Maximizing the Life Span of Your Relays

Application Note 1399

Who should read this application note?

This application note is for automated test engineers and engineers who use a datalogger for R&D or production testing. In it, you will find information that will help you select the right relays for your switching application, realistically predict the longevity of your relays, and prevent early failures.

Introduction

Electromechanical relays can be used as actuators, as switches to route power to electrical devices, or for signal routing within a device or between different instruments. In data acquisition applications, relays are used to connect multiple transducers to a single measuring device.

Most electromechanical relays are driven electromagnetically. A magnetic flux is generated by passing current through a coil. This magnetic flux causes an armature to move, and the movement causes isolated electrical contacts to open or close, thus making or breaking electrical connections.

As with all mechanical devices, relays eventually wear out. If you use the right relays for the type of measurements you are making and derate them appropriately, you can protect your relays against early failure and prevent damage to your test instruments.

Selecting the right relay

Selecting the correct relay for your application is critical to the longevity of your relays. Four types of relays are commonly used in switching and signal routing; each offers distinct advantages and disadvantages, and each works best for certain applications.

Reed relays — When you need to switch at high speeds, reed relays typically are a good choice. In general, reed relays switch much faster than armature relays, have very low contact resistance and offer the added benefit of being hermetically sealed. They do not have the capacity to carry as high voltages and currents as armature relays.

Mercury-wetted relays — Mercury-wetted relays have long lives, don't suffer from contact bounce, and have very low contact resistance. However, they are position-sensitive, and must be mounted in the correct orientation to operate properly. Environmental concerns about mercury have limited the popularity of mercury-wetted relays.

Armature relays — Because of their ruggedness and ability to handle higher currents and voltages, armatures are the most commonly used relays. Armature relays usually have low resistance. They generally have slower switch times, and they are somewhat more susceptible to arcing than the other types. Some armature relays are sealed; others are not.

Solid-state relays — Solid-state relays typically are used for switching high-power circuits, such as ac line voltages. Solid-state relays have no moving parts and are arc-free. However, they generally have a higher "on resistance" than is acceptable in low-level signal switching applications.

Agilent Technologies

Table 1 summarizes general characteristics of the different relay types.

Predicting relay life spans

Relay manufacturers specify how long their relays will last, but the expected lifetime will vary depending on the loads they are subjected to. For resistive loads, manufacturers' specifications are typically fairly accurate. On the other hand, if you are using capacitance or inductance, your relay life span will be shorter than the manufacturers specification. How much shorter depends on the type of loads you are switching. Derating gives you a realistic picture of how long your relay will last.

Loads can be classified into five general groups.

Resistive loads – Relay manufacturers assume you will be using resistive loads when they rate their relays. The load is a simple resistive element, and it is assumed that the current flow through the contacts will be fairly constant, although some increase may occur due to arcing during "make" or "break." Ideally, a relay with a purely resistive load can be operated at its stated voltage and current ratings and attain its full lifetime. Industry practice, however, is to derate to 75 percent of the relay's stated capacity.

Inductive loads – Switching inductive loads is difficult, primarily because current tends to continue to flow in inductors, even as contacts are being broken. The stored energy in inductors induces arcing; arc-suppression schemes are frequently used. When you are switching inductive loads, you typically will want to derate relay contacts to 40 percent of the resistive load rating.

Capacitive loads – Capacitors resemble short circuits when they are charging, so the in-rush current from a capacitive load can be very high. Series resistors are often used to limit in-rush current; without a limiting resistor, contact welding may occur. When you are switching capacitive loads, you typically will want to derate your relay to 75 percent of the resistive rating.

Motor loads – When an electric motor starts up, it has very low impedance and requires a large in-rush current to begin building a magnetic field and begin rotating. Once it is running, it generates a back electromagnetic force (emf), which can cause a large inductive spike when the switch is opened. The result is a large in-rush current at "turn-on" and arcing at "turn-off." When you are switching a motor load, typical industry practice is to derate to 20 percent of the resistive rating.

Incandescent loads – An incandescent lamp is considered a resistive load. However, the resistance of a hot tungsten filament is 10 to 15 times greater than its resistance when it is cold. The high in-rush current into a cold filament can easily damage relay contacts. When you are switching incandescent loads, you will want to derate relay values to 10 percent of the resistive load rating. When possible, consider placing a current-limiting resistor in series with the filament to limit this in-rush current.

Table 1. Relay characteristics

	Relay type			
	Reed	**Mercury-wetted**	**Armature**	**Solid-state**
Contact resistance	Very low	Very low	Low	High
Switch speed	1000/s	100/s	50/s	1,000/s
Life	10 million	10 million	1 million	Infinite
Typical failure mode	Fails open	Fails open	Fails open	Fails shorted
Typical max. input	100 V/100 mA	100 V/100 mA	250 V/2 A	250 V/10 A
Use for	High-speed, low-level switching applications	Not recommended because of environmental concerns	Low-level switching with higher currents and voltages	High-power circuits

Table 2 summarizes relay switch derating factors based on the type of load switched:

**Table 2.
Relay derating factors for common load types**

Type ofload	Percent of rated value
Resistive	75
Inductive	40
Capacitive	75
Motor	20
Incandescent	10

Prolonging relay life

Over time, your switching system typically accumulates a large number of switch closures, so prolonging relay life is important. The most common relay types—with the exception of solid-state relays—rely on the mechanical closing of metal-based contacts that are covered with a thin surface film. As these electrical contacts are closing, a large electrical field is generated between them, which can initiate an arc. An arc also can form when these contacts open. This is particularly true if the load you are switching is inductive. Arcing, and the welding of contacts that is associated with it, affects relay contact reliability and life span. Other factors that affect contact reliability and life include the types of loads being switched, high-power or high-voltage switching, the heat capacity and thermal resistance of the contacts themselves, and the surrounding ambient temperature.

The maximum voltage, current, and power specifications of the relay contacts must be within the expected signal levels being switched. Switch contacts often can carry more energy than they can break at a switching point. In all cases, your contacts will last longer if you switch lower energy.

Suppression circuits

As we mentioned earlier, you may want to limit the surge current into the relay contacts. Whenever a relay contact opens or closes, electrical breakdown or arcing can occur between the contacts. Arcing can cause high-frequency noise radiation, voltage and current surges, and physical damage to the relay contacts. For capacitive loads, you can use a simple resistor, inductor, or thermistor in series with the load to reduce the in-rush current. For inductive loads, you can use techniques to clamp the voltage.

You also can place clamps, a diode, a zener diode, a varistor, or a resistor/capacitor (RC) network in parallel with the load as a snubber or suppression circuit. In the next section, we'll take a closer look at RC networks and varistors (Figure 1).

RC protection networks

When you design RC protection networks, you select the protection resistor (R_p) as a compromise between two resistance values. The maximum acceptable relay contact current (I_{max}) determines the minimum value of R_p. If you assume the maximum allowable relay current (I_{max}) is 1 A dc or ac rms, the minimum value for R_p is V/I_o, where V is the peak value of the supply voltage.

$$R_p = \frac{V}{I_{max}} = \frac{V}{2}$$

Usually, the maximum value for R_p is made equal to the load resistance (R_L).

Therefore, the limits on R_p can be stated as:

$$\frac{V}{I_{max}} < R_p < R_L$$

The actual value of the current (I_o) in a circuit is determined by the equation:

$$I_o = \frac{V}{R_L}$$

where V is the peak value of the source voltage, and R_L is the resistance of the load. You will use the value for I_o to determine the value of the protection capacitor (C_p).

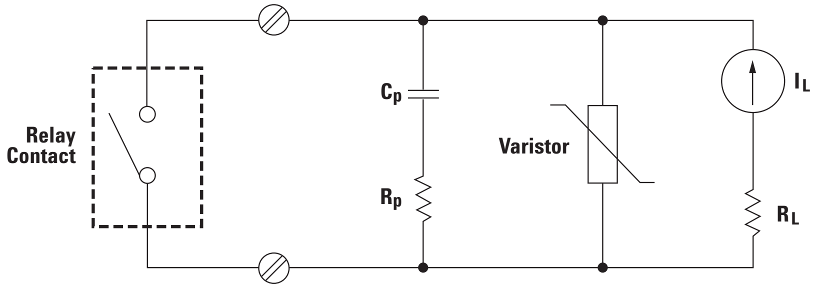
You need to consider several factors when you want to determine the value of the protection network capacitor (C_p). First, the total circuit capacitance (C_{tot}) must be such that the peak voltage across the open relay contacts does not exceed the maximum voltage rating of the relay. For a rating of 300 Vrms, the equation for determining the minimum allowable circuit capacitance is:

$$C_{tot} > (I_o / 300)^2 \times L$$

where L is the inductance of the load, and I_o is the current value calculated earlier.

The total circuit capacitance (C_{tot}) is made up of the wiring capacitance plus the value of the protection network capacitor C_p. Therefore, the minimum value for C_p should be the value obtained for the total circuit capacitance (C_{tot}). The actual value used for C_p should be substantially greater than the value calculated for C_{tot}.

Figure 1. Suppression circuit for limiting surge voltage



Using varistors

Use a varistor when adding an absolute voltage limit across the relay contacts. Varistors are available for a wide range of voltage and clamp energy ratings. Once the circuit reaches the varistor's voltage rating, the varistor's resistance declines rapidly. A varistor can supplement an RC network, and is especially useful when the required capacitance (C_p) is too large.

Conclusion

You can maximize your relay's potential life if you choose the correct relay type, if you keep voltage, current and power ratings within the relay's ratings (derated as appropriate for a given load type), and if you add snubber circuits as required.

References

Agilent 34970 Data Acquisition and Control Unit Users Manual

Electronic Engineer's Reference Book, Edited by FF Mazda

Electronic Engineer's Handbook, Fourth Edition, Donald Christiansen

Glossary

Derate—lowering the manufacturer's ratings for a relay based on the load type

Snubber circuit—same as suppression circuit

Suppression circuit—a circuit used to limit the surge current into relay contacts

Varistor—a protective device used on low-voltage ac circuits to limit transient overvoltages and divert transient currents

Zener diode—a device used as a voltage regulator

Related Agilent Literature

Product Overview—34970A Data Acquisition/Switch Unit, pub. no. 5965-5290EN

Agilent Email Updates

www.agilent.com/find/emailupdates
Keep up to date with Agilent's free Email Updates. As a subscriber, you will receive regular, customized email updates on the topics you select. Updates cover support issues, new products and services, application information, promotions, events, and other areas. It is easy to unsubscribe or change your preferences. Subscribe today: **http://www.agilent.com/find/emailupdates.**

Agilent is committed to respecting and protecting your privacy. Be assured that Agilent Technologies will never sell or rent your information to other companies. Unless you give your consent to have your information shared with others, the information you provide will be shared only with other Agilent entities and business partners who are providing services on behalf of Agilent and are bound by confidentiality agreements. Please see the details of our commitment to you regarding your privacy in the Agilent Privacy Statement at **http://www.agilent.com/go/privacy.** In addition, Agilent is a participant in the Better Business Bureau On-Line Privacy Program. Visit the BBB On-line at **http://www.bbbonline.com** to see the high standards we have agreed to follow. Please direct any questions about Agilent's privacy program to **privacy_advocate@agilent.com.**

Agilent T&M Software and Connectivity
Agilent’s Test and Measurement software and connectivity products, solutions and developer network allows you to take time out of connecting your instruments to your computer with tools based on PC standards, so you can focus on your tasks, not on your connections.
Visit **www.agilent.com/find/connectivity for more information**.

This app note is based on an article written by an Agilent author for Chipcenter, **www.chipcenter.com.**

By internet, phone, or fax, get assistance with all your test & measurement needs
Online assistance:
www.agilent.com/find/assist

Phone or Fax

United States:
(tel) 1 800 452 4844
Canada:
(tel) 1 877 894 4414
(fax) (905) 282 6495
China:
(tel) 800 810 0189
(fax) 800 820 2816
Europe:
(tel) (31 20) 547 2323
(fax) (31 20) 547 2390
Japan:
(tel) (81) 426 56 7832
(fax) (81) 426 56 7840
Korea:
(tel) (82 2) 2004 5004
(fax) (82 2) 2004 5115
Latin America:
(tel) (305) 269 7500
(fax) (305) 269 7599
Taiwan:
(tel) 0800 047 866
(fax) 0800 286 331
Other Asia Pacific Countries:
(tel) (65) 6375 8100
(fax) (65) 6836 0252
(e-mail) tm_asia@agilent.com

Printed in the USA June 11, 2002
5988-6917 EN

Agilent Technologies