

Alternating Current or Direct Current?

Dr Owen Williams – University of Wales TSD:



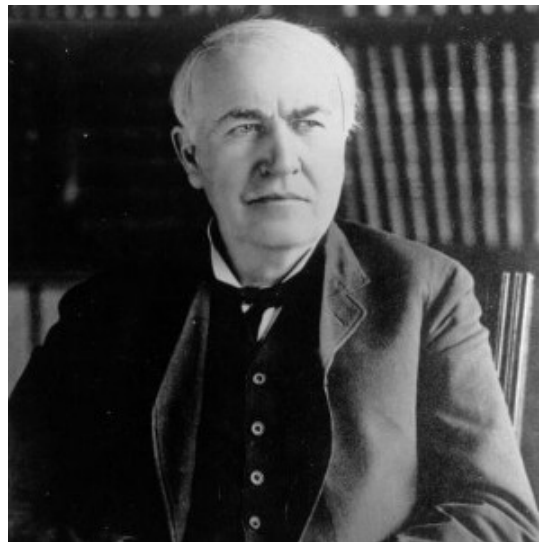
Not That!! https://youtu.be/n_GFN3a0yj0

The Historical Context...

Almost every home and business is wired for AC. However, this was not an overnight decision. In the late 1880s, a variety of inventions across the United States and Europe led to a full-scale battle between alternating current and direct current distribution.

In 1886, Ganz Works, an electric company located in Budapest, electrified all of Rome with AC. Thomas Edison, on the other hand, had constructed 121 DC power stations in the United States by 1887.

A turning point in the battle came when George Westinghouse, a famous industrialist from Pittsburgh, purchased Nikola Tesla's patents for AC motors and transmission the next year. AC vs. DC

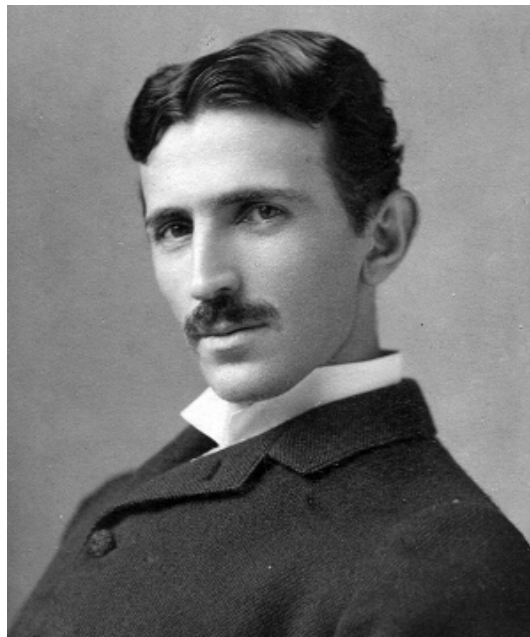


Thomas Edison

In the late 1800s, DC could not be easily converted to high voltages. As a result, Edison proposed a system of small, local power plants that would power individual neighbourhoods or city sections.

Power was distributed using three wires from the power plant: +110 volts, 0 volts, and -110 volts. Lights and motors could be connected between either the +110V or 110V socket and 0V (neutral). 110V allowed for some voltage drop between the plant and the load (home, office, etc.).

Even though the voltage drop across the power lines was accounted for, power plants needed to be located within 1 mile of the end user. This limitation made power distribution in rural areas extremely difficult, if not impossible.



Nikola Tesla

With Tesla's patents, Westinghouse worked to perfect the AC distribution system. Transformers provided an inexpensive method to step up the voltage of AC to several thousand volts and back down to usable levels. At higher voltages, the same power could be transmitted at much lower current, which meant less power lost due to resistance in the wires.

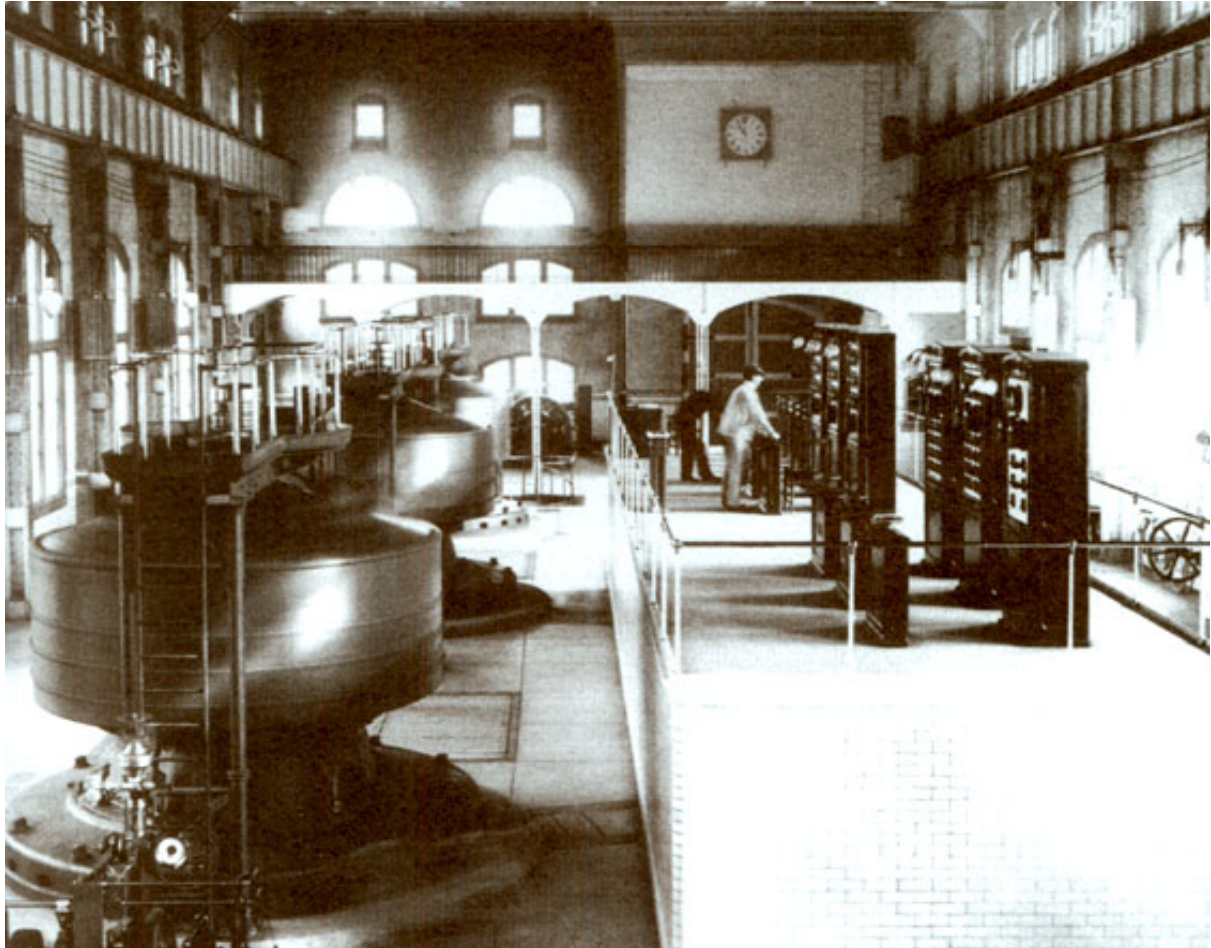
As a result, large power plants could be located many miles away and service a greater number of people and buildings.

Edison's Smear Campaign

Over the next few years, Edison ran a campaign to highly discourage the use of AC in the United States, which included lobbying state legislatures and spreading disinformation about AC. Edison also directed several technicians to publicly electrocute animals with AC in an attempt to show that AC was more dangerous than DC. In attempt to display these dangers, Harold P. Brown and Arthur Kennelly, employees of Edison, designed the first electric chair for the state of New York using AC.

The Rise of AC

In 1891, the International Electro-Technical Exhibition was held in Frankfurt, Germany and displayed the first long distance transmission of three-phase AC, which powered lights and motors at the exhibition. Several representatives from what would become General Electric were present and were subsequently impressed by the display. The following year, General Electric formed and began to invest in AC technology.



Edward Dean Adams Power Plant at Niagara Falls, 1896

Westinghouse won a contract in 1893 to build a hydroelectric dam to harness the power of Niagara Falls and transmit AC to Buffalo, NY. The project was completed on November 16, 1896 and AC power began to power industries in Buffalo. This milestone marked the decline of DC in the United States. While Europe would adopt an AC standard of 220-240 volts at 50 Hz, the standard in North America would become 120 volts at 60 Hz.

Alternating Current (AC).

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Alternating current describes the flow of charge that changes direction periodically. As a result, the voltage level also reverses along with the current. AC is used to deliver power to houses, office buildings, etc.

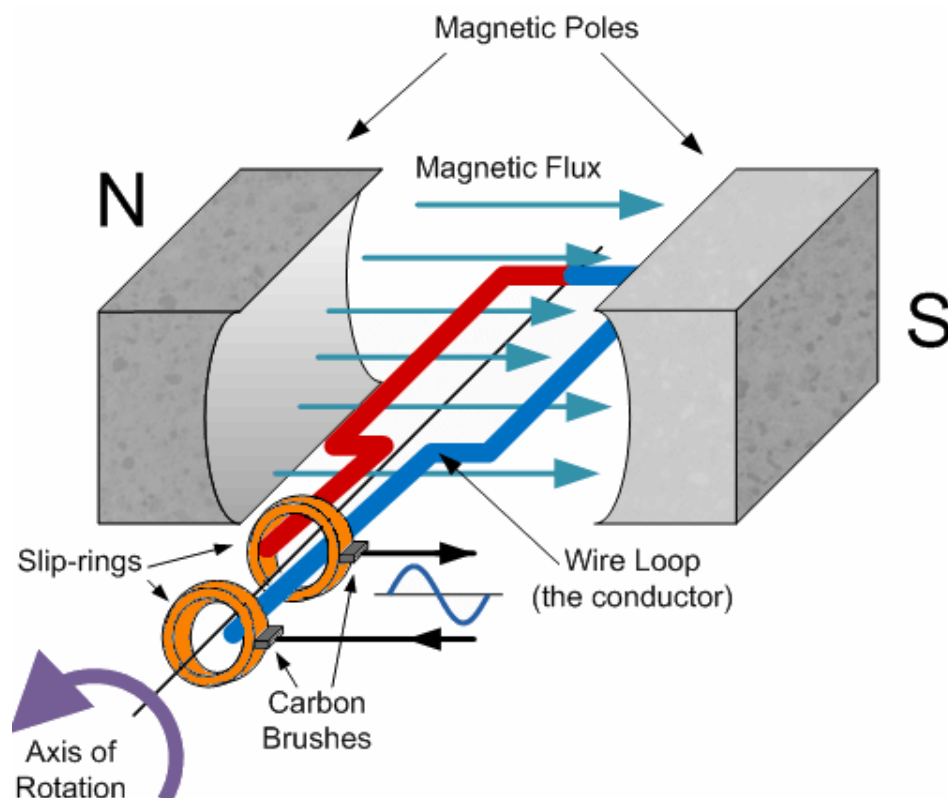
Generating AC

AC can be produced using a device called an *alternator*. This device is a special type of electrical generator designed to produce alternating current.

A loop of wire is spun inside of a magnetic field, which induces a current along the wire. The rotation of the wire can come from any number of means: a wind turbine, a steam turbine, flowing water, and so on. Because the wire spins and enters a different magnetic polarity periodically, the voltage and current alternates on the wire. Here is a short animation showing this principle:

<https://youtu.be/i-j-1j2gD28>

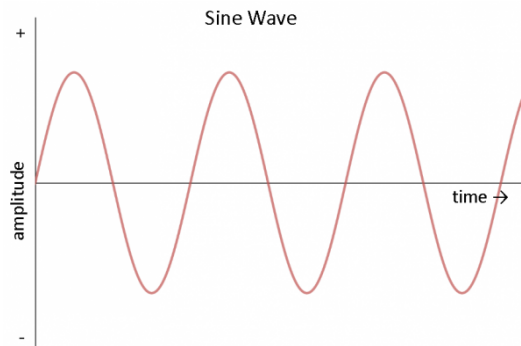
(Video credit: Khurram Tanvir)



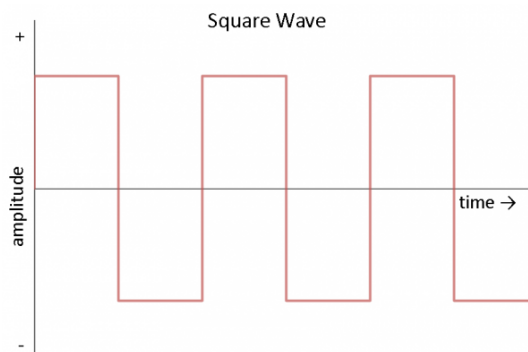
WAVEFORMS

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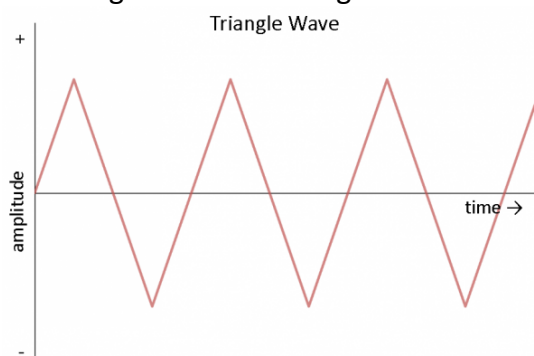
AC can come in a number of forms, as long as the voltage and current are alternating. If we hook up an oscilloscope to a circuit with AC and plot its voltage over time, we might see a number of different waveforms. The most common type of AC is the sine wave. The AC in most homes and offices have an oscillating voltage that produces a sine wave.



Other common forms of AC include the square wave and the triangle wave:



Square waves are often used in digital and switching electronics to test their operation.



Triangle waves are found in sound synthesis and are useful for testing linear electronics like amplifiers.

Describing a Sine Wave

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We often want to describe an AC waveform in mathematical terms. For this example, we will use the common sine wave. There are three parts to a sine wave: *amplitude, frequency, and phase*.

Looking at just voltage, we can describe a sine wave as the mathematical function:

$$V(t) = V_p \sin(2\pi ft + \phi)$$

$V(t)$ is our voltage as a function of time, which means that our voltage changes as time changes. The equation to the right of the equals sign describes how the voltage changes over time.

V_p is the *amplitude*. This describes the maximum voltage that our sine wave can reach in either direction, meaning that our voltage can be $+V_p$ volts, $-V_p$ volts, or somewhere in between.

The **$\sin()$** function indicates that our voltage will be in the form of a periodic sine wave, which is a smooth oscillation around 0V.

2π is a constant that converts the frequency from cycles (in hertz) to angular frequency (radians per second).

f describes the *frequency* of the sine wave.

The frequency tells how many times a particular wave form (in this case, one cycle of our sine wave - a rise and a fall) occurs within one second.

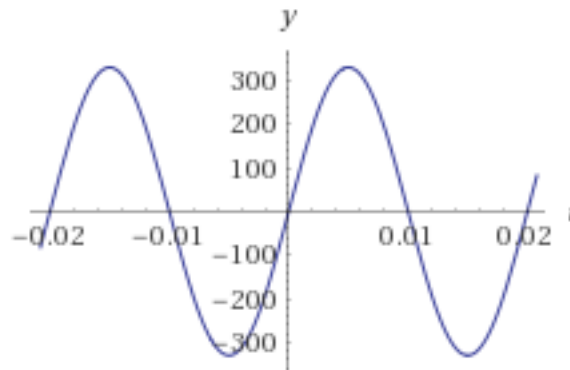
t is our independent variable: time (measured in seconds). As time varies, our waveform varies.

ϕ describes the *phase* of the sine wave. Phase is a measure of how shifted the waveform is with respect to time. It is often given as a number between 0 and 360 and measured in degrees. Because of the periodic nature of the sine wave, if the wave form is shifted by 360° it becomes the same waveform again, as if it was shifted by 0°. For simplicity, we will assume that phase is 0° for the rest of this tutorial.

We can turn to our trusty wall socket for a good example of how an AC waveform works. In the UK, the power provided to our homes is AC with about 330V zero-to-peak (amplitude) and 50Hz (frequency). We can plug these numbers into our formula to get the equation (remember that we are assuming our phase is 0):

$$V(t) = 330 \sin(2\pi 50t)$$

We can use our handy graphing tool to see what this looks like:
(Wolfram Alpha)



Notice that, as we predicted, the voltage rises up to 330V and down to -330V periodically. Additionally, 50 cycles of the sine wave occur every second.

If we were to measure the voltage in wall sockets with an oscilloscope, this is what we would see (**WARNING:** do not attempt to measure the voltage in an outlet with an oscilloscope! This will likely damage the equipment).

NOTE: You might have heard that AC voltage in the UK is 240V. This is also correct. How?

When talking about AC (since the voltage changes constantly), it is often easier to use an average or mean. To accomplish that, we use a method called "Root mean squared." (RMS).

It is often helpful to use the RMS value for AC when you want to calculate electrical power. Even though, in our example, we had the voltage varying from -330V to 330V, the root mean square is 240V RMS.

The easiest way to look at this is:

$$V_{RMS} = \frac{1}{\sqrt{2}} \times V_{Peak}$$

$$V_{RMS} = 0.707 \times V_{Peak}$$

$$V_{RMS} = 0.707 \times 330$$

$$V_{RMS} = 233.31$$

The UK mains supply is about **230 volts AC**. It used to be 240V, but it has been brought down in a stage in the transition to 220V (like the rest of Europe).

Applications

Home and most industrial outlets are almost always AC. This is because generating and transporting AC across long distances is relatively easy. At high voltages (over 110kV), less energy is lost in electrical power transmission. Higher voltages mean lower currents, and lower currents mean less heat generated in the power line due to resistance. AC can be converted to and from high voltages easily using transformers.

AC is also capable of powering electric motors. Motors and generators are the exact same device, but motors convert electrical energy into mechanical energy (if the shaft on a motor is spun, a voltage is generated at the terminals!). This is useful for many large appliances like dishwashers, refrigerators, and so on, which run on AC.

Direct Current (DC).

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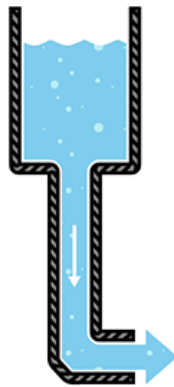
Direct current is a bit easier to understand than alternating current. Rather than oscillating back and forth, DC provides a constant voltage or current.

Generating DC

DC can be generated in a number of ways:

- An AC generator equipped with a device called a "commutator" can produce direct current
- Use of a device called a "rectifier" that converts AC to DC
- Batteries provide DC, which is generated from a chemical reaction inside of the battery
-

Using our water analogy again, DC is similar to a tank of water with a hose at the end.



The tank can only push water one way: out the hose. Similar to our DC-producing battery, once the tank is empty, water no longer flows through the pipes.

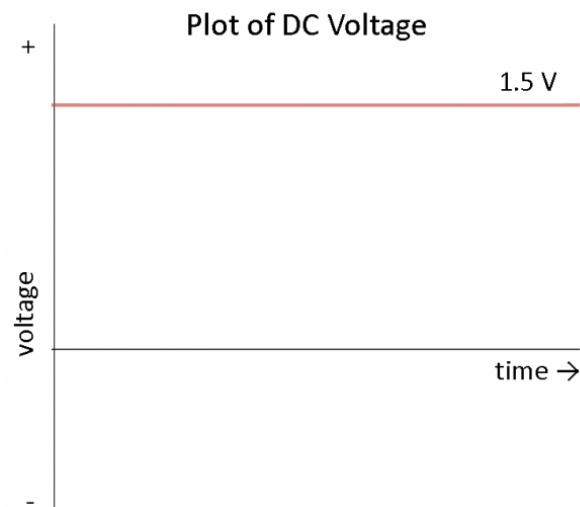
Describing DC Current.

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DC is defined as the "unidirectional" flow of current; current only flows in one direction. Voltage and current can vary over time so long as the direction of flow does not change. To simplify things, we will assume that voltage is a constant. For example, we assume that a AA battery provides 1.5V, which can be described in mathematical terms as:

$$V(t) = 1.5V$$

If we plot this over time, we see a constant voltage:



What does this mean? It means that we can count on most DC sources to provide a constant voltage over time. In reality, a battery will slowly lose its charge, meaning that the voltage will drop as the battery is used. For most purposes, we can assume that the voltage is constant.

Applications

Almost all normal electronics run on DC. Everything that runs off of a battery, plugs in to the wall with an AC adapter, or uses a USB cable for power relies on DC. Examples of DC electronics include:

- Mobile phones
- Most computer or electronic circuit boards
- Flat-screen TVs (AC goes into the TV, which is converted to DC)
- Flashlights
- Hybrid and electric vehicles (mostly)

Which brings us nicely onto the next topic of interest...

Domestic Electrical Safety.

Dr Owen Williams – University of Wales TSD:



What is the Earth lead for? What is it connected to?

It is pretty well universally true that any electrical socket outlet in a domestic property intended to be used to plug in a variety of consumer appliances will have 3 connections;

Line(live), Neutral & Earth.

It's becoming standard practice in electrical wiring installations to call the "hot" wire the "Line" now instead of the "Live" so I will stick to that so we can get used to it if you want to read further, e.g. Wiring Regulations Handbooks, etc.

The power for the appliance is supplied via the Line and Neutral connections. The current will, under no fault conditions, be the same. If a 10 Amp supply current is flowing through the Line conductor, then 10 Amps is also flowing through the Neutral conductor (for that one socket/appliance).

The purpose of the third connection, the Earth conductor, is ONLY for safety. Specifically, to reduce or eliminate the possibility of a harmful electric shock AND the possibility of an electrically ignited fire.

Many domestic electrical appliances have a case made of metal, this includes items like a convector heater, a fridge, a microwave oven and so on. The case is metal for structural/design reasons (not electrical reasons). For example, a plastic cased convector heater might be a very silly and dangerous idea (think about it!). IF we have a metal case it is possible, in the event of an internal fault, for the case to become electrically live and thus impart an electric shock, possibly fatal, to anyone touching it.

We therefore connect the metal case to the earth wire of the socket using one separate core of the 3-core flex. The appliance is then "earthed".

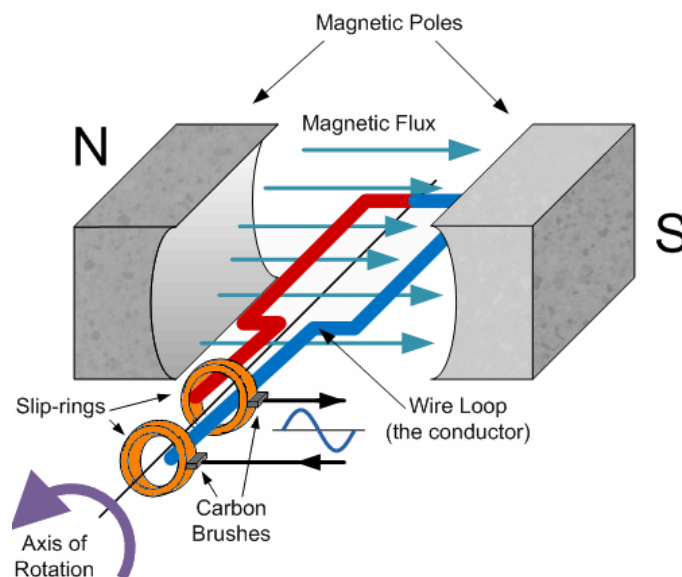
Consider now what happens with a faulty appliance. Some electrical current due to the internal fault can flow through the earth wire of the electrical installation back to the source (e.g. Since earth and neutral are connected at the substation). We can detect this current in the earth wire as a "fault condition" and trip the circuit thus removing the supply and alerting the user to the possibility of a fault. In modern type installations which include an Earth Leakage Circuit Breaker (aka RCD or RCCD) the detection of earth fault current flowing in the earth wire is very fast ($< 40\text{ms}$).

You should under no circumstances attempt to connect a load of any kind between a line conductor and an earth conductor. Neither should you attempt to connect a bulb or anything else across the neutral and earth conductor. In fact, it can be dangerous to even use a cheap multimeter to measure voltages on your domestic electrical installation wires (they are not rated for the impulse voltages that may appear on the mains sometimes). By all means read about domestic electrical wiring systems but do not experiment on them!

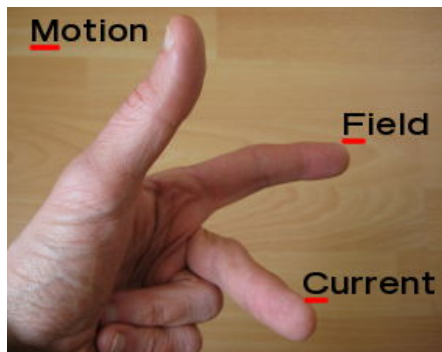
The Electric Motor.

Dr Owen Williams – University of Wales TSD:

The link between electricity, magnetism, and movement was originally discovered in 1820 by French physicist **André-Marie Ampère** (1775–1867) and it's the basic science behind an electric motor. But if we want to turn this amazing scientific discovery into a more practical bit of technology to power our electric cars and toothbrushes, we've got to take it a little bit further. The inventors who did that were Englishmen **Michael Faraday** (1791–1867) and **William Sturgeon** (1783–1850) and American **Joseph Henry** (1797–1878). Here's how they arrived at their brilliant invention.



Suppose we bend our wire into a squarish, U-shaped loop so there are effectively two parallel wires running through the magnetic field. One of them takes the electric current away from us through the wire and the other one brings the current back again. Because the current flows in opposite directions in the wires, Fleming's Left-Hand Rule tells us the two wires will move in opposite directions. In other words, when we switch on the electricity, one of the wires will move upward and the other will move downward.



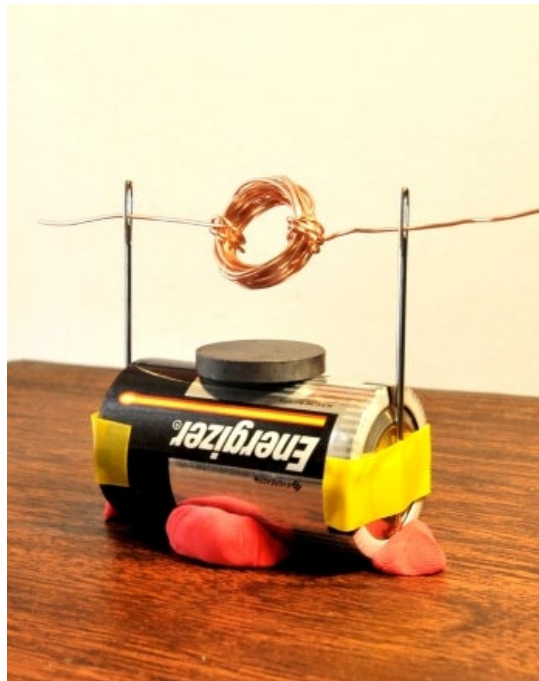
You can figure out the direction in which the wire will jump using a handy mnemonic (memory aid) called **Fleming's Left-Hand Rule** (sometimes called the Motor Rule).

Hold out the thumb, first finger, and second finger of your left hand so all three are at right angles. If you point the seCond finger in the direction of the **C**urrent (which flows from the positive to the negative terminal of the battery), and the **F**irst finger in the direction of the **F**ield (which flows from the North to the South pole of the magnet), your thuMb will show the direction in which the wire **M**oves.

That's...

- **F**irst finger = **F**ield
- **S**e**C**ond finger = **C**urrent
- **T**hu**M**b = **M**otion

If the coil of wire could carry on moving like this, it would rotate continuously—and we'd be well on the way to making an electric motor. But that can't happen with our present setup: the wires will quickly tangle up. Not only that, but if the coil could rotate far enough, something else would happen. Once the coil reached the vertical position, it would flip over, so the electric current would be flowing through it the opposite way. Now the forces on each side of the coil would reverse. Instead of rotating continuously in the same direction, it would move back in the direction it had just come! Imagine an electric train with a motor like this: it would keep shuffling back and forward on the spot without ever actually going anywhere.



There are two ways to overcome this problem. One is to use a kind of electric current that periodically reverses direction, which is known as an alternating current (AC). In the kind of small, battery-powered motors we use around the home, a better solution is to add a component called a commutator to the ends of the coil. (Don't worry about the meaningless technical name: this slightly old-fashioned word "commutation" is a bit like the word "commute".

It simply means to change back and forth in the same way that commute means to travel back and forth.) In its simplest form, the commutator is a metal ring divided into two separate halves and its job is to reverse the electric current in the coil each time the coil rotates through half a turn. One end of the coil is attached to each half of the commutator. The electric current from the battery connects to the motor's electric terminals.

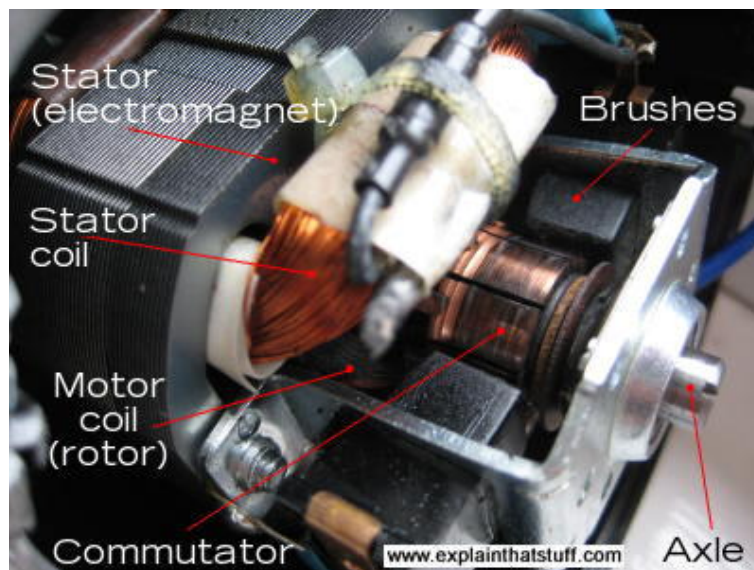
These feed electric power into the commutator through a pair of loose connectors called brushes, made either from pieces of graphite (soft carbon similar to pencil "lead") or thin lengths of springy metal, which (as the name suggests) "brush" against the commutator. With the commutator in place, when electricity flows through the circuit, the coil will rotate continually in the same direction.

The Universal Motor.

Dr Owen Williams – University of Wales TSD:

DC motors like this are great for battery-powered toys (things like model trains, radio-controlled cars, or electric shavers), but you don't find them in many household appliances. Small appliances (things like coffee grinders or electric food blenders) tend to use what are called **universal motors**, which can be powered by either AC or DC. Unlike a simple DC motor, a universal motor has an electromagnet, instead of a permanent magnet, and it takes its power from the DC or AC power you feed in:

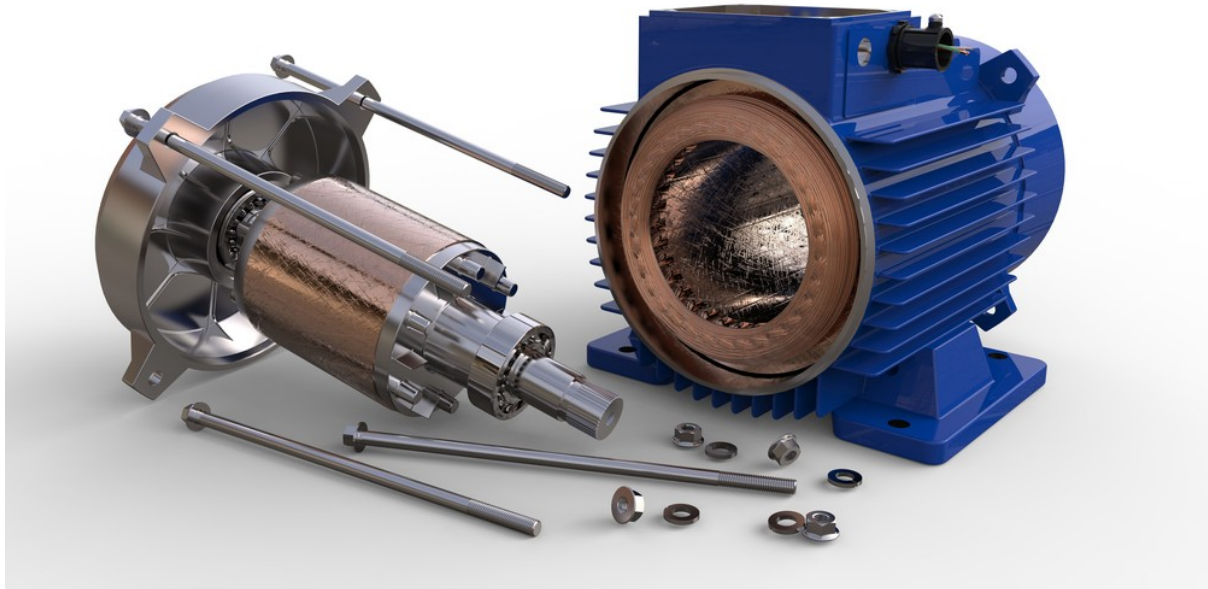
- When you feed in DC, the electromagnet works like a conventional permanent magnet and produces a magnetic field that's always pointing in the same direction. The commutator reverses the coil current every time the coil flips over, just like in a simple DC motor, so the coil always spins in the same direction.
- When you feed in AC, however, the current flowing through the electromagnet and the current flowing through the coil *both* reverse, exactly in step, so the force on the coil is always in the same direction and the motor always spins either clockwise or counter-clockwise. What about the commutator? The frequency of the current changes much faster than the motor rotates and, because the field and the current are always in step, it doesn't actually matter what position the commutator is in at any given moment.



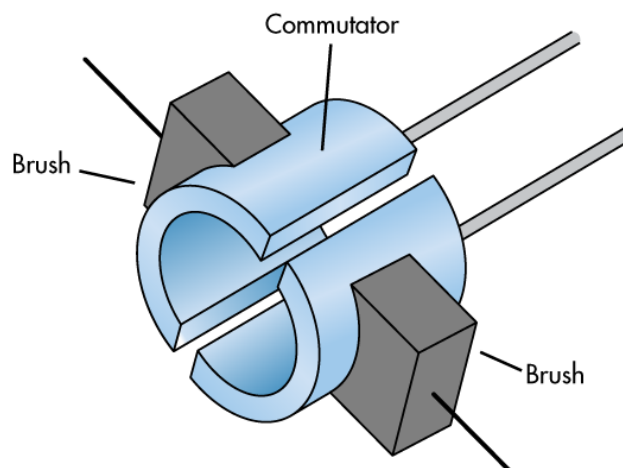
Brushed or Brushless?

Dr Owen Williams – University of Wales TSD:

Brushed DC Motors



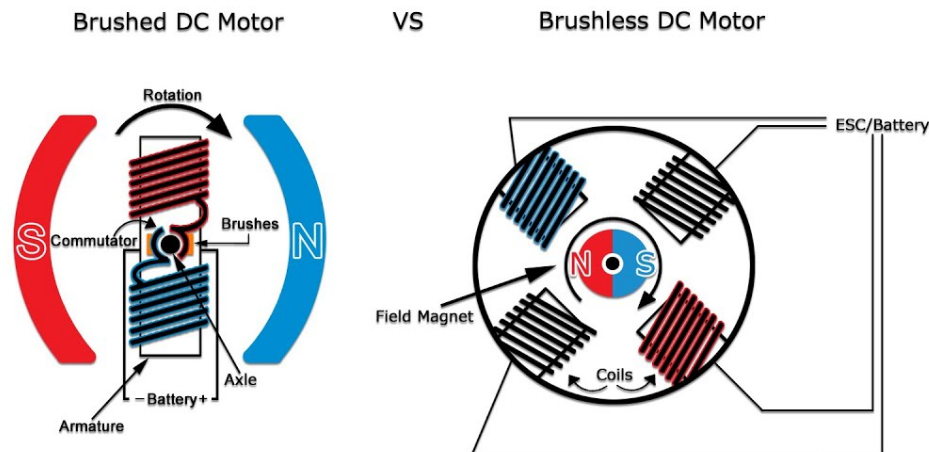
The motor's properties are determined by the material it's made of, the number of coils wound around it, and the density of the coils. The armature or rotor is an electromagnet, and the field magnet is a permanent magnet. The commutator is a split-ring device wrapped around the axle that physically contacts the brushes, which are connected to opposite poles of the power source.



The brushes charge the commutator inversely in polarity to the permanent magnet, in turn causing the armature to rotate. The rotation's direction, clockwise and/or counter clockwise, can be reversed easily by reversing the polarity of the brushes, i.e., reversing the leads on the battery.

Brushless DC Motors

In terms of differences, the name is a dead giveaway. BLDC motors lack brushes. But their design differences are bit more sophisticated. A BLDC motor mounts its permanent magnets, usually four or more, around the perimeter of the rotor in a cross pattern.



Efficiency is a primary selling feature for BLDC motors. Because the rotor is the sole bearer of the magnets, it requires no power, i.e., no connections, no commutator, and no brushes.

In place of these, the motor employs control circuitry. To detect where the rotor is at certain times, BLDC motors employ, along with controllers, rotary encoders or a Hall sensor

BLDC motors are synchronous motors, which means their rotors and stators turn at the same frequency. They come in single-, dual-, and tri-phase configurations

To Brush

When it comes to a loosely defined range of basic applications, one could use either a brush or brushless motor. And like any comparable and competing technologies, brush and brushless motors have their pros and cons.

On the pro side, brush motors are generally inexpensive and reliable. They also offer simple two-wire control and require fairly simple control or no control at all in fixed-speed designs. If the brushes are replaceable, these motors also boast a somewhat extended operational life. And because they need few external components or no external components at all, brush motors tend to handle rough environments reliably.

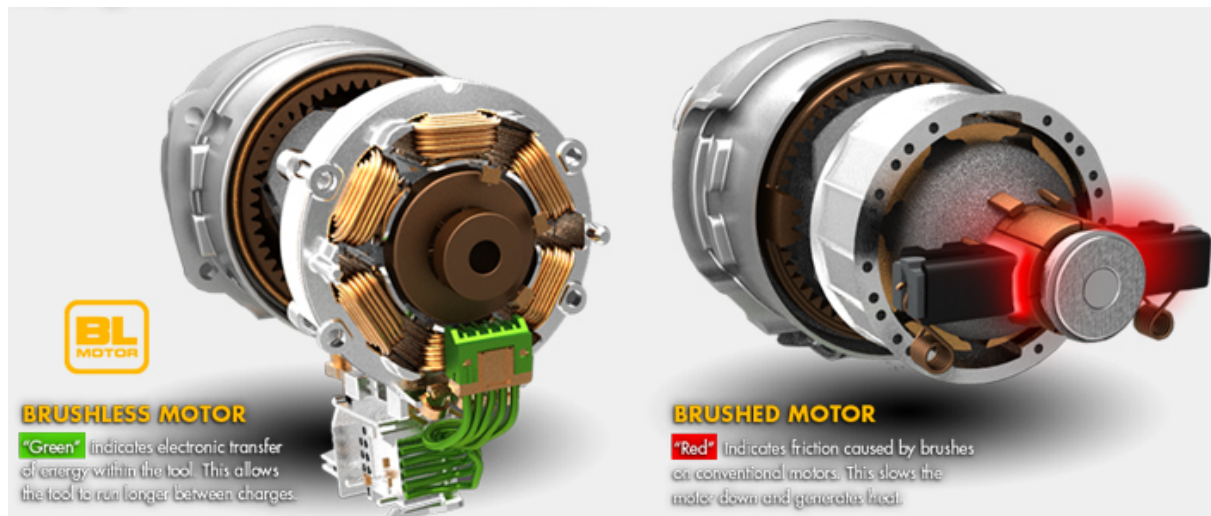
For the downside, brush motors require periodic maintenance as brushes must be cleaned and replaced for continued operation, ruling them out for critical designs. Also, if high torque is required, brush motors fall a bit flat. As speed increases, brush friction increases and viable torque decreases.

However, torque may not be an issue in some applications and could actually be desirable. For example, electric toothbrushes require higher speeds with decreasing torque, which is good for the brush and your teeth and gums.

Other disadvantages of brush dc motors include inadequate heat dissipation caused by the rotor limitations, high rotor inertia, low speed range due to limitations imposed by the brushes, and electromagnetic interference (EMI) generated by brush arcing.

Or Not to Brush...

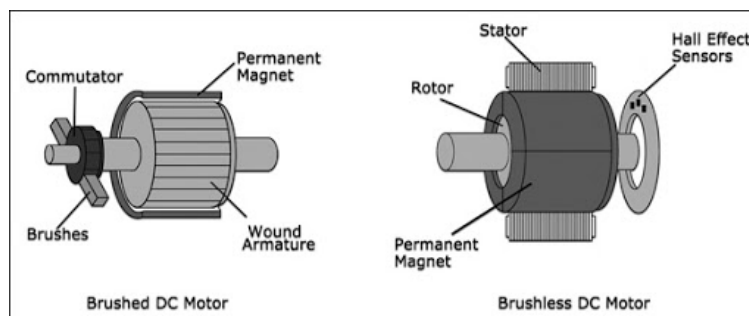
BLDC motors have a number of advantages over their brush brothers. For one, they're more accurate in positioning apps, relying on Hall effect position sensors for commutation.



They also require less and sometimes no maintenance due to the lack of brushes. They beat brush motors in the speed/torque trade-off with their ability to maintain or increase torque at various speeds.

Importantly, there's no power loss across brushes, making the components significantly more efficient. Other BLDC pros include high output power, small size, better heat dissipation, higher speed ranges, and low-noise (mechanical and electrical) operation.

Nothing is perfect, though. BLDC motors have a higher cost of construction. They also require control strategies that can be both complex and expensive. And, they require a controller that can cost almost as much as if not more than the BLDC motor it governs.



Hybrid and Electric Motors.

Dr Owen Williams – University of Wales TSD:

Curtis 1239e-8521 HPEVS AC-51 Brushless AC Motor Kit - 144 Volt (\$5,000)

https://www.evwest.com/catalog/product_info.php?cPath=8&products_id=172

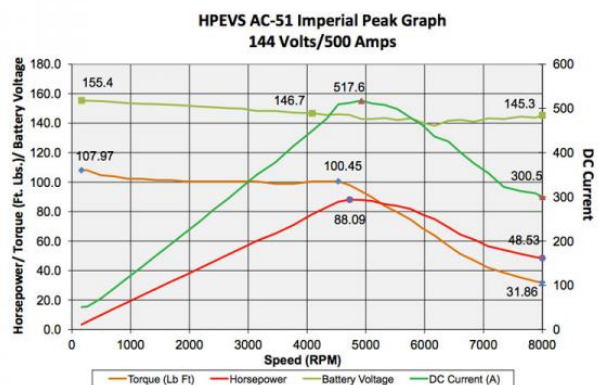
The AC51 is an AC motor that operates at a higher 144-170 volts. It can draw up to 500 amps producing up to 88 HP and 108 ft-lbs of torque. This kit works very well in a medium sized cars & lightweight vehicle and has a more horsepower heavy power curve than the AC50. Features regenerative braking and idle function as well. This is basically the high-performance version of the well proven AC50.

This kit includes:

- HPEVS AC51 Motor
- Curtis 1239e-8521 Controller
- 35 Pin Connector and Wire Harness
- Gigavac GV200-MA Contactor
- 12 Volt HV Relay
- Precharge Resistor
- Curtis 840 Dash Gauge
- SPST Menu Button
- SPST Mode Switch



Motor Face: B-Face
Motor Diameter: 8.980 Inches
Motor Case Length: 13.798 Inches
Motor Shaft Length End to End: 17.5 Inches
Motor Type: AC Induction
Brushes: No
Interpoles: No
Weight: 52 Kg (115 lbs)
Max Voltage Input: 171
Terminal Stud Size: 3/8 Inch
Integrated Sensors: Encoder
Rated Torque: 108 Lb Ft
Rated Power: 88 HP
Continuous RPM: 5,000
Max RPM: 10,000
RPM Sensor: No
Drive End Shaft: 1 1/8 Inch With 1/4 Inch Keyway
Acc/Commutator End Shaft: Optional 7/8 Inch With 3/16 Keyway
Max Efficiency: 88%
Thermal Cooling: Internal Fan
Max Temperature: 180 Degrees Celsius (356 Degrees Fahrenheit)
Matching Controller Included In Price: [1239-8501 Curtis Controller](#)



HPEVS Curtis 1239e-8521 144V 500 AMP Controller (\$2,740)

Curtis 1239-8501 AC controller that operates at 120-170V. It can draw up to 500A producing up to 88HP and 108ft-lbs of torque. This kit works very well in a medium sized cars and lightweight vehicles. Features regenerative braking and idle function as well. At a modest 144 volts it makes a safer low voltage system that will give you lots of reliable EV miles. Available with after-market Chill Plate adapter that allows for liquid cooling.

Max Current 500 Amps With Liquid Cooling (2 Min. Max)

Rated Power: 65 KW (88HP)

Input Voltage 120-170 Volts

Length: 10.82 Inch (275mm)

Width: 9.14 Inch (232mm)

Height: 3.15 Inch (80mm)

Weight: 5.45 Kg, 12 Lbs

Adjustable Max Output Voltage: 144



Switching Frequency: N/A

Brake Input Overrides: Yes

Error Output Warning Indicator: Yes

Precharge Circuit: Included

Computer Interface: Ethernet Port

Data Logging Capabilities: Yes

Tach Output: Yes 1, 2, 4, 6, 8 Pulses

Limp home Mode: Yes, Controller Will Derate To Keep Pack Above Minimal Battery Voltage

Firmware Upgradable: Yes

Internal Contactor: No

Thermal Derating: Yes, Derates After Temperature Gets Above 80 Degrees Celsius (176 Degrees Fahrenheit)

Reverse Capability: Yes

Adjustable Acceleration (Slew Rate): Yes

Idle Function: Yes, 500-1500 RPM (Modern Vehicles Idle from 600-800 RPM)

Programmable Inputs: Yes

Programmable Outputs: Yes

Terminal Stud Size: 3/8 Inch

RPM Sensor: Internal

Max Efficiency: 88%

Thermal Cooling: Yes, Chill Plate Sold Separately

Warranty Period: 1 Year

AM Racing AMR 250-90 Single AC Motor - Liquid Cooled, Permanent Magnet - Remy Cartridge (\$9,288)

This AM Racing motor is based on the very proven Remy 250-90 cartridge rotor using their HVH technology. (High Voltage Hairpin) This high efficiency permanent magnet motor is housed in a billet aluminium case with an integrated oil pump, and water/glycol heat exchanger. Mainly used in race applications, this motor is designed for long life use, and is perfectly suited for high output daily driving applications. Can be used in conjunction with the Rhinehart 100kW or 150kW motor controller/inverter.

Motor Diameter: 10.5 Inches
Motor Case Length: 11.25 Inches
Motor Shaft Length End to End: 12.25 Inches
Motor Type: Brushless Permanent Magnet
Brushes: No

Weight: 150 lbs.
Max Voltage Input: 360 Volts
Integrated Sensors: Encoder, temperature
Peak Torque: 280 Lb Ft Peak (w/150kW controller)
Peak Power: 210 HP Peak (w/150kW controller)
Max RPM: 10,000
Drive End Shaft: 32 spline 35.5 mm
Thermal Cooling: Internal oil pump with water heat exchange
Warranty Period: 1 Year



Cascadia Rinehart PM150DX/DZ 150KW AC Motor Controller (\$9,360)

The Rinehart Motion Systems (RMS) AC Traction Controllers are designed for on and off-road Electric (EV) or Hybrid Electric (HEV) applications. The PM-Series family is typically the lightest and smallest inverter for its power due to its high heat flux thermal design approach. Used in automotive, commercial vehicles, motorsports and military vehicle traction applications.

PM150DX - 450Arms continuous, 160 - 360VDC

PM150DZ - 250Arms continuous, 300 - 720VDC

Motor Controls:

AC Induction and Permanent Magnet motor control algorithms.

Electric Motors Supported by the RMS Traction Inverter:

Siemens/Ford Ranger Induction Motor

Remy HVH 250

Remy HVH410

MES-DEA 200-250 Induction Motor

EVO AF-140 4T

EVO AF-140 3T

EVO AF-130 3T

EVO AF-230 6T/ AF-130 6T

EVO AF-130 3T 5x Resolver

EVO AF-130 6T 5x Resolver

EVO AF 130-5T

EVO AF-140 4T 1/2 Stack

Yasa 750 PM Motor

Siemens 1PV5135-4WS28

Siemens 1PV5135-4WS14

Parker PM Motor

Remy HVH250HT Motor (In Development)

EVO AF-140-12 PM Motor

MES Induction motor

UQM-75 Motor

EMRAX PM Motor

Yasa 400 PM Motor w/ sin/cos encoder

Remy HVH410-150S



Electric Vehicle Kits.

Dr Owen Williams – University of Wales TSD:

Toyota MR2 EV Conversion Kit, Regen Brakes, AC Motor 1991-1999



The EV West Toyota MR2 Starter Kit components were carefully picked out to be the best available for this vehicle. Perfect for those looking for a professional fit and finish on the drive components but are willing to build and install their own battery system.

This kit comes with your AC motor with regenerative braking, programmable controller, high voltage charger, bell housing adapter plate, flywheel coupler, motor controller liquid cooling plate, coolant pump, radiator, state of charge instrumentation, throttle controller, and DC/DC convertor.

After mounting this kit, the only thing left is to add a battery system, including cables, fuses, and contactor box, and you are ready to drive your Toyota MR2 on all electric drive.

This kit contains the following:

Motor: [HPEVS AC-50](#)

Controller: [Curtis 1238 650 Amp, 96 Volt](#)

Instrumentation: [Xantrex Link Pro](#)

Shunt: [Deltec 600 Amp](#)

Transmission Adapter Kit: [Cast Aluminum](#)

Charger: [Elcon PFC2500](#)

J1772 Charge: [Yes, J1772 Inlet, and Controller](#)

Chill Plate: [EV West](#)

Cooling System: [EV West](#)

Throttle Control: [Toyota Prius Hall Effect](#)

DC/DC Converter: [SEVCON DC/DC 300W Converter](#)

https://www.youtube.com/watch?time_continue=44&v=BmDyK4Dyu-E&feature=emb_logo