The Different Types of AC Power Connectors in North America

White Paper 20

Revision 2

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> Executive summary

A confusing array of AC power plugs and receptacles exist to deliver power to various electronic loads. This white paper describes the different types of connectors used to power computer equipment in North America. An illustration guide is provided at the end of the paper to help identify the various connectors by appearance and size.

Contents

Click on a section to jump to it

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Introduction

The connection of electronic equipment to the AC power supply is usually accomplished using detachable connectors. The alternative of "hard-wiring" equipment to the building wiring makes service and movement of equipment more costly and less convenient. Therefore, many types of connectors exist. As a result, much confusion is generated as to what the various connection types are, when they are used, and what they should look like.

This white paper describes the different types of connectors used for powering computer equipment in North America, including internationally recognized connectors. A guide for identifying the connectors is provided as a reference (see **Appendix**) to help identify particular connectors by name, appearance, and size.

Connectors for multiple applications

Different styles of AC connectors exist in order to address different wiring systems and to ensure user safety. Within the North American NEMA standard alone, approximately 150 different styles of AC connectors are defined. Power distribution and utilization standards dictate that connectors have a specific number of pins. These recognized standards are listed in **Table 1**.

Table 1

Applications and pin count for different wiring systems

AC power distribution system	Number of pins	Application
Single-phase without safety ground	2	Lamps, double insulated appliances
Single-phase with safety ground	3	Most business equipment
Three-phase without safety ground	3	Uncommon; historical
Single-phase center tapped without safety ground	3	Residential ovens and clothes dryers
Three-phase with safety ground	4	Three-phase business equipment and machines
Single-phase center tapped with safety ground	4	Residential large appliances
Three-phase with neutral without safety ground	4	Uncommon; historical
Three-phase with neutral with safety ground	5	Three-phase equipment with unbalanced loads

An international standard

Standards for wall receptacles are often set by individual countries. The International Electrotechnical Commission, or IEC, has published international standards for AC interconnections between equipment. Two IEC standards are presented here: IEC 60320 and IEC 60309. When equipment uses connectors that comply with these standards, worldwide compatibility is achieved.

Virtually all computer equipment is equipped with a detachable power cord. The end of the cord that plugs into the equipment is an IEC standard connector. The IEC 60320 C13 / 14 connector type is seen on almost all personal computers and monitors. It has a rating of 10 amps and the female connector end is noted as C13 while the male connector end is noted

as C14. The IEC 60320 C19 / 20 connectors are rated for 16 amps and again have a female connector end (C19) and a male connector end (C20). C19 / 20 connectors are commonly used for devices such as some servers and UPS systems.

IEC 60309 is an international standard for "plugs, socket-outlets and couplers for industrial purposes". It specifies general functional and safety requirements for any form of industrial high-current power connector. The IEC 60309 connectors are produced in many varieties and are designed so that a plug of one type can only be inserted into a socket of the same type. For each current rating (i.e. 16 A, 32 A, and 63 A), the plugs are a different diameter, the pins are a different size, and the separation between pins is varied.

Different voltage and frequency combinations are distinguished by the location of the ground pin. Specifically, the ground pin can be in one of twelve locations spaced at 30 degree intervals around the circle on which all the pins lie (also referred to as clock positions). The ground pin has a larger diameter than the other pins, preventing the wrong type of plug from being inserted in a socket.

Table 2 illustrates the two common IEC 60320 connectors used for computers and servers. The table also illustrates three variations of the IEC 60309 pin and sleeve connectors. These diagrams illustrate how the number of pins can vary.

Figure 1 illustrates two examples of IEC 60309 connectors. The first illustration shows two phases, a neutral, and a ground. The second illustration depicts three-phases, and a ground.

Table 2

IEC international standard business equipment connectors

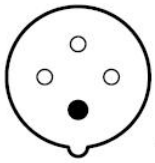
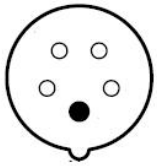
IEC connector type	Diagram of connector type	Comments
IEC 60320 C13 / C14		C 13 is the female connector end and C14 is the male connector end
IEC 60320 C19 / C20		C 19 is the female connector end and C20 is the male connector end
IEC 60309 2 Phase + Earth		Variations of different amperage (diameter of connector), voltage & frequency (grounding pin location and color coding)
IEC 60309 3 Phase + Earth		Variations of different amperage (diameter of connector), voltage & frequency (grounding pin location and color coding)
IEC 60309 3 Phase + Earth + Neutral		Variations of different amperage (diameter of connector), voltage & frequency (grounding pin location and color coding)

Figure 1

Examples of EIC 60309 connectors:

2 phases + neutral +ground (left) and 3 phases + ground (right)

North American standard AC connectors

A wide variety of connectors support business computers and electronic equipment in North America. The typical 120 volt and 208 volt connectors for single-phase business equipment are illustrated in **Table 3** and **Table 4**. The tables show that at several power ratings, the equipment manufacturers offer two different plug styles. One is called the "straight-blade" style and the other is called the "twist-lock" style. The 120 V 15 A NEMA 5-15 straight-blade style is far more common than the NEMA L5-15 twist lock style. However, at other ratings, straight-blade and twist-lock styles are both popular.

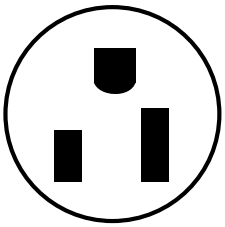
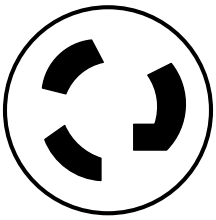
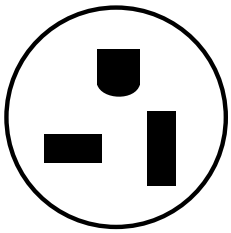
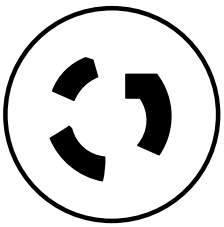
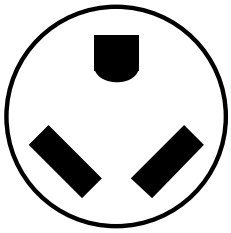
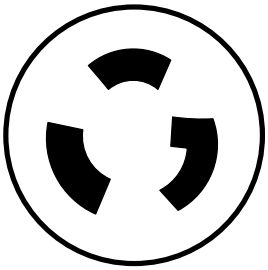
Each connector has a voltage and current rating as shown. These ratings limit the amount of power which can be drawn by equipment using the connector. The limit set by Underwriters Laboratories (UL) is 80% of the connector rating. The volt-amp limits for each connector type are shown in the tables. For example, an equipment component that operates at 2600 VA, if rated for 120 volts, would require a 30 amp connector. If rated for 208 volts, the component would require a 20 amp connector.

Abbreviations are used to describe characteristics of the plugs. P refers to the plug and R refers to the receptacle. In the tables, the plugs are illustrated but the receptacles are not. The receptacles are the same shape as the plugs except for the fact that they have holes where the plugs have prongs.

One anomaly in the NEMA connector family organization is the receptacle for the 20 amp straight blade connectors, the NEMA 5-20R and 6-20R. In this case the receptacle is designed to accept either the 20 amp or the 15 amp plug by use of a special "T" shaped slot. This is permitted in the US since the National Electrical Code permits 15 amp outlets to be fed from a 20 amp circuit breaker. The Canadian electrical code does not permit this arrangement and therefore in Canada the 20 amp receptacles will only accept 20 amp plugs. This means that equipment with "T" slot receptacles cannot be sold in Canada. It is a common practice today to wire office buildings in the US with NEMA 5-20R "T" slot type receptacles. For this reason, the 20 amp NEMA 5-20P plug has become popular for use on small minicomputers which have an input power requirement between 1440 VA and 1920 VA.

Table 3

Common North American single-phase AC power connectors (120 V, 60 Hz)

Size / type	Straight-blade connector	Twist-lock connector	Comments
120 volt 15 amp	 NEMA 5-15P	 NEMA L5-15P	1440 VA equipment load
120 volt 20 amp	 NEMA 5-20P	 NEMA L5-20P	1920 VA equipment load
120 volt 30 amp	 NEMA TT-30P	 NEMA L5-30P	2880 VA equipment load

Safety issues

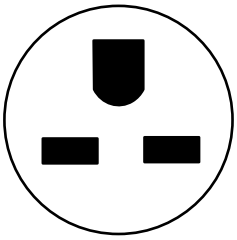
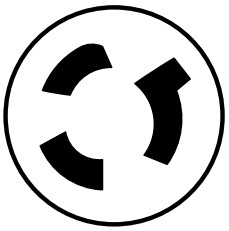
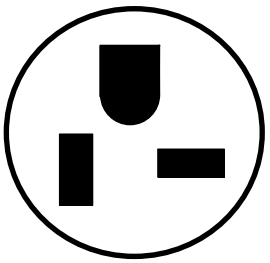
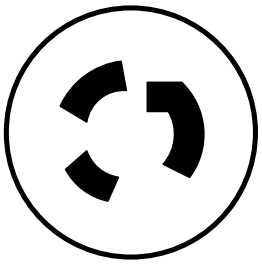
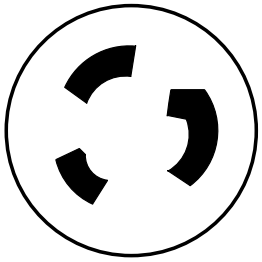
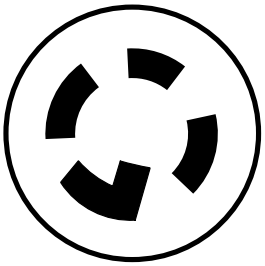
A key reason why different styles of connectors exist within a country is to prevent misapplication by users. For this reason, receptacles are designed so that they will only accept appropriate connectors.

Connectors are often manufactured differently for various utilization voltages in order to prevent equipment designed for one voltage to be inadvertently connected to another. Applying a voltage higher or lower than the voltage the equipment is designed for can be damaging to the equipment and may present a fire hazard.

Connectors are also manufactured differently to accommodate utilization at several power levels even at the same utilization voltage. This is to prevent unknowing users from connecting equipment to a power distribution circuit which is not rated to handle the power requirement; thereby preventing overloading and overheating of building wiring.

Table 4

Common North American single-phase AC power connectors (208-240 V, 60 Hz)

Size / type	Straight-blade connector	Twist-lock connector	Comments
208 Volt 15 Amp	 NEMA 6-15P	 NEMA L6-15P	2496 VA equipment load
208 Volt 20 Amp	 NEMA 6-20P	 NEMA L6-20P	3328 VA equipment load
208 Volt 30 Amp	None	 NEMA L6-30P	4992 VA equipment load
125 Volt 3-phase 30 Amp	None	 NEMA L14-30P	8640 VA equipment load

Conclusion

Without the standardization of plugs and receptacles thousands of equipment manufacturers would be free to design and use any type of plug they desired. This would lead to large quantities of unique plugs, requiring other manufacturers to build and stock hundreds of backplates and adapters to allow a connection between the devices.

The standards in place rate plug types for a maximum RMS voltage and maximum amperage. This paper provides guidelines for how common plugs and receptacles are configured and identified.

About the author

James Spitaels is a Consulting Engineer for Schneider Electric. He has Bachelors and Masters Degrees in Electrical Engineering from Worcester Polytechnic Institute. During his 16 years with the company he has developed UPSs, communications products, architectures and protocols, equipment enclosures, and power distribution products and has managed multiple product development teams. He holds four US Patents related to UPS and power systems.

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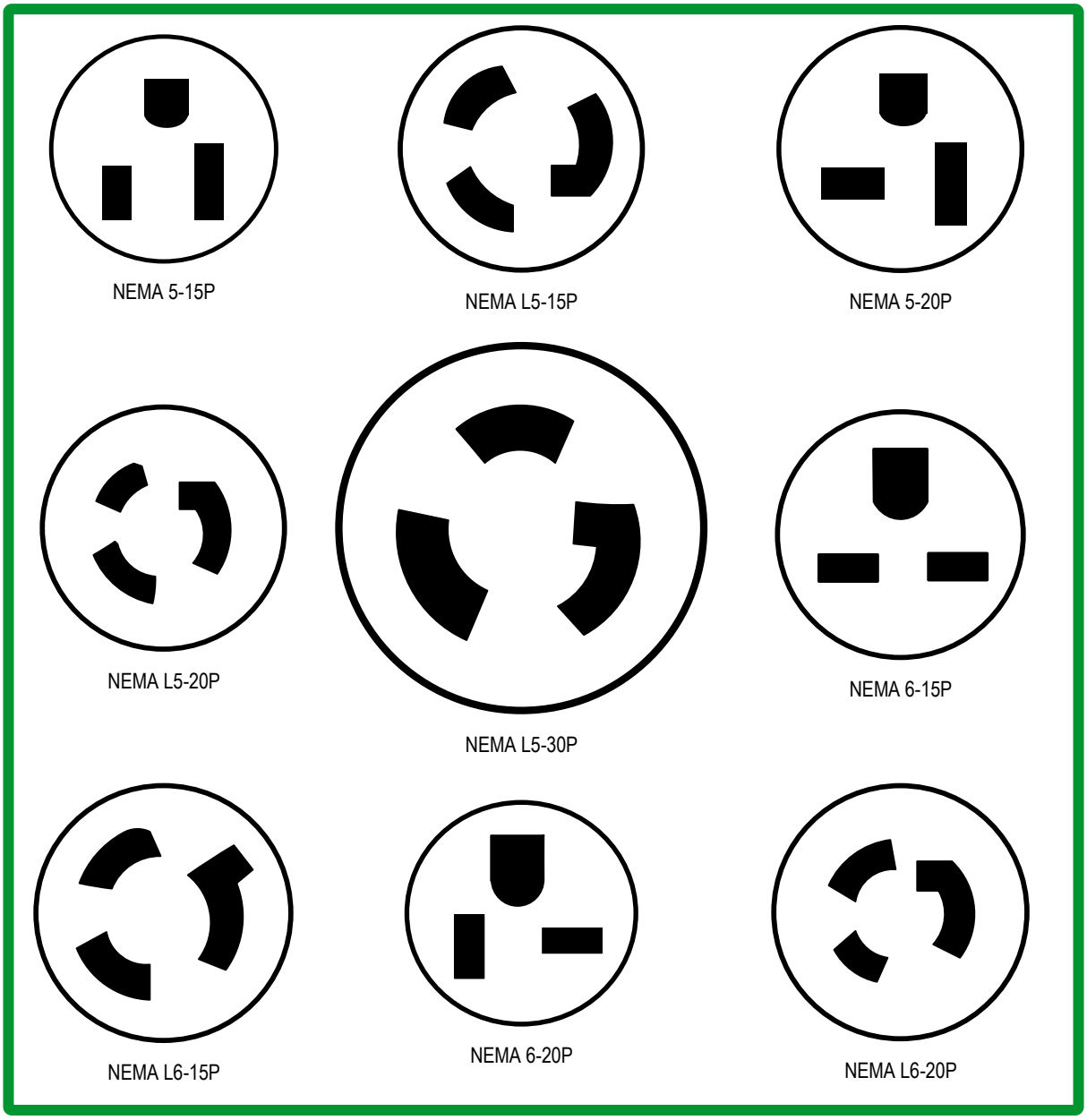
Appendix

The reference guide in this appendix can help to identify unknown connector types. Each diagram is illustrated in its actual size along with its name. Note – Only male connectors are shown (with abbreviation "P"), which are simply the plugs of the plug / receptacle set. Also note – While the prong shapes and positions are standard, the actual shape of the insulated plug casings can vary greatly. For instance, rather than a circular shape, the NEMA 5-15 plugs often have a rounded triangular or rectangular shape.

Figure a1

Quick reference guide



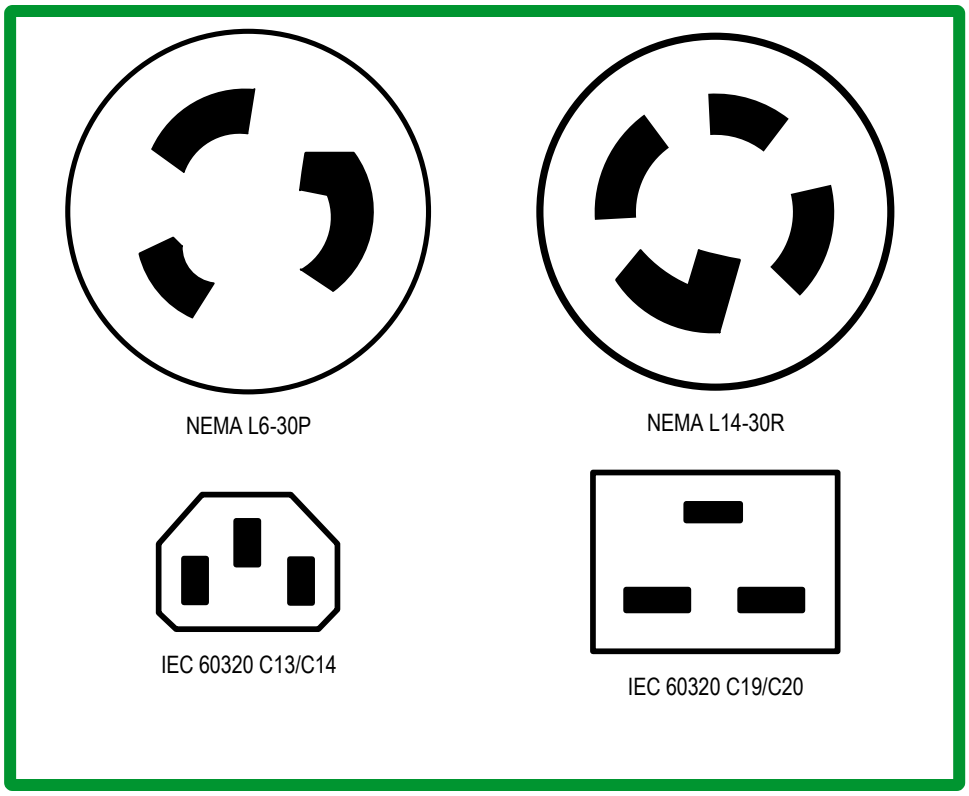


Figure a1 (cont.)

Quick reference guide