Automotive Actuators and Medium-size Motors
Application Overview

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Problem/Solution

System designers must protect automobile electric motors against overheating that can damage temperature sensitive components. These fault conditions are usually temporary so devices with a reset capability that allow the circuit to return to normal operation once the power is removed and the fault is cleared are preferred over fuses. However, some resettable devices such as bimetallic and magnetic circuit breakers, as well as ceramic positive coefficient devices have disadvantages.

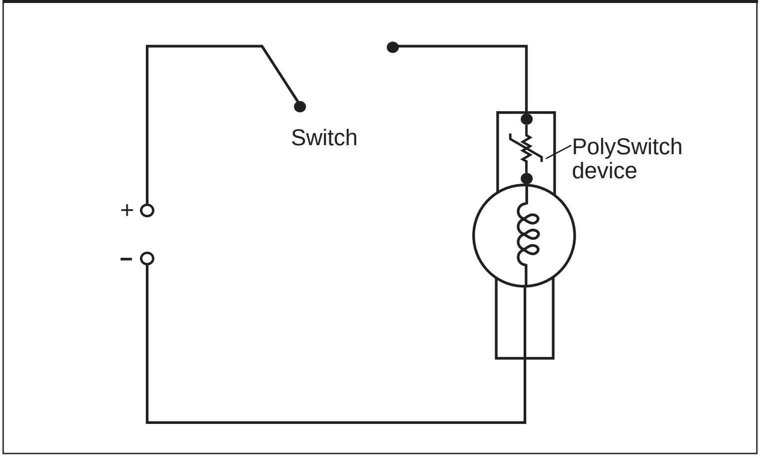
PolySwitch devices, generically know as Polymer Positive Temperature Coefficient (PPTC) resistors, offer several advantages over other resettable protection products and have been used for several years in automotive applications. These advantages include, but are not limited to:

- PPTC devices do not cycle on and off during the fault condition. Unlike Type I circuit-breakers, which cycle at about a 50% duty-cycle and therefore still deliver about 50% of the fault energy to the motor, PPTC devices latch in the tripped state, reducing the fault energy by several orders of magnitude.
- PPTC devices do not have mechanical contacts that can go out of calibration as a result of the effects of shock or vibration.
- PPTC devices do not have mechanical contacts that can erode, weld closed or cause electromagnetic interference (EMI) due to arcing, a phenomenon that is particularly evident when switching an inductive load such as a motor.
- PPTC devices do not have mechanical contacts that can develop insulating silica deposits, which can occur when a silicone lubricant is used in the presence of an arc.
- PolySwitch PPTC devices with advanced polymer technology are more resistant to the effects of hydrocarbon oils and greases that can contaminate the contacts of circuit breakers and affect the resistivity of conventional PPTC products.
- The PPTC device, being a polymer based component, tends to trip in a manner that 'tracks' the current, temperature and time to damage of polymer components in the motor, including wire insulation, bobbin formers and bearing supports. As the ambient temperature rises and the motor becomes more vulnerable to damage, the PPTC device becomes more sensitive and continues to help protect the motor.
- PPTC devices have much lower resistance than ceramic positive temperature coefficient (CPTC) devices that have been used to protect small motors.

Protecting Intermittent Operation Motors

In order to reduce cost and size, intermittent operation motors are usually designed to operate for a limited time and/or with limited travel. Examples include motors used in power windows, seat tracks, mirrors and locks. Operation for longer than the design maximum will usually result

Figure 1. Actuator Circuit



in overheating and eventually in failure. Most of these motors may also be subject to stall conditions that can result in overheating.

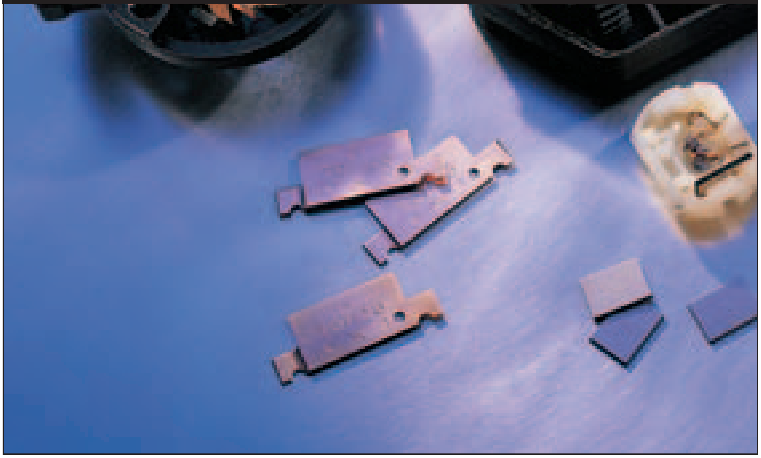
At the same time, the protection in the motor must not trip sooner than intended, which would result in a nuisance condition for the user. Consequently, it is essential to design protection devices that meet all the requirements for protecting the motor without nuisance tripping, especially when the system is operated over a wide temperature and voltage range. For this reason, most motor protection devices are custom built to work with a particular motor, and quite often for a specific application.

Figure 1 shows how a PPTC device is typically installed in a motor circuit. When the device is enclosed within the motor housing it is sensitive to the current flowing in the motor, and also to the temperature rise that will occur with a fault condition. Fault conditions may arise if the switch is held on, either because of contact failure, abuse, or error on the part of the user. Stall currents in motors of this type are about three times the normal run current. Note that on closing the switch, there will be an in-rush current of a magnitude determined by the resistance of the motor, which will flow until opposed by the back EMF of the rotating motor. A correctly sized PPTC device will have sufficient thermal mass to avoid tripping during this brief event.

Intermittent operation motors often have an electrical contact to connect to the switch and power source, and a metal fret or bus to route current within the motor. As a result, the PPTC devices used in such motors are frequently referred to as Terminal Devices (TD), one example of which is shown in Figure 2. Note that the PolySwitch device in Figure 1 is connected on one side to a motor brush and on the other to the external wiring. For the PolySwitch TD device shown in Figure 2, the external connection to the brush is usually achieved by welding the brush wire to the tab that can be seen on the far left side of the device.

The additional thermal mass of a TD type PPTC device provides it the characteristic of relatively slow operation. Many of the intermittent use motors in seat mechanisms and power windows are required to operate for a limited number of cycles without incurring damage, but operation beyond this level could result in heat damage. TD type PPTC devices can have a trip current substantially below the normal operating current of the motor but a time-to-trip several times longer than a full system operating cycle. Therefore, the device will trip after a number of system cycles but will operate much faster in the event of a stall situation where the

Figure 2. PPTC Terminal Device Packaging



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motor current is several times the PPTC trip current.

The polymer technology making PolySwitch PPTC devices generally inert to motor lubricants, also enhances the resistance to nuisance tripping during motor start-up and brief stall situations. This allows conventional radial-leaded and simple chip-style devices to protect motors in applications providing both cost and size reduction. The chip style PPTC is used almost exclusively in very small motors such as those found in door locks and mirror actuators.

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Note that although a door lock motor may be operated from a body control module that provides a timed pulse of current to the motor; this does not prevent the motor from being operated beyond its design duty-cycle if a user continually cycles the lock. While such unreasonable operation would be classified as customer abuse, it is hard to prove and define, making motor protection prudent to avoid warranty and poor quality perception issues. Electronic circuits that count the motor operational cycles and then enforce a "time-out" before re-use can be both more expensive and less user-friendly. The electronic circuit would have to be "worst-case" designed for the maximum number of cycles and minimum time-out that can be tolerated in a black vehicle operated in a hot desert region. This low probability situation imposes unreasonable limitations for operation in more common temperate or cold regions.

Protecting Continuous Operation Motors

The motors most commonly considered as continuously or almost continuously operated in a motor vehicle, such as those used in the radiator fan and in the HVAC systems, are also those that would seem to be beyond the protection capability of PPTC devices, which are generally able to be used with continuous currents of around 15A maximum at 25°C. However, these motors are even more difficult to protect with conventional fuses.

Once again, continuous operation motors are designed for minimum size and cost for the application. Since they drive fans, some airflow can be diverted through the motor to allow operating under more stress than would otherwise be possible. As a result, the stall current of fan motors is usually only two times the run current, compared to a ratio of three or four times common in other applications. This makes it difficult to find a fuse that will (1) open reliably over the lifetime of the vehicle if the fan becomes blocked and (2) not nuisance blow when the motor is first switched on.

As discussed in intermittent operation motors, unlike fuses, and to a more accurate degree than circuit breakers, PPTC devices lend themselves to motor protection by altering their characteristics as the motor's vulnerability changes over temperature, offering slower response when necessary. More importantly, in applications where a fan is driven, both the PPTC device and the motor can benefit from being placed in the air stream. In these designs, the trip current of the PPTC device will be greatly increased because the airflow tends to prevent it from reaching its trip temperature. However, if the fan stalls for any reason, the cooling effect of the airflow ceases causing the motor to heat up quickly as well as the PPTC device, which then trips and helps protect the motor.

Device Selection

A variety of custom and standard terminal devices (TD) are available for motor applications. Additionally, PolySwitch PPTC chips may be suitable for some small motor applications in which the chip must be held between spring clips. Devices from the Automotive (AHR, AGR, AHS, ASMD series) family may also be used. Raychem's ROV line of varistors is also applicable to motor and actuator applications.

Please contact your local Raychem Circuit Protection representative for information on TD and chip devices.