

Review of the Pictures of Damaged R15100 Rev A, the Electrosystem Alternator and Dallas Avionics Capacitor

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From examining the emailed pictures, it appears that these are components damaged in the R15100 Rev. A, serial number W13123: D1, R5, Q1. Reference pictures R0012226, R0012228 and R0012234.

From our experience and from electrical charging system theory, the damage observed is consistent with a significant inductive kickback or high energy produced in the field of the alternator that flowed backward from ground into D1 and other components of the R15100 Rev. A. D1 is a free-wheeling diode that protects the main output transistor Q1 from the normal inductive kickback produced by the field (rotor or rotating inductor) of the alternator. The damage seen on D1 indicates that there was intermittent ground on the field of the alternator or there the system experienced a significant load dump condition. D1 serves the same function as the battery relay diode. From what you indicated, it seems the same cause damaged D1 and the aircraft's battery relay diode.

The counter-EMF, freewheeling, catching or flywheel diode

A fully open or intermittently open ground on a rotating alternator that has power applied to its field will generate an output voltage much higher than its normal output. As indicated in the attached article and others on inductive kickback, counter-EMF, freewheeling diode, catching diode and flywheel diode, breaking the current path suddenly in an inductive circuit can result in high-energy spikes with both negative and positive components.

Load Dump Condition – Causes, Effects and Prevention

A load dump condition caused by the sudden removal of the battery from a rotating alternator may cause these types of damage. In a load dump condition the when the battery goes off-line, the output of a 12V alternator can suddenly increase to 30V or higher, especially when there is no ground on the voltage regulator or alternator controller.

The suddenly or intermittent opening of the battery relay may lead to a load dump condition. The freewheeling diode put across the coil of the battery relates in the aircraft serves as an inductive kickback suppressor or protection device. In this role, it also helps reduce relay contact chatter. Losing this diode may negatively impact the operation and the life of the battery relay. A negative going pulse of a magnitude higher than its forward current rating can damage the diode.

Load dump conditions can happen if the main alternator circuit breaker opens and closes suddenly while the alternator controller is still supplying current to the alternator's field. Sometimes pilots will pull and push back in the alternator's output circuit breaker at cruise speed. This is the point the alternator is capable of supplying very high and destructive voltage and current output. Pulling the breaker under this condition leaves the alternator's stator with all the energy it produced pent up. Pushing in a breaker under this condition connects alternator to the bus and introduces the uncontrolled pent up energy on the system bus as very high voltage and current pulses. These pulses seek the best/easiest current paths and can damage electrical loads in the system. For this reason, we recommend to the pilots and mechanics that we deal with that they avoid pulling any main alternator circuit breaker while the alternator is rotating. The energy experienced in this situation is similar to what happens in a spark plug. To turn off a rotating alternator that has power to its field the best and safest practice is to turn off the alternator field switch first and then if necessary pull the main breaker.

Some circuit breakers (due to age or other reasons) operate intermittently. For example a 60A breaker will start tripping at 30A because of increase in contact resistance that causes the bi-metallic strip contacts to open. When the contacts cool down, they will reconnect. The continuous opening and closing of the contact at this wrong current set point can lead to catastrophic load dump conditions. Certain load dump conditions can even damage over voltage protection relays. The FAA has no requirement that I know of for checking the condition of electrical connections and components at any regular interval on GA aircraft. Many POH do not categorically advise pilots against pulling and closing the main alternator circuit breaker while there is power on the field of a rotating alternator. This is a serious safety issue that needs attention.

Apart from the main circuit breaker, any sudden opening and closing of connections in the path from the alternator's battery terminal to the bus can create load dump conditions.

Tests on another R15100 Rev A

As you and I discussed, we tested another R15100 Rev A with an alternator rotating at 5420 RPM (driving motor to alternator pulley ratio – 1:3.37). With the unit connected in its normal configuration and the battery online, the bus voltage was 14.27V at 30A. When we removed the ground from the unit, the bus voltage increased to 17.7V because the current path was incomplete. The result with ground restored to the unit was 14.27V. This evidences the necessity of ground to the unit and the charging system – the normal system configuration.

We repeated the test at the same speed with the battery turned off. The bus voltage was 14.17V at 27A. Removing ground from the unit caused the bus voltage to increase to 30.45V because the current path was incomplete. The result with ground restored to the unit was 14.17V. This shows that even with the battery disconnected from the system, the R15100 Rev will keep the alternator on line at normal safe operating bus voltage. However, removing ground from a unit connected to a rotating alternator without the battery in the system can cause a load dump condition. These tests did not damage the R15100 Rev A.

Conclusion

The damage observed in the R15100 Rev A serial W13123 appears to stem from a load dump condition that originated in an open or intermittent grounding of the alternator, a sudden open or intermittent connection between the alternator's output and the bus, or other conditions that resulted in a high negative going pulse that damaged D1, stressed or burnt R5, probably damaged Q1 in the unit; as well as damaged the battery relay diode. The damaged R15100 Rev A will not take the battery off-line (bus). Unless the battery relay was open due to a bad switch or relay, or the connection to or from the relay open, a closed battery switch should keep the battery on line.

The pictures (R0012244, R0012252 to R0012256) of the alternator, and filter capacitor, appear to indicate that the ground connection on the alternator (where the filter capacitors mounts) was loose and experienced arcing severe enough to melt the copper terminal of the ground wire. The molten copper splatter on the capacitor and worn capacitor mounting-hole indicate loose nut on the ground terminal. It is possible that since the capacitor was not well grounded and as such will have a positive charge (voltage) on its case instead of ground; that lead to some of the arcing observed on the alternator's case. This probably contributed to the damage seen in the R15100 Rev A and the damaged battery relay diode.

[Article: Catching diode](#)