Electrical Systems 101 - by Don Hoying

Lots of folks seem to have questions about the electrical system on their tractor. Despite being mechanically inclined, many of us just don't understand electricity. This "primer" is intended to be a basic introduction to how the electrical systems work on a Ford N tractor. This is not a manual or trouble shooting guide - this is basically all the stuff the manual assumes you already know!!! After reading this, it should take some of the mystery out of why things work (or don't), and what you are really doing when you follow the trouble shooting guide in your manual. I own an 850 (which is pretty close to an 8N), so not every detail will match every tractor, but the basics are the same. Those of you who own 9N/2N tractors will notice some differences on how things are wired, etc.

Electricity Basics

Just in case you are a true novice around electricity, here are a few basics. As you've no doubt noticed, electricity needs a complete path to work. On your tractor, the electricity flows from the battery to the starter/ignition/lights/etc. and back. The only difference between that and a household appliance is that the tractor uses the chassis as the return path. Thus, your starter, ignition, and lights only have a single electrical line going to them. The electricity flows through the power wire, to the device in question, then down through the chassis, and finally back up to the battery via the ground cable/strap.

Positive/Negative Ground

By now you've heard the term "positive ground" and/or "negative ground". All this means is that either the positive terminal of the battery, or the negative terminal, is wired directly to the chassis. Whichever side is connected is considered to be the ground. Fortunately, in most cases, the electrical components don't care which direction the current flows. But, for certain connections it is very important, such as the generator and voltage regulator. For this write-up, we'll stick with the factory positive ground configuration which has the positive terminal connected to ground (wired directly to the chassis).

Major Systems

The electrical system is made up of several interconnected systems; the ignition system, the charging system, the starting system, and the accessories (lights). Each one of these systems is relatively simple - it is when they are interconnected that things tend to get confusing. The following breaks them down one-by-one.

Starting System

The starting system is the first part of the electrical system that you probably think of, and is also one of the simplest. Starting with the battery, there is a large cable running from the negative terminal down to a small can called the solenoid - solenoid is just a fancy name for a switch. When the solenoid is engaged, current flows from the battery, through the solenoid, and into the other large cable on the other side of the solenoid that goes to the starter. Since the starter case is grounded to the chassis (like the battery),
this completes the rest of the circuit. Current flows and the starter turns. It's that simple. The only question left is, what makes the solenoid engage. That is done by pressing the starter button which allows current to flow through the relay coil in the solenoid - that is simply a small electromagnet that throws the starter switch. The relay coil gets power from the solenoid terminal that connects to the battery. The other end is connected to the starter switch, which completes the circuit to ground when pressed. So, when the starter button is pressed, current can flow through the relay and the solenoid engages. Pretty simple, right! If you have a 9N/2N it is even simpler - instead of an electrically actuated solenoid, you have a simple mechanical relay. The starter button moves a rod that mechanically throws the switch. Either way, the starter button is designed to only engage when the transmission is in neutral. This is an important safety feature that should not be bypassed.

Ignition System

Of course, the starter alone won't get your tractor running - you need a spark. For most people, this is the most mysterious part of the electrical system, but it is not too confusing when you break it down. Once again, we start with the battery. Power flows from the battery down to the solenoid, as we just went over. What you may have also noticed is that there is one more wire coming from the battery side of the solenoid. Because this wire disappears into a maze of wire bundles and connectors, this is where most of us lose the trail. Where this mystery wire goes is to the ammeter and from there to a small plastic terminal block with two terminal screws (we'll talk about the ammeter later). Basically, this terminal block has an "always-hot" terminal and a "switched" terminal. The always-hot terminal is always connected to the battery via the wire coming from the solenoid. From the always-hot terminal a wire goes to the ignition switch, and then another wire goes over to the switched terminal - thus the switched terminal only has power when the ignition switch is on. From the switched terminal, a wire runs down to the coil to power the ignition system. So, now that we have power to the ignition system, just how do we get a spark when we need one? The system that generates the spark is really two circuits; a primary (6V) circuit, and a secondary high voltage (~40,000 V) circuit. The coil is the component that converts the low voltage current into a high voltage surge to generate the spark. Basically, like its name suggest, the coil is a metal core wrapped many times with wire. The primary circuit has a hundred or so wraps. The secondary circuit has thousands of wraps. When current flows through the primary circuit it generates a magnetic field in the coil (each wrap makes the field stronger). Conversely, the magnetic field induces a voltage in the secondary circuit. Because of the large number of wraps in the secondary circuit, the voltage is proportionally higher than the primary circuit - but not yet high enough to generate a spark. In addition to providing a mechanism to increase voltage, the coil has another unique electrical property; the magnetic field has what can most easily be described as "inertia". Once it gets going, it doesn't like to stop suddenly. However, this is exactly what is about to happen. Inside the distributor, when the piston reaches the top of its travel, the distributor has been "timed" such that the breaker arm forces open the points and breaks the primary circuit. Suddenly the magnetic field in the coil has no current to sustain it. Since it can't push current through the open primary circuit, it exerts its influence on the secondary circuit. With its many thousands of wraps the magnetic field in the coil is able to produce very high voltages in the secondary circuit - high enough to jump the gap in the spark plug and complete the secondary circuit. This current flows out through the secondary coil wire (large wire) to the distributor which directs it to the correct spark plug wire via the distributor rotor. Shortly thereafter, the points close again and the primary circuit is re-energized and the magnetic field is re-established in the coil for the next spark. The last remaining element is the condenser which is simply a capacitor. Capacitors have the ability to hold a voltage, sort of like a tiny battery. Why this element is important is that at the moment the points begin to open, the coil would be perfectly happy to push current through the primary circuit and throw a spark across the barely open points. This would not only diminish the energy that goes to the spark plug, but would wear out the points very quickly. By holding a voltage in the now open primary circuit, the condenser "pushes back" against the desire of the coil to surge a current through the primary circuit. With the primary circuit no longer an option, the energy stored in the magnetic field of the coil has no where else to go but through the secondary circuit, thus generating a spark.

Charging System

While the systems we've talked about so far have all been described as receiving power from the battery, the battery alone cannot power the tractor indefinitely - thus the need for a charging system. The original generator system will be discussed here, but an alternator works very similarly. Basically, a generator is an electric motor run in reverse. Power from the engine (via the belt/pulley) runs the generator which generates an electric current. However, to provide the amount of charge that the battery needs, and no more, the generator is wired to a voltage regulator. One significant difference between the generator and an electric motor is the lack of permanent magnets in the generator. In a generator, some of the current that is produced by the rotating windings in the generator (armature) is fed back into the outer stationary winding (field). This energizes the field making it act like a magnet. With the field energized, the armature (spinning through the magnetic field) produces voltage. As this voltage increases, so does the current to the field, which increases the strength of the field, which in turn increases the voltage, even more. As you may have guessed, this is where the voltage regulator comes in. When the generator voltage reaches a certain threshold, the voltage regulator cuts out the current going to the field which kills the magnetic field. This crude, but effective, system is known as a "cut-out" regulator. (More modern regulators reduce the field current to achieve the desired output voltage instead of cutting the current to the field completely). By quickly switching on and off, the cut-out regulator prevents the generator from producing more voltage than the system can handle. A failed voltage regulator will result in either very little voltage (stuck open) or way too much (stuck closed). The end result is that the regulated generator output is fed from the "battery" terminal of the voltage regulator to the always-hot side of the terminal block. The current that is not used directly by the tractor flows back into the battery by way of the ammeter, to the battery-side terminal on the solenoid, and then to the battery. Thus, the ammeter reads only the current that is flowing into or out of the battery (not including the current that goes to the starter motor). The generator may actually be producing quite a bit more current than what the ammeter displays when the tractor is running and high current draw devices, like the lights, are running. If your ammeter indicates a high rate of battery discharge when your lights are on and the tractor is running, this is an indication of a weak charging system. For those of you paying close attention, you may have wondered how the generator gets going in the first place if it requires power from itself to energize the field. The answer is that there is a small amount of residual magnetism in the metal core of the windings. Thus when the generator first starts to rotate, it produces a small current, which energizes the field slightly, which in turn increases the current output of the generator and increases the field strength even more, and so on and so on. This is why it is so important to "polarize" the generator whenever the electrical system has been worked on. Because the generator does not use permanent magnets, this residual magnetism can be reversed if current has been introduced into the generator in the wrong direction in the course of performing maintenance. This situation would cause the generator to produce current/voltage in the wrong direction which will quickly burn out the voltage regulator. A momentary touch of power from the battery is all that is required to ensure that the residual magnetism is aligned in the proper direction (consult your repair manual for the proper procedure depending upon which model tractor you own). This ingenious system has several advantages over a permanent magnet generator. First, by self-exciting, it can produce useful voltages at low motor RPMs. Secondly, by working with the regulator it produces only as much power as needed. This reduces unnecessary power draw from the engine, and eliminates the need to dump the excess power somewhere.

Accessories

The final electrical system are the accessories. For most old tractors, this simply means lights, but a radio, flasher, or other optional items could be added. The power for the accessories comes from the always-hot terminal on the terminal junction block. This allows the lights to work when the tractor is off. Other accessories could be added to the switched side of the terminal block, but I would recommend against any high amperage devices (like lights) since the ignition switch wasn't intended to handle such loads. Like the other electrical systems, there is only one wire going to the lights. The return path for the current is through the chassis of the tractor. However, unlike the starter and ignition, the lights are not directly mounted on the engine block - they have to rely on the electrical contact between the hood/fenders and the rest of the tractor. If you are having difficulty with the lighting, you may consider adding an additional wire from the lights to the ground on the tractor to ensure a quality electrical connection.

Well, I hope this helps - and hasn't left you more confused than before!

Don Hoying