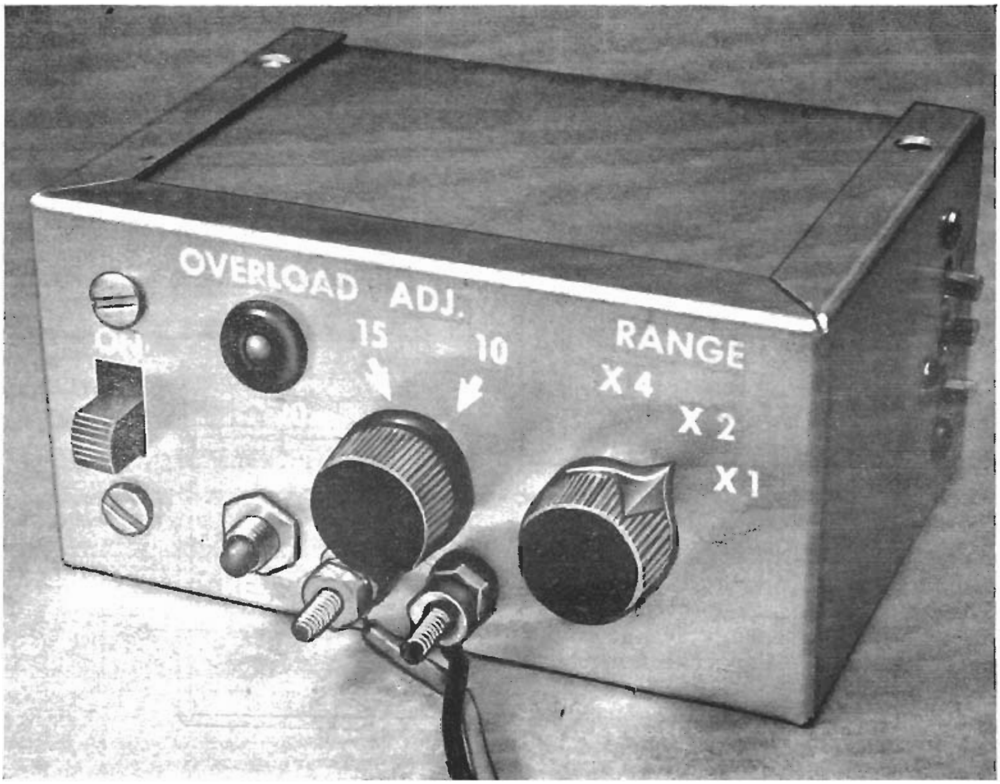


ELECTRONIC

Overload Protection

CURRENT LIMITER FOR YOUR SEMICONDUCTORS

BY JOHN L. KEITH

ELECTRONICS experimenters are finding more and more uses for the latest microminiature solid-state devices—and with good reason. These components simplify circuit design and construction, making it possible for the experimenter to build projects that were formerly too complex and expensive to duplicate. There is one great care the experimenter must exercise, however: most semiconductor devices are extremely current sensitive. Exceed the rating just a little bit, and the device may be permanently damaged. To prevent such occurrences, try the electronic overload protector described here.

When connected between the power supply and the experimental circuit, the overload protector automatically limits the current drawn by the circuit to a value consistent with the known ratings of the semiconductor devices you are using.

The protector, whose circuit is shown in Fig. 1, operates on the principle of a shunt current meter. The load current must flow through one of the range resistors, *R8-R10*. The voltage drop across the resistor is then applied through potentiometer *R11* to the base of *Q1*. The use of *R11* makes each range continuously variable.

With no overload condition, *Q1* conducts slightly, allowing *Q2* to conduct

PARTS LIST

D1,D2—1N34A diode
D3—1N2096 diode
I1—#327R incandescent pilot lamp (28 volts at 40 mA)
K1—S.p.d.t. relay, 5500-ohm at 2.9-mA winding
Q1,Q2—2N508 transistor (see text)
R1—680-ohm
R2—220-ohm
R3,R5—220,000-ohm
R4—82,000-ohm
R6—9100-ohm
R7—10,000-ohm (see text)
R8—20-ohm
R9—10-ohm
R10—5-ohm
(R1–R10: *All resistors ½-watt*)
R11—5000-ohm linear taper potentiometer
S1—S.p.s.t. slide or toggle switch
S2—Momentary-action, push-to-close switch
S3—Three-position, non-shorting rotary switch
7—Five-way binding posts or banana jacks for contacts 1 through 7
1—metal utility box
Misc.—Rubber grommet for I1; hardware; hook-up wire; solder; etc.

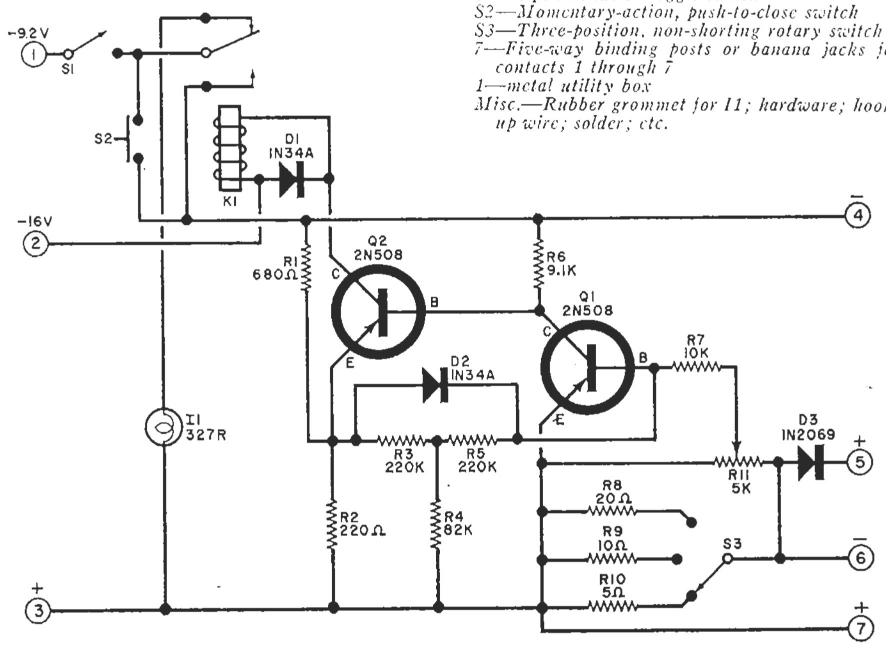
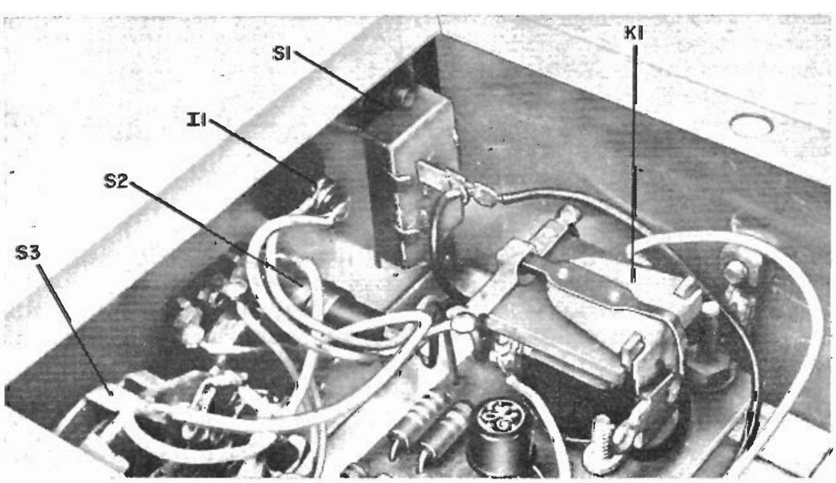


Fig. 1. Input power is applied via contacts 1 and 2; separate 16-volt supply for K1 via 2 and 3; load via 4 and 5. Load current is measured as voltage drop between 6 and 7 and converted to current with Ohm's Law.

Switches S1-S3, potentiometer R11, and indicator lamp I1 mount directly to front panel of utility box. Load connectors, also on front panel, can be five-way binding posts.



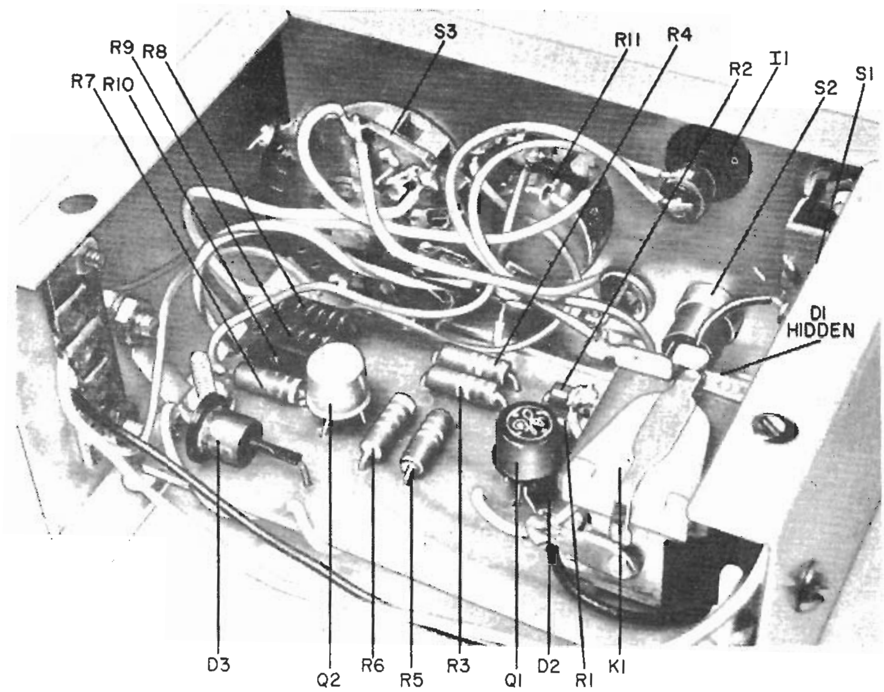


Fig. 2. Although printed circuit board construction is shown, circuit is simple enough to be assembled with point-to-point wiring. Terminal strip at left is for power inputs.

heavily and energize relay *K1*. Emitter-to-base negative feedback is used as temperature compensation.

When an overload occurs, *Q1* becomes forward biased, lowering the *Q2* bias and deenergizing *K1*. This action disables the output circuit. Then when reset switch *S2* is momentarily depressed, bias is restored to *Q1*, *Q2*, and the output. If the overload still exists, *Q2* will remain cut off, and *K1* will not energize. But if the overload is removed, *Q1* conducts and energizes *K1* when *S2* is depressed.

The three ranges chosen provide accurate current control in steps of 10-25 mA, 20-50 mA, and 40-100 mA at 9 volts d.c. Also provided are connections for measuring the voltage drop across the range resistors (contacts 6 and 7). This voltage can be converted, by Ohm's Law, to current and indicated on a graph.

Although designed for 9-volt operation, the overload protection circuit can be used with other input voltages to provide corresponding output voltages. Just be sure to take into account the change of current flowing through the range resistors with the new voltage.

The construction and layout of the electronic overload protection circuit are not critical. While the original prototype shown in Fig. 2 was assembled with the aid of a printed circuit board, the circuit is simple enough to permit point-to-point wiring. Almost any general-purpose transistor should work satisfactorily, provided that the one employed as the shunt

VOLTAGE TO CURRENT RELATIONSHIPS

	RANGE SWITCH POSITION		
VOLTS	A	B	C
0.2	10 mA	20 mA	40 mA
0.3	15 mA	30 mA	60 mA
0.4	20 mA	40 mA	80 mA
0.5	25 mA	50 mA	100 mA

amplifier has high enough gain, and the transistor for relay control has a V_{CBO} of 16 volts or more. If the transistor (*Q2*) gain is too low, the value of *R7* might have to be reduced to 4700 ohms.

For your convenience, the table gives the voltage-to-current specifications for the three settings of range switch *S3*. This table can be cut out or copied and pasted to the enclosure. —30—

Low-loss shunt protects high-current supplies

by Roy Hartkopf and Ron Kilgour
Alphington, Victoria, Australia

The usual method for providing short-circuit protection in low-voltage, high-current power supplies is to employ a current-sensing resistor in series with the load. Unfortunately, this scheme develops an appreciable voltage drop across the resistor when large currents flow and may consequently reduce the available output voltage to a great degree. The voltage drop can be virtually eliminated with an alternative method, shown here, which uses an audio transformer and a single-turn winding to sense the overcurrent condition at the secondary of the supply's power input transformer. Besides being inexpensive, the current sensor will react faster to overloads than some of the more conventional circuits.

As shown in the figure, current protection may be secured for a typical 27-volt, 20-ampere supply by winding a single turn of 10-gauge wire, which is placed in series with the power transformer's secondary and the supply's rectifier bridge, onto a small audio transformer connected in the control section of the supply. During normal operation, transistor Q_1 will be saturated because current is delivered to its base from the 27-v supply line. Note that the secondary of the audio transformer, in conjunction with diode D_1, will contribute a relatively small negative voltage at the summing junction of P_1.

Should the current demands increase, however, the magnitude of the negative voltage developed at the audio transformer's secondary will increase and, consistent with the setting of potentiometer P_1, pull the base-to-emitter voltage down to cut off Q_1. The 2N2646 unijunction transistor will then turn on and trigger the silicon controlled rectifier, and the control signal will be brought low. Thus this signal can be used to cut off the supply. This action will be instantaneous, occurring on the first overload cycle. □

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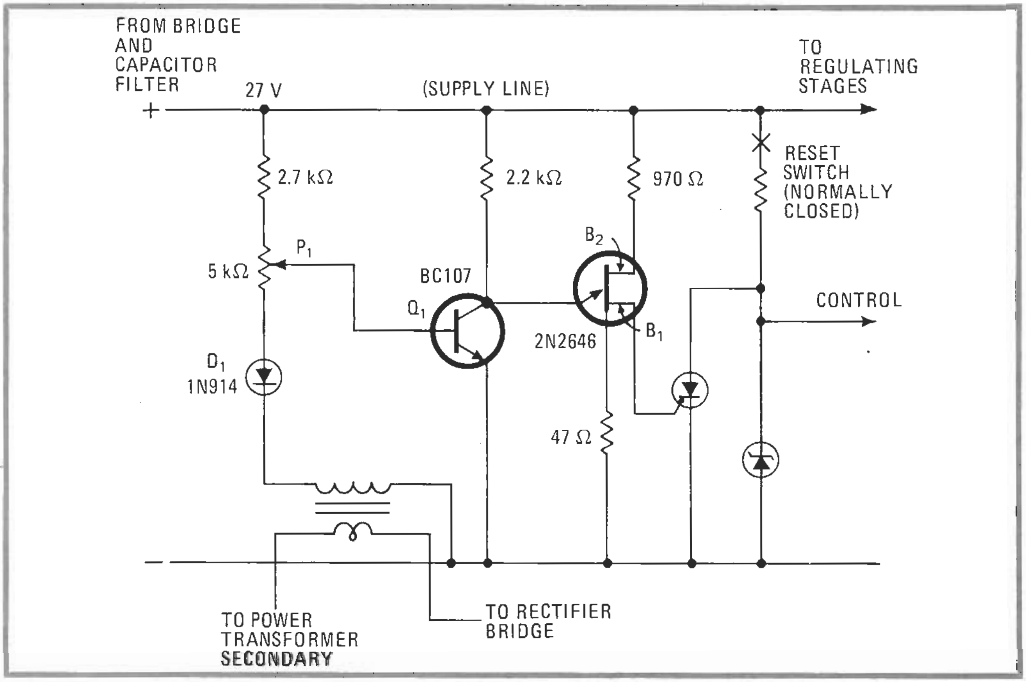


Current gauge. An audio transformer and a single turn of heavy-gauge wire, placed between input transformer's secondary and rectifier, give high-current supplies overload protection without introducing input-to-output voltage drop that occurs with units employing current-sensing resistors. Potentiometer P_1 sets the overload point. Overload detection is instantaneous, occurring on the first positive cycle of input voltage.

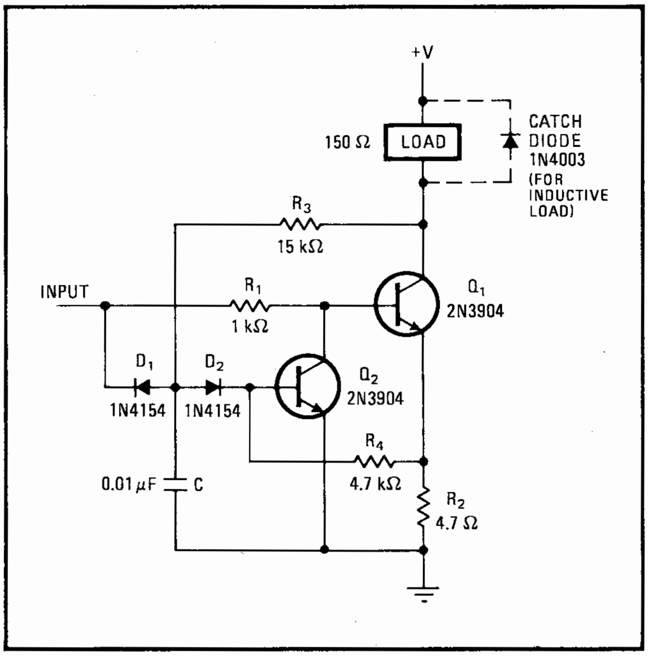
Current and power limiter protects switching transistor

by R.M. Stitt
Burr-Brown Research Corp., Tucson, Ariz.

Although a switching transistor dissipates little power in normal operation, it must be protected from destructive current and power overloads. Current-limiting alone is not sufficient protection; power-limiting is also necessary. But fortunately, a few components can be added to conventional current-limiting circuitry to provide power-limiting. A voltage rise across a transistor is sensed and used to cut down the drive current.

To understand why current-limiting alone fails to provide adequate protection, consider a switching transistor controlling a 100-ohm load connected to a 100-volt supply. The power dissipated in the load might be about 100 watts, but the maximum power dissipated in the transistor is merely the load current times the transistor's saturation voltage (if switching losses are neglected). The load current is about 1 ampere, so the transistor dissipates less than 1 W. A designer might use a 3-W device and provide a current-limiting level of 1.5 amperes.

Suppose, however, that the load is short-circuited so



Two-way protection. Switching transistor Q_1 is protected against excess current and/or excess power dissipation. If load current approaches limit, IR_2 drop turns on transistor Q_2 to shunt base drive from Q_1. A voltage rise across Q_1 acts through R_3 to turn on Q_2 and turn off Q_1. Capacitor C provides delay that allows Q_2 to saturate with each new cycle, and lets power-limiter ignore transient high currents. Diodes D_1 and D_2 reset power-limiter when input is low.

that the collector of the switching transistor is connected directly to the 100-V supply. Then the transistor dissipates 150 W, which destroys it.

To prevent this destruction, a power-limiter is required. Power-limiting can be added to a standard current-limiter by use of only four simple components. In Fig. 1, Q is the switching transistor, and the conventional current-limiter is formed by Q_2, R_2, and R_4. The power-limiter consists of capacitor C, diodes D_1 and D_2, and resistor R_3. To illustrate the operation of the circuit, assume that Q_1 is saturated and in normal operation. As the load current increases, the voltage drop across R_2 increases, turning on transistor Q_2 and thus shunting drive current away from the base of Q_1. Therefore, Q_1 begins to come out of saturation, so its collector voltage rises. This voltage across Q_1 further turns on Q_2 through R_3 and regeneratively turns off Q_1.

Diodes D_1 and D_2 form a switch so that the collector voltage of Q_1 is sampled only when its input is high. This switch also resets the power-limiting circuitry with each cycle of the input. The value of capacitor C is chosen to give the power-limiting portion of the circuit a turn-on delay, allowing time for Q_2 to become saturated. This delay also permits higher current transients to flow during switching, such as those that might occur in a switching regulator in which the catch diode must be discharged during each cycle.

The current-limiting portion of the circuitry is active at all times, protecting the switching transistor from current overloads. The circuit was set up to be driven by a TTL-level signal and to switch a 100-mA load at 400 Hz to +15 V. The protection circuit can easily be modified for nearly any input and output configuration. If a pnp-transistor switch is to be protected, transistor Q_2 should also be a pnp, and the polarities of D_1 and D_2 should be reversed. □

Two diodes protect logic-level translator

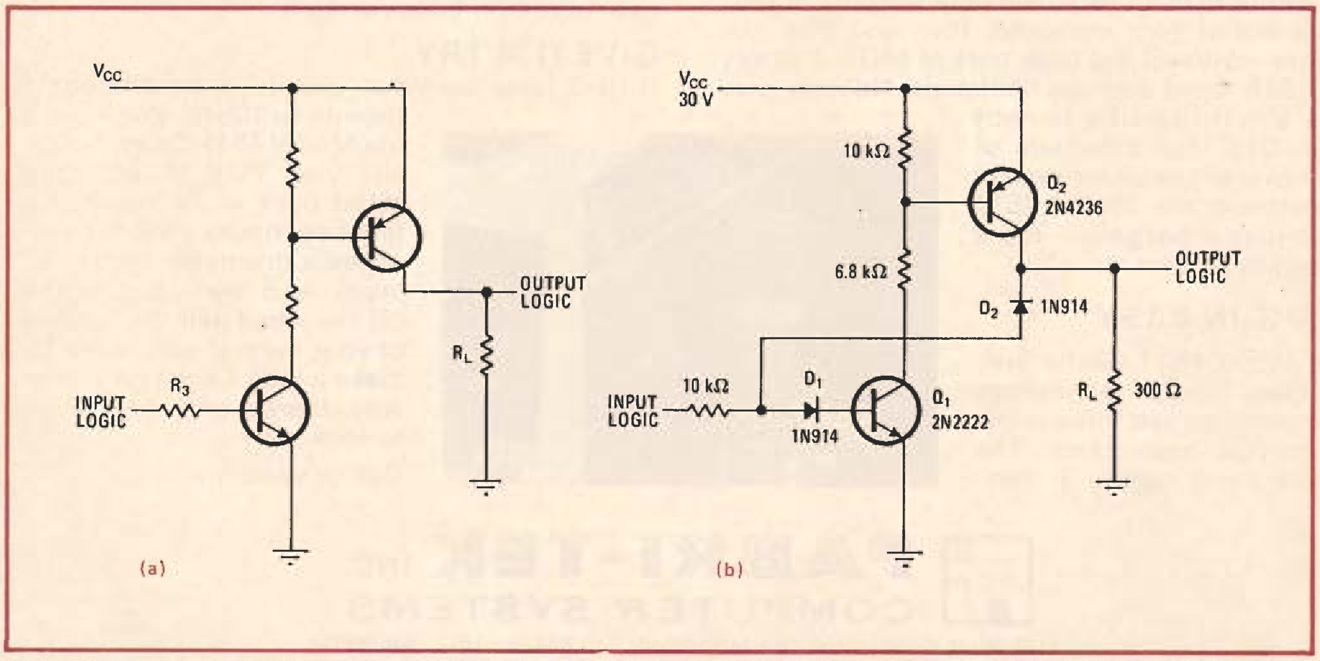
by P. R. K. Chetty
Indian Scientific Satellite Project, Bangalore, India

A level translator is used to interface between two circuits that operate at different logic levels. But the translating transistor (or level-up transistor) is often burned out when its load is accidentally short-circuited to ground. The addition of two diodes to the conventional level-up circuit can protect the transistor. Even a transistor that operates at 30 volts (as well as those meeting lower voltage requirements) can be safeguarded by the circuit modification described here.

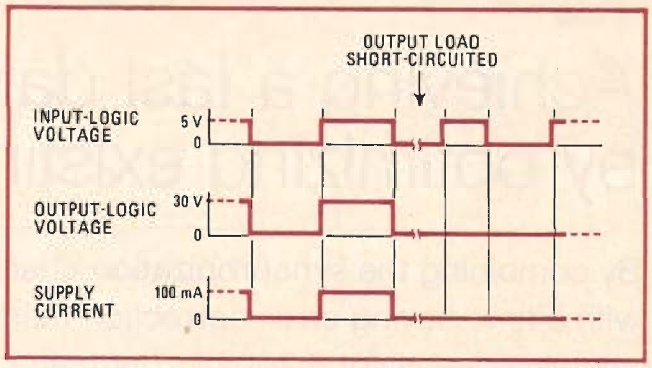
The conventional translation circuit (or logic level-up circuit) is shown in Fig. 1(a), and a modified version with two protection diodes added is shown in Fig. 1(b). The component values shown are chosen to provide a normal load current of about 100 milliamperes. In normal operation, when the input logic is high (logic 1), diode D_1 is forward-biased; Q_1 is turned on, and therefore Q_2 is turned on. Diode D_2 is reverse-biased, so the output-logic voltage across the load is nearly V_{CC}. When the input logic is low (logic 0), the transistors are turned off, and the output logic is zero.

If the output load is shorted to ground when the input is a logic 1, the anode of D_1 is above ground only by the amount of the forward-voltage drop through D_2. This voltage is not great enough to let Q_1 conduct because a voltage of at least two diode drops, V_{D1} and V_{BE}, would be required to turn on Q_1. Therefore Q_1 is turned off, and, as a result, transistor Q_2 is turned off too, which prevents it from conducting a destructive current straight to ground. The circuit remains shut down as long as the load is short-circuited, and it returns to normal operation when the short is removed.

Levels of input-logic voltage, output-logic voltage, and current from the high-voltage supply are shown in Fig. 2 for both normal operation of the circuit and the short-circuited-output condition. No current is drawn from the V_{CC} supply while the load is grounded. □



1. Protection. Conventional logic-level translator shown in (a) is modified by addition of two diodes in (b). Diodes protect translation transistor Q_2 from destructive current that would otherwise flow if load resistor were short-circuited. Diodes turn off both transistors, so no current is drawn from supply while load is shorted. In normal operation, load current of about 100 milliamperes is unaffected by diodes.



2. Waveforms. During normal operation of the logic-level translator, the output voltage and the current from the V_{CC} supply go on and off as the input logic goes high and low. If output load is short-circuited, diodes turn off transistors so that no currents flow.

Resettable electronic fuse consists of SCR and relay

by Russell Quong
Palos Verdes, Calif.

Most direct-current power supplies rely on a circuit breaker, current-sensing circuit, or fuse for current-overload protection, but this simple resettable-fuse circuit has advantages over all three. Built around a silicon controlled rectifier and a line relay, it is faster than a circuit breaker, less complex than most current-sensing circuits, and never in need of replacement.

How the circuit operates is evident from (a). Momentarily depressing S_1 closes the relay so that current flows from the supply to the load. In normal operation, the voltage across points PQ will be equal to the nominal supply voltage, and the normal operating voltage will appear across the relay winding. The relay and resistor R_2 are selected according to the dc supply voltage used and the relay's rated coil voltage, respectively.

Excessive current to the load causes a voltage drop across R_1 greater than 0.65 volt and switches on the SCR. The anode-to-cathode voltage of the SCR in the conducting region is approximately 2 v. This voltage, also across the relay coil, is far below the relay's holding voltage. Consequently, the relay opens, disconnecting the load from the supply. The relay may be reset by depressing S_1 again.

If a variable threshold point for SCR switching is desired, the SCR's gate can be connected to R_1 through potentiometer R_3. Resistor R_1 is calculated as before. □

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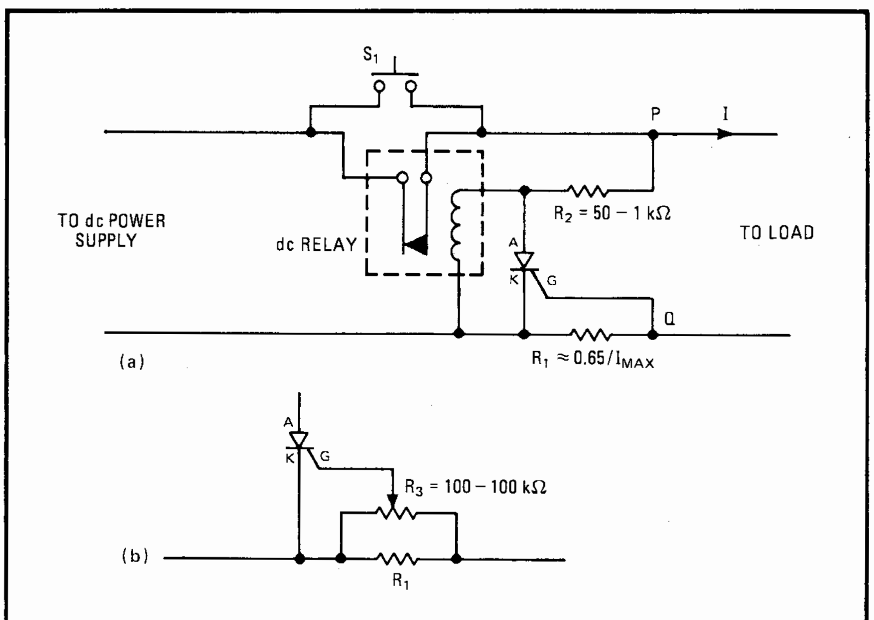


Electronic fuse. SCR and relay form resettable fuse for dc power supplies. When I_{max} is reached, SCR turns on, opening relay and disconnecting power from load. Depressing S_1 reinitializes circuit (a). SCR switching point may be adjusted with R_3 (b).

Voltage regulator protects logic pull-up transistors

by Stephen F. Moore
Resdel Engineering Corp., Arcadia, Calif.

A monolithic three-terminal voltage regulator and a Norton-type operational amplifier can provide excellent short-circuit protection—particularly for the transistor that's providing active pull-up at the output of a logic circuit.

All too often, transistors operated in this way are destroyed when the logic output is inadvertently shorted to ground. Sometimes, too, protecting these transistors is further complicated because the logic must be run at 28 volts. An easy solution would appear to be a current regulator. But most current limiters have one of two drawbacks—either they introduce an unacceptably large voltage drop, or they create excessive heat in biasing resistors.

A monolithic three-terminal voltage regulator, however, has neither defect. When the regulator is not overloaded, the voltage drop across the device is only about 1.5 V. When it is overloaded, the heat it creates remains within an acceptable range. Usually, the highest output voltage that one of these regulators can supply is 24 V. But, if the device's ground terminal is biased at 2 V (depending on the manufacturer's recommendations), the output of a 24-V regulator can be increased to 26.5 V.

When connected as shown, the regulator provides current limiting in two ways. Through its internal circuitry, it acts as a surge-current limiter of about 2 amperes. It also operates as a thermal-current limiter that reduces that output voltage when the current demand becomes excessive. This keeps the power dissipated in the regulator from exceeding the maximum allowable limit. Here, the thermal-current limiting will start at around 400 milliamperes.

Limiting the current available for the active-pull-up transistor will prevent the transistor from being destroyed as long as it is kept in saturation or in cutoff. A Norton amplifier allows both these conditions to be met—its current-sinking capability is greater than 30 mA, and it has an active pull-up in its output circuit. Because of the voltage drop across the regulator, this active pull-up creates a reverse bias on the transistor being protected, eliminating the need for the transistor's pull-up resistor. Also, a Norton amplifier will work reliably with a single-ended power supply at, as well as above, a supply voltage of 28 V.

The diode at the output of the circuit protects the transistor from overvoltages. For example, this diode will guard against an overvoltage caused by an inductive kickback that could forward-bias the base-collector junction of the transistor. □

Guarding against short circuits. An IC voltage regulator and a Norton amplifier keep this active-pull-up transistor from being permanently damaged if the input logic signal is mistakenly shorted to ground. The regulator provides both surge-current limiting and thermal-current limiting. The Norton amplifier keeps the transistor either fully saturated or fully cut off, and the output diode protects against overvoltages.

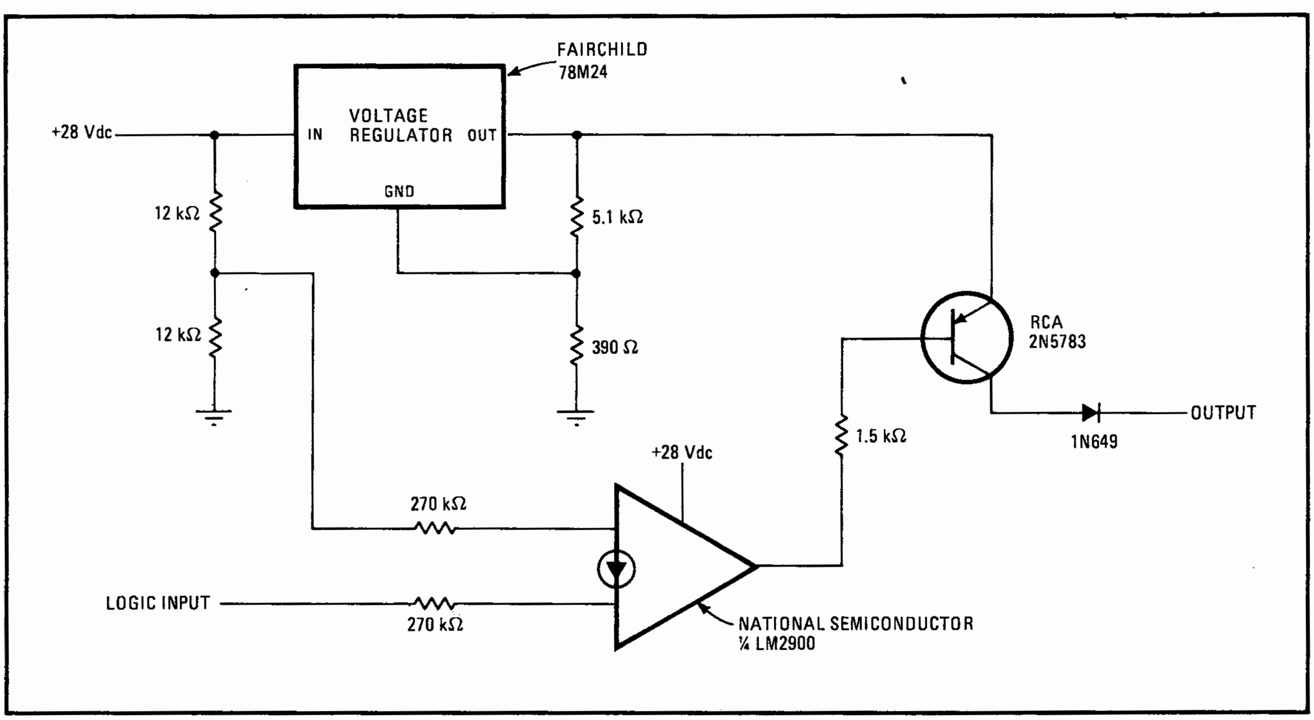
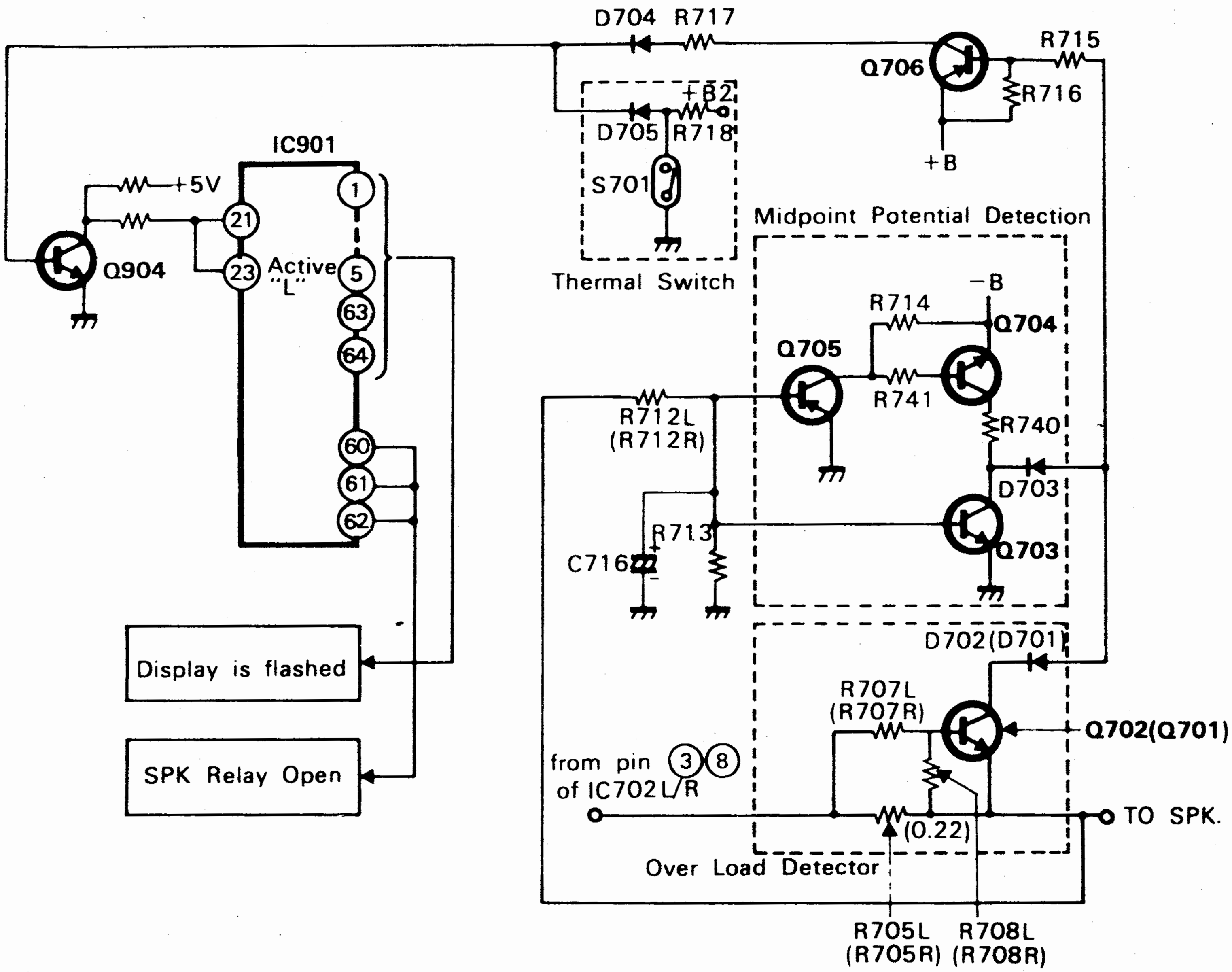


FIG. C4-1 OUTPUT PROTECTION BLOCK DIAGRAM



Current Protection from a VCR

DESIGNERS NOTEBOOK

Overcurrent protection circuit is fast, fuseless

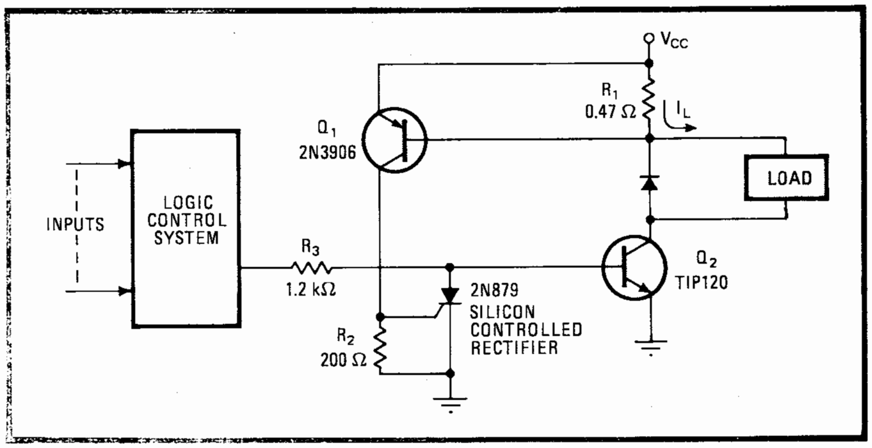
by Michael Maranzano, Engineering Manager
Locknetics Security Products, Hamden, Conn.

When loads are driven by power transistors, adequate overcurrent protection must be provided to prevent damage to the transistors. Fuses may be too slow to react compared to the I_t of the transistor.

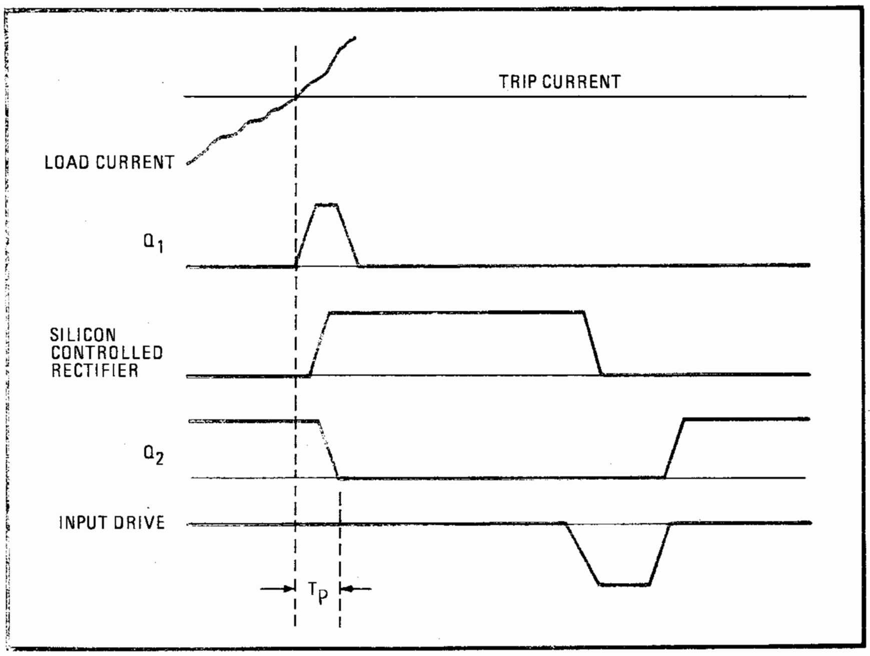
The circuit in Fig. 1 overcomes this difficulty by sensing the overcurrent and quickly grounding the power device's base to turn it off. The timing diagram in Fig. 2 shows the operation of the circuit. The output load current rises at an arbitrary rate until the voltage drop across R_1 turns transistor Q_1 on. The collector current now raises the voltage on the gate of the silicon controlled rectifier and fires it. When the SCR turns on, it shunts the base of Q_2 to ground and interrupts the current through R_1. Transistor Q_1 now is turned off. The SCR remains on as long as there is an input drive applied to base resistor R_3. By removing the input, the SCR turns off and the circuit is reset.

When the input is restored, the circuit will go through the cycle again if the output is still shorted or overloaded. It turns off in less than 10 μs after the trip current is reached. The value of R_1 determines the value of the trip current. The turn-off time depends on the transistors and the SCR's parameters.

There are two primary advantages of this design: No components need be replaced, and no separate reset buttons are required to restore power after a short or overload. By acting on the control logic to reenergize the load, the protection circuit resets and is ready to power the load again upon a new command. Resistor R_3 must be chosen so that it can provide enough holding current to keep the SCR on after it has fired. It also must be able to supply enough base current to drive Q_2 into saturation. This is especially important when the output device is a Darlington pair that requires little base current to enter saturation. This current must be larger than the holding current of the SCR, but its magnitude is not critical for good operation. Resistor R_2 is not critical either, provided it can raise the gate of the SCR above the triggering level. □



1. Protection circuit. Normally, Darlington power transistor Q_2 is on, providing load current. The logic-control system should provide a higher voltage than Q_2 requires for a good noise margin against transients. R_1 is chosen to vary the trip current. The diode protects against back electromotive force.



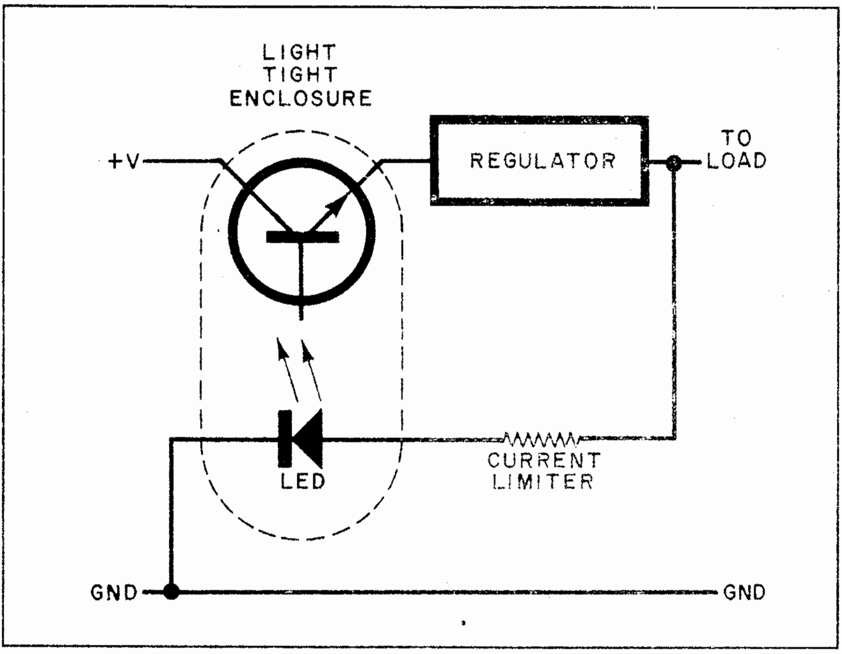
2. Timing it right. Transistor Q_1 turns on when the trip current is reached. The silicon controlled rectifier will fire when the gate reaches its threshold voltage, thereby shunting the base of Q_2 to ground. With Q_2 turned off, the current is interrupted through R_1. Interval Tp is the trip time.

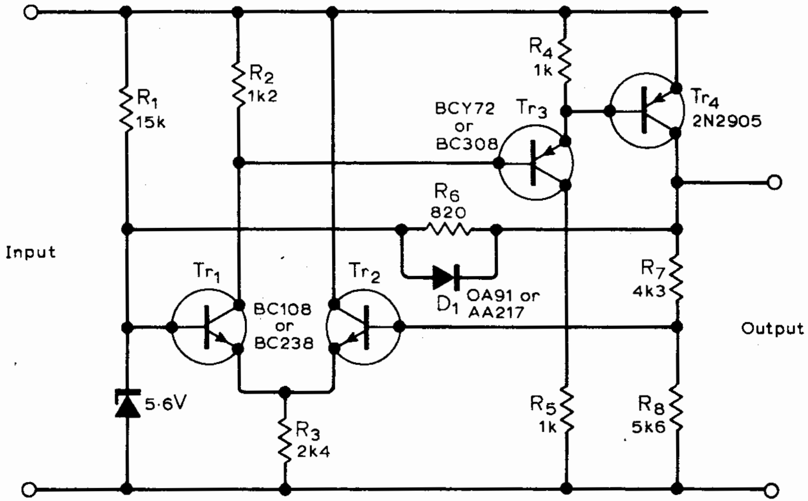
Protection Circuit. Being an avid dabbler in hardware, I have created my fair share of accidental short circuits. To save the cost of replacing relatively expensive voltage regulators and power supplies when I make such mistakes, I have recently concocted an automatic power-down protection circuit. A schematic is shown in the accompanying diagram.

The circuit is faster than a fuse and automatically "resets" itself when the short is removed. The normal regulated dc input line is opened, and a phototransistor or photoresistor (any type that can handle the current) is connected in series with the source and regulator. Between the output of the regulator (which can be almost any desired voltage) and ground is a LED and an associated current-limiting resistor, whose value depends on the dc voltage being monitored. The LED is placed physically close to the surface of the photosensitive device and the two are covered by a layer of black electrical tape to form a light-tight enclosure. As long as the regulator is delivering its rated output, the LED glows and causes the photo device to have a low resistance. Full current is thus allowed to flow.

If, for any reason, a short circuit occurs on the output side of the regulator, the LED goes dark, the resistance of the photo device increases, and the regulator shuts off. When the short is removed, the LED glows, and the regulator resumes operation.

Like most of the circuits I have discussed in this column, this one is basic, and the reader is urged to experiment with it. For example, if your power requirements are more than a simple photo device can handle, use a high-power npn transistor whose base is driven by the photo device, which, in turn, is controlled by the LED. In fact, not even the regulator is required since this protection circuit can be used as "plain vanilla" in series with the power lead. Once you get the idea of how the thing works, it's simple. So why not try your ideas. ◇





Germanium diode for regulator protection

Power regulator protection is a perennial problem and this circuit offers a simple and economical solution. Under normal conditions, D_1 is reverse biased by the voltage across R_6 and does not affect the regulator operation. When the output is shorted, however, D_1 turns on and draws current through R_1 which removes the reference voltage across the zener diode. Because D_1 is a germanium type, Tr_1 is held off which also turns Tr_3 and Tr_4 off. When the short is removed, the circuit recovers and resumes normal operation.

D. E. O'N. Waddington,
St Albans,
Herts.

Foldback limiter protects high-current regulators

by A. D. V. N. Kularatna
Ratmalana, Sri Lanka

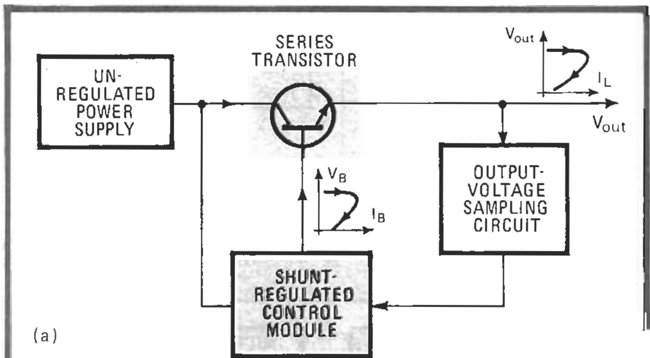
This circuit provides foldback protection for a series-regulated source that has to deliver high current. Because it requires no current-monitoring resistor, the circuit achieves wide dynamic response at good efficiency. It draws only 2% of maximum load current and its cost is reasonable.

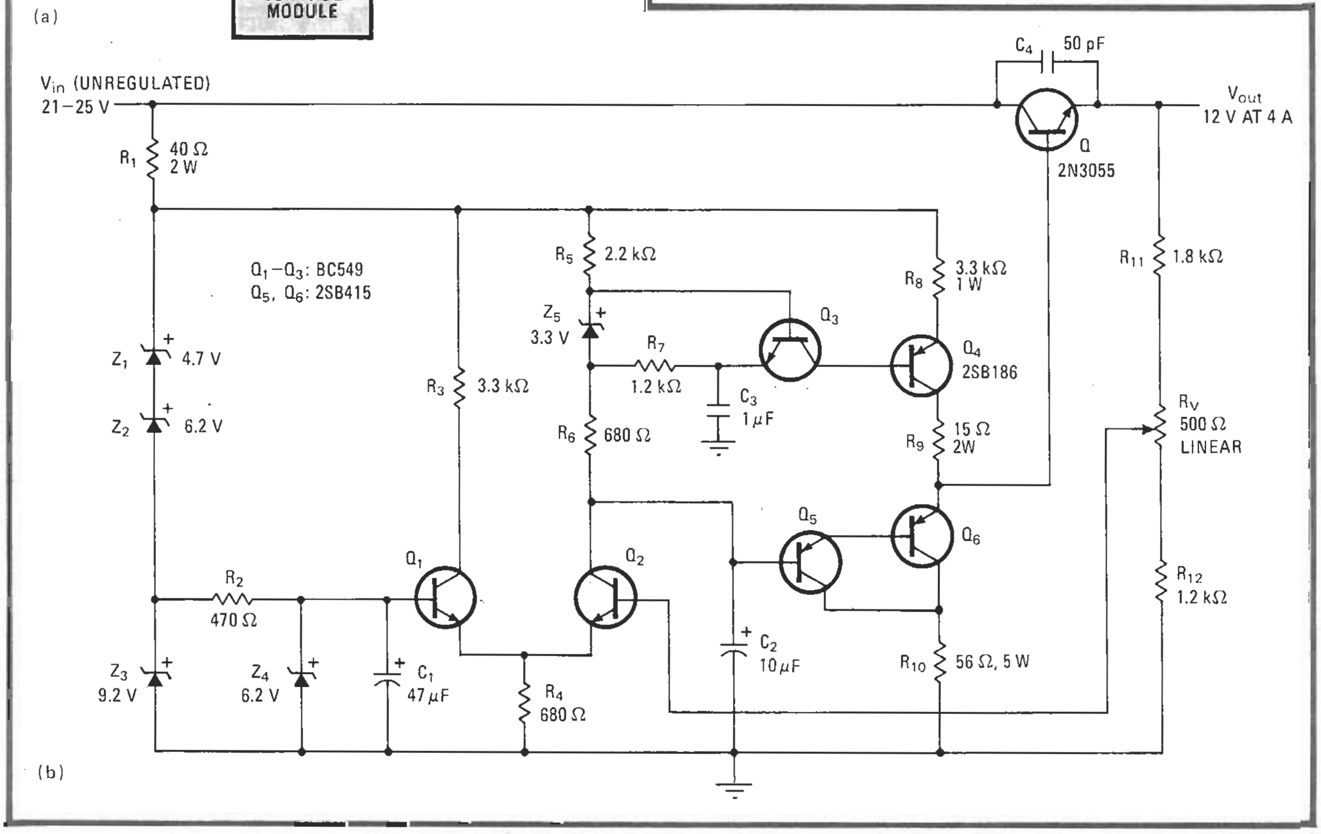
Here, a low-current shunt-regulated module (a) provides the overload protection. This module is configured into the conventional regulator system to work as a switch, in which role it quickly turns off a series-pass transistor when the load current exceeds some predetermined value.

The circuit details are explained with the aid of the diagram (b) for a representative regulator designed to deliver 12 volts at 4 amperes. Transistors Q_1 and Q_2 form a differential amplifier, which compares a 6.2-V reference to a potential derived from the 12-V output through potentiometer R_V. Shunt elements Q_5–Q_6 act to maintain the potential at the base of Q constant for any load condition by taking up the difference between the set and the actual base drive.

It is necessary that the current source Q_3-Q_4 be set to I_L/h_{fe} for proper tracking, where I_L is the maximum load current and h_{fe} is the current gain of Q. The value of the constant current, I, is $h_{fe\,Q4}(V_{Z5} - V_{be\,Q3})/R_7$, so that the current is most easily set by adjusting resistor R_7.

The module requires a current of 70 to 80 milliamperes under maximum load conditions. The short-circuit output current is less than 200 mA, because the drop in





High handling. Low-current shunt regulator (a) provides foldback limiting for high-current power sources at good efficiency and reasonable cost. Circuit (b) for 12-V regulator uses differential pair Q_1–Q_2 for detecting differences in reference and output voltage, Q_3–Q_6 for maintaining output potential by suitably controlling base drive to series pass transistor Q. Z_1–Z_3 minimize output ripple.

output voltage switches transistor Q_2 off. The voltage across zener diode Z_5 is then reduced to a very low value, and this action in turn lowers the voltage at Q_6 and cuts down the base drive to Q.

Zener diodes Z_1–Z_3 were added to improve the ripple characteristics of the supply. As configured, the source has an output ripple of 6 mV peak to peak.

The shunt regulator module can be easily configured for any output voltage mainly by selecting the appropriate zener-diode values. □