Heat and electricity - the basics of welding

At a glance:

- Welding is a process that uses heat to joint metals.
- Electric welders operate using a basic electrical circuit which is formed when an arc is struck. Welders use either an alternating current (AC) or direct current (DC) electricity supply. DC welders are more versatile.
- All welds need to be shielded from atmospheric gases which can affect their strength.

Put simply, welding is a process that uses heat to join metal to create a strong bond.

The heat, commonly generated with an electric arc or gas flame, needs to be hot enough to melt the metals being welded. The melting process is usually accompanied by a filling process, where additional metal is added to make a strong joint.

Brazing and soldering are not welding processes by definition as the parent metal is not heated to a temperature sufficient to melt it. Instead, silver, copper or lead alloys are used to 'glue' the metals together — the heat simply melts the glue and encourages it to adhere to the parent metal.

As most welding methods use an electrical arc to generate heat, it is useful to have a basic understanding of how electricity works during welding.

Electric welding basics

With any electrical circuit power will only flow when the circuit is connected to the power source in a loop (see Figure 1). This is called a closed circuit — electricity flows from the power source through a switch to the load, in this case a light globe, and back to the power source.

The circuit has a negative and a positive terminal, with the current flowing from the negative terminal to the positive terminal. The flow of electricity is actually a flow of electrons, which are sub-atomic particles carrying a negative charge.

The voltage of an electrical flow is a measure of the potential difference between two points, or between the positive and negative terminals.

The best way to imagine voltage is to liken it to water flowing through a pipe. Voltage is similar to the head of water in a pipe, or the difference in height between the inlet and the outlet, which will govern the amount of pressure created at the outlet.

Current is a measure of the flow rate of voltage, measured in amperes (amps). To use the water and pipe analogy, current is like the speed or flow rate of water flowing through a pipe, which depends on ▶

pressure and the diameter and length of the pipe. It is similar to electricity — the size of the current flow depends on the electrical pressure (voltage) and the diameter and length of the wire.

More current can flow through a thick short wire than a long skinny one. This restriction to current flow is called resistance and is measured in ohms (Ω).

Resistance depends not only on the diameter and length of a wire but also on the material it is made of. Metals in general have a low resistance to the flow of electricity (for example, copper is commonly used in electrical wiring because it has a low resistance to current flow). Materials that have a high resistance are called insulators, while materials that have a low resistance and readily conduct electricity are called conductors.

Heat is generated when current flows through an area of high resistance. The tungsten filament in the light globe in Figure 1 has a much higher resistance to current flow than the wires in the circuit, so heat and light are generated.

The same process is used to generate heat for welding, except the area of high resistance is the electrical arc between the electrode and the work. The higher the current, the more heat that is generated.

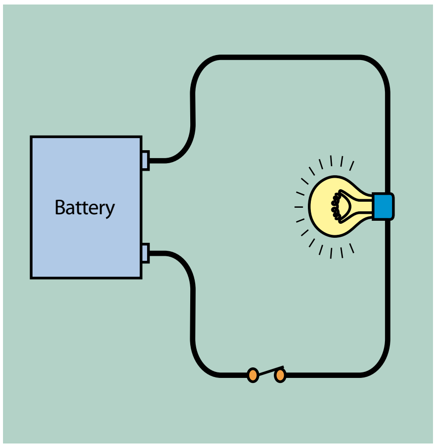


FIGURE 1 Closed electrical circuit

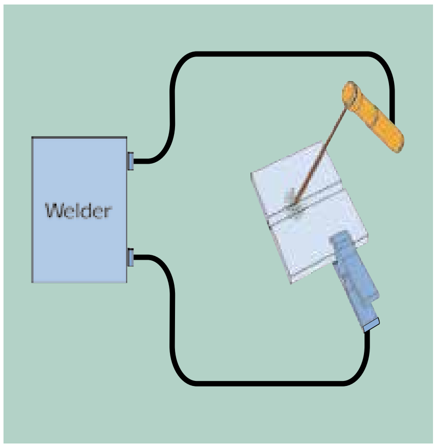


FIGURE 2 Basic welder circuit

Putting theory into practice

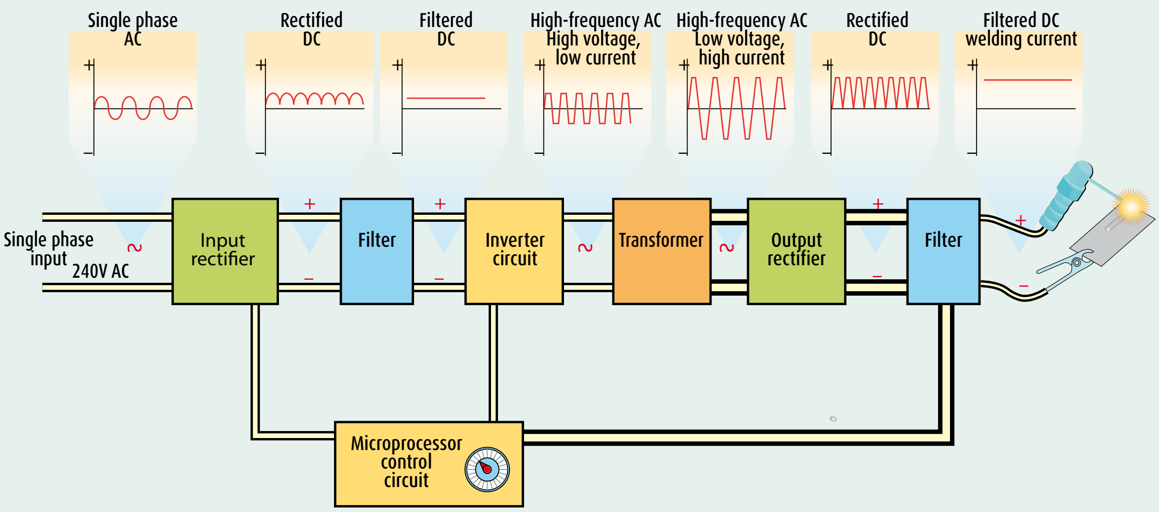
A welder operates on the same principle as the closed circuit in Figure 1. The switch is closed when the electrode tip touches the work (see Figure 2). The current flows through the arc between the electrode tip and the work, creating heat, and then flows back to the welder though the earth cable which is attached to the work.

The welder also reduces the mains electricity from 240 or 415 volts to a much safer level. The welder is basically an adjustable transformer which boosts current by lowering voltage. This high current will create enormous heat when it

Inverter welders – new kids on the block

Traditional heavyweight AC welders use a large transformer to drop the supply voltage and boost the current to a sufficient level for welding. Due to the lower supply frequency and the level of current output, a large amount of heat is generated, resulting in poor efficiency.
This is also the reason why the transformer is so large and heavy, as it needs to dissipate so much heat.
The inverter welder is a more complicated machine, and requires microprocessor control to produce DC welding current from a small package.
Here's how it works:
A DC supply cannot be simply passed through a transformer, as the transformer requires a changing current direction for it to operate, such as found with AC current. The 240 volts 50 hertz supply is passed through a rectifier, which 'chops off' the negative half of the waveform. Switching circuits boost the frequency of the supply to tens of thousands of hertz, far in excess of the supply frequency.
This can then be passed through a far smaller, more efficient transformer, which does not have to dissipate anywhere near the amount of heat generated by an older AC welder. The output of the transformer is then rectified and filtered into the welding current used at the electrode.

How inverter welders work



flows through an area with a high resistance.

The welding and earth cables both have a large diameter and can carry a high amount of current with little resistance. But when the current has to flow through the welding arc and into the work, it meets greater resistance and heat is created. The heat melts the parent metal which is then free to combine with filler metal and fuse across a joint.

AC or DC?

Current flowing from a battery as shown in Figure 1 is called direct current (DC) because it always flows in the same direction (Figure 3).

Older, heavy transformer-based welding units running from mains power use alternating current (AC), which means the current direction regularly changes from negative to positive (Figure 4). Australian supply voltage is regulated to a frequency of 50 Hertz, which means the current changes from positive to negative 50 times a second.

DC or direct current welders are more versatile than AC units and can handle a range of specialised welding tasks and consumables. DC current, just like the supply from a battery, does not change direction. Modern compact inverter-based welding units produce DC current, as well as engine-powered welders.

DC welders are more versatile as the polarity (negative or positive electrode) can be reversed to suit different situations, such as increasing metal penetration for thick steel or reducing it for thinner sections. Arcs are also easier to strike with a DC welder.

DC positive electrode

If the electrode holder is connected to the positive terminal and the work to the negative, the DC welder is set up for DC positive or reverse polarity welding (see Figure 5).

DC positive welding concentrates the heat at the electrode tip, producing a steadier arc and smooth metal transfer. It also creates a wide weld bead with relatively low penetration. Positive electrode is the most common DC welding method and is suited to out-of position welding such as overhead and vertical because of the strong arc force.

DC negative electrode

DC negative or straight polarity welding connects the electrode to the negative terminal and the work to the positive (see Figure 6). This welding set-up concentrates heat in the work, leading to a narrow, deeply penetrating weld. DC negative welding is more suited to welding in flat positions.

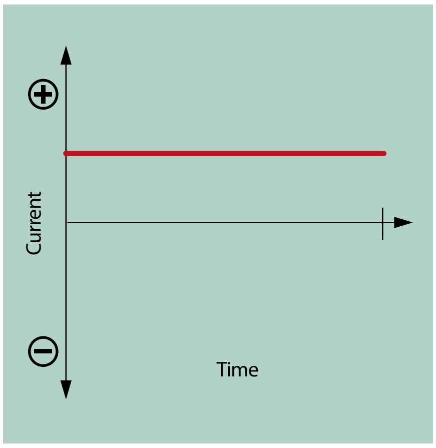


FIGURE 3 Direct current (DC)

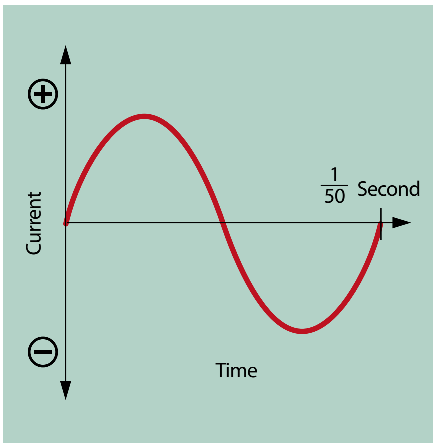


FIGURE 4 Alternating current (AC)

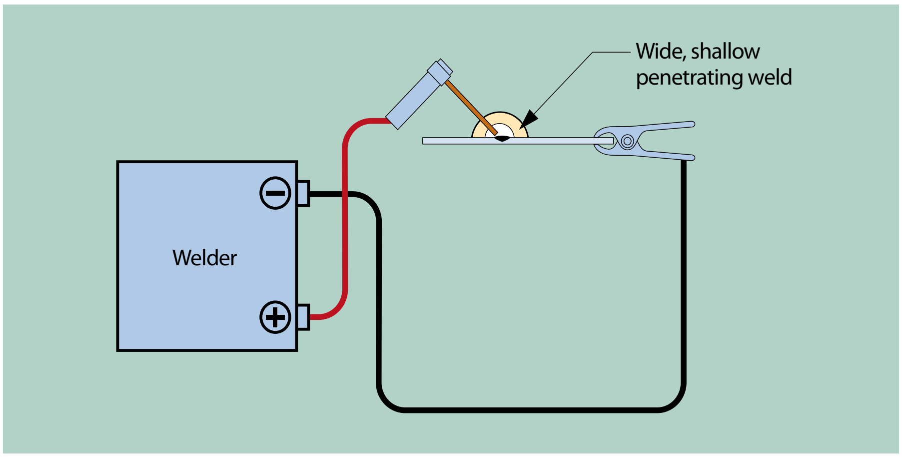


FIGURE 5 DC positive electrode welding

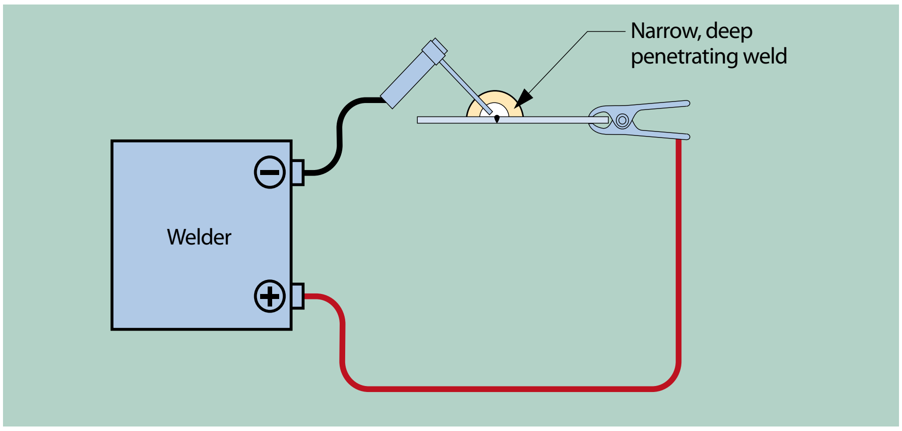


FIGURE 6 DC negative electrode welding

Excluding atmospheric gases

One aspect of welding which cannot be overlooked is shielding. Shielding is the process by which atmospheric gases such as oxygen and nitrogen are excluded from the weld pool.

A weld that is not shielded will become oxidised and porous and will not be able to handle a load without failing.

Shielding can take many forms but is most commonly applied as a gas which envelops the pool of molten weld metal. The gas can either be generated by vapourising a flux coating on a welding electrode, such as with stick welding, or by applying the gas directly to the weld from a compressed gas cylinder, such as with metal inert gas (MIG) or tungsten inert gas (TIG) welding. Oxyacetylene welding shields the weld using a gas flame, which burns up oxygen before it comes into contact with the weld.