RTS provides a unique testing service for electromechanical relays that are used in many electronic applications, including ATE and communications equipment. RTS provides Weibull data analysis for life testing in addition to full parametric testing/screening of incoming parts.

Electromechanical Relays
“The Blessing or the Achilles Heel of the ATE World”

The Wonderful Relay

Who said relays are old hat and passé? While electromechanical relays have been switching electrical signals for over 150 years, they continue to be the switch of choice for many applications. One primary application is in ATE (Automated Test Equipment), where sensitive measurements are required over an array of multiplexed signals. An electromechanical relay offers practically zero closed impedance (< 50 milliohms) and almost infinite open impedance (> 100G Ohms), while providing high bandwidth characteristics (> 100 MHz). However, this remarkable device can become the Achilles heel of very expensive ATE equipment if not selected properly for the application. A single ATE can use thousands of relays, and poor relay reliability can translate into serious downtime and expensive field repairs. Proper selection and effective testing can improve contact reliability in the end product, while reducing the overall cost of using relays.

Quality vs. Reliability

One factor that affects achieving the highest reliability is the relationship between quality and reliability. Many component users make the mistake of comparing reject rates of two suppliers and assume that the lot with the highest yield will offer the best performance. The user may still be disappointed with the performance of the relay in the end product, unless a relationship between quality and reliability has been established for their particular application.

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Quality is generally defined as a measure of how well a component complies with a specification before it is installed in the end product. In many cases, this measure of performance against test limits does not consider component life. Reliability is a measure of component performance during the useful life of the end product. While semiconductor life is a function of time and temperature, relay contact life is measured in terms of contact load and the number of contact operations. Life testing is necessary before a meaningful relay specification can define a relationship between quality and reliability.

Life testing should be performed during relay qualification to confirm that the contacts satisfy the minimum life value. The relay user should be cautious in accepting published life test data. This data may not be relevant, if the life testing was performed at a contact load other than the user’s worst-case load. Published data may be based on typical - rather than minimum – life, and would not tell the user when to expect the first failure. In addition, the data may be based on a 10% failure rate during the life test when the user may require a failure rate of less than 0.1% in the end product.

Proper Selection

The relay specification should define the requirements of the end application. The operating voltages (turn-on and turn-off) and the timing (close and release times) should be specified with sufficient margin to assure good, reliable performance, as with all other electrical components. The life expectancy should be defined in terms of relay cycles. This is often difficult for the designer to specify, since most designers are familiar with either specifying the total hours required (MTBF) or the minimum acceptable failure rate (FITS). Unlike other electrical components, relays do not age until they are actually switched. Therefore, relays are specified in terms of millions of cycles of operation. Encapsulated dry-reed relays typically will operate for hundreds of millions of cycles, while the life of armature-type relays is typically an order of magnitude lower.

Assessing the application requirements for life is very important. This involves looking at the maximum switching frequency and the total life expectancy of the system. For example, if a relay were switched at just 25 Hz continuously, it would only take 11 hours to reach 1 million cycles, 111 hours for 10 million cycles, and 1111 hours for 100 million cycles. This part would wear out in only a couple of months in this application. Therefore, even a high-life reed relay should only be used in circuits that will switch at a rate to assure long life. Take an example where the test cycle for an ATE is 10 seconds and the relay is switched one time during each test cycle. It would take 4 months to reach 1 million cycles, about 3 years to reach 10 million cycles, and about 30 years to reach 100 million cycles. This is one reason why properly judging the application is critical to selecting the proper life specification for the relay. The total cycles per year for the relay should be specified well below the requirement to assure that its failure rate is in the same range as a solid-state device. The specified usage of a relay in the application is critical to achieving the desired operating life.

Load Effect on Reliability

Another application factor that can greatly reduce the specified life of electromechanical relays is the switched load. The load-carrying capability of the relay is often confused with its ability to switch a particular load repeated times. The ideal way to switch relays is to first remove the load, operate the switch, and then reapply the load. Low voltage levels of 1 to 2 Volts can be switched without significantly affecting the life of the relay. However, life degradation occurs rapidly when switching 10 Volts or higher, due to arcing at the contacts.

In one study, samples of a reed relay were life tested with loads of 1 Volt/10 mA, 10 Volt/1 mA, 10 Volts/100 mA, 10 Volt/1 Amp and 30 Volts/100 mA. The results from these five life tests are plotted on the Weibull chart in Figure 1. From this chart, the effects of switching higher load voltages can be clearly seen. It can also be observed that current limiting can be very beneficial to improving the life expectancy for the same load voltage. There is a marked difference for the 10 Volt load from 1 mA to1 Amp (the life test results show the total cycles improved by over an order of magnitude when the current was limited). It can also be observed that the life expectancy was reduced by two orders of magnitude when the load was increased from 1 Volt to 30 Volts.

How To Find the Best Reliability?

For applications requiring the absolute highest life from the relay, there are methods to improve the statistics after the application has been optimized. Relays that have smooth, clean, and well-aligned contacts exhibit the best life characteristics. This may sound very simple, but it is often difficult to weed out parts that will have future reliability issues. Good contacts will demonstrate tightly controlled and repeatable contact resistance measurements over many cycles. One way to identify potential problem parts is to take repeated contact resistance measurements (at least 50), and then compare the maximum and minimum values (RDEL). Parts with high differences in this reading have an increased probability of early life failures.

Another method that has been used to determine the integrity of the contact surfaces is called magnetostrictive twist (Twist). This phenomenon is unique to dry-reed relays and is caused by the magnetic flux of the coil current interacting with the flux of the contact load current. When contacts are held loosely closed, this interaction of fluxes causes the blades to twist laterally in relation to each other. Contact resistance measurements made during this test have identified contact surface irregularities that caused eventual contact failure.

In a study, 28 dry-reed relays were life tested for 25 million operations switching a 10 Volt, 4 mA contact load. There were four failures at 8.4M, 12.2M, 21.8M, and 22.6M cycles. Two of the failures were predictable from the initial parametric data. The device that failed at 12.2 million operations had a RDEL value of 5.4 milliohms (the population mean was 1.0 milliohm, with a sigma of 1.1 milliohms). The device that failed at 21.8 million cycles had a Twist value that was 18 milliohms above the maximum contact resistance reading, with nominal coil voltage applied. The mean for this population was 8.4 milliohms, with a sigma of 2.2 milliohms.

These tests can significantly reduce the overall failures experienced during the life of the part, and a 50% reduction was observed in this study. A parametric test with three sigma limits for RDEL (5 milliohms) and Twist (15 milliohms) would reject two parts from this population that ultimately experienced early life failure. The predicted reliability, with and without screening, is shown in the Weibull plot in Figure 2. The improvement to Eta (life expectancy at the point where 63% of the population has failed) was 514% (79M cycles to 485M cycles). The second parameter from the two parameter Weibull distribution is Beta. Beta values greater than 1 indicate wear-out failures (increasing failure rate), while a Beta equal to 1 indicates a constant failure rate. The Beta for the unscreened population was equal to 1.6, and for the screened population was equal to 1. The screened population had a failure rate of approximately 0.2% per million cycles over its life. The unscreened population had an increasing failure rate that ranged from 0.5% per million cycles at the 20 million-cycle point to approximately 0.8% per million cycles at the 50 million-cycle point. The improvement in failure rate for this study was between 150% to 300%.

Conclusion

Electromechanical relays continue to be a valuable component in the measurement world, and high reliability can be achieved through a combination of accurately specifying the operating environment, rigorous life testing to determine life expectancy in its operating environment, and application of special parametric testing that is tied to the life test results.

Understanding the operating conditions and their effect upon the life of the relay is essential to achieving the goals for the expected life in the end system. The number of cycles that the part will be expected to operate over its lifetime and the effect of the load are critical in determining the life expectancy.

We know that for most components there is a relationship between quality and reliability. For relay devices, this relationship can often be defined, and this means that special up-front testing can be used to improve the long-term reliability. Special tests like RDEL and Twist can effectively improve field reliability. The cost of field failures is very high when considering the cost to repair, the down time, and the customer dissatisfaction.

Figure 1: Effects of Load on Life

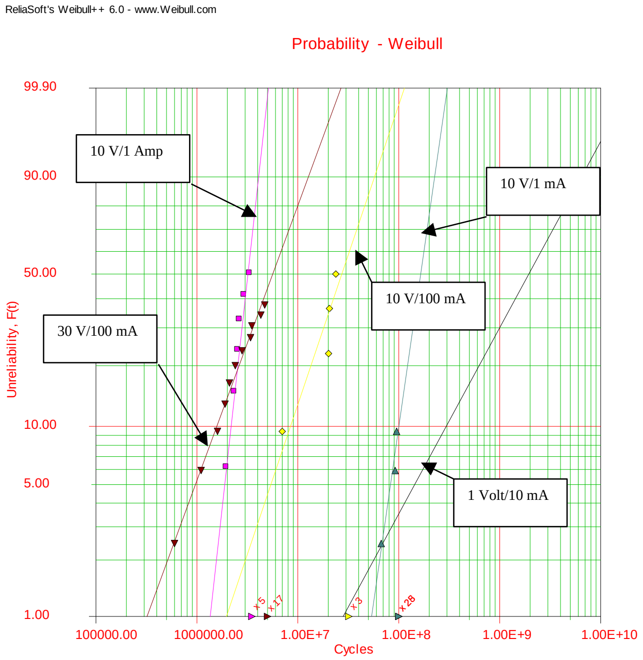
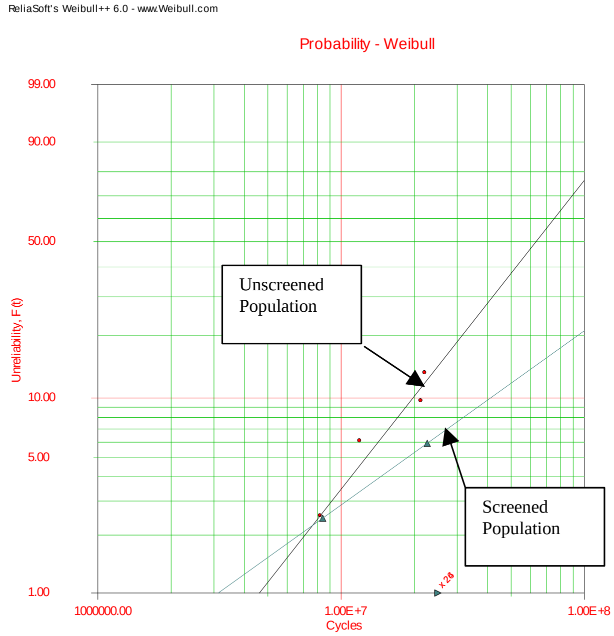


Figure 2: Effects of Proper Testing on Life



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