TABLE D1.2. Connectors

Type	*Coupling*	*Impedance* (Ω)	*Peak Voltage* (*V*)	*Maximum Frequency* (*GHz*)	*Typical Cable*
BNC (regular)	Bayonet	nonconstant	500	0.3	RG–55,58,59,162
BNC (improved)	Bayonet	50	500	10*	RG–55,58,59,162
TNC	Threaded	50	500	10*	RG–55,58,59,162
N	Threaded	50,70	500	10*	RG–8,9
UHF	Threaded	—	500	0.4	RG–8,9

* The maximum frequency of operation really depends on the connector *and* cable. If an appreciable impedance discontinuity exists at the cable–connector interface, an appreciable percentage of power will be reflected and a high VSWR will exist. As a general rule-of-thumb, if the electrical length of the connector is $\lambda/50$ or less, an impedance mismatch is not serious. For a BNC connector pair (male and female) this corresponds to frequencies of less than approximately 150 MHz. Above this frequency the cable and connector impedance should be carefully matched (e.g., don't use a 50-Ω connector with a 75-Ω cable), and extreme care should be taken when attaching the cable to the connector: no gap should exist between the cable core and the connector insulator, all shoulders should be square, and so forth. Careful attention should be given to the cutting and soldering of the cable to the connector.

APPENDIX E

Complex Numbers

E.1 DEFINITION

Any complex number z means simply $z = a + jb$, where $j^2 = -1$ ($j = \sqrt{-1}$), and a and b are real numbers (positive or negative). a is called the *real* part of z, and b is called the *imaginary* part of z. Both a and b must have the same dimensions, e.g., both ohms or both volts and so forth. The $a + jb$ form for a complex number is often called the *Cartesian* form. Examples: $z = 2 + 3j$, $z = -4 + 2j$, $z = R + j\omega L$, $z = R - j/\omega C$.

E.2 COMPLEX CONJUGATE

The *complex conjugate* of z, written as z^*, means $z^* = a - jb$. To obtain the complex conjugate of any complex number, no matter how complicated, merely replace j by $-j$ and $-j$ by j. Examples: If $z = 2 + 3j$, $z^* = 2 - 3j$. If $z = re^{j\theta}$, $z^* = re^{-j\theta}$.

E.3 GEOMETRIC REPRESENTATION

We can represent any complex number by a single point in two-dimensional space by plotting the imaginary part along the vertical axis and the real part along the horizontal axis (Fig. E1.1). The *absolute value* of z or the

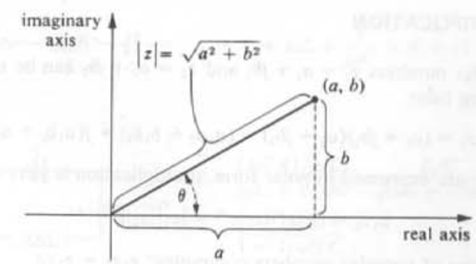


FIGURE E1.1 Geometric representation of a complex number.

R. E. Simpson, Introductory electronics for scientists and engineers, Prentice Hall, 1987.

magnitude of z, written $|z|$, means the distance from the origin to the point (a, b): $|z| = +\sqrt{a^2 + b^2}$. Notice $|z|$ is always real and positive; and z can represent an impedance, a voltage, or a current.

E.4 POLAR FORM

Any complex number z can also be written in polar form as $z = |z|e^{j\theta}$. Using the trigonometric identity $e^{j\theta} = \cos\theta + j\sin\theta$, we see that $z = |z|\cos\theta + j|z|\sin\theta$. Thus, the real part of z is given by $a = |z|\cos\theta$, and the imaginary part by $b = |z|\sin\theta$. Also $|z| = +\sqrt{a^2 + b^2}$ and $\theta = \tan^{-1}(b/a)$. In polar form the complex conjugate of z is written $z^* = |z|e^{-j\theta}$.

E.5 EQUALITY

Two complex numbers $z_1 = a_1 + jb_1$ and $z_2 = a_2 + jb_2$ are equal if and only if $a_1 = a_2$ and $b_1 = b_2$. In words, their real parts must be equal, *and* their imaginary parts must be equal. If z_1 and z_2 are written in polar form, then $z_1 = z_2$ if and only if $|z_1|e^{j\theta_1} = |z_2|e^{j\theta_2}$: $|z_1|\cos\theta_1 = |z_2|\cos\theta_2$ *and* also $|z_1|\sin\theta_1 = |z_2|\sin\theta_2$.

E.6 ADDITION

Two complex numbers $z_1 = a_1 + jb_1$ and $z_2 = a_2 + jb_2$ can be added or subtracted by the following rule:

$$(z_1 \pm z_2) = (a_1 \pm a_2) + j(b_1 \pm b_2)$$

It is very inconvenient to add two complex numbers in polar form but very easy in the Cartesian form $a + jb$. Addition commutes: $z_1 + z_2 = z_2 + z_1$. Example: $(2 + 3j) + (4 + 5j) = 6 + 8j$.

E.7 MULTIPLICATION

Two complex numbers $z_1 = a_1 + jb_1$ and $z_2 = a_2 + jb_2$ can be multiplied by the following rule:

$$z_1 z_2 = (a_1 + jb_1)(a_2 + jb_2) = (a_1 a_2 - b_1 b_2) + j(a_1 b_2 + a_2 b_1)$$

If z_1 and z_2 are expressed in polar form, multiplication is very easy:

$$z_1 z_2 = |z_1|e^{j\theta_1}|z_2|e^{j\theta_2} = |z_1||z_2|e^{j(\theta_1+\theta_2)}$$

Multiplication of complex numbers commutes: $z_1 z_2 = z_2 z_1$.

E.8 DIVISION

Two complex numbers can be divided by the following rule:

$$\frac{z_1}{z_2} = \frac{a_1 + jb_1}{a_2 + jb_2} = \frac{a_1 + jb_1}{a_2 + jb_2} \times \frac{a_2 - jb_2}{a_2 - jb_2} = \frac{a_1 a_2 + b_1 b_2}{a_2^2 + b_2^2} + j\frac{a_2 b_1 - a_1 b_2}{a_2^2 + b_2^2}$$

where we have multiplied and divided z_1/z_2 by $(a_2 - jb_2)$ to get z_1/z_2 in Cartesian form. Division is much easier if z_1 and z_2 are in polar form:

$$\frac{z_1}{z_2} = \frac{|z_1|e^{j\theta_1}}{|z_2|e^{j\theta_2}} = \frac{|z_1|}{|z_2|}e^{j(\theta_1-\theta_2)}$$

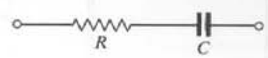
E.9 MISCELLANEOUS

It is often desired to calculate quickly the magnitude of a complex number. Perhaps the most useful technique is to multiply the number by its complex conjugate and to take the square root of the product:

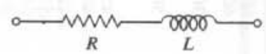
$$zz^* = (a + jb)(a - jb) = a^2 + b^2 = |z|^2$$

Therefore $|z| = \sqrt{zz^*}$.

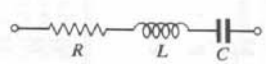
Some common ac *RLC* circuits and their complex impedances are given below.



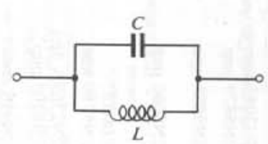
$$z = R + \frac{1}{j\omega C} = R - \frac{j}{\omega C}$$



$$z = R + j\omega L$$



$$z = R + j\omega L + \frac{1}{j\omega C} = R + j\left(\omega L - \frac{1}{\omega C}\right)$$



$$z = \frac{(j\omega L)(1/j\omega C)}{j\omega L + 1/j\omega C} = \frac{L/C}{j(\omega L - 1/\omega C)} = \frac{-j/\omega C}{1 - 1/\omega^2 LC}$$