FLUKE®

Alternator testing:

An old science with a few new tricks

Application Note

Testing Functions

Case Study

Tools: Fluke ScopeMeter® Test Tools

Tester: Andy Wendt, technical specialist at Kelly Aerospace

Tests: Ripple voltage and pulsed dc voltage waveform analysis – shape, duration, and amplitude

For Andy Wendt, a technical specialist at Kelly Aerospace, an oscilloscope is a tool for finding any fast-occurring event. "We use scopes in product development, where it's not enough to say a signal has a voltage spike. A pulse may have a duration of .5 milliseconds. We have to see the pulse to discover the shape of the spike, its duration and its amplitude."

Kelly Aerospace is a supplier of subsystems to general-aviation OEM and aftermarket customers, and a component in these subsystems is the alternator. A key focus for Andy Wendt, Technical Specialist at Kelly, is the ripple voltage that is a byproduct of rectification, and voltage spikes that occur in the process. "If you look at the output of the stator in an alternator of a 12 V system, the regulated voltage will typically be 14.4 V. In a 24 V system, the regulated voltage will typically be 28.8 V. But you will see 'peaks' of the ripple exceed those limits—as high as 30 V and as low as 26 V," says Wendt. With added capacitance, he says, the ripple can be attenuated.

"It's more or less a pulsed dc signal, and the scope is the only way we can actually see it," says Andy Wendt. "We can take an average reading of it, or take a true rms reading with a digital multimeter. But to actually see what's happening at a given time, the scope is the only tool for the job."

Profiling alternators

For Wendt, regulating the output of an alternator is as much art as science. In part, this is because the airborne alternator is tasked to conform to two very different profiles. When the aircraft is idling, as during boarding or following landing, the alternator needs to produce high current output at low engine RPMs, because at low RPMs all of the aircraft's systems may be running. "Typically you'll need the air conditioning primarily while you're on the ground. The ambient air is much cooler once you reach altitude, where you can then switch your supply to lights or other systems in the cabin. But, on the ground, when the pilot needs running lights and air conditioning, that condition places a big load on the alternator."

Alternators at a glance

The field section, or rotor, is the rotating part of the alternator. When dc current is supplied to the field, and the alternator shaft is rotated, the field sweeps magnetic lines across the stator windings, inducing an ac current at the stator output terminals. The ac current is converted to dc current by the rectifier assembly and directed to the B+ terminal to power external loads.

In normal operation, a voltage regulator monitors the B+ terminal voltage level and automatically modulates current to the field (F1 terminal) to maintain a constant voltage on the B+ terminal as changing loads demand varying currents.

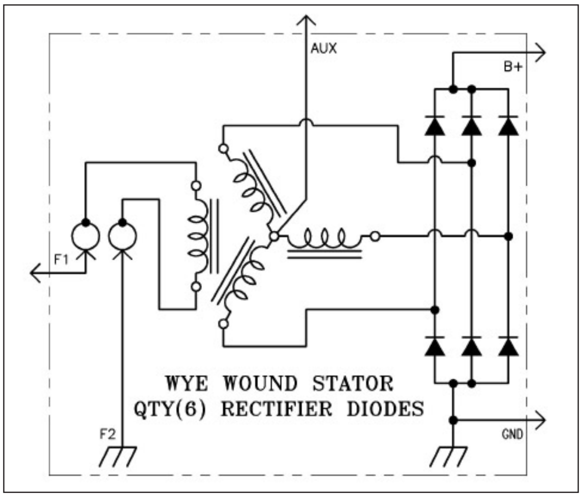


Figure 1a.

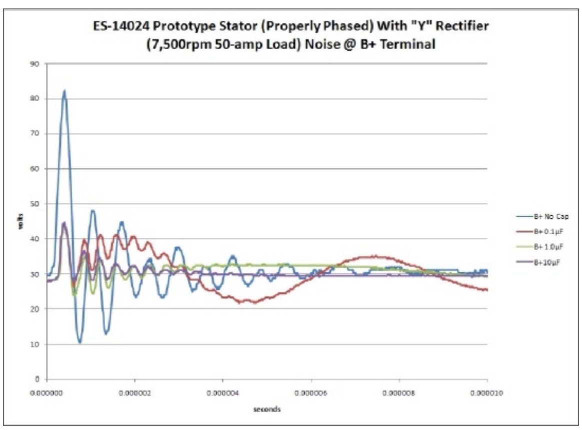


Figure 1b.

Figure 1c.

Figure 1. Capacitor filters on the output (B+) terminal of an alternator (Figure 1a) reduce ripple. In separate instances, capacitors were connected from B+ to GND, and data was collected with the ScopeMeter leads connected from B+ to GND (Figure 1b). Reflective tape applied to the alternator shaft triggers an optical sensor, which provides a trigger signal to the ScopeMeter Test Tool (Figure 1c).

In the noncommercial aircraft's onboard systems, the airframe bus—used to distribute electrical power throughout the plane—will be either nominally 12 V or 24 V, and a single alternator will be use to drive those systems. (At times there are other systems that require a completely separate alternator, such as to drive a wing-deicing system that operates at 70 V.)

Wendt's objective is to find an alternator output profile that will match the requirements of onboard systems for power delivery at both low and high engine RPMs. "This is product development. I may have half a dozen stators that are wound differently, and I need to determine if some of these stators produce cleaner output than others. And I need to determine what kind of filtering I can apply to control any voltage spikes that the resulting alternator design will generate." The reward, he says, comes with insightful new configurations of alternator windings, along with dutiful testing for optimum performance with the ScopeMeter® Test Tool. "Through lab testing of prototype stators, I've seen performance improvements with a 27 % increase in output current, and with efficiency improvements of 15 %. Testing of prototype alternators of proprietary design shows output current increases of 64 %."

Wendt's prototypes are all wound to his specifications. "I may have one wound, and I'll take the total circular mil fill that I can get in a slot in that stator and determine what wire size I can put in there to get a certain number of turns. Then I may wind one that has one or two fewer turns, but with larger-diameter wire; and that configuration should give me a lot higher output current." Wendt explains that this process could result in raising the "cut-in RPM," the lowest speed at which the alternator begins to produce voltage sufficient to charge a battery. That would be undesirable. His goal is to produce power at low RPMs, but, in changing the impedance of a stator, he could also be creating a condition in which the alternator is more likely to generate voltage spikes.

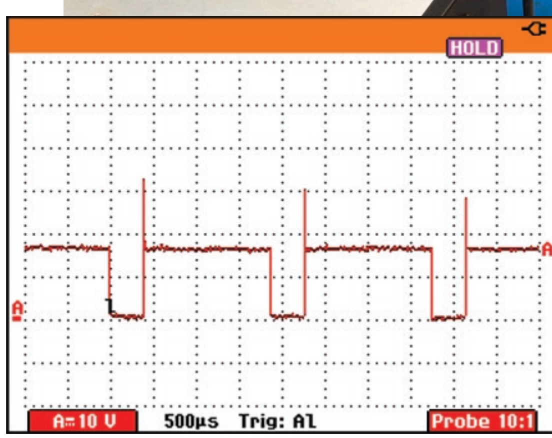
Triggering on recurring or random events

As Wendt describes it, he may find either a recurring or a random anomaly in the output signal, and the nature of the anomaly will determine his troubleshooting methodology.

"In the lab we developed a test bench that has a three-phase motor with a variable-frequency drive so we can control the RPMs at which we're driving the alternator. I put a piece of reflective tape on the pulley that's on the alternator shaft, and I have an optical tach sensor that I use to provide a trigger signal for the scope. (Refer again to Figure 1.) Then I can look at the ripple coming off of the rectifier assembly, and if I get an event that's occurring at exactly the same place every time, it means I have uncovered what I might call a predictable event. If the anomaly doesn't occur predictably, I'll be looking for a random event, and instead of triggering on the shaft, I'll trigger on the spike itself."

Wendt offers a tip from his own troubleshooting: "I adjust the triggering level on the ScopeMeter until I don't see any trace, and I set the ScopeMeter to do a single trace and then hold. Then I keep lowering that trigger level until I start seeing traces. In that way I can identify that all of the spikes are below this trigger level." That methodology helps him isolate the source of the anomaly. For each relevant signal trace, he will save the data corresponding as a .csv file and export it to a spreadsheet for charting, calculations and reports.

Wendt notes that the ScopeMeter® test tool has helped Kelly Aerospace align its alternator-winding configurations with the optimal power profiles of an airplane at idle and in flight. He says that an alternator driven relatively fast at engine idle RPMs also creates high 'pulley ratios.' As engine RPMs increase, the alternator RPMs may exceed the speed at which the alternator produces maximum efficiency. "Our inevitable compromise," he says, "is between optimum efficiency and idle performance. Greater efficiency can reduce engine loading and increase belt life, and can achieve Holy Grail of all aircraft components—greater efficiency and reduced weight."



By adjusting ScopeMeter® test tool's trigger level, the technician can further isolate the causes of spikes.

A ripple voltage is a small, regular variation in a direct current voltage that remains after rectification and filtering of an alternating current voltage. If the ripple voltage is excessive, a bypass capacitor can often be used to reduce it.

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