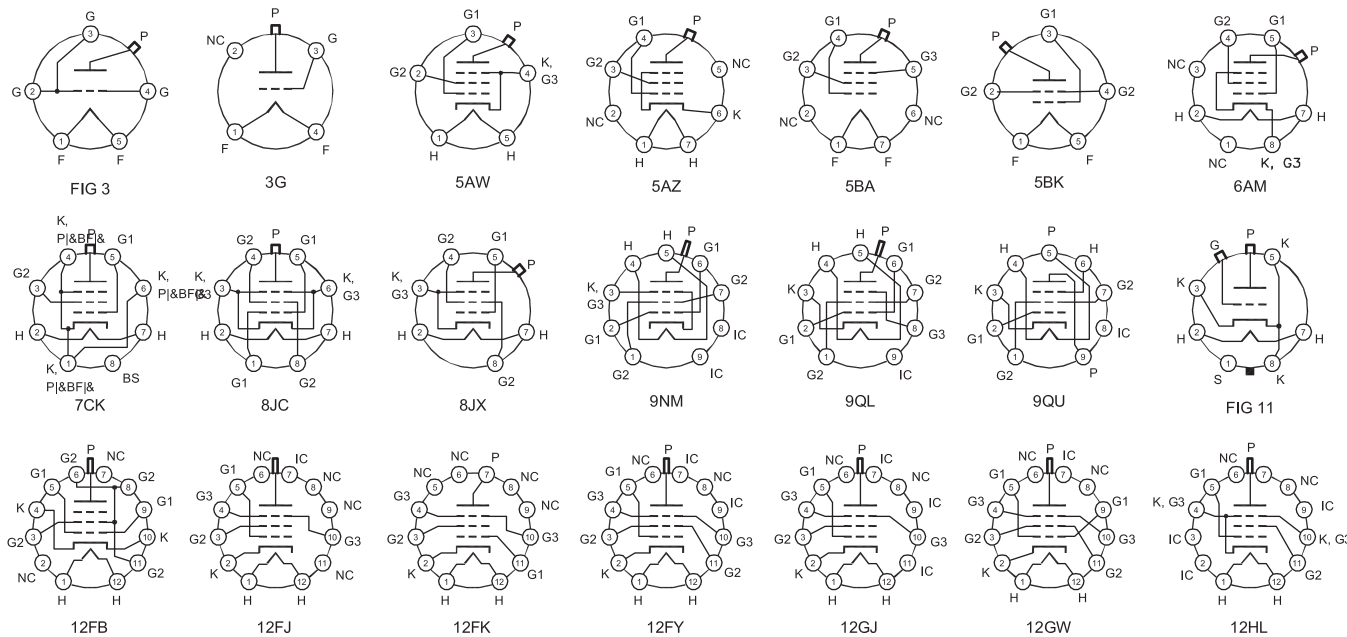
Tetrode Transmitting Tubes

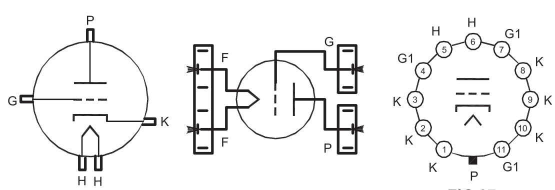
Also see **www.arrl.org/hf-tube-amplifiers.**

Type	Max. Plate Diss. (W)	Max. Plate Volts (V)	Max. Screen Diss. (W)	Max. Screen Volts (V)	Max. Freq. (MHz)	Filament Volts (V)	Amps (A)	C_{IN} (pF)	C_{GP} (pF)	C_{OUT} (pF)	Base	Serv. Class[1]	Plate (V)	Screen (V)	Grid (V)	Plate (mA)	Screen (mA)	Grid (mA)	P_{IN} (W)	P-P (kΩ)	P_{OUT} (W)
6146/	25	750	3	250	60	6.3	1.25	13	0.24	8.5	7CK	CT	500	170	–66	135	9	2.5	0.2	—	48
6146A												CT	700	160	–62	120	11	3.1	0.2	—	70
8032	25	750	3	250	60	12.6	0.585	13	0.24	8.5	7CK	CT[6]	400	190	–54	150	10.4	2.2	3.0	—	35
6883												CP	400	150	–87	112	7.8	3.4	0.4	—	32
												CP	600	150	–87	112	7.8	3.4	0.4	—	52
6159B/	25	750	3	250	60	26.5	0.3	13	0.24	8.5	7CK	AB_2[8]	600	190	–48	28/270	1.2/20	22	0.3	5	113
												AB_2[8]	750	165	–46	22/240	0.3/20	2.6[2]	0.4	7.4	131
												AB_1[8]	750	195	–50	23/220	1/26	100[3]	0	8	120
807, 807W	30	750	3.5	300	60	6.3	0.9	12	0.2	7	5AW	CT	750	250	–45	100	6	3.5	0.22	—	50
5933												CP	600	275	–90	100	6.5	4	0.4	—	42.5
												AB_1	750	300	–35	15/70	3/8	753	0	—	72
1625	30	750	3.5	300	60	12.6	0.45	12	0.2	7	5AZ	B[5]	750	—	0	15/240	—	555[3]	5.3[2]	6.65	120
6146B	35	750	3	250	60	6.3	1.125	13	0.22	8.5	7CK	CT	750	200	–77	160	10	2.7	0.3	—	85
8298A												CP	600	175	–92	140	9.5	3.4	0.5	—	62
												AB_1	750	200	–48	24/125	6.3	—	—	3.5	61
813	125	2500	20	800	30	10.0	5.0	16.3	0.25	14.0	5BA	CTO	1250	300	–75	180	35	12	1.7	—	170
												CTO	2250	400	–155	220	40	15	4	—	375
												AB1	2500	750	–95	25/145	27[2]	0	0	—	245
												AB_2[8]	2000	750	–90	40/315	1.5/58	230[3]	0.1[2]	16	455
												AB_2[8]	2500	750	–95	35/260	1.2/55	235[3]	0.35[2]	17	650
4CX250B	250	2000	12	400	175	6.0	2.9	18.5	0.04	4.7	—	CTO	2000	250	–90	250	25	27	2.8	—	410
												CP	1500	250	–100	200	25	17	2.1	—	250
												AB_1[8]	2000	350	–50	500	30	100	0	8.26	650
4-400A	400[4]	4000	35	600	110	5.0	14.5	12.5	0.12	4.7	5BK	CT/CP	4000	300	–170	270	22.5	10	10	—	720
												GG	2500	0	0	80/270[9]	55[9]	100[9]	39[9]	4.0	435
												AB_1	2500	750	–130	95/317	0/14	0	0	—	425
4CX400A	400	2500	8	400	500	6.3	3.2	24	0.08	7	See[11]	AB_2GD	2200	325	–30	100/270	22	2	9	—	405
												AB_2GD	2500	400	–35	100/400	18	1	13	—	610
4CX800A	800	2500	15	350	150	12.6	3.6	51	0.9	11	See[12]	AB_2GD	2200	350	–56	160/550	24	1	32	—	750
4-1000A	1000	6000	75	1000	—	7.5	21	27.2	0.24	7.6	—	CT	3000	500	–150	700	146	38	11	—	1430
8166												CP	3000	500	–200	600	145	36	12	—	1390
												AB_2	4000	500	–60	300/1200	0/95	—	11	7	3000
												GG	3000	0	0	100/700[9]	105[9]	170[9]	130[9]	2.5	1475
4CX1000A	1000	3000	12	400	110	6.0	9.0	81.5	0.01	11.8	—	AB_1[8]	2000	325	–55	500/2000	–4/60	—	—	2.5	2160
												AB_1[8]	2500	325	–55	500/2000	–4/60	—	—	3.1	2920
												AB_1[8]	3000	325	–55	500/1800	–4/60	—	—	3.85	3360
4CX1500B	1500	3000	12	400	110	6.0	10.0	81.5	0.02	11.8	—	AB_1	2750	225	–34	300/755	–14/60	0.95	1.5	1.9	1100
4CX1600B	1600	3300	20	350	250	12.6	4.4	86	0.15	12	See[13]	AB_2GD	2400	350	–53	500/1100	20	2	28	—	1600
												AB_2GD	2400	350	–70	200/870	48	2	83[10]	—	1500
												AB_2GD	3200	240	–57	200/740	21	1	33	—	1600

[1]Service Class Abbreviations:
AB_2GD=AB_2 linear with 50-Ω passive grid circuit.
B=Class-B push-pull
CP=Class-C plate-modulated phone
CT=Class-C telegraph
GG=Grounded-grid (grid and screen connected together)
[2]Maximum signal value
[3]Peak grid-grid volts
[4]Forced-air cooling required.
[5]Two tubes triode-connected, G2 to G1 through 20kΩ to G2.
[6]Typical operation at 175 MHz.
[7]±1.5 V.
[8]Values are for two tubes.
[9]Single tone.
[10]24-Ω cathode resistance.
[11]Base same as 4CX250B. Socket is Russian SK2A.
[12]Socket is Russian SK1A.
[13]Socket is Russian SK3A.

Table 22.41
EIA Vacuum-Tube Base Diagrams





Base diagrams correspond to the codes in "Base" columns of the tube-data tables. Bottom views are shown throughout. Base connections are abbreviated as follows:

BS - Base sleeve	NC - No connection
F - Filament	P - Plate
G - Grid	P_{BF} - Beam plates
H - Heater	S - Shell
IC - Internal connection	K - Cathode

HBK05_07-14

Alphabetical subscripts (D = diode, P = pentode, T = triode and HX = hexode) indicate structures in multistructure tubes. Subscript CT indicates filament or heater center tap.

Generally, when pin 1 of a metal-envelope tube (except all triodes) is shown connected to the envelope, pin 1 of a glass-envelope counterpart (suffix G or GT) is connected to an internal shield.

Table 22.42

Metal-Oxide Varistor (MOV) Transient Suppressors

Listed by voltage

Type No.	*ECG/NTE†† no.*	*V acRMS*	*Maximum Applied Voltage V acPeak*	*Maximum Energy (Joules)*	*Maximum Peak Current (A)*	*Maximum Power (W)*	*Maximum Varistor Voltage (V)*
V180ZA1	1V115	115	163	1.5	500	0.2	285
V180ZA10	2V115	115	163	10.0	2000	0.45	290
V130PA10A		130	184	10.0	4000	8.0	350
V130PA20A		130	184	20.0	4000	15.0	350
V130LA1	1V130	130	184	1.0	400	0.24	360
V130LA2	1V130	130	184	2.0	400	0.24	360
V130LA10A	2V130	130	184	10.0	2000	0.5	340
V130LA20A	524V13	130	184	20.0	4000	0.85	340
V150PA10A		150	212	10.0	4000	8.0	410
V150PA20A		150	212	20.0	4000	15.0	410
V150LA1	1V150	150	212	1.0	400	0.24	420
V150LA2	1V150	150	212	2.0	400	0.24	420
V150LA10A	524V15	150	212	10.0	2000	0.5	390
V150LA20A	524V15	150	212	20.0	4000	0.85	390
V250PA10A		250	354	10.0	4000	0.85	670
V250PA20A		250	354	20.0	4000	7.0	670
V250PA40A		250	354	40.0	4000	13.0	670
V250LA2	1V250	250	354	2.0	400	0.28	690
V250LA4	1V250	250	354	4.0	400	0.28	690
V250LA15A	2V250	250	354	15.0	2000	0.6	640
V250LA20A	2V250	250	354	20.0	2000	0.6	640
V250LA40A	524V25	250	354	40.0	4000	0.9	640

††ECG and NTE numbers for these parts are identical, except for the prefix. Add the "ECG" or "NTE" prefix to the numbers shown for the complete part number.

Table 22.43
Crystal Holders

Note: Solder Seal, Cold Weld, and Resistance Weld sealing methods are commonly available. All dimensions are in inches

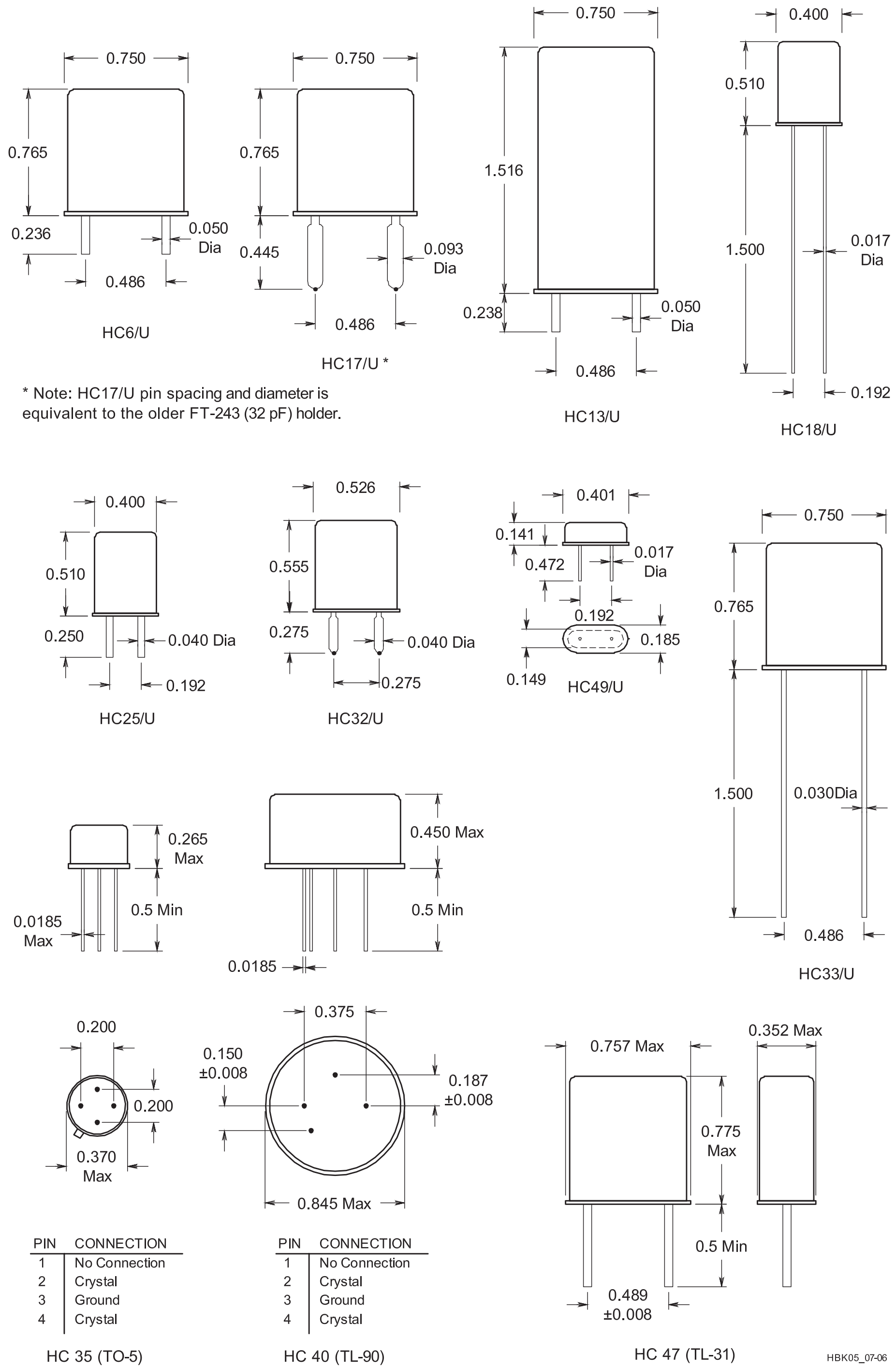


Table 22.44

Copper Wire Specifications

Bare and Enamel-Coated Wire

One mil = 0.001 inch

Wire Size (AWG)	*Diam (Mils)*	*Area (CM[1])*	*Enamel Wire Coating Turns / Linear inch[2] Single*	*Heavy*	*Triple*	*Feet per Pound Bare*	*Ohms per 1000 ft 25° C*	*Current Carrying Capacity Continuous Duty[3] at 700 CM per Amp[4]*	*Open air*	*Conduit or bundles*	*Nearest British SWG No.*
1	289.3	83694.49				3.948	0.1239	119.564			1
2	257.6	66357.76				4.978	0.1563	94.797			2
3	229.4	52624.36				6.277	0.1971	75.178			4
4	204.3	41738.49				7.918	0.2485	59.626			5
5	181.9	33087.61				9.98	0.3134	47.268			6
6	162.0	26244.00				12.59	0.3952	37.491			7
7	144.3	20822.49				15.87	0.4981	29.746			8
8	128.5	16512.25				20.01	0.6281	23.589			9
9	114.4	13087.36				25.24	0.7925	18.696			11
10	101.9	10383.61				31.82	0.9987	14.834			12
11	90.7	8226.49				40.16	1.2610	11.752			13
12	80.8	6528.64				50.61	1.5880	9.327			13
13	72.0	5184.00				63.73	2.0010	7.406			15
14	64.1	4108.81	15.2	14.8	14.5	80.39	2.5240	5.870	32	17	15
15	57.1	3260.41	17.0	16.6	16.2	101.32	3.1810	4.658			16
16	50.8	2580.64	19.1	18.6	18.1	128	4.0180	3.687	22	13	17
17	45.3	2052.09	21.4	20.7	20.2	161	5.0540	2.932			18
18	40.3	1624.09	23.9	23.2	22.5	203.5	6.3860	2.320	16	10	19
19	35.9	1288.81	26.8	25.9	25.1	256.4	8.0460	1.841			20
20	32.0	1024.00	29.9	28.9	27.9	322.7	10.1280	1.463	11	7.5	21
21	28.5	812.25	33.6	32.4	31.3	406.7	12.7700	1.160			22
22	25.3	640.09	37.6	36.2	34.7	516.3	16.2000	0.914		5	22
23	22.6	510.76	42.0	40.3	38.6	646.8	20.3000	0.730			24
24	20.1	404.01	46.9	45.0	42.9	817.7	25.6700	0.577			24
25	17.9	320.41	52.6	50.3	47.8	1031	32.3700	0.458			26
26	15.9	252.81	58.8	56.2	53.2	1307	41.0200	0.361			27
27	14.2	201.64	65.8	62.5	59.2	1639	51.4400	0.288			28
28	12.6	158.76	73.5	69.4	65.8	2081	65.3100	0.227			29
29	11.3	127.69	82.0	76.9	72.5	2587	81.2100	0.182			31
30	10.0	100.00	91.7	86.2	80.6	3306	103.7100	0.143			33
31	8.9	79.21	103.1	95.2		4170	130.9000	0.113			34
32	8.0	64.00	113.6	105.3		5163	162.0000	0.091			35
33	7.1	50.41	128.2	117.6		6553	205.7000	0.072			36
34	6.3	39.69	142.9	133.3		8326	261.3000	0.057			37
35	5.6	31.36	161.3	149.3		10537	330.7000	0.045			38
36	5.0	25.00	178.6	166.7		13212	414.8000	0.036			39
37	4.5	20.25	200.0	181.8		16319	512.1000	0.029			40
38	4.0	16.00	222.2	204.1		20644	648.2000	0.023			
39	3.5	12.25	256.4	232.6		26969	846.6000	0.018			
40	3.1	9.61	285.7	263.2		34364	1079.2000	0.014			
41	2.8	7.84	322.6	294.1		42123	1323.0000	0.011			
42	2.5	6.25	357.1	333.3		52854	1659.0000	0.009			
43	2.2	4.84	400.0	370.4		68259	2143.0000	0.007			
44	2.0	4.00	454.5	400.0		82645	2593.0000	0.006			
45	1.8	3.10	526.3	465.1		106600	3348.0000	0.004			
46	1.6	2.46	588.2	512.8		134000	4207.0000	0.004			

Teflon Coated, Stranded Wire

(As supplied by Belden Wire and Cable)

Size	*Strands[5]*	*Turns per Linear inch[2] UL Style No. 1180*	*1213*	*1371*
16	19×29	11.2		
18	19×30	12.7		
20	7×28	14.7	17.2	
20	19×32	14.7	17.2	
22	19×34	16.7	20.0	23.8
22	7×30	16.7	20.0	23.8
24	19×36	18.5	22.7	27.8
24	7×32		22.7	27.8
26	7×34		25.6	32.3
28	7×36		28.6	37.0
30	7×38		31.3	41.7
32	7×40			47.6

Notes

[1]A circular mil (CM) is a unit of area equal to that of a one-mil-diameter circle (π/4 square mils). The CM area of a wire is the square of the mil diameter.

[2]Figures given are approximate only; insulation thickness varies with manufacturer.

[3]Maximum wire temperature of 212°F (100°C) with a maximum ambient temperature of 135°F (57°C) as specified by the manufacturer. The *National Electrical Code* or local building codes may differ.

[4]700 CM per ampere is a satisfactory design figure for small transformers, but values from 500 to 1000 CM are commonly used. The *National Electrical Code* or local building codes may differ.

[5]Stranded wire construction is given as "count" × "strand size" (AWG).

Table 22.45
Standard vs American Wire Gauge

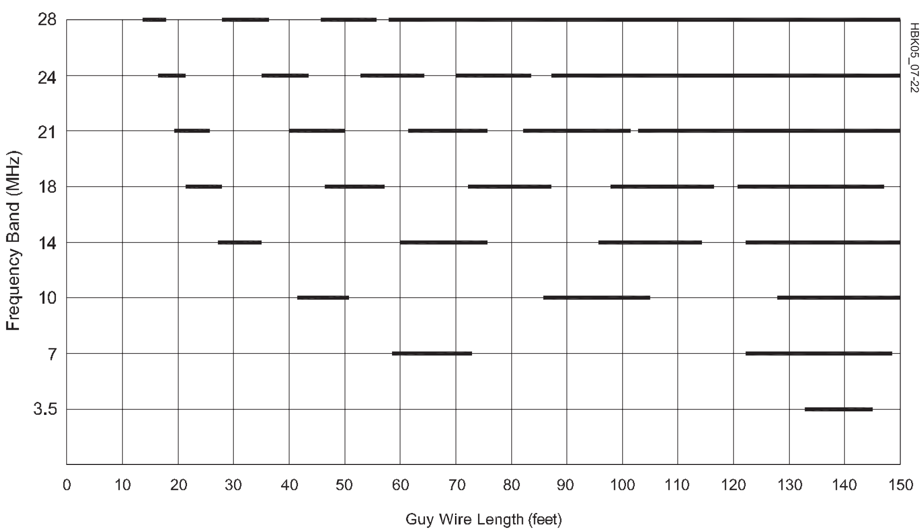
SWG	*Diam (in.)*	*Nearest AWG*
12	0.104	10
14	0.08	12
16	0.064	14
18	0.048	16
20	0.036	19
22	0.028	21
24	0.022	23
26	0.018	25
28	0.0148	27
30	0.0124	28
32	0.0108	29
34	0.0092	31
36	0.0076	32
38	0.006	34
40	0.0048	36
42	0.004	38
44	0.0032	40
46	0.0024	—

Table 22.46
Antenna Wire Strength

American Wire Gauge	*Recommended Tension[1] (pounds)*		*Weight (pounds per 1000 feet)*	
	Copper-clad steel[2]	*Hard-drawn copper*	*Copper-clad steel[2]*	*Hard-drawn copper*
4	495	214	115.8	126
6	310	130	72.9	79.5
8	195	84	45.5	50
10	120	52	28.8	31.4
12	75	32	18.1	19.8
14	50	20	11.4	12.4
16	31	13	7.1	7.8
18	19	8	4.5	4.9
20	12	5	2.8	3.1

[1]Approximately one-tenth the breaking load. Might be increased 50% if end supports are firm and there is no danger of ice loading.
[2]"Copperweld," 40% copper.

Table 22.47
Guy Wire Lengths to Avoid



The black bars indicate ungrounded guy wire lengths to avoid for the eight HF amateur bands. This chart is based on resonance within 10% of any frequency in the band. Grounded wires will exhibit resonance at odd multiples of a quarter wavelength. *(Jerry Hall, K1TD)*

Table 22.48
Aluminum Alloy Specifications

Common Alloy Numbers

Type	*Characteristic*
2024	Good formability, high strength
5052	Excellent surface finish, excellent corrosion resistance, normally not heat treatable for high strength
6061	Good machinability, good weldability, can be brittle at high tempers
7075	Good formability, high strength

General Uses

Type	*Uses*
2024-T3	Chassis boxes, antennas, anything that will be bent or flexed repeatedly
7075-T3	
6061-T6	Mounting plates, welded assemblies or machined parts

Common Tempers

Type	*Characteristics*
T0	Special soft condition
T3	Hard
T6	Very hard, possibly brittle
TXXX	Three digit tempers—usually specialized high-strength heat treatments, similar to T6

Table 22.49
Impedance of Two-Conductor Twisted Pair Lines

	Twists per Inch				
Wire Size	*2.5*	*5*	*7.5*	*10*	*12.5*
#20	43	39	35		
#22	46	41	39	37	32
#24	60	45	44	43	41
#26	65	57	54	48	47
#28	74	53	51	49	47
#30			49	46	47

Measured in ohms at 14.0 MHz.

This illustrates the impedance of various two-conductor lines as a function of the wire size and number of twists per inch.

Table 22.50
Attenuation per Foot of Two-Conductor Twisted Pair Lines

	Twists per Inch				
Wire Size	*2.5*	*5*	*7.5*	*10*	*12.5*
#20	0.11	0.11	0.12		
#22	0.11	0.12	0.12	0.12	0.12
#24	0.11	0.12	0.12	0.13	0.13
#26	0.11	0.13	0.13	0.13	0.13
#28	0.11	0.13	0.13	0.16	0.16
#30			0.25	0.27	0.27

Measured in decibels at 14.0 MHz.

Attenuation in dB per foot for the same lines as shown above.

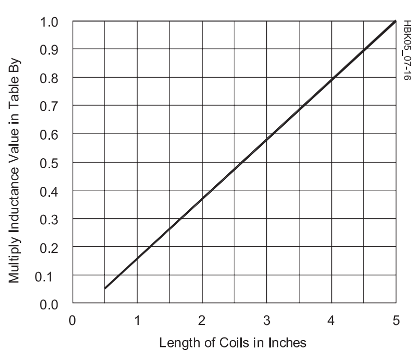
Table 22.51

Large Machine-Wound Coil Specifications

Coil Dia, Inches	*Turns Per Inch*	*Inductance in µH Per Inch*
1¼	4	2.75
	6	6.3
	8	11.2
	10	17.5
	16	42.5
1½	4	3.9
	6	8.8
	8	15.6
	10	24.5
	16	63
1¾	4	5.2
	6	11.8
	8	21
	10	33
	16	85
2	4	6.6
	6	15
	8	26.5
	10	42
	16	108
2½	4	10.2
	6	23
	8	41
	10	64
3	4	14
	6	31.5
	8	56
	10	89

Table 22.52

Inductance Factor for Large Machine-Wound Coils



Factor to be applied to the inductance of large coils for coil lengths up to 5 inches.

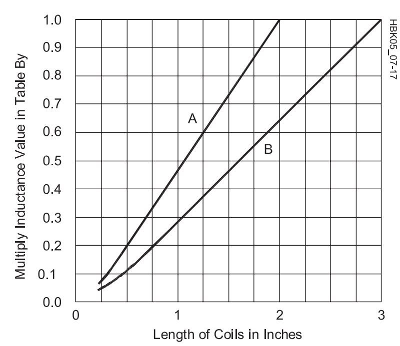
Table 22.53

Small Machine-Wound Coil Specifications

Coil Dia, Inches	*Turns Per Inch*	*Inductance in µH Per Inch*
½ (A)	4	0.18
	6	0.40
	8	0.72
	10	1.12
	16	2.8
	32	12
⅝ (A)	4	0.28
	6	0.62
	8	1.1
	10	1.7
	16	4.4
	32	18
¾ (B)	4	0.6
	6	1.35
	8	2.4
	10	3.8
	16	9.9
	32	40
1 (B)	4	1.0
	6	2.3
	8	4.2
	10	6.6
	16	16.9
	32	68

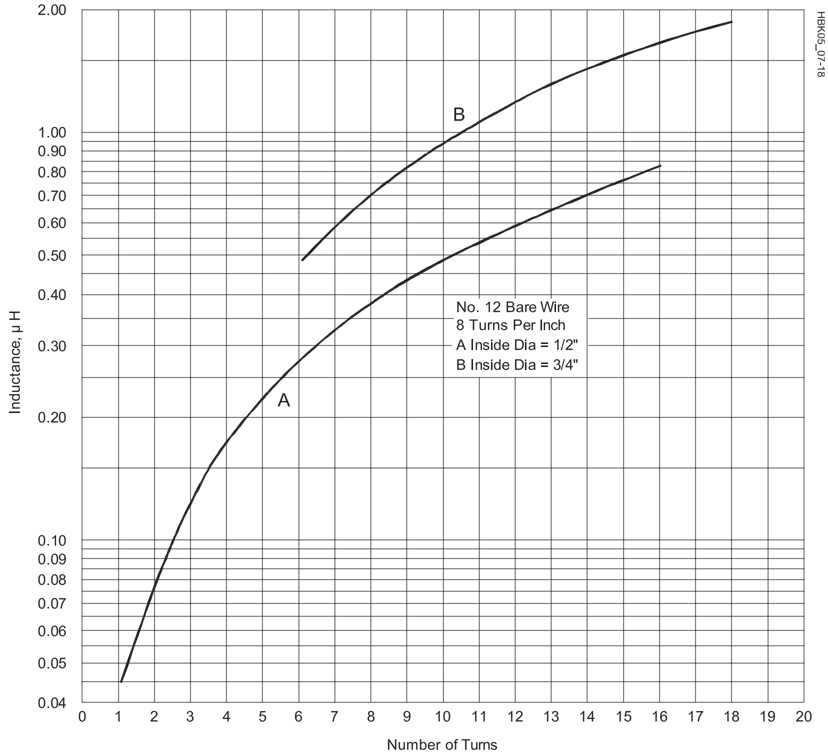
Table 22.54

Inductance Factor for Small Machine-Wound Coils



Factor to be applied to the inductance of small coils as a function of coil length. Use curve A for coils marked A, and curve B for coils marked B.

Table 22.55
Measured Inductance for #12 AWG Wire Windings



Values are for inductors with half-inch leads and wound with eight turns per inch.

Table 22.56
Relationship Between Noise Figure and Noise Temperature

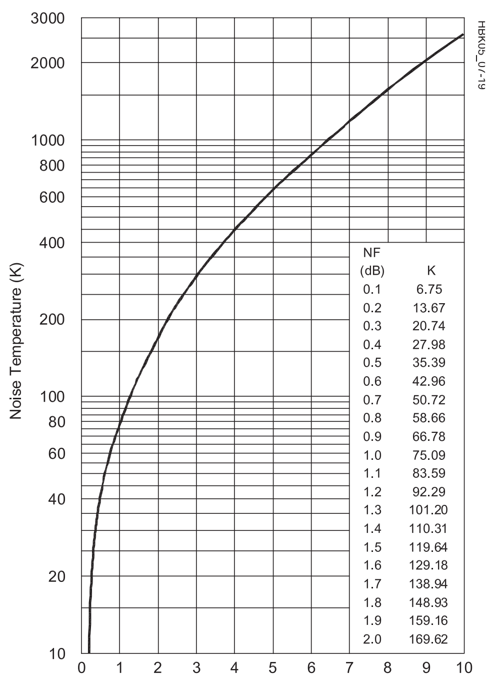


Table 22.57
Pi-Network Resistive Attenuators (50 Ω)

dB Atten.	*R1 (Ohms)*	*R2 (Ohms)*
1.0	870	5.77
2.0	436	11.6
3.0	292	17.6
4.0	221	23.8
5.0	178	30.4
6.0	150	37.4
7.0	131	44.8
8.0	116	52.8
9.0	105	61.6
10.0	96.2	71.2
11.0	89.2	81.7
12.0	83.5	93.2
13.0	78.8	106
14.0	74.9	120
15.0	71.6	136
16.0	68.8	154
17.0	66.4	173
18.0	64.4	195
19.0	62.6	220
20.0	61.1	248
21.0	59.8	278
22.0	58.6	313
23.0	57.6	352
24.0	56.7	395
25.0	56.0	443
30.0	53.2	790
35.0	51.8	1405
40.0	51.0	2500
45.0	50.5	4446
50.0	50.3	7906
55.0	50.2	14,058
60.0	50.1	25,000

Note: A PC board kit for the Low-Power Step Attenuator (Sep 1982 *QST*) is available from FAR Circuits. Project details are in the *Handbook* **template package STEP ATTENUATOR.**

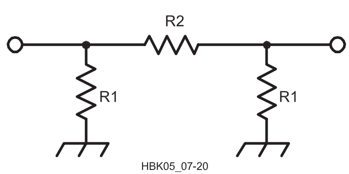
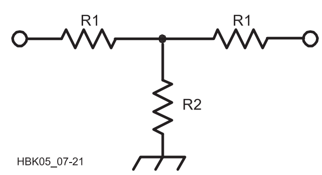


Table 22.58
T-Network Resistive Attenuators (50 Ω)

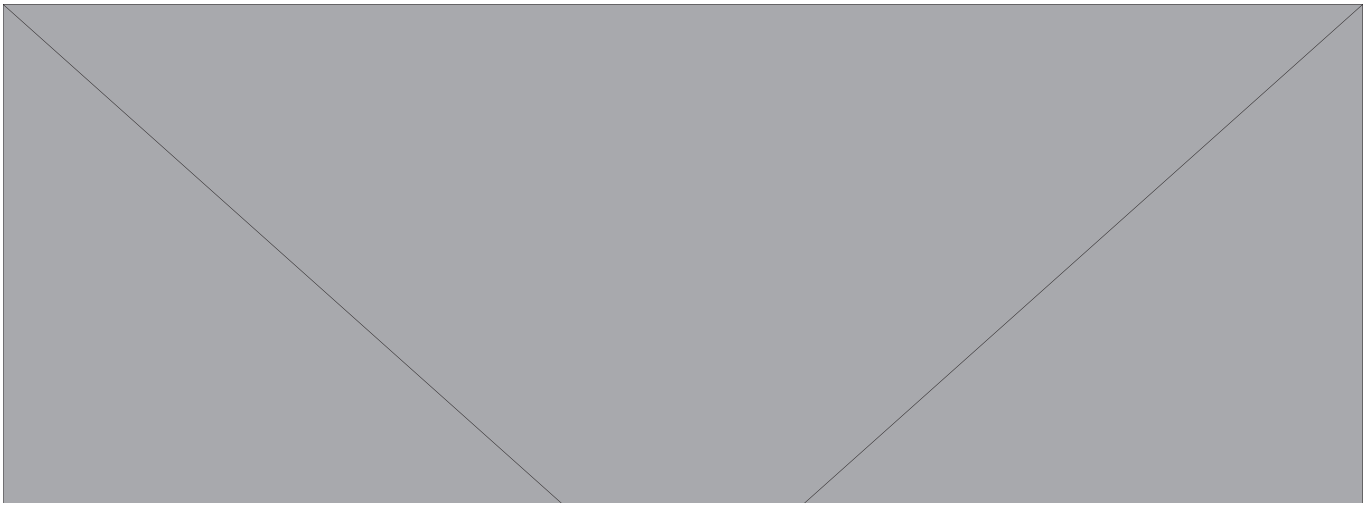
dB Atten.	*R1 (Ohms)*	*R2 (Ohms)*
1.0	2.88	433
2.0	5.73	215
3.0	8.55	142
4.0	11.3	105
5.0	14.0	82.2
6.0	16.6	66.9
7.0	19.1	55.8
8.0	21.5	47.3
9.0	23.8	40.6
10.0	26.0	35.1
11.0	28.0	30.6
12.0	30.0	26.8
13.0	31.7	23.5
14.0	33.3	20.8
15.0	35.0	18.4
16.0	36.3	16.2
17.0	37.6	14.4
18.0	38.8	12.8
19.0	40.0	11.4
20.0	41.0	10.0
21.0	41.8	9.0
22.0	42.6	8.0
23.0	43.4	7.1
24.0	44.0	6.3
25.0	44.7	5.6
30.0	47.0	3.2
35.0	48.2	1.8
40.0	49.0	1.0
45.0	49.4	0.56
50.0	49.7	0.32
55.0	49.8	0.18
60.0	49.9	0.10

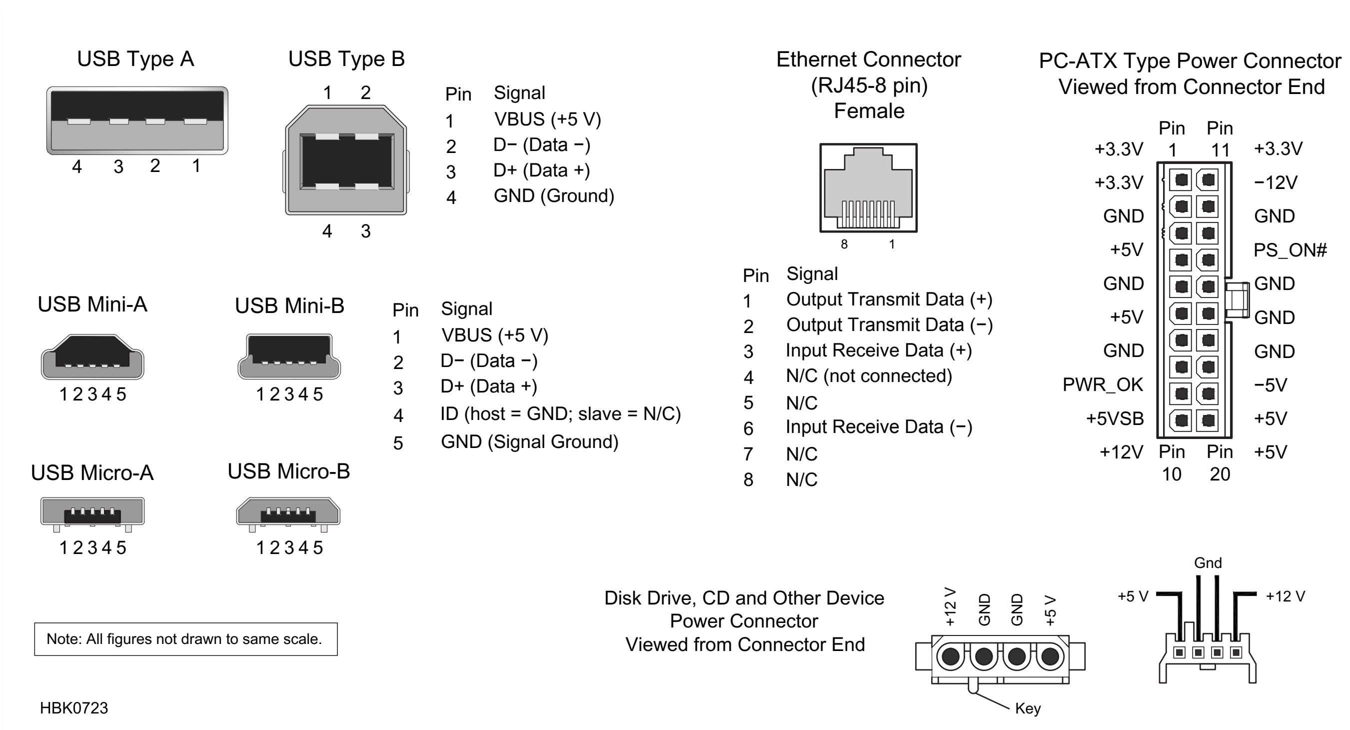


22.8 Computer Connectors

Most connections between computers and their peripherals are made with some form of multi-conductor cable. Examples include shielded, unshielded and ribbon cable. **Table 22.59** shows a variety of computer connectors and pin outs, including some used for internal connections, such as power supplies and disk drives.

Table 22.59
ComputerConnector Pinouts





22.9 RF Connectors and Transmission Lines

There are many different types of transmission lines and RF connectors for coaxial cable, but the three most common for amateur use are the UHF, Type N and BNC families. The type of connector used for a specific job depends on the size of the cable, the frequency of operation and the power levels involved. **Table 22.60** shows the characteristics of many popular transmission lines, while **Table 22.61** details coax connectors.

22.9.1 UHF Connectors

The so-called UHF connector (the series name is not related to frequency) is found on most HF and some VHF equipment. It is the only connector many hams will ever see on coaxial cable. PL-259 is another name for the UHF male, and the female is also known as the SO-239. These connectors are rated for full legal amateur power at HF. They are poor for UHF work because they do not present a constant impedance, so the UHF label is a misnomer. PL-259 connectors are designed to fit RG-8 and RG-11 size cable (0.405-inch OD). Adapters are available for use with smaller RG-58, RG-59 and RG-8X size cable. UHF connectors are not weatherproof.

Fig 22.19 shows how to install the solder type of PL-259 on RG-8 cable. Proper preparation of the cable end is the key to success. Follow these simple steps. Measure back about ¾-inch from the cable end and slightly score the outer jacket around its circumference. With a sharp knife, cut through the outer jacket, through the braid and through the dielectric — almost to the center conductor. Be careful not to score the center conductor. Cutting through all outer layers at once keeps the braid from separating. (Using a coax stripping tool with preset blade depth makes this and subsequent trimming steps much easier.)

Pull the severed outer jacket, braid and dielectric off the end of the cable as one piece. Inspect the area around the cut, looking for any strands of braid hanging loose and snip them off. There won't be any if your knife was sharp enough. Next, score the outer jacket about 5⁄16-inch back from the first cut. Cut through the jacket lightly; do not score the braid. This step takes practice. If you score the braid, start again. Remove the outer jacket.

Tin the exposed braid and center conductor, but apply the solder sparingly and avoid melting the dielectric. Slide the coupling ring onto the cable. Screw the connector body onto the cable. If you prepared the cable to the right dimensions, the center conductor will protrude through the center pin, the braid will show through the solder holes, and the body will actually thread onto the outer cable jacket. A very small amount of lubricant on the cable jacket will help the threading process.

Solder the braid through the solder holes. Solder through all four holes; poor connection

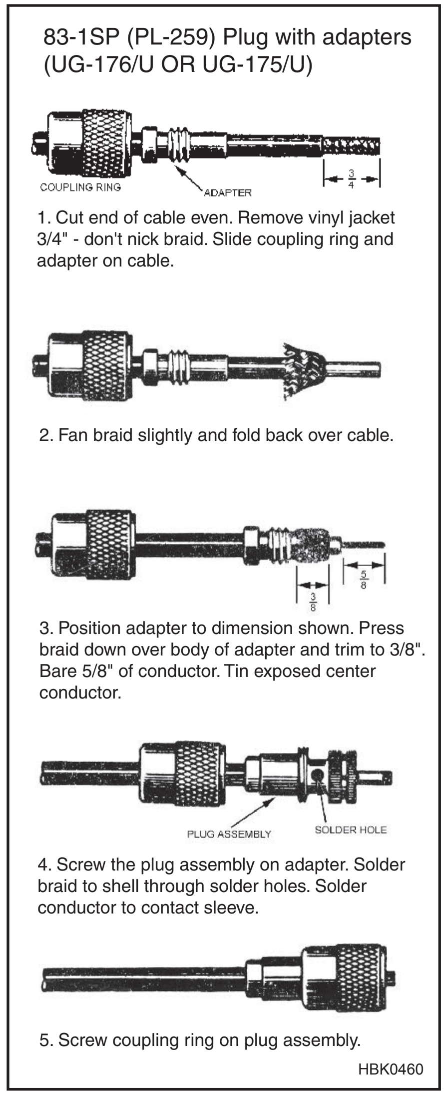


Fig 22.20 — Installing PL-259 plugs on RG-58 or RG-59 cable requires the use of UG-175 or UG-176 adapters, respectively. The adapter screws into the plug body using the threads of the connector that grip the jacket on larger cables. (*Courtesy Amphenol Electronic Components*)

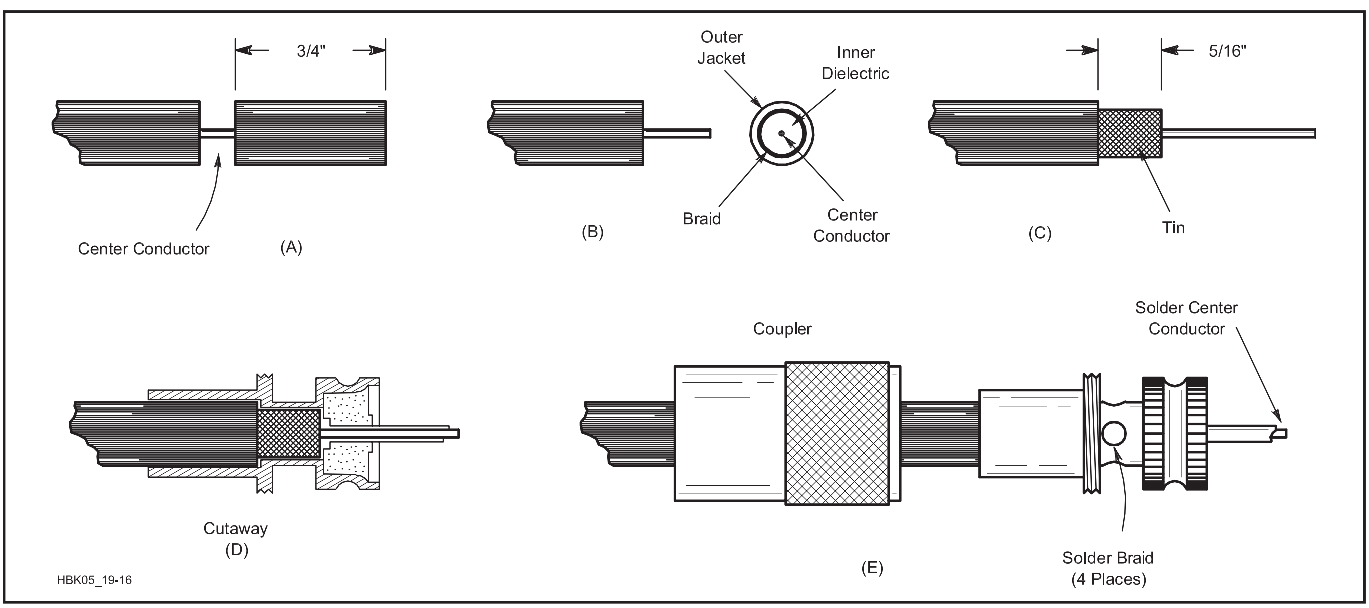


Fig 22.19 — The PL-259, or UHF, connector is almost universal for amateur HF work and is popular for equipment operating in the VHF range. Steps A through E are described in detail in the text.

to the braid is the most common form of PL-259 failure. A good connection between connector and braid is just as important as that between the center conductor and connector. Use a large soldering iron for this job. With practice, you'll learn how much heat to use. If you use too little heat, the solder will bead up, not really flowing onto the connector body. If you use too much heat, the dielectric will melt, letting the braid and center conductor touch. Most PL-259s are nickel plated, but silver-plated connectors are much easier to solder and only slightly more expensive.

Solder the center conductor to the center pin. The solder should flow on the inside, not the outside, of the center pin. If you wait until the connector body cools off from soldering the braid, you'll have less trouble with the dielectric melting. Trim the center conductor to be even with the end of the center pin. Use a small file to round the end, removing any solder that built up on the outer surface of the center pin. Use a sharp knife, very fine sandpaper or steel wool to remove any solder flux from the outer surface of the center pin. Screw the coupling ring onto the body, and you're finished.

Fig 22.20 shows how to install a PL-259 connector on RG-58 or RG-59 cable. An adapter is used for the smaller cable with standard RG-8 size PL-259s. (UG-175 for RG-58 and UG-176 for RG-59.) Prepare the cable as shown. Once the braid is prepared, screw the adapter into the PL-259 shell and finish the job as you would a PL-259 on RG-8 cable.

Fig 22.21 shows the instructions and dimensions for crimp-on UHF connectors that fit all common sizes of coaxial cable. While amateurs have been reluctant to adopt crimp-on connectors, the availability of good quality connectors and inexpensive crimping tools make crimp technology a good choice, even for connectors used outside. Soldering the center conductor to the connector tip is optional.

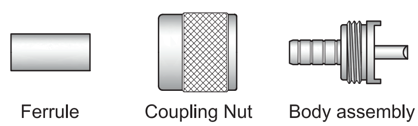
UHF connectors are not waterproof and must be waterproofed whether soldered or crimped as shown in the section of the **Safety** chapter on Antenna and Tower Safety.

22.9.2 BNC, N and F Connectors

The BNC connectors illustrated in **Fig 22.22** are popular for low power levels at VHF and UHF. They accept RG-58 and RG-59 cable, and are available for cable mounting in both male and female versions. Several different styles are available, so be sure to use the dimensions for the type you have. Follow the installation instructions carefully. If you prepare the cable to the wrong dimensions, the center pin will not seat properly with connectors of the opposite gender. Sharp scissors are a big help for trimming the braid evenly. Crimp-on BNC connectors are also available, with a large number of

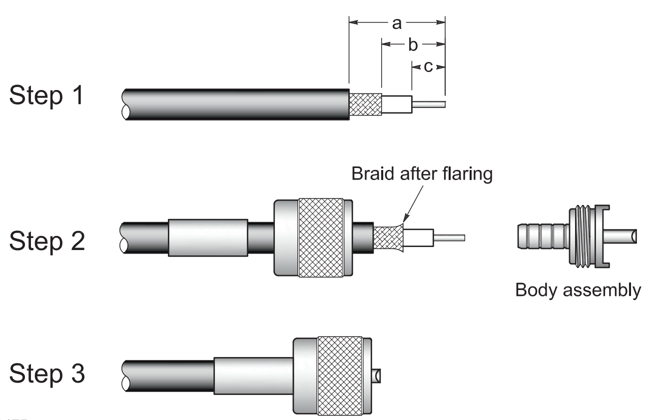
(Text continues on page 22.51)

UHF Connectors
Braid Crimp - Solder Center Contact



Amphenol	Cable RG-/U	Cable Attachment		Hex Crimp Data			Stripping Dims, inches (mm)		
		Outer	Inner	Cavity for Outer Ferrule	Die Set Tool 227-994	CTL Series Tool No.	a	b	c
83-58SP	58, 141	Crimp	Solder	0.213(5.4)	227-1221-11	CTL-1	1.14 (29.0)	0.780 (19.9)	0.250 (6.4)
83-58SP-1002	400	Crimp	Solder	0.213(5.4)	227-1221-11	CTL-1	1.14 (29.0)	0.780 (19.9)	0.250 (6.4)
83-59DCP-RFX	59	Crimp	Solder	0255(6.5)	227-1221-13	CTL-1	1.22 (30.9)	0.574 (22.6)	0.543 (13.8)
83-58SCP-RFX	58	Crimp	Solder	0.213(5.4)	227-1221-11	CTL-1	1.22 (30.9)	0.574 (22.6)	0.543 (13.8)
83-59SP	59	Crimp	Solder	0.255(6.5)	227-1221-13	CTL-1	1.22 (30.9)	0.574 (22.6)	0.543 (13.8)
83-8SP-RFX	8	Crimp	Solder	0.429(10.9)	227-1221-25	CTL-3	1.22 (30.9)	0.574 (22.6)	0.543 (13.8)

See www.AmphenolRF.com for assembly instructions for all other connectore types. These dimensions only apply to Amphenol connectors and may not be correct for other manufacturers.



Step 1 Cut end of cable even. Strip cable to dimensions shown in table. All cuts are to be sharp and square. Do not nick braid, dielectric or center conductor. Tin center conductor avoiding excessive heat.

Step 2 Slide coupling nut and ferrule over cable jacket. Flair braid slightly as shown. Install cable into body assembly, so inner ferrule portion slides under braid, until braid butts shoulder. Slide outer ferrule over braid until it butts shoulder. Crimp ferrule with tool and die set indicated in table.

Step 3 Soft solder center conductor to contact. Avoid heating contact excessively to prevent damaging insulator. Slide/screw coupling nut over body.

HBK0475

Fig 22.21 — Crimp-on UHF connectors are available for all sizes of popular coaxial cable and save considerable time over soldered connectors. The performance and reliability of these connectors is equivalent to soldered connectors, if crimped properly. (*Courtesy Amphenol Electronic Components*)

Table 22.60

Nominal Characteristics of Commonly Used Transmission Lines

RG or Type	Part Number	Nom. Z_0 Ω	VF %	Cap. pF/ft	Cent. Cond. AWG	Diel. Type	Shield Type	Jacket Matl	OD inches	Max V (RMS)	Matched Loss (dB/100')			
											1 MHz	10	100	1000
RG-6	Belden 1694A	75	82	16.2	#18 Solid BC	FPE	FC	P1	0.275	300	0.3	.7	1.8	5.9
RG-6	Belden 8215	75	66	20.5	#21 Solid CCS	PE	D	PE	0.332	2700	0.4	0.8	2.7	9.8
RG-8	Belden 7810A	50	86	23.0	#10 Solid BC	FPE	FC	PE	0.405	300	0.1	0.4	1.2	4.0
RG-8	TMS LMR400	50	85	23.9	#10 Solid CCA	FPE	FC	PE	0.405	600	0.1	0.4	1.3	4.1
RG-8	Belden 9913	50	84	24.6	#10 Solid BC	ASPE	FC	P1	0.405	300	0.1	0.4	1.3	4.5
RG-8	CXP1318FX	50	84	24.0	#10 Flex BC	FPE	FC	P2N	0.405	600	0.1	0.4	1.3	4.5
RG-8	Belden 9913F	50	83	24.6	#11 Flex BC	FPE	FC	P1	0.405	300	0.2	0.6	1.5	4.8
RG-8	Belden 9914	50	82	24.8	#10 Solid BC	FPE	FC	P1	0.405	300	0.2	0.5	1.5	4.8
RG-8	TMS LMR400UF	50	85	23.9	#10 Flex BC	FPE	FC	PE	0.405	600	0.1	0.4	1.4	4.9
RG-8	DRF-BF	50	84	24.5	#9.5 Flex BC	FPE	FC	PE	0.405	600	0.1	0.5	1.6	5.2
RG-8	WM CQ106	50	84	24.5	#9.5 Flex BC	FPE	FC	P2N	0.405	600	0.2	0.6	1.8	5.3
RG-8	CXP008	50	78	26.0	#13 Flex BC	FPE	S	P1	0.405	600	0.1	0.5	1.8	7.1
RG-8	Belden 8237	52	66	29.5	#13 Flex BC	PE	S	P1	0.405	3700	0.2	0.6	1.9	7.4
RG-8X	Belden 7808A	50	86	23.5	#15 Solid BC	FPE	FC	PE	0.240	300	0.2	0.7	2.3	7.4
RG-8X	TMS LMR240	50	84	24.2	#15 Solid BC	FPE	FC	PE	0.242	300	0.2	0.8	2.5	8.0
RG-8X	WM CQ118	50	82	25.0	#16 Flex BC	FPE	FC	P2N	0.242	300	0.3	0.9	2.8	8.4
RG-8X	TMS LMR240UF	50	84	24.2	#15 Flex BC	FPE	FC	PE	0.242	300	0.2	0.8	2.8	9.6
RG-8X	Belden 9258	50	82	24.8	#16 Flex BC	FPE	S	P1	0.242	300	0.3	0.9	3.2	11.2
RG-8X	CXP08XB	50	80	25.3	#16 Flex BC	FPE	S	P1	0.242	300	0.3	1.0	3.1	14.0
RG-9	Belden 8242	51	66	30.0	#13 Flex SPC	PE	SCBC	P2N	0.420	5000	0.2	0.6	2.1	8.2
RG-11	Belden 8213	75	84	16.1	#14 Solid BC	FPE	S	PE	0.405	300	0.1	0.4	1.3	5.2
RG-11	Belden 8238	75	66	20.5	#18 Flex TC	PE	S	P1	0.405	300	0.2	0.7	2.0	7.1
RG-58	Belden 7807A	50	85	23.7	#18 Solid BC	FPE	FC	PE	0.195	300	0.3	1.0	3.0	9.7
RG-58	TMS LMR200	50	83	24.5	#17 Solid BC	FPE	FC	PE	0.195	300	0.3	1.0	3.2	10.5
RG-58	WM CQ124	52	66	28.5	#20 Solid BC	PE	S	PE	0.195	1400	0.4	1.3	4.3	14.3
RG-58	Belden 8240	52	66	29.9	#20 Solid BC	PE	S	P1	0.193	1400	0.3	1.1	3.8	14.5
RG-58A	Belden 8219	53	73	26.5	#20 Flex TC	FPE	S	P1	0.195	300	0.4	1.3	4.5	18.1
RG-58C	Belden 8262	50	66	30.8	#20 Flex TC	PE	S	P2N	0.195	1400	0.4	1.4	4.9	21.5
RG-58A	Belden 8259	50	66	30.8	#20 Flex TC	PE	S	P1	0.192	1400	0.5	1.5	5.4	22.8
RG-59	Belden 1426A	75	83	16.3	#20 Solid BC	FPE	S	P1	0.242	300	0.3	0.9	2.6	8.5
RG-59	CXP 0815	75	82	16.2	#20 Solid BC	FPE	S	P1	0.232	300	0.5	0.9	2.2	9.1
RG-59	Belden 8212	75	78	17.3	#20 Solid CCS	FPE	S	P1	0.242	300	0.2	1.0	3.0	10.9
RG-59	Belden 8241	75	66	20.4	#23 Solid CCS	PE	S	P1	0.242	1700	0.6	1.1	3.4	12.0
RG-62A	Belden 9269	93	84	13.5	#22 Solid CCS	ASPE	S	P1	0.240	750	0.3	0.9	2.7	8.7
RG-62B	Belden 8255	93	84	13.5	#24 Flex CCS	ASPE	S	P2N	0.242	750	0.3	0.9	2.9	11.0
RG-63B	Belden 9857	125	84	9.7	#22 Solid CCS	ASPE	S	P2N	0.405	750	0.2	0.5	1.5	5.8
RG-83	WM165	35	66	44.0	#10 Solid BC	PE	S	P2	0.405	2000	0.23	0.8	2.8	9.6
RG-142	CXP 183242	50	69.5	29.4	#19 Solid SCCS	TFE	D	FEP	0.195	1900	0.3	1.1	3.8	12.8
RG-142B	Belden 83242	50	69.5	29.0	#19 Solid SCCS	TFE	D	TFE	0.195	1400	0.3	1.1	3.9	13.5
RG-174	Belden 7805R	50	73.5	26.2	#25 Solid BC	FPE	FC	P1	0.110	300	0.6	2.0	6.5	21.3
RG-174	Belden 8216	50	66	30.8	#26 Flex CCS	PE	S	P1	0.110	1100	0.8	2.5	8.6	33.7
RG-213	Belden 8267	50	66	30.8	#13 Flex BC	PE	S	P2N	0.405	3700	0.2	0.6	2.1	8.0
RG-213	CXP213	50	66	30.8	#13 Flex BC	PE	S	P2N	0.405	600	0.2	0.6	2.0	8.2
RG-214	Belden 8268	50	66	30.8	#13 Flex SPC	PE	D	P2N	0.425	3700	0.2	0.7	2.2	8.0
RG-216	Belden 9850	75	66	20.5	#18 Flex TC	PE	D	P2N	0.425	3700	0.2	0.7	2.0	7.1
RG-217	WM CQ217F	50	66	30.8	#10 Flex BC	PE	D	PE	0.545	7000	0.1	0.4	1.4	5.2
RG-217	M17/78-RG217	50	66	30.8	#10 Solid BC	PE	D	P2N	0.545	7000	0.1	0.4	1.4	5.2
RG-218	M17/79-RG218	50	66	29.5	#4.5 Solid BC	PE	S	P2N	0.870	11000	0.1	0.2	0.8	3.4
RG-223	Belden 9273	50	66	30.8	#19 Solid SPC	PE	D	P2N	0.212	1400	0.4	1.2	4.1	14.5
RG-303	Belden 84303	50	69.5	29.0	#18 Solid SCCS	TFE	S	TFE	0.170	1400	0.3	1.1	3.9	13.5
RG-316	CXP TJ1316	50	69.5	29.4	#26 Flex BC	TFE	S	FEP	0.098	1200	1.2	2.7	8.0	26.1
RG-316	Belden 84316	50	69.5	29.0	#26 Flex SCCS	TFE	S	FEP	0.096	900	0.8	2.5	8.3	26.0
RG-393	M17/127-RG393	50	69.5	29.4	#12 Flex SPC	TFE	D	FEP	0.390	5000	0.2	0.5	1.7	6.1
RG-400	M17/128-RG400	50	69.5	29.4	#20 Flex SPC	TFE	D	FEP	0.195	1400	0.4	1.3	4.3	15.0
LMR500	TMS LMR500UF	50	85	23.9	#7 Flex BC	FPE	FC	PE	0.500	2500	0.1	0.4	1.2	4.0
LMR500	TMS LMR500	50	85	23.9	#7 Solid CCA	FPE	FC	PE	0.500	2500	0.1	0.3	0.9	3.3
LMR600	TMS LMR600	50	86	23.4	#5.5 Solid CCA	FPE	FC	PE	0.590	4000	0.1	0.2	0.8	2.7
LMR600	TMS LMR600UF	50	86	23.4	#5.5 Flex BC	FPE	FC	PE	0.590	4000	0.1	0.2	0.8	2.7
LMR1200	TMS LMR1200	50	88	23.1	#0 Copper Tube	FPE	FC	PE	1.200	4500	0.04	0.1	0.4	1.3
Hardline														
1/2”	CATV Hardline	50	81	25.0	#5.5 BC	FPE	SM	none	0.500	2500	0.05	0.2	0.8	3.2
1/2”	CATV Hardline	75	81	16.7	#11.5 BC	FPE	SM	none	0.500	2500	0.1	0.2	0.8	3.2
7/8"	CATV Hardline	50	81	25.0	#1 BC	FPE	SM	none	0.875	4000	0.03	0.1	0.6	2.9
7/8"	CATV Hardline	75	81	16.7	#5.5 BC	FPE	SM	none	0.875	4000	0.03	0.1	0.6	2.9
LDF4-50A	Heliax – ½"	50	88	25.9	#5 Solid BC	FPE	CC	PE	0.630	1400	0.02	0.2	0.6	2.4
LDF5-50A	Heliax – ⅞"	50	88	25.9	0.355" BC	FPE	CC	PE	1.090	2100	0.03	0.10	0.4	1.3
LDF6-50A	Heliax – 1¼”	50	88	25.9	0.516" BC	FPE	CC	PE	1.550	3200	0.02	0.08	0.3	1.1
Parallel Lines														
TV Twinlead (Belden 9085)		300	80	4.5	#22 Flex CCS	PE	none	P1	0.400	**	0.1	0.3	1.4	5.9
Twinlead (Belden 8225)		300	80	4.4	#20 Flex BC	PE	none	P1	0.400	8000	0.1	0.2	1.1	4.8
Generic Window Line		450	91	2.5	#18 Solid CCS	PE	none	P1	1.000	10000	0.02	0.08	0.3	1.1
WM CQ 554		440	91	2.7	#14 Flex CCS	PE	none	P1	1.000	10000	0.04	0.01	0.6	3.0
WM CQ 552		440	91	2.5	#16 Flex CCS	PE	none	P1	1.000	10000	0.05	0.2	0.6	2.6
WM CQ 553		450	91	2.5	#18 Flex CCS	PE	none	P1	1.000	10000	0.06	0.2	0.7	2.9
WM CQ 551		450	91	2.5	#18 Solid CCS	PE	none	P1	1.000	10000	0.05	0.02	0.6	2.8
Open-Wire Line		600	0.95-99***	1.7	#12 BC	none	none	none	**	12000	0.02	0.06	0.2	—

Approximate Power Handling Capability (1:1 SWR, 40°C Ambient):

	1.8 MHz	*7*	*14*	*30*	*50*	*150*	*220*	*450*	*1 GHz*
RG-58 Style	1350	700	500	350	250	150	120	100	50
RG-59 Style	2300	1100	800	550	400	250	200	130	90
RG-8X Style	1830	840	560	360	270	145	115	80	50
RG-8/213 Style	5900	3000	2000	1500	1000	600	500	350	250
RG-217 Style	20000	9200	6100	3900	2900	1500	1200	800	500
LDF4-50A	38000	18000	13000	8200	6200	3400	2800	1900	1200
LDF5-50A	67000	32000	22000	14000	11000	5900	4800	3200	2100
LMR500	18000	9200	6500	4400	3400	1900	1600	1100	700
LMR1200	52000	26000	19000	13000	10000	5500	4500	3000	2000

Legend:

**	Not Available or varies
***	Varies with spacer material and spacing
ASPE	Air Spaced Polyethylene
BC	Bare Copper
CC	Corrugated Copper
CCA	Copper Cover Aluminum
CCS	Copper Covered Steel
CXP	Cable X-Perts, Inc.
D	Double Copper Braids
DRF	Davis RF
FC	Foil + Tinned Copper Braid
FEP	Teflon ® Type IX
Flex	Flexible Stranded Wire
FPE	Foamed Polyethylene
Heliax	Andrew Corp Heliax
N	Non-Contaminating
P1	PVC, Class 1
P2	PVC, Class 2
PE	Polyethylene
S	Single Braided Shield
SC	Silver Coated Braid
SCCS	Silver Plated Copper Coated Steel
SM	Smooth Aluminum
SPC	Silver Plated Copper
TC	Tinned Copper
TFE	Teflon®
TMS	Times Microwave Systems
UF	Ultra Flex
WM	Wireman

Fig 22.22 (below) — BNC connectors are common on VHF and UHF equipment at low power levels. (*Courtesy Amphenol Electronic Components*)

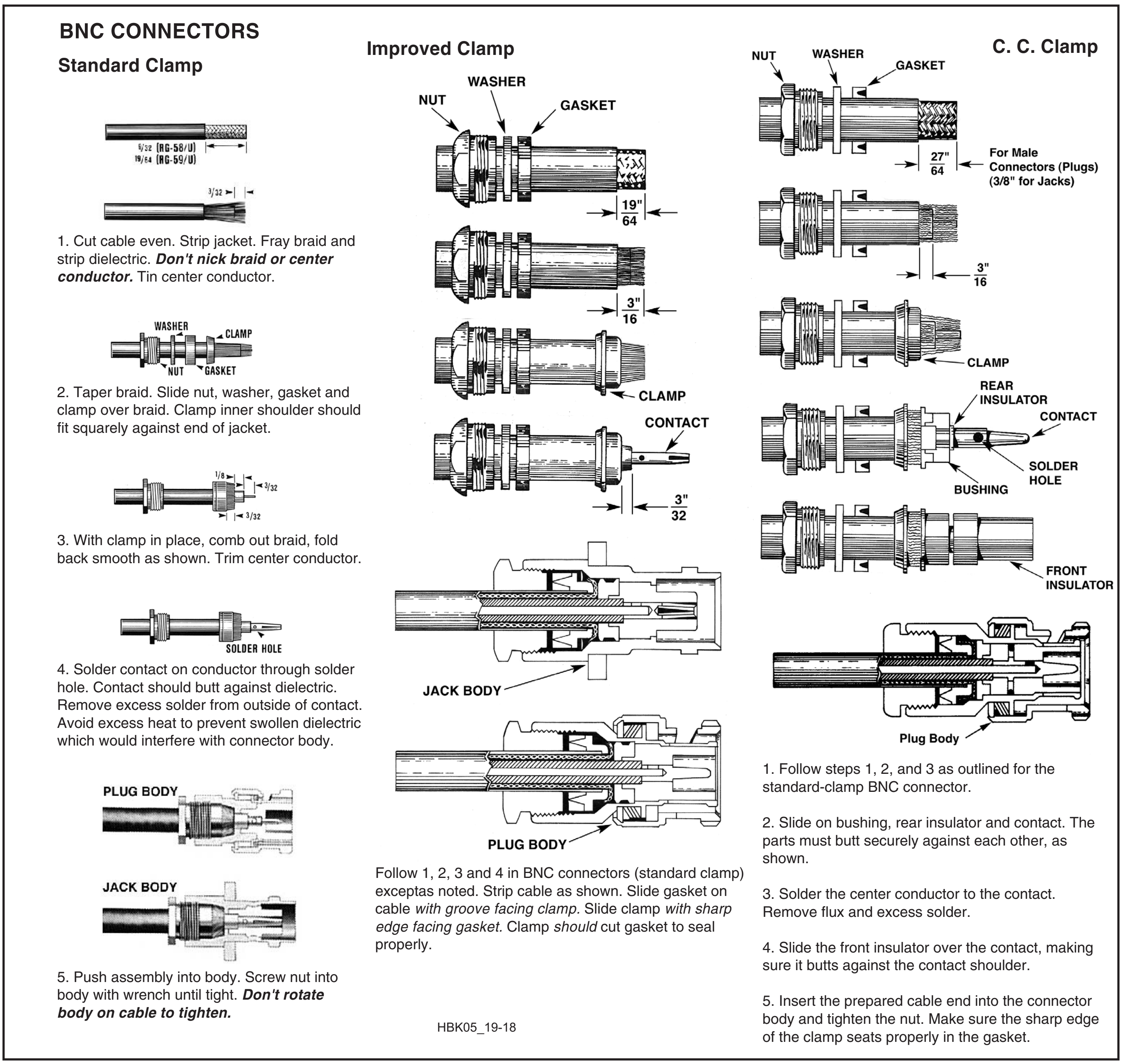


Table 22.61

Coaxial Cable Connectors

UHF Connectors

Military No.	*Style*	*Cable RG- or Description*
PL-259	Str (m)	8, 9, 11, 13, 63, 87, 149, 213, 214, 216, 225
UG-111	Str (m)	59, 62, 71, 140, 210
SO-239	Pnl (f)	Std, mica/phenolic insulation
UG-266	Blkhd (f)	Rear mount, pressurized, copolymer of styrene ins.

Adapters

PL-258	Str (f/f)	Polystyrene ins.
UG-224,363	Blkhd (f/f)	Polystyrene ins.
UG-646	Ang (f/m)	Polystyrene ins.
M-359A	Ang (m/f)	Polystyrene ins.
M-358	T (f/m/f)	Polystyrene ins.

Reducers

UG-175		55, 58, 141, 142 (except 55A)
UG-176		59, 62, 71, 140, 210

Family Characteristics:

All are nonweatherproof and have a nonconstant impedance. Frequency range: 0-500 MHz. Maximum voltage rating: 500 V (peak).

N Connectors

Military No.	*Style*	*Cable RG-*	*Notes*
UG-21	Str (m)	8, 9, 213, 214	50 Ω
UG-94A	Str (m)	11, 13, 149, 216	70 Ω
UG-536	Str (m)	58, 141, 142	50 Ω
UG-603	Str (m)	59, 62, 71, 140, 210	50 Ω
UG-23, B-E	Str (f)	8, 9, 87, 213, 214, 225	50 Ω
UG-602	Str (f)	59, 62, 71, 140, 210	—
UG-228B, D, E	Pnl (f)	8, 9, 87, 213, 214, 225	—
UG-1052	Pnl (f)	58, 141, 142	50 Ω
UG-593	Pnl (f)	59, 62, 71, 140, 210	50 Ω
UG-160A, B, D	Blkhd (f)	8, 9, 87, 213, 214, 225	50 Ω
UG-556	Blkhd (f)	58, 141, 142	50 Ω
UG-58, A	Pnl (f)		50 Ω
UG-997A	Ang (f)		50 Ω

Panel mount (f) with clearance above panel

M39012/04-	Blkhd (f)	Front mount hermetically sealed
UG-680	Blkhd (f)	Front mount pressurized

N Adapters

Military No.	*Style*	*Notes*
UG-29,A,B	Str (f/f)	50 Ω, TFE ins.
UG-57A.B	Str (m/m)	50 Ω, TFE ins.
UG-27A,B	Ang (f/m)	Mitre body
UG-212A	Ang (f/m)	Mitre body
UG-107A	T (f/m/f)	—
UG-28A	T (f/f/f)	—
UG-107B	T (f/m/f)	—

Family Characteristics:

N connectors with gaskets are weatherproof. RF leakage: –90 dB min @ 3 GHz. Temperature limits: TFE: –67° to 390°F (–55° to 199°C). Insertion loss 0.15 dB max @ 10 GHz. Copolymer of styrene: –67° to 185°F (–55° to 85°C). Frequency range: 0-11 GHz. Maximum voltage rating: 1500 V P-P. Dielectric withstanding voltage 2500 V RMS. SWR (MIL-C-39012 cable connectors) 1.3 max 0-11 GHz.

BNC Connectors

Military No.	*Style*	*Cable RG-*	*Notes*
UG-88C	Str (m)	55, 58, 141, 142, 223, 400	

Military No.	*Style*	*Cable RG-*	*Notes*
UG-959	Str (m)	8, 9	
UG-260,A	Str (m)	59, 62, 71, 140, 210	Rexolite ins.
UG-262	Pnl (f)	59, 62, 71, 140, 210	Rexolite ins.
UG-262A	Pnl (f)	59, 62, 71, 140, 210	nwx, Rexolite ins.
UG-291	Pnl (f)	55, 58, 141, 142, 223, 400	
UG-291A	Pnl (f)	55, 58, 141, 142, 223, 400	nwx
UG-624	Blkhd (f)	59, 62, 71, 140, 210	Front mount Rexolite ins.
UG-1094A	Blkhd		Standard
UG-625B	Receptacle		
UG-625			

BNC Adapters

Military No.	*Style*	*Notes*
UG-491,A	Str (m/m)	
UG-491B	Str (m/m)	Berylium, outer contact
UG-914	Str (f/f)	
UG-306	Ang (f/m)	
UG-306A,B	Ang (f/m)	Berylium outer contact
UG-414,A	Pnl (f/f)	# 3-56 tapped flange holes
UG-306	Ang (f/m)	
UG-306A,B	Ang (f/m)	Berylium outer contact
UG-274	T (f/m/f)	
UG-274A,B	T (f/m/f)	Berylium outer contact

Family Characteristics:

Z = 50 Ω. Frequency range: 0-4 GHz w/low reflection; usable to 11 GHz. Voltage rating: 500 V P-P. Dielectric withstanding voltage 500 V RMS. SWR: 1.3 max 0-4 GHz. RF leakage –55 dB min @ 3 GHz. Insertion loss: 0.2 dB max @ 3 GHz. Temperature limits: TFE: –67° to 390°F (–55° to 199°C); Rexolite insulators:
–67° to 185°F (–55° to 85°C). “Nwx” = not weatherproof.

HN Connectors

Military No.	*Style*	*Cable RG-*	*Notes*
UG-59A	Str (m)	8, 9, 213, 214	
UG-1214	Str (f)	8, 9, 87, 213, 214, 225	Captivated contact
UG-60A	Str (f)	8, 9, 213, 214	Copolymer of styrene ins.
UG-1215	Pnl (f)	8, 9, 87, 213, 214, 225	Captivated contact
UG-560	Pnl (f)		
UG-496	Pnl (f)		
UG-212C	Ang (f/m)		Berylium outer contact

Family Characteristics:

Connector Styles: Str = straight; Pnl = panel; Ang = Angle; Blkhd = bulkhead. Z = 50 Ω. Frequency range = 0-4 GHz. Maximum voltage rating = 1500 V P-P. Dielectric withstanding voltage = 5000 V RMS SWR = 1.3. All HN series are weatherproof. Temperature limits: TFE: –67° to 390°F (–55° to 199°C); copolymer of styrene: –67° to 185°F (–55° to 85°C).

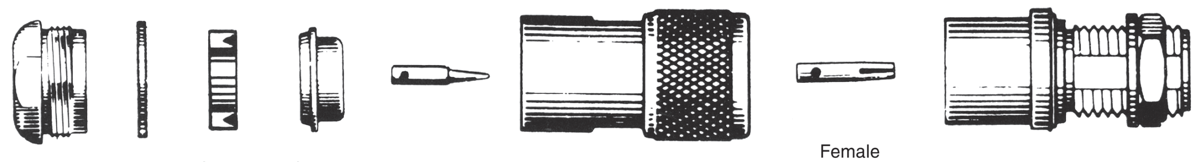
Cross-Family Adapters

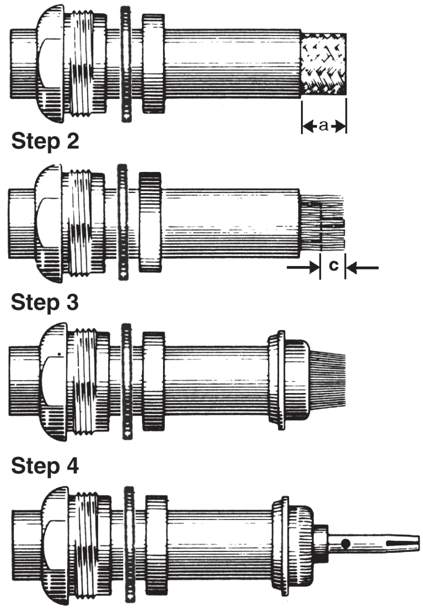
Families	*Description*	*Military No.*
HN to BNC	HN-m/BNC-f	UG-309
N to BNC	N-m/BNC-f	UG-201,A
	N-f/BNC-m	UG-349,A
	N-m/BNC-m	UG-1034
N to UHF	N-m/UHF-f	UG-146
	N-f/UHF-m	UG-83,B
	N-m/UHF-m	UG-318
UHF to BNC	UHF-m/BNC-f	UG-273
	UHF-f/BNC-m	UG-255

Type N assembly instructions

HBK05_19-19

CLAMP TYPES





Amphenol Number	Connector Type	Cable RG-/U	Strip Dims., inches (mm)	
			a	c
82-61	N Plug	8, 9, 144, 165, 213, 214, 216, 225	0.359(9.1)	0.234(6.0)
82-62	N Panel Jack	8, 9, 87A, 144, 165, 213, 214, 216, 225	0.312(7.9)	0.187(4.7)
82-63	N Jack		0.281(7.1)	0.156(4.0)
82-67	N Bulkhead Jack			
82-202	N Plug	8, 9, 144, 165, 213, 214, 216, 225	0.359(9.1)	0.234(6.0)
82-202-RFX	N Plug	8, 213, 214	0.315(8.0)	0.177(4.5)
82-202-1006	N Plug	Belden 9913	0.359(9.1)	0.234(6.0)
82-835	N Angle Plug	8, 9, 87A, 144, 165, 213, 214, 216, 225	0.281(7.1)	0.156(4.0)
18750	N Angle Plug	58, 141, 142	0.484(12.3)	0.234(5.9)
34025	N Plug		0.390(9.9)	0.203(5.2)
34525	N Plug	59, 62, 71, 140, 210	0.410(10.4)	0.230(5.8)
35025	N Jack	58, 141, 142	0.375(9.5)	0.187(4.7)
36500	N Jack	59, 62, 71, 140, 210	0.484(12.3)	0.200(5.1)

See www.AmphenolRF.com for assembly instructions for all other connector types. These dimensions only apply to Amphenol connectors and may not be correct for other manufacturers.

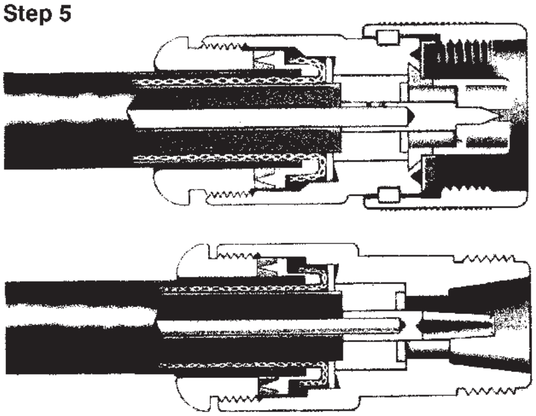
Step 1 Place nut, washer, and gasket, with "V" groove toward clamp, over cable and cut off jacket to dimension a.

Step 2 Comb out braid and fold out. Cut off cable dielectric to dim. c as shown.

Step 3 Pull braid wires forward and taper toward center conductor. Place clamp over braid and push back against cable jacket.

Step 4 Fold back braid wires as shown, trim braid to proper length and form over clamp as shown. Solder contact to center conductor.

Step 5



Step 5 Insert cable and parts into connector body. Make sure sharp edge of clamp seats properly in gasket. Tighten nut.

Fig 22.23 — Type N connectors are a must for high-power VHF and UHF operation. (*Courtesy Amphenol Electronic Components*)

(Continued from page 22.47)

variations, including a twist-on version. A guide to installing these connectors is available on the CD-ROM accompanying this book.

The Type N connector, illustrated in **Fig 22.23**, is a must for high-power VHF and UHF operation. N connectors are available in male and female versions for cable mounting and are designed for RG-8 size cable. Unlike UHF connectors, they are designed to maintain a constant impedance at cable joints. Like BNC connectors, it is important to prepare the cable to the right dimensions. The center pin must be positioned correctly to mate with the center pin of connectors of the opposite gender. Use the right dimensions for the connector style you have. Crimp-on N connectors are also available, again with a large number of variations. A guide to installing these connectors is available on the CD-ROM accompanying this book.

Type F connectors, used primarily on cable TV connections, are also popular for receive-

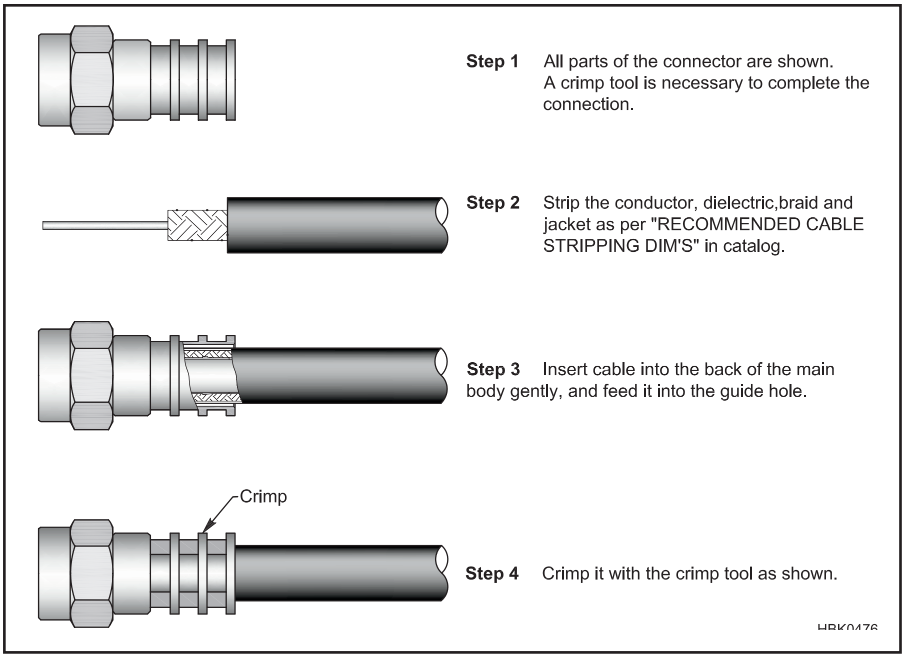


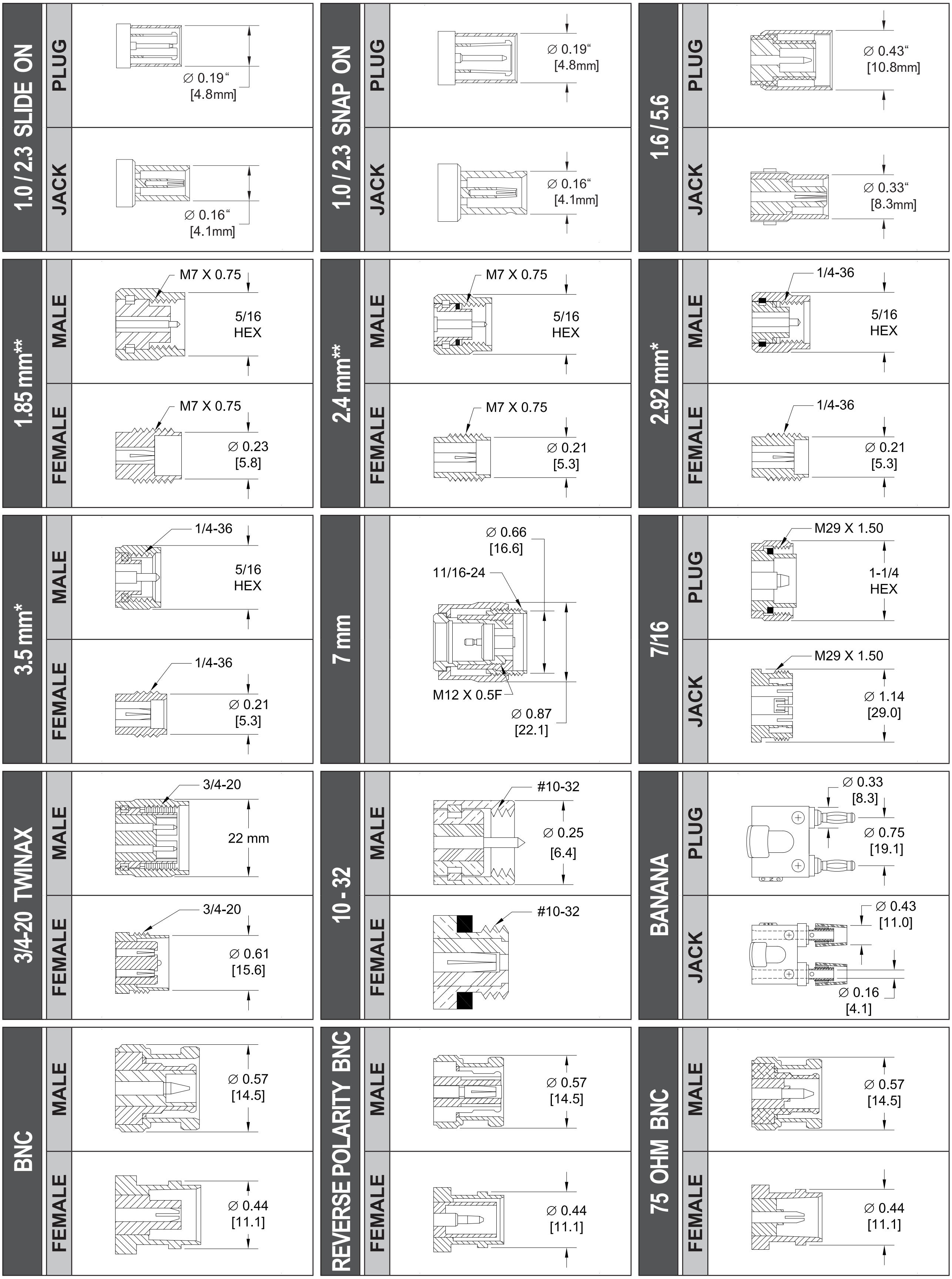
Fig 22.24 — Type F connectors, commonly used for cable TV connections, can be used for receive-only antennas with inexpensive RG-59 and RG-6 cable. (*Courtesy Amphenol Electronic Components*)

only antennas and can be used with RG-59 or the increasingly popular RG-6 cable available at low cost. Crimp-on connectors are the only option for these connectors and **Fig 22.24** shows a general guide for installing them. The exact dimensions vary between connector styles and manufacturers — information on crimping is generally provided with the connectors. There are two styles of crimp; ferrule and compression. The ferrule crimp method is similar to that for UHF, BNC, and N connectors in which a metal ring is compressed around the exposed coax shield. The compression crimp forces a bushing into the back of the connector, clamping the shield against the connector body. In all cases, the exposed center conductor of the cable — a solid wire — must end flush with the end of the connector. A center conductor that is too short may not make a good connection.

22.9.3 Connector Identifier and Range Chart

The following pages of figures provide dimensions and side views to help identify the different types of connectors used for RF through microwave frequencies. Dimensions are provided in both imperial and metric units as appropriate. For mm-wave and microwave connectors, calipers or a micrometer may be required to provide an accurate measurement capable of distinguishing between similar connectors. These specifications are intended for connector identification only and should not be the sole dimensions used when laying out a circuit board or drilling a mounting hole.

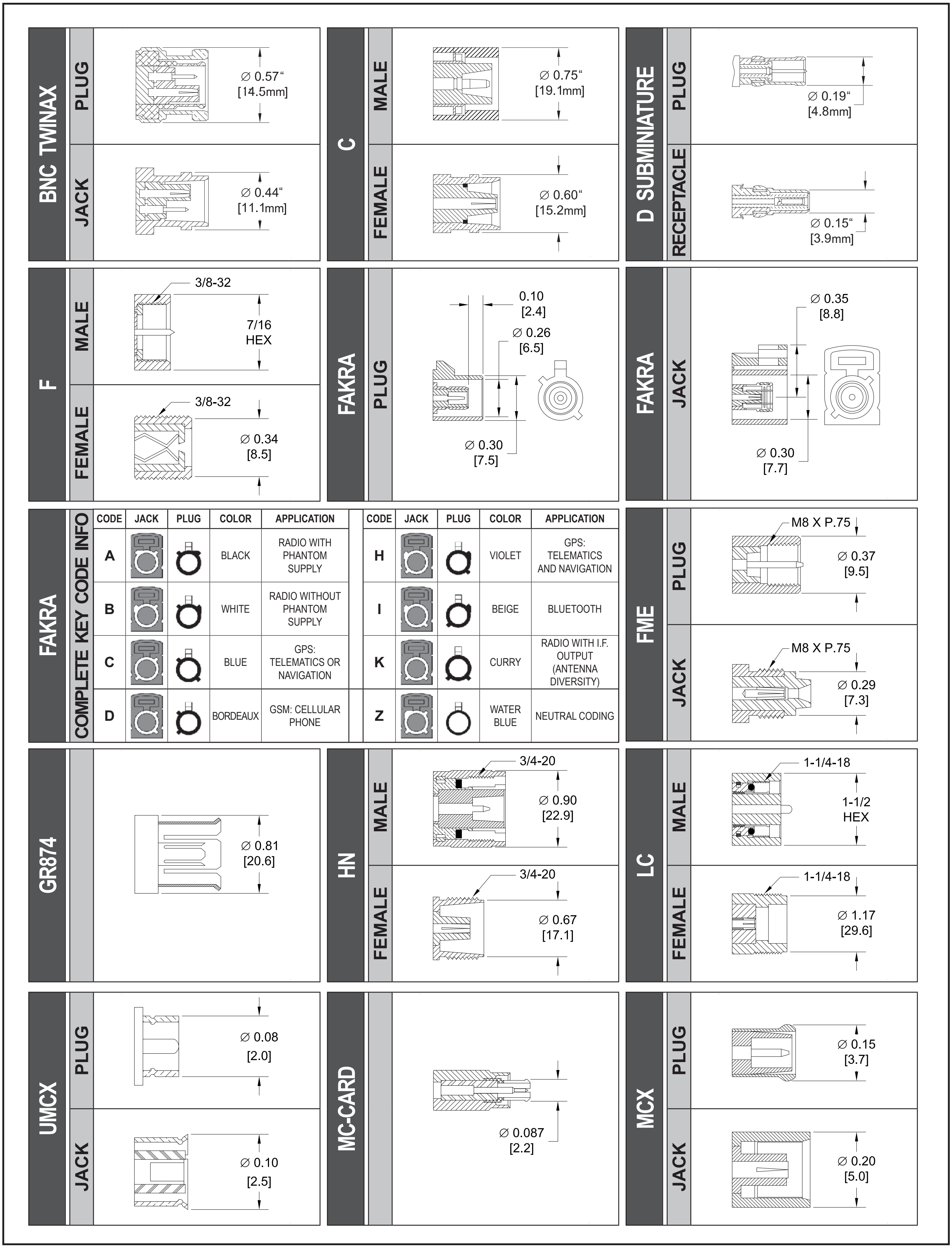
These figures and chart were provided by Pasternack (**www.pasternack.com**), a major distributor of coaxial connectors, cable, tools, and other RF materials and supplies.



*SMA, 2.92mm, & 3.5mm CONNECTORS WILL MATE MECHANICALLY & ELECTRICALLY TO EACH OTHER.

**1.85mm & 2.4mm CONNECTORS WILL MATE MECHANICALLY & ELECTRICALLY TO EACH OTHER.

Figure 22.25A — Connector side views, set 1 of 4. [Courtesy of Pasternak]



CODE	JACK	PLUG	COLOR	APPLICATION
A			BLACK	RADIO WITH PHANTOM SUPPLY
B			WHITE	RADIO WITHOUT PHANTOM SUPPLY
C			BLUE	GPS: TELEMATICS OR NAVIGATION
D			BORDEAUX	GSM: CELLULAR PHONE
H			VIOLET	GPS: TELEMATICS AND NAVIGATION
I			BEIGE	BLUETOOTH
K			CURRY	RADIO WITH I.F. OUTPUT (ANTENNA DIVERSITY)
Z			WATER BLUE	NEUTRAL CODING

Figure 22.25B — Connector side views, set 2 of 4. [Courtesy of Pasternak]

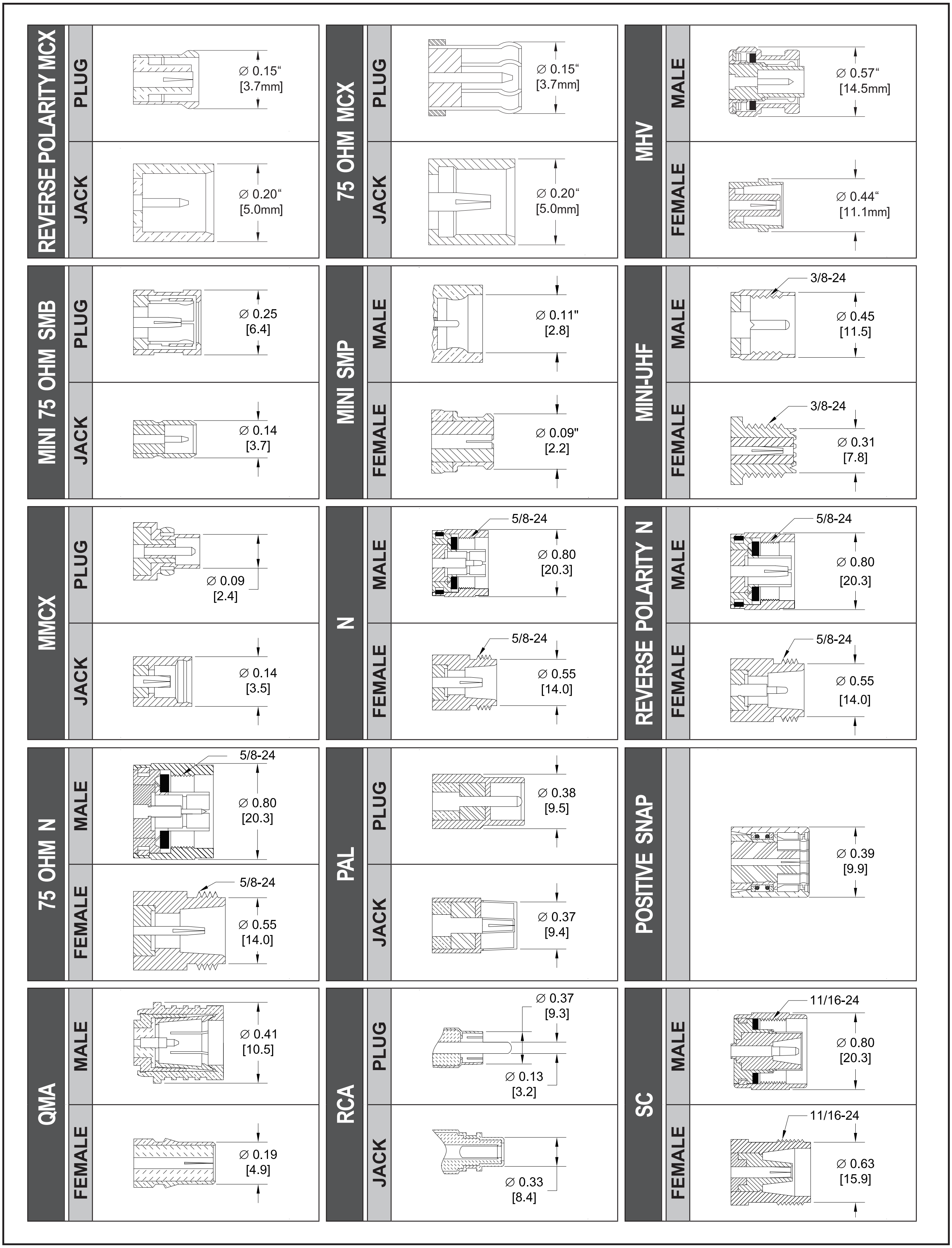


Figure 22.25C — Connector side views, set 3 of 4. [Courtesy of Pasternak]

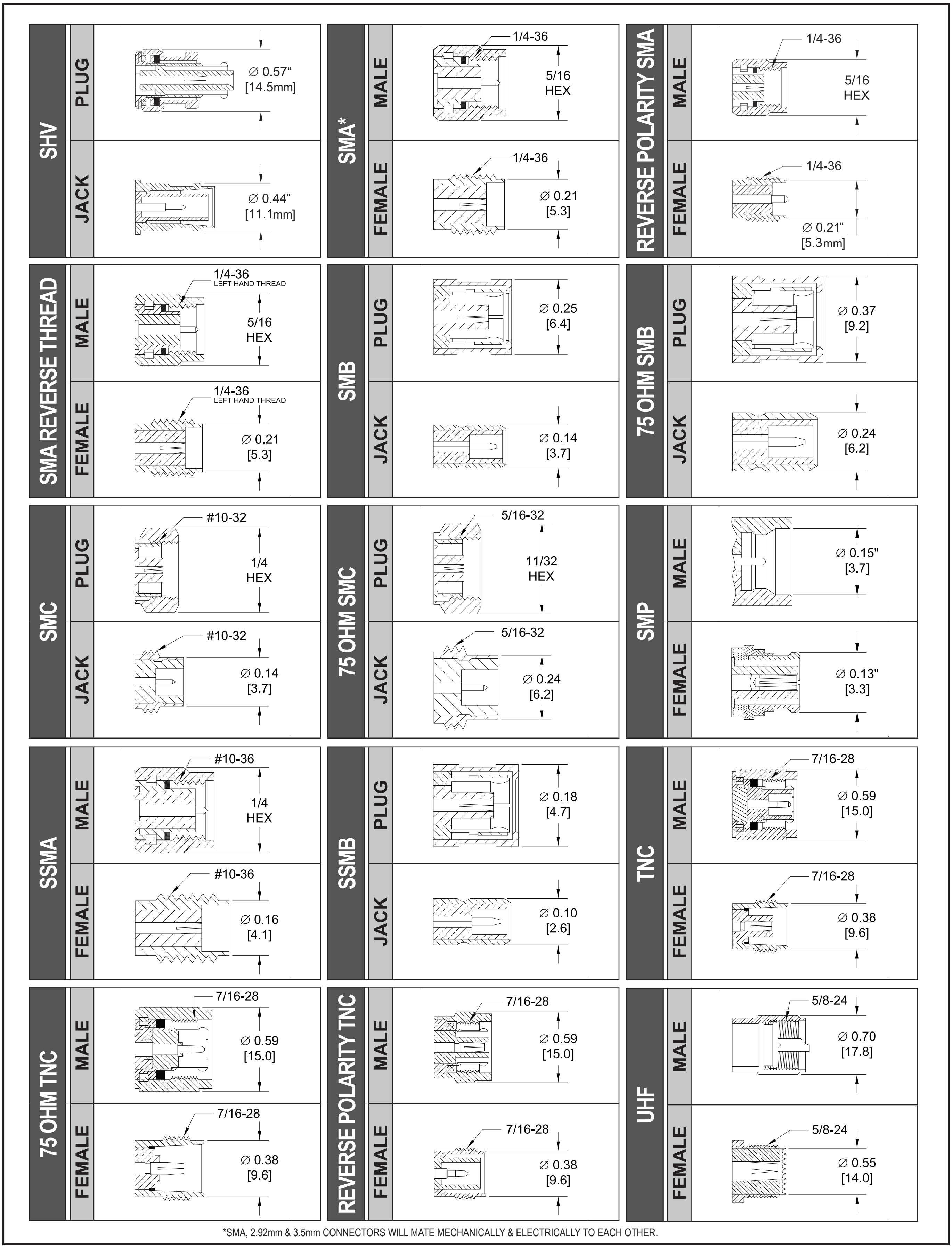
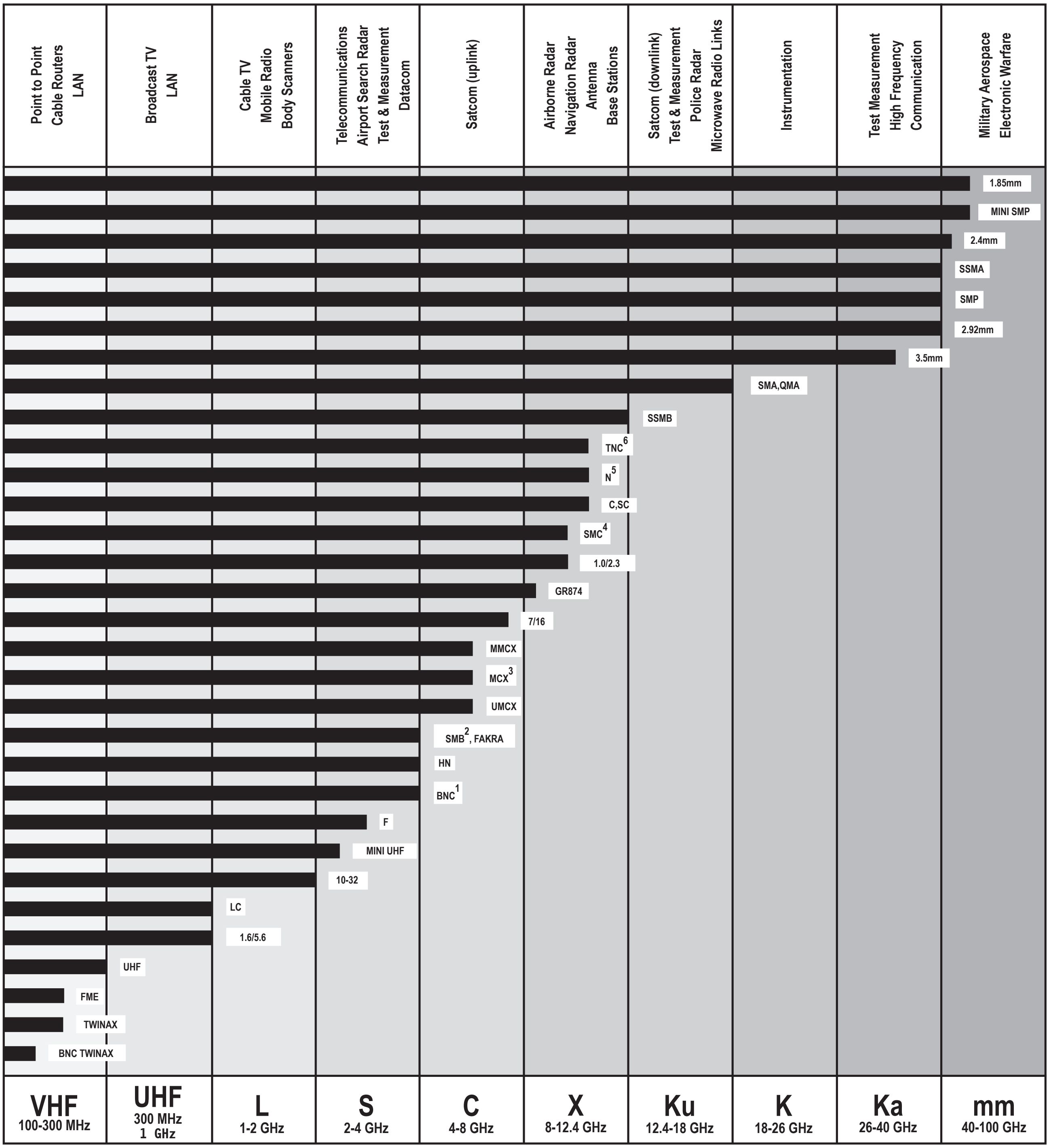


Figure 22.25D — Connector side views, set 4 of 4. [Courtesy of Pasternak]



Notes:

1: BNC-75 Ohm connectors operate up to 1 GHz
2: SMB-75 Ohm & Mini SMB-75 Ohm connectors operate up to 4 GHz
3: MCX-75 Ohm connectors operate up to 6 GHz
4: SMC-75 Ohm connectors operate up to 10 GHz
5: N-75 Ohm connectors operate up to 1.5 GHz
6: TNC-75 Ohm connectors operate up to 1 GHz

Figure 22.26 — Recommended frequency ranges by connector type. [Courtesy of Pasternak]

22.10 Reference Tables

Table 22.62
US Customary Units and Conversion Factors

Linear Units

12 inches (in) = 1 foot (ft)
36 inches = 3 feet = 1 yard (yd)
1 rod = $5^1/_2$ yards = $16^1/_2$ feet
1 statute mile = 1760 yards = 5280 feet
1 nautical mile = 6076.11549 feet

Area

1 ft^2 = 144 in^2
1 yd^2 = 9 ft^2 = 1296 in^2
1 rod^2 = $30^1/_4$ yd^2
1 acre = 4840 yd^2 = 43,560 ft^2
1 acre = 160 rod^2
1 $mile^2$ = 640 acres

Volume

1 ft^3 = 1728 in^3
1 yd^3 = 27 ft^3

Liquid Volume Measure

1 fluid ounce (fl oz) = 8 fluid drams = 1.804 in
1 pint (pt) = 16 fl oz
1 quart (qt) = 2 pt = 32 fl oz = $57^3/_4$ in^3
1 gallon (gal) = 4 qt = 231 in^3
1 barrel = $31^1/_2$ gal

Dry Volume Measure

1 quart (qt) = 2 pints (pt) = 67.2 in^3
1 peck = 8 qt
1 bushel = 4 pecks = 2150.42 in^3

Avoirdupois Weight

1 dram (dr) = 27.343 grains (gr) or (gr a)
1 ounce (oz) = 437.5 gr
1 pound (lb) = 16 oz = 7000 gr
1 short ton = 2000 lb, 1 long ton = 2240 lb

Troy Weight

1 grain troy (gr t) = 1 grain avoirdupois
1 pennyweight (dwt) or (pwt) = 24 gr t
1 ounce troy (oz t) = 480 grains
1 lb t = 12 oz t = 5760 grains

Apothecaries' Weight

1 grain apothecaries' (gr ap)
= 1 gr t = 1 gr
1 dram ap (dr ap) = 60 gr
1 oz ap = 1 oz t = 8 dr ap = 480 gr
1 lb ap = 1 lb t = 12 oz ap = 5760 gr

Conversion

Metric Unit = Metric Unit × US Unit

(Length)		
mm	25.4	inch
cm	2.54	inch
cm	30.48	foot
m	0.3048	foot
m	0.9144	yard
km	1.609	mile
km	1.852	nautical mile
(Area)		
mm^2	645.16	$inch^2$
cm^2	6.4516	in^2
cm^2	929.03	ft^2
m^2	0.0929	ft^2
cm^2	8361.3	yd^2
m^2	0.83613	yd^2
m^2	4047	acre
km^2	2.59	mi^2
(Mass)	**(Avoirdupois Weight)**	
grams	0.0648	grains
g	28.349	oz
g	453.59	lb
kg	0.45359	lb
tonne	0.907	short ton
tonne	1.016	long ton
(Volume)		
mm^3	16387.064	in^3
cm^3	16.387	in^3
m^3	0.028316	ft^3
m^3	0.764555	yd^3
ml	16.387	in^3
ml	29.57	fl oz
ml	473	pint
ml	946.333	quart
l	28.32	ft^3
l	0.9463	quart
l	3.785	gallon
l	1.101	dry quart
l	8.809	peck
l	35.238	bushel
(Mass)	**(Troy Weight)**	
g	31.103	oz t
g	373.248	lb t
(Mass)	**(Apothecaries' Weight)**	
g	3.387	dr ap
g	31.103	oz ap
g	373.248	lb ap

Multiply →
Metric Unit = Conversion Factor × US Customary Unit

← **Divide**
Metric Unit ÷ Conversion Factor = US Customary Unit

Table 22.63

International System of Units (SI)—Metric Units

Prefix	*Symbol*	*Multiplication Factor*		
exe	E	10^{18}	=	1,000,000 000,000,000,000
peta	P	10^{15}	=	1,000 000,000,000,000
tera	T	10^{12}	=	1,000,000,000,000
giga	G	10^{9}	=	1,000,000,000
mega	M	10^{6}	=	1,000,000
kilo	k	10^{3}	=	1,000
hecto	h	10^{2}	=	100
deca	da	10^{1}	=	10
		10^{0}	=	1
deci	d	10^{-1}	=	0.1
centi	c	10^{-2}	=	0.01
milli	m	10^{-3}	=	0.001
micro	μ	10^{-6}	=	0.000001
nano	n	10^{-9}	=	0.000000001
pico	p	10^{-12}	=	0.000000000001
femto	f	10^{-15}	=	0.000000000000001
atto	a	10^{-18}	=	0.000000000000000001

Linear

1 meter (m) = 100 centimeters (cm) = 1000 millimeters (mm)

Area

1 $m^2 = 1 \times 10^4$ $cm^2 = 1 \times 10^6$ mm^2

Volume

1 $m^3 = 1 \times 10^6$ $cm^3 = 1 \times 10^9$ mm^3
1 liter (l) = 1000 $cm^3 = 1 \times 10^6$ mm^3

Mass

1 kilogram (kg) = 1000 grams (g)
(Approximately the mass of 1 liter of water)
1 metric ton (or tonne) = 1000 kg

Table 22.64

Voltage-Power Conversion Table

Based on a 50-ohm system

Voltage			Power	
RMS	*Peak-to-Peak*	*dBmV*	*Watts*	*dBm*
0.01 μV	0.0283 μV	–100	2×10^{-18}	–147.0
0.02 μV	0.0566 μV	–93.98	8×10^{-18}	–141.0
0.04 μV	0.113 μV	–87.96	32×10^{-18}	–134.9
0.08 μV	0.226 μV	–81.94	128×10^{-18}	–128.9
0.1 μV	0.283 μV	–80.0	200×10^{-18}	–127.0
0.2 μV	0.566 μV	–73.98	800×10^{-18}	–121.0
0.4 μV	1.131 μV	–67.96	3.2×10^{-15}	–114.9
0.8 μV	2.236 μV	–61.94	12.8×10^{-15}	–108.9
1.0 μV	2.828 μV	–60.0	20.0×10^{15}	–107.0
2.0 μV	5.657 μV	–53.98	80.0×10^{-15}	–101.0
4.0 μV	11.31 μV	–47.96	320.0×10^{-15}	–94.95
8.0 μV	22.63 μV	–41.94	1.28×10^{-12}	–88.93
10.0 μV	28.28 μV	–40.00	2.0×10^{-12}	– 86.99
20.0 μV	56.57 μV	–33.98	8.0×10^{-12}	–80.97
40.0 μV	113.1 μV	–27.96	32.0×10^{-12}	–74.95
80.0 μV	226.3 μV	–21.94	128.0×10^{-12}	–68.93
100.0 μV	282.8 μV	–20.0	200.0×10^{-12}	–66.99
200.0 μV	565.7 μV	–13.98	800.0×10^{-12}	–60.97
400.0 μV	1.131 mV	–7.959	3.2×10^{-9}	–54.95
800.0 μV	2.263 mV	–1.938	12.8×10^{-9}	–48.93
1.0 mV	2.828 mV	0.0	20.0×10^{-9}	–46.99
2.0 mV	5.657 mV	6.02	80.0×10^{-9}	–40.97
4.0 mV	11.31 mV	12.04	320×10^{-9}	–34.95
8.0 mV	22.63 mV	18.06	1.28 μW	–28.93
10.0 mV	28.28 mV	20.00	1 2.0 μW	–26.99
20.0 mV	56.57 mV	26.02	8.0 μW	–20.97
40.0 mV	113.1 mV	32.04	32.0 μW	–14.95
80.0 mV	226.3 mV	38.06	128.0 μW	–8.93
100.0 mV	282.8 mV	40.0	200.0 μW	–6.99
200.0 mV	565.7 mV	46.02	800.0 μW	–0.97
223.6 mV	632.4 mV	46.99	1.0 mW	0
400.0 mV	1.131 V	52.04	3.2 mW	5.05
800.0 mV	2.263 V	58.06	12.80 mW	11.07
1.0 V	2.828 V	60.0	20.0 mW	13.01
2.0 V	5.657 V	66.02	80.0 mW	19.03
4.0 V	11.31 V	72.04	320.0 mW	25.05
8.0 V	22.63 V	78.06	1.28 W	31.07
10.0 V	28.28 V	80.0	2.0 W	33.01
20.0 V	56.57 V	86.02	8.0 W	39.03
40.0 V	113.1 V	92.04	32.0 W	45.05
80.0 V	226.3 V	98.06	128.0 W	51.07
100.0 V	282.8 V	100.0	200.0 W	53.01
200.0 V	565.7 V	106.0	800.0 W	59.03
223.6 V	632.4 V	107.0	1,000.0 W	60.0
400.0 V	1,131.0 V	112.0	3,200.0 W	65.05
800.0 V	2,263.0 V	118.1	12,800.0 W	71.07
1000.0 V	2,828.0 V	120.0	20,000 W	73.01
2000.0 V	5,657.0 V	126.0	80,000 W	79.03
4000.0 V	11,310.0 V	132.0	320,000 W	85.05
8000.0 V	22,630.0 V	138.1	1.28 MW	91.07
10,000.0 V	28,280.0 V	140.0	2.0 MW	93.01

Table 22.65
Reflection Coefficient, Attenuation, SWR and Return Loss

Reflection Coefficient (%)	*Attenuation (dB)*	*Max SWR*	*Return Loss, dB*
1.000	0.000434	1.020	40.00
1.517	0.001000	1.031	36.38
2.000	0.001738	1.041	33.98
3.000	0.003910	1.062	30.46
4.000	0.006954	1.083	27.96
4.796	0.01000	1.101	26.38
5.000	0.01087	1.105	26.02
6.000	0.01566	1.128	24.44
7.000	0.02133	1.151	23.10
7.576	0.02500	1.164	22.41
8.000	0.02788	1.174	21.94
9.000	0.03532	1.198	20.92
10.000	0.04365	1.222	20.00
10.699	0.05000	1.240	19.41
11.000	0.05287	1.247	19.17
12.000	0.06299	1.273	18.42
13.085	0.07500	1.301	17.66
14.000	0.08597	1.326	17.08
15.000	0.09883	1.353	16.48
15.087	0.10000	1.355	16.43
16.000	0.1126	1.381	15.92
17.783	0.1396	1.433	15.00
18.000	0.1430	1.439	14.89
19.000	0.1597	1.469	14.42
20.000	0.1773	1.500	13.98
22.000	0.2155	1.564	13.15
23.652	0.2500	1.620	12.52
24.000	0.2577	1.632	12.40
25.000	0.2803	1.667	12.04
26.000	0.3040	1.703	11.70
27.000	0.3287	1.740	11.37
28.000	0.3546	1.778	11.06
30.000	0.4096	1.857	10.46
31.623	0.4576	1.925	10.00
32.977	0.5000	1.984	9.64
33.333	0.5115	2.000	9.54
34.000	0.5335	2.030	9.37
35.000	0.5675	2.077	9.12
36.000	0.6028	2.125	8.87
37.000	0.6394	2.175	8.64
38.000	0.6773	2.226	8.40
39.825	0.75000	2.324	8.00
40.000	0.7572	2.333	7.96
42.000	0.8428	2.448	7.54
42.857	0.8814	2.500	7.36
44.000	0.9345	2.571	7.13
45.351	1.0000	2.660	6.87
48.000	1.1374	2.846	6.38
50.000	1.2494	3.000	6.02
52.000	1.3692	3.167	5.68
54.042	1.5000	3.352	5.35
56.234	1.6509	3.570	5.00
58.000	1.7809	3.762	4.73
60.000	1.9382	4.000	4.44
60.749	2.0000	4.095	4.33
63.000	2.1961	4.405	4.01
66.156	2.5000	4.909	3.59
66.667	2.5528	5.000	3.52
70.627	3.0000	5.809	3.02
70.711	3.0103	5.829	3.01

$$\rho = \frac{SWR - 1}{SWR + 1}$$

where ρ = 0.01 × (reflection coefficient in %)

$$\rho = 10^{-RL/20}$$

where RL = return loss (dB)

$$\rho = \sqrt{1 - (0.1^{X})}$$

where X = A/10 and A = attenuation (dB)

$$SWR = \frac{1 + \rho}{1 - \rho}$$

Return loss (dB) = –8.68589 ln (ρ) = –3.77155 log (ρ)
where ln is the natural log (log to the base e)

Attenuation (dB) = –4.34295 ln ($1 - \rho^2$) = 1.88578 log ($1 - \rho^2$)
where ln is the natural log (log to the base e)

Table 22.66

Abbreviations List

A

a—atto (prefix for 10^{-18})
A—ampere (unit of electrical current)
ac—alternating current
ACC—Affiliated Club Coordinator
ACSSB—amplitude-compandored single sideband
A/D—analog-to-digital
ADC—analog-to-digital converter
AF—audio frequency
AFC—automatic frequency control
AFSK—audio frequency-shift keying
AGC—automatic gain control
Ah—ampere hour
ALC—automatic level control
AM—amplitude modulation
AMRAD—Amateur Radio Research and Development Corporation
AMSAT—Radio Amateur Satellite Corporation
AMTOR—Amateur Teleprinting Over Radio
ANT—antenna
ARA—Amateur Radio Association
ARC—Amateur Radio Club
ARES—Amateur Radio Emergency Service
ARQ—Automatic repeat request
ARRL—American Radio Relay League
ARS—Amateur Radio Society (station)
ASCII—American National Standard Code for Information Interchange
ATV—amateur television
AVC—automatic volume control
AWG—American wire gauge
az-el—azimuth-elevation

B

B—bel; blower; susceptance; flux density, (inductors)
balun—balanced to unbalanced (transformer)
BC—broadcast
BCD—binary coded decimal
BCI—broadcast interference
Bd—baud (bids in single-channel binary data transmission)
BER—bit error rate
BFO—beat-frequency oscillator
bit—binary digit
bit/s—bits per second
BM—Bulletin Manager
BPF—band-pass filter
BPL—Brass Pounders League
BPL—Broadband over Power Line
BT—battery
BW—bandwidth
Bytes—Bytes

C

c—centi (prefix for 10^{-2})
C—coulomb (quantity of electric charge); capacitor
CAC—Contest Advisory Committee
CATVI—cable television interference
CB—Citizens Band (radio)
CBBS—computer bulletin-board service
CBMS—computer-based message system
CCITT—International Telegraph and Telephone Consultative Committee
CCTV—closed-circuit television
CCW—coherent CW
ccw—counterclockwise
CD—civil defense
cm—centimeter
CMOS—complementary-symmetry metal-oxide semiconductor
coax—coaxial cable
COR—carrier-operated relay
CP—code proficiency (award)
CPU—central processing unit
CRT—cathode ray tube
CT—center tap
CTCSS—continuous tone-coded squelch system
cw—clockwise
CW—continuous wave

D

d—deci (prefix for 10^{-1})
D—diode
da—deca (prefix for 10)
D/A—digital-to-analog
DAC—digital-to-analog converter
dB—decibel (0.1 bel)
dBi—decibels above (or below) isotropic antenna
dBm—decibels above (or below) 1 milliwatt
DBM—double balanced mixer
dBV—decibels above/below 1 V (in video, relative to 1 V P-P)
dBW—decibels above/below 1 W
dc—direct current
D-C—direct conversion
DDS—direct digital synthesis
DEC—District Emergency Coordinator
deg—degree
DET—detector
DF—direction finding; direction finder
DIP—dual in-line package
DMM—digital multimeter
DPDT—double-pole double-throw (switch)
DPSK—differential phase-shift keying
DPST—double-pole single-throw (switch)
DS—direct sequence (spread spectrum); display
DSB—double sideband
DSP—digital signal processing
DTMF—dual-tone multifrequency
DV—digital voice
DVM—digital voltmeter
DX—long distance; duplex
DXAC—DX Advisory Committee
DXCC—DX Century Club

E

e—base of natural logarithms (2.71828)
E—voltage
EA—ARRL Educational Advisor
EC—Emergency Coordinator
ECL—emitter-coupled logic
EHF—extremely high frequency (30-300 GHz)
EIA—Electronic Industries Alliance
EIRP—effective isotropic radiated power
ELF—extremely low frequency
ELT—emergency locator transmitter
EMC—electromagnetic compatibility
EME—earth-moon-earth (moonbounce)
EMF—electromotive force
EMI—electromagnetic interference
EMP—electromagnetic pulse
EOC—emergency operations center
EPROM—erasable programmable read only memory

F

f—femto (prefix for 10^{-15}); frequency
F—farad (capacitance unit); fuse
fax—facsimile
FCC—Federal Communications Commission
FD—Field Day
FEMA—Federal Emergency Management Agency
FET—field-effect transistor
FFT—fast Fourier transform
FL—filter
FM—frequency modulation
FMTV—frequency-modulated television
FSK—frequency-shift keying
FSTV—fast-scan (real-time) television
ft—foot (unit of length)

G

g—gram (unit of mass)
G—giga (prefix for 10^9); conductance
GaAs—gallium arsenide
GB—gigabytes
GDO—grid- or gate-dip oscillator
GHz—gigahertz (10^9 Hz)
GND—ground

H

h—hecto (prefix for 10^2)
H—henry (unit of inductance)
HF—high frequency (3-30 MHz)
HFO—high-frequency oscillator; heterodyne frequency oscillator
HPF—highest probable frequency; high-pass filter
Hz—hertz (unit of frequency, 1 cycle/s)

I

I—current, indicating lamp
IARU—International Amateur Radio Union
IC—integrated circuit
ID—identification; inside diameter
IEEE—Institute of Electrical and Electronics Engineers
IF—intermediate frequency

IMD—intermodulation distortion
in.—inch (unit of length)
in./s—inch per second (unit of velocity)
I/O—input/output
IRC—international reply coupon
ISB—independent sideband
ITF—Interference Task Force
ITU—International Telecommunication Union
ITU-T—ITU Telecommunication Standardization Bureau

J-K

j—operator for complex notation, as for reactive component of an impedance (+*j* inductive; –*j* capacitive)
J—joule (kg m^2/s^2) (energy or work unit); jack
JFET—junction field-effect transistor
k—kilo (prefix for 10^3); Boltzmann's constant (1.38×10^{-23} J/K)
K—kelvin (used without degree symbol) absolute temperature scale; relay
kB—kilobytes
kBd—1000 bauds
kbit—1024 bits
kbit/s—1024 bits per second
kbyte—1024 bytes
kg—kilogram
kHz—kilohertz
km—kilometer
kV—kilovolt
kW—kilowatt
kΩ—kilohm

L

l—liter (liquid volume)
L—lambert; inductor
lb—pound (force unit)
LC—inductance-capacitance
LCD—liquid crystal display
LED—light-emitting diode
LF—low frequency (30-300 kHz)
LHC—left-hand circular (polarization)
LO—local oscillator; Leadership Official
LP—log periodic
LS—loudspeaker
lsb—least significant bit
LSB—lower sideband
LSI—large-scale integration
LUF—lowest usable frequency

M

m—meter (length); milli (prefix for 10^{-3})
M—mega (prefix for 10^6); meter (instrument)
mA—milliampere
mAh—milliampere hour
MB—megabytes
MCP—multimode communications processor
MDS—Multipoint Distribution Service; minimum discernible (or detectable) signal
MF—medium frequency (300-3000 kHz)
mH—millihenry
MHz—megahertz
mi—mile, statute (unit of length)
mi/h (MPH)—mile per hour
mi/s—mile per second
mic—microphone
Mil—one-thousandth of an inch
min—minute (time)
MIX—mixer
mm—millimeter
MOD—modulator
modem—modulator/demodulator
MOS—metal-oxide semiconductor
MOSFET—metal-oxide semiconductor field-effect transistor
MS—meteor scatter
ms—millisecond
m/s—meters per second
msb—most-significant bit
MSI—medium-scale integration
MSK—minimum-shift keying
MSO—message storage operation
MUF—maximum usable frequency
mV—millivolt
mW—milliwatt
MΩ—megohm

N

n—nano (prefix for 10^{-9}); number of turns (inductors)
NBFM—narrow-band frequency modulation
NC—no connection; normally closed
NCS—net-control station; National Communications System
nF—nanofarad
NF—noise figure
nH—nanohenry
NiCd—nickel cadmium
NM—Net Manager
NMOS—N-channel metal-oxide silicon
NO—normally open
NPN—negative-positive-negative (transistor)
NPRM—Notice of Proposed Rule Making (FCC)
ns—nanosecond
NTIA—National Telecommunications and Information Administration
NTS—National Traffic System

O

OBS—Official Bulletin Station
OD—outside diameter
OES—Official Emergency Station
OO—Official Observer
op amp—operational amplifier
ORS—Official Relay Station
OSC—oscillator
OSCAR—Orbiting Satellite Carrying Amateur Radio
OTC—Old Timer's Club
oz—ounce (1⁄16 pound)

P

p—pico (prefix for 10^{-12})
P—power; plug
PA—power amplifier
PACTOR—digital mode combining aspects of packet and AMTOR
PAM—pulse-amplitude modulation
PBS—packet bulletin-board system
PC—printed circuit
PD—power dissipation
PEP—peak envelope power
PEV—peak envelope voltage
pF—picofarad
pH—picohenry
PIC—Public Information Coordinator
PIN—positive-intrinsic-negative (semiconductor)
PIO—Public Information Officer
PIV—peak inverse voltage
PLC—Power Line Carrier
PLL—phase-locked loop
PM—phase modulation
PMOS—P-channel (metal-oxide semiconductor)
PNP—positive negative positive (transistor)
pot—potentiometer
P-P—peak to peak
ppd—postpaid
PROM—programmable read-only memory
PSAC—Public Service Advisory Committee
PSHR—Public Service Honor Roll
PTO—permeability-tuned oscillator
PTT—push to talk

Q-R

Q—figure of merit (tuned circuit); transistor
QRP—low power (less than 5-W output)
R—resistor
RACES—Radio Amateur Civil Emergency Service
RAM—random-access memory
RC—resistance-capacitance
R/C—radio control
RCC—Rag Chewer's Club
RDF—radio direction finding
RF—radio frequency
RFC—radio-frequency choke
RFI—radio-frequency interference
RHC—right-hand circular (polarization)
RIT—receiver incremental tuning
RLC—resistance-inductance-capacitance
RM—rule making (number assigned to petition)
r/min (RPM)—revolutions per minute
rms—root mean square
ROM—read-only memory
r/s—revolutions per second
RS—Radio Sputnik (Russian ham satellite)
RST—readability-strength-tone (CW signal report)
RTTY—radioteletype
RX—receiver, receiving

S

s—second (time)
S—siemens (unit of conductance); switch
SASE—self-addressed stamped envelope
SCF—switched capacitor filter
SCR—silicon controlled rectifier
SEC—Section Emergency Coordinator

SET—Simulated Emergency Test
SGL—State Government Liaison
SHF—super-high frequency (3-30 GHz)
SM—Section Manager; silver mica (capacitor)
S/N—signal-to-noise ratio
SPDT—single-pole double-throw (switch)
SPST—single-pole single-throw (switch)
SS—ARRL Sweepstakes; spread spectrum
SSB—single sideband
SSC—Special Service Club
SSI—small-scale integration
SSTV—slow-scan television
STM—Section Traffic Manager
SX—simplex
sync—synchronous, synchronizing
SWL—shortwave listener
SWR—standing-wave ratio

T

T—tera (prefix for 10^{12}); transformer
TA—ARRL Technical Advisor
TC—Technical Coordinator
TCC—Transcontinental Corps (NTS)
TCP/IP—Transmission Control Protocol/Internet Protocol
tfc—traffic
TNC—terminal node controller (packet radio)
TR—transmit/receive
TS—Technical Specialist
TTL—transistor-transistor logic
TTY—teletypewriter
TU—terminal unit
TV—television
TVI—television interference
TX—transmitter, transmitting

U

U—integrated circuit
UHF—ultra-high frequency (300 MHz to 3 GHz)
USB—upper sideband
UTC—Coordinated Universal Time (also abbreviated Z)
UV—ultraviolet

V

V—volt; vacuum tube
VCO—voltage-controlled oscillator
VCR—video cassette recorder
VDT—video-display terminal
VE—Volunteer Examiner
VEC—Volunteer Examiner Coordinator
VFO—variable-frequency oscillator
VHF—very-high frequency (30-300 MHz)
VLF—very-low frequency (3-30 kHz)
VLSI—very-large-scale integration
VMOS—V-topology metal-oxide-semiconductor
VOM—volt-ohmmeter
VOX—voice-operated switch
VR—voltage regulator
VSWR—voltage standing-wave ratio
VTVM—vacuum-tube voltmeter
VUCC—VHF/UHF Century Club
VXO—variable-frequency crystal oscillator

W

W—watt (kg m^2s^{-3}), unit of power
WAC—Worked All Continents
WAS—Worked All States
WBFM—wide-band frequency modulation
WEFAX—weather facsimile
Wh—watthour
WPM—words per minute
WRC—World Radiocommunication Conference
WVDC—working voltage, direct current

X

X—reactance
XCVR—transceiver
XFMR—transformer
XIT—transmitter incremental tuning
XO—crystal oscillator
XTAL—crystal
XVTR—transverter

Y-Z

Y—crystal; admittance
YIG—yttrium iron garnet
Z—impedance; also see UTC

Numbers/Symbols

5BDXCC—Five-Band DXCC
5BWAC—Five-Band WAC
5BWAS—Five-Band WAS
6BWAC—Six-Band WAC
°—degree (plane angle)
°C—degree Celsius (temperature)
°F—degree Fahrenheit (temperature)
α—(alpha) angles; coefficients, attenuation constant, absorption factor, area, common-base forward current-transfer ratio of a bipolar transistor
β—(beta) angles; coefficients, phase constant, current gain of common-emitter transistor amplifiers
γ—(gamma) specific gravity, angles, electrical conductivity, propagation constant
Γ—(gamma) complex propagation constant
δ—(delta) increment or decrement; density; angles
Δ—(delta) increment or decrement determinant, permittivity
ε—(epsilon) dielectric constant; permittivity; electric intensity
ζ—(zeta) coordinates; coefficients
η—(eta) intrinsic impedance; efficiency; surface charge density; hysteresis; coordinate
θ—(theta) angular phase displacement; time constant; reluctance; angles
ι—(iota) unit vector
K—(kappa) susceptibility; coupling coefficient
λ—(lambda) wavelength; attenuation constant
Λ—(lambda) permeance
μ—(mu) permeability; amplification factor; micro (prefix for 10^{-6})
μF—microfarad
μH—microhenry
μP—microprocessor
ξ—(xi) coordinates
π—(pi) $\approx$3.14159
ρ—(rho) resistivity; volume charge density; coordinates; reflection coefficient
σ—(sigma) surface charge density; complex propagation constant; electrical conductivity; leakage coefficient; deviation
Σ—(sigma) summation
τ—(tau) time constant; volume resistivity; time-phase displacement; transmission factor; density
ϕ—(phi) magnetic flux angles
Φ—(phi) angles
χ—(chi) electric susceptibility; angles
Ψ—(psi) dielectric flux; phase difference; coordinates; angles
ω—(omega) angular velocity 2 πF
Ω—(omega) resistance in ohms; solid angle