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Converting Starters From 6 Volts to 12 Volts

Many automobiles, trucks, tractors and equipment that were manufactured in the first half of the 20th century were built using a 6-volt electrical system. A large number of those have since been converted to 12 volts—usually to solve a slow-cranking problem. Too often, customers are told that they can use the original starter with 12 volts. Nothing could be further from the truth. The fact is that cranking a 6-volt starter with 12 volts wreaks havoc with designed torque and armature speed. We can prove this using Ohm's Law and Watt's Law.

It's The Law

Ohm's Law is a formula that is used to calculate volts, amperes and resistance (expressed in ohms). If any two of the values are known, the third can be calculated (*see Figure 1*).

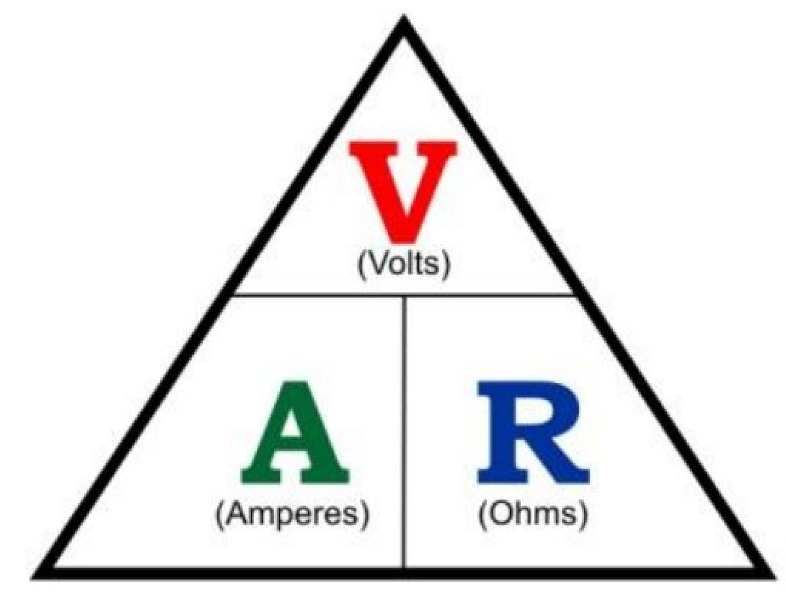
Watt's Law is a formula that is used to calculate watts, amperes and volts. As with Ohm's Law, if any two of the values are known, the third can be calculated (*see Figure 1*). A *watt* is a unit of power. More watts means more power.

When increasing from 6 volts to 12 volts, by using Ohm's Law, we see that the starter amperage doubles if the resistance in the starter stays the same. Remember Voltage = Amps x Ohms.

For example, a Delco 1109611 starter used on the Farmall Cub tractor from 1940 to 1964 will draw 60 amps free spinning on 5.7 volts by the original Delco specification. Using Watt's Law, 60 amps at 5.7 volts produces 342 watts of power. If the voltage is doubled to 11.4 volts, it doubles the amperage to 120 amps (if the resistance remains the same). Watt's Law now shows that the starter is producing 1368 watts of power. The power developed has just quadrupled. The pinion will hit the ring gear with ***four times the force it was designed to handle***.

Damaged pinions, cracked ring gears, broken DE housings, or bent armature shafts can result when

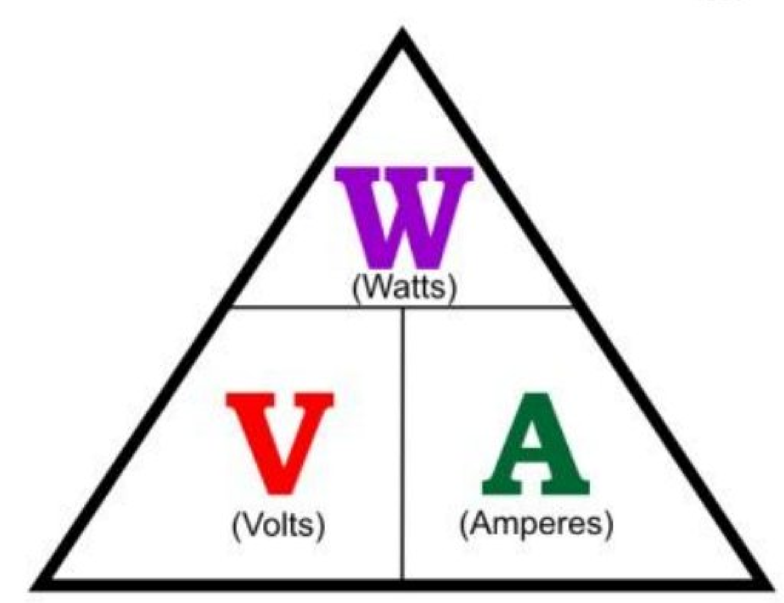
Ohm's Law Triangle[1]



To use the triangle: Cover over the value that you want to calculate and perform the operation shown on the other two values.

Example: To calculate amps, cover over the A. This shows V divided by R equals A.

Watt's Law Triangle[1]



To use the triangle: Cover over the value that you want to calculate and perform the operation shown on the other two values.

Example: To calculate watts, cover over the W. This shows A multiplied by V equals W.

Figure 1—Ohm's Law and Watt's Law

you quadruple the impact force of the pinion striking the ring gear. In addition, armature speeds can increase to the point of throwing commutator bars and hairpins - destroying the armature. You may get away with it for a while, but long term use of a 6-volt starter in a 12-volt system is like playing Russian roulette. Eventually, something is going to break. Why take the chance? It does not take much effort to convert any 6-volt starter to 12 volts. Because most of the resistance in the starter circuit is in the field coils, you simply have to change the field coils (and the electric solenoid if it has one).

While some 6V-to-12V conversion coils are available, many are not, including the 1109611 mentioned earlier. If you find yourself trying to convert a starter for which no conversion coils are available, it does not mean you cannot do the conversion. It all depends on how the original 6-volt coils are configured. Typically, most 6-volt starters used either a two-coil parallel configuration (*see Figure 2*) or a four-coil series-parallel configuration (*see Figure 3)*. With a little patience, you can convert these coils yourself using tools and parts you already have in your shop. This is assuming that the original field coils are serviceable.

By The Numbers

Using Ohm's Law you can calculate the resistance in the Farmall Cub starter as it is being run in a free spin test.

$$5.7\ Volts\ = 60\ Amps\ X\ .095\ Ohms$$

We'll explain later why the resistance in any starter decreases as the speed at which the armature spins increases. And we'll explain why most of the .095 ohms of resistance that was calculated from the free spin test is actually in the field coils. For simplicity's sake, we'll say that all of the resistance is in the field coils. While this will slightly exaggerate the calculations it does not affect the outcome. Remember, the original field coils in this starter are connected in parallel.

- When field coils are connected in *parallel*, the **total circuit resistance** is less than the lowest individual coil's resistance. This is why the total resistance calculated above is .095 ohms, even when each individual coil is .190 ohms (see *Footnote 2* for calculations)
- When field coils are connected in *series*, the **total circuit resistance** is the sum of each coil's resistance added together.

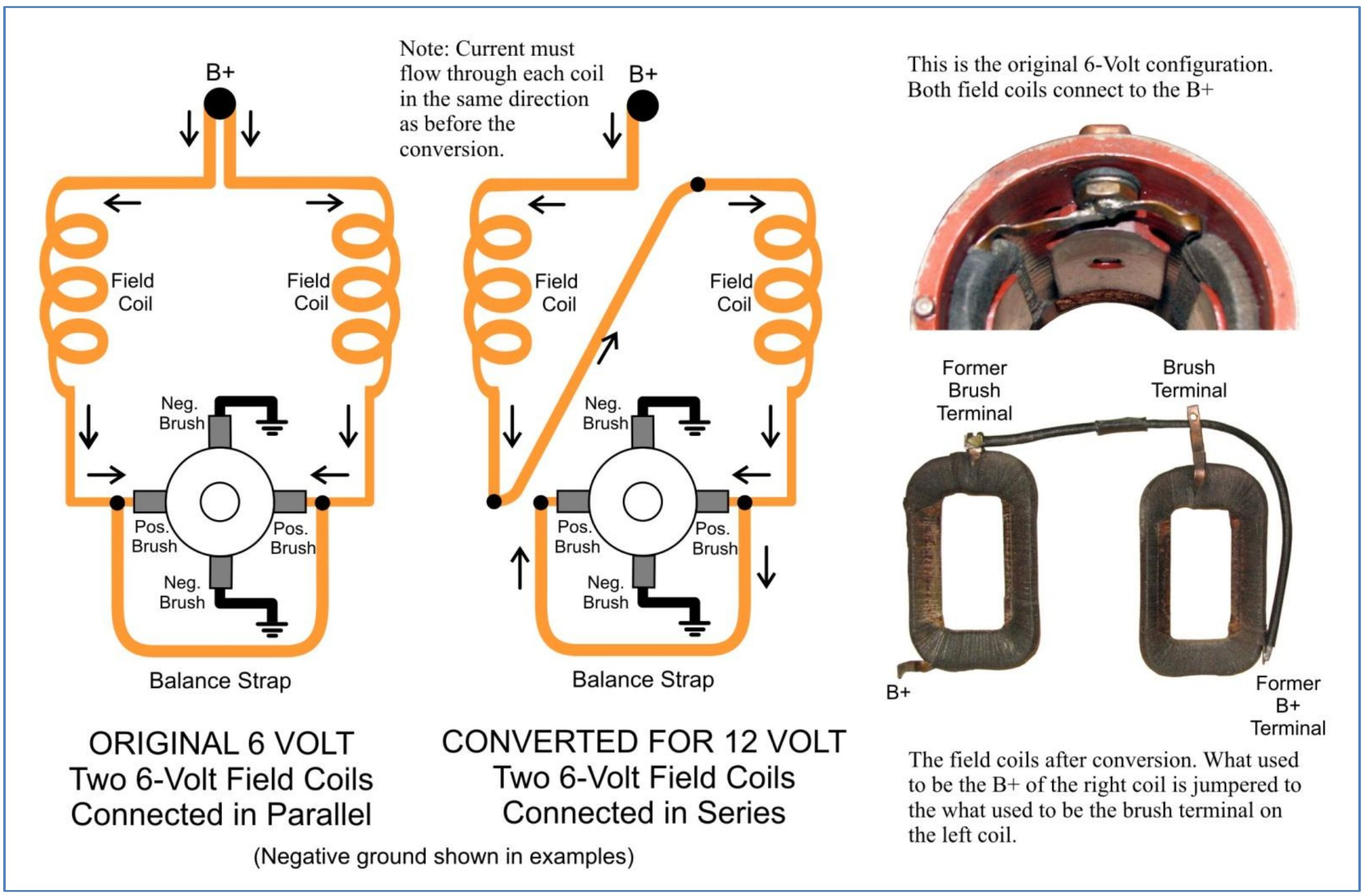


Figure 2—Converting Two 6-Volt Parallel Coils

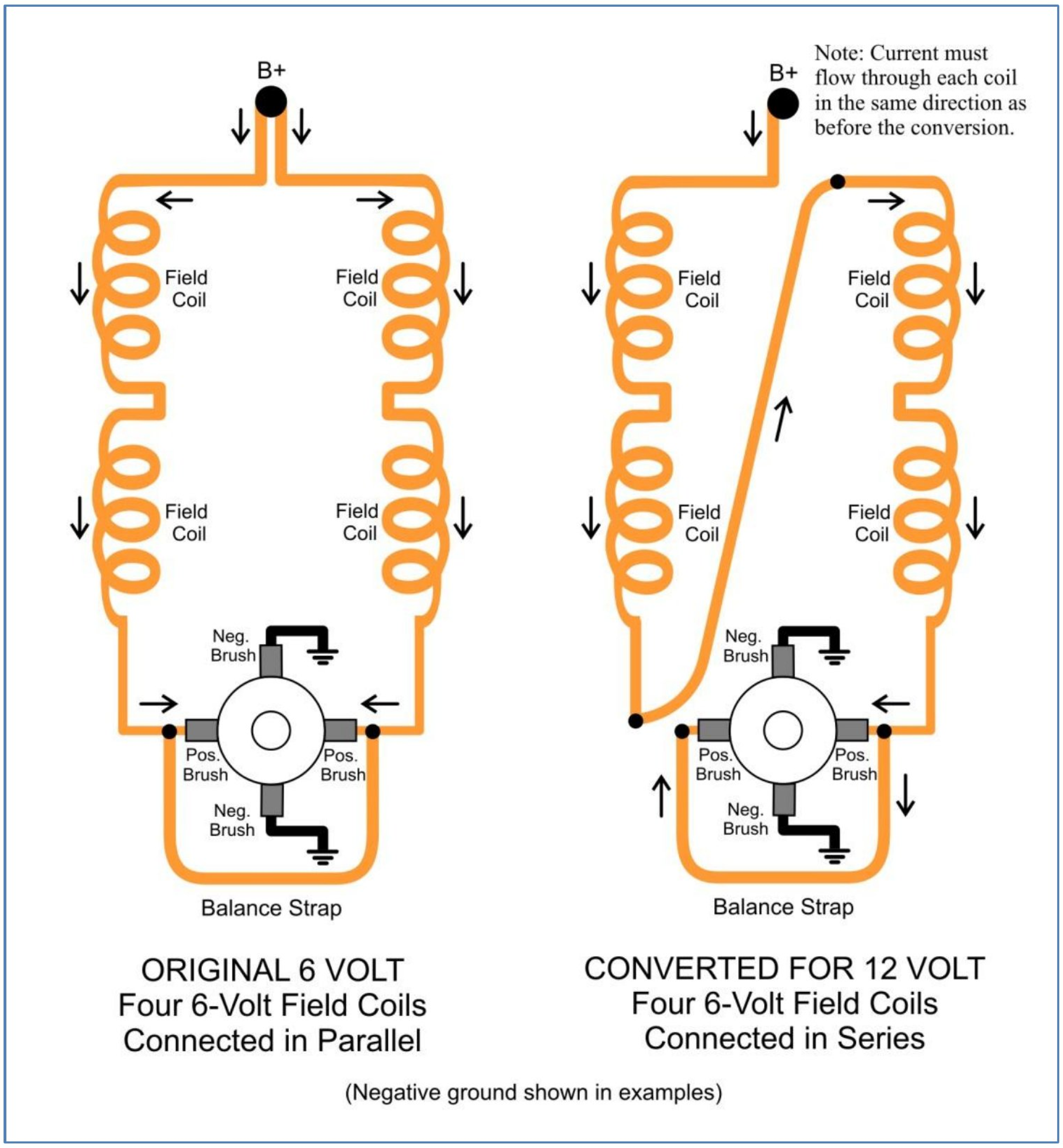


Figure 3—Converting Four 6-Volt Series-Parallel Coils

So, in this case, when we connect the two .190-ohm field coils together in series, the total circuit resistance is increased to .380 ohms.

After converting the coils to series, recalculate with Ohm's Law and Watt's Law using the new voltage and resistance values:

$$11.4\ Volts = 30\ Amps\ X\ .380\ Ohms$$

$$11.4\ Volts\ X\ 30\ Amps = 342\ Watts$$

Now the starter will draw 30 amps at 11.4 volts free spinning. The power (watts) of the starter remains the same as in the original design, preventing damage to the starter or ring gear.

How To Convert The Coils

Figure 2 shows how a set of parallel-connected coils is configured in a Delco 1109611 starter. Notice the B+ stud connects to one end of each coil. The other end of each coil goes to a positive brush. There is a balance strap connecting the two positive brushes to help equalize the current as it is split between the parallel coils.

In this conversion example, a 10MT repair lead is used to make the series connection. Care must be taken to ensure that the current travels through both coils in the same direction it did as when the coils were connected in parallel. Only one coil is left connected to the B+ terminal. It is altered by removing the brush lead. The second coil is disconnected from the B+ terminal. Next, what was the brush-end of the first coil is connected to what was the battery-end of the second coil using a brush lead or strap as a jumper. The jumper must be at least as heavy as the wires comprising the field coils in order to handle the required amperage. The last step is to supply current to the brush that originally was connected to the end of the first field coil. In this Farmall starter, the balance strap serves this purpose.

Brushes

The brushes are an important part of any starter and account for more of the total resistance than most rebuilders realize. There is significant difference between the composition of 6 and 12 volt brushes. Generally, a lower voltage brush contains more copper. It is always advisable to change the brushes when doing a conversion, assuming a suitable 12 volt brush is available. In most cases it is. With less copper content the 12 volt brush will increase total resistance while the additional carbon will reduce commutator wear at the same time.

How Armature Resistance Changes

If you spin a starter motor using an external force you will find that it works as a generator and produces voltage or Electromotive Force (EMF) on its own. Whenever a starter is being operated normally with current passing through it from the battery, it actually generates voltage at the same time. This generated voltage is known as *Counter Electromotive Force (CEMF),* or back-voltage. Note that CEMF is reverse polarity of that being applied by the battery. The faster the armature spins the higher the CEMF.

This back-voltage pushes against the forward voltage from the battery, creating the effect of higher resistance in the armature. That's why the armature does not appear to have the same resistance when free spinning that it had at a dead stop. When you bench test any starter you can watch it yourself. Amperage draw starts high and then drops as the armature accelerates to its maximum speed.

We assumed earlier that all of the starter's resistance was in the field coils. While that's not a fact, in a practical sense it is close enough. Because of CEMF, the actual resistance of the armature is not nearly as important as the resistance in the field coils.

Take note: When under a load, like cranking an engine, the armature slows, reducing the effect of CEMF. A starter that's been converted in the manner we described will always have noticeably more cranking power than it did on 6 volts prior to the conversion. On a bench test it will also draw more amperage than our calculations show. However, this increase will not be sufficient to cause catastrophic damage, but it will be enough to satisfy the end user.

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Footnotes

[1] Most engineering and physics guides use different letters to express voltage, amps and watts in their formulae. They express Volts as *E*, Amperes as *I* and Watts as *P*. Since there are very few electrical engineers or physicists running rebuilding shops, we have taken the liberty of simplifying Ohm's Law and Watt's Law by using the first letters of the values that they represent. Thus, *V* stands for *Volts*, *A* stands for *Amperes* and *W* stands for *Watts*.

[2] Calculating the total resistance of a circuit when resistors are connected in *parallel* is not a straight forward procedure. You cannot simply add up the resistances and find the average. Here, the reciprocal ($\frac{1}{R}$) values of the individual resistances are all added together instead of the resistances themselves. The inverse of the algebraic sum, gives the total resistance as shown. The formula is:

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} \dots \frac{1}{R_n}\ etc.$$

This is how we calculated the individual resistance of each coil connected in the original parallel circuit:

Our starting numbers are:

5.7 volts, 60 amps

Watt's law gives: 5.7V x 60A = 342 Watts

Ohm's Law gives: 5.7V / 60A = .095 Ohms

For simplicity we placed all resistance in the field coils, even though in reality some resistance is in the brushes and armature.

We also assume that both field coils have the same resistance.

So now we need to calculate the resistance of each individual field coil. We enter the total resistance and use the *parallel* formula:

$$\frac{1}{.095} = \frac{1}{R_1} + \frac{1}{R_2}$$

Since $R_1 = R_2$ (both coils are the same resistance) we can condense the equation to:

$$\frac{1}{.095} = \frac{2}{R}$$

Cross multiply and get:

$$1R = 2 \times .095$$

Simplify as: R = .190

The calculated resistance of each field coil is .190 ohms.

