


Pocket white-LED torch is power efficient

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 This Design Idea describes a single white-LED torch, which can be housed in an empty glue-stick tube and has a long rechargeable-battery life. The circuit is constructed with just a few

commonly available parts. This torch has proven to be highly durable; the prototype model constructed by the author has been in service for nearly five years and is still in good working condition.

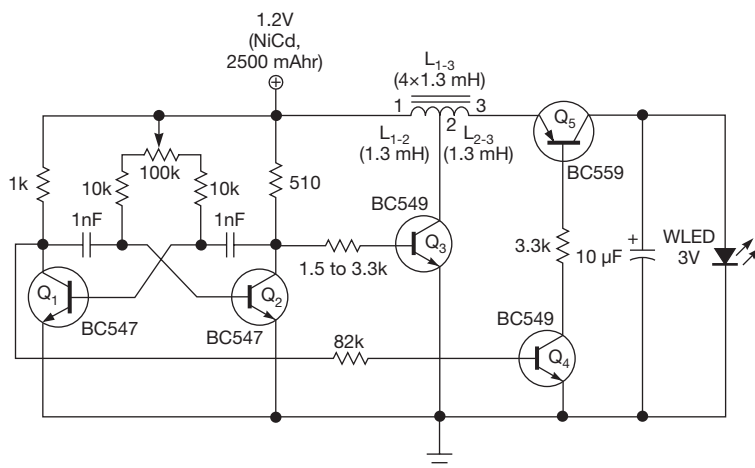


Figure 1 An inductive voltage booster powers the white LED.

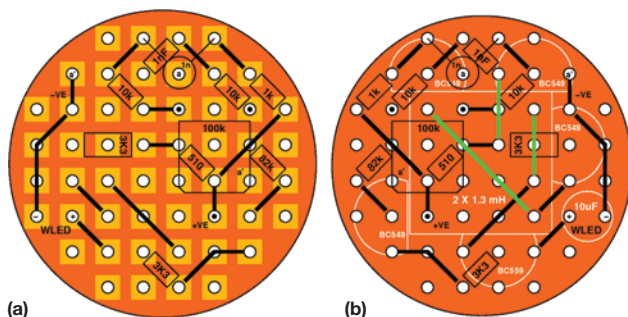


Figure 2 The circuit's components can be assembled onto the two sides of a circular general-purpose board: Connections on the lower surface have been mirrored (a); from the top, component placement is shown in white, and connections are shown in green (b).

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A single 1.2V/2500-mAhr nickel-cadmium cell powers the torch (**Figure 1**). A simple transistorized boost switcher based on a tapped inductor is used to increase the voltage efficiently (up to approximately 80%) to the voltage needed for a typical white LED¹—in this case, about 3V. Q₁ and Q₂ form an astable multivibrator producing rectangular waveforms at their collectors that are 180° out of phase.

Assume that at power-up, Q₂ is off and Q₁ is on. Under these conditions and with Q₂'s collector high, Q₃ is turned on via Q₂'s collector resistor. With Q₃ on, current flows through the first half of the inductor (from terminals 1 to 2).

At the end of this first half-cycle of operation, the multivibrator flips to the other state: Q₂ turns on and Q₁ turns off, and its collector goes high. Q₃ is switched off; Q₄ and Q₅ are switched on via Q₁'s collector resistor. The decaying inductor current now flows through terminals 1 and 3. Since L₁₋₂ is equal to L₂₋₃, and since they are on a common core, the inductance of L₁₋₃ is four times that of L₁₋₂ and L₂₋₃. This increased inductance (and the corresponding additional turns on the core) leads to a reduction in the magnitude of the current but an increase in voltage across the LED. During this phase, current flows

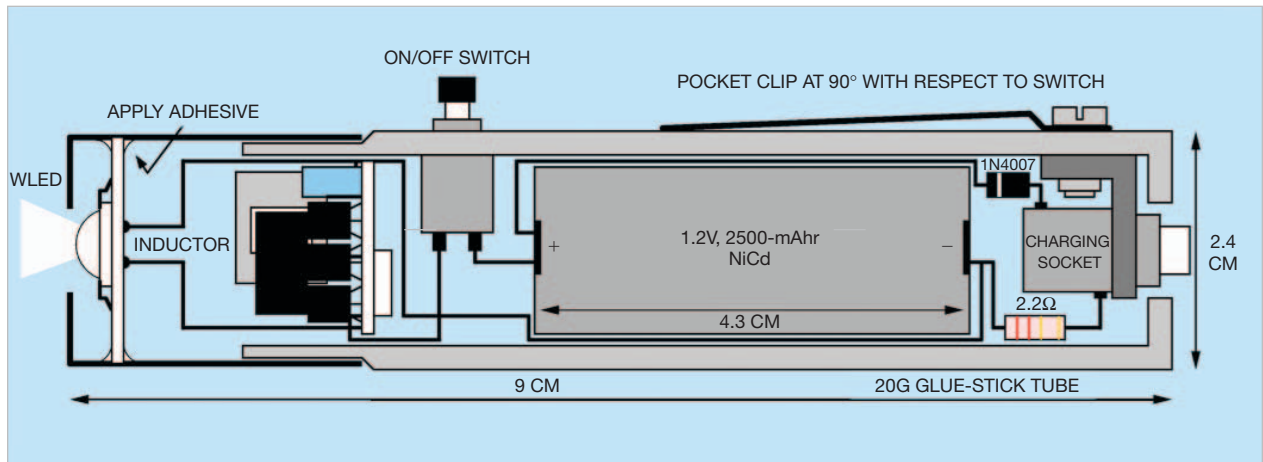


Figure 3 The white-LED torch can be assembled inside an empty glue-stick tube.

through the LED and, simultaneously, the 10- μ F capacitor is charged. This phase lasts for a time period determined by the RC values in the astable circuit.

Once the RC time constant passes, the process repeats: Q_1 turns on, Q_2 turns off, and the other transistors switch as previously described. The current through terminals 1 and 2 of the coil again increases, storing energy from the battery in the inductor. During this phase, the 10- μ F capacitor powers the LED.

Figure 2 shows how the circuit's components can be assembled onto the two sides of a circular general-purpose board. **Figure 3** shows how the torch could be assembled inside the glue-stick tube. Once the torch is assembled and powered up, adjust the 100-k Ω potentiometer in the astable circuit for maximum brightness. Note that, if needed, an additional transistor can be used in parallel with Q_3 to boost the energy stored in the $L_{1,2}$ inductor. The need is

dictated by how quickly and deeply Q_3 goes into saturation.


Photographs of the working circuit can be seen in the online version of this Design Idea at www.edn.com/4412618. An online appendix contains the quantitative aspects of the circuit. **EDN**

REFERENCE

1 "LT1932 constant-current DC/DC LED driver in ThinSOT," Linear Technology, <http://bit.ly/17YVEdw>.

Gnat-power sawtooth oscillator works on low supply voltages

Bruce D Moore, Consulting Analog Engineer

 This sawtooth-oscillator circuit, drawing less than 3.2 μ A and working at under 1V, is a useful building block that fits the bill for extremely low-power consumption and operation to low supply voltages. It could be used as the basis for a PWM control loop, a timer, or a VCO, or as a capacitance-to-frequency converter. It's a nifty circuit for two reasons: It uses an open-drain comparator output to make an accurate switched current source, and it uses a latch function to make a simple comparator into a window comparator, while needing no extra components.

The appeal of this circuit is found in the combination of the tiny size, the ridiculously low number of exter-

nal components, a low supply current, and the ability to maintain a constant amplitude and frequency despite the variable battery voltage. Unlike the classic op-amp astable multivibrator, this design features comparator thresholds that are set by precision reference voltages rather than the output swing of the op amp in combination with resistor feedback.

A ratiometric fixed-frequency design of this type usually results in a variable-amplitude sawtooth waveform, which is undesirable in PWM control loops because it can affect the loop gain. As a side benefit, the up/down ramps can be independently controlled by scaling R_1 and R_2 .

Referring to **Figure 1**, there are only eight components in this circuit: two ICs, four resistors, a capacitor, and a power-supply-bypass capacitor. The key bits are two Touchstone Semiconductor analog building-block ICs in 4-mm² TDFN packages (the TS12011 and the

THE APPEAL OF THIS CIRCUIT INCLUDES ITS SMALL SIZE AND LOW EXTERNAL-COMPONENT COUNT.

TS12012), each containing an op amp, a comparator, and a reference. By leaning on their characteristics, the design can be kept terrifically tiny and simple.

Here's how the circuit works: A summing integrator feeding a window comparator generates the sawtooth

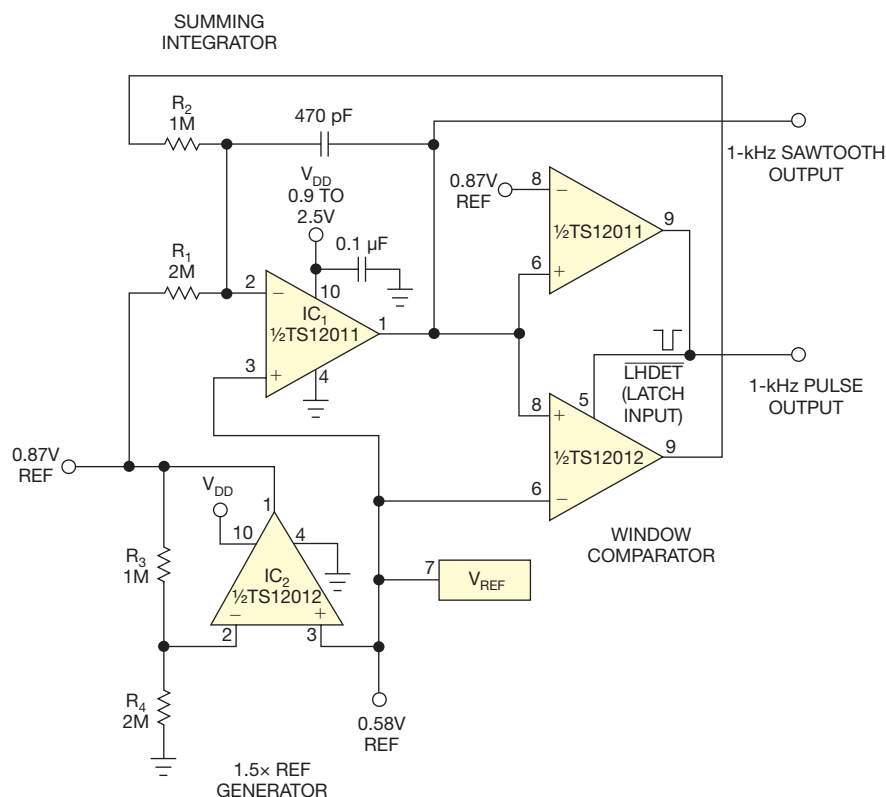


Figure 1 This low-voltage sawtooth generator uses only eight components and draws extremely low power.

wave. The integrator-summing node is held at V_{REF} by the feedback action of the amplifier. Thus, a fixed positive reference current set by R_1 is balanced by a larger-amplitude switched negative current set by R_2 . The lower comparator block has an open-drain output; when its output is low, current is pulled from the summing node via R_2 : $I_{R1} = (0.87 \times V_{\text{REF}} - 0.58 \times V_{\text{REF}}) / R_1$ and I_{R2} (switched) $= 0.58 \times V_{\text{REF}} / R_2$. If I_{R2} is set to $2 \times I_{R1}$, a symmetrical triangle wave results.

The frequency is set as follows:

$$f = \frac{1}{[1/I_{p1} + 1/I_{p2}] \times C \times V},$$

where V is the difference between $0.87 \times V_{\text{REF}}$ and $0.58 \times V_{\text{REF}}$. Here, $f=850$ Hz.

Figure 2 shows the waveforms at the sawtooth and pulse outputs.

The window comparator employs a built-in latch function of the TS12012 to provide hysteresis. The latch func-

tion has a sly feature: When $\overline{\text{LHDET}}$ is pulled low, the comparator inputs are still active and sensing the input

Design Idea is courtesy of EDN.com's sister site, Planet Analog: <http://bit.ly/11IkNeK>. **EDN**

state, until the inputs cross. The comparator in IC₂ gets set when the ramp crosses the lower threshold at $0.58 \times V_{\text{REF}}$ and reset when the ramp crosses $0.87 \times V_{\text{REF}}$. The reset pulse is momentary, but puts the latch in a state where the comparator inputs crossing cause it to set and latch again (which happens due to the switched reference current causing the integrator to ramp negative). The net result: No glue logic is needed.

The battery voltage ranges down to 0.9V with a miserly V_{DD} current of 3.2 μ A. Maximum operating frequency is limited by the op-amp slew rate and prop delays to about 3 kHz. Disconnecting R_1 and driving it with a voltage source greater than $0.58 \times V_{REF}$ gives you a VCO function.

Editor's note: This

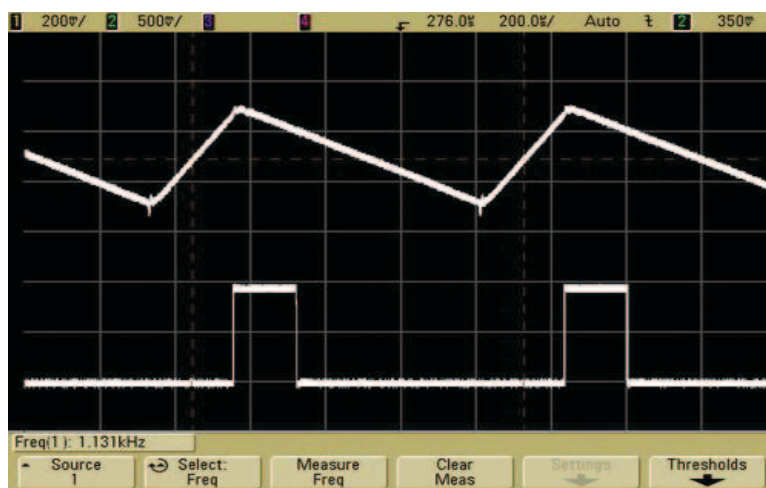


Figure 2 The waveforms at the sawtooth and pulse outputs are shown. The pulse train is used to reset the latching comparator.

Connect a 4×3 matrix keyboard to a microcontroller using two I/O pins

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Matrix keyboards are common as an input device in microcontroller-based projects. A conventional way of connecting a matrix keyboard to a microcontroller is to use multiple I/O pins of the MCU. The MCU then uses a scanning algorithm to identify which keys are pressed. A drawback of this method is that it requires a large

number of the MCU's I/O pins to connect the keyboard. For example, to connect a 4×3 keyboard requires seven digital I/O pins. This becomes a problem when the project is based on a low-pin-count MCU or when the MCU being used does not have enough free I/O pins.

Two solutions for this issue are

available: Use readily available I/O expanders, or assign a unique voltage to each key using a resistor network and then use an analog pin to read the voltage and determine which key is pressed. Each solution has its own disadvantages.

Since most of the time I/O expanders require a special communication protocol (I²C or SPI, for example) to read and write data, the MCU should have built-in communication modules, or the user has to implement the relevant communication-protocol software wisely, which adds significantly to the overhead of the MCU. On the

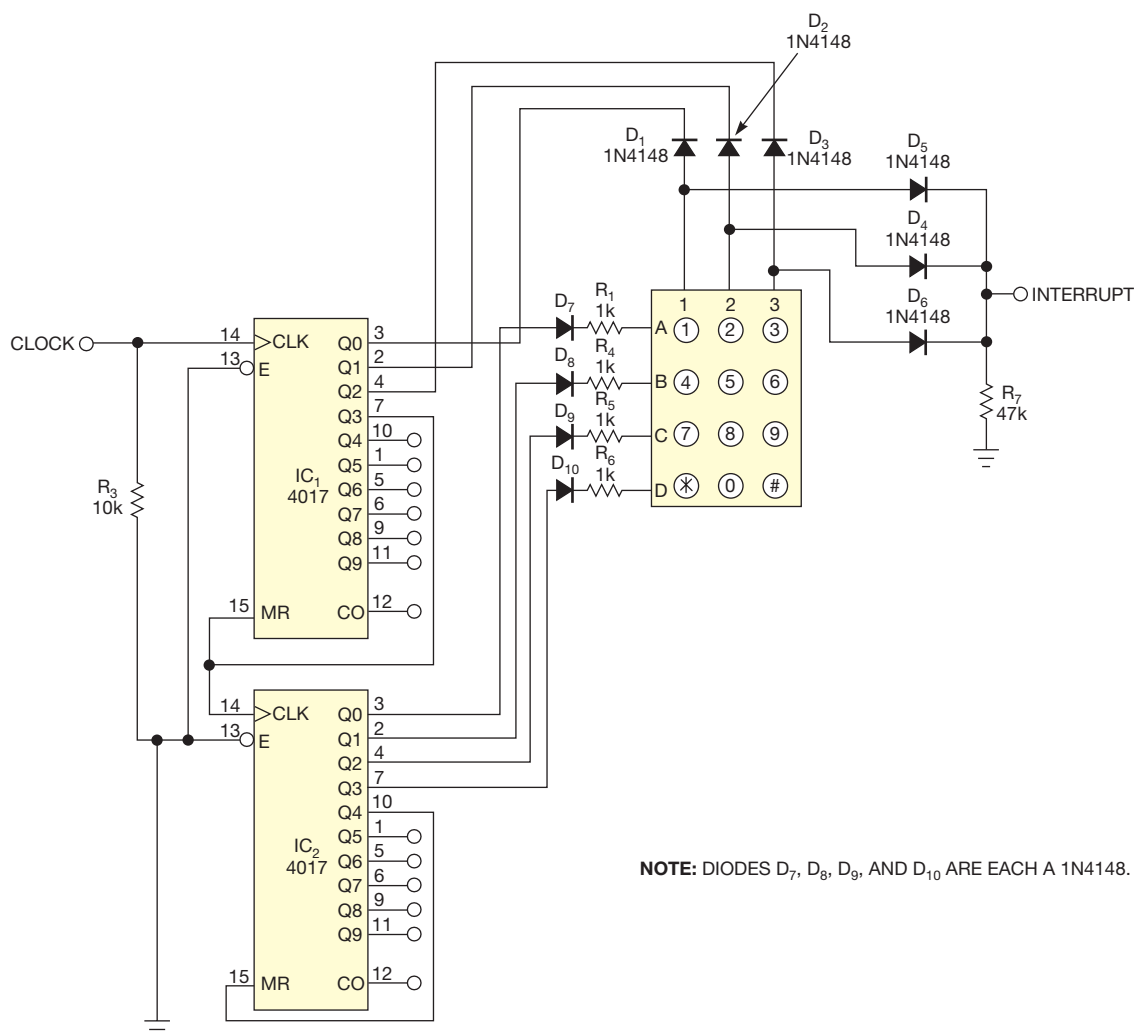


Figure 1 This circuit for a 4×3 keyboard shows a more efficient architecture using two CD4017 Johnson counters with only two I/O pins.

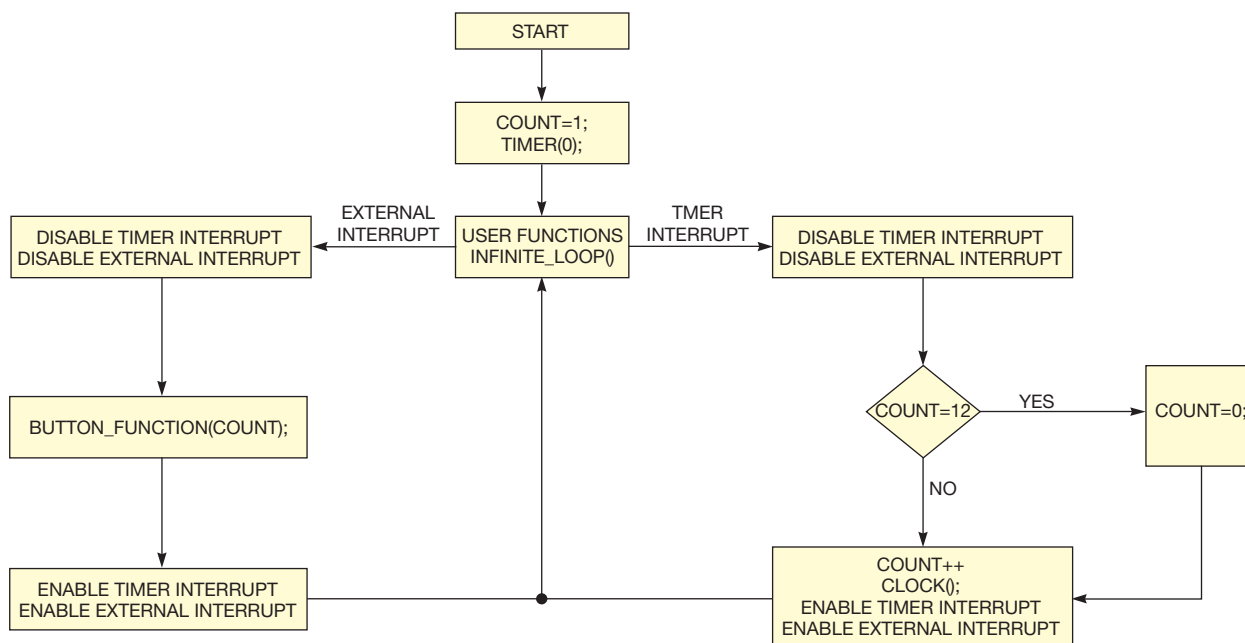


Figure 2 The clock count kept in the MCU increments as it generates clock pulses in intervals; this count is equal to the switch number focused at the moment.

other hand, assigning a unique voltage to each key using a resistor network becomes troublesome as the number of keys becomes high, which will lead to tight voltage margins. Then, as resistor values tend to change with temperature, the use of tight voltage margins can cause incorrect readings. Even switch bouncing can play a major role in producing incorrect voltages with this method. Another major drawback of this method is that it requires the presence in the MCU of an analog input pin.

The Design Idea described here addresses all of the above problems in an efficient manner and has several advantages: It requires only two I/O pins regardless of the number of switches connected; it does not require a special communication protocol; and it does not require an analog pin. The idea is based on two CD4017 Johnson counters, which are both common and inexpensive.

Figure 1 shows the circuit for a 4×3 keyboard. R_1 , R_4 , R_5 , and R_6 are used for current limiting; R_7 , D_4 , D_5 , and D_6 form an OR gate.

The example described here shows how to implement this method to read a 4×3 matrix keyboard. One CD4017 is used to control the keyboard rows, while the other is used to control the columns.

The MCU generates a clock signal and feeds it to the counter IC controlling the columns. Initially, the 0th output of the column counter and row counter is at logic high, and the column counter increments as it receives clock pulses. At the fourth clock pulse, the column counter resets and simultaneously increments by one the counter controlling the rows. As the column controller resets, the row controller increments and the row controller resets with the fifth clock pulse from the column controller. As clock pulses generate, a count variable on the MCU should be incremented and should reset to one upon the fifth clock pulse to the row controller. The output of the keyboard is OR'ed and connected to an external interrupt pin of the MCU.

An interrupt occurs only if a button pressed when both the row and the

column of the respective button are at the logic-high level. If either row or column of the button is logic zero, an interrupt will not occur.

When an interrupt occurs, the MCU reads the count value at the moment; that value is equal to the button just pressed.

The clock count kept in the MCU increments as it generates clock pulses in intervals; this count is equal to the switch number on the keypad that could generate an interrupt if pressed. The flow chart in **Figure 2** illustrates this scenario.

Note that even though this example shows a 4×3 keyboard, you can also read a 10×10 keyboard by using the remaining outputs of both 4017 counters. Furthermore, you can cascade additional 4017 ICs to expand the keyboard size as necessary. **EDN**

REFERENCE

1 Rubasinghe, Aruna, "Read 10 or more switches using only two I/O pins of a microcontroller," *EDN*, Feb 28, 2013, www.edn.com/4408027.

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Bender senses shocks

Don Sherman, Maxim Integrated Products, Sunnyvale, CA

With the aid of a simple mounting system and some soldered-on weights, a piezoelectric “bender” can detect mechanical shocks. The bender comprises a piezoelectric-ceramic element bonded to a thin brass disc. Such assemblies form the heart of many telephone annunciators and wrist-watch or panel-mounted alarms.

Depending on the mounting scheme, the bender can sense shocks in one axis (**Figure 1a**) or three axes (**Figure 1b**). For one-axis sensing, sol-

der one edge of the bender to a mounting bolt. Opposite the mounting bolt, solder a weight to increase the bender's sensitivity. A small hook affixed to the mounting substrate limits motion so that the brittle piezoelectric element will not crack.

For three-axis sensitivity, solder one edge to a mounting bolt as before. At the other edge, solder a flat-head bolt that points away from the mounting substrate. Use a pair of jam nuts to increase the assembly's polar moment

of inertia. The jam nuts' position determines the bender's sensitivity.

In both cases, apply your soldering iron as briefly as possible to the bender to avoid damaging the piezoelectric element's bond to the brass disc.

Figure 2 shows a simple alarm circuit. Giving the bender a good smack will develop several volts across R_1 , the 10-M Ω resistor. The dual-timer IC, IC₁, will then pulse the output alarm for one minute at a 1-Hz rate. The alarm has its own driver circuit and sounds a piercing 90-dB tone when energized.

The bender and alarm are both available from Projects Unlimited, Dayton, OH. **EDN**

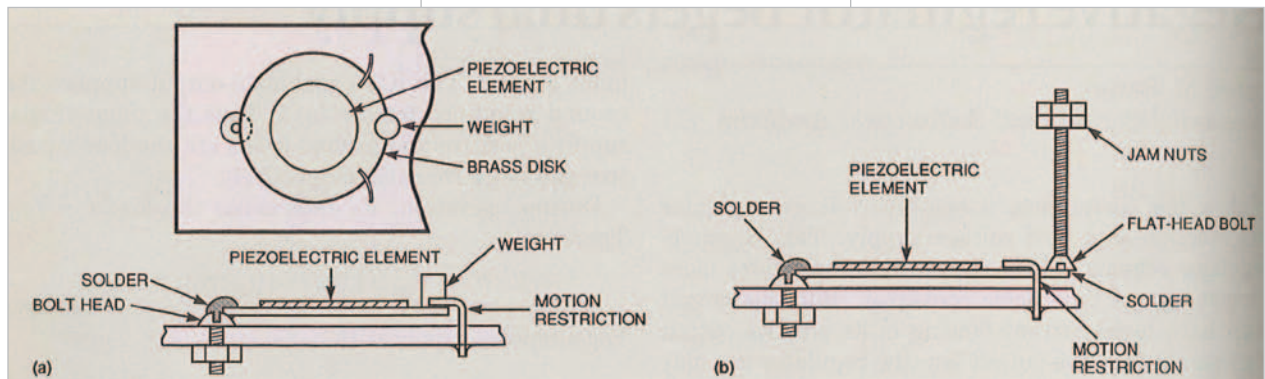


Figure 1 Solidly mounting one end of a piezoelectric “bender” and affixing a weight to the opposite edge transforms the bender into a shock sensor. Here, “a” is sensitive to vertical-axis shocks only; “b” senses shocks in all three axes.

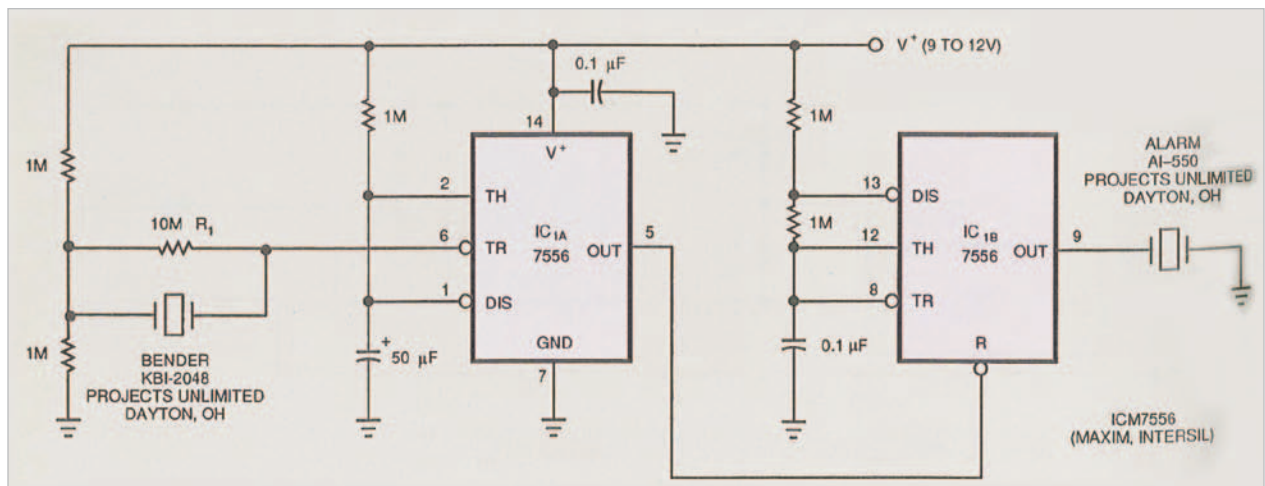


Figure 2 The circuit sounds a 1-sec alarm whenever you give the bender a good smack.