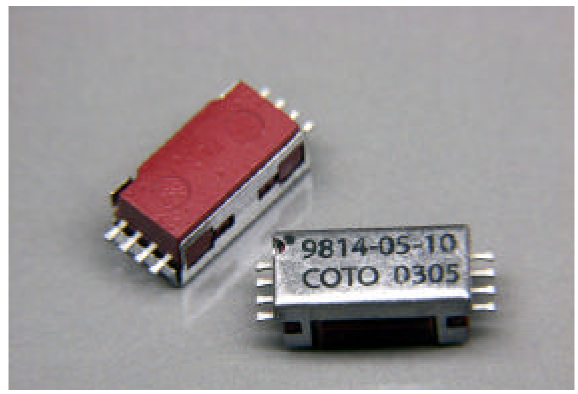
Coto Technology 9814 Reed Relay

Coto Technology has recently released a new version of its flagship ATE grade 9800 series relay, the 9814 model. The 9814 is a logical successor to previous members of the 9800 relay family, widely accepted by the Automated Testing Equipment industry as the most reliable small surface-mount reed relay available.

What is different about the 9814?
The 9814 relay is designed as a drop-in replacement for the 9800 relay. Like the 9800, it is manufactured using semiconductor-grade fabrication techniques, including automated coil winding and lead termination, thermoset plastic automolding and computerized vision system checking for lead coplanarity. The key improvement in the 9814 is enhanced reliability. In fact, the 9814 has about four times the demonstrated switching reliability of the 9800 relay. The expected life of the 9814 using a signal switching load of 1V and 1 mA exceeds one billion cycles, compared to the 250 million cycles specified for the 9800. The 9814 also incorporates an external magnetic shield, giving it greater protection against magnetic interaction effects than the 9800.



9814 Reed Relay (axial lead configuration)

Technical Background on reliability improvement
Reed relays eventually fail in one of three ways: the reed switch fails to close when the relay coil is activated (called "missing"), or fails to open when the coil is de-activated ("sticking"). The third mode of failure is an unacceptable increase in static contact resistance. Research at Coto Technology's test laboratories in the USA and in the Netherlands has shown that switching reliability within a given switch class is strongly correlated to three adjustable parameters: first, the magnetomotive force required to close the reed switch, expressed in amp-turns (AT); second, the degree of "overdrive" applied to the switch; and third, the geometric and mechanical attributes of the reed switch blades.

The AT rating of the switch is related to the spring force that has to be overcome to close the switch. Higher AT switches have a stronger spring constant, which tends to pull the blades apart with more force when the reed relay coil is de-activated. Thus, higher AT switches are more resistant to sticking failures, provided that overdrive levels are adequate.

Overdrive relates to the power applied to the coil compared to the power just needed to close the switch. Low levels of overdrive produce low contact switching force, that can result in high and unstable contact resistance, or excessive contact sticking under certain load conditions.

Given that available coil drive power is always finite, the effects of switch AT and overdrive are interactive, and need balancing to produce optimum reliability. Gains in reliability from high switch AT can be lost if overdrive levels are inadequate.

The design strategy with the 9814 was to increase the switch AT to an appropriate amount, without reducing overdrive to a level of diminishing return. Before releasing the 9814 relay, Coto Technology undertook an exhaustive series of tests to optimize these parameters. The result was a switch with a 90% boost in AT rating over that used in the 9800, while preserving an optimized level of overdrive.

An obvious question comes up: where does the extra electrical energy come from, to boost the coil efficiency by 90%? The answer was not to require more coil power, but to use the available coil power more efficiently. A 9814 relay requires no more power to operate than a 9800. It simply uses the available electrical energy more efficiently. This is achieved by improved magnetic efficiency. Instead of the copper alloy leadframe used in the 9800, the 9814 relay has a leadframe made of nickel-iron alloy, a material with a very high magnetic permeability. Recall the experiment most of us did in high school, where we wrapped an iron nail in insulated copper wire and made our own battery-powered electromagnet. Without the nail, the electromagnet was far weaker. The technical reason, though we might not have understood it at the time, was that the ferrous iron nail was focusing and returning the magnetic field lines to make the coil more efficient at using electrical energy. The nickel-iron lead frame in the 9814 relay works the same way, providing an efficient return for the available magnetic field lines and thus allowing a higher AT switch to be driven with the same electrical energy. The magnetic shell fitted to the 9814 also contributes substantially to magnetic efficiency.

The improved magnetic efficiency of the 9814 also allows us to offer it in both 3.3 volt and 5.0 volt versions, while using the same high-AT reed switch in both models.

Magnetic Shell

Apart from improving coil efficiency, the primary function of the magnetic shell fitted to the 9814 relay is to reduce the effects of magnetic interference. Close packing of relays, required for compact ATE equipment, can result in interactive effects between relays. This is due to the interference between the magnetic fields generated by the relay's coils. The magnetic shell reduces these interactions between adjacent relays by a factor of about four. This topic is covered in more detail in the Coto Technology Product Catalog.

Reed Switch Blade Design

Apart from the optimization of switch AT and overdrive, the third 9814 improvement involves the reed switch design. The 9814 relay incorporates a new switch combining the proven reliability of the sputtered Ruthenium contacts used in its predecessor, with a new blade design. At a given AT, the new switch has a larger contact gap than before. This results in a significant reduction in certain types of sticking failures, and has the added benefit of reduced electrical capacitance, important for high frequency switching applications.

Switch Contact Design

No subject in reed switch engineering is more controversial than switch contact design. What contact coating should be used? Ruthenium, rhodium, or iridium? Should it be electroplated or sputtered? What is the right coating thickness? How will the chosen coating handle inrush currents and other abusive loads? What layer structure should be used? Unlike most reed relay manufacturers, Coto Technology manufactures its own reed switches, and has had many years experience in evaluating these issues. We are convinced that the sputtered ruthenium coating used in the switch of the 9814 relay is the best choice for ATE applications. The hardness and high boiling point of ruthenium compared to other platinum group metals provides superb contact wear characteristics and resistance to sticking. Applying ruthenium by sputtering is a slower and more expensive process than electrolytic plating, but provides superior contact reliability by eliminating impurity inclusions. These qualities have been demonstrated by controlled side-by-side testing of Coto reed switches against those manufactured by our competitors. A recent independent study supports these conclusions.[1] Oshiyama *et. al.* found that metal transfer under hot switching conditions was the principal cause of sticking failures, and that switches with ruthenium contacts were seven times less prone to this effect than switches having rhodium contacts.

Demonstrated 9814 Relay Reliability

The ultimate measure of the reliability of a reed relay may depend on the physical chemistry of the contacts, but what matters to the user is its life under field conditions. The type RI71 reed switch used in the 9814 relay is a logical successor to the highly reliable type RI70 switch used in the 9800 series relays. Tested as a bare switch, the RI71 is significantly more reliable than a RI70 switch having the same AT value, with demonstrated MCBF (mean cycles before failure) values three to five times higher. Increasing the AT rating of the switch used in the 9814 pushes this multiplier even higher. The net result is a new relay

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[1] Oshiyama, Y., M. Fukushima and F. Katada, "**Life Time Diagnosis of Reed Relays Operated Under Hot Conditions**." *Proceedings of the 50th Int'l Relay Conference, Newport Beach, Ca., USA, April 14-17, 2003.* pp 4/1 – 4/5

that is not only more reliable than its Coto predecessor, but also significantly more reliable than its nearest competition, that still uses rhodium-plated switches.

For example, a sample of 16 type 9814 relays was tested to 300 million closure cycles using a resistive test load of 1V / 1mA. The relays were continuously monitored for missing, sticking or excessive contact resistance during this month-long test. No failures resulted. Standard Weibull reliability statistics [2] indicate a lower 90% confidence limit for the MCBF of 990 million cycles from this data, almost four times the expected life specified for the 9800 relay.

The 9814 relay has also been tested using a 5V 10 mA resistive load. The tests show an MCBF of 404 million cycles (90% confidence limits, 211 to 772 million cycles.) The 9814 relay is a newly released part, and reliability tests with larger numbers of test relays at different load levels are continuing. Contact Coto if you have questions concerning different test load levels, and how the 9814 relay can be best used in your particular application.

Some typical life test data for the 9814 relay compared to its predecessors is plotted on the following pages.

Interpretation of Weibull reliability plots

In the Weibull plots that follow, the Y-axis shows the unreliabity of the part, which is closely correlated to the cumulative percentage of relays that have failed after a certain number of cycles. The X-axis indicates the number of cycles to failure.

The legends on the right hand side of the graph identify the relay type, the number of failures (F), and the number of parts that survived the test without failure (S) The solid regression lines show the actual Weibull plot relating the number of parts failing to the number of cycles tested. Reading off the 50% unreliability level gives an approximation to the 50% failure rate for the part. Likewise, the 1% or 10% failure rates can also be read off. (More accurate numerical methods are used to calculate the MCBF, or mean cycles to failure.)

Curved dotted lines to the left and right of the Weibull regression lines show the upper and lower 90% confidence limits for the Weibull plot. The legends at the base of the graphs show (in the same vertical order as the legends on the right hand side) the numerical estimate of the Weibull slope (b-parameter), the characteristic life (h-parameter), and the regression correlation coefficient (r-parameter). Characteristic life is an alternative measure of reliability and represents the expected life before 63% of parts will fail.

Life data shown in this report is based on the first recorded failure of any kind (missing, sticking or excessive contact resistance events 1ms after relay activation/deactivation.)

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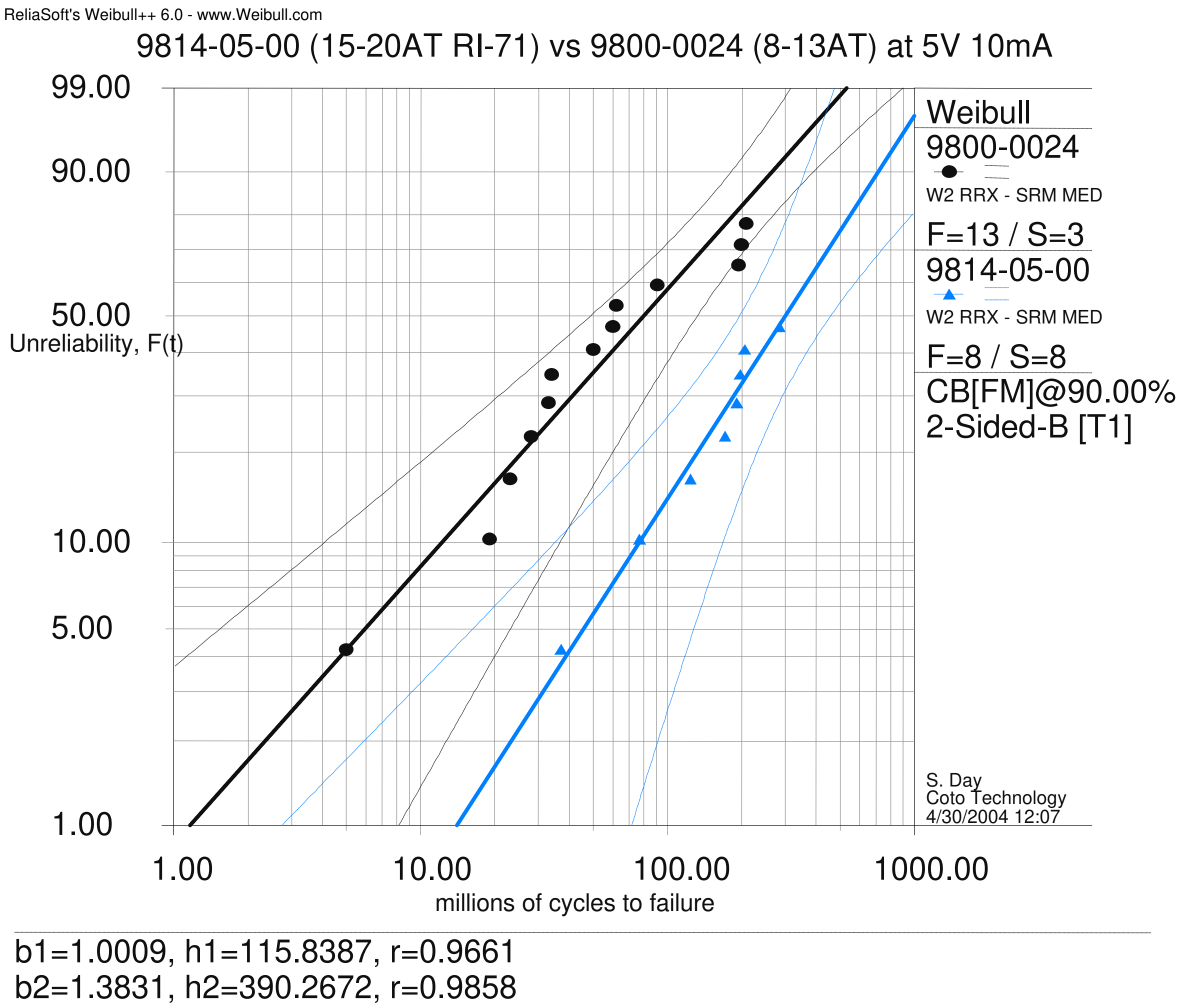
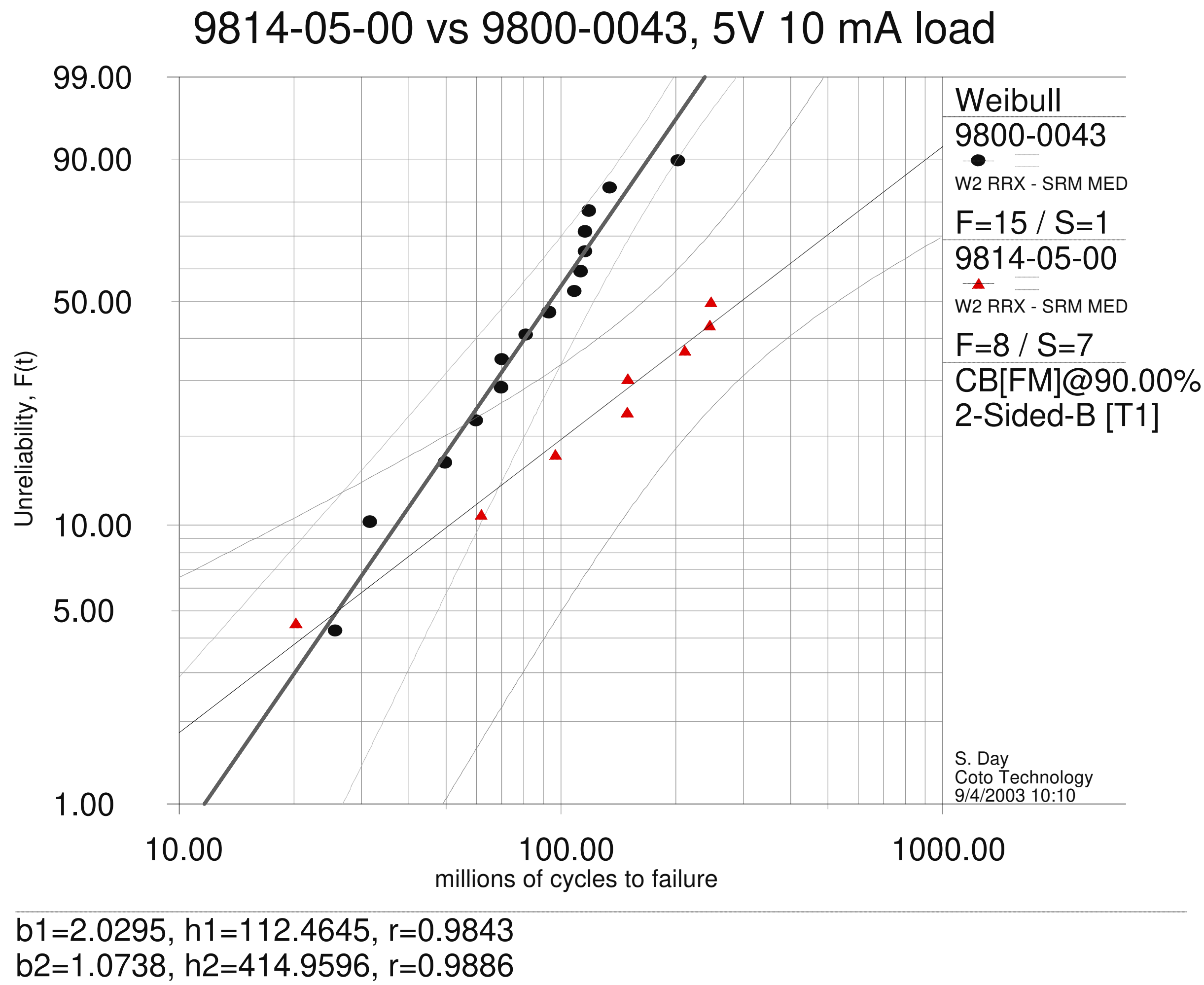
[2] Computed with *Weibull++ Version 6* software from Reliasoft Corporation, using the maximum likelihood estimation method. A Weibull slope (beta) estimate of 1.5 and single parameter Weibull computation was used, since there were too few failures in this data set to compute the Weibull slope. This value is typical for reliability data sets from similar life tests.

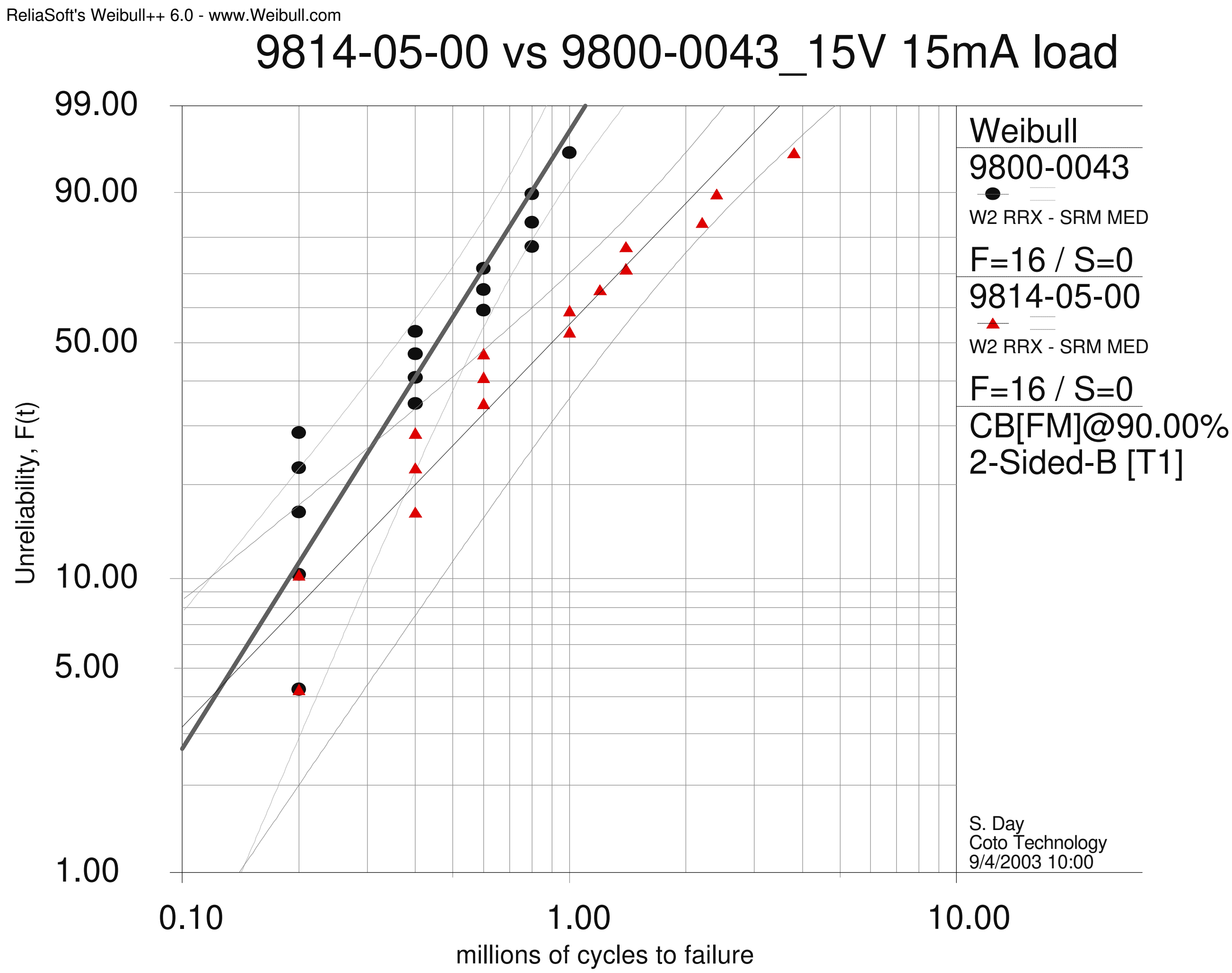


This Weibull plot compares the life of the 9814 relay with that of a previous relay, the 9800-0024, which incorporates an 8-13 AT Oki reed switch having plated rhodium contacts. The tests were run with a 5V 10 mA load. The 9800-0024 does not have a magnetic shell, and uses a copper leadframe.

ReliaSoft's Weibull++ 6.0 - www.Weibull.com

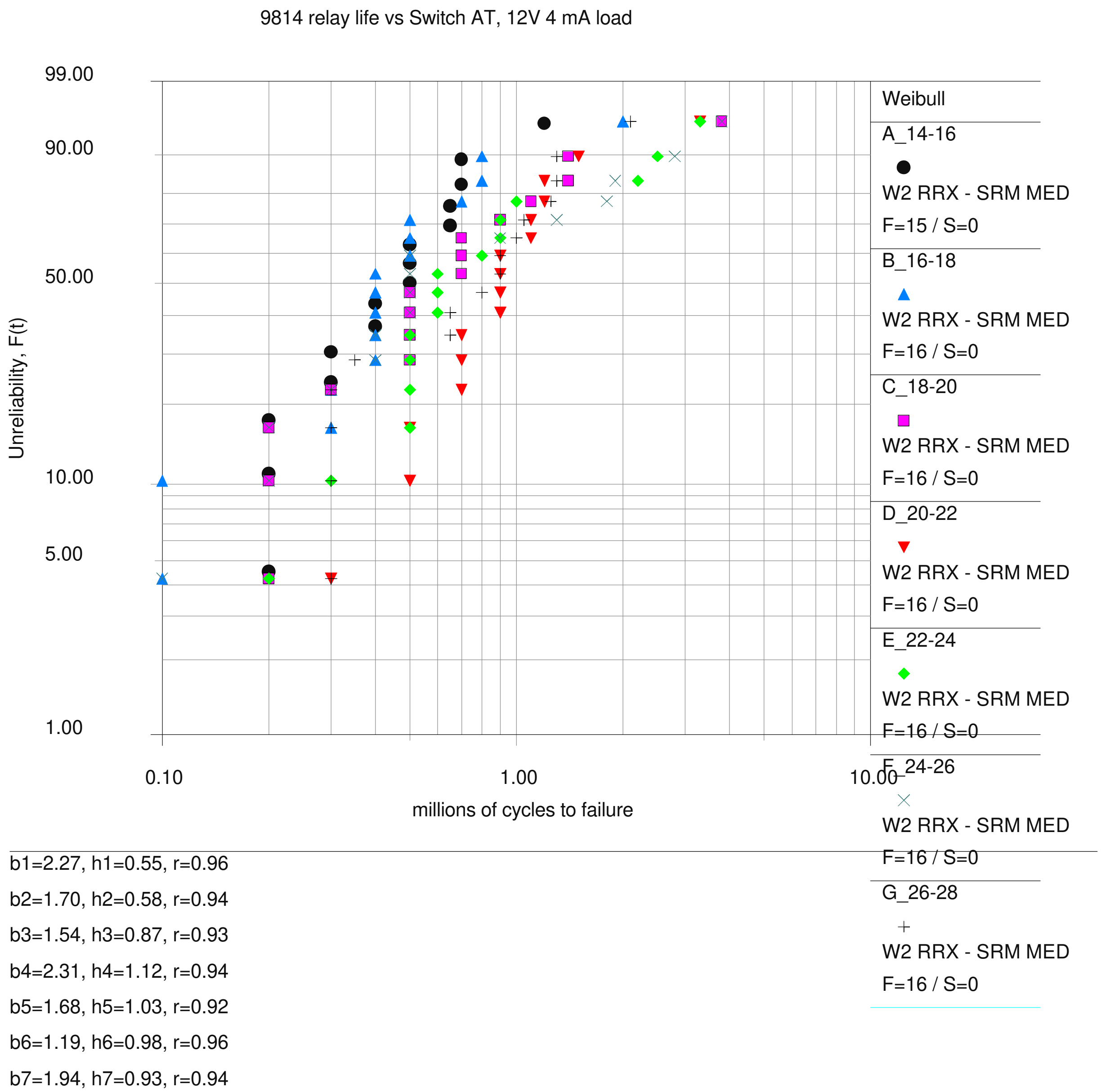


This Weibull plot compares the life of the 9814 relay with that of a previous relay, the 9800-0043 incorporating a Coto 10-15 AT reed switch. The tests were run with a 5V 10 mA load. The 9800-0043 does not have a magnetic shell, and uses a copper leadframe



b1=2.1453, h1=0.5390, r=0.9231
b2=1.3970, h2=1.1717, r=0.9656

This Weibull plot also compares the life of the 9814 relay with that of the 9800-0043 incorporating a Coto 10-15 AT reed switch. This test was run with a 15V 15mA load.



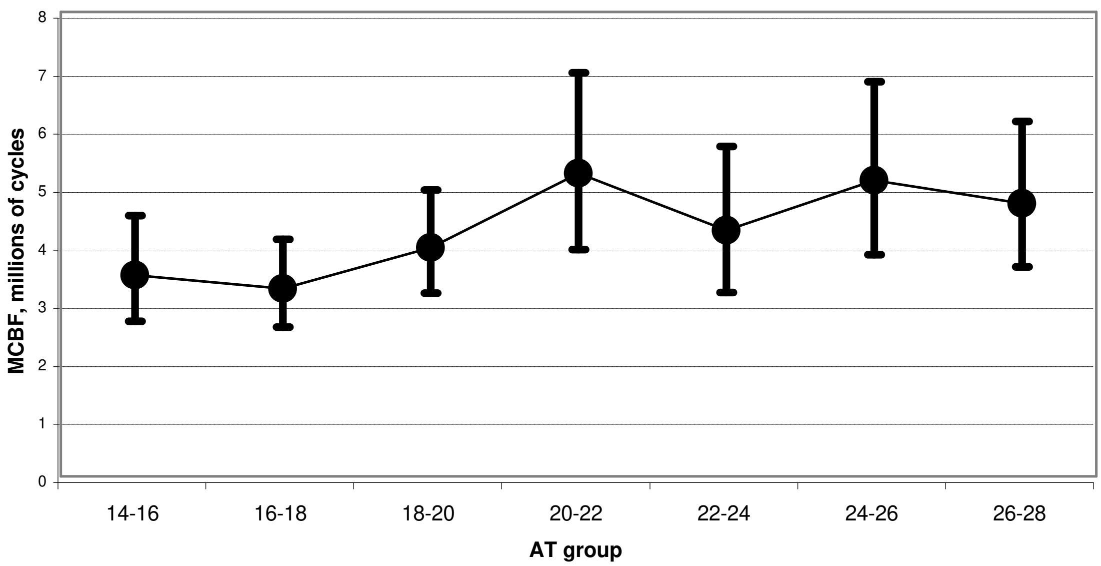
These Weibull plots shows the life of the 9814 relay using increasing ranges of switch AT rating, from 14-16 up to 26-28 AT. The test load was 12V 4mA; this is an aggressive load known to reveal problems due to sticking contacts. The coil voltage for each relay was individually adjusted to a fixed 50% overdrive, to ensure that differing levels of overdrive did not bias the life test results (Coto Technology has shown from separate experiments, not reported here, that percentage overdrive has a significant effect on relay contact life)

Note the significant increase in life for higher AT switches.

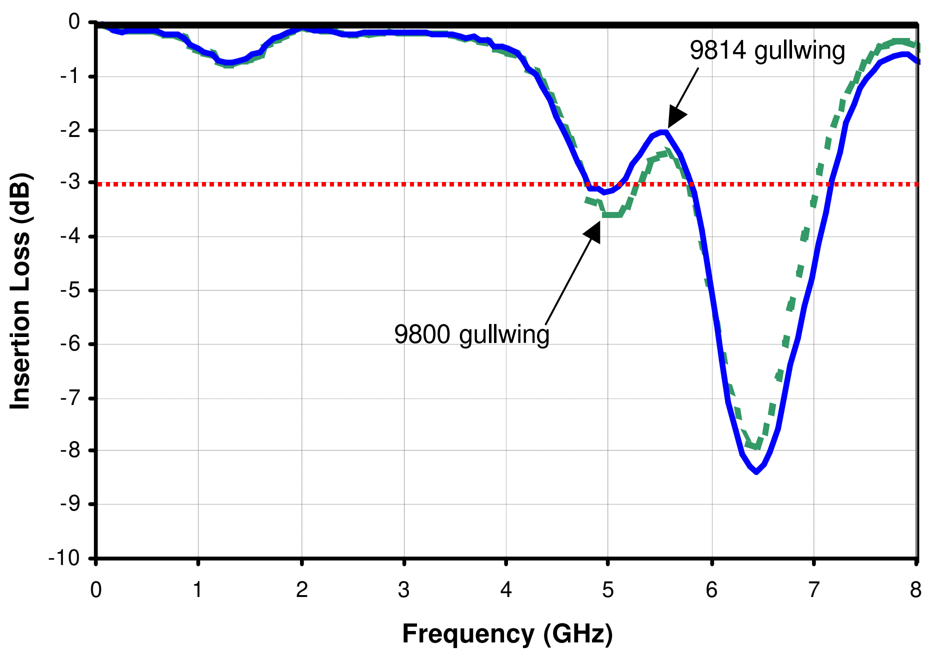
This chart shows the MCBF recorded for each switch AT range, with upper and lower 90% confidence limits. Failures were registered after 10 failure events had been recorded, to average out random errors for this comparative test.

Vertical separation of the confidence bands indicates a significant difference in MCBF. This analysis proves that under 12V 4mA load conditions switches with AT ratings greater than 20 give a higher MCBF than switches in the 14-20 AT range.

9814-05-00 Life vs switch AT, shutdown on 11th failure
(with upper and lower 90% confidence limits)



RF Insertion Loss Comparison, 9800 and 9814 Relays



RF Performance of the 9814 relay

The 9814 relay uses a nickel-iron leadframe, compared the copper based leadframe used in the 9800. Since these relays are often applied in applications requiring a wide RF bandwidth, we tested the insertion loss, isolation and return loss characteristics using an Agilent HP5719 vector network analyzer. This comparison is important, because of the possibility of high frequency skin effects that theoretically might be higher in the longer nickel-iron signal path of the 9814. The insertion loss plots for the 9814 and 9800 gullwing form are compared in the plot shown above. Note that the insertion loss plots are essentially identical, with both relays rolling off to –3dB at approximately 4.7 GHz. No increased losses due to skin effect are apparent. For clarity, only gullwing plots are shown here; plots for other leadforms and for isolation/return loss as shown for both relay types in the latest release of the Coto Technology Product Catalog, 2003 Edition.

Summary

The 9814 relay offers several advantages over both the 9800 relay and comparable competitive parts:

1. External magnetic shield fitted as a standard option, reducing magnetic interaction by a factor of four compared to an unshielded part.

2. Identical RF performance to the 9800 relay, and exceeded only by ball grid array parts such as the Coto B40 and B10 relays.

3. Demonstrated small signal switching reliability of approximately one billion cycles, four times greater than the expected life specified for the 9800 relay.

4. Uses sputtered Ruthenium contact technology, ensuring the best possible small signal switching performance and superior reliability to competitive relays with Rhodium contacts.

5. Drop-in replacement for the 9800 relay, ensuring compatibility with future applications.

6. Due to improved magnetic efficiency, available in 3.3V versions (70 ohm coil) and 5.0V (150 ohms) The 9800 relay is only available in a 5.0V version.

For further information about the type 9814 reed relay contact:

Coto Technology
55, DuPont Drive
Providence
RI 02907
USA

Tel: (401) 943 2686
Fax: (401) 942 0920
www.cotorelay.com