Understanding 240V AC Power for Heavy-Duty Power Tools

METALWORKING TECHNOLOGY WORKSHOP

By Tim Deagan November 2nd, 2016

If you're about to buy a 240V plasma cutter, or a MIG or TIG welder, you're likely to experience a very common problem. The plug won't fit your outlet. You can solve this with a simple adapter, but your first step should be learning enough about 240V power to be safe. Once you have a good understanding of the information presented here, you can follow along with my homebrewed 240V power adapter project.

No plasma cutting until I figure this out! Photography and diagrams by Tim Deagan

Caution: This information doesn't even scratch the surface of what a licensed electrician knows. Electricity has no mercy, and permit inspectors rarely have much more. Always get professional help installing permanent circuits, wiring, or outlets in your home or shop.

Alternating current (AC) was Nikola Tesla's solution to transporting electricity long distances. Instead of having fixed polarity like direct current (DC), the polarity oscillates between positive and negative in a sinusoidal wave. In the United States, it performs this oscillation 60 times a second (60Hz). The **voltage** is the amplitude of the wave. Like DC power, AC requires a potential difference to do work. For 120V plugs with two wires, the difference is between a **hot wire** (connected to the electrical source), and a **neutral wire** (connected to the electrical source and to the earth). For 240V circuits, the potential difference is between two hot wires that are 180° out of phase (see Figure 1). Because we only measure across two wires, both 120V and 240V are referred to as **single-phase power**. (It's rare to find three-phase AC power in residential situations).

Figure 1: 120V and 240V AC power waveforms

Neutral and ground are related but serve different roles. The neutral wire is the current return path for 120V circuits. It's connected to earth (grounded) at multiple points along its path from generator to outlet (see Figure 2). The oscillating current in the hot legs creates magnetic fields that induce undesirable currents in the neutral wire. Connecting the neutral to earth stabilizes the signal. Many electrical outlets are also "grounded outlets," meaning they have a ground wire. Under normal operation, the ground wire never carries current. If the hot wire shorts to ground (or the grounded case,) the ground wire path has less resistance and more current flows through the circuit breaker than it is rated for, causing it to trip, cutting off power. The ground wire is "bonded" to the neutral wire at the box to assure it has a viable connection to earth.

Figure 2: Generalized AC power distribution components

There's a lot of confusion about voltage values. You'll see references to 220V appliances, 230V, 240V, and NEMA (the National Electrical Manufacturer's Association) connectors are even rated at 250V. Despite all these different numbers, everyone is pretty much referring to the same thing: the U.S. 240V standard. (Actually, the U.S. has five standard voltages for different purposes — 120V, 208V, 240V, 277V, and 480V — but we'll stick to 240V.)

Residential 240V outlets usually have three or four connectors, which provide two hot 120V wires and either a ground wire, a neutral wire, or both (see Figure 3). The neutral wire provides a way for the appliance to use just one of the hot wires for 120V appliances like a clock or fan. As long as your outlet has the wires your plug needs, wiring an adapter is straightforward. The first thing to do is to identify the outlet type and understand what it provides.

Figure 3: 240V receptacles use combinations of the same wires

There are at least 20 types of 3- or 4-wire 240V connectors defined by NEMA. They designate them with a group number and an amperage rating. Locking connectors start with “L,” plugs end with “P,” and receptacles end with “R.” (See Figure 4)

Figure 4: NEMA connector naming standard

The most common of these are either Type 6 (2-pole, 3-wire grounding connectors that have two hot wires and a ground) or Type 14 connectors (3-pole, 4-wire connectors that have two hot wires, a neutral and a ground). For most combinations of type and amperage rating, there are straight blade and locking versions (see Figure 5).

Figure 5: Common NEMA 240V receptacles

To convert from one type to another we need to answer two questions: "What's the amperage?" and "Do I need a neutral connection?" Let's start with amperage.

Never connect equipment to a circuit rated for less than the device's amperage draw. The delightful word for this is ampacity. Keep in mind that this means the ampacity of the wiring as well as the breaker. If you're trying to pull 45A through a circuit that has wire rated for 30A, the wire becomes a heating element. Always use wire rated at, or above, the value of the circuit's breaker. The breaker should trip if you try to draw more current than it's rated for, but you don't want your gear shutting down like that. (And I hate having to trust breakers to keep my house from burning down, so why push them?)

It’s generally safer to attach a device to a circuit that draws less current than the circuit’s ampacity. The only risk is that the equipment might draw more current than it’s rated for before something trips. If you’re building an adapter to convert an outlet rated for 50A into an outlet rated for 30A, you should put a 30A breaker in the adapter to protect your gear.

Figure 6: Type 14 to Type 6 converter

The second question involves the neutral wire. Since it has all four wires, a Type 14 can convert into a Type 6 of the same or lesser amperage (see Figure 6). A Type 6 cannot convert into a Type 14 because it doesn’t have the neutral wire that the Type 14 requires (see Figure 7). A Type 14 can convert into two 120V circuits, one from each of the hot legs combined with the neutral (see Figure 8). A Type 6 cannot convert into 120V because it has no neutral to tie one of the hot legs to.

Figure 7: Type 6 can't convert into a Type 14

Figure 8: Type 14 can convert into two 120V circuits

You can purchase adapters to convert between various plugs and receptacles. If you have experience working with AC wiring, you can construct many of these yourself. In a fit of frustration, I built myself an adapter to allow me to use my 14-50R 50A RV outlet with a 6-50P, an L6-30P, a 14-50P, and then I tossed in two 15A 120V circuits (using pre-wired outlet strips) (see Figure 9). You may not need something this involved, but know that as long as you have the service, you can get your new gear up and running!

Figure 9: My custom-built adapter

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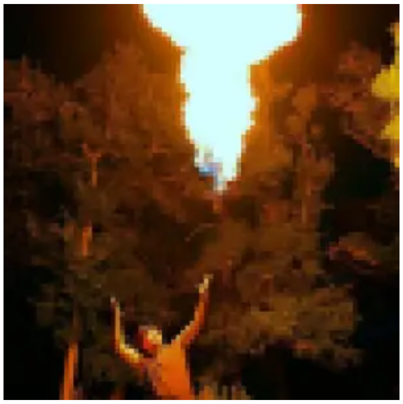

Tim Deagan

Tim Deagan (@TimDeagan) likes to make things. He casts, prints, screens, welds, brazes, bends, screws, glues, nails, and dreams in his Austin, Texas, shop. He's spent decades gathering tools based on the idea that one day he will come up with a project that has a special use for each and every one of them.

Tim likes to learn and try new things. A career troubleshooter, he designs, writes, and debugs code to pay the bills. He has worked as a stagehand, meat cutter, speechwriter, programmer, sales associate at Radio Shack, VJ, sandwich maker, computer tech support specialist, car washer, desk clerk, DBA, virtual CIO, and technical writer. He's run archeology field labs, darkrooms, produce teams, video stores, ice cream shops, consulting teams, developers, and QA teams. He's written for Make: magazine, Nuts & Volts, Lotus Notes Advisor and Databased Advisor. View more articles by Tim Deagan