# Chapter 7 <br> Component Data and References 

## Component Data

None of us has the time or space to collect all the literature available on the many different commercially available manufactured components. Even if we did, the task of keeping track of new and obsolete devices would surely be formidable. Fortunately, amateurs tend to use a limited number of component types. This section, by Douglas Heacock, AAØMS, provides information on the components most often used by the Amateur Radio experimenter.

## COMPONENT VALUES

Throughout this Handbook, resistors and small-value capacitors are specified in terms of a system of "pre-ferred values." This system allows manufacturers to supply these components in a standard set of values, which, when considered along with component tolerances, satisfy the vast majority of circuit requirements.

The preferred values are based on a roughly logarithmic scale of numbers between 1 and 10 . One decade of these values for three common tolerance ratings is shown in Table 7.1.

Table 7.1 represents the two significant digits in a resistor or capacitor value. Multiply these numbers by multiples of ten to get other standard values. For example, $22 \mathrm{pF}, 2.2 \mu \mathrm{~F}, 220 \mu \mathrm{~F}$, and $2200 \mu \mathrm{~F}$ are all standard capacitance values, available in all three tolerances. Standard resistor values include $3.9 \Omega, 390 \Omega, 39000 \Omega$ and 3.9 $\mathrm{M} \Omega$ in $\pm 5 \%$ and $\pm 10 \%$ tolerances. All standard resistance values, from less than $1 \Omega$ to about $5 \mathrm{M} \Omega$ are based on this table.

Each value is greater than the next smaller value by a multiplier factor that depends on the 1 tolerance. For $\pm 5 \%$
devices, each value is approximately 1.1 times the next lower one. For $\pm 10 \%$ devices, the multiplier is 1.21 , and for $\pm 20 \%$ devices, the multiplier is 1.47 . The resultant values are rounded to make up the series.
Tolerance refers to a range of acceptable values above and below the specified component value. For example, a $4700-\Omega$ resistor rated for $\pm 20 \%$ tolerance can have an actual value anywhere between $3760 \Omega$ and $5640 \Omega$. You may always substitute a

Table 7.1

## Standard Values for Resistors and

 Capacitors| $\pm 5 \%$ | $\pm 10 \%$ | $\pm 20 \%$ |
| :---: | :---: | :---: |
| 1.0 | 1.0 | 1.0 |
| 1.1 |  |  |
| 1.2 | 1.2 |  |
| 1.3 |  |  |
| 1.5 | 1.5 | 1.5 |
| 1.6 |  |  |
| 1.8 | 1.8 |  |
| 2.0 |  |  |
| 2.2 | 2.2 | 2.2 |
| 2.4 |  |  |
| 2.7 | 2.7 |  |
| 3.0 |  |  |
| 3.3 | 3.3 | 3.3 |
| 3.6 |  |  |
| 3.9 | 3.9 |  |
| 4.3 |  |  |
| 4.7 | 4.7 | 4.7 |
| 5.1 |  |  |
| 5.6 | 5.6 |  |
| 6.2 |  |  |
| 6.8 | 6.8 | 6.8 |
| 7.5 |  |  |
| 8.2 | 8.2 |  |
| 9.1 |  | 10.0 |
| 10.0 | 10.0 |  |

closer-tolerance device for one with a wider tolerance. For projects in this Handbook, assume a $10 \%$ tolerance if none is specified.

## COMPONENT MARKINGS

The values, tolerances or types of most small components are typically marked with a color code or an alphanumeric code according to standards agreed upon by component manufacturers. The Electronic Industries Alliance (EIA) is a US agency that sets standards for electronic components, testing procedures, performance and device markings. 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.

The standard EIA color code is used to identify a variety of electronic components. Most resistors are marked with color bands according to the code, shown in Table 7.2. Some types of capacitors and inductors are also marked using this color code.

## Resistor Markings

Carbon-composition, carbon-film, and metal-film resistors are typically manufactured in roughly cylindrical cases with axial leads. They are marked with color bands as shown in Fig 7.1 with the color codes detailed in Table 7.2. The markings in Fig 7.1A are typically used for $2 \%, 5 \%$ and $10 \%$ tolerance resistors. There are four bands, with the fourth band spaced widely from the first three. The first two bands

Table 7.2 Resistor Color Codes

| Color | Significant <br> Figure | Decimal <br> Multiplier | Tolerance <br> (\%) |
| :--- | :--- | :--- | :--- |
| 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 |



Fig 7.2—Typical resistor sizes.
represent the two significant digits of the component value, the third band represents the multiplier, and the fourth band represents the tolerance. If the fourth (tolerance) band is not present, the tolerance is $\pm 20 \%$. For example, if a resistor of the type shown in Fig 7.1A is marked with the bands red, red, orange and silver, the significant figures are 2 and 2, the multiplier is 1000 , and the tolerance is $\pm 10 \%$. The device is a $22,000-\Omega, \pm 10 \%$ unit.

Precision resistors $(0.1 \%, 0.25 \%, 0.5 \%$ and $1 \%$ tolerance) are marked with five bands, as shown in Fig 7.1B. Note that the fifth band is spaced widely from the first four bands. For example, if a resistor of the type shown in Fig 7.1A is marked with the bands red, red, orange, black and brown, the significant figures are 2,2 and 3 , the multiplier is 1 , and the tolerance is $\pm 1 \%$. The device is a $223-\Omega, \pm 1 \%$ unit.

Some military (mil-spec) resistors (Fig 7.1C) are marked with a fifth band that represents reliability information. On these resistors, the fifth band is spaced closely with the first four and represents the percentage of resistance change per 1000 hours of operation: brown $=1 \%$; red $=0.1 \%$; orange $=0.01 \%$; and yellow $=0.001 \%$.

Some resistors are made with radial leads (Fig 7.1D) and are marked with a color code in a slightly different scheme. For example, a resistor as shown in Fig 7.1D is marked as follows: body $(\mathrm{A})=$ blue; end $(\mathrm{B})=$ gray; dot $(C)=$ red; end $(D)=$ gold. The significant figures are 6 and 8 , the multiplier is 100, and the tolerance is $\pm 5 \% ; 6800 \Omega$ with $\pm 5 \%$ tolerance.

## Resistor Power Ratings

Carbon-film and metal-film are the most commonly available resistors today, having largely replaced the less-stable carboncomposition resistors. Carbon-film and metal-film resistors are available in standard
power ratings of $1 / 6,1 / 4,1 / 2,1$ and 2 W and generally have tolerances of $5 \%$ or better. Carbon-composition resistors are available in $1 / 10,1 / 8,1 / 4,1 / 2,1$ and 2 W ratings, but are harder to find. The $1 / 4,1 / 2,1$ and $2-\mathrm{W}$ resistor


Fig 7.1 - Color codes for fixed resistors. See Table 7.2 and text for more information on identifying the resistor values.
packages are drawn to scale in Fig 7.2. Carbon- and metal-film resistors are typically slightly smaller than carboncomposition units of the same power rating. Film resistors can usually be identified by a glossy enamel coating and an hourglass profile.

## Capacitor Markings

A variety of systems for capacitor markings are in use. Some use color bands, some use combinations of numbers and letters. Capacitors may be marked with their value, tolerance, temperature characteristics, voltage ratings or some subset of these specifications. Fig 7.3 shows several popular capacitor marking systems.

In addition to the value, ceramic disk capacitors may be marked with an alphanumeric code signifying temperature characteristics. Table 7.3 explains the EIA code for ceramic-disk capacitor temperature characteristics. The code is made up of one character from each column in the table. For example, a capacitor marked Z 5 U is suitable for use between +10 and $+85^{\circ} \mathrm{C}$, with a maximum change in capacitance of $-56 \%$ or $+22 \%$.

Capacitors with highly predictable temperature coefficients of capacitance are sometimes used in oscillators that must be frequency stable with temperature. If an application called for a temperature coefficient of $-750 \mathrm{ppm} /{ }^{\circ} \mathrm{C}$ (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 7.4. 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.


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

(A)


| Multiplier |  |
| :---: | :--- |
| Number | Multiply By |
| 0 | NONE |
| 1 | 10 |
| 2 | 100 |
| 3 | 1000 |
| 4 | 10,000 |

Ceramic Capacitors
(E)


Capacitance in pF. First two digits significant figures, third digit indicates zeros. Letter R , when used, indicates the decimal point when three-significant-figure values are required. (Value shown is 561.0 pF.)

HBK05_07-003

EIA or MIL Designation for Mica Capacitors
(G)

(D)


(F)

| Letter <br> Designator | "Characteristic" <br> Max Capacitance <br> Drift | "Characteristic" <br> Max Range of <br> Temp Coeff <br> (ppm / deg. C) | MIL Voltage <br> Rating (V) | Capactitance <br> Tolerance <br> (Percent) |
| :---: | :---: | :---: | :---: | :---: |
| A | - | - | 100 | - |
| B | Not Specified | Not Specified | 250 | - |
| C | $\pm(0.5 \%+0.1 \mathrm{pF})$ | $\pm 200$ | 300 | - |
| D | $\pm(0.3 \%+0.1 \mathrm{pF})$ | $\pm 100$ | 500 | - |
| E | $\pm(0.1 \%+0.1 \mathrm{pF})$ | -20 to +100 | 600 | - |
| F | $\pm(0.05 \%+0.1 \mathrm{pF})$ | 0 to +70 | 1000 | $\pm 1$ |
| G | - | - | 1200 | $\pm 2$ |
| H | - | - | 1500 | - |
| J | - | - | 2000 | $\pm 5$ |
| K | - | - | 2500 | $\pm 10$ |
| L | - | - | 3000 | - |
| M | - | 4000 | $\pm 20$ |  |
| MIL voltage ratings for other letter designators: $\mathrm{N}=5000 \mathrm{~V}, \mathrm{P}=6000 \mathrm{~V}, \mathrm{Q}=8000$ |  |  |  |  |
| 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 7.3-Capacitors can be identified by color codes and markings. Shown here are identifying markings found on many common capacitor types.

Some capacitors, such as dipped silvermica units, have a letter designating the capacitance tolerance. These letters are deciphered in Table 7.5.

## Surface-Mount Resistor and Capacitor Markings

Many different types of electronic components, both active and passive, are now available in surface-mount packages. These are commonly known as chip resistors and capacitors. 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.

Surface-mount resistors are typically marked with a three- or four-digit value code and a character indicating tolerance. 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 ten. (It may be easier to remember the multiplier as the number of zeros you must add to the significant figures.) For values less than $100 \Omega$, the letter R is substituted for one of the significant digits and represents a decimal point. Here are some examples:

## Resistor

| Code | Value |
| :--- | :--- |
| 101 | 10 and 1 zero $=100 \Omega$ |
| 224 | 22 and 4 zeros $=220,000 \Omega$ |
| 1R0 | 1.0 and no zeros $=1 \Omega$ |
| 22R | 22.0 and no zeros $=22 \Omega$ |
| R10 | 0.1 and no zeros $=0.1 \Omega$ |

If the tolerance of the unit is narrower than $\pm 2 \%$, 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 a decimal point. For example, 1001 indicates a $1000-\Omega$ unit, and 22 R0 indicates a $22-\Omega$ unit. The tolerance rating for a surface-mount resistor is expressed with a single character at the end of the numeric value code in Table 7.6.

Surface-mount capacitors are marked with a two-character code consisting of a letter indicating the significant digits (see Table 7.7) and a number indicating the multiplier (see Table 7.8). The code represents the capacitance in picofarads. For example, a chip capacitor marked "A4" would have a capacitance of $10,000 \mathrm{pF}$, or $0.01 \mu \mathrm{~F}$. A unit marked "N1" would be a $33-\mathrm{pF}$ capacitor. If there is sufficient space on the device package, a tolerance code may be included (see Fig 7.3E for tolerance codes). Surface-mount capacitors

Table 7.3

## EIA Temperature Characteristic Codes for Ceramic Disc Capacitors

| Minimum <br> temperature | Maximum <br> temperature | Maximum capacitance <br> change over temperature range |
| :--- | :--- | :--- |
| $\mathrm{X}-55^{\circ} \mathrm{C}$ | $2+45^{\circ} \mathrm{C}$ | $\mathrm{A} \pm 1.0 \%$ |
| $\mathrm{Y}-30^{\circ} \mathrm{C}$ | $4+65^{\circ} \mathrm{C}$ | $\mathrm{B} \pm 1.5 \%$ |
| $\mathrm{Z}+10^{\circ} \mathrm{C}$ | $5+85^{\circ} \mathrm{C}$ | $\mathrm{C} \pm 2.2 \%$ |
|  | $6+105^{\circ} \mathrm{C}$ | $\mathrm{D} \pm 3.3 \%$ |
|  | $7+125^{\circ} \mathrm{C}$ | $\mathrm{E} \pm 4.7 \%$ |
|  | F $\pm 7.5 \%$ |  |
|  | P $\pm 10 \%$ |  |
|  | R $\pm 15 \%$ |  |
|  | S $\pm 22 \%$ |  |
|  | T $-33 \%,+22 \%$ |  |
|  | U $-56 \%,+22 \%$ |  |
|  | V $-82 \%,+22 \%$ |  |

## Table 7.4

EIA Capacitor TemperatureCoefficient Codes

| Industry | EIA |
| :--- | :--- |
| NP0 | C0G |
| N033 | S1G |
| N075 | U1G |
| N150 | P2G |
| N220 | R2G |
| Industry | EIA |
| N330 | S2H |
| N470 | U2J |
| N1500 | P3K |
| N2200 | R3L |


|  |  |
| :--- | :---: |
|  |  |
| Table 7.5 |  |
| EIA Capacitor |  |
| Tolerance Codes |  |
| Code | Tolerance |
| C | $\pm \neq 1 / \mathrm{pF}$ |
| D | $\pm 1 / \mathrm{pF}$ |
| F | $\pm 1 \mathrm{pF}$ or $\pm 1 \%$ |
| G | $\pm 2 \mathrm{pF}$ or $\pm 2 \%$ |
| J | $\pm 5 \%$ |
| K | $\pm 10 \%$ |
| L | $\pm 15 \%$ |
| M | $\pm 20 \%$ |
| N | $\pm 30 \%$ |
| P or GMV* | $-0 \%,+100 \%$ |
| W | $-20 \%,+40 \%$ |
| Y | $-20 \%,+50 \%$ |
| Z | $-20 \%,+80 \%$ |
| *GMV $=$ guaranteed minimum value. |  |

can be very small; you may need a magnifying glass to read the markings.

## INDUCTORS AND CORE MATERIALS

Inductors, both fixed and variable, are

Table 7.6
SMT Resistor Tolerance Codes

| Letter | Tolerance |
| :--- | :--- |
| D | $\pm 0.5 \%$ |
| F | $\pm 1.0 \%$ |
| G | $\pm 2.0 \%$ |
| J | $\pm 5.0 \%$ |

Table 7.7
SMT Capacitor Significant Figures Code

| Character | Significant <br> Figures | Character | Significant <br> 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 |  |  |

Table 7.8
SMT Capacitor Multiplier Codes

| Numeric | Decimal <br> Character |
| :--- | :--- |
| Multiplier |  |

### 7.4 Chapter 7

Table 7.9

## Powdered-Iron Toroidal Cores: Magnetic Properties

## Inductance and Turns Formula

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

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

where $\mathrm{N}=$ number of turns; $\mathrm{L}=$ desired inductance $(\mu \mathrm{H})$; $\mathrm{A}_{\mathrm{L}}=$ inductance index ( $\mu \mathrm{H}$ per 100 turns).*

| 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 |

*The units of $A L$ ( $\mu \mathrm{H}$ per 100 turns) are an industry standard; however, to get a correct result use AL only in the formula above.
**Mix-26 is similar to the older Mix-41, but can provide an extended frequency range.

## Magnetic Properties Iron Powder Cores

| Mix | Color | Material | $\mu$ | Temp stability (ppm/ ${ }^{\circ} \mathrm{C}$ ) | $f(\mathrm{MHz})$ | 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 temp. stability for $20-50 \mathrm{MHz}$ |
| 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.
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 7.2. See Fig 7.4 for another marking system for tubular encapsulated RF chokes.

Most powdered-iron toroid cores that we amateurs use are manufactured by Micrometals, who uses paint to identify the material used in the core. The Micrometals color code is part of Table 7.9. Table 7.10 gives the physical characteristics of pow-dered-iron toroids. Ferrite cores are not typically painted, so identification is more


Fig 7.4-Color coding for tubular encapsulated RF chokes. At A, an example of the coding for an $8.2-\mu \mathrm{H}$ choke is given. At B , the color bands for a $330-\mu \mathrm{H}$ inductor are illustrated. The color code is given in Table 7.2.

Table 7.10

## Powdered-Iron Toroidal Cores: Dimensions

| Red E Cores- $\mathbf{5 0 0} \mathbf{k H z}$ to $\mathbf{3 0} \mathbf{~ M H z}(\boldsymbol{\mu}=\mathbf{1 0})$ |  |  |  |
| :--- | :--- | :--- | :--- |
| No. | $O D$ (in) | $I D$ (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- $\mathbf{3 0} \mathbf{M H z}$ to $\mathbf{2 0 0} \mathbf{M H z}(\mu=\mathbf{6})$ |  |  |  |
| :--- | :--- | :--- | :--- |
| No. | OD (In) | ID (In) | $\mathbf{H}$ (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 $90 \mathrm{MHz}(\mu=8)$ |  |  |  |
| :---: | :---: | :---: | :---: |
| No. | $O D$ (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.
difficult. See Table 7.11 for information about ferrite cores.

## 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 7.12, 7.13 and 7.14 usually apply.
In addition, many miniature IF transformers are tuned with slugs that are color-coded to signify their application. Table 7.15 lists application vs slug color.

## SEMICONDUCTORS

Most semiconductor devices are clearly marked with the part number and in some


Fig 7.5-Color coding for semi-conductor diodes. At A, the cathode is identified by the double-width first band. At B, the bands are grouped toward the cathode. Two-figure designations are signified by a black first band. The color code is given in Table 7.2. The suffix-letter code is A-Brown, B-red, C-orange, D-yellow, E-green, F-blue. The 1 N prefix is understood.
cases, a manufacturer's date code as well. Identification of semiconductors can be difficult, however, when the parts are "house-marked" (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.

## Diodes

Most diodes are marked with a part number and some means of identifying which lead is the cathode. Some diodes are marked with a color-band code (see Fig 7.5). Important diode parameters include maximum forward current, maximum peak inverse voltage (PIV) and the power-handling capacity.

## Transistors

Some important parameters for transistor selection are voltage and current limits, power-handling capability, beta or gain characteristics and useful frequency range. The case style may also be an issue; some transistors are available in several different case styles.

## Integrated Circuits

Integrated circuits (ICs) come in a variety of packages, including transistor-like metal cans, dual and single in-line pack-

### 7.6 Chapter 7

Table 7.11
Ferrite Toroids: $A_{L}$ Chart (mH per 1000 turns) Enameled Wire

| Core | 63/67-Mix | 61-Mix | 43-Mix | 77 (72)-Mix | $J(75)$-Mix |
| :--- | :--- | :--- | :--- | :--- | :--- |
| Size | $\mu=40$ | $m=125$ | $\mu=850$ | $\mu=2000$ | $\mu=5000$ |
| FT-23 | 7.9 | 24.8 | 188.0 | 396 | 980 |
| FT-37 | 19.7 | 55.3 | 420.0 | 884 | 2196 |
| FT-50 | 22.0 | 68.0 | 523.0 | 1100 | 2715 |
| FT-82 | 22.4 | 73.3 | 557.0 | 1170 | NA |
| FT-114 | 25.4 | 79.3 | 603.0 | 1270 | 3170 |

Number of turns $=1000 \sqrt{\text { desired } \mathrm{L}(\mathrm{mH}) \div A_{\mathrm{L}} \text { value (above) }}$

## Ferrite Magnetic Properties

| Property | Unit | 63/67-Mix | 61-Mix | 43-Mix | 77 (72)-Mix | $J$ (75)-Mix |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Initial perm. | ( $\mu_{\mathrm{i}}$ ) | 40 | 125 | 850 | 2000 | 5000 |
| Max. perm. |  | 125 | 450 | 3000 | 6000 | 8000 |
| Saturation flux density @ 10 oer | Gauss | 1850 | 2350 | 2750 | 4600 | 3900 |
| Residual flux density | Gauss | 750 | 1200 | 1200 | 1150 | 1250 |
| Curie temp. | ${ }^{\circ} \mathrm{C}$ | 450 | 350 | 130 | 200 | 140 |
| Vol. resistivity | ohm/cm | $1 \times 10^{8}$ | $1 \times 10^{8}$ | $1 \times 10^{5}$ | $1 \times 10^{2}$ | $5 \times 10^{2}$ |
| 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 |
| Loss | $\frac{1}{\mu_{\mathrm{i}} \mathrm{Q}}$ | $110 \times 10^{-6}$ | $32 \times 10^{-6}$ | $120 \times 10^{-6}$ | $4.5 \times 10^{-6}$ | $15 \times 10^{-6}$ |
| factor |  | @ 25 MHz | @ 2.5 MHz | @1 MHz | @ 0.1 MHz | @ 0.1 MHz |
| Coercive force | Oer | 2.40 | 1.60 | 0.30 | 0.22 | 0.16 |
| Temp. Coef. of initial perm. | $\begin{aligned} & \% /{ }^{\circ} \mathrm{C} \\ & \left(20^{\circ}-70^{\circ}\right) \end{aligned}$ | 0.10 | 0.15 | 1.0 | 0.60 | 0.90 |

Ferrite Toroids-Physical Properties

| Core |  |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| Size | $O D$ | $I D$ | Height | $A_{e}$ | $I_{e}$ | $V_{e}$ | $A_{S}$ | $A_{W}$ |
| FT-23 | 0.230 | 0.120 | 0.060 | 0.00330 | 0.529 | 0.00174 | 0.1264 | 0.01121 |
| FT-37 | 0.375 | 0.187 | 0.125 | 0.01175 | 0.846 | 0.00994 | 0.3860 | 0.02750 |
| FT-50 | 0.500 | 0.281 | 0.188 | 0.02060 | 1.190 | 0.02450 | 0.7300 | 0.06200 |
| FT-82 | 0.825 | 0.520 | 0.250 | 0.03810 | 2.070 | 0.07890 | 1.7000 | 0.21200 |
| FT-114 | 1.142 | 0.750 | 0.295 | 0.05810 | 2.920 | 0.16950 | 2.9200 | 0.43900 |

OD-Outer diameter (inches)
ID-Inner diameter (inches)
Height (inches)
$\mathrm{A}_{\mathrm{w}}$-Total window area (in) ${ }^{2}$
$\mathrm{A}_{\mathrm{e}}$-Effective magnetic cross-sectional area (in) ${ }^{2}$
$\mathrm{I}_{\mathrm{e}}$-Effective magnetic path length (inches)
$\mathrm{V}_{\mathrm{e}}$ - Effective magnetic volume (in) ${ }^{3}$
$\mathrm{A}_{\mathrm{S}}$-Surface area exposed for cooling (in) ${ }^{2}$
Courtesy of Amidon Assoc.

Table 7.12
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 7.13

| 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 <br> is green-and-black striped, and black is <br> used for the center-tap lead. |  |

Table 7.14
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 |  |
|  | 2nd or 3rd IF | Green <br> Orange, <br> Brown or <br> Black |

Note: These markings also apply to line-togrid and tube-to-line transformers.
ages (DIPs and SIPs), flat-packs and sur-face-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. ICs are frequently house-marked, and the cross-reference directories mentioned above can be helpful in identification and replacement.

Another very useful reference tool for working with ICs is IC Master, 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. See www.icmaster.com.
IC part numbers usually contain a few digits that identify the circuit die or

Table 7.16
Copper Wire Specifications
Bare and Enamel-Coated Wire

| Wire | Diam | Area | Enamel Wire Coating |  |  | Feet per | Ohms per | Current Carrying Capacity Continuous Duty ${ }^{3}$ |  |  | Nearest |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  | at |  |  | Conduit |  |
| Size |  |  | Turns | Linear i | $\mathrm{ch}^{2}$ |  | Pound | 1000 ft | 700 CM | Open |  | SWG |
| (AWG) | (Mils) | (CM ${ }^{1}$ ) | Single | Heavy | Triple | Bare | $25^{\circ} \mathrm{C}$ | per Amp $^{4}$ | air | bundles | 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)
Turns per Linear inch ${ }^{2}$
UL Style No.

| Size | Strands $^{5}$ | 1180 | 1213 | 1371 |
| :--- | ---: | ---: | ---: | ---: |
| 16 | $19 \times 29$ | 11.2 |  |  |
| 18 | $19 \times 30$ | 12.7 |  |  |
| 20 | $7 \times 28$ | 14.7 | 17.2 |  |
| 20 | $19 \times 32$ | 14.7 | 17.2 |  |
| 22 | $19 \times 34$ | 16.7 | 20.0 | 23.8 |
| 22 | $7 \times 30$ | 16.7 | 20.0 | 23.8 |
| 24 | $19 \times 36$ | 18.5 | 22.7 | 27.8 |
| 24 | $7 \times 32$ |  | 22.7 | 27.8 |
| 26 | $7 \times 34$ |  | 25.6 | 32.3 |
| 28 | $7 \times 36$ |  | 28.6 | 3.0 |
| 30 | $7 \times 38$ |  | 31.3 | 41.7 |
| 32 | $7 \times 40$ |  |  | 47.6 |

## Notes

${ }^{1}$ A circular mil (CM) is a unit of area equal to that of a one-mil-diameter circle ( $\pi / 4$ 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 $212^{\circ} \mathrm{F}\left(100^{\circ} \mathrm{C}\right)$ with a maximum ambient temperature of $13^{\circ} \mathrm{F}\left(57^{\circ} \mathrm{C}\right)$ 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 7.17
Color Code for Hookup Wire
Wire Color Type of Circuit
Black Grounds, grounded elements and returns
Brown Heaters or filaments, off ground
Red Power Supply B plus
Orange $\quad$ Screen grids and base 2 of transistors
Yellow Cathodes and transistor emitters
Green Control grids, diode plates, and base 1 of transistors
Blue Plates and transistor collectors
Violet Power supply, minus leads
Gray Ac power line leads
White Bias supply, B or C minus, AGC
Note: Wires with tracers are coded in the same manner as solid-color wires, allowing additional circuit identification over solid-color wiring. The body of the wire is white and the color band spirals around the wire lead. When more than one color band is used, the widest band represents the first color.

Table 7.18

## Aluminum Alloy Characteristics

| 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 highstrength heat treatments, similar to T6 |

which may prevent lines from reaching the "high" condition. Fanout tells how many inputs a device can drive. The fanout of a replacement should be equal to, or greater than, that required in the circuit. Operating speed and propagation delay are also significant. Choose a replacement IC that operates at or above the circuit clock speed. (Be careful: Increased speed can increase EMI and cause other problems.) Some circuits may not function if the propagation delay varies much from the specified part. Look at the Electrical Signals and Components chapter for details of how these operating characteristics relate to circuit performance.

Analog ICs have similar characteristics. Input and output capacities are often defined as how much current an analog IC can "sink" (accept at an input) or "source" (pass to a load). A replacement should be able to source or sink at least as much current as the device it replaces. Analog speed is sometimes listed as bandwidth (as in discrete-component circuits) or slew rate (common in op amps). Each of these quantities should meet or exceed that of the replaced component.

Some ICs are available in different operating temperature ranges. Op amps , for example, are commonly available in three standard ranges:

- Commercial: $\quad 0^{\circ} \mathrm{C}$ to $70^{\circ} \mathrm{C}$
- Industrial: $\quad-25^{\circ} \mathrm{C}$ to $85^{\circ} \mathrm{C}$
- Military: $\quad-55^{\circ} \mathrm{C}$ to $125^{\circ} \mathrm{C}$

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.

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.

## OTHER SOURCES OF COMPONENT DATA

There are many sources you can consult for detailed component data. These days, 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. Distributors such as Digi-Key and Mouser include links to useful information in their online catalogs as well.
Some manufacturers publish data books for the components they make, and parts catalogs themselves are often good sources

Table 7.19
Crystal Holders

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


* Note: HC17/U pin spacing and diameter is equivalent to the older FT-243 (32 pF) holder.



| PIN | CONNECTION |
| :--- | :--- |
| 1 | No Connection |
| 2 | Crystal |
| 3 | Ground |
| 4 | Crystal |

HC 35 (TO-5)


$$
\begin{array}{l|l}
\text { PIN } & \text { CONNECTION } \\
\hline 1 & \text { No Connection } \\
2 & \text { Crystal } \\
3 & \text { Ground } \\
4 & \text { Crystal }
\end{array}
$$

HC 40 (TL-90)


HC 47 (TL-31)
нвк05_07-06

* Note: HC17/U pin spacing and diameter is equivalent to the older FT-243 (32 pF) holder.
of component data.


## THE ARRL TECHNICAL INFORMATION SERVICE (TIS)

The ARRL answers questions of a technical nature for ARRL members and nonmembers alike through the Technical Information Service. Questions may be submitted via email (tis@arrl.org); fax (860-594-0259); or
mail (TIS, ARRL, 225 Main St, Newington, CT 06111). The TIS also maintains a home page on ARRL Web site: www.arrl.org/tis. This site contains links to detailed, commonly needed information in many technical areas.

The TISfind search engine contains over 2000 providers of products, services and information of interest to radio amateurs.

Before contacting TIS for the address of someone who can repair your radio, or sells antennas, or has old manuals or schematics, look in TISfind. This valuable software is included on the Handbook CD-ROM bundled with this book or online at www.arrl.org/tis/tisfind.html.

Table 7.20
Miniature Lamp Guide


| Type | Bulb | Base | V | A | Life | Type | Bulb | Base | V | A | Life |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| PR2 | B-31/2 | FSCMN | 2.38 | 0.500 | 15 | 82 | G-6 | BDC | 6.50 | 1.020 | 500 |
| PR3 | B-31/2 | FSCMN | 3.57 | 0.500 | 15 | 85 | T-13/4 | WSMN | 28.00 | 0.040 | 7K |
| PR4 | B-31/2 | FSCMN | 2.33 | 0.270 | 10 | 86 | T-13/4 | WSMN | 6.30 | 0.200 | 20K |
| PR6 | B-31/2 | FSCMN | 2.47 | 0.300 | 30 | 88 | S-8 | BDC | 6.80 | 1.910 | 300 |
| PR7 | B-31/2 | FSCMN | 3.70 | 0.300 | 30 | 93 | S-8 | BSC | 12.80 | 1.040 | 700 |
| PR12 | B-31/2 | FSCMN | 5.95 | 0.500 | 15 | 112 | TL-3 | SMN | 1.20 | 0.220 | 5 |
| PR13 | B-31/2 | FSCMN | 4.75 | 0.500 | 15 | 130 | G-31/2 | BMN | 6.30 | 0.150 | 5K |
| 10 | G-31/2 | MTP | 2.50 | 0.500 | 3K | 131 | G-31/2 | SMN | 1.30 | 0.100 | 50 |
| 12 | G-31/2 | MTP | 6.30 | 0.150 | 5K | 158 | T-31/4 | W | 14.00 | 0.240 | 500 |
| 13 | G-31/2 | SMN | 3.70 | 0.300 | 15 | 159 | T-31/4 | W | 6.30 | 0.150 | 5K |
| 14 | G-31/2 | SMN | 2.47 | 0.300 | 15 | 161 | T-31/4 | W | 14.00 | 0.190 | 4K |
| 19 | G-31/2 | MTP | 14.4 | 0.100 | 1K | 168 | T-31/4 | W | 14.00 | 0.350 | 1.5K |
| 27 | G-41/2 | SMN | 4.90 | 0.300 | 30 | 219 | G-31/2 | BMN | 6.30 | 0.250 | 5 K |
| 37 | T-13/4 | WSMN | 14.00 | 0.090 | 1.5K | 222 | TL-3 | SMN | 2.25 | 0.250 | 0.5 |
| 40 | T-31/4 | SMN | 6.30 | 0.150 | 3 K | 239 | T-31/4 | BMN | 6.30 | 0.360 | 5K |
| 43 | T-31/4 | BMN | 2.50 | 0.500 | 3K | 240 | T-31/4 | BMN | 6.30 | 0.360 | 5K |
| 44 | T-31/4 | BMN | 6.30 | 0.250 | 3K | 259 | T-31/4 | W | 6.30 | 0.250 | 5K |
| 45 | T-31/4 | BMN | 3.20 | 0.350 | 3K | 268 | T-13/4 | FSCMD | 2.50 | 0.350 | 10K |
| 46 | T-31/4 | SMN | 6.30 | 0.250 | 3 K | 305 | S-8 | BSC | 28.00 | 0.510 | 300 |
| 47 | T-31/4 | BMN | 6.30 | 0.150 | 3K | 307 | S-8 | BSC | 28.00 | 0.670 | 300 |
| 48 | T-31/4 | SMN | 2.00 | 0.060 | 1K | 308 | S-8 | BDC | 28.00 | 0.670 | 300 |
| 49 | T-31/4 | BMN | 2.00 | 0.060 | 1K | 313 | T-31/4 | BMN | 28.00 | 0.170 | 500 |
| 50 | G-31/2 | SMN | 7.50 | 0.220 | 1K | 323 | T-11/4 | SPTHD | 3.00 | 0.190 | 350 |
| 51 | G-31/2 | BMN | 7.50 | 0.220 | 1K | 327 | T-13/4 | FSCMD | 28.00 | 0.040 | 4 K |
| 52 | G-31/2 | SMN | 14.40 | 0.100 | 1 K | $327 A S 15$ | T-13/4 | FSCMD | 28.00 | 0.040 | 4K |
| 53 | G-31/2 | BMN | 14.40 | 0.120 | 1 K | 328 | T-13/4 | FSCMD | 6.00 | 0.200 | 1K |
| 55 | G-41/2 | BMN | 7.00 | 0.410 | 500 | 330 | T-13/4 | FSCMD | 14.00 | 0.080 | 1.5K |
| 57 | G-41/2 | BMN | 14.00 | 0.240 | 500 | 331 | T-13/4 | FSCMD | 1.35 | 0.060 | 3 K |
| 63 | G-6 | BSC | 7.00 | 0.630 | 1K | 334 | T-13/4 | GMD | 28.00 | 0.040 | 4 K |
| 73 | T-13/4 | WSMN | 14.00 | 0.080 | 15K | 335 | T-13/4 | SMD | 28.00 | 0.040 | 4 K |
| 74 | T-13/4 | WSMN | 14.00 | 0.100 | 500 | 336 | T-13/4 | GMD | 14.00 | 0.080 | 1.5K |


| Type | Bulb | Base | v | A | Life | Type | Bulb | Base | V | A | Life |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 337 | T-13/4 | GMD | 6.00 | 0.200 | 1 K | 1866 | T-31/4 | BMN | 6.30 | 0.250 | 5K |
| 338 | T-13/4 | FSCMD | 2.70 | 0.060 | 6 K | 1869 | T-13/4 | WT | 10.00 | 0.014 | 50K |
| 342 | T-13/4 | SMD | 6.00 | 0.040 | 10K | 1891 | T-31/4 | BMN | 14.00 | 0.240 | 500 |
| 344 | T-13/4 | FSCMD | 10.00 | 0.014 | 50K | 1892 | T-31/4 | BMN | 14.40 | 0.120 | 1K |
| 345 | T-13/4 | FSCMD | 6.00 | 0.040 | 10K | 1893 | T-31/4 | BMN | 14.00 | 0.330 | 7.5 K |
| 346 | T-13/4 | GMD | 18.00 | 0.040 | 10K | 1895 | G-41/2 | BMN | 14.00 | 0.270 | 2 K |
| 349 | T-13/4 | FSCMD | 6.30 | 0.200 | 5K | 2102 | T-13/4 | WT | 18.00 | 0.040 | 10K |
| 370 | T-13/4 | FSCMD | 18.00 | 0.040 | 10K | 2107 | T-13/4 | WT | 10.00 | 0.040 | 5K |
| 373 | T-13/4 | SMD | 14.00 | 0.080 | 1.5K | 2158 | T-13/4 | WT | 3.00 | 0.015 | 10K |
| 375 | T-13/4 | FSCMD | 3.00 | 0.015 | 10K | 2162 | T-13/4 | WT | 14.00 | 0.100 | 10K |
| 376 | T-13/4 | FSCMD | 28.00 | 0.060 | 25K | 2169 | T-13/4 | WT | 2.50 | 0.350 | 20K |
| 380 | T-13/4 | FSCMD | 6.30 | 0.040 | 20K | 2180 | T-13/4 | WT | 6.30 | 0.040 | 20K |
| 381 | T-13/4 | FSCMD | 6.30 | 0.200 | 20K | 2181 | T-13/4 | WT | 6.30 | 0.200 | 20K |
| 382 | T-13/4 | FSCMD | 14.00 | 0.080 | 15K | 2182 | T-13/4 | WT | 14.00 | 0.080 | 40K |
| 385 | T-13/4 | FSCMD | 28.00 | 0.040 | 10K | 2187 | T-13/4 | WT | 28.00 | 0.040 | 7K |
| 386 | T-13/4 | GMD | 14.00 | 0.080 | 15K | 2304 | T-13/4 | BP | 3.00 | 0.300 | 1.5K |
| 387 | T-13/4 | FSCMD | 28.00 | 0.040 | 7K | 2307 | T-13/4 | BP | 6.30 | 0.200 | 5K |
| 388 | T-13/4 | GMD | 28.00 | 0.040 | 7K | 2314 | T-13/4 | BP | 28.00 | 0.050 | 1K |
| 397 | T-13/4 | GMD | 10.00 | 0.040 | 5 K | 2316 | T-13/4 | BP | 18.00 | 0.040 | 10K |
| 398 | T-13/4 | GMD | 6.30 | 0.200 | 5 K | 2324 | T-13/4 | BP | 28.00 | 0.040 | 4K |
| 399 | T-13/4 | SMD | 28.00 | 0.040 | 7K | 2335 | T-13/4 | BP | 14.00 | 0.080 | 15K |
| 502 | G-41/2 | SMN | 5.10 | 0.150 | 100 | 2337 | T-13/4 | BP | 6.30 | 0.200 | 20K |
| 555 | T-31/4 | W | 6.30 | 0.250 | 3 K | 2342 | T-13/4 | BP | 28.00 | 0.040 | 25K |
| 656 | T-31/4 | W | 28.00 | 0.060 | 2.5 K | 3149 | T-13/4 | BP | 5.00 | 0.060 | 5K |
| 680AS15 | T-1 | WT | 5.00 | 0.060 | 60K | 6803AS25 | T-3/4 | WT | 5.00 | 0.060 | 60K |
| 682AS15 | T-1 | FSMD | 5.00 | 0.060 | 60K | 6833AS15 | T-3/4 | WT | 5.00 | 0.060 | 25K |
| 683AS15 | T-1 | WT | 5.00 | 0.060 | 25K | 6838 | T-1 | WT | 28.00 | 0.024 | 4K |
| 685AS15 | T-1 | FSMD | 5.00 | 0.060 | 25K | 6839 | T-1 | FSMD | 28.00 | 0.024 | 4K |
| 715AS15 | T-1 | WT | 5.00 | 0.115 | 40K | 7001 | T-13/4 | BP | 24.00 | 0.050 | 2 K |
| 715AS25 | T-1 | WT | 5.00 | 0.115 | 40K | 7003 | T-13/4 | BP | 24.00 | 0.050 | 2K |
| 718AS25 | T-1 | FSMD | 5.00 | 0.115 | 40K | $7153 A S 15$ | T-3/4 | WT | 5.00 | 0.115 | 40K |
| 755 | T-31/4 | BMN | 6.30 | 0.150 | 20K | 7265 | T-1 | BP | 5.00 | 0.060 | 5K |
| 756 | T-31/4 | BMN | 14.00 | 0.080 | 15K | 7327 | T-13/4 | BP | 28.00 | 0.040 | 4K |
| 757 | T-31/4 | BMN | 28.00 | 0.080 | 7.5K | 7328 | T-13/4 | BP | 6.00 | 0.200 | 1K |
| 1034 | S-8 | BIDC | 14.00 | 0.590 | 5 K | 7330 | T-13/4 | BP | 14.00 | 0.080 | 1.5K |
| 1073 | S-8 | BSC | 12.80 | 1.800 | 200 | 7344 | T-13/4 | BP | 10.00 | 0.014 | 50K |
| 1130 | S-8 | BDC | 6.40 | 2.630 | 200 | 7349 | T-13/4 | BP | 6.30 | 0.200 | 5K |
| 1133 | RP-11 | BSC | 6.20 | 3.910 | 200 | 7361 | T-13/4 | BP | 5.00 | 0.060 | 25K |
| 1141 | S-8 | BSC | 12.80 | 1.440 | 1 K | 7362 | T-13/4 | BP | 5.00 | 0.115 | 40K |
| 1143 | RP-11 | BSC | 12.50 | 1.980 | 400 | 7367 | T-13/4 | BP | 10.00 | 0.040 | 5K |
| 1184 | RP-11 | BDC | 5.50 | 6.250 | 100 | 7370 | T-13/4 | BP | 18.00 | 0.040 | 10K |
| 1251 | G-6 | BSC | 28.00 | 0.230 | 2K | 7371 | T-13/4 | BP | 12.00 | 0.040 | 10K |
| 1445 | G-31/2 | BMN | 14.40 | 0.130 | 2 K | 7373 | T-13/4 | BP | 14.00 | 0.100 | 10K |
| 1487 | T-31/4 | SMN | 14.00 | 0.200 | 3K | 7374 | T-13/4 | BP | 28.00 | 0.040 | 10K |
| 1488 | T-31/4 | BMN | 14.00 | 0.150 | 200 | 7375 | T-13/4 | BP | 3.00 | 0.015 | 10K |
| 1490 | T-31/4 | BMN | 3.20 | 0.160 | 3K | 7376 | T-13/4 | BP | 28.00 | 0.065 | 10K |
| 1493 | S-8 | BDC | 6.50 | 2.750 | 100 | 7377 | T-13/4 | BP | 6.30 | 0.075 | 1K |
| 1619 | S-8 | BSC | 6.70 | 1.900 | 500 | 7380 | T-13/4 | BP | 6.30 | 0.040 | 30K |
| 1630 | S-8 | PFDC | 6.50 | 2.750 | 100 | 7381 | T-13/4 | BP | 6.30 | 0.200 | 20K |
| 1691 | S-8 | BSC | 28.00 | 0.610 | 1K | 7382 | T-13/4 | BP | 14.00 | 0.080 | 15K |
| 1705 | T-13/4 | WT | 14.00 | 0.080 | 1.5 K | 7387 | T-13/4 | BP | 28.00 | 0.040 | 7K |
| 1728 | T-13/4 | WT | 1.35 | 0.060 | 3K | 7410 | T-13/4 | BP | 14.00 | 0.080 | 15K |
| 1730 | T-13/4 | WT | 6.00 | 0.040 | 20K | 7839 | T-1 | BP | 28.00 | 0.025 | 4K |
| 1738 | T-13/4 | WT | 2.70 | 0.060 | 6K | 7876 | T-13/4 | BP | 28.00 | 0.060 | 25K |
| 1762 | T-13/4 | WT | 28.00 | 0.040 | 4 K | 7931 | T-13/4 | BP | 1.35 | 0.060 | 3K |
| 1764 | T-13/4 | WT | 28.00 | 0.040 | 4 K | 7945 | T-13/4 | BP | 6.00 | 0.040 | 20K |
| 1767 | T-13/4 | SMD | 2.50 | 0.200 | 500 | 7968 | T-13/4 | BP | 2.50 | 0.200 | 500 |
| 1768 | T-13/4 | SMD | 6.00 | 0.200 | 1 K | 8099 | T-1 | BP | 18.00 | 0.020 | 16K |
| 1775 | T-13/4 | SMD | 6.30 | 0.075 | 1 K | 8362 | T-13/4 | SMD | 14.00 | 0.080 | 15K |
| 1813 | T-31/4 | BMN | 14.40 | 0.100 | 1K | 8369 | T-13/4 | SMD | 28.00 | 0.065 | 10K |
| 1815 | T-31/4 | BMN | 14.00 | 0.200 | 3 K |  |  |  |  |  |  |
| 1816 | T-31/4 | BMN | 13.00 | 0.330 | 1K |  |  |  |  |  |  |
| 1818 | T-31/4 | BMN | 24.00 | 0.170 | 250 |  |  |  |  |  |  |
| 1819 | T-31/4 | BMN | 28.00 | 0.040 | 2.5 K |  |  |  |  |  |  |
| 1820 | T-31/4 | BMN | 28.00 | 0.100 | 1 K |  |  |  |  |  |  |
| 1821 | T-31/4 | SMN | 28.00 | 0.170 | 500 |  |  |  |  |  |  |
| 1822 | T-31/4 | BMN | 36.00 | 0.100 | 1K |  |  |  |  |  |  |
| 1828 | T-31/4 | BMN | 37.50 | 0.050 | 3 K |  |  |  |  |  |  |
| 1829 | T-31/4 | BMN | 28.00 | 0.070 | 1 K |  |  |  |  |  |  |
| 1835 | T-31/4 | BMN | 55.00 | 0.050 | 5K |  |  |  |  |  |  |
| 1847 | T-31/4 | BMN | 6.30 | 0.150 | 5 K |  |  |  |  |  |  |
| 1850 | T-31/4 | BMN | 5.00 | 0.090 | 1.5K |  |  |  |  |  |  |
| 1864 | T-31/4 | BMN | 28.00 | 0.170 | 1.5K |  |  |  |  |  |  |

Standard Line-Voltage Lamps

| Type | V | W | Bulb | Base |
| :---: | :---: | :---: | :---: | :---: |
| 10C7DC | 115-125 | 10 | C-7 | BDC |
| 3S6 | 120, 125 | 3 | S-6 | SC |
| 6S6 | $\begin{array}{r} 30,48, \\ 115,120,125, \\ 130,135,145, \\ 155 \end{array}$ | 6 | S-6 | SC |
| 6S6/R | 115-125 | 6 | S-6 (red) | SC |
| 6S6/W | 115-125 | 6 | S-6 (white) | SC |
| 6T4-1/2 | 120, 130 | 6 | T-41/2 | SC |
| 7 C 7 | 115-125 | 7 | C-7 | SC |
| 7C7/W | 115-125 | 7 | $\mathrm{C}-7$ (white) | SC |
| 10C7 | 115-125 | 10 | C-7 | SC |
| $10 \mathrm{S6}$ | 120 | 10 | S-6 | SC |
| 10S6/10 | 220, 230, 250 | 10 | S-6 | SC |
| 6S6DC | $\begin{gathered} 30,120, \\ 125,145 \end{gathered}$ | 6 | S-6 | BDC |
| 10S6/10DC | - 230, 250 | 10 | S-6 | BDC |
| 40S11 N | 115-125 | 40 | S-11 | SI |
| 120MB | 120 | 3 | T-21/2 | BMN |
| 120MB/6 | 120 | 6 | T-21/2 | BMN |
| 120PSB | 120 | 3 | T-2 | SL |
| 120PS | 120 | 3 | T-2 | WT |
| 120PS/6 | 120 | 6 | T-21/2 | WT |

Indicator Lamps
Each has a T-2 bulb and a slide base.

| Type | $V$ | $A$ | Life |
| :--- | ---: | ---: | ---: |
| 6PSB | 6.00 | 0.140 | 20 K |
| 12PSB | 12.00 | 0.170 | 12 K |
| 24PSB | 24.00 | 0.073 | 10 K |
| 28PSB | 28.00 | 0.040 | 5 K |
| 48PSB | 48.00 | 0.050 | 10 K |
| 60PSB | 60.00 | 0.050 | 7.5 K |
| 120PSB | 120.00 | 0.025 | 7.5 K |

## Neon Glow Lamps

Operating circuit voltage 105-125
Breakdown Voltage

| Breakdown Voltage |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Type | AC | $D C$ | Bulb | Base | W | External Resistance |
| NE-2 | 65 | 90 | T-2 | WT | 1/12 | 150k |
| NE-2A | 65 | 90 | T-2 | WT | 1/15 | 100k |
| NE-2D | 65 | 90 | T-2 | FSCMD | 1/12 | 100k |
| NE-2E | 65 | 90 | T-2 | WT | 1/12 | 100k |
| NE-2H | 95 | 135 | T-2 | WT | 1/4 | 30k |
| NE-2J | 95 | 135 | T-2 | FSCMD | $1 / 4$ | 30k |
| NE-2V | 65 | 90 | T-2 | WT | $1 / 2$ | 100k |
| NE-45 | 65 | 90 | T-41/2 | SC | 1/4 | None |
| NE-51 | 65 | 90 | T-31/4 | BMN | $1 / 25$ | 220k |
| NE-51H | 95 | 135 | T-31/4 | BMN | $1 / 7$ | 47k |
| NE-84 | 95 | 135 | T-2 | SL | $1 / 4$ | 30k |
| NE-120PSB | 95 | 95 | T-2 | SL | $1 / 4$ | None |

Table 7.21
Metal-Oxide Varistor (MOV) Transient Suppressors
Listed by voltage

|  |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  |  |  | Maximum <br> Applied <br> Voltage | Maximum <br> Energy <br> (Joules) | Maximum <br> Peak <br> Current <br> (A) | Maximum | Maximum <br> Vawistor |
| (W) |  |  |  |  |  |  |  |

†tECG 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 7.22
Voltage-Variable Capacitance Diodes ${ }^{\dagger}$
Listed numerically by device

|  | Nominal Capacitance |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | pF | Capacitance | $Q$ |  |  | pF | Capacitance | $Q$ |  |
|  | $\pm 10 \%$ @ | Ratio | @ 4.0 V |  |  | $\pm 10 \%$ @ | Ratio | @ 4.0 V |  |
|  | $V_{R}=4.0 \mathrm{~V}$ | 2-30 V | 50 MHz | Case |  | $V_{R}=4.0 \mathrm{~V}$ | 2-30 V | 50 MHz | Case |
| Device | $f=1.0 \mathrm{MHz}$ | Min. | Min. | Style | Device | $f=1.0 \mathrm{MHz}$ | Min. | Min. | Style |
| 1N5441A | 6.8 | 2.5 | 450 |  | 1N5471A | 39 | 2.9 | 450 |  |
| 1N5442A | 8.2 | 2.5 | 450 |  | 1N5472A | 47 | 2.9 | 400 |  |
| 1N5443A | 10 | 2.6 | 400 | DO-7 | 1N5473A | 56 | 2.9 | 300 | DO-7 |
| 1N5444A | 12 | 2.6 | 400 |  | 1N5474A | 68 | 2.9 | 250 |  |
| 1N5445A | 15 | 2.6 | 450 |  | 1N5475A | 82 | 2.9 | 225 |  |
| 1N5446A | 18 | 2.6 | 350 |  | 1N5476A | 100 | 2.9 | 200 |  |
| 1N5447A | 20 | 2.6 | 350 |  | MV2101 | 6.8 | 2.5 | 450 | TO-92 |
| 1N5448A | 22 | 2.6 | 350 | DO-7 | MV2102 | 8.2 | 2.5 | 450 |  |
| 1N5449A | 27 | 2.6 | 350 |  | MV2103 | 10 | 2.0 | 400 |  |
| 1N5450A | 33 | 2.6 | 350 |  | MV2104 | 12 | 2.5 | 400 |  |
| 1N5451A | 39 | 2.6 | 300 |  | MV2105 | 15 | 2.5 | 400 |  |
| 1N5452A | 47 | 2.6 | 250 |  | MV2106 | 18 | 2.5 | 350 | TO-92 |
| 1N5453A | 56 | 2.6 | 200 | DO-7 | MV2107 | 22 | 2.5 | 350 |  |
| 1N5454A | 68 | 2.7 | 175 |  | MV2108 | 27 | 2.5 | 300 |  |
| 1N5455A | 82 | 2.7 | 175 |  | MV2109 | 33 | 2.5 | 200 |  |
| 1N5456A | 100 | 2.7 | 175 |  | MV2110 | 39 | 2.5 | 150 |  |
| 1N5461A | 6.8 | 2.7 | 600 |  | MV2111 | 47 | 2.5 | 150 | TO-92 |
| 1N5462A | 8.2 | 2.8 | 600 |  | MV2112 | 56 | 2.6 | 150 |  |
| 1N5463A | 10 | 2.8 | 550 | DO-7 | MV2113 | 68 | 2.6 | 150 |  |
| 1N5464A | 12 | 2.8 | 550 |  | MV2114 | 82 | 2.6 | 100 |  |
| 1N5465A | 15 | 2.8 | 550 |  | MV2115 | 100 | 2.6 | 100 |  |
| 1N5466A | 18 | 2.8 | 500 |  |  |  |  |  |  |
| 1N5467A | 20 | 2.9 | 500 |  | ${ }^{\dagger}$ For pack | shape, size an | pin-connection | formation |  |
| 1N5468A | 22 | 2.9 | 500 | DO-7 | manufac | ers' data sheet | pin-connection |  |  |
| 1N5469A | 27 | 2.9 | 500 |  |  |  |  |  |  |
| 1N5470A | 33 | 2.9 | 500 |  |  |  |  |  |  |

Table 7.23

## Zener Diodes




### 7.16 Chapter 7



Table 7.24

## Semiconductor Diode Specifications ${ }^{\dagger}$

Listed numerically by device

| Device | Type | Material | Peak <br> Inverse Voltage, PIV <br> (V) | Average Rectified Current Forward (Reverse) $I_{O}(A)\left(I_{R}(A)\right)$ | Peak Surge Current, I I ${ }_{\text {FSM }}$ $1 s @ 25^{\circ} \mathrm{C}$ <br> (A) | Average <br> Forward Voltage, $V_{F}$ (V) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1N34 | Signal | Ge | 60 | $8.5 \mathrm{~m}(15.0 \mu)$ |  | 1.0 |
| 1N34A | Signal | Ge | 60 | $5.0 \mathrm{~m}(30.0 \mu)$ |  | 1.0 |
| 1N67A | Signal | Ge | 100 | $4.0 \mathrm{~m}(5.0 \mu)$ |  | 1.0 |
| 1N191 | Signal | Ge | 90 | 15.0 m |  | 1.0 |
| 1N270 | Signal | Ge | 80 | 0.2 (100 $\mu$ ) |  | 1.0 |
| 1 N914 | 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 $\mu$ ) |  | 0.6 |
| 1N3666 | Signal | Ge | 80 | $0.2(25.0 \mu)$ |  | 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 $\mu$ ) |  | 0.8 |
| 1N4445 | Signal | Si | 100 | 0.1 (50.0 n) |  | 1.0 |
| 1N5400 | RFR | Si | 50 | 3.0 (500 $\mu$ ) | 200 |  |
| 1N5401 | RFR | Si | 100 | 3.0 (500 $\mu$ ) | 200 |  |
| 1N5402 | RFR | Si | 200 | 3.0 (500 $\mu$ ) | 200 |  |
| 1N5403 | RFR | Si | 300 | 3.0 (500 $\mu$ ) | 200 |  |
| 1N5404 | RFR | Si | 400 | 3.0 (500 $\mu$ ) | 200 |  |
| 1N5405 | RFR | Si | 500 | 3.0 (500 $\mu$ ) | 200 |  |
| 1N5406 | RFR | Si | 600 | 3.0 (500 $\mu$ ) | 200 |  |
| 1N5408 | RFR | Si | 1000 | 3.0 (500 $\mu$ ) | 200 |  |
| 1N5711 | Schottky | Si | 70 | 1 m (200 n) | 15 m | 0.41 @ 1 mA |
| 1 N5767 | Signal | Si |  | $0.1(1.0 \mu)$ |  | 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.
${ }^{\dagger}$ 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 7.25
Suggested Small-Signal FETs


Notes:
${ }^{125} 5^{\circ} \mathrm{C}$.
For package shape, size and pin-connection information, see manufacturers' data sheets.

(1)

(2)

(3)

(4)

(5)

(6)

(7)

Table 7.26
Low-Noise Transistors

| Device | NF (dB) | $F(M H z)$ | $f_{T}(G H z)$ | $I_{C}(m A)$ | Gain (dB) | $F(M H z)$ | $V_{(B R) C E O}(V)$ | $I_{C}(m A)$ | $P_{T}(m W)$ | 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 | $2 N 4957$ |
| 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.


TO-226AA


TO-206AF
TO-206AF



Macro-X (Top)


Table 7.27
Monolithic Amplifiers (50 $\Omega$ )
Mini-Circuits Labs MMICs

| Device | Freq Range (MHz) | $\begin{aligned} & \text { Gain (dB) at } \\ & 1000 \mathrm{MHz} \end{aligned}$ | Output Level 1 dB Comp (dBm) | $N F(d B)$ | $I_{\text {max }}(m A)$ | $P_{\text {max }}(m W)$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ERA-1 | dc - 8000 | 12.1 | +12.0 | 4.3 | 75 | 330 |
| ERA-2 | dc - 6000 | 15.8 | +13.0 | 4.0 | 75 | 330 |
| ERA-3 | dc - 3000 | 21.0 | +12.5 | 3.5 | 75 | 330 |
| ERA-4 | dc - 4000 | 14.0 | +17.3 | 4.2 | 120 | 650 |
| ERA-5 | dc - 4000 | 19.5 | +18.4 | 4.3 | 120 | 650 |
| ERA-6 | dc - 4000 | 12.5 | +17.9 | 4.5 | 12 | 650 |
| GAL-1 | dc - 8000 | 12.5 | +12.2 | 4.5 | 55 | 225 |
| GAL-2 | dc - 8000 | 15.8 | +12.9 | 4.6 | 55 | 225 |
| GAL-3 | dc - 8000 | 21.1 | +12.5 | 3.5 | 55 | 225 |
| GAL-4 | dc - 8000 | 14.1 | +17.5 | 4.0 | 85 | 475 |
| GAL-5 | dc - 8000 | 19.4 | +18.0 | 3.5 | 85 | 475 |
| GAL-6 | dc - 8000 | 12.2 | +18.2 | 4.5 | 85 | 475 |
| GAL-21 | dc - 8000 | 13.9 | +12.6 | 4.0 | 55 | 225 |
| GAL-33 | dc - 8000 | 18.7 | +13.4 | 3.9 | 55 | 265 |
| GAL-51 | dc - 8000 | 17.5 | +18.0 | 3.5 | 85 | 475 |
| HELA-10B | 50-1000 | 12.0 | +30.0 | 3.5 | 525 | 7150 |
| HELA-10D | 8-300 | 11.0 | +30.0 | 3.5 | 525 | 7150 |
| MAR-1 | dc - 1000 | 15.5 | +1.5 | 5.5 | 40 | 200 |
| MAR-2 | dc - 2000 | 12.0 | +4.5 | 6.5 | 60 | 325 |
| MAR-3 | dc - 2000 | 12.0 | +10.0 | 6.0 | 70 | 400 |
| MAR-4 | dc - 1000 | 8.0 | +12.5 | 6.5 | 85 | 500 |
| MAR-6 | dc - 2000 | 16.0 | +2.0 | 3.0 | 50 | 200 |
| MAR-7 | dc - 2000 | 12.5 | +5.5 | 5.0 | 60 | 275 |
| MAR-8 | dc - 1000 | 22.5 | +12.5 | 3.3 | 65 | 500 |
| MAV-1 | dc - 1000 | 15.0 | +1.5 | 5.5 | 40 | 200 |
| MAV-2 | dc - 1500 | 11.0 | +4.5 | 6.5 | 60 | 325 |
| MAV-3 | dc - 1500 | 11.0 | +10.0 | 6.0 | 70 | 400 |
| MAV-4 | dc - 1000 | 7.5 | +11.5 | 7.0 | 85 | 500 |
| MAV-11 | dc - 1000 | 10.5 | +17.5 | 3.6 | 80 | 550 |
| RAM-1 | dc - 1000 | 15.5 | +1.5 | 5.5 | 40 | 200 |
| RAM-2 | dc - 2000 | 11.8 | +4.5 | 6.5 | 60 | 325 |
| RAM-3 | dc - 2000 | 12.0 | +10.0 | 6.0 | 80 | 425 |
| RAM-4 | dc - 1000 | 8.0 | +12.5 | 6.5 | 100 | 540 |
| RAM-6 | dc - 2000 | 16.0 | +2.0 | 2.8 | 50 | 200 |
| RAM-7 | dc - 2000 | 12.5 | +5.5 | 4.5 | 60 | 275 |
| RAM-8 | dc - 1000 | 23.0 | +12.5 | 3.0 | 65 | 420 |
| VAM-3 | dc - 2000 | 11.0 | +9.0 | 6.0 | 60 | 240 |
| VAM-6 | dc - 2000 | 15.0 | +2.0 | 3.0 | 40 | 125 |
| VAM-7 | dc - 2000 | 12.0 | +5.5 | 5.0 | 50 | 175 |
| VNA-25 | 500-2500 | 18.0 | +18.2 | 5.5 | 105 | 1000 |

Mini-circuits Labs Web site: www.minicircuits.com/.

## Avago Technologies MMICs

| Device | Freq Range (MHz) | Typical Gain (dB) | Output Level 1 dB Comp (dBm) | $N F(d B)$ | $I_{\text {max }}(m A)$ | $\begin{aligned} & P_{\max } \\ & (m W) \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| MGA-725M4 | 100-6000 | 17.6 | +13.1 | 1.2 | 80 | 250 |
| MGA-86576 | 1.5-8000 | 23.0 | +6.3 | 2.0 | 16 | - |
| MSA-02xx | dc - 2800 | 12.5 | +4.5 | 6.5 | 60 | 325 |
| MSA-03xx | dc - 2800 | 12.5 | +10.0 | 6.0 | 80 | 425 |
| MSA-04xx | dc - 4000 | 8.3 | +11.5 | 7.0 | 85 | 500 |
| MSA-05xx | dc- 2800 | 7.0 | +19.0 | 6.5 | 135 | 1.5 |
| MSA-06xx | dc - 800 | 19.5 | +2.0 | 3.0 | 50 | 200 |
| MSA-07xx | dc - 2500 | 13.0 | +5.5 | 4.5 | 50 | 175 |
| MSA-08xx | dc - 6000 | 32.5 | +12.5 | 3.0 | 65 | 500 |
| MSA-09xx | dc - 6000 | 7.2 | +10.5 | 6.2 | 65 | 500 |
| MSA-11xx | 50-1300 | 12.0 | +17.5 | 3.6 | 80 | 550 |

Avago Web site: www.avagotech.com.

## Motorola Hybrid Amplifiers (50 $\Omega$ )

| Device type | Freq Range (MHz) | Gain (dB) $\min / t y p$ | Supply Voltage <br> (V) | Output Level, <br> 1 dB Comp (dBm) | $\begin{aligned} & N F \text { at } 250 \mathrm{MHz} \\ & \text { (dB) } \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| MWA110 | 0.1-400 | 13/14 | 2.9 | -2.5 | 4.0 |
| MWA120 | 0.1-400 | 13/14 | 5 | +8.2 | 5.5 |
| MWA130 | 0.1-400 | 13/14 | 5.5 | +18.0 | 7.0 |
| MWA131 | 0.1-400 | 13/14 | 5.5 | +20.0 | 5.0 |
| MWA210 | 0.1-600 | 9/10 | 1.75 | +1.5 | 6.0 |
| MWA220 | 0.1-600 | 9/10 | 3.2 | +10.5 | 6.5 |
| MWA230 | 0.1-600 | 9/10 | 4.4 | +18.5 | 7.5 |
| MWA310 | 0.1-1000 | 7/8 | 1.6 | +3.5 | 6.5 |
| MWA320 | 0.1-1000 | 7/8 | 2.9 | +11.5 | 6.7 |
| MWA330 | 0.1-1000 | na/6.2 | 4 | +15.2 | 9.0 |

Note: Motorola no longer manufactures these modules but they may be available from distributors.

Table 7.28

## General-Purpose Transistors

Listed numerically by device


Table 7.29
RF Power Amplifier Modules
Listed by frequency

| Device | Supply (V) | Frequency Range (MHz) | Output Power <br> (W) | Power Gain (dB) | Package ${ }^{\dagger}$ | 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 | MO; class C |
| BGY35 | 12.5 | 132-156 | 18 | 20.8 | SOT132B | P |
| 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 | MO; class C |
| MHW720-2 | 12.5 | 440-470 | 20 | 21 | 700-04/1 | MO; class C |
| M57789 | 17 | 890-915 | 12 | 33.8 | H3B | MI |
| MHW912 | 12.5 | 880-915 | 12 | 40.8 | 301R-01/1 | MO; class AB |
| MHW820-3 | 12.5 | 870-950 | 18 | 17.1 | 301G-03/1 | MO; class C |

Manufacturer codes: $\mathrm{MO}=$ Motorola; $\mathrm{MI}=$ Mitsubishi; $\mathrm{P}=$ Philips; $\mathrm{T}=$ Toshiba .
${ }^{\dagger}$ 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 7.30
General Purpose Silicon Power Transistors
TO-220 Case, Pin 1=Base, Pin 2, Case = Collector; Pin 3 = Emitter TO-204 Case (TO-3), Pin 1=Base, Pin $2=$ Emitter, Case = Collector;

| NPN PNP | $\begin{aligned} & I^{\prime} C \\ & \operatorname{Max}(A) \end{aligned}$ | $\begin{aligned} & V_{C E O} \\ & \operatorname{Max}(V) \end{aligned}$ | $h_{\text {FE }}$ Min | $F_{T}$ (MHz) | Power <br> Dissipation <br> (W) | $\begin{aligned} & \text { NPN } \quad \text { PNP } \\ & \text { tion } \end{aligned}$ | ${ }^{\prime} C$ | $V_{\text {CEO }}$ |  | $F_{T}$ | Power Dissipa- |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| D44C8 | 4 | 60 | 100/220 | 50 | 30 | 2N3055A | May (A) | M ${ }_{80}$ (V) |  | (0.8Hz) | 146 |
| D45C8 | 4 | 60 | 40/120 | 50 | 30 | 2N3055 | 15 | 60 | 20/70 | 2.5 | 115 |
| TIP29 | 1 | 40 | 15/75 | 3 | 30 | MJ2955 | 15 | 60 | 20/70 | 2.5 | 115 |
| TIP30 | 1 | 40 | 15/75 | 3 | 30 | 2N6545 | 8 | 400 | 7/35 | 6 | 125 |
| TIP29A | 1 | 50 | 15/75 | 3 | 30 | 2N5039 | 20 | 75 | 20/100 | - | 140 |
| TIP30A | 1 | 60 | 15/75 | 3 | 30 | 2N3771 | 30 | 40 | 15 | 0.2 | 150 |
| TIP29B | 1 | 80 | 15/75 | 3 | 30 | 2N3789 | 10 | 60 | 15 | 4 | 150 |
| TIP29C | 1 | 100 | 15/75 | 3 | 30 | 2N3715 | 10 | 60 | 30 | 4 | 150 |
| TIP30C | 1 | 100 | 15/75 | 3 | 30 | 2N3791 | 10 | 60 | 30 | 4 | 150 |
| TIP47 | 1 | 250 | 30/150 | 10 | 40 | 2N5875 | 10 | 60 | 20/100 | 4 | 150 |
| TIP48 | 1 | 300 | 30/150 | 10 | 40 | 2N3790 | 10 | 80 | 15 | 4 | 150 |
| TIP49 | 1 | 350 | 30/150 | 10 | 40 | 2N3716 | 10 | 80 | 30 | 4 | 150 |
| TIP50 | 1 | 400 | 30/150 | 10 | 40 | 2N3792 | 10 | 80 | 30 | 4 | 150 |
| TIP110* | 2 | 60 | 500 | > 5 | 50 | 2N3773 | 16 | 140 | 15/60 | 4 | 150 |
| TIP115 * | 2 | 60 | 500 | > 5 | 50 | 2N6284 | 20 | 100 | 750/18K | - | 160 |
| TIP116 | 2 | 80 | 500 | 25 | 50 | 2N6287 | 20 | 100 | 750/18K | - | 160 |
| TIP31 | 3 | 40 | 25 | 3 | 40 | 2N5881 | 15 | 60 | 20/100 | 4 | 160 |
| TIP32 | 3 | 40 | 25 | 3 | 40 | 2N5880 | 15 | 80 | 20/100 | 4 | 160 |
| TIP31A | 3 | 60 | 25 | 3 | 40 | 2N6249 | 15 | 200 | 10/50 | 2.5 | 175 |
| TIP32A | 3 | 60 | 25 | 3 | 40 | 2N6250 | 15 | 275 | 8/50 | 2.5 | 175 |
| TIP31B | 3 | 80 | 25 | 3 | 40 | 2N6546 | 15 | 300 | 6/30 | 6-28 | 175 |
| TIP32B | 3 | 80 | 25 | 3 | 40 | 2N6251 | 15 | 350 | 6/50 | 2.5 | 175 |
| TIP31C | 3 | 100 | 25 | 3 | 40 | 2N5630 | 16 | 120 | 20/80 | 1 | 200 |
| TIP32C | 3 | 100 | 25 | 3 | 40 | 2N5301 | 30 | 40 | 15/60 | 2 | 200 |
| 2N6124 | 4 | 45 | 25/100 | 2.5 | 40 | 2N5303 | 20 | 80 | 15/60 | 2 | 200 |
| 2N6122 | 4 | 60 | 25/100 | 2.5 | 40 | 2N5885 | 25 | 60 | 20/100 | 4 | 200 |
| MJE1300 | 4 | 300 | 6/30 | 4 | 60 | 2N5302 | 30 | 60 | 15/60 | 2 | 200 |
| TIP120* | 5 | 60 | 1000 | > 5 | 65 | 2N4399 | 30 | 60 | 15/60 | 4 | 200 |
| TIP125 * | 5 | 60 | 1000 | $>10$ | 65 | 2N5886 | 25 | 80 | 20/100 | 4 | 200 |
| TIP42 | 6 | 40 | 15/75 | 3 | 65 | 2N5884 | 25 | 80 | 20/100 | 4 | 200 |
| TIP41A | 6 | 60 | 15/75 | 3 | 65 | MJ802 | 30 | 100 | 25/100 |  | 200 |
| TIP41B | 6 | 80 | 15/75 | 3 | 65 | MJ4502 | 30 | 100 | 25/100 | 2 | 200 |
| 2N6290 | 7 | 50 | 30/150 | 4 | 40 | MJ15003 | 20 | 140 | 25/150 | 2 | 250 |
| 2N6109 |  | 50 | 30/150 | 4 | 40 | MJI5004 | 20 | 140 | 25/150 | 2 | 250 |
| 2N6292 | 7 | 70 | 30/150 | 4 | 40 | MJ15024 | 25 | 250 | 15/60 | 4 | 250 |
| 2N6107 | 7 | 70 | 30/150 | 4 | 40 |  |  |  |  |  |  |
| MJE3055T | 10 | 50 | 20/70 | 2 | 75 | = Compl | imentary p | pairs |  |  |  |
| MJE2955T | 10 | 60 | 20/70 | 2 | 75 | * = Darlington tran | sistor |  |  |  |  |
| 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 |  |  |  |  |  |  |

Useful URLs for finding transistor/IC data sheets:

1. General-purpose substitution URL: www.nteinc.com
2. Philips semiconductors: www.semiconductors.philips.com
3. Mitsubishi: www.mitsubishichips.com
4. Motorola: www.freescale.com
5. STMicroelectronics: www.st.com
6. Toshiba: www.semicon.toshiba.co.jp/eng

Table 7.31
RF Power Transistors


| Device | Outpu Power (W) | Input Power (W) | Gain <br> (dB) | Typ Supply Voltage (V) | Case | Mfr |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 2SC2932 | 6 |  | 7.8 | 12.5 | T-31 B | MI |
| SD1398 | 6 | 0.6 | 10 | 24 | M142 | ST |
| 2SC2933 | 14 | 3 | 6.7 | 12.5 | T-31 B | MI |
| SD1400-03 | 14 | 1.6 | 9.5 | 24 | M118 | ST |
| MRF873 | 15 | 3 | 7 | 12.5 | 319-06/2 | MO |
| SD1495-03 | 30 | 6 | 7 | 24 | M142 | ST |
| SD1424 | 30 | 5.3 | 7.5 | 24 | M156 | ST |
| MRF897 | 30 | 3 | 10 | 24 | 395B-01/1 | MO |
| MRF847 | 45 | 16 | 4.5 | 12.5 | 319-06/1 | MO |
| BLV101A | 50 |  | 8.5 | 26 | SOT273 | PH |
| SD1496-03 | 55 | 10 | 7.4 | 24 | M142 | ST |
| MRF898 | 60 | 12 | 7 | 24 | 333A-02/1 | MO |
| MRF880 | 90 | 12.7 | 8.5 | 26 | 375A-01/1 | MO |
| MRF899 | 150 | 24 | 8 | 26 | 375A-01/1 | MO |

## Manufacturer codes:

MI = Mitsubishi; MO = Motorola; PH Philips;
ST = STMicroelectronics
There is a bewildering variety of package types, sizes and pin-out connections. (For example, for the 137 different transistors in this table there are 54 different packages.) See the data sheets on each manufacturer's Web pages for details.

Mitsubishi: www.mitsubishichips.com
Motorola: www.freescale.com
Philips semiconductors: www.semiconductors.philips.com STMicroelectronics: www.st.com

Table 7.32
RF Power Transistors Recommended for New Designs

| Device | Output <br> Power <br> (W) | Type | Gain $(d B)$ | Typ Sup Voltage (V) | Case | Mfr | Device | Output Power (W) | Type | $\begin{aligned} & \text { Gain } \\ & (d B) \end{aligned}$ | Typ Sup Voltage (V) | Case | Mf |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1.5 to $\mathbf{3 0} \mathrm{MHz}$, HF SSB/CW |  |  |  |  |  |  | VHF to 470 MHz |  |  |  |  |  |  |
| MRF171A | 30 | MOS | 20 | 28 | 211-07/2 | MO | BLT50 | 1.2 | BJT | 10 | 7.5 | SOT223 | PH |
| BLF145 | 30 | MOS | 24 | 28 | SOT123A | PH | SD2900 | 5 | MOS | 13.5 | 28 | M113 | ST |
| MRF148A | 30 | MOS | 18 | 50 | 211-07/2 | MO | SD1433 | 10 | BJT | 7 | 12.5 | M122 | ST |
| SD2918 | 30 | MOS | 18 | 50 | M113 | ST | SD2902 | 15 | MOS | 12.5 | 28 | M113 | ST |
| SD1405 | 75 | BJT | 13 | 12.5 | M174 | ST | SD2904 | 30 | MOS | 10 | 28 | M113 | ST |
| SD1733 | 75 | BJT | 14 | 50 | M135 | ST | SD2903 | 30 | MOS | 13 | 28 | M229 | ST |
| SD1487 | 100 | BJT | 11 | 12.5 | M174 | ST | SD1488 | 38 | BJT | 5.8 | 12.5 | M111 | ST |
| SD1407 | 125 | BJT | 15 | 28 | M174 | ST | SD1434 | 45 | BJT | 5 | 12.5 | M111 | ST |
| SD1729 | 130 | BJT | 12 | 28 | M174 | ST | MRF392 | 125 | BJT | 8 | 28 | 744A-01/1 | MO |
| BLF147 | 150 | MOS | 17 | 28 | SOT121B | PH | SD2921 | 150 | MOS | 12.5 | 50 | M174 | ST |
| BLF177 | 150 | MOS | 20 | 50 | SOT121B | PH | VHF to 512 MHz |  |  |  |  |  |  |
| BLF175 | 150 | MOS | 24 | 50 | SOT123A | PH |  |  |  |  |  |  |  |
| SD1726 | 150 | BJT | 14 | 50 | M174 | ST | BLF521 | 2 | MOS | 10 | 12.5 | SOT172D | PH |
| SD1727 | 150 | BJT | 14 | 50 | M164 | ST | MRF158 | 2 | MOS | 17.5 | 28 | 305A-01/2 | MO |
| MRF150 | 150 | MOS | 17 | 50 | 211-07/2 | MO | MRF160 |  | MOS | 17 | 28 | 249-06/3 | MO |
| SD1411 | 200 | BJT | 16 | 40 | M153 | ST | BLF542 | 5 | MOS | 13 | 28 | SOT171A | PH |
| SD1730 | 220 | BJT | 12 | 28 | M174 | ST | VLF544 | 20 | MOS | 11 | 28 | SOT171A | PH |
| SD1731 | 220 | BJT | 13 | 50 | M174 | ST | MRF166C | 20 | MOS | 16 | 28 | 319-07/3 | MO |
| SD1728 | 250 | BJT | 14.5 | 50 | M177 | ST | MRF166W | 40 | MOS | 14 | 28 | 412-01/1 | MO |
| SD2923 | 300 | MOS | 16 | 50 | M177 | ST | BLF546 | 80 | MOS | 11 | 28 | SOT268A | PH |
| SD2933 | 300 | MOS | 18 | 50 | M177 | ST | MRF393 | 100 | BJT | 7.5 | 28 | 744A-01/1 | MO |
| MRF154 | 600 | MOS | 17 | 50 | 368-03/2 | MO | MRF275L | 100 | MOS | 8.8 | 28 | 333-04/2 | MO |
| 50 to 175 MHz |  |  |  |  |  |  | BLF548 | 150 | MOS | 10 | 28 | SOT262A | PH |
|  |  |  |  |  |  |  | MRF275G | 150 | MOS | 10 | 28 | 375-04/2 | MO |
| BLF202 | 2 | MOS | 10 | 12.5 | SOT409A | PH | UHF to 960 MHz |  |  |  |  |  |  |
| BLF242 | 5 | MOS | 13 | 28 | SOT123A | PH |  |  |  |  |  |  |  |
| SD1274 | 30 | BJT | 10 | 13.6 | M135 | ST | BLT70 | 0.6 | BJT | 6 | 4.8 | SOT223 | PH |
| BLF245 | 30 | MOS | 13 | 28 | SOT123 | PH | BLT80 | 0.6 | BJT | 6 | 7.5 | SOT223 | PH |
| SD1275 | 40 | BJT | 9 | 13.6 | M135 | ST | BLT71/8 | 1.2 | BJT | 6 | 4.8 | SOT223 | PH |
| BLF246B | 60 | MOS | 14 | 28 | SOT161A | PH | BLT81 | 1.2 | BJT | 6 | 7.5 | SOT223 | PH |
| SD1477 | 100 | BJT | 6 | 12.5 | M111 | ST | BLF1043 | 10 | MOS | 16 | 26 | SOT538A | PH |
| SD1480 | 100 | BJT | 9.2 | 28 | M111 | ST | BLF1046 | 45 | MOS | 14 | 26 | SOT467C | PH |
| SD2921 | 150 | MOS | 12.5 | 50 | M174 | ST | BLF1047 | 70 | MOS | 14 | 26 | SOT541A | PH |
| MRF141 | 150 | MOS | 13 | 28 | 211-11/2 | MO | BLF1048 | 90 | MOS | 14 | 26 | SOT502A | PH |
| MRF151 | 150 | MOS | 13 | 50 | 211-11/2 | MO |  |  |  |  |  |  |  |
| SD2931 | 150 | MOS | 14 | 50 | M174 | ST | Notes: <br> Manufacturer codes: $\mathrm{MI}=$ Mitsubishi; $\mathrm{MO}=$ Motorola; <br> PH = Philips; ST = STMicroelectronics |  |  |  |  |  |  |
| BLF248 | 300 | MOS | 10 | 28 | SOT262 | PH |  |  |  |  |  |  |  |
| SD2932 | 300 | MOS | 15 | 50 | M244 | ST |  |  |  |  |  |  |  |
| VHF to 220 MHz |  |  |  |  |  |  | There is a bewildering variety of package types, sizes and pinout connections. (For example, for the 71 different transistors in |  |  |  |  |  |  |
| MRF134 | 5 | MOS | 10.6 | 28 | 211-07/2 | MO |  |  |  |  |  |  |  |
| MRF136 | 15 | MOS | 16 | 28 | 211-07/2 | MO | this table there are 35 different packages.) See the data sheets on each manufacturer's Web pages for details. |  |  |  |  |  |  |
| MRF173 | 80 | MOS | 13 | 28 | 211-11/2 | MO |  |  |  |  |  |  |  |
| MRF174 | 125 | MOS | 11.8 | 28 | 211-11/2 | MO | Mitsubishi: www.mitsubishichips.com <br> Motorola: www.freescale.com <br> Philips semiconductors: www.semiconductors.philips.com <br> STMicroelectronics: www.st.com |  |  |  |  |  |  |
| BLF278 | 250 | MOS | 14 | 50 | SOT261A1 | PH |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Table 7.33
Power FETs

| Device | Type | $V D S S$ min (V) | RDS(on) max ( $\Omega$ ) | ID max (A) | PD max (W) | Caset | Mfr |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| BS250P | P-channel | 45 | 14 | 0.23 | 0.7 | E-line | Z |
| IRFZ30 | N -channel | 50 | 0.050 | 30 | 75 | TO-220 | IR |
| MTP50N05E | N -channel | 50 | 0.028 | 25 | 150 | TO-220AB | M |
| 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 | M |
| MTP2955E | P-channel | 60 | 0.3 | 6 | 25 | TO-220AB | M |
| IRF531 | N -channel | 60 | 0.180 | 14 | 75 | TO-220AB | M |
| MTP23P06 | P-channel | 60 | 0.12 | 11.5 | 125 | TO-220AB | M |
| IRFZ44 | N -channel | 60 | 0.028 | 50 | 150 | TO-220 | 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 | M |
| IRF520 | N -channel | 100 | 0.27 | 5 | 40 | TO-220AB | M |
| IRF150 | N -channel | 100 | 0.055 | 40 | 150 | TO-204AE | M |
| 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 | M |
| MTP6P20E | P-channel | 200 | 1 | 3 | 75 | TO-220AB | M |
| IRF220 | N -channel | 200 | 0.400 | 8 | 75 | TO-220AB | M |
| IRF640 | N -channel | 200 | 0.18 | 10 | 125 | TO-220AB | M |

Manufacturers: $I R=$ International Rectifier; $M=$ Motorola; $S=$ Siliconix; $Z=$ Zetex.
${ }^{\dagger}$ 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 7.34

## Logic IC Families

|  |  |  |  | Power |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Propagation Delay for $C_{L}=50$ pF Max Clock |  |  | Dissipation | Output |  |  |  |  |  |
|  | (ns) |  | Frequency | @ 1 MHz | @ 0.5 V | Current | Threshold | Supply | Voltage |  |
| Type | Typ | Max | (MHz) | (mW/gate) | $\max (m A)$ | (Max mA) | 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 |
| $\begin{gathered} 4000 \mathrm{~B} / 74 \mathrm{C} \\ (10 \mathrm{~V}) \end{gathered}$ | 30 | 60 | 5 | 1.2 | 1.3 | 0 | $\mathrm{V}+$ /2 | 3 | 5-15 | 18 |
| $\begin{aligned} & 4000 \mathrm{~B} / 74 \mathrm{C} \\ & (5 \mathrm{~V}) \end{aligned}$ | 50 | 90 | 2 | 3.3 | 0.5 | 0 | $\mathrm{V}+$ /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 |

[^0]Table 7.35
Three-Terminal Voltage Regulators

| Listed numerically by device |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Device | Description | Package | Voltage | Current (Amps) | Device | Description | Package | Voltage | Current <br> (Amps) |
| 317 | Adj Pos | TO-205 | +1.2 to +37 | 0.5 | 78TXX |  | TO-204 |  | 3.0 |
| 317 | Adj Pos | TO-204,TO-220 | +1.2 to +37 | 1.5 | 79XX | Fixed Neg | TO-204,TO-220 | Note 1 | 1.0 |
| 317L | Low Current Adj Pos | TO-205,TO-92 | +1.2 to +37 | 0.1 | $\begin{aligned} & \text { 79LXX } \\ & \text { 79MXX } \end{aligned}$ |  | $\begin{aligned} & \text { TO-205,TO-92 } \\ & \text { TO-220 } \end{aligned}$ |  | $\begin{aligned} & 0.1 \\ & 0.5 \end{aligned}$ |
| 317M | Med Current Adj Pos | TO-220 | +1.2 to +37 | 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 $15-\mathrm{V}$ regulator, and a 7924 is a negative $24-\mathrm{V}$ regulator. |  |  |  |  |
| 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 | The regulator package may be denoted by an additional suffix, according to the following: |  |  |  |  |
| 337 | Adj Neg | TO-204,TO-220 | -1.2 to -37 | 1.5 | Package Suffix |  |  |  |  |
| 337M | Med Current | TO-220 | -1.2 to -37 | 0.5 |  |  |  |  |  |
|  | Adj Neg |  |  |  | $\begin{aligned} & \text { TO-204 (TO-3) } \\ & \text { TO-220 } \end{aligned}$ |  |  |  |  |
| 309 |  | TO-205 | +5 | 0.2 |  |  |  |  |  |
| 309 |  | TO-204 | +5 | 1.0 | TO-205 (TO-39) H, G |  |  |  |  |
| 323 |  | TO-204,TO-220 | +5 | 3.0 | TO-92 P, Z |  |  |  |  |
| 140-XX | Fixed Pos | TO-204,TO-220 | Note 1 | 1.0 | For example, a 7812 K is a positive $12-\mathrm{V}$ regulator in a TO-204 package. An LM340T-5 is a positive $5-\mathrm{V}$ regulator in a TO-220 package. In addition, different manufacturers use different prefixes. An LM7805 is equivalent to a mA7805 or MC7805. |  |  |  |  |
| 340-XX |  | TO-204,TO-220 |  | 1.0 |  |  |  |  |  |
| 78XX |  | TO-204,TO-220 |  | 1.0 |  |  |  |  |  |
| 78LXX |  | TO-205,TO-92 |  | 0.1 |  |  |  |  |  |

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

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

## Package

TO-204 (TO-3)
TO-220
TO-205 (TO-39)
$\begin{array}{ll}\text { TO-92 } & \mathrm{H}, \mathrm{G} \\ \mathrm{P}, \mathrm{Z}\end{array}$
For example, a 7812 K is a positive $12-\mathrm{V}$ 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 mA7805 or MC7805.

78XX
78LXX
78MXX


Center Lead is Connected to the Heat Sink

H, G Suffix
TO-205 Package


Table 7.36
Op Amp ICs
Listed by device number

|  |  |  |  |  | Max | Min dc | Min | Min Small- | Min |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | Max | Min Input | Offset | Open- | Output | Signal | Slew |  |
|  |  | Freq | Supply* | Resistance | Voltage | Loop | Current | Bandwidth | Rate |  |
| Device | Type | Comp | (V) | (MS) | (mV) | Gain (dB) | (mA) | (MHz) | ( $V / \mu s$ ) | 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 |  |
| 1458 S | 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 | $1.5 \times 106$ | 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 |




LT1001 Precision op amp, low offset voltage ( $15 \mu \mathrm{~V}$ max), low drift $\left(0.6 \mu \mathrm{~V} /{ }^{\circ} \mathrm{C}\right.$ max), low noise ( $0.3 \mu \mathrm{~V}$ p-p)
LT1007
LT1007 Extremely low noise ( $0.06 \mu \mathrm{~V}$ p-p), very high gain ( $20 \times 10^{6}$ into $2 \mathrm{k} \Omega$ load)
LT1360

| NE5514 | Bipolar | int | $\pm 16$ | 100 | 1 |  | 10 | 3 | 0.6 |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| NE5532 | Bipolar | int | $\pm 20$ | 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


Top Views


84 CN
Table 7.37
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/notes/1921/pwrtubes.pdf. 5
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 $\stackrel{1}{n}$ in in OOOLOO O n 응 웅 810 읏 09ع 1500
1520
${ }^{1}$ Service Class Abbreviations:
$A B_{2} G D=A B_{2}$ linear with $50-\Omega$
passive grid circuit.
$B=$ Class- push-pull
$C P=$ 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 $20 \mathrm{k} \Omega$ to G 2 . ${ }^{6}$ Typical operation at 175 MHz . ${ }^{7} \pm 1.5 \mathrm{~V}$.
8 Values are for two tubes.
${ }^{9}$ Single tone.
${ }^{10} 24-\Omega$ cathode resistance. ${ }^{11}$ Base same as 4CX250B. Socket is Russian SK2A. ${ }^{12}$ Socket is Russian SK1A. ${ }^{13}$ Socket is Russian SK3A.


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& 0
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\hline
\end{array}
$$

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Table 7.38
Tetrode and Pentode Transmitting Tubes

$$
\begin{array}{ll}
{ }^{2} & \mathrm{AB}_{2} \mathrm{GD} 2200 \\
\hline \mathrm{CT} & 3000 \\
\mathrm{CT} & 3000 \\
\mathrm{CP} & \\
\mathrm{AB}_{2} & 4000 \\
\mathrm{GG} & 3000
\end{array}
$$




| 4CX1500B 1500 | 3000 | 12 | 400 | 110 | 6.0 | 10.0 | 81.5 | 0.02 | 11.8 | - | $\mathrm{AB}_{1}$ | 2750 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 4CX1600B 1600 | 3300 | 20 | 350 | 250 | 12.6 | 4.4 | 86 | 0.15 | 12 | See ${ }^{13}$ | ${ }^{\text {B }}$ | 2400 |

Table 7.39
TV Deflection Tubes
Output
© ©

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$$
\begin{aligned}
& \text { Plate Screen } \\
& \text { Diss. }
\end{aligned}
$$

 $\square$| 6JE6 | 30 |
| :--- | :--- |
| 6JM6 | 17.5 |
| 6JN6 | 17.5 |
| 6JS6C | 30 |
| 6KD6 | 33 |
| 6LB6 | 30 |

$$
\begin{array}{llll}
\text { 6JM6 } & 17.5 & 3.5 & 7.3 \mathrm{k}
\end{array}
$$

$$
\begin{array}{llll}
\hline \text { 6JN6 } & 17.5 & 3.5 & 7.3 \mathrm{k}
\end{array}
$$

$$
\begin{array}{llll}
\text { 6JN6 } & 17.5 & 3.5 & 7.3 \mathrm{k} \\
\text { 6JS6C } & 30 & 5.5 & - \\
\hline
\end{array}
$$

$$
\begin{array}{llll}
6 K D 6 & 33 & 5 & 14 k
\end{array}
$$

$$
11.5 \mathrm{k}
$$

$$
14 \mathrm{k}
$$

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Table 7.40

## EIA Vacuum-Tube Base Diagrams



FIG 3


3G


5AW


8JX

12FK


5AZ


5BA

5BK

6AM



12FJ

9NM

9QL

9QU

FIG 11

12FB



12FY

12GJ

12GW

12HL
FIG 41


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 | $\mathrm{P}_{\text {BF }}$ - Beam plates |
| H - Heater | S - Shell |
| IC - Internal connection | K - Cathode |

HBK05_07-14

[^1]
## Table 7.41

## Properties of Common Thermoplastics

## Polyvinyl Chloride (PVC)

## Advantages:

- Can be compounded with plasticizers, filters, stabilizers, lubricants and impact modifiers to produce a wide range of physical properties
- Can be pigmented to almost any color
- Rigid PVC has good corrosion and stain resistance, thermal \& electrical insulation, and weatherability
Disadvantages:
- Base resin can be attacked by aromatic solvents, ketones, aldehydes, naphthalenes, and some chloride, acetate, and acrylate esters
- Should not be used above $140^{\circ}$

Applications:

- Conduit
- Conduit boxes
- Housings
- Pipe
- Wire and cable insulation


## Polystyrene

## Advantages.

- Low cost
- Moderate strength
- Electrical properties only slightly affected by temperature and humidity
- Sparkling clarity
- Impact strength is increased by blending with rubbers, such as polybutadiene
Disadvantages:
- Brittle
- Low heat resistance

Applications:

- Capacitors
- Light shields
- Knobs


## Polyphenylene Sulfide (PPS)

Advantages:

- Excellent dimensional stability
- Strong
- High-temperature stability
- Chemical resistant
- Inherently completely flame retardant
- Completely transparent to microwave radiation

Applications:

- R3-R5 have various glass-fiber levels that are suitable for applications demanding high mechanical and impact strength as well as good dielectric properties
- R8 and R10 are suitable for high arc-resistance applications
- R9-901 is suitable for encapsulation of electronic devices


## Polypropylene

## Advantages:

- Low density
- Good balance of thermal, chemical, and electrical properties
- Moderate strength (increases significantly with glass-fiber reinforcement)
Disadvantages:
- Electrical properties affected to varying degrees by temperature (as temperature goes up, dielectric strength increases and volume resistivity decreases)
- Inherently unstable in presence of oxidative and UV radiation

Applications:

- Automotive battery cases
- Blower housings
- Fan blades
- Insulators
- Lamp housings
- Support for current-carrying electrical components
- TV yokes


## Polyethylene (PE)

Advantages: Low Density PE

- Good toughness
- Excellent chemical resistance
- Excellent coefficient of friction
- Near zero moisture absorption
- Easy to process
- Relatively low heat resistance

Disadvantages:

- Susceptible to environmental and some chemical stress cracking
- Wetting agents (such as detergents) accelerate stress cracking

Advantages: High Density PE

- Same as above, plus increased rigidity and tensile strength

Advantages: Ultra-High Molecular Weight PE

- Outstanding abrasion resistance
- Low coefficient of friction
- High impact strength
- Excellent chemical resistance
- Material does not break in impact strength tests using standard notched specimens
Applications:
- Bearings
- Components requiring maximum abrasion resistance, impact strength, and low coefficient of friction


## Phenolic

Advantages:

- Low cost
- Superior heat resistance
- High heat-deflection temperatures
- Good electrical properties
- Good flame resistance
- Excellent moldability
- Excellent dimensional stability
- Good water and chemical resistance

Applications:

- Commutators and housings for small motors
- Heavy duty electrical components
- Rotary-switch wafers
- Insulating spacers


## Nylon

Advantages:

- Excellent fatigue resistance
- Low coefficient of friction
- Toughness as a function of degree of crystalinity
- Resists many fuels and chemicals
- Good creep- and cold-flow resistance as compared to less rigid thermoplastics
- Resists repeated impacts

Disadvantages:

- All nylons absorb moisture
- Nylons that have not been compounded with a UV stabilizer are sensitive to UV light, and thus not suitable for extended outdoor use

Applications:

- Bearings
- Housings and tubing
- Rope
- Wire coatings
- Wire connectors
- Wear plates


## Table 7.42

## Coaxial Cable End Connectors

## UHF Connectors

| Military No. | Style | Cable RG- or Description |
| :---: | :---: | :---: |
| PL-259 | Str (m) | $\begin{aligned} & 8,9,11,13,63,87,149,213,214,216, \\ & 225 \end{aligned}$ |
| 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 ( $\mathrm{f} / \mathrm{m}$ ) | Polystyrene ins. |
| M-359A | Ang (m/f) | Polystyrene ins. |
| M-358 | T (f/m/f) | Polystyrene ins. |
| Reducers |  |  |
| UG-175 UG-176 |  | 55, 58, 141, 142 (except 55A) |
| UG-176 |  | 59, 62, 71, 140, 210 |

BNC Connectors

| Military No. | Style | Cable RG- | Notes |
| :---: | :---: | :---: | :---: |
| UG-88C | Str (m) | $\begin{aligned} & 55,58,141,142 \\ & 223,400 \end{aligned}$ |  |
| 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) | $\begin{aligned} & 55,58,141,142,223, \\ & 400 \end{aligned}$ |  |
| UG-291A | Pnl (f) | $\begin{aligned} & 55,58,141,142,223, \\ & 400 \end{aligned}$ | nwx |
| UG-624 | Blkhd (f) | 59, 62, 71, 140, 210 | Front mount Rexolite ins. |
| UG-1094A | Blkhd |  | Standard |
| UG-625B UG-625 | Recepta |  |  |

BNC Adapters

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

## Family Characteristics:

$Z=50 \Omega$. Frequency range: $0-4 \mathrm{GHz}$ w/low reflection; usable to 11 GHz . Voltage rating: 500 V P-P. Dielectric withstanding voltage 500 V RMS. SWR: $1.3 \mathrm{max} 0-4 \mathrm{GHz}$. RF leakage -55 dB $\min @ 3 \mathrm{GHz}$. Insertion loss: $0.2 \mathrm{~dB} \max @ 3 \mathrm{GHz}$. Temperature limits: TFE: $-67^{\circ}$ to $390^{\circ} \mathrm{F}\left(-55^{\circ}\right.$ to $\left.199^{\circ} \mathrm{C}\right)$; Rexolite insulators: $-67^{\circ}$ to $185^{\circ} \mathrm{F}\left(-55^{\circ}\right.$ to $\left.85^{\circ} \mathrm{C}\right)$. "Nwx" = not weatherproof.

## HN Connectors

| Military No. | Style | Cable RG- | Notes |
| :--- | :--- | :--- | :--- |
| UG-59A | Str (m) $8,9,213,214$ |  |  |
| UG-1214 | Str (f) $8,9,87,213$, | Captivated contact |  |
| UG-60A | Str (f) | $8,9,213,225$ |  |
| UG-1215 | Pnl (f) $8,9,87,213$, | Copolymer of styrene ins. |  |
|  |  | 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. $Z=50 \Omega$. Frequency range $=0-4 \mathrm{GHz}$. Maximum voltage rating $=1500 \mathrm{~V}$ P-P. Dielectric withstanding voltage $=$ 5000 V RMS SWR $=1.3$. All HN series are weatherproof. Temperature limits: TFE: $-67^{\circ}$ to $390^{\circ} \mathrm{F}\left(-55^{\circ}\right.$ to $199^{\circ} \mathrm{C}$ ); copolymer of styrene: $-67^{\circ}$ to $185^{\circ} \mathrm{F}\left(-55^{\circ}\right.$ to $\left.85^{\circ} \mathrm{C}\right)$.

## 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 |

## References

Table 7.43

## US Customary Units

## Linear Units

12 inches (in) = 1 foot (ft)
36 inches $=3$ feet $=1$ yard ( yd )
$1 \mathrm{rod}=5^{1 / 2}$ yards $=16^{1 / 2}$ feet
1 statute mile = 1760 yards $=5280$ feet
1 nautical mile $=6076.11549$ feet

## Area

$$
\begin{aligned}
& 1 \mathrm{ft}^{2}=144 \mathrm{in}^{2} \\
& 1 \mathrm{yd}^{2}=9 \mathrm{ft}^{2}=1296 \mathrm{in}^{2} \\
& 1 \mathrm{rod}^{2}=301 / 4 \mathrm{yd}^{2} \\
& 1 \mathrm{acre}^{2}=4840 \mathrm{yd}^{2}=43,560 \mathrm{ft}^{2} \\
& 1 \mathrm{acre}=160 \mathrm{rod}^{2} \\
& 1 \mathrm{mile}^{2}=640 \text { acres }
\end{aligned}
$$

## Volume

$1 \mathrm{ft}^{3}=1728 \mathrm{in}^{3}$
$1 \mathrm{yd}^{3}=27 \mathrm{ft}^{3}$

## Liquid Volume Measure

1 fluid ounce ( fl oz) $=8$ fluid drams $=1.804$ in
1 pint (pt) $=16 \mathrm{fl} \mathrm{oz}$
1 quart $(\mathrm{qt})=2 \mathrm{pt}=32 \mathrm{fl} \mathrm{oz}=573 / 4 \mathrm{in}^{3}$
1 gallon (gal) $=4 \mathrm{qt}=231 \mathrm{in}^{3}$
1 barrel = $31^{11 / 2}$ gal

## Dry Volume Measure

1 quart (qt) $=2$ pints $(p t)=67.2 \mathrm{in}^{3}$
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) $=437.5 \mathrm{gr}$
1 pound (lb) = $16 \mathrm{oz}=7000 \mathrm{gr}$
1 short ton $=2000 \mathrm{lb}, 1$ long ton $=2240 \mathrm{lb}$

## Troy Weight

1 grain troy ( grt t ) $=1$ grain avoirdupois
1 pennyweight (dwt) or (pwt) $=24 \mathrm{grt}$
1 ounce troy (oz t) $=480$ grains
$1 \mathrm{lbt}=12 \mathrm{ozt}=5760$ grains

## Apothecaries' Weight

1 grain apothecaries' (gr ap)
$=1 \mathrm{grt}=1 \mathrm{gr}$
1 dram ap (dr ap) $=60 \mathrm{gr}$
$1 \mathrm{oz} \mathrm{ap}=1 \mathrm{ozt}=8 \mathrm{drap}=480 \mathrm{gr}$
$1 \mathrm{lb} \mathrm{ap}=1 \mathrm{lb} \mathrm{t}=12 \mathrm{oz} \mathrm{ap}=5760 \mathrm{gr}$

## Conversion

Metric Unit $=$ Metric Unit $\times$ 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) |  |  |
| $\mathrm{mm}^{2}$ | 645.16 | inch2 |
| $\mathrm{cm}^{2}$ | 6.4516 | in $^{2}$ |
| $\mathrm{~cm}^{2}$ | 929.03 | $\mathrm{ft}^{2}$ |
| $\mathrm{~m}^{2}$ | 0.0929 | $\mathrm{ft}^{2}$ |
| $\mathrm{~cm}^{2}$ | 8361.3 | $\mathrm{yd}^{2}$ |
| $\mathrm{~m}^{2}$ | 0.83613 | $\mathrm{yd}^{2}$ |
| $\mathrm{~m}^{2}$ | 4047 | $\mathrm{acre}^{2}$ |
| $\mathrm{~km}^{2}$ | 2.59 | $\mathrm{mi}^{2}$ |


| (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)

| $\mathrm{mm}^{3}$ | 16387.064 | $\mathrm{in}^{3}$ |
| :--- | :---: | :--- |
| $\mathrm{~cm}^{3}$ | 16.387 | $\mathrm{in}^{3}$ |
| $\mathrm{~m}^{3}$ | 0.028316 | $\mathrm{ft}^{3}$ |
| $\mathrm{~m}^{3}$ | 0.764555 | $\mathrm{yd}^{3}$ |

16.387 in ${ }^{3}$
29.57 fl oz
473 pint
946.333 quart
$28.32 \mathrm{ft}^{3}$
0.9463 quart
3.785 gallon
1.101 dry quart
8.809 peck
35.238 bushel
(Troy Weight)
373.248 lb t

| (Mass) | (Apothecaries' Weight) |  |
| :--- | :---: | :---: |
| g | 3.387 | dr ap |
| g | 31.103 | oz ap |
| g | 373.248 | lb ap |

Multiply $\longrightarrow$
Metric Unit $=$ Conversion Factor $\times$ US Customary Unit

## $\longleftarrow$ Divide

Metric Unit $\div$ Conversion Factor $=$ US Customary Unit

Table 7.44
International System of Units (SI)—Metric Units

| Prefix | Symbol | ___Multiplication Factor- |  |  |
| :---: | :---: | :---: | :---: | :---: |
| exe | E | $10^{18}$ | = | 1,000,000 000,000,000,000 |
| peta | P | 1015 | = | 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 |
| (unit) |  | $10^{0}$ | = | 1 |
| deci | d | $10^{-1}$ | = | 0.1 |
| centi | c | 10-2 | = | 0.01 |
| milli | m | 10-3 | = | 0.001 |
| micro | $\mu$ | $10^{-6}$ | = | 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 $(\mathrm{cm})=1000$ millimeters $(\mathrm{mm})$

## Area

$1 \mathrm{~m}^{2}=1 \times 10^{4} \mathrm{~cm}^{2}=1 \times 10^{6} \mathrm{~mm}^{2}$

## Volume

$1 \mathrm{~m}^{3}=1 \times 10^{6} \mathrm{~cm}^{3}=1 \times 10^{9} \mathrm{~mm}^{3}$
1 liter $(I)=1000 \mathrm{~cm}^{3}=1 \times 10^{6} \mathrm{~mm}^{3}$

## Mass

1 kilogram (kg) = 1000 grams ( g )
(Approximately the mass of 1 liter of water)
1 metric ton (or tonne) $=1000 \mathrm{~kg}$

## Table 7.45

## 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
BCl —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
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 ( $30-300 \mathrm{GHz}$ )
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 ( $10^{9} \mathrm{~Hz}$ )
GND-ground

## H

h—hecto (prefix for $10^{2}$ )
H -henry (unit of inductance)
HF -high frequency ( $3-30 \mathrm{MHz}$ )
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 ( $\mathrm{kg} \mathrm{m}^{2} / \mathrm{s}^{2}$ ) (energy or work unit); jack
JFET-junction field-effect transistor
k—kilo (prefix for 103); Boltzmann's constant ( $1.38 \times 10^{-23} \mathrm{~J} / \mathrm{K}$ )
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
k $\Omega$-kilohm

## 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 ( $30-300 \mathrm{kHz}$ )
LHC-left-hand circular (polarization)
LO—local oscillator; Leadership Official
LP—log periodic
LS—loudspeaker
Isb-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 ( $300-3000 \mathrm{kHz}$ )
mH -millihenry
MHz -megahertz
mi-mile, statute (unit of length)
$\mathrm{mi} / \mathrm{h}$ (MPH)—mile per hour
$\mathrm{mi} / \mathrm{s}$-mile per second
mic-microphone
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
$\mathrm{m} / \mathrm{s}$-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
$\mathrm{M} \Omega$-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
0
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 ( $3-30 \mathrm{GHz}$ )
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 1012); 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 (30300 MHz )
VLF-very-low frequency ( $3-30 \mathrm{kHz}$ )
VLSI-very-large-scale integration
VMOS-V-topology metal-oxidesemiconductor
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 ( $\mathrm{kg} \mathrm{m}^{2} \mathrm{~s}^{-3}$ ), 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
${ }^{\circ}$-degree (plane angle)
${ }^{\circ} \mathrm{C}$-degree Celsius (temperature)
${ }^{\circ} \mathrm{F}$-degree Fahrenheit (temperature)
$\alpha$-(alpha) angles; coefficients, attenuation constant, absorption factor, area, common-base forward current-transfer ratio of a bipolar transistor
$\beta$-(beta) angles; coefficients, phase constant, current gain of commonemitter transistor amplifiers
$\gamma$-(gamma) specific gravity, angles, electrical conductivity, propagation constant
$\Gamma$-(gamma) complex propagation constant
$\delta$-(delta) increment or decrement; density; angles
$\Delta$-(delta) increment or decrement determinant, permittivity
ع-(epsilon) dielectric constant; permittivity; electric intensity
$\zeta$-(zeta) coordinates; coefficients
$\eta$-(eta) intrinsic impedance; efficiency; surface charge density; hysteresis; coordinate
$\theta$-(theta) angular phase displacement; time constant; reluctance; angles
-(iota) unit vector
K-(kappa) susceptibility; coupling coefficient
$\lambda$-(lambda) wavelength; attenuation constant
$\Lambda$-(lambda) permeance
$\mu$-(mu) permeability; amplification
factor; micro (prefix for $10^{-6}$ )
$\mu \mathrm{F}$-microfarad
$\mu \mathrm{H}$-microhenry
$\mu \mathrm{P}$-microprocessor
$\xi$-(xi) coordinates
$\pi$-(pi) $\approx 3.14159$
$\rho$-(rho) resistivity; volume charge density; coordinates; reflection coefficient
$\sigma$-(sigma) surface charge density; complex propagation constant; electrical conductivity; leakage coefficient; deviation
$\Sigma$-(sigma) summation
$\tau$-(tau) time constant; volume resistivity; time-phase displacement; transmission factor; density
$\phi$-(phi) magnetic flux angles
$\Phi$-(phi) summation
$\chi$-(chi) electric susceptibility; angles
$\Psi$-(psi) dielectric flux; phase difference; coordinates; angles
$\omega$-(omega) angular velocity $2 \pi \mathrm{~F}$
$\Omega$-(omega) resistance in ohms; solid angle

Table 7.46

## Computer Connector Pinouts


(D)

Serial Port (DB 25 pin)
Male


| Pin Signal | Pin Signal |  |
| :--- | :--- | :--- |
| 1 | N/C (not connected) | 20 |
| 2 | DTR (Data Terminal Ready) |  |
| 3 | RxD (Receive Data) | 21 |
| N/C (Rens |  |  |
| 4 | RTS (Request To Send) | 22 |
| 5 | RTS (Clear To Send) | 23 |
| N/C $/ C$ |  |  |
| 6 | DSR (Data Set Ready) | 24 |
| N/C $/ C$ |  |  |
| 7 | GND (Signal Ground) | 25 |
| N/C |  |  |
| 8 | DCD (Data Carrier Detect) |  |
| $9-19$ N/C |  |  |

(E)

Ethernet Connector (RJ45-8 pin)


| Pin Signal |  |
| :--- | :--- |
| 1 | Output Transmit Data (+) |
| 2 | Output Transmit Data (-) |
| 3 | Input Receive Data (+) |
| 4 | N/C (not connected) |
| 5 | N/C |
| 6 | Input Receive Data (-) |
| 7 | N/C |
| 8 | N/C |

(F)

Ethernet Connector (RJ45-10 pin)


> Pin Signal
> 1 DCD (Data Carrier Detect)
> 2 DTR (Data Terminal Ready)
> CTS (Clear To Send) GND (Signal Ground) 5 RxD (Receive Data) TxD (Transmit Data) GND (Frame Ground) RTS (Request To Send) DSR (Data Set Ready)
> 10 RI (Ring Indicator)
(G)


Pin Signal
1 N/C (not connected)
2 Data
$\begin{array}{ll}3 & \text { Clock } \\ 4 & \text { N/C }\end{array}$
5 GND (Signal Ground)
6 N/C
7 RTS (12-9 V)
8 N/C
(J)

PC-AT Type Power Connector

PC-ATX Type Power Connector Viewed from Connector End

HBKOO3O


Table 7.47
Voltage-Power Conversion Table
Based on a 50 -ohm system

| RMS | Peak-to-Peak | dBmV |
| :---: | :---: | :---: |
| $0.01 \mu \mathrm{~V}$ | $0.0283 \mu \mathrm{~V}$ | -100 |
| $0.02 \mu \mathrm{~V}$ | $0.0566 \mu \mathrm{~V}$ | -93.98 |
| $0.04 \mu \mathrm{~V}$ | $0.113 \mu \mathrm{~V}$ | -87.96 |
| $0.08 \mu \mathrm{~V}$ | $0.226 \mu \mathrm{~V}$ | -81.94 |
| $0.1 \mu \mathrm{~V}$ | $0.283 \mu \mathrm{~V}$ | -80.0 |
| $0.2 \mu \mathrm{~V}$ | $0.566 \mu \mathrm{~V}$ | -73.98 |
| $0.4 \mu \mathrm{~V}$ | $1.131 \mu \mathrm{~V}$ | -67.96 |
| $0.8 \mu \mathrm{~V}$ | $2.236 \mu \mathrm{~V}$ | -61.94 |
| $1.0 \mu \mathrm{~V}$ | $2.828 \mu \mathrm{~V}$ | -60.0 |
| $2.0 \mu \mathrm{~V}$ | $5.657 \mu \mathrm{~V}$ | -53.98 |
| $4.0 \mu \mathrm{~V}$ | $11.31 \mu \mathrm{~V}$ | -47.96 |
| $8.0 \mu \mathrm{~V}$ | 22.63 V V | -41.94 |
| 10.0 MV | $28.28 \mu \mathrm{~V}$ | -40.00 |
| 20.0 V | $56.57 \mu \mathrm{~V}$ | -33.98 |
| 40.0 M V | 113.1 $\mu \mathrm{V}$ | -27.96 |
| $80.0 \mu \mathrm{~V}$ | 226.3 $\mu \mathrm{V}$ | -21.94 |
| $100.0 \mu \mathrm{~V}$ | 282.8 ¢ V | -20.0 |
| $200.0 \mu \mathrm{~V}$ | $565.7 \mu \mathrm{~V}$ | -13.98 |
| $400.0 \mu \mathrm{~V}$ | 1.131 mV | -7.959 |
| $800.0 \mu \mathrm{~V}$ | 2.263 mV | -1.938 |
| 1.0 mV | 2.828 mV | 0.0 |
| 2.0 mV | 5.657 mV | 6.02 |
| 4.0 mV | 11.31 mV | 12.04 |
| 8.0 mV | 22.63 mV | 18.06 |
| 10.0 mV | 28.28 mV | 20.00 |
| 20.0 mV | 56.57 mV | 26.02 |
| 40.0 mV | 113.1 mV | 32.04 |
| 80.0 mV | 226.3 mV | 38.06 |
| 100.0 mV | 282.8 mV | 40.0 |
| 200.0 mV | 565.7 mV | 46.02 |
| 223.6 mV | 632.4 mV | 46.99 |
| 400.0 mV | 1.131 V | 52.04 |
| 800.0 mV | 2.263 V | 58.06 |
| 1.0 V | 2.828 V | 60.0 |
| 2.0 V | 5.657 V | 66.02 |
| 4.0 V | 11.31 V | 72.04 |
| 8.0 V | 22.63 V | 78.06 |
| 10.0 V | 28.28 V | 80.0 |
| 20.0 V | 56.57 V | 86.02 |
| 40.0 V | 113.1 V | 92.04 |
| 80.0 V | 226.3 V | 98.06 |
| 100.0 V | 282.8 V | 100.0 |
| 200.0 V | 565.7 V | 106.0 |
| 223.6 V | 632.4 V | 107.0 |
| 400.0 V | 1,131.0 V | 112.0 |
| 800.0 V | 2,263.0 V | 118.1 |
| 1000.0 V | 2,828.0 V | 120.0 |
| 2000.0 V | 5,657.0 V | 126.0 |
| 4000.0 V | 11,310.0 V | 132.0 |
| 8000.0 V | 22,630.0 V | 138.1 |
| 10,000.0 V | 28,280.0 V | 140.0 |

Voltage, $\mathrm{V}_{\mathrm{p}-\mathrm{p}}=\mathrm{V}_{\mathrm{RMS}} \times 2 \sqrt{2}$
Voltage, $\mathrm{dBmV}=20 \times \log _{10}\left[\frac{\mathrm{~V}_{\text {RMS }}}{0.001 \mathrm{~V}}\right]$ or $20 \times \log _{10}\left[\mathrm{mV}_{\text {RMS }}\right]$

| Watts | dBm |
| :---: | :---: |
| $2 \times 10^{-18}$ | -147.0 |
| $8 \times 10^{-18}$ | -141.0 |
| $32 \times 10^{-18}$ | -134.9 |
| $128 \times 10^{-18}$ | -128.9 |
| $200 \times 10^{-18}$ | -127.0 |
| $800 \times 10^{-18}$ | -121.0 |
| $3.2 \times 10^{-15}$ | -114.9 |
| $12.8 \times 10^{-15}$ | -108.9 |
| $20.0 \times 10^{15}$ | -107.0 |
| $80.0 \times 10^{-15}$ | -101.0 |
| $320.0 \times 10^{-15}$ | -94.95 |
| $1.28 \times 10^{-12}$ | -88.93 |
| $2.0 \times 10^{-12}$ | -86.99 |
| $8.0 \times 10^{-12}$ | -80.97 |
| $32.0 \times 10^{-12}$ | -74.95 |
| $128.0 \times 10^{-12}$ | -68.93 |
| $200.0 \times 10^{-12}$ | -66.99 |
| $800.0 \times 10^{-12}$ | -60.97 |
| $3.2 \times 10^{-9}$ | -54.95 |
| $12.8 \times 10^{-9}$ | -48.93 |
| $20.0 \times 10^{-9}$ | -46.99 |
| $80.0 \times 10^{-9}$ | -40.97 |
| $320 \times 10^{-9}$ | -34.95 |
| $1.28 \mu \mathrm{~W}$ | -28.93 |
| $12.0 \mu \mathrm{~W}$ | -26.99 |
| $8.0 \mu \mathrm{~W}$ | -20.97 |
| $32.0 \mu \mathrm{~W}$ | -14.95 |
| 128.0 HW | -8.93 |
| 200.0 ¢W | -6.99 |
| $800.0 \mu \mathrm{~W}$ | -0.97 |
| 1.0 mW | 0 |
| 3.2 mW | 5.05 |
| 12.80 mW | 11.07 |
| 20.0 mW | 13.01 |
| 80.0 mW | 19.03 |
| 320.0 mW | 25.05 |
| 1.28 W | 31.07 |
| 2.0 W | 33.01 |
| 8.0 W | 39.03 |
| 32.0 W | 45.05 |
| 128.0 W | 51.07 |
| 200.0 W | 53.01 |
| 800.0 W | 59.03 |
| 1,000.0 W | 60.0 |
| 3,200.0 W | 65.05 |
| 12,800.0 W | 71.07 |
| 20,000 W | 73.01 |
| 80,000 W | 79.03 |
| 320,000 W | 85.05 |
| 1.28 MW | 91.07 |
| 2.0 MW | 93.01 |

Power, watts $=\left[\frac{\mathrm{V}_{\mathrm{RMS}}{ }^{2}}{50 \Omega}\right]$
Power, $\mathrm{dBm}=10 \times \log _{10}\left[\frac{\text { Power (watts) }}{0.001 \mathrm{~W}}\right]$ or $10 \times \log _{10}\left[\mathrm{~mW}_{\text {RMS }}\right]$

Table 7.48
Large Machine-Wound Coil Specifications
Coil Dia
Inches
Inch
$11 / 4$
Turns
Per Inch

| 4 | 2.75 |
| ---: | ---: |
| 6 | 6.3 |
| 8 | 11.2 |
| 10 | 17.5 |
| 16 | 42.5 |


| $11 / 2$ | 4 | 3.9 |
| :--- | ---: | ---: |
|  | 6 | 8.8 |
|  | 8 | 15.6 |
|  | 10 | 24.5 |
|  | 16 | 63 |
|  |  |  |
| $13 / 4$ | 4 | 5.2 |
|  | 6 | 11.8 |
|  | 8 | 21 |
|  | 10 | 33 |
|  | 16 | 85 |

2

| 2 | 4 | 6.6 |
| :--- | ---: | ---: |
|  | 6 | 15 |
|  | 8 | 26.5 |
|  | 10 | 42 |
|  | 16 | 108 |
|  |  |  |
|  | $1 / 2$ | 4 |
|  | 6 | 10.2 |
|  | 8 | 23 |
|  | 10 | 41 |
|  |  | 64 |

3
Inductance
in $\mu H$
2.75
6.3
11.2
17.5
42.5

3.9
8.8
15.6
24.5
63

5.2
11.8
21
33
85
6.6
26.5

108
10.2

23
64
14
31.5

56
89

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 7.50
Small Machine-Wound Coil Specifications
\(\left.\begin{array}{lcc}Coil Dia, \& Turns <br>
Inches \& Per Inch \& Inductance <br>

in \mu \mathrm{H}\end{array}\right]\)| 1/2 (A) |
| :--- |

Table 7.51
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 7.52
Measured Inductance for \#12 Wire Windings


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

Table 7.53
Relationship Between Noise Figure and Noise Temperature
Note: Reference temperature is 290 kelvin


Table 7.54

## Antenna Wire Strength

American Wire Gauge

4
6
8
10
12
14
16
18
20

Recommended Tension ${ }^{1}$ (pounds)
Copper-clad Hard-drawn stee ${ }^{2}$

495
310
195
120
75
50
31
19
12
copper

214 130 84 84 32 32 20 13

Weight (pounds per 1000 feet)
Copper-clad Hard-drawn
steel ${ }^{2}$ copper
$115.8 \quad 126$
$72.9 \quad 79.5$
$45.5 \quad 50$
$28.8 \quad 31.4$
$18.1 \quad 19.8$
$11.4 \quad 12.4$
$7.1 \quad 7.8$
4.5
2.8
4.9
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 7.55
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 7.56
Pi-Network Resistive Attenuators (50 $\Omega$ )

| dB Atten. | R1 (Ohms) | $R 2$ (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 | 1406 |
| 55.0 | 50.2 | 25000 |
| 60.0 | 50.1 |  |

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 7.57
T-Network Resistive Attenuators (50 $\Omega$ )

| $d B$ 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 |
| $0-\sim_{0}^{R 1} \sim \sim_{0}^{R 1}$ |  |  |

Table 7.58
Impedance of Various Two-Conductor Lines
—— Twists per Inch -_

| Wire Size | 2.5 | 5 | 7.5 | 10 | 12.5 |
| :--- | :--- | :--- | :--- | :--- | :--- |
| no. 20 | 43 | 39 | 35 |  |  |
| no. 22 | 46 | 41 | 39 | 37 | 32 |
| no. 24 | 60 | 45 | 44 | 43 | 41 |
| no. 26 | 65 | 57 | 54 | 48 | 47 |
| no. 28 | 74 | 53 | 51 | 49 | 47 |
| no. 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 7.59
Attenuation per Foot for Lines

|  |  |  |  |  | Twists per Inch |
| :--- | :--- | :--- | :--- | :--- | :--- |
|  | Sire Size |  |  | 2.5 | 5 |
| 7.5 | 10 | 12.5 |  |  |  |
| no. 20 | 0.11 | 0.11 | 0.12 |  |  |
| no. 22 | 0.11 | 0.12 | 0.12 | 0.12 | 0.12 |
| no. 24 | 0.11 | 0.12 | 0.12 | 0.13 | 0.13 |
| no. 26 | 0.11 | 0.13 | 0.13 | 0.13 | 0.13 |
| no. 28 | 0.11 | 0.13 | 0.13 | 0.16 | 0.16 |
| no. 30 |  |  | 0.25 | 0.27 | 0.27 |

Measured in decibels at 14.0 MHz .
Attenuation in $d B$ per foot for the same lines as shown above.

Table 7.60

## Equivalent Values of Reflection Coefficient, Attenuation, SWR and Return Loss

| Reflection | Attenuation | Max |  |  |  |  |
| ---: | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| Coefficient (\%) | (dB) | Return | Reflection <br> Coefficient (\%) | Attenuation <br> (dB) | Max | Return <br> Loss, dB |

Table 7.61
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 7.62
Morse Code Character Set ${ }^{1}$

| A | didah | - - |
| :---: | :---: | :---: |
| B | dahdididit | - ••• |
| C | dahdidahdit | -•-• |
| D | dahdidit | -•• |
| E | dit | - |
| F | dididahdit | -•-• |
| G | dahdahdit | --• |
| H | didididit | -0.0 |
| I | didit | - |
| J | didahdahdah | -- - - |
| K | dahdidah | -•- |
| L | didahdidit | --•• |
| M | dahdah | - - |
| N | dahdit | -• |
| O | dahdahdah | - - - |
| P | didahdahdit | ---• |
| Q | dahdahdidah | --•- |
| R | didahdit | --• |
| S | dididit | $\bullet \bullet$ |
| T | dah | - |
| U | dididah | -•- |
| V | didididah | -•• |
| W | didahdah | -- - |
| X | dahdididah | -•• |
| Y | dahdidahdah | -•-- |
| Z | dahdahdidit | - |
| 1 | didahdahdahdah | ---- |
| 2 | dididahdahdah | -•--- |
| 3 | didididahdah | -••- - |
| 4 | dididididah | -0.0 |
| 5 | dididididit | -0.0• |
| 6 | dahdidididit | - -0.* |
| 7 | dahdahdididit | -•• |
| 8 | dahdahdahdidit | ---••• |
| 9 | dahdahdahdahdit | ----• |
| 0 | dahdahdahdahdah | ---- |

At [@]
Period [.]:
Comma [,]:
Question mark or
request for repetition [?]:
Error:
Hyphen or dash [- ]:
Double dash [=]
Colon [:]:
Semicolon [;]:
Left parenthesis [(]:
Right parenthesis [)]:
Fraction bar [/]:
Quotation marks ["]:
Dollar sign [\$]:
Apostrophe [']:
Paragraph [ 7$]$ :
Underline [_]:
Starting signal:
Wait:
End of message or cross [+]:
Invitation to transmit [K]:
End of work:
Understood:

## Notes:

1. Not all Morse characters shown are used in FCC code tests. License applicants are responsible for knowing, and may be tested on, the 26 letters, the numerals 0 to 9 , the period, the comma, the question mark, AR, SK, BT and fraction bar [DN].

| 2. The follo | wing letters are used in |  | Esperanto cha | rs: |
| :---: | :---: | :---: | :---: | :---: |
| certain Eur | pean languages which use | $\hat{\text { ® }}$ |  |  |
| the Latin a | lphabet: | C | dahdidahdidit | -•-•• |
| Ä, A | didahdidah | $\hat{\text { s }}$ |  |  |
| Á, À, À, Â | didahdahdidah | S | didididahdit |  |
| Ç, Ć | dahdidahdidit -•-•• | $\hat{\jmath}$ |  |  |
| É, È, E | dididahdidit $\quad \bullet-\bullet$ |  | didahdahdahdit |  |
| E | didahdididah •-••- | $\hat{H}$ | dahdidahdahdit | -• |
|  | dahdididahdit - - - |  |  |  |
| Ö, O̊, Ó | dahdahdahdit | U | dididahdah | -•-- |
| N Ü | dahdahdidahdah --•-- |  |  |  |
| ジ | dididahdah | G | dahdahdidahdit | --•-• |
| Ż | dahdahdidit |  |  |  |
| Z | dahdahdididah --••- |  |  |  |
| CH , Ş | dahdahdahdah |  |  |  |

4. Signals used in other radio services:

| Interrogatory | dididahdidah | $\bullet \bullet$ - - | $\overline{\text { INT }}$ |
| :---: | :---: | :---: | :---: |
| Emergency silence | dididididahdah | -•••-- | $\overline{\mathrm{HM}}$ |
| Executive follows | dididahdididah | -•-•• - | IX |
| Break-in signal | dahdahdahdahdah | ----- | TTTTT |
| Emergency signal | didididahdahdahdididit | -••---*•• | $\overline{\text { SOS }}$ |
| Relay of distress | dahdididahdididahdidit | -•-•• | DDD |

Table 7.63
Morse Abbeviated ("Cut") Numbers

| Numeral |  | Long Number |  | Abbreviated Number | Equivalent Character |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | didahdahdahdah | - - - - - | didah | - - | A |
| 2 | dididahdahdah | -•--- | dididah | -•- | U |
| 3 | didididahdah | -••-- | didididah | -••- | V |
| 4 | dididididah | -...- | dididididah | -•••- | 4 |
| 5 | dididididit | - . | dididididit | -.... or - | 5 or E |
| 6 | dahdidididit | -••• | dahdidididit | . . . | 6 |
| 7 | dahdahdididit | - ••• | dahdididit | -• | B |
| 8 | dahdahdahdidit | - - - •• | dahdidit | - | D |
| 9 | dahdahdahdahdit | ----• | dahdit | -• | N |
| 0 | dahdahdahdahdah | ----- | dah | - | T |

Note: These abbreviated numbers are not legal for use in call signs. They should be used only where there is agreement between operators and when no confusion will result.

## Table 7.64

The ASCII Coded Character Set

|  |  |  |  |  | 6 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  | 5 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| Number |  |  |  |  | 4 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
|  |  |  |  | Hex | 1st | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 3 | 2 | 1 | 0 | 2nd |  |  |  |  |  |  |  |  |  |
| 0 | 0 | 0 | 0 | 0 |  | NUL | DLE | SP | 0 | @ | P | ، | p |
| 0 | 0 | 0 | 1 | 1 |  | SOH | DC1 | ! | 1 | A | Q | a | q |
| 0 | 0 | 1 | 0 | 2 |  | STX | DC2 | " | 2 | B | R | b | r |
| 0 | 0 | 1 | 1 | 3 |  | ETX | DC3 | \# | 3 | C | S | c | s |
| 0 | 1 | 0 | 0 | 4 |  | EOT | DC4 | \$ | 4 | D | T | d | t |
| 0 | 1 | 0 | 1 | 5 |  | ENQ | NAK | \% | 5 | E | U | e | u |
| 0 | 1 | 1 | 0 | 6 |  | ACK | SYN | \& | 6 | F | V | f | v |
| 0 | 1 | 1 | 1 | 7 |  | BEL | ETB | ' | 7 | G | W | g | w |
| 1 | 0 | 0 | 0 | 8 |  | BS | CAN | ( | 8 | H | X | h | x |
| 1 | 0 | 0 | 1 | 9 |  | HT | EM | ) | 9 | I | Y | i | , |
| 1 | 0 | 1 | 0 | A |  | LF | SUB | * | : | $J$ | Z | j | z |
| 1 | 0 | 1 | 1 | B |  | VT | ESC | + | , | K | [ | k | 1 |
| 1 | 1 | 0 | 0 | C |  | FF | FS | , | < | L | 1 | , | \| |
| 1 | 1 | 0 | 1 | D |  | CR | GS | - | = | M | ] | m | \} |
| 1 | 1 | 1 | 0 | E |  | SO | RS | . | > | N | $\wedge$ | n | $\sim$ |
| 1 | 1 | 1 | 1 | F |  | SI | US | i | ? | O | - | - | DEL |

## Notes

1. "1" = mark, "0" = space.
2. Bit 6 is the most-significant bit (MSB). Bit 0 is the least-significant bit (LSB).

## Table 7.65

## Voluntary HF Band Plans

The following frequencies are generally recognized for certain modes or activities (all frequencies are in MHz ).
Nothing in the rules recognizes a net's, group's or any individual's special privilege to any specific frequency. Section $97.101(\mathrm{~b})$ of the Rules states that "Each station licensee and each control operator must cooperate in selecting transmitting channels and in making the most effective use of the amateur service frequencies. No frequency will be assigned for the exclusive use of any station." No one "owns" a frequency.

It's good practice-and plain old common sense-for any operator, regardless of mode, to check to see if the frequency is in use prior to engaging operation. If you are there first, other operators should make an effort to protect you from interference to the extent possible given that $100 \%$ inter-ference-free operation is an unrealistic expectation in today's congested bands.

| 1.800-1.810 | Digital Modes | 14.285 | QRP SSB calling frequency |
| :---: | :---: | :---: | :---: |
| 1.810 | CW QRP | 14.286 | AM calling frequency |
| 1.800-2.000 | CW |  |  |
| 1.843-2.000 | SSB, SSTV and other wideband modes | 18.100-18.105 | Data |
| 1.910 | SSB QRP | 18.105-18.110 | Automatically controlled data stations |
| 1.995-2.000 | Experimental |  |  |
| 1.999-2.000 | Beacons | 21.060 | QRP CW calling frequency |
|  |  | 21.070-21.090 | Data |
| 3.500-3.510 | CW DX | 21.090-21.100 | Automatically controlled data stations |
| 3.590 | RTTY DX | 21.340 | SSTV |
| 3.580-3.620 | Data | 21.385 | QRP SSB calling frequency |
| 3.620-3.635 | Automatically controlled data stations |  |  |
| 3.790-3.800 | DX window | 24.920-24.925 | Data |
| 3.845 | SSTV | 24.925-24.930 | Automatically controlled data stations |
| 3.885 | AM calling frequency |  |  |
| 3.985 | QRP SSB calling frequency | 28.060 | QRP CW calling frequency |
|  |  | 28.070-28.120 | Data |
| 7.040 | RTTY DX | 28.120-28.189 | Automatically controlled data stations |
|  | QRP CW calling frequency | 28.190-28.225 | Beacons |
| 7.075-7.100 | Phone in KH/KL/KP only | 28.385 | QRP SSB calling frequency |
| 7.080-7.100 | Data | 28.680 | SSTV |
| 7.100-7.105 | Automatically controlled data stations |  |  |
| 7.171 | SSTV | 29.000-29.200 | AM |
| 7.290 | AM calling frequency | 29.300-29.510 | Satellite downlinks |
|  |  | 29.520-29.580 | Repeater inputs |
| 10.106 | QRP CW calling frequency | 29.600 | FM simplex |
| 10.130-10.140 | Data | 29.620-29.680 | Repeater outputs |
| 10.140-10.150 | Automatically controlled data stations | Notes |  |
| 14.060 | QRP CW calling frequency Data | ARRL band plans for frequencies above 28.300 MHz are shown in |  |
| 14.070-14.095 |  | The ARRL Repeater Directory The FCC Rule Book |  |
| 14.095-14.0995 | Automatically controlled data stations | QST |  |
| 14.100 | IBP/NCDXF beacons |  |  |
| 14.1005-14.112 | Automatically controlled data stations |  |  |
| 14.230 | SSTV |  |  |

Table 7.66
VHF/UHF/EHF Calling Frequencies
Band (MHz) Calling Frequency
50
50.125 SSB
50.620 digital (packet)
52.525 National FM simplex frequency

144

222

432

902
144.010 EME
144.100, 144.110 CW
144.200 SSB
146.520 National FM simplex frequency
222.100 CW/SSB
223.500 National FM simplex frequency
432.010 EME
432.100 CW/SSB
446.000 National FM simplex frequency
902.100 CW/SSB
903.1 Alternate CW, SSB
906.500 National FM simplex frequency

1296

2304

10000

## VHF/UHF Activity Nights

Some areas do not have enough VHF/UHF activity to support contacts at all times. This schedule is intended to help VHF/UHF operators make contact. This is only a starting point; check with others in your area to see if local hams have a different schedule.

| Band $(\mathrm{MHz})$ | Day | Local Time |
| ---: | :--- | :--- |
| 50 | Sunday | 6 PM |
| 144 | Monday | 7 PM |
| 222 | Tuesday | 8 PM |
| 432 | Wednesday | 9 PM |
| 902 | Friday | 9 PM |
| 1296 | Thursday | 10 PM |

### 7.52 Chapter 7

Table 7.67
ITU Regions


The International Telecommunication Union divides the world into three regions. Geographic details appear in The FCC Rule Book.

Table 7.68
Allocation of International Call Signs

| AAA-ALZ | United States of America | EKA-EKZ | Armenia | H4A-H4Z |
| :--- | :--- | :--- | :--- | :--- |
| AMA-AOZ | Spain | ELA-ELZ | Liberia | H6A-H7Z | Nicaragua Islands


| P3A-P3Z | Cyprus |
| :---: | :---: |
| P4A-P4Z | Aruba |
| P5A-P9Z | Democratic People's |
|  | Republic of Korea |
| RAA-RZZ | Russian Federation |
| SAA-SMZ | Sweden |
| SNA-SRZ | Poland |
| SSA-SSM | Egypt |
| SSN-STZ | Sudan |
| SUA-SUZ | Egypt |
| SVA-SZZ | Greece |
| S2A-S3Z | Bangladesh |
| S5A-S5Z | Slovenia |
| S6A-S6Z | Singapore |
| S7A-S7Z | Seychelles |
| S8A-S8Z | South Africa |
| S9A-S9Z | Sao Tome and Principe |
| TAA-TCZ | Turkey |
| TDA-TDZ | Guatemala |
| TEA-TEZ | Costa Rica |
| TFA-TFZ | Iceland |
| TGA-TGZ | Guatemala |
| THA-THZ | France |
| TIA-TIZ | Costa Rica |
| TJA-TJZ | Cameroon |
| TKA-TKZ | France |
| TLA-TLZ | Central Africa |
| TMA-TMZ | France |
| TNA-TNZ | Congo (Republic of the) |
| TOA-TQZ | France |
| TRA-TRZ | Gabon |
| TSA-TSZ | Tunisia |
| TTA-TTZ | Chad |
| TUA-TUZ | Ivory Coast |
| TVA-TXZ | France |
| TYA-TYZ | Benin |
| TZA-TZZ | Mali |
| T2A-T2Z | Tuvalu |
| T3A-T3Z | Kiribati |
| T4A-T4Z | Cuba |
| T5A-T5Z | Somalia |
| T6A-T6Z | Afghanistan |
| T7A-T7Z | San Marino |
| T8A-T8Z | Palau |
| T9A-T9Z | Bosnia and Herzegovina |
| UAA-UIZ | Russian Federation |
| UJA-UMZ | Uzbekistan |
| UNA-UQZ | Kazakhstan |
| URA-UZZ | Ukraine |
| VAA-VGZ | Canada |
| VHA-VNZ | Australia |
| VOA-VOZ | Canada |
| VPA-VQZ | United Kingdom of Great Britain and Northern Ireland |
| VRA-VRZ | China (People's Republic of)-Hong Kong |
| VSA-VSZ | United Kingdom of Great Britain and Northern Ireland |
| VTA-VWZ | India |
| VXA-VYZ | Canada |
| VZA-VZZ | Australia |
| V2A-V2Z | Antigua and Barbuda |
| V3A-V3Z | Belize |
| V4A-V4Z | Saint Kitts and Nevis |
| V5A-V5Z | Namibia |
| V6A-V6Z | Micronesia |
| V7A-V7Z | Marshall Islands |
| V8A-V8Z | Brunei |
| WAA-WZZ | United States of America |


| XAA-XIZ | Mexico |
| :---: | :---: |
| XJA-XOZ | Canada |
| XPA-XPZ | Denmark |
| XQA-XRZ | Chile |
| XSA-XSZ | China |
| XTA-XTZ | Burkina Faso |
| XUA-XUZ | Cambodia |
| XVA-XVZ | Viet Nam |
| XWA-XWZ | Laos |
| XXA-XXZ | Portugal |
| XYA-XZZ | Myanmar |
| YAA-YAZ | Afghanistan |
| YBA-YHZ | Indonesia |
| YIA-YIZ | Iraq |
| YJA-YJZ | Vanuatu |
| YKA-YKZ | Syria |
| YLA-YLZ | Latvia |
| YMA-YMZ | Turkey |
| YNA-YNZ | Nicaragua |
| YOA-YRZ | Romania |
| YSA-YSZ | El Salvador |
| YTA-YUZ | Yugoslavia |
| YVA-YYZ | Venezuela |
| YZA-YZZ | Yugoslavia |
| Y2A-Y9Z | Germany |
| ZAA-ZAZ | Albania |
| ZBA-ZJZ | United Kingdom of Great Britain and Northern Ireland |
| ZKA-ZMZ | New Zealand |
| ZNA-ZOZ | United Kingdom of Great Britain and Northern Ireland |
| ZPA-ZPZ | Paraguay |
| ZQA-ZQZ | United Kingdom of Great Britain and Northern Ireland |
| ZRA-ZUZ | South Africa |
| ZVA-ZZZ | Brazil |
| Z2A-Z2Z | Zimbabwe |
| Z3A-Z3Z | Macedonia (Former Yugoslav Republic) |
| 2AA-2ZZ | United Kingdom of Great Britain and Northern Ireland |
| 3AA-3AZ | Monaco |
| 3BA-3BZ | Mauritius |
| 3CA-3CZ | Equatorial Guinea |
| 3DA-3DM | Swaziland |
| 3DN-3DZ | Fiji |
| 3EA-3FZ | Panama |
| 3GA-3GZ | Chile |
| 3HA-3UZ | China |
| 3VA-3VZ | Tunisia |
| 3WA-3WZ | Viet Nam |
| 3XA-3XZ | Guinea |
| 3YA-3YZ | Norway |
| 3ZA-3ZZ | Poland |
| 4AA-4CZ | Mexico |
| 4DA-4IZ | Philippines |
| 4JA-4KZ | Azerbaijani Republic |
| 4LA-4LZ | Georgia |
| 4MA-4MZ | Venezuela |
| 4NA-4OZ | Yugoslavia |
| 4PA-4SZ | Sri Lanka |
| 4TA-4TZ | Peru |
| * 4UA-4UZ | United Nations |
| 4VA-4VZ | Haiti |
| * 4WA-4WZ | United Nations |
| 4XA-4XZ | Israel |
| * 4YA-4YZ | International Civil Aviation Organization |
| 4ZA-4ZZ | Israel |


| 5AA-5AZ | Libya |
| :---: | :---: |
| 5BA-5BZ | Cyprus |
| 5CA-5GZ | Morocco |
| 5HA-5IZ | Tanzania |
| 5JA-5KZ | Colombia |
| 5LA-5MZ | Liberia |
| 5NA-5OZ | Nigeria |
| 5PA-5QZ | Denmark |
| 5RA-5SZ | Madagascar |
| 5TA-5TZ | Mauritania |
| 5UA-5UZ | Niger |
| 5VA-5VZ | Togo |
| 5WA-5WZ | Western Samoa |
| 5XA-5XZ | Uganda |
| 5YA-5ZZ | Kenya |
| 6AA-6BZ | Egypt |
| 6CA-6CZ | Syria |
| 6DA-6JZ | Mexico |
| 6KA-6NZ | Republic of Korea |
| 6OA-6OZ | Somalia |
| 6PA-6SZ | Pakistan |
| 6TA-6UZ | Sudan |
| 6VA-6WZ | Senegal |
| 6XA-6XZ | Madagascar |
| 6YA-6YZ | Jamaica |
| 6ZA-6ZZ | Liberia |
| 7AA-7IZ | Indonesia |
| 7JA-7NZ | Japan |
| 70A-7OZ | Yemen |
| 7PA-7PZ | Lesotho |
| 7QA-7QZ | Malawi |
| 7RA-7RZ | Algeria |
| 7SA-7SZ | Sweden |
| 7TA-7YZ | Algeria |
| 7ZA-7ZZ | Saudi Arabia |
| 8AA-8IZ | Indonesia |
| $8 \mathrm{JA}-8 \mathrm{NZ}$ | Japan |
| 80A-80Z | Botswana |
| 8PA-8PZ | Barbados |
| 8QA-8QZ | Maldives |
| 8RA-8RZ | Guyana |
| 8SA-8SZ | Sweden |
| 8TA-8YZ | India |
| 8ZA-8ZZ | Saudi Arabia |
| 9AA-9AZ | Croatia |
| 9BA-9DZ | Iran |
| 9EA-9FZ | Ethiopia |
| 9GA-9GZ | Ghana |
| 9HA-9HZ | Malta |
| 91A-9JZ | Zambia |
| 9KA-9KZ | Kuwait |
| 9LA-9LZ | Sierra Leone |
| 9MA-9MZ | Malaysia |
| 9NA-9NZ | Nepal |
| 90A-9TZ | Democratic Republic of the Congo |
| 9UA-9UZ | Burundi |
| 9VA-9VZ | Singapore |
| 9WA-9WZ | Malaysia |
| 9XA-9XZ | Rwanda |
| 9YZ-9ZZ | Trinidad and Tobago |

Notes:

[^2]Table 7.69

## FCC-Allocated Prefixes for Areas Outside the Continental US

| Prefix | Location |
| :--- | :--- |
| AH1, KH1, NH1, WH1 | Baker, Howland Is |
| AH2, KH2, NH2, WH2 | Guam |
| AH3, KH3, NH3, WH3 | Johnston I |
| AH4, KH4, NH4, WH4 | Midway I |
| AH5K, KH5K, NH5K, WH5K | Kingman Reef |
| AH5, KH5, NH5, WH5 (except K suffix) | Palmyra, Jarvis Is |
| AH6-7, KH6-7, NH6-7, WH6-7 | Hawaii |
| AH7K, KH7K, NH7K, WH7K | Kure I |
| AH8, KH8, NH8, WH8 | American Samoa |
| AH9, KH9, NH9, WH9 | Wake, Wilkes, Peale Is |
| AHØ, KHØ, NHø, WHØ | Northern Mariana Is |
| AL, KL, NL, WL | Alaska |
| KP1, NP1, WP1 | Navassa |
| KP2, NP2, WP2 | Virgin Is |
| KP3-4, NP3-4, WP3-4 | Puerto Rico |
| KP5, NP5, WP5 | Desecheo |

Table 7.70

## DX Operating Code

## For W/VE Amateurs

Some DXers have caused considerable confusion and interference in their efforts to work DX stations. The points below, if observed by all W/VE amateurs, will help make DX more enjoyable for all.

1) Call DX only after he calls CQ, QRZ? or signs $\overline{S K}$, or voice equivalents thereof. Make your calls short.
2) Do not call a DX station:
a) On the frequency of the station he is calling until you are sure the QSO is over ( $\overline{\mathrm{SK}}$ ).
b) Because you hear someone else calling him.
c) When he signs $\overline{K N}, \overline{A R}$ or CL.
d) Exactly on his frequency.
e) After he calls a directional CQ, unless of course you are in the right direction or area.
3) Keep within frequency band limits. Some DX stations can get away with working outside, but you cannot.
4) Observe calling instructions given by DX stations. Example: 15U means "call 15 kHz up from my frequency." 15D means down, etc.
5) Give honest reports. Many DX stations depend on W/VE reports for adjustment of station and equipment.
6) Keep your signal clean. Key clicks, ripple, feedback or splatter gives you a bad reputation and may get you a citation from the FCC.
7) Listen and call the station you want. Calling CQ DX is not the best assurance that the rare DX will reply.
8) When there are several W or VE stations waiting, avoid asking DX to "listen for a friend." Also avoid engaging him in a ragchew against his wishes.

## For Overseas Amateurs

To all overseas amateur stations:
In their eagerness to work you, many W and VE amateurs resort to practices that cause confusion and QRM. Most of this is good-intentioned but ill-advised; some of it is intentional and selfish. The key to the cessation of unethical DX operating practices is in your hands. We believe that your adoption of certain operating habits will increase your enjoyment of Amateur Radio and that of amateurs on this side who are eager to work you. We recommend your adoption of the following principles:

1) Do not answer calls on your own frequency.
2) Answer calls from W/VE stations only when their signals are of good quality.
3) Refuse to answer calls from other stations when you are already in contact with someone, and do not acknowledge calls from amateurs who indicate they wish to be "next."
4) Give everybody a break. When many W/VE amateurs are patiently and quietly waiting to work you, avoid complying with requests to "listen for a friend."
5) Tell listeners where to call you by indicating how many kilohertz up (U) or down (D) from your frequency you are listening.
6) Use the ARRL-recommended ending signals, especially $\overline{\mathrm{KN}}$ to indicate to impatient listeners the status of the QSO. $\overline{K N}$ means "Go ahead (specific station); all others keep out."
7) Let it be known that you avoid working amateurs who are constant violators of these principles.

Table 7.71

## W1AW SCHEDULE

| Pacific | Mtn | Central | East | Mon | Tue | Wed | Thu | Fri |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 6 AM | 7 AM | 8 AM | 9 AM |  | Fast Code | Slow <br> Code | Fast Code | Slow <br> Code |
| $\begin{array}{\|l} 7 \mathrm{AM} \\ 1 \mathrm{PM} \end{array}$ | $\begin{aligned} & \hline 8 \text { AM - } \\ & 2 \text { PM } \end{aligned}$ | $\begin{aligned} & \hline 9 \text { AM - } \\ & 3 \text { PM } \end{aligned}$ | $\begin{aligned} & 10 \mathrm{AM}- \\ & 4 \mathrm{PM} \end{aligned}$ | Visiting Operator Time (12 PM - 1 PM closed for lunch) |  |  |  |  |
| 1 PM | 2 PM | 3 PM | 4 PM | Fast Code | Slow Code | Fast Code | Slow <br> Code | Fast Code |
| 2 PM | 3 PM | 4 PM | 5 PM | Code Bulletin |  |  |  |  |
| 3 PM | 4 PM | 5 PM | 6 PM | Teleprinter Bulletin |  |  |  |  |
| 4 PM | 5 PM | 6 PM | 7 PM | Slow Code | Fast Code | Slow <br> Code | Fast Code | Slow <br> Code |
| 5 PM | 6 PM | 7 PM | 8 PM | Code Bulletin |  |  |  |  |
| 6 PM | 7 PM | 8 PM | 9 PM | Teleprinter Bulletin |  |  |  |  |
| 6:45 PM | 7:45 PM | 8:45 PM | 9:45 PM | Voice Bulletin |  |  |  |  |
| 7 PM | 8 PM | 9 PM | 10 PM | Fast Code | Slow Code | Fast Code | $\begin{aligned} & \text { Slow } \\ & \text { Code } \end{aligned}$ | Fast Code |
| 8 PM | 9 PM | 10 PM | 11 PM | Code Bulletin |  |  |  |  |

W1AW's schedule is at the same local time throughout the year. The schedule according to your local time will change if your local time does not have seasonal adjustments that are made at the same time as North American time changes between standard time and daylight time. From the first Sunday in April to the last Sunday in October, UTC = Eastern Time +4 hours. For the rest of the year, UTC $=$ Eastern Time +5 hours.

## Morse code transmissions:

Frequencies are 1.818, 3.5815, 7.0475, 14.0475, 18.0975, 21.0675, 28.0675 and 147.555 MHz .
Slow Code $=$ practice sent at $5,71 / 2,10,13$ and 15 wpm .
Fast Code = practice sent at $35,30,25,20,15,13$ and 10 wpm.
Code practice text is from the pages of QST. The source is given at the beginning of each practice session and alternate speeds within each session. For example, "Text is from June 2003 QST, pages 9 and 81 ," indicates that the plain text is from the article on page 9 and mixed number/letter groups are from page 81.
Code bulletins are sent at 18 wpm .
W1AW qualifying runs are sent on the same frequencies as the Morse code transmissions. West Coast qualifying runs are transmitted on approximately 3.590 MHz by K6YR. At the beginning of each code practice session, the schedule for the next qualifying run is presented. Underline one minute of the highest speed you copied, certify that your copy was made without aid, and send it to ARRL for grading. Please include your name, call sign (if any) and complete mailing address. The fee structure is $\$ 10$ for a certificate and $\$ 7.50$ for endorsements.

## Teleprinter transmissions:

Frequencies are $3.625,7.095,14.095,18.1025,21.095,28.095$ and 147.555 MHz .
Bulletins are sent at 45.45 -baud Baudot and 100-baud AMTOR, FEC Mode B. 110-baud ASCII will be sent only as time allows.
On Tuesdays and Fridays at 6:30 PM Eastern Time, Keplerian elements for many amateur -satellites are sent on the regular teleprinter frequencies.
Voice transmissions:
Frequencies are $1.855,3.99,7.29,14.29,18.16,21.39,28.59$ and 147.555 MHz .

## Miscellanea:

On Fridays, UTC, a DX bulletin replaces the regular bulletins.
W1AW is open to visitors from 10 AM until noon and from 1 PM until 3:45 PM on Monday through Friday. FCC-licensed amateurs may operate the station during that time. Be sure to bring your current FCC amateur license or a photocopy. In a communication emergency, monitor W1AW for special bulletins as follows: voice on the hour, teleprinter at 15 minutes past the hour, and CW on the half hour.
Headquarters and W1AW are closed on New Year's Day, President's Day, Good Friday, Memorial Day, Independence Day, Labor Day, Thanksgiving and the following Friday, and Christmas Day and the following day.

Table 7.72

## ARRL Procedural Signals (Prosigns)

In general, the CW prosigns are used on all data modes as well, although word abbreviations may be spelled out. That is, "CLEAR" might be used rather than "CL" on radioteletype. Additional radioteletype conventions appear at the end of the table.

Situation
check for a clear frequency
seek contact with any station
after call to specific named station or to indicate end of message
invite any station to transmit
invite a specific named station to transmit
invite receiving station to transmit
all received correctly
please stand by
end of contact (sent before call sign)
going off the air

| CW | Voice |
| :---: | :---: |
| QRL? | Is the frequency in use? |
| CQ | CQ |
| AR | over, end of message |
| K | go |
| $\overline{\mathrm{KN}}$ | go only |
| BK | back to you |
| R | received |
| AS | wait, stand by |
| SK | clear |
| CL | closing station |

## Additional RTTY prosigns

SK QRZ-Ending contact, but listening on frequency.
SK KN-Ending contact, but listening for one last transmission from the other station.
SK SZ-Signing off and listening on the frequency for any other calls.

Table 7.73

## Q Signals

These $Q$ signals most often need to be expressed with brevity and clarity in amateur work. ( Q abbreviations take the form of questions only when each is sent followed by a question mark.)
QRA What is the name of your station? The name of your station is
QRG Will you tell me my exact frequency (or that of _____)? Your exact frequency (or that of ____) is ____ kHz.
QRH Does my frequency vary? Your frequency varies.
QRI How is the tone of my transmission? The tone of your transmission is ____ (1. Good; 2. Variable; 3. Bad).
QRJ Are you receiving me badly? I cannot receive you. Your signals are too weak.
QRK What is the intelligibility of my signals (or those of

QRL Are you busy? I am busy (or I am busy with _____). Please do not interfere.
QRM Is my transmission being interfered with? Your transmission is being interfered with (1. Nil; 2. Slightly; 3. Moderately; 4. Severely; 5. Extremely.)
QRN Are you troubled by static? I am troubled by static ____ ( $1-5$ as under QRM).
QRO Shall I increase power? Increase power
QRP Shall I decrease power? Decrease power.
QRQ Shall I send faster? Send faster (___ WPM).
QRS Shall I send more slowly? Send more slowly (___ WPM).
QRT Shall I stop sending? Stop sending. QSV
QRU Have you anything for me? I have nothing for you.
QRV Are you ready? I am ready.
QRW Shall I inform $\qquad$ that you are calling on $\qquad$ kHz? Please inform $\qquad$ that I am calling on $\qquad$ kHz.
QRX When will you call me again? I will call you again at
$\qquad$ hours (on $\qquad$ kHz ).
QRY What is my turn? Your turn is numbered $\qquad$
$\qquad$ (on
QRZ Who is calling me? You are being called by
$\qquad$ kHz ).

What is the strength of my signals (or those of _)? The strength of your signals (or those of $\qquad$ ___ (1. Scarcely perceptible; 2. Weak; 3. Fairly good; 4. Good; 5. Very good).
Are my signals fading? Your signals are fading.
Is my keying defective? Your keying is defective.
Shall I send $\qquad$ messages at a time? Send messages at a time.
Can you hear me between your signals and if so can I break in on your transmission? I can hear you between my signals; break in on my transmission.
SL Can you acknowledge receipt? I am acknowledging receipt.
SM Shall I repeat the last message which I sent you, or some previous message? Repeat the last message which you sent me [or message(s) number(s) _____].
Did you hear me (or ____) on $\qquad$ kHz ? I did hear you (or $\qquad$ ) on $\qquad$ kHz .
Can you communicate with $\qquad$ direct or by relay? I can communicate with $\qquad$ direct (or by relay through
$\qquad$
Will you relay to $\qquad$ ? I will relay to $\qquad$
General call preceding a message addressed to all amateurs and ARRL members. This is in effect "CQ ARRL."
Shall I send or reply on this frequency (or on $\qquad$ kHz). kHz )? Send or reply on this frequency (or $\qquad$
Shall I send a series of Vs on this frequency (or on on $\qquad$ kHz )? Send a series of Vs on this frequency (or kzz.
Will you send on this frequency (or on $\qquad$ kHz )? । am going to send on this frequency (or on $\qquad$ kHz ).
Will you listen to $\qquad$ on $\qquad$ kHz ? I am listening to
$\qquad$ on $\qquad$ kHz.
Shall I change to transmission on another frequency? Change to transmission on another frequency (or on ___ kHz).

| QSZ | Shall I send each word or group more than once? Send each word or group twice (or $\qquad$ times). | QNL QNM* | Your net frequency is Low. <br> You are QRMing the net. Stand by. |
| :---: | :---: | :---: | :---: |
| QTA | Shall I cancel message number $\qquad$ ? Cancel message number $\qquad$ | QNN | Net control station is $\qquad$ . What station has net control? |
| QTB | Do you agree with my counting of words? I do not agree with your counting of words. I will repeat the first letter or digit of each word or group. | $\begin{aligned} & \text { QNO } \\ & \text { QNP } \end{aligned}$ | Station is leaving the net. Unable to copy you. Unable to copy |
| QTC | How many messages have you to send? I have $\qquad$ messages for you (or for $\qquad$ ). | QNQ* | Move frequency to $\qquad$ and wait for $\qquad$ to finish handling traffic. Then send him traffic for $\qquad$ |
| QTH | What is your location? My location is | QNR* | Answer ___ and Receive traffic. |
| QTR | What is the correct time? The correct time is | QNS | Following Stations are in the net.* (follow with list.) Request list of stations in the net. |
| QTV | Shall I stand guard for you? Stand guard for me. | QNT | I request permission to leave the net for ____ minutes. |
| QTX | Will you keep your station open for further communication with me? Keep your station open for me. | QNU* | The net has traffic for you. Stand by. |
| QUA | Have you news of ____ ? I have news of _____. | QNV* | Establish contact with $\qquad$ on this frequency. If successful, move to $\qquad$ and send him traffic for |
| ARRL | N Signals |  |  |
| QNA* | Answer in prearranged order. | QNW | How do I route messages for ___ ? |
| QNB | Act as relay between ____ and | QNX | You are excused from the net.* |
| QNC | All net stations copy. I have a message for all net stations. | QNY* | Shift to another frequency (or to $\qquad$ kHz ) to clear traffic with $\qquad$ _. |
| QND* | Net is Directed (Controlled by net control station.) | QNZ | Zero beat your signal with mine. |
| QNE* | Entire net stand by. | *For use only by the Net Control Station. |  |
| QNF | Net is Free (not controlled). | Notes on Use of QN Signals |  |
| QNG | Take over as net control station | These QN signals are special ARRL signals for use in amateur CW nets only. They are not for use in casual amateur conversation. Other meanings that may be used in other services do not apply. Do not use QN signals on phone nets. Say it with words. QN signals need not be followed by a question mark, even though the meaning may be interrogatory. |  |
| QNH | Your net frequency is High. |  |  |
| QNI | Net stations report in. I am reporting into the net. (Follow with a list of traffic or QRU.) |  |  |
| QNJ | Can you copy me? |  |  |
| QNK* | Transmit messages for ___ to ___ |  |  |

Table 7.74
The RST System

Readability
1—Unreadable.
2-Barely readable, occasional words distinguishable.
3-Readable with considerable difficulty.
4-Readable with practically no difficulty.
5-Perfectly readable.

## Signal Strength

1-Faint signals, barely perceptible.
2-Very weak signals.
3-Weak signals.
4-Fair signals.
5-Fairly good signals.
6-Good signals.
7-Moderately strong signals.
8-Strong signals.
9-Extremely strong signals.

[^3]Table 7.75
CW Abbreviations

| AA | All after | GUD | Good | SIG | Signature; signal |
| :---: | :---: | :---: | :---: | :---: | :---: |
| AB | All before | HI | The telegraphic laugh; high | SINE | Operator's personal initials or |
| AB | About | HR | Here, hear |  | nickname |
| ADR | Address | HV | Have | SKED | Schedule |
| AGN | Again | HW | How | SRI | Sorry |
| ANT | Antenna | LID | A poor operator | SSB | Single sideband |
| BCl | Broadcast interference | MA, MILS | Milliamperes | SVC | Service; prefix to service |
| BCL | Broadcast listener | MSG | Message; prefix to radiogram |  | message |
| BK | Break; break me; break in | N | No | T | Zero |
| BN | All between; been | NCS | Net control station | TFC | Traffic |
| BUG | Semi-automatic key | ND | Nothing doing | TMW | Tomorrow |
| B4 | Before | NIL | Nothing; I have nothing for | TNX-TKS | Thanks |
| C | Yes |  | you | TT | That |
| CFM | Confirm; I confirm | NM | No more | TU | Thank you |
| CK | Check | NR | Number | TVI | Television interference |
| CL | I am closing my station; call | NW | Now; I resume transmission | TX | Transmitter |
| CLD-CLG | Called; calling | OB | Old boy | TXT | Text |
| CQ | Calling any station | OC | Old chap | UR-URS | Your; you're; yours |
| CUD | Could | OM | Old man | VFO | Variable-frequency oscillator |
| CUL | See you later | OP-OPR | Operator | VY | Very |
| CW |  | OT | Old timer; old top | WA | Word after |
|  | radiotelegraph) | PBL | Preamble | WB | Word before |
| DE | From | PSE | Please | WD-WDS | Word; words |
| DLD-DLVD | Delivered | PWR | Power | WKD-WKG | Worked; working |
| DR | Dear | PX | Press | WL | Well; will |
| DX | Distance, foreign countries | R RCD | Received as transmitted; are Received | WX | Weather |
| ES | And, \& | RCVR (RX) | Received | XCVR | Transceiver |
| FB | Fine business, excellent |  |  | XMTR (TX) | Transmitter |
| FM | Frequency modulation | REF | Refer to; referring to; | XTAL | Crystal |
| GA | Go ahead (or resume sending) | RFI | reference Radio Frequency Interference | XYL (YF) | Wife |
| GB | Good-by | RIG | Station equipment | 73 | Best regards |
| GBA | Give better address | RPT | Repeat; I repeat; report | 88 | Love and Kisses |
| GE | Good evening | RTTY | Radioteletype | Although abbreviations help to cut down unnecessary transmission, make it a rule not to abbreviate unnecessarily when working an operator of unknown experience. |  |
| GG | Going | RX | Receiver |  |  |
| GM | Good morning | SASE | Self-addressed, stamped |  |  |
| GN | Good night |  | envelope |  |  |
| GND | Ground | SED | Said |  |  |

## Table 7.76

## ITU Recommended Phonetics

A - Alfa (AL FAH)
B - Bravo (BRAH VOH)
C - Charlie (CHAR LEE OR SHAR LEE)
D - Delta (DELL TAH)
E - Echo (ECK OH)
F - Foxtrot (FOKS TROT)
G - Golf (GOLF)
H - Hotel (HOH TELL)
I - India (IN DEE AH)
J - Juliet (JEW LEE ETT)
K - Kilo (KEY LOH)
L - Lima (LEE MAH)
M - Mike (MIKE)
N - November (NO VEM BER)
O - Oscar (OSS CAH)
P - Papa (PAH PAH)

Q - Quebec (KEH BECK)
R - Romeo (ROW ME OH)
S - Sierra (SEE AIR RAH)
T - Tango (TANG GO)
U - Uniform (YOU NEE FORM or OO NEE FORM)
V — Victor (VIK TAH)
W - Whiskey (WISS KEY)
X - X-Ray (ECKS RAY)
Y - Yankee (YANG KEY)
Z - Zulu (ZOO LOO)
Note: The Boldfaced syllables are emphasized. The pronunciations shown in the table were designed for speakers from all international languages. The pronunciations given for "Oscar" and "Victor" may seem awkward to English-speaking people in the U.S.

Table 7.77
ARRL Log


The ARRL Log is adaptable for all types of operating-ragchewing, contesting, DXing. References are to pages in the ARRL Log.

Table 7.78

## ARRL Operating Awards

Award
Worked All States (WAS)
Worked All Continents (WAC)
DX Century Club (DXCC)
VHF/UHF Century Club (VUCC)
A-1 Operator Club
Code Proficiency

## Qualification

QSLs from all 50 US states
QSLs from all six continents
QSLs from at least 100 different countries
QSLs from many grid squares
Recommendation by two A-1 operators
One minute of perfect copy from W1AW qualifying run

Table 7.79
ARRL Membership QSL Card


The ARRL membership QSL card. This example is from Harris Ruben, N2ERN, who designed the card. Your card would reflect your own call sign and address; awards and VUCC grid-square are optional. ARRL does not print or sell the cards. Inquire with printers who advertise in the QST Ham Ads.

Table 7.80
Mode Abbreviations for QSL Cards

| Abbreviation | Explanation <br> CW |
| :--- | :--- |
| DATA | Telegraphy <br> Telemetry, telecommand and computer <br> communications (includes packet radio) |
|  | Facsimile and television |
| IMAGE | Tone-modulated telegraphy |
| MCW | Speech and other sound |
| PHONE | Modulated main carrier |
| PULSE | Direct-printing telegraphy (includes AMTOR) |
| RTTY | Spread Spectrum |
| SS | Emissions containing no information |

Note: For additional information on emission types refer to latest edition of The FCC Rule Book.


A map showing US states, Canadian provinces and ARRL/RAC Sections.

Table 7.82
ARRL Grid Locator Map for North America
This and a World Grid Locator Map are available from ARRL.


Table 7.83

## Amateur Message Form

Every formal radiogram message originated and handled should contain the following component parts in the order given.

## I PREAMBLE

a. Number (begin with 1 each month or year)
b. Precedence (R, W, P or EMERGENCY)
c. Handling Instructions (optional, see text)
d. Station of Origin (first amateur handler)
$e$. Check (number of words/groups in text only)
$f$. Place of Origin (not necessarily location of station of origin)
$g$. Time Filed (optional with originating station)
$h$. Date (must agree with date of time filed)

II ADDRESS (as complete as possible, include zip code and telephone number)

III TEXT (limit to 25 words of less, if possible)

## IV SIGNATURE

## CW MESSAGE EXAMPLE

I NR 1 R HXG W1AW 8 NEWINGTON CT 1830Z JULY 1

| $a$ | $b$ | $c$ | $d$ | $e$ | $f$ | $g$ | $h$ |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |

## II

DONALD SMITH AA
160 EAST SIXTH AVE $\overline{\mathrm{AA}}$
NORTH RIVER CITY MO $00789 \overline{\mathrm{AA}}$
7334868 BT
III
HAPPY BIRTHDAY X SEE YOU SOON X LOVE $\overline{\mathrm{BT}}$
IV
DIANA $\overline{\mathrm{AR}}$
Note that X , when used in the text as punctuation, counts as a word.
$\mathbf{C W}$ : The prosign $\overline{\mathrm{AA}}$ separates the parts of the message. $\overline{\mathrm{BT}}$ separates the address from the text the text from the signature. $\overline{\mathrm{AR}}$ marks the end of message; this is followed by B if there is another message to follow, by N if this is the only or last message. It is customary to copy the preamble, parts of the address, text and signature on separate lines.

RTTY: Same as CW procedure above, except (1) use extra space between parts of address, instead of $\overline{\mathrm{AA}}$; (2) omit CW procedure sign BT to separate text from address and signature, using line spaces instead; (3) add a CFM line under the signature, consisting of all names, numerals and unusual words in the message in the order transmitted.

PACKET/AMTOR BBS: Same format as shown in the CW message example above, except that the $\overline{\mathrm{AA}}$ and $\overline{\mathrm{AR}}$ prosigns may be omitted. Most AMTOR and Packet BBS software in use today allow formal message traffic to be sent with the "ST" command. Always avoid the use of spectrum-wasting multiple line feeds and indentations.

PHONE: Use prowords instead of prosigns, but it is not necessary to name each part of the message as you send it. For example, the above message would be sent on phone as follows: "Number one routine HX

Golf W1AW eight Newington Connecticut one eight three zero zulu July one Donald Smith Figures one six four East Sixth Avenue North River City Missouri zero zero seven eight nine Telephone seven three three four nine six eight Break Happy Birthday X-ray see you soon X-ray love Break Diana End of Message Over. "End of Message" is followed by "More" if there is another message to follow, "No More" if it is the only or last message. Speak clearly using VOX (or pause frequently on push-to-talk) so that the receiving station can get his fills. Spell phonetically all difficult or unusual words-do not spell out common words. Do not use CW abbreviations or Q-signals in phone traffic handling

## PRECEDENCES

The precedence will fill the message number. For example, on CW 207 R or 207 EMERGENCY. On phone, "Two Zero Seven Routine (or Emergency)."

EMERGENCY-Any message having life and death urgency to any person or group of persons, which is transmitted by Amateur Radio in the absence of regular commercial facilities. This includes official messages of welfare agencies during emergencies requesting supplies, materials or instructions vital to relief of stricken populace in emergency areas. During normal times, it will be very rare. On CW, RTTY and other digital modes this designation will always be spelled out. When in doubt, do not use it.

PRIORITY-Important messages having a specific time limit. Official messages not covered in the Emergency category. Press dispatches and other emergency-related traffic not of the utmost urgency. Notification of death or injury in a disaster area, personal or official. Use the abbreviation P on CW.

WELFARE-A message that is either (a) an inquiry as to the health and welfare of an individual in the disaster area (b) an advisory or reply from the disaster area that indicates that all is well should carry this precedence, which is abbreviated W on CW. These messages are handled after Emergency and Priority traffic but before Routine.

ROUTINE—Most traffic normal times will bear this designation. In disaster situations, traffic labeled Routine ( R on CW ) should be handled last, or not at all when circuits are busy with Emergency, Priority or Welfare traffic.

## Handling Instructions (Optional)

HXA-(Followed by number.) Collect landline delivery authorized by addressee within ......miles. (If no number, authorization is unlimited.) HXB-(Followed by number.) Cancel message if not delivered within ......hours of filing time; service originating station.
$\mathbf{H X C}$-Report date and time of delivery (TOD) to originating station.
HXD-Report to originating station the identify of station from which received, plus date and time. Report identity of station to which relayed, plus date and time, or if delivered report date, time and method of delivery.
HXE-Delivering station get reply from addressee, originate message back.
HXF - (Followed by number.) Hold delivery until.......(date).
HXG-Delivery by mail or landline toll call not required. If toll or other expense involved, cancel message and service originating station.

For further information on traffic handling, consult The ARRL Operating Manual, published by the ARRL.

Table 7.84
A Simple NTS Formal Message


Table 7.85

## Handling Instructions

HXA-(Followed by number.) Collect landline delivery authorized by addressee within $\qquad$ miles. (If no number, authorization is unlimited.)
HXB—(Followed by number.) Cancel messages if not delivered within $\qquad$ hours of filing time; service originating station.
HXC-Report date and time of delivery (TOD) to originating station.
HXD-Report to originating station the identity of station from which received, plus date and time. Report identity of station to which relayed, plus date and time, or if delivered report date, time and method of delivery.
HXE-Delivering station get reply from addressee, originate message back.

HXF-(Followed by number.) Hold delivery until $\qquad$ (date). HXG-Delivery by mail or landline toll call not required. If toll or other expense involved, cancel message and service originating station.

An HX prosign (when used) will be inserted in the message preamble before the station of origin, thus: NR 207 R HXA50 W1AW 12...(etc). If more than one HX prosign is used they can be combined if no numbers are to be inserted; otherwise the HX should be repeated, thus: NR 207 R HXAC W1AW... (etc), but: NR 207 R HXA50 HXC W1AW...(etc). On phone, use phonetics for the letter or letters following the HX, to ensure accuracy.

## Table 7.86

## ARL Numbered Radiograms

The letters ARL are inserted in the preamble in the check and in the text before spelled out numbers, which represent texts from this list. Note that some ARL texts include insertion of numerals. Example: NR 1 R W1AW ARL 5 NEWINGTON CONN DEC 25 DONALD R SMITH AA 164 EAST SIXTH AVE AA NORTH RIVER CITY MO AA PHONE 7333968 BT ARL FIFTY ARL SIXTY ONE BT DIANA AR.

Group One—For possible "Relief Emergency" Use

## ONE TW TH FIV SIX

SEVEN $\quad \begin{aligned} & \text { Please reply by Amateur Radio through the } \\ & \text { amateur delivering this message. This is a }\end{aligned}$ free public service.
EIGHT

NINE

TEN

ELEVEN

TWELVE

THIRTEEN
FOURTEEN
FIFTEEN Please advise your condition and what help is needed.
Property damage very severe in this area.
REACT communications services also available. Establish REACT communications with $\qquad$ on channel $\qquad$ .
EIGHTEEN

NINETEEN

TWENTY

TWENTY ONE

TWENTY TWO

TWENTY THREE

TWENTY FOUR

TWENTY FIVE
Everyone safe here. Please don't worry. Coming home as soon as possible.
Am in $\qquad$ hospital. Receiving excellent care and recovering fine.
\(\left.$$
\begin{array}{ll}\text { FOUR } & \begin{array}{l}\text { Only slight property damage here. Do not } \\
\text { be concerned about disaster reports. } \\
\text { Am moving to new location. Send no } \\
\text { further mail or communication. Will inform }\end{array}
$$ <br>

you of new address when relocated.\end{array}\right\}\)| Will contact you as soon as possible. |
| :--- |
| SIX |
| SEVEN |
| Elease reply by Amateur Radio through the |
| amateur delivering this message. This is a |
| free public service. |

Please contact . Advise to standby and provide further emergency information, instructions or assistance.
Establish Amateur Radio emergency communications with $\qquad$ on $\qquad$ MHz.
Anxious to hear from you. No word in some time. Please contact me as soon as possible.
Medical emergency situation exists here.
Situation here becoming critical. Losses and damage from $\qquad$ increasing.

SIXTEEN SEVENTEEN

Please contact me as soon as possible at
Request health and welfare report on ____. (State name, address and telephone number.)
Temporarily stranded. Will need some assistance. Please contact me at $\qquad$ _.

Search and Rescue assistance is needed by local authorities here. Advise availability.
Need accurate information on the extent and type of conditions now existing at your location. Please furnish this information and reply without delay.
Report at once the accessibility and best way to reach your location.
Evacuation of residents from this area urgently needed. Advise plans for help.
Furnish as soon as possible the weather conditions at your location.

## TWENTY SIX

Emergency/priority messages originating from official sources must carry the signature of the originating official.
Group Two-Routine messages

FORTY SIX

FIFTY
FIFTY ONE

FIFTY TWO

FIFTY THREE

FIFTY FOUR
FIFTY FIVE
FIFTY SIX

FIFTY SEVEN
FIFTY EIGHT

FIFTY NINE
*SIXTY
SIXTY ONE
*SIXTY TWO
SIXTY THREE
SIXTY FOUR
SIXTY FIVE

SIXTY SIX

SIXTY SEVEN

SIXTY EIGHT
SIXTY NINE

$$
\begin{aligned}
& \text { Greetings on your birthday and best } \\
& \text { wishes for many more to come. } \\
& \text { Greetings by Amateur Radio. } \\
& \text { Greetings by Amateur Radio. This } \\
& \text { message is sent as a free public service by } \\
& \text { ham radio operators here at ___. Am } \\
& \text { having a wonderful time. }
\end{aligned}
$$

Really enjoyed being with you. Looking forward to getting together again.
Received your $\qquad$ It's appreciated; many thanks.
Many thanks for your good wishes.
Good news is always welcome. Very delighted to hear about yours.
Congratulations on your $\qquad$ , a most worthy and deserved achievement.
Wish we could be together.
Have a wonderful time. Let us know when you return.
Congratulations on the new arrival. Hope mother and child are well.

Wishing you the best of everything on

| Wishing you a very merry Christmas and a happy New Year. <br> Greetings and best wishes to you for a pleasant $\qquad$ holiday season. <br> Victory or defeat, our best wishes are with you. Hope you win. <br> Arrived safely at $\qquad$ . <br> Arriving $\qquad$ on $\qquad$ Please arrange to meet me there. <br> DX QSLs are on hand for you at the $\qquad$ QSL Bureau. Send $\qquad$ selfaddressed envelopes. <br> Your message number $\qquad$ undeliverable because of $\qquad$ Please advise. <br> Sorry to hear you are ill. Best wishes for a speedy recovery. <br> Welcome to the $\qquad$ We are glad to have you with us and hope you will enjoy the fun and fellowship of the organization. |
| :---: |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

* Can be used for all holidays.

Note: ARL numbers should be spelled out at all times.

Table 7.87

## How to be the Kind of Net Operator the Net Control Station (NCS) Loves

As a net operator, you have a duty to be self-disciplined. A net is only as good as its worst operator. You can be an exemplary net operator by following a few easy guidelines.

1) Zero beat the NCS. The NCS doesn't have time to chase all over the band for you. Make sure you're on frequency, and you will never be known at the annual net picnic as "old so-and-so who's always off frequency."
2) Don't be late. There's no such thing as "fashionably late" on a net. Liaison stations are on a tight timetable. Don't hold them up by checking in 10 minutes late with three pieces of traffic.
3) Speak only when spoken to by the NCS. Unless it is a bona fide emergency situation, you don't need to "help" the NCS unless asked. If you need to contact the NCS, make it brief. Resist the urge to help clear the frequency for the NCS or to "advise" the NCS. The NCS, not you, is boss.
4) Unless otherwise instructed by the NCS, transmit only to the NCS. Side comments to another station in the net are out of order.
5) Stay until you are excused. If the NCS calls you and you don't respond because you're getting a "cold one" from the fridge, the NCS may assume you've left the net, and net business may be stymied. If you need to leave the net prematurely, contact the NCS and simply ask to be excused (QNX PSE ON CW).
6) Be brief when transmitting to the NCS. A simple "yes" (C) or "no" (N) will usually suffice. Shaggy dog tales only waste valuable net time.
7) Know how the net runs. The NCS doesn't have time to explain procedure to you. After you have been on the net for a while, you should already know these things.

## Table 7.88

## Checking Your Message

Traffic handlers don't have to dine out to fight over the check! Even good ops find much confusion when counting up the text of a message. You can eliminate some of this confusion by remembering these basic rules:

1) Punctuation ("X-rays," "Querys") count separately as a word.
2) Mixed letter-number groups (1700Z, for instance) count as one word.
3) Initial or number groups count as one word if sent together, two if sent separately.
4) The signature does not count as part of the text, but any closing lines, such as "Love" or "Best wishes" do.

Here are some examples:

- Charles J McClain-3 words
- W B Stewart-3 words
- St Louis-2 words
-3 PM-2 words
- SASE-1 word
- ARL FORTY SIX—3 words
- 2N1601-1 word
- Seventy-three-2 words
- 73-1 word

Telephone numbers count as 3 words (area code, prefix, number), and ZIP codes count as one, ZIP + 4 codes count as two words. Canadian postal codes count as two words (first three characters, last three characters.)
Although, it is improper to change the text of a message, you may change the check. Always do this by following the original check with a slash bar, then the corrected check. On phone, use the words "corrected to."

Table 7.89

## Tips on Handling NTS Traffic by Packet Radio

## Listing Messages

- After logging on to your local NTS-supported bulletin board, type the command LT, meaning List Traffic. The BBS will sort and display an index of all NTSXX traffic awaiting delivery.


## Receiving Messages

- To take a message off the Bulletin Board for telephone delivery to the third party, or for relay to a NTS Local or Section Net, type the R command, meaning Read Traffic, and the message number. R 188 will cause the BBS to find the BBS message number 188. This RADIOGRAM will look like any other, with preamble, address, text and signature; only some additional packet-related message header information is added. This information includes the routing path of the message for auditing purposes; e.g., to discern any excessive delays in the system.
- After the message is saved to the printer or disk, the message should be KILLED by using the KT command, meaning Kill Traffic, and the message number. In the above case, at the BBS prompt, type KT 188. This prevents the message from being delivered twice. Some of the newer BBS software requires use of $K$ rather than $K T$.
- At the time the message is killed, many BBSs will automatically send a message back to the station in the FROM field with information on who took the traffic, and when it was taken!


## Delivering or Relaying A Message

- A downloaded RADIOGRAM should, of course, be handled expeditiously in the traditional way: telephone delivery, or relay to another net.


## Sending Messages

- To send a RADIOGRAM, use the ST command meaning Send Traffic. The BBS will prompt you for the NTS routing
(0611@NTSCT, for example), the message title which should contain the city in the address of the RADIOGRAM (QTC 1 Dayton), and the text of the message in RADIOGRAM format. The BBS, usually within the hour, will check its outgoing mailpouch, find the NTSCT message and automatically forward it to the next packet station in line to the NTSCT node. Note: Some states have more than one ARRL Section. If you do not know the destination ARRL Section ("Is San Angelo in the ARRL North, South or West Texas Section?"), then simply use the state designator NTSTX.
*Note: While NTS/packet radio message forwarding is evolving rapidly, there are still some gaps. When uploading an NTS message destined for a distant state, use handling instruction "HXC" to ask the delivering station to report back to you the date and time of delivery.


## We Want You!

Local and Section BBSs need to be checked daily for NTS traffic. SYSOPs and STMs can't do it alone. They need your help to clear NTS RADIOGRAMs every day, seven days a week, for delivery and relay. If you are a traffic handler/packeteer, contact your Section Traffic Manager or Section Manager for information on existing NTS/packet procedures in your Section.

If you are a packeteer, and know nothing of NTS traffic handling, contact ARRL HQ, your Section Manager or Section Traffic Manager for information on how you can put your packet radio gear to use in serving the public in routine times, but especially in time of emergency!

And, if you enjoy phone/CW traffic handling, but aren't on packet yet, discover the incredible speed and accuracy of packet radio traffic handling. You probably already have a small computer and 2-meter rig; all you need is a packet radio "black box" to connect between your 2-meter rig and computer. For more information on packet radio, see Practical Packet Radio, published by the ARRL.


[^0]:    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.

[^1]:    Alphabetical subscripts ( $\mathrm{D}=$ diode, $\mathrm{P}=$ pentode, $\mathrm{T}=$ triode and $\mathrm{HX}=$ 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.

[^2]:    *Series allocated to an international organization
    ${ }^{\dagger}$ In response to Resolution 99 (Minneapolis, 1998) of the Plenipotentiary Conference

[^3]:    Tone
    1-Sixty-cycle ac or less, very rough and broad.
    2-Very rough ac, very harsh and broad.
    3-Rough ac tone, rectified but not filtered.
    4-Rough note, some trace of filtering.
    5-Filtered rectified ac but strongly ripple-modulated.
    6-Filtered tone, definite trace of ripple modulation.
    7-Near pure tone, trace of ripple modulation.
    8-Near perfect tone, slight trace of modulation.
    9-Perfect tone, no trace of ripple of modulation of any kind. If the signal has the characteristic steadiness of crystal control, add the letter X to the RST report. If there is a chirp, add the letter C. Similarly for a click, add K. (See FCC Regulations §97.307, Emissions Standards.) The above reporting system is used on both CW and voice; leave out the "tone" report on voice.

