Process and Industrial Controls
Application Note

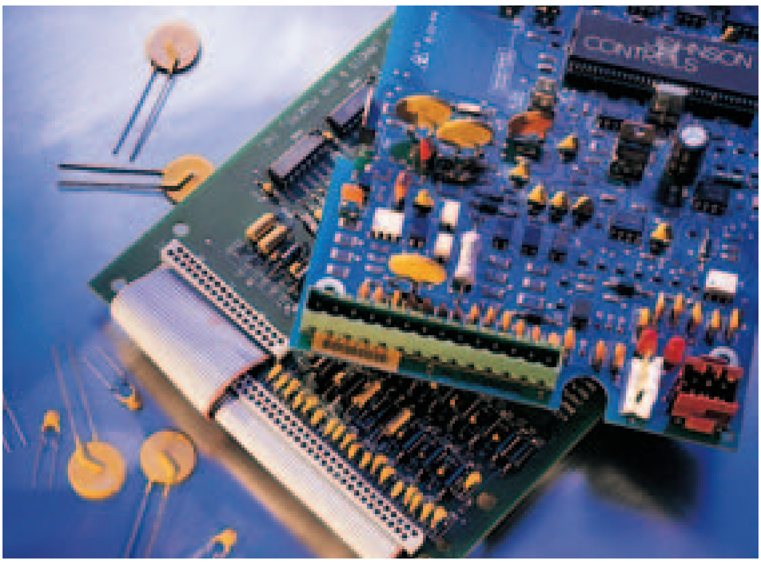
With the continuing automation of industrial processes, remote monitoring and control is becoming increasingly important in industrial-control arenas. Modern installations need control systems that guarantee accurate communications between different decision centers and machines and throughout an installation.

Many designers provide the means to monitor the environment in factories, schools, and office buildings and communicate the resulting information back to a central processor. This feedback is used to control the surrounding environment. However, because these systems can be damaged by faults that result in excessive current, monitor and industrial-control manufacturers are increasingly turning to PolySwitch resettable devices to limit fault currents to safe levels.

The Problem

Remote monitoring and control systems are inherently complex and present designers with several potential problem areas. Installers, for example, can inadvertently short-circuit power lines, or a cable can be pinched when it is installed in a conduit. A fault condition can also arise from the installation of an incorrectly wired cable that connects the wrong power source to the load.

If the current that results from these kinds of faults is high enough, wiring can overheat, components can fail, and circuit board traces can burn. The consequences of such faults can be extensive damage to expensive equipment and the loss of a critical system for an extended period. Because of these consequences, critical circuits must be protected against overcurrent conditions.



The Solution

PolySwitch resettable devices can react to the faults that are caused by overcurrent and overtemperature conditions and can help to protect monitoring, sensing, and control systems.

Monitoring and Sensing Applications

Many process control architectures exist. In a closed-loop system, such as the one shown in Figure 1, numerous serial drops with a range of several thousand feet can be connected together. In these kinds of multidrop systems, the state of the process variable affects the control system. Remote monitors extract data regarding such parameters as temperature, pressure, and velocity. If any of the process parameters exceed preset limits, the host computer can issue instructions to the appropriate units to alter the environment to bring the process back under control.

When communications over several hundreds or thousands of feet are required, they are often handled through a serial RS-485 twisted-pair transmission link that can connect the host to several monitor sites. The RS-485 drive includes a differential voltage of +5V. Since the distance covered can be quite long, miswiring and short-circuits are not unusual. To prevent damage, overload protection is essential. As shown in Figure 2, the proper protection scheme can come from a Zener diode and a small PolySwitch resettable device such as an RXE010 device. Circuit protection would be placed immediately after the interface to the printed circuit board before the transceiver for the twisted pair.

An additional benefit to using a PolySwitch device in this configuration is the ability to downsize other protection devices, such as the Zener diode in this case. A transorb or Zener diode acting as a voltage clamp on a 5V signal line protects the circuit by creating a very low resistance path to ground if the voltage on the protected line exceeds its breakdown voltage. However, since significant current can flow through the device, it must be large enough to handle the maximum anticipated current flow under worst-case conditions. If a PolySwitch resettable device is used to limit the current that flows through the clamping device, the device will not have to dissipate as much power and therefore can be much smaller and less expensive.

Figure 1. Closed Loop Monitoring Circuitry

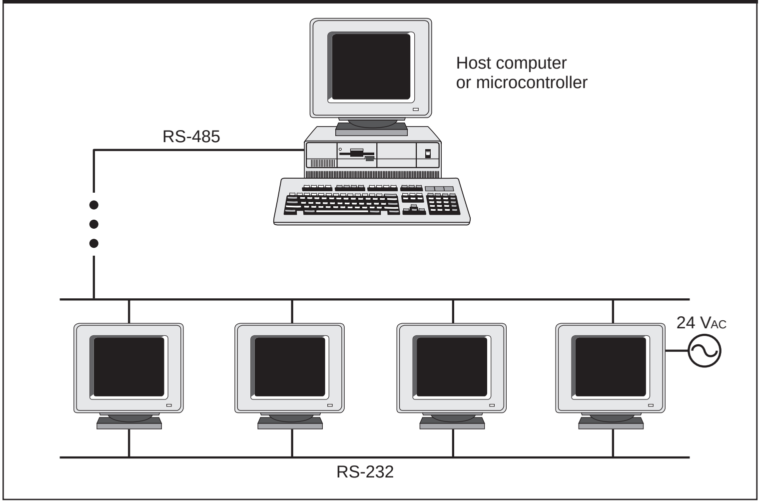
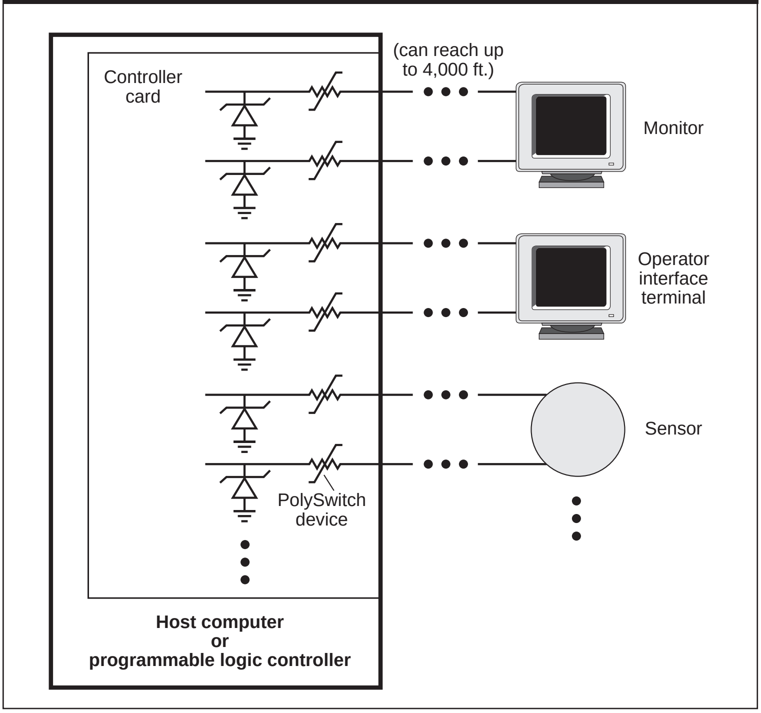


Figure 2. RS-485 Signal with Protection



In other types of industrial monitoring applications, such as environmental control, many times it is necessary to provide communication between sensors and a microcontroller. A typical block diagram, Figure 3, describes this data acquisition architecture. Numerous sensors can be located throughout the building.

These sensors can be of three types: voltage, current, and temperature. The devices will feed back information through an operational amplifier, then to an analog-to-digital converter, where the microcontroller will read the input. If the input is not within a specified or acceptable range, the microcontroller can instruct the control circuitry as required. Should an overcurrent condition occur, damage could result to the op-amp, the analog-to-digital converter, the circuit traces, or even the microcontroller itself.

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Figure 3. Data Acquisition Architecture

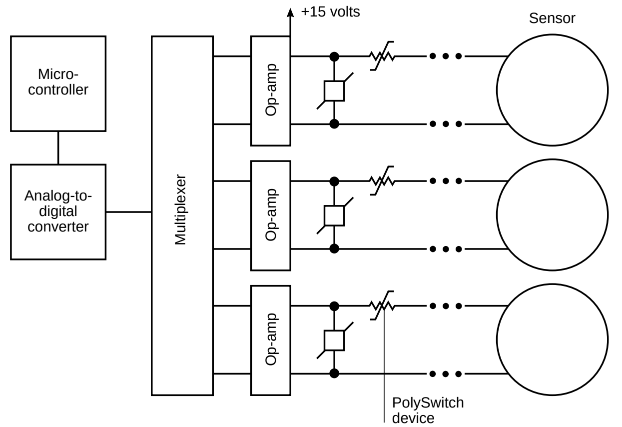


Figure 4. RS-232 Signal with Protection

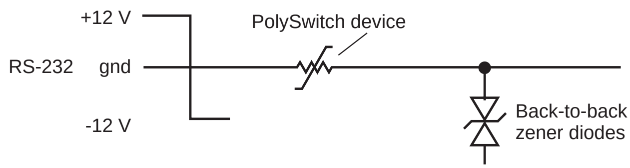
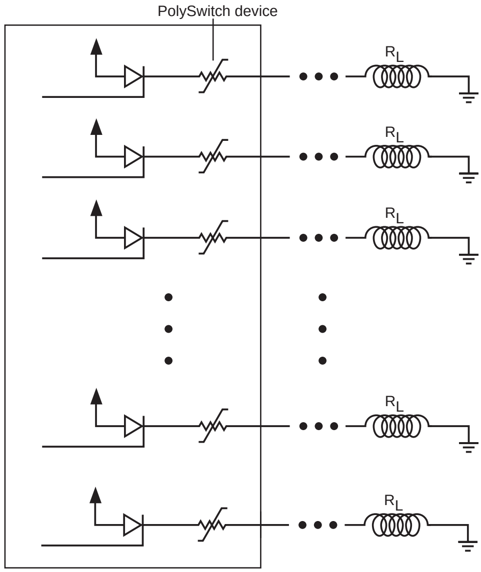


Figure 5. Typical SCR Master-Slave Configuration



A protection scheme is also noted in Figure 4. Since these sensor lines can cover long distances, they are typically found in the same conduit with other voltages. If an overvoltage situation should occur, and the rail voltage of the op-amp is exceeded, the overvoltage device will immediately break down. The PolySwitch device will then trip if the fault is prolonged, helping to protect the circuitry, including the overvoltage device.

Other types of microcontroller/sensor configurations are popular. In a second example, the sensor feedback is read by the change in voltage across a 250 to 300Ω series resistor. In this system, the microcontroller will monitor this change in voltage, and if the range is exceeded in any way, the microcontroller will instruct the control circuitry to make appropriate adjustments.

The use of the resistor is one potential solution to protect against damage from these faults. Since the microcontroller has to read small changes in voltage, the resistor has to be very precise. The power rating of the resistor must also be robust enough to sink any anticipated fault that may occur. Whether the designer chooses a thick-film or wire-wound resistor, the size will be quite large. A ceramic resistor can typically dissipate about 4W per square inch. If a resistor is used to dissipate the energy from a fault, the result is a much larger protection device when compared to a PolySwitch resettable device. The designer is also faced with constant power dissipation. The cost of such a resistor may also be an issue.

If the microcontroller is required to scan numerous sensors in this design, scan time and resolution become critical. In some applications, a complete scan may take nearly 1.0 second to run a complete check. If a fault occurs and the microcontroller does not see it in time, damage will occur to the circuit. A PolySwitch device in this application can react to the fault and help to protect the circuit from damage. This also frees up the channel of the microcontroller to perform more useful operations in the system.

It is not uncommon in a given process control architecture to change the range for the process variables. This can be accomplished by downloading the parameters to the monitors through the RS-232 connection. The RS-232 link is also used to verify calibration between the monitor and the host. Either application requires the use of external equipment to the host's RS-232 port. The RS-232 drive includes a low-current ±12V signal. If an incorrectly wired cable is used or pins are accidentally shorted, damage can quickly occur. A strategy similar to that used for the RS-485 port can also be used for the RS-232 port, but it requires the use of back-to-back Zener diodes to accommodate the drive voltage, as shown in Figure 4.

The monitors themselves also pose potential problems. Many are powered by a 24V source, as shown in Figure 1. Should the power connections be miswired and inadvertently directed onto low-voltage signal lines, significant damage can result. A PolySwitch resettable device in series with the secondary side of the power supply can help to protect against this damage.

Control Circuits

When a process variable is out of its specified range, the host can instruct control circuits to correct the problem. The host does this by turning a motor on, energizing a solenoid, closing a valve, or taking some other appropriate action. Each action, however, requires some type of switching. Today, most switching is solid-state and often performed by a silicon-controlled rectifier (SCR). An SCR is a diode that normally does not conduct in either direction, but can be turned on in the forward direction by the application of a low-voltage control signal to its gate (Figure 5 is a typical SCR master-slave configuration). Although a robust device, if the SCR is incorrectly wired or if connected to a malfunctioning load, it can overheat and fail. A Poly-Switch device which trips before the SCR on the board fails eliminates the need to replace the SCR. Now, only service of the load is required and the control card can stay functional.

Electromechanical relays are still used in some process control equipment but they are not immune from potentially damaging overcurrent faults. For example, if the load out in the field fails or shorts, excessive current will flow through the contacts causing them to weld shut and fail short. This relay failure will result in significant system down-time until the relay on the card, along with any other damaged components, are replaced. A PolySwitch device in series with the relay contacts helps protect against the damage that can occur, Figure 6. The PolySwitch in its high-resistance state helps protect the contacts until the load is repaired.

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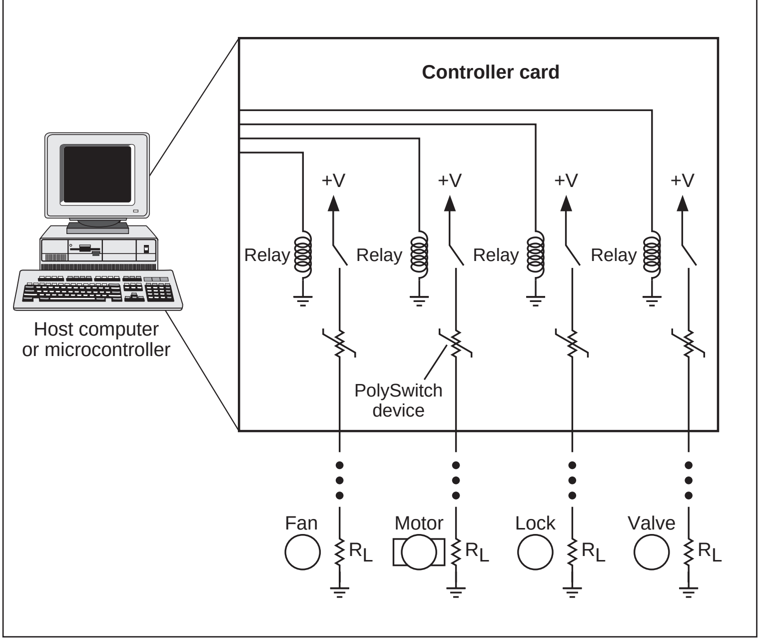
Figure 6. Controller Protection



A long-standing tradition that contributes to miswiring is that both power (less than 100 V_{DC}) and signal lines are often run in the same conduit. At the remote end, which can be thousands of feet away from the host, it is not difficult to connect the wires incorrectly, wire the hot lines to ground, or superimpose powered lines on low-voltage data lines.

Technology Comparison

Traditionally, fuses and ceramic positive temperature coefficient (CPTC) resistors have been used to limit current in remote monitoring and control systems. However, both technologies present some disadvantages.

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While fuses can reliably prevent damage or fire due to a short-circuit or low resistance fault, they are one-use devices that must be replaced when they blow. If the circuit experiences a transient current, a fuse can nuisance blow and will make the circuit inoperable. PolySwitch devices will typically not trip during a transient current, since the power is too small to sufficiently heat the device. If the device does trip due to an overcurrent fault, it can reset without replacement once the circuit power and fault are removed. With the continuing miniaturization of components and the use of surface-mount technology, the replacement of most fuses may require a service technician.

CPTC resistors also function by increasing their internal resistance as their temperature rises. As their resistance increases, the current flowing through them and the protected load decreases. Eventually, a thermal equilibrium is established that maintains the current at a level low enough to ensure the load is not damaged. However, CPTC resistors have a relatively high resistance under normal operating conditions and can dissipate noticeable power. PolySwitch devices typically switch to high resistance at lower temperatures and dissipate significantly less power under normal operating conditions.

To have a sufficiently low resistance, CPTC resistors are relatively large, which may be a concern in applications where space is at a premium. Also, being a ceramic material, they may be vulnerable to cracking as a result of mechanical shock or vibration.

Device Selection

RXE010-RXE030, miniSMDC014, miniSMDC020, SMD030, or SMD050 devices are typically used in this application.

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