Substitute Current Shunt

Shuts off power when excessive current is drawn and restores power when safe to do so—all automatically and without the need for fuses or circuit breakers

By Mike McGlinchy

Traditional current shunts are usually bulky, heavy and expensive, which is why they're used only to protect expensive equipment when current drawn becomes excessive. Going the less expensive route of installing a fuse or circuit breaker, though compact and inexpensive, is far from the ideal solution. Once the fuse blows or circuit breaker trips, you must be present to replace the former or reset the latter. Here, we'll describe an inexpensive alternative to the traditional current shunt that works automatically.

Our Substitute Current Shunt continuously monitors the current drawn by an electrical device. Installed between the power source and device being monitored, when the Shunt detects excessive current flow it automatically opens a pair of relay contacts and deprives the device being protected of power. Shutdown is not permanent, as is the case with a fuse or circuit breaker. The Substitute Current Shunt automatically restores power to the device when the current drawn falls below the predetermined threshold.

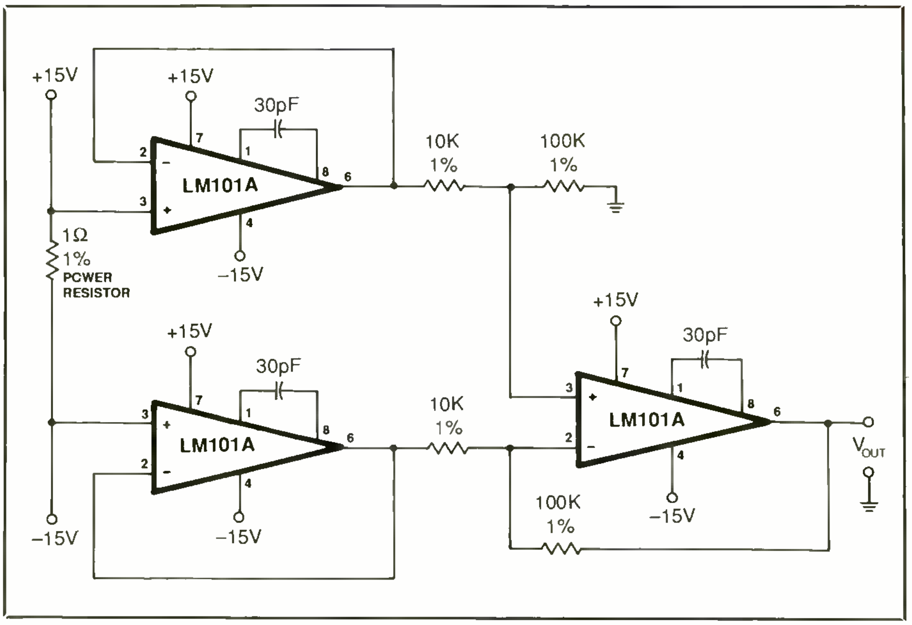

Fig. 1. Schematic diagram of a basic solid-state substitute current shunt.

About the Circuit

Shown in Fig. 1 is a schematic diagram of a basic current shunt circuit built around commonly available LM101A integrated-circuit differential amplifiers. The 1-ohm sense resistor goes in series with the main power bus to the device being protected. The value of this resistor is low enough to have only a negligible effect on operation of the device. Its power-handling capability (wattage) must be selected to safely accommodate the maximum power expected to be drawn by the device being protected.

Assume that the device being protected draws nominally 400 milliamperes under ideal operating conditions and, furthermore, that it should never under any circumstances draw more than 450 milliamperes. This being the case, if the device begins to draw 500 milliamperes, something is most definitely wrong and corrective measures must be taken to prevent its destruction.

Using Ohm's Law, you can calculate the the voltage drop that appears across the sense resistor by multiplying 500 milliamperes by the resistor's 1-ohm value, which yields 500 millivolts. This voltage drop is fed to the inputs of the differential amplifier. In this example, the gain of the differential amplifier is set at 10 (from 100,000 ohms/10,000 ohms). Therefore, 500 millivolts × 10 = 5 volts, which is the potential that appears at pin 6 of the LM101A differential amplifier and is, thus, the output from the circuit.

Shown in Fig. 2 is a more complete schematic diagram of the Substitute Current Shunt that is the subject of this article. This schematic lacks only

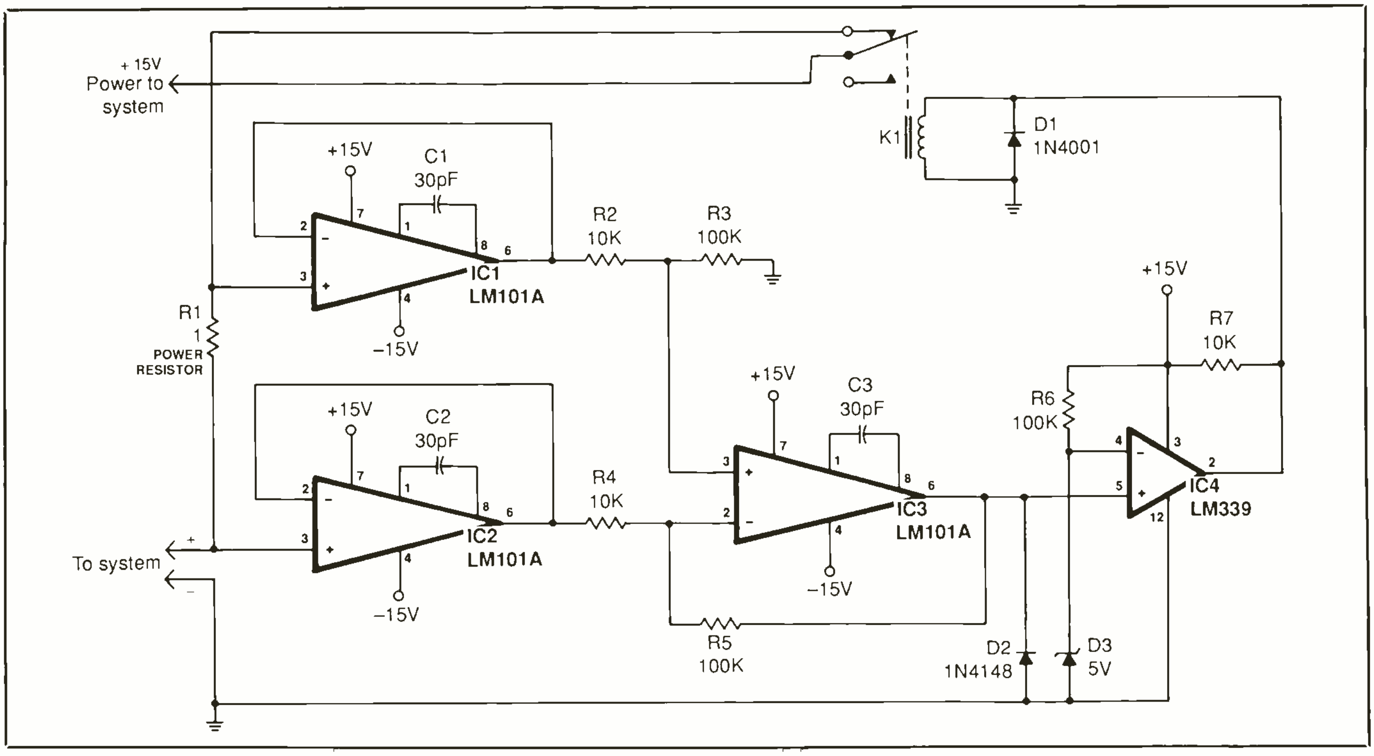

Fig. 2 Schematic diagram of the complete Substitute Current Shunt circuit, including the relay switching circuit that automatically interrupts power to the protected system when excessive current is drawn and restores power when conditions return to normal.

PARTS LIST

Semiconductors
D1—1N4001 or similar rectifier diode
D2—1N4148 or similar silicon switching diode
D3—5-volt zener diode
IC1 thru IC3—LM101A differential amplifier
IC4—LM339 voltage comparator

Capacitors
C1,C2,C3—30-pF disc

Resistors (¼-watt, 10% tolerance)
R2,R4,R7—10,000 ohms
R3,R5,R6—100,000 ohms
R1—1-ohm power resistance (wattage according to amount of current drawn under abnormal conditions—see text)

Miscellaneous
K1—12-volt dc spst relay
Printed-circuit board or perforated board and suitable soldering or Wire Wrap hardware (see text); sockets for all ICs; suitable enclosure and small rubber grommet (if needed—see text); machine hardware; hookup wire; solder; etc.

the ±15-volt supply needed to power the circuitry. Note here that the circuitry containing differential amplifiers *IC1*, *IC2* and *IC3* and their associated components is identical to that shown in Fig. 1. The difference in this circuit is the addition of the *IC4* LM339 voltage comparator circuit and relay *K1*.

Zener diode *D3* provides a 5-volt reference to the noninverting (+) input at pin 4 of *IC4*. It's this reference against which the voltage at output pin 6 of *IC3* is compared. As in the Fig. 1 circuit, the magnitude of this potential is determined by the voltage dropped across sense resistor *R1*.

As long as the potential being fed to noninverting input pin 5 of *IC4*, the output at pin 2 of this IC is nominally 0 volt. However, when the *IC3* differential amplifier outputs +5 volts or greater to pin 5 of *IC4*, as would occur when 500 milliamperes is being drawn by the system in the above example, pin 2 of *IC5* will go to +15 volts. When this occurs, relay *K1* energizes. Its contacts then spring open to deprive the device or system being protected of its power source.

Once the circuit trips, the voltage dropped across sense resistor *R1* drops to 0 volt. In turn, this causes the output of *IC3* at pin 6 to drop to nominally 0 volt, which is applied to the noninverting pin 5 input of *IC4*. The pin 2 output then drops to 0 volt, causing *K1* to deenergize and apply power back to the system or device being protected. If the current flowing through *R1* still exceeds the preset "safe" level, the Substitute Current Shunt circuit will once again cause the relay to energize to deprive the protected system or device of power. Should the project determine that the voltage dropped across *R1* is within safe limits once again, however, it restores power to the protected device or system.

Diode *D2* shown installed between noninverting pin 5 of *IC4* and circuit ground is in the circuit to protect the LM339 from negative voltages. Diode *D1* protects the output of *IC4* from damage that might otherwise occur if it weren't in the circuit to absorb the inductive kickback from the relay's coil when it is deenergized.

The above example and Fig. 2 both assume that the device or system being protected will be powered by a 15-volt or less dc power supply. Of course, this needn't be the case. You can rig the circuit to work with any other low dc-voltage circuit or system.

Not shown in Fig. 2 is the bipolar dc power supply needed to operate the Substitute Current Shunt circuit. Because current drain of the Shunt is minimal, just about any ±15-volt power supply will do.

Construction & Checkout

Because of the simplicity of the circuitry that makes up the Substitute Current Shunt, any traditional wiring technique can be used to build the circuit. For example, you can mount the components on perforated board that has holes on 0.1-inch centers and use soldering or Wire Wrap hardware to make interconnections between the components. Alternatively, you can design and fabricate a printed-circuit board. Whichever way you go, however, it is a good idea to use sockets for the ICs. All components, including the relay (unless it is large and heavy), should be mounted on the board.

Be sure to observe proper polarity when installing *D1*, *D2* and *D3*. Also, make sure to use heavy wire for the connection from the relay's normally-closed contact and *R1* and from *R1* to the circuit or system being protected. Additionally, mount power resistor *R1* so that it sits about ½ inch above the surface of the circuit board to allow air to freely circulate around it and carry off heat.

Do *not* install the ICs in their respective sockets. Once you have wired the entire circuit, clip the common lead of an audible continuity checker or multimeter set to the ohms function to a convenient point in the circuit that is to be at ground potential. Then touching the "hot" lead or probe to pins 4 and 7 of the *IC1*, *IC2* and *IC3* sockets and pin 3 of the *IC4* socket should yield no audible indication from the continuity checker or an infinity reading on the meter in all cases.

Now connect either lead or probe to any point along the +15-volt bus. Touching the other lead or probe to pin 7 of the *IC1* through *IC3* sockets and pin 3 of the *IC4* socket should cause the continuity checker to sound an audible tone or ohmmeter to register a 0-ohm reading.

Finish up your tests by checking the −15-volt distribution bus. To do this, connect one lead or probe to any convenient point along the −15-volt bus. Then, touching the other lead or probe to pin 4 of *IC1* through *IC3* should cause a tone to be generated or a 0-ohm reading to be registered.

If you do not obtain any of the cited indications, locate the cause of and rectify the problem. Do not attempt to put the circuit into service until you are certain that it is properly wired. When you are sure the circuit is properly wired, install the ICs in their respective sockets. Make sure that each is properly oriented and that no pins overhang the socket or fold under between IC and socket.

If possible, install the project inside the enclosure that houses the circuit or system to be protected. If there is no room or the circuit or system to be protected has no ±15 volts to power the project, house the project and its dc power supply in a separate enclosure.

For the separately housed Substitute Current Shunt and its power supply, bring out the leads that connect to the movable contact's lug of *K1* and the two wires labeled TO SYSTEM through a rubber-grommet-lined hole in the enclosure. Label the first lead V+ and the two remaining leads SYSTEM + (upper arrowed lead in Fig. 2) and SYSTEM GND.

If you are installing the project inside the protected equipment's enclosure, make sure that no part of the Substitute Current Shunt electrically contacts any portion of the protected equipment's circuitry. The *only* connections that are to be made to the protected circuitry are via the V+ and ground leads.

To make the installation, first solidly connect the project's SYSTEM GND lead to the circuit or system's ground bus. Next, locate the circuit or system's V+ bus and track it back to the final output capacitor in the power supply, and interrupt the bus at this point. Connect and solder the free end of the SYSTEM + wire to the circuit side of the interrupted connection and the V+ wire to the power-supply side. This completes installation.