By Sam Ulbing, N4UAU

Surface Mount Technology—You *Can* Work with It!

Part 3—This more-complex SM project employs a total of four ICs and seven other parts on a PC board three-quarters of an inch square! Despite its small size, it can control current levels of up to 10 A—without using mechanical relays!

When Hurricane Georges came through in 1998, my friend, Dave, N0LSK, had left his boat at a marina in the Keys. Although he had the boat tied up well, he forgot that his refrigerator shifts to battery power if the ac-line power is lost. When he returned to the boat after the storm, his boat was okay, but its battery was dead. With the switch about to be described, Dave wouldn't have lost his expensive battery.

Project 3—A Low-Voltage Battery-Protection Switch

This switch, based on a MAX835 (available only in an SOT-23 case), is a *latching* voltage monitor—ideal for controlling a switch. A recent *QST* project used a MAX8211 (a DIP IC) in an undervoltage circuit,[18,19] but because it doesn't latch, that chip wouldn't work well for controlling a switch. Here's why: Every time the voltage dropped low enough to trip the monitor, it would disconnect the load, and the voltage would rise and turn the monitor back on. Such cycling could injure the equipment.

Figure 12 is a schematic of the switch. When V_{CC} drops below 12 V, and the voltage at U1 pin 4 goes below 1.2 V. That causes the output voltage on pin 5 to drop from about 5 V to 0 V. Pin 2 of U2, an MIC5014, accepts a logic-level signal and uses it to control an on-board charge pump. Q1 and Q2 are N-channel MOSFETs used as a 10 A high-side switch. (See the sidebar "Selecting a MOSFET for Power Control.") To turn the switch on, the gate must be at least 10 V above the source voltage (5 V for logic-level MOSFETs). That means you need 22 V to turn on the switch. This voltage is supplied by the charge pump in U2. U2 also acts as a buffer for U1, which cannot operate at 12 V. R1 through R4 provide a nominal 5 V power source for U1 and provide the voltage-level input signal to pin 4 of U1. Pull-down resis-

tor R5 prevents unplanned resetting. Although the data sheet doesn't show that R5 is required, the very high impedance of this pin (the current drain is 1 nA) makes a pull-down resistor a wise investment, especially in an RF environment.

Depending on your circuit needs, you

will use a variety of values for R1 to R4. Here's how I selected my values: U1 can operate with voltages of 2.5 to 11 V, so the R1-R4 divider must keep the voltage at pin 3 in this range as V_{CC} changes. The maximum V_{CC} I ever expected to encounter was 15 V, and the least, 11 V. U1 draws 2 μA,
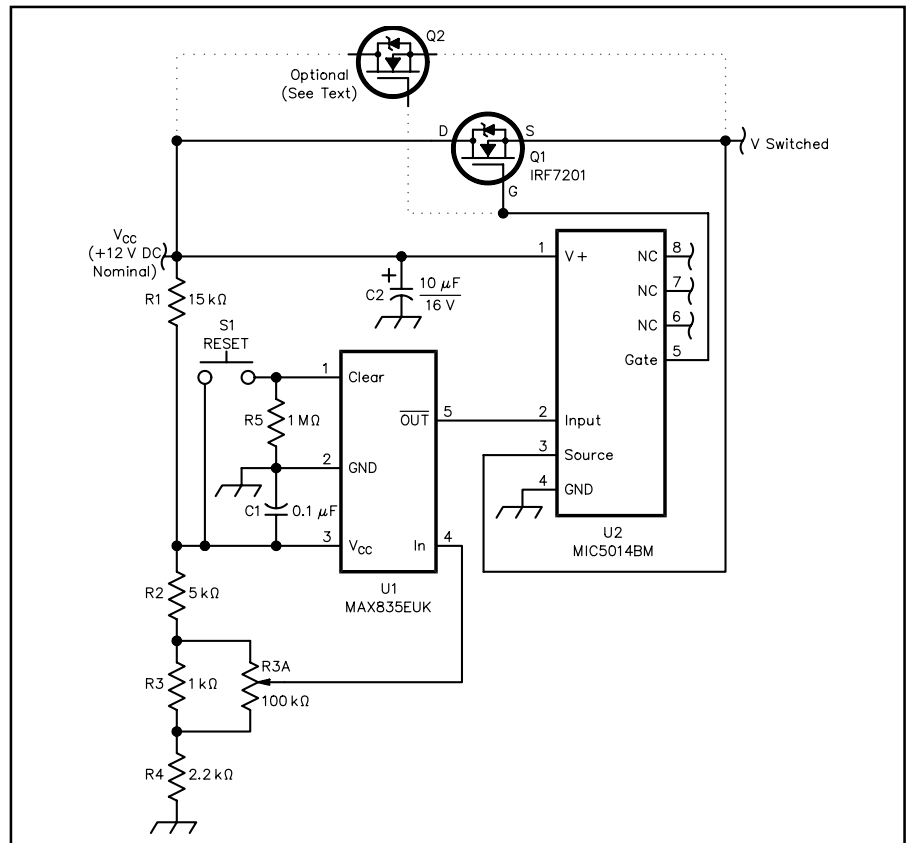

Figure 12—The low-voltage battery-protection circuit schematic. Unless otherwise specified, resistors are $\frac{1}{8}$ W chip resistors in a 1206 package. Equivalent parts can be substituted. See Note 21 and notes and sidebar in Part 1 for parts availability.

C2—10 μF, 16 V tantalum
R3A—100 kΩ pot
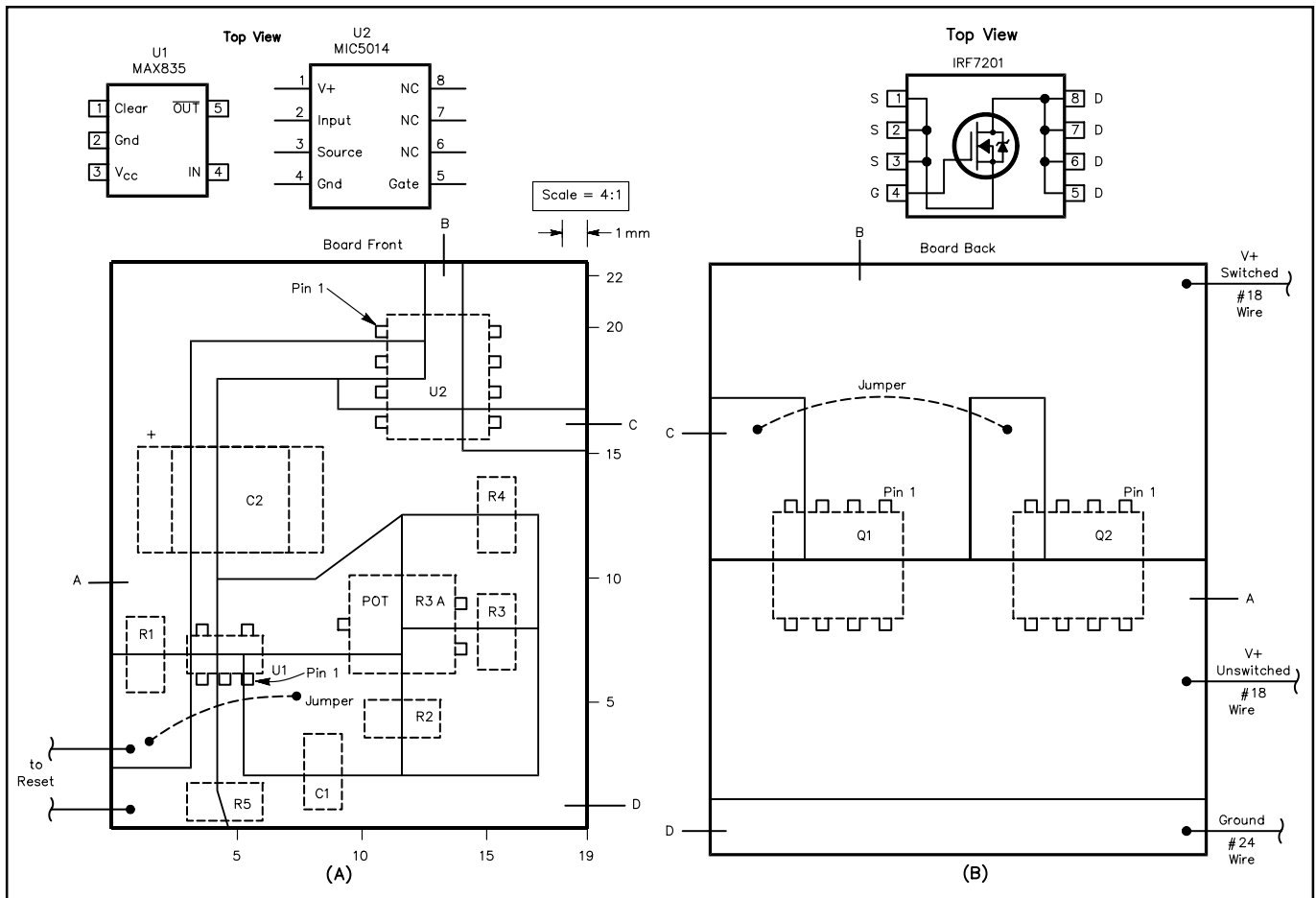S1—SPST pushbutton

Q1, Q2—IRF7201
U1—MAX835EUK
U2—MIC5014BM

Figure 13—Part placement for the PC-board top (A) and back sides (B), respectively.

so to keep a stiff supply, I wanted the current through the voltage divider to be at least 200 µA. This calls for a total resistance of not more than 50 kΩ. As current drain is not important, I decided to use a total resistance of about 20 kΩ. Using an Excel spreadsheet, I calculated the values shown. The voltage on pin 3 is 5.3 V for V_{CC} of 15 V, and 3.8 V for V_{CC} of 11 V. I used four fixed-value resistors and a SM potentiometer (R3B) in parallel with R3 to allow better control when setting the trip level at 12.0 V. You can run U1 at a lower voltage, but keep in mind that U2 needs at least 2 V to trigger it.

This basic circuit can be optimized for other uses. To handle more current, you need only replace the MOSFET with a more-robust one. I use an IRFZ46 and a heat sink with my ICOM IC-735. If you want to control a low-voltage NiCd-powered circuit, you could use U1 alone, connecting it directly to a logic level *low-side* N-channel MOSFET. In that case, increase the resistances of R1 to R4 for minimum current drain.

The Technology

There is a lot of new technology in this simple circuit. The entire project—including the 10 A MOSFET switch—is on a PC

board smaller than the MAX8211 project. Because the quiescent current of U1 is only 2 µA—and it has a wide operating-voltage range (2.7 to 11 V)—it's possible to power it from a resistive divider rather than a 5 V regulator. U2 is a single-chip charge pump that requires no external parts. Like U1, it can operate over a wide voltage range (2.75 to 30 V) and draws only a few microamperes. U2 is designed to let low-level signals control high-voltage and high-current circuits through low resistance *N-channel* MOSFETs used on the *high side*. This arrangement is important for at least two reasons: High-side switches are usually needed with Amateur Radio applications because there is almost always more than one path to ground: the antenna, keyer, computer etc. A low-side switch would force the current to go through one of those connections rather than shutting off the rig. Second, N-channel MOSFETs have much lower resistance than equivalent P-channel MOSFETs (typically, 2.5 times less[20]). This permits the use of smaller MOSFETs for a given current.

MOSFET technology has advanced dramatically. The circuit shown uses two small SO-8 MOSFETs in parallel to control the power to my Kenwood TM-241, which draws a maximum of 11 A on high power.

The two MOSFETs in parallel have an *on* resistance of only 15 mΩ (milliohms). The voltage drop across the plug connections and fuses is greater than the drop across the MOSFET! Unlike power transistors, no equalization resistors are needed when paralleling MOSFETs. That's because MOSFET *on* resistance increases with temperature, so they tend to be self-equalizing. MOSFETs make better circuit breakers than fuses or relays because they have no moving parts, are resettable, do not arc or bounce, emit less EMI and are much faster than relays or fuses. The latter can be important in an overcurrent situation. Typical MOSFET shut-down time is less than a microsecond (excluding circuit delays). The blow time on a fast-acting fuse is usually longer than 1000 µs.

U1 and U2 have families. U1 has a push-pull output; the output is internally held at either 0 or V_{CC}. The other version (MAX834) has an open-drain output that requires a pull-up resistor to provide the logic-high output. This is a common family in the SM world. One advantage of the open-drain output is that you can control a circuit with a voltage level different than the V_{CC} of the IC itself. U2's brother is the MIC5015, which operates exactly like the
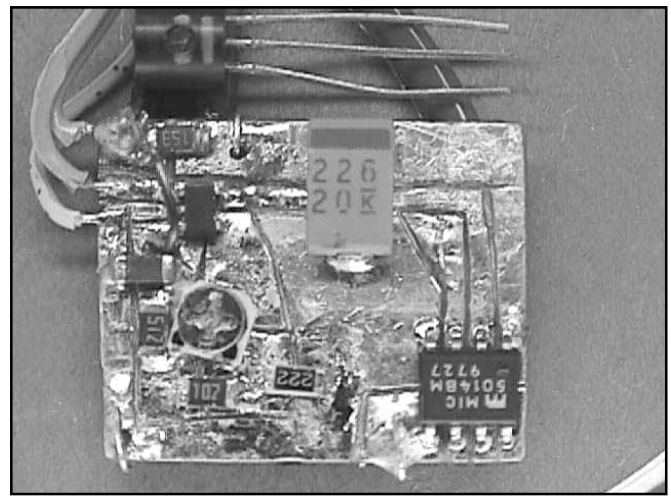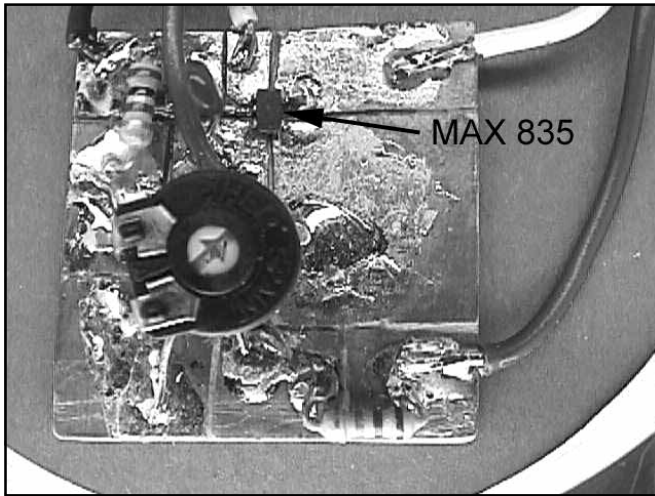
Figure 14—Close-up views of the low-voltage battery-protection switch using a Maxim MAX835 SM IC. At A (left) is a trial board made using the MAX835 and non-SM parts. The MAX835 can be seen above the large pot and to the right of the $1/4$-W resistor. At B (right) is the top side of a PC board made using the hobby tool and all SM parts. The MAX835 is above the SM pot and to the left of the tantalum capacitor. The board size can be compared to the TO-92 case transistor above it. The MIC5014 is at the bottom right of the board. The SM MOSFETs are on the bottom side of the board and not shown.

'5014, but 0 V at the input turns it on, and a high level turns it off.

Making the PC Board

Figures 13A and B show the part placement for the top and back sides of the PC board for this project.[21] Before I made the all-SM version (shown in Figure 14B), I built a quick-and-dirty prototype using two PC boards. Except for the ICs, I used all standard-size leaded parts (one side of one of these boards is shown in Figure 14A), so the only critical cutting area was around the IC; all the rest was old-fashioned pad construction such as used in Project 0A. If you want to use an SM-only IC but don't need small size, this is an easy way to do it. You can also add solid wires as leads from the board and plug the entire circuit into a protoboard to use the subcircuit in a larger through-hole circuit. If you realize that SM projects needn't require *only* SM devices, experimentation becomes easier.

Once more, four jumpers (A, B, C and D) make connections between the top and bottom sides of the board where necessary. Because the board has parts on both sides, soldering is a little trickier than dealing with a board with parts mounted only on one side. Once you solder parts to one side of the board and turn the board over to solder the backside parts, it won't lie flat. Here's where a small vise can help by holding the board steady. I place parts on the more-congested side first. It isn't difficult to use the two SO-8 chips because they are so large; soldering SOT-23 packages would be more of a challenge.

Tune In Again

Before we wrap up this series next month, we'll look at a project with a large number of small parts mounted on both sides of the board. This project is one you can use as an appeasement gift to your

loved ones for spending so much time at the workbench!

Notes
[18]Parts 1 and 2 of this series appear in the April and May 1999 issues of *QST*, pages 33-39 and 48-50, respectively.
[19]Donald G. Varner, WB3ECH, "A Battery-Voltage Indicator," *QST*, October 1998, pp 50-51.
[20]Micrel Applications Note 5 (Micrel, 1849 Fortune Dr, San Jose, CA 95131; tel 408-944-0800; http://www.micrel.com).
[21]If you are interested in learning to make your own boards as described in this series, I have a limited number of parts kits available. Each consists of a 3 × 6-inch double-sided, copper-clad board, eight cut-off wheels (two 0.005 inch, four 0.009 inch and two 0.025 inch) and the special mandrel recommended

for use with the ultra-fine cut-off wheels. Order from Sam Ulbing, N4UAU, 5200 NW 43rd St, Suite 102-177, Gainesville, FL 32606; n4uau@afn.org. Price $13. (Florida residents must add sales tax). For orders outside the US, please add $3 for shipping.

A limited number of parts kits for Project 3 are available from me for $12 without a PC board. If you want a premade PC board, add $1.50. (Florida residents add sales tax). The kit includes only one IRF7201 MOSFET. If you want to parallel more MOSFETs or try an IRFZ46, Digi-Key, Newark and other suppliers carry those parts.

You can contact Sam Ulbing, N4UAU, at 5200 NW 43rd St, Suite 102-177, Gainesville, FL 32606; n4uau@afn.org.

Selecting A MOSFET for Power Control

The MIC5014 can drive just about any N-channel MOSFET. Which MOSFET you use depends on your current load. My circuit uses two small SO-8 MOSFETs in parallel. Although the specs show the maximum current for each as 7 A, a check of the I^2R (power) loss and thermal resistance shows that 4 or 5 A is a more reasonable amount when the chip is mounted on a small PC board. Using two MOSFETs in parallel, the circuit has no problem passing 10 A continuously. When selecting a different MOSFET, *calculate its heat loss* and don't be fooled by the maximum-current figure which—for nonsurface-mounted MOSFETs—is achievable only with a perfect heat sink.

The data sheets give the thermal resistance as temperature rise per watt of heat dissipated in the MOSFET ($^oC/W$). For surface-mount MOSFETs, the data sheet gives a single number: junction-to-ambient thermal resistance. For the IRF7201 used in the project, that is 50°C/W. At 10 A total, each MOSFET carries 5 A, and the I^2R loss is $25 \times 0.030 = 0.75$ W, giving a temperature rise of 37.5°C (100°F) above room temperature.

For nonSMT MOSFETs, the junction-to-ambient figure applies *only* if you are *not* using a heat sink. To gain the most from the MOSFET, you need to use a heat sink. In this case, you can determine the thermal resistance by adding the thermal resistances of the junction to case, the case to sink and the sink to ambient, which depends on the heat sink used. (This is just like electrical circuits: Resistances in series are added.) When in doubt, try a heat sink and see if things get hot. If so, use a larger heat sink, or add another MOSFET in parallel to reduce the current through each one.*—Sam Ulbing, N4UAU

*If you want to use a junk-box MOSFET, be sure to check its *on* resistance as it will probably be much higher than those of the MOSFETs I am using. The IRF510, a common MOSFET in a TO-220 package, has an *on* resistance of 0.54 Ω. Even with a rather large heat sink, the *maximum* current it can pass is about 4 A.