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READERS SOLVE DESIGN PROBLEMS

Current-sense monitor and MOSFET boost output current

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DIs Inside

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A previous Design Idea describes a programmable current source that used a three-terminal National Semiconductor (www.national.com) LM317 adjustable regulator (**Reference 1**). Although that circuit lets you program the output current, the load current flowed through the BCD (binary-coded-decimal) switches. However, you may find it difficult to purchase BCD switches that can handle more than 25 mA, limiting the circuit's output current. By applying the simple, four-pin Zetex (www.zetex.com) ZXCT1010 current-sense-monitor chip, you can boost current because it doesn't flow through BCD switches (**Figure 1**). The load current results in a voltage on the sense resistor R_{SENSE}. The voltage on R_1, the 100Ω resistor, is the same as that on R_{SENSE}, generating an output current on R_1: $I_{OUT}\times 100=I_{LOAD}\times R_{SENSE}$, and $V_{OUT}=I_{OUT}\times R_{OUT}$, where I_{OUT} is the output current, I_{LOAD} is the load current, and V_{OUT} is the output voltage. You can apply the output voltage as a control voltage to regulate the load current.

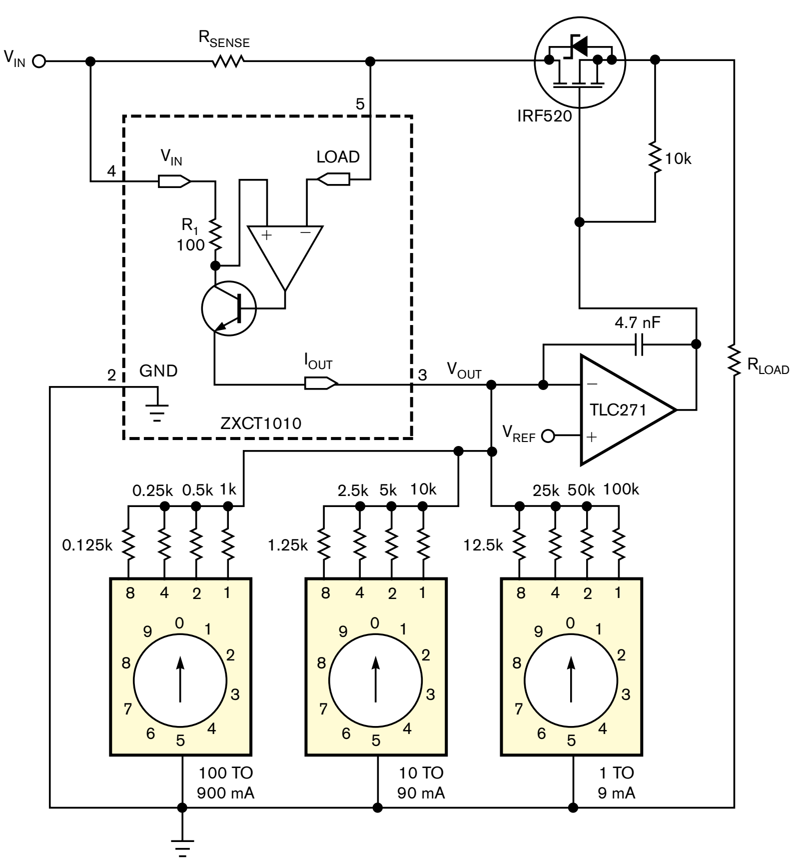

Figure 1 Passing current through a MOSFET and regulating it with a current-sense monitor bypasses the BCD switches, letting you increase load current.

One application for this circuit would be to refill accumulators in portable devices. In this case, the circuit works at 18V. The Fairchild Semiconductor (www.fairchildsemi.com) IRF520 is an N-channel, power-MOSFET chip in an aluminum heat sink with as much as 9.2A current and 0.27Ω drain-to-source resistance to connect the load current. An op amp controls the IRF520 in the feedback of the load current. In this application, the maximum output current is 1A, and the value of the sense resistor is 0.1Ω. The PCB (printed-circuit board) can also have this small resistance value, which you calculate using the cuprum material's 35-micron-thick layer. The BCD switches are in parallel and connect from 125Ω to 100 kΩ to adjust the output voltage on the op amp's negative input. The equations to calculate resistor values are: $V_{SENSE}=R_{SENSE}\times I_{LOAD}$, $I_{OUT}=R_{SENSE}\times I_{LOAD}/100$, and $R_0=V_{REF}\times 100/(R_{SENSE}\times I_{LOAD})$. If you choose a value of 0.1Ω for the sense resistor and a value of 0.1V for the reference voltage, the **equation** becomes $R_0=100/I_{LOAD}$.

Applying this **equation**, you can calculate the four weighting resistors of the three BCD switches, which you can determine when the current flows through only that resistor. For currents of 800, 400, 200, 100, 80, 40, 20, 10, 8, 4, 2, and 1 mA, the corresponding resistances would be 0.125, 0.25, 0.5, 1, 1.25, 2.5, 5, 10, 12.5, 25, 50, and 100 kΩ. If the load current is 1A, then the output current is only 1 mA, and, if the load current is 1 mA, then the output current is only 1 μA. Note that the IRF520's surface is on the drain potential.**EDN**

REFERENCE

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Multiplexed, programmable-gain, track-and-hold amplifier has instrumentation inputs

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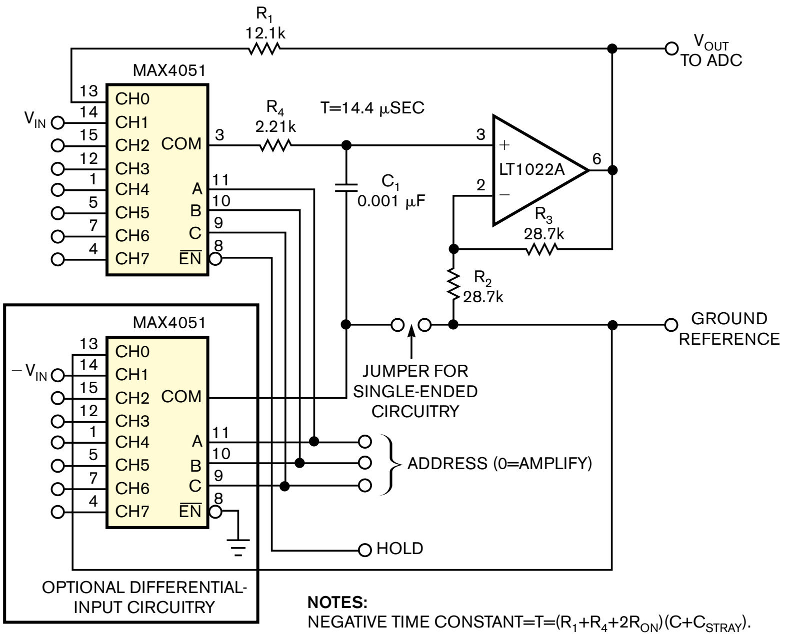
ADCs need adequate signal-acquisition analog interfaces to perform at their best. The classic general-purpose ADC front end includes multiple channels of differential input, digitally programmable gain, and track-and-hold capability. This Design Idea presents a new, complete, high-performance, low-parts-count ADC front end that implements the standard ensemble of functions (**Figure 1**). However, it also incorporates the concepts of the flying-capacitor differential input and the divergent-exponential negative-time constant that an earlier Design Idea describes (**Reference 1**). This Design Idea adds to that circuit multiplexed inputs and a versatile track-and-hold function.

The multiplexer address and the state of the hold-mode bit control signal acquisition and conditioning. With a hold state of zero and the multiplexer's address equal to the selected input channel, the flying capacitor, C_1, connects to the positive and negative differential-input terminals, which acquire the input voltage. Moving the hold state to one isolates C_1 from the input. Then, the multiplexer's address becomes zero, and the hold state returns to zero, initiating regenerative negative-time-constant exponential amplification of the input voltage. From that point until the point when hold reasserts and a connected ADC samples and converts the output voltage, the input voltage and the output voltage are divergent exponential functions of time, with a gain equal to $2^{(1+t/10\ \mu sec)}$.

Building on the assets of that earlier design, this new circuit has the desirable features of multiple instrumentation-style differential inputs. Also, neither resistor matching nor the CMR (common-mode rejection) of the op amp limits the circuit's CMR. Stray-capacitance issues do have an effect on CMR, but you can minimize this capacitance by careful circuit layout. The circuit also has rail-to-rail inputs and virtually unlimited programmable gain. Further,



NOTES:
NEGATIVE TIME CONSTANT=$T=(R_1+R_4+2R_{ON})(C+C_{STRAY})$.
$V_{OUT}=V_{IN}[1+(R_3/R_2)E^{(t/T)}]=V_{IN}2^{(1+t/10\ \mu SEC)}$.

Figure 1 This high-performance, low-parts-count ADC front end implements the standard ensemble of functions.

only the resolution of the amplify interval's timing limits gain-set resolution (**figures** 2 and 3). This circuit also has ±10V output-amplitude capability—two to four times greater than that of monolithic digitally programmable-gain instrumentation amplifiers.

The inherent noise and dc accuracy of the chosen op amp, the accuracy and repeatability of the timing of exponential generation, ADC sampling resolution, and RC-time-constant stability are the main limits on signal-processing performance and the amplifier's precision—for example, its gain-programming accuracy, dc error, noise, and jitter. In the circuit, 1 nsec of the amplify-interval timing error or jitter equates to 0.007% of gain-programming error.**EDN**

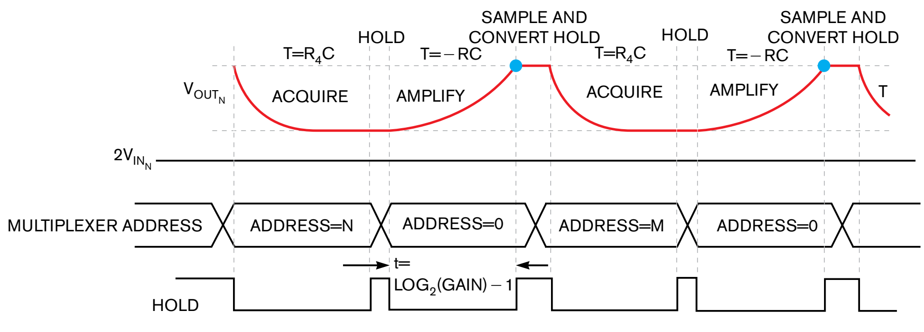


Figure 2 Only the resolution of the amplify interval's timing limits gain-set resolution.

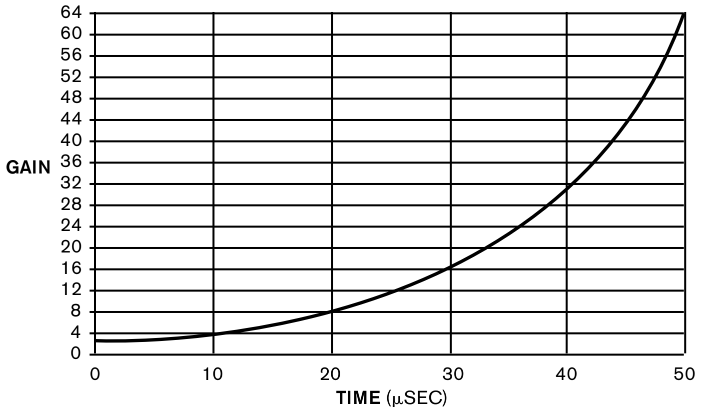


Figure 3 This graph of input- and output-voltage gain shows the time elapsed since the track/amplify-logic transition.

REFERENCE

1 Woodward, W Stephen, "Flying capacitor and negative time constant make digitally programmable-gain instrumentation amplifier," *EDN*, Feb 5, 2009, pg 48, www.edn.com/article/CA6632372.

Simple circuit smoothly drives stepper motors

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The circuit in this Design Idea drives low-power, unipolar stepper motors using only a shift register, a few resistors, and low-power transistors. Adding an inexpensive 4053 analog switch allows bidirectional switching. Compared with other simple stepper-motor-drive circuits, it has better-than-half-step characteristics (**Figure 1**).

After power-up, all shift-register outputs are in a zero state. Pin QP3 feeds back to the serial input through an inverter—transistor Q_5 in **Figure 2** and analog-switch IC_2 in **Figure 3**. The circuit generates a sequence of four ones and then four zeros. You can use this pattern to drive, for example, NPN transistors with emitters that tie to ground and collectors that tie to the stepper-motor coils. However,

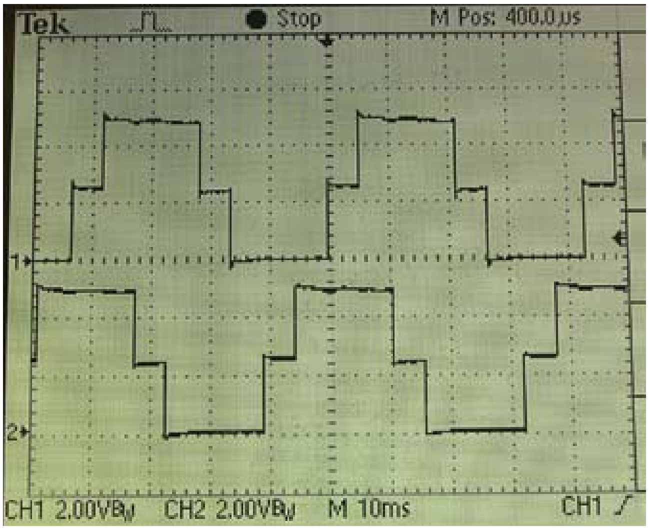

Figure 1 An oscilloscope snapshot shows the base voltages of Q_1 and Q_2 in figures 2 and 3.

to achieve smoother drive characteristics, the shift-register outputs drive four simple DACs, each comprising two identical resistors.

These DACs can generate output voltages of 0, 2.5, and 5V to drive four emitter followers. A snapshot from an oscilloscope shows the base voltages of Q_1 and Q_2 (**Figure 1**). They come close to a quarter-step drive pattern. The circuit can use almost any 8-bit shift register. **EDN**

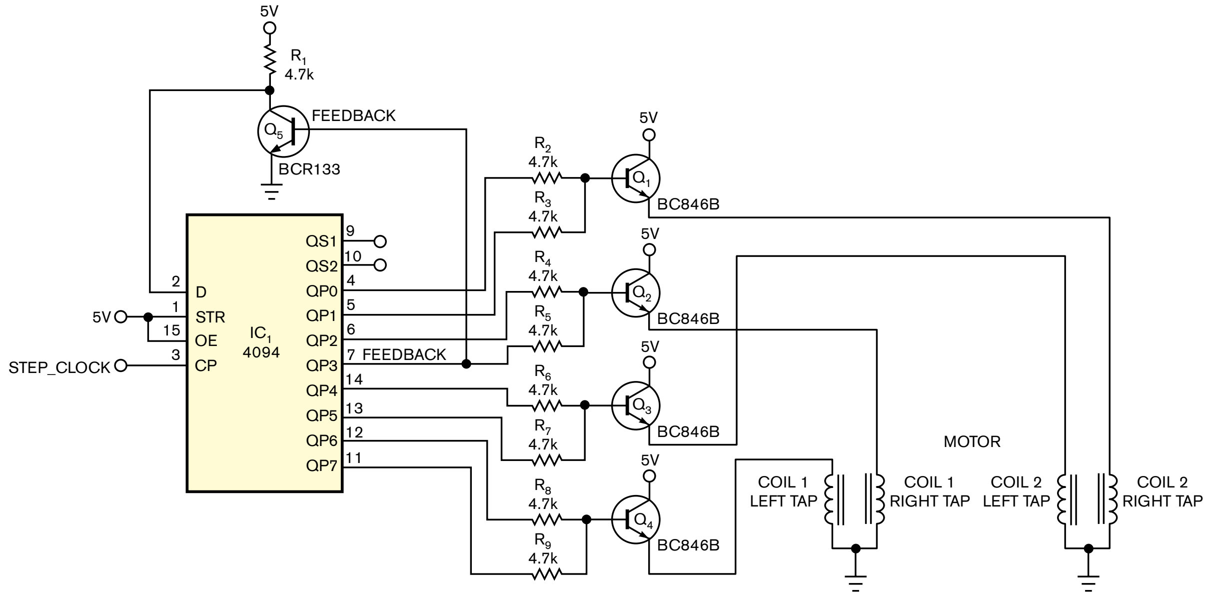

Figure 2 This circuit drives low-power, unipolar stepper motors using only shift-register IC_1 and a few resistors and transistors.

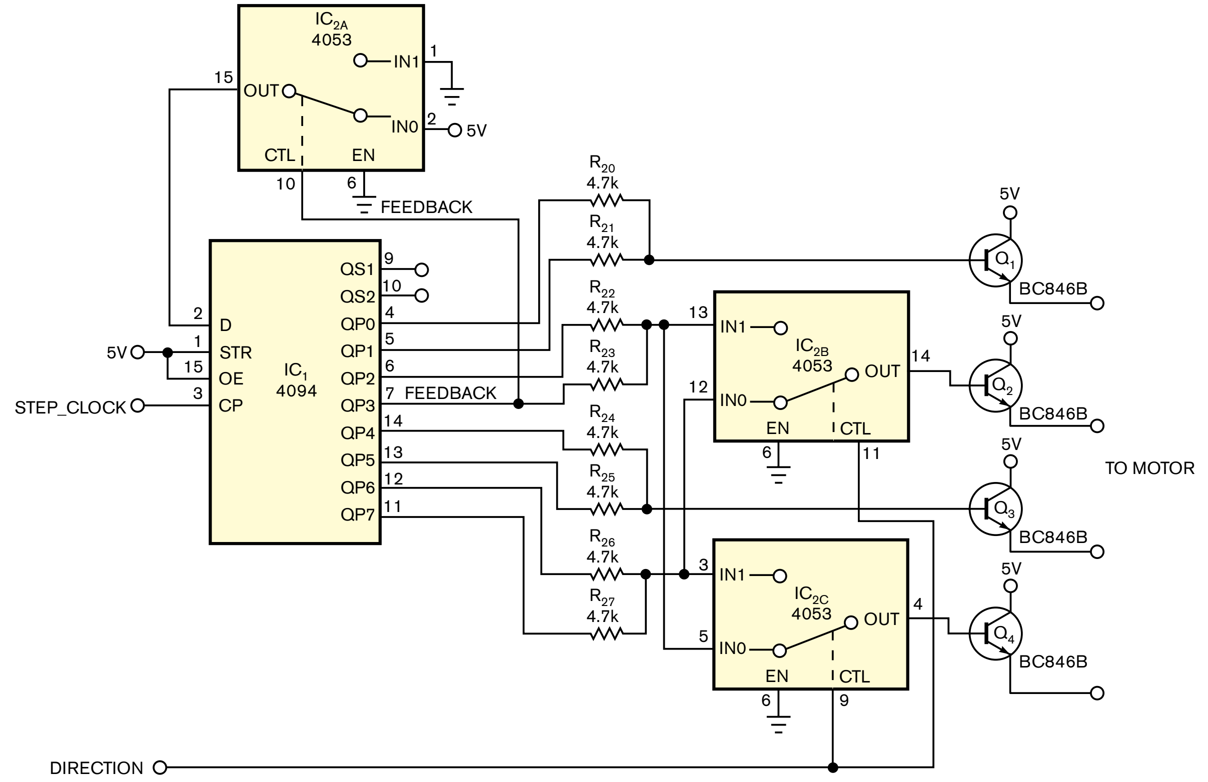

Figure 3 This circuit enhances the one in Figure 2 by adding an inexpensive 4053 analog switch, allowing bidirectional switching.

Excel spreadsheet yields RLC best-fit calculator

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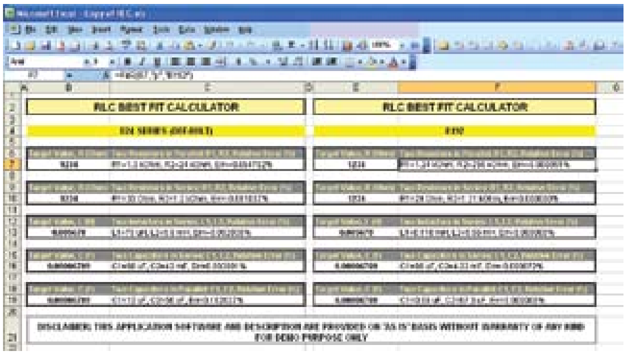

Figure 1 In the user interface, you enter the user-defined functions FitR 1234, P, or E192 into any cell of the Excel worksheet.

Commercial off-the-shelf software such as Microsoft (www.microsoft.com) Excel lets you automate engineering functions (**references 1 through 3**). This Design Idea explains how you can use Excel to calculate the values of two passive components—resistors, inductors, or capacitors—from the standard E-Series, which comprises E6, E12, E24, E48, E96, and E192, that you can use in circuits such as filters. The application's results depend on whether you select a parallel- or a series-connected topology.

The calculations appear in an Excel spreadsheet that you can download from the online version of this Design Idea at www.edn.com/090528dia. The VBA (Visual Basic for Applications) source code for this project resides in a single code module (**Listing 1**, which is also available with the online version of this article). It contains three main public functions, FitR(), FitL(), and FitC(), and several private auxiliary functions. The key algorithm loops through the range of values, trying to find the best fit for the target. There is an inner loop for the first value of RLC and an outer loop for the second one.

Figure 1 shows the user interface. You can enter the user-defined functions FitR 1234, P, or E192 into any cell of the Excel worksheet. The cells accept four arguments and return a text string containing the best-fit values, R_1 and R_2 in this case, and the relative error of approximation. **Table 1** shows the functions' parameter list. For better readability, the spreadsheet returns the values of R_1 and R_2 in commonly used electrical-engineering format by applying a scientific-to-engineering format-conversion function, E2BOM().

The computation engine for electrical resistance and inductance components uses the same formulas: a simple sum of the resistance for the series connection and a sum of conductance for parallel topology, whereas, in the case of the capacitors, the formula is vice versa. You can also fine-tune the functions by changing the constant values corresponding to the upper and lower search limits (**Listing 1**). Thus, you can extend the search range and increase the accuracy, although this process requires more computation time. If you use Microsoft Office 2007, you must contend with an increased security level and set the proper permission level to run the VBA content of the Excel workbook.

This approach is essentially a desktop application, extending the functions of the popular Excel application. You can install the application on either a computer or a network. To further extend its accessibility and bring it to the global level, you should consider an online Web application. The modern RIA (rich-Internet-application) concept and corresponding development tools, available on the market, let you build Web applications with the level of interactivity and responsiveness close to those of the desktop application. A Web-based application provides for easy implementation and maintenance. The user needs only a Web browser. Web applications are essentially platform-independent and globally accessible. Web-based applications of the RLC calculator don't require the user's machine to have MS Office. You can also place the application in password-protected directories from which you can control access to them. A demo version of an online RLC best-fit calculator incorporates the latest set of Microsoft technologies, such as ASP.NET, C#, and Ajax, providing a rich user experience with high interactivity and responsiveness (**Reference 4**).EDN

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3 Bell, Alexander, "Voice feedback enhances engineering calculator," *EDN*, July 11, 2002, pg 108, www.edn.com/article/CA231578.

4 Bell, Alexander, "Best Fit RLC Calculator," www.alexanderbell.us/RLC/RLC.aspx.

TABLE 1 FUNCTIONS FITR(), FITL(), AND FITC() PARAMETER LIST

No.	Parameter	Description	Required
1	R	Target value	Yes
2	ParSer	Topology: parallel or serial connection	Yes
3	ESeries	Standard series: E6, E12, E24, E48, E96, or E192	No: Default value is E24
4	ExtSearch	Flag to use preferred search limit or extended	No: Default is preferred search range

Automatically turn secondary lamp on or off

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You may sometimes need to turn on a secondary device, such as a lamp or an alarm, when a device that is normally on loses power. You can build a simple circuit using just a transformer and a relay for this purpose. In the circuit, a primary load is in series with an ac-mains transformer (**Figure 1**). The transformer connects in an unusual way. Its usual secondary low-voltage winding is Winding 1, and its primary ac-mains winding is Winding 2. Under these conditions, the main lamp's voltage is slightly less than during its ordinary operation—the ac-mains voltage minus the voltage drop over Winding 1. That situation is acceptable in most cases because the lower voltage doesn't greatly affect the operation of the load—that is, the luminosity of the main lamp. Select Winding 1 to match the main load's current needs. In this circuit, a 220V, 50-Hz ac voltage appears at Winding 2.

Connect a relay to Winding 2 so that the secondary loss connects to the relay's NC (normally closed) terminal. Use a relay with a winding that can operate at 220V, 50 Hz for your ac-mains voltage. For example, you can use a TR91-220VAC-SC-C relay from Tai-Shing Electronics Components Corp (www.tai-shing.com.tw). This relay's coil operates at a 220V, 50-Hz, SPDT (single-pole/double-throw) commutation of 240V ac under a 40A load.

Using an SPDT relay adds flexibility in controlling the spare load. It lets you switch a load on or off with no need for additional electronic components. In the **figure**, a spare lamp turns on when the main lamp burns out because the secondary load connects to the relay's NC contact.

Select a transformer whose secondary winding (Winding 1 in the **figure**) has a low-rated voltage that provides sufficient current for the main load—the lamp. Match the relay's rated coil voltage to the ac-mains voltage and frequency specifications. **EDN**

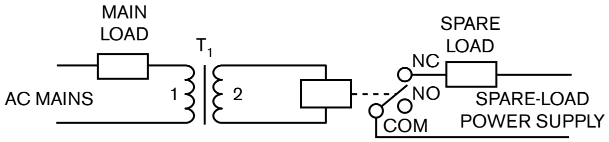

Figure 1 A transformer and a relay are all you need to control a secondary load should the main load fail.