

## Single, Split-Phase and Three Phase Power

### Introduction

This application note discusses single and 3 phase power primarily for the USA. Common NEMA connectors used for both single and 3 phase applications are also covered.

QuadTech's 31000 Series AC source can be used for both single and 3 phase applications to simulate a variety of both normal and abnormal supply conditions.



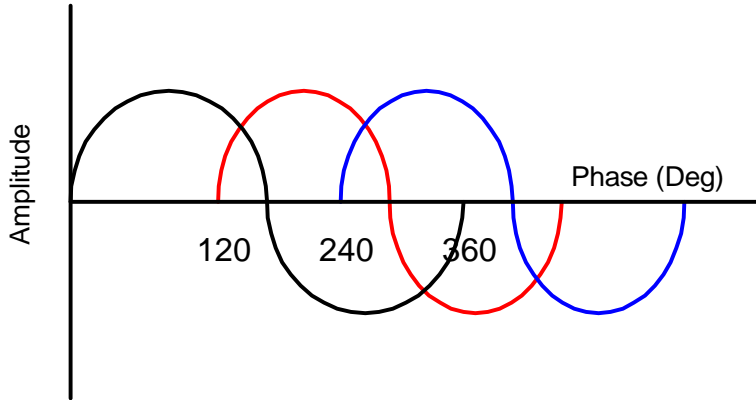
### Three Phase

There are three common types of power used in North America. Single phase and split-phase are most common to household power. Most power distribution uses polyphase system, typically 3-phase. 3 phase is primarily used because it is more economical and efficient than single phase distribution. 3 Phase power is also used in industrial applications where there is high power consumption.

3 conductors are used in three phase systems to transmit three sinusoidal currents. The currents are balanced so that each of the conductors carries the same current. The sinusoidal currents are shifted by 120 degrees in phase from one another. This allows loads to be placed between one conductor and another. 3 Phase power uses two configurations: Wye "Y" and Delta  $\Delta$ . A Wye configuration uses 3 conductors plus a neutral. Delta uses only the 3 conductors. Wye configuration makes it easier to address low voltage applications as the load can be placed between line and neutral. In a Delta configuration the load must be placed between line and line.

In Wye configuration, since the load can be placed between line and line or line and neutral, there are 4 different voltages. Two of the more commonly used voltages in North America for three phase Wye configurations are 270/480V and 120/208V. The 270 and 120 are the voltage between Line and Neutral. The line to line voltage can be calculated by multiplying the L-N voltage by  $\sqrt{3}$ . As an example:

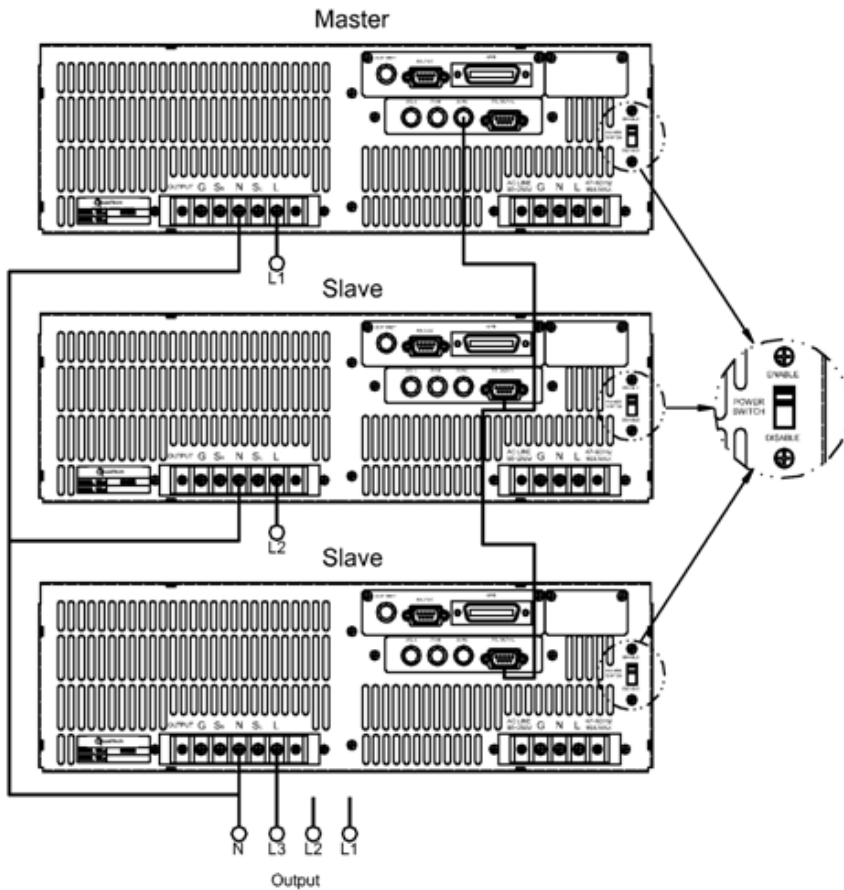
$$270 * \sqrt{3} = 480V\text{-L-L.}$$



**Figure 1. 3 Phase Relationship**

The colors of the lines in North America are found in the [American Color Code for 3-phase wiring](#). Colors are defined as follows: black= $V_{L1}$ , red= $V_{L2}$ , and blue= $V_{L3}$

AC sources such as the QuadTech 31000 AC Programmable Power Source Series can be used individually for single phase applications or linked together for 3 phase applications. The use of an AC source such as the QuadTech 31000 Series allows manufacturers to vary amplitude and phase between conductors for product testing under various conditions. The AC power source also allows accurate measurement of voltage, current, power factor and inrush current.



**Figure 2. 3 Phase Configuration of QuadTech AC Sources**

### Single Phase

Single phase power as stated earlier is the most commonly used power for residential applications in North America. Single phase power uses one conductor, line plus neutral. The load is placed between line and neutral conductors. The voltage is 120VAC L-N at 60Hz for North America. The color code for the U.S. is black for hot conductor and white for neutral. Residential wiring will also contain a ground which is a bare wire with no plastic insulation. Most household appliances such as refrigerators, blenders, toasters, radios, lamp etc operate at 120VAC single phase.

Appliances such as hot water heaters, electric ranges, electric dryers, HVAC and well pumps use what is called split phase.

### Split Phase

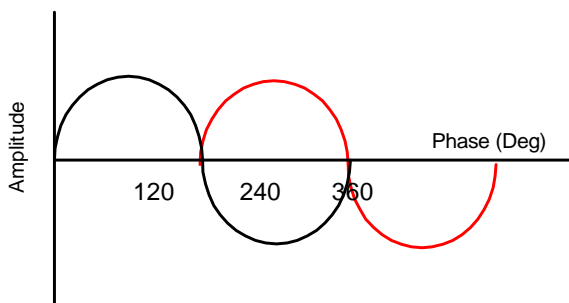
Split Phase power is actually what is delivered to most US households. There are three wires that connect into the utility meter on the residence. There are two hot wires each supplying 120VAC L-N which are black, and one neutral wire which is black and normally wrapped with white tape. The voltage measured between the two hot wires is 240VAC L-L (see figure 5). The 240VAC is achieved using a split phase transformer where phase relationship between the two hot wires is 180 degrees (see figure 4). In residential applications for appliances that consume a lot of energy, split phase is used due to higher voltage that reduces current draw and losses.

Circuits using split phase use a two pole circuit breaker. The circuit breaker looks like two individual circuit breakers tied together (see figure 3).

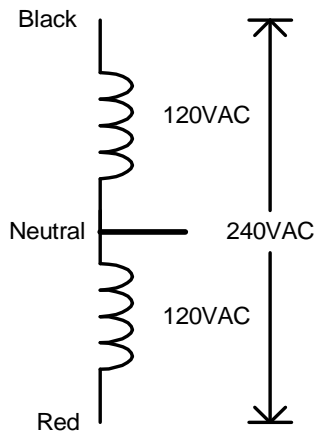


**Figure 3. Double Pole Circuit Breaker (Courtesy GE)**

Split phase is not the same as two phase power that uses just two legs of a three phase power distribution system. Phase relationship between hot conductors for 3 phase is 120 degrees and the phase relationship is 180 degrees for split phase.



### Figure 4. Phase Relationship for Split Phase



### Figure 5. Voltages for Split Phase

#### Power Plugs and Receptacles

NEMA 5-15R is the most commonly seen receptacle in homes in North America. NEMA stands for [National Electrical Manufacturers Association](http://www.nema.org) and there are a variety of different connector shapes, dimensions, blade widths and orientations that cover different voltage and current combinations. The NEMA code is broken down with the set of letters and/or numbers outlining the type of NEMA connector then a dash, followed by current rating and then either "P" for plug or "R" for receptacle. The dimensional standard for electrical connectors is ANSI/NEMA WD-6. Copy of WD-6 is available from [nema.org](http://www.nema.org) at this link: <http://www.nema.org/stds/wd6.cfm#download>

NEMA 1 is two wire non grounded and rated for 125VAC. The plugs are seen on a lot of common electrical device that have two blades and no ground pin. The 1-15R receptacles were widely used in homes until 1962 when NEC National Electrical Code required household receptacles to be grounded and polarized which required the use of a NEMA 5 receptacle. The polarity of the plug and receptacle is determined by one blade being wider than the other. The wider blade is the neutral conductor. On receptacles that use a screw to attach the conductor the brass or copper colored screw is the hot connection and the silver is the neutral conductor to keep proper polarity.



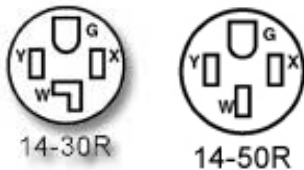
Figure 6. NEMA 1-15P

NEMA 5 devices are three-wire grounded receptacles or plugs with a rating of 125 VAC. The 5-15, 5-20 and 5-30 being grounded versions of the NEMA 1, with current ratings of 15A, 20A and 30A respectively. Note that in 2008 NEC now requires all receptacles to be tamper proof having a shutter mechanism to prevent insertion of objects.



**Figure 7. NEMA 5-15R (courtesy LEVITON)**

NEMA 14 connectors are four-wire grounded plugs and receptacles available in ratings from 15 A to 60 A and rated voltage of 250VAC. The four wires are (2) Hot leads, (1) Neutral and (1) Ground. The 14-30 is used for electric clothes dryers and the 14-50 for electric cooking ranges. These receptacles are typically connected to **split phase** in most homes to provide 240V for ranges, cloths dryer, well pumps, air compressors and similar products.



**Figure 8. NEMA 14-30R and 14-50R**

NEMA L22 connectors are used with circuits with a maximum specified voltage of 277/480 V AC. Supply connections are intended to be three-phase, five-wire L-L-L-N-G circuits with a nominal supply voltage of 460 VL-L and 265 VL-N. 480VL-L is typically for industrial facilities in North America.

#### References:

Leviton.com Important 2008 NEC Code Change  
 Wikipedia.com NEMA Connector  
 Nema.org  
 3phasepower.org