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High-impedance buffer amplifier's input includes ESD protection

Eugene Palatnik, Waukesha, WI

Certain measurement applications, such as for pH (acidity) and bio-potentials, require a high-impedance buffer amplifier. Although several semiconductor manufacturers offer amplifier ICs featuring low bias and offset-input currents, attaching a sensor cable to an amplifier circuit can inflict damage from ESD (electrostatic discharge). Figure 1 shows one

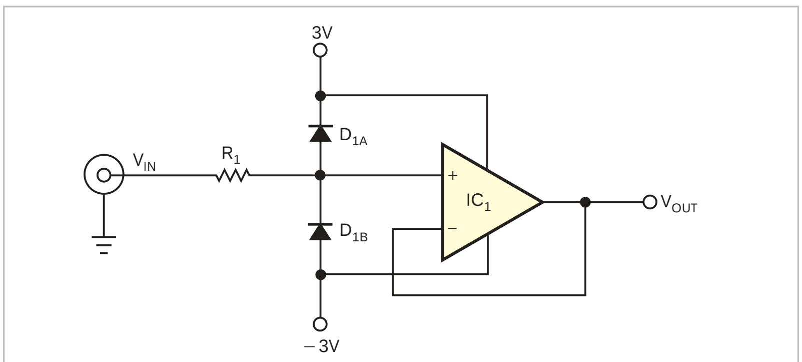

Figure 1 In a conventional ESD-suppression circuit, diodes clamp an amplifier's input voltage to its power-supply rails but introduce unwanted leakage currents.

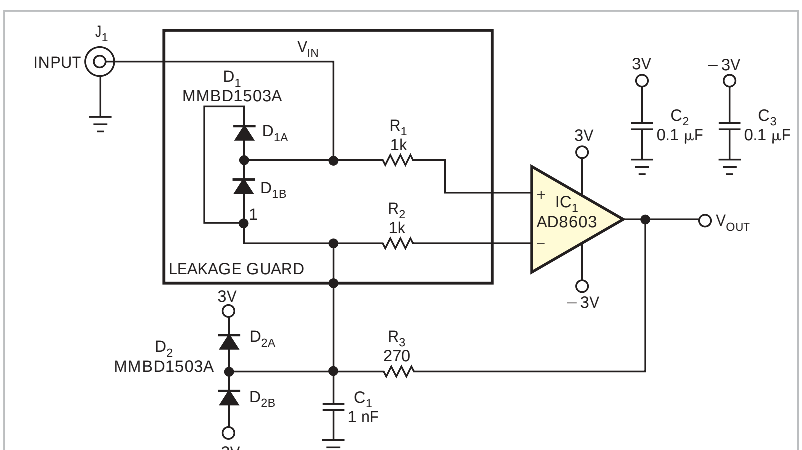

Figure 2 In this alternative design, voltage across both halves of D_1 normally approaches 0V and introduces no leakage currents. During an ESD event, both D_1 and D_2 conduct to protect IC_1's inputs.

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unsatisfactory approach to ESD protection. Resistor R_1 limits an ESD event's discharge current, and diodes D_{1A} and D_{1B} clamp amplifier IC_1's input to its power-supply rails. Unfortunately, when shunting a pH sensor's 400-MΩ input impedance, even low-leakage diodes, such as Fairchild Semiconductor's (www.fairchildsemi.com) MMBD-1503A, introduce significant offset voltages.

The circuit in Figure 2 offers an alternative approach. An Analog Devices (www.analog.com) low-input-bias, low-offset-current AD8603 amplifier, IC_1, serves as a unity-gain input buffer. For any normal input, the circuit's output voltage, V_{OUT}, equals its input voltage, V_{IN}. Thus, the voltage across ESD-protection diode D_{1A} or D_{1B} approaches 0V, and neither diode's leakage current affects the sensor's output signal. Depending on the polarity of an ESD event you apply to the circuit's input connector, its high-voltage spike discharges through diode D_{1A} or D_{1B} into the positive or the negative power-supply rail. Capacitor C_1 acts as an intermediate "charge reservoir" that slows the ESD spike's rate of rise and protects IC_1's output stage from latching until diode D_{2A} or D_{2B} begins diversion of the ESD transient into the positive or the negative supply rail. In effect, C_1 compensates for D_1's parasitic capacitance. Resistor R_3 allows IC_1 to drive the capacitive load that C_1 presents without going into oscillation.

During an ESD event, both D_1 and D_2 can conduct, but the voltage at V_{IN} exceeds the power-supply-rail voltage by only two forward-biased diode voltage drops. Resistors R_1 and R_2 limit the amplifier input's currents below the manufacturer's recommended 5-mA maximum rating.

When packaging the circuit, pay special attention to the pc board's layout. Imperfections in the board's dielectric properties can provide parasitic-leakage-current paths. Adding copper traces on both sides of the board to form guard rings around the circuit's high-impedance nodes diverts leakage currents (Figure 3).EDN

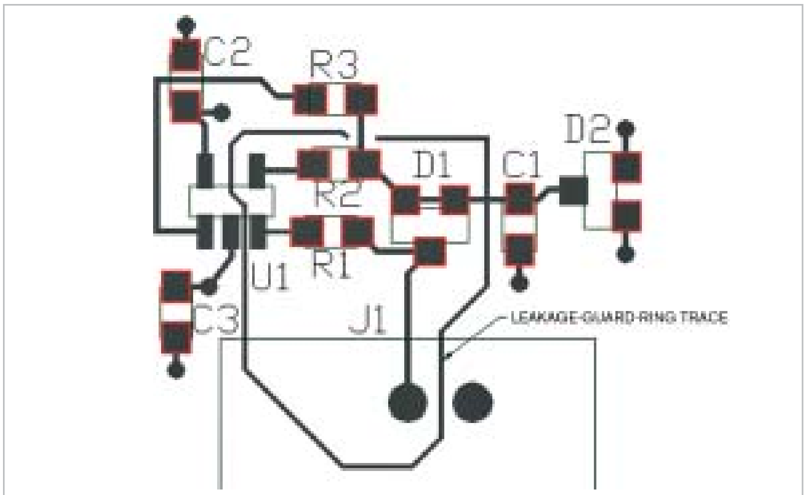

Figure 3 For best performance, place copper traces around the amplifier's high-impedance points to intercept leakage currents.

Composite-VGA encoder/decoder eases display upgrade

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An older computer system fed RGB video and composite-synchronization signals through four 75Ω coaxial cables to an RGB color monitor 150 feet away. To upgrade it, the replacement VGA video cards could directly drive the 75Ω loads that the VGA monitors' internal terminations presented. However, the VGA standard uses separate horizontal and vertical positive-going synchronization signals. Adding an extra coaxial cable to the original cables to carry the separate synchronization signals presented a difficult and expensive proposition. An obvious solution would be to combine the separate synchronization signals into a composite format.

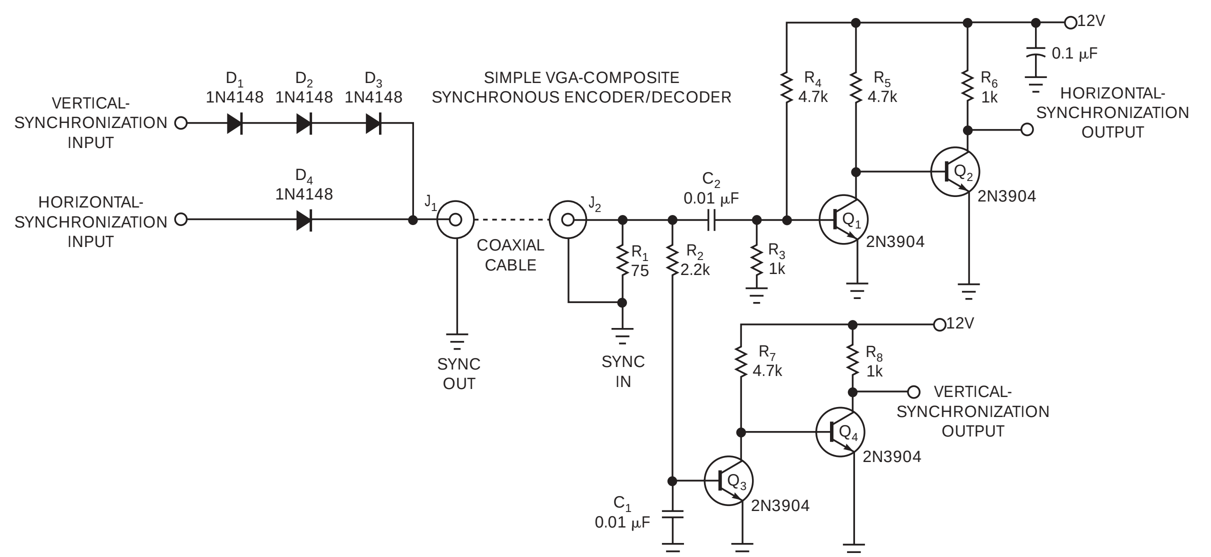

Figure 1 The synchronization-pulse combiner and recovery circuits comprise readily available and inexpensive components.

The combiner circuit in Figure 1 offers simplicity, low cost, and rapid assembly from readily available spare parts.

In operation, two 1N4148 diodes, D_1 and D_2, attenuate the VGA signal's 5V logic-level vertical-synchronization pulses by 1.4V, and diodes D_3 and D_4 form a diode-logical-OR gate to combine the vertical- and horizontal-synchronization pulses. The resultant output signal comprises an approximately 4.3V horizontal-synchronization signal superimposed on a 2.9V vertical-synchronization signal.

At the receiving end, a capacitively coupled highpass filter extracts the horizontal-synchronization signal, and a simple RC (resistor-capacitor) lowpass circuit removes horizontal-synchronization pulses from the directly coupled vertical-synchronization signal. Transistors Q_1 and Q_2 amplify the recovered horizontal-synchronization pulses, and transistors Q_3 and Q_4 amplify the vertical-synchronization pulses. The circuit's resulting outputs consist of clean synchronization pulses that closely approximate those of the original and provide extremely stable synchronization pulses for a VGA monitor operating at 640×480-pixel resolution (Figure 2). EDN

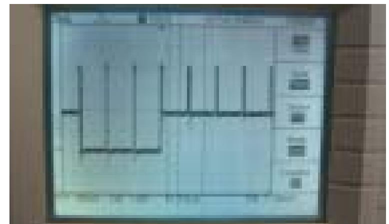

Figure 2 Applying the diode-gated composite-synchronization waveform to a 75Ω load results in clean synchronization pulses.

Solenoid-protection circuit limits duty cycle

Panagiotis Kosioris, Inos Automation Software, Stuttgart, Germany

Several safety-critical solenoids in a laser-measurement system on an automotive-assembly line required protection from internal overheating during normal operation. After a 60-sec activation, the solenoids required 180 sec to cool before their next activation. One apparently straightforward protection circuit would comprise a timer based on a microcontroller, some support components, and a short program written in C++. However, the project would require evaluation and selection of a suitable microcontroller, purchase or rental of a device programmer, and considerable time in programming the microcontroller and evaluating its operational hazards.

As an alternative, I recalled the words of my tutor: "Decrease the number of dangerous components to decrease the risk of danger." A simple analog circuit would be safer, smaller, and easier to maintain. The circuit in Figure 1 uses a traditional analog method of measuring time: the charge and discharge behavior of a resistance-capacitance circuit.

Figure 2 highlights the circuit's timing components. Capacitor C_2, a tantalum electrolytic with ±10% tolerance, diode D_1, and resistors R_2 and R_5 constitute a double-RC (resistor-

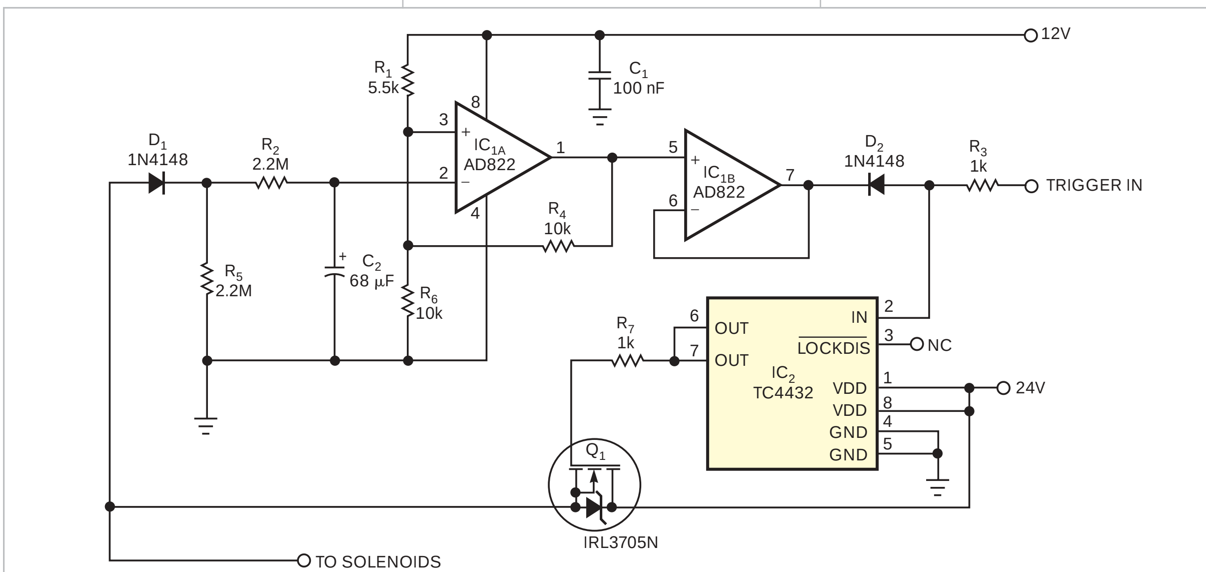

Figure 1 An externally triggered solenoid driver features an analog duty-cycle limiter.

capacitor) circuit. During solenoid activation, R_2 provides a charging path for C_2, and diode D_1 prevents C_2 from discharging through the solenoids. When the solenoids are off, the discharge path comprises R_2 plus R_5, which provides a longer time constant. The difference between the two time constants determines the solenoids' activation and recovery periods. A Schmitt trigger designed around one-half of IC_1, an Analog Devices (www.analog.com) AD822 dual operational amplifier, senses the voltage across C_2 and defines the solenoids' cutoff- and turn-on-timing intervals. An intermediate buffer stage, IC_{1B}, drives a Microchip (www.microchip.com) TC4432 MOSFET driver, which in turn controls the gate of Q_1, an N-channel power MOSFET that drives the solenoids from 24V.

When Q_1 switches on, the voltage level across C_2 increases, and, after 60 sec, the output of the Schmitt trigger falls from 12 to 0V. The buffer stage drives the cathode of diode D_2 to 0V. The voltage at D_2's anode reaches 0.7V and is insufficient to trigger MOSFET-driver IC_2. Q_1 now switches off, removing supply voltage from the solenoids and reverse-biasing diode D_1. Capacitor C_2 starts to discharge through R_2 and R_5, and the input voltage you apply to the Schmitt trigger falls at a slower rate than during the charging interval. After 180 sec, the Schmitt trigger's output rises to 12V, and the circuit awaits arrival of another external trigger pulse through resistor R_3. EDN

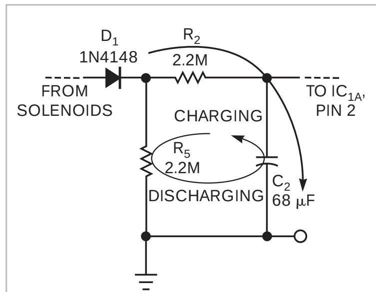

Figure 2 A resistance-capacitance circuit determines on- and off-time intervals.

SPST pushbutton switch combines power-control, user-input functions

Eugene Kaplounovski, Vancouver, BC, Canada

This Design Idea describes an enhancement to a previous one (Reference 1). The circuit in Figure 1 uses a normally open SPST pushbutton switch, S_1, instead of the SPDT switch that the original design required. You can use a membrane switch to significantly simplify the industrial design of the device and enhance its ergonomics. In addition, this circuit slightly reduces the current drain in active mode by eliminating current flow through the unactuated switch.

In standby mode, MOSFET Q_1 remains off and consumes less than 1 µA of leakage current from the battery. Pressing switch S_1 turns on Q_1 by pulling its gate to ground through diode D_1. Voltage regulator IC_1 turns on and supplies power to microcontroller IC_2. The microcontroller boots up and asserts its P1.1 output high, turning on transistor Q_2 and latching on the system's power to allow release of S_1. Meanwhile, resistor R_3 pulls the microcontroller's input, P1.2, to V_{CC}. Pressing the switch a second time pulls the microcontroller's P1.2 input low through diode D_2 and signals the button-pressed event to the firmware. After completing its program, the microcontroller asserts its output P1.1 low to turn off Q_2 and, consequently, Q_1, removing power from the system until the user presses S_1 and restarts the process.

When selecting components, ensure that Q_1's gate-source breakdown voltage exceeds the highest possible input voltage; otherwise, use a zener diode to limit Q_1's applied gate-source voltage. You can omit Q_1 if voltage regulator IC_1 includes an on/off-control pin. To replace Q_1 with a different power-switching device, such as an NPN bipolar transistor or a relay, specify Q_2 to provide the control current that the switching device requires. To further reduce the circuit's component count, replace diodes D_1

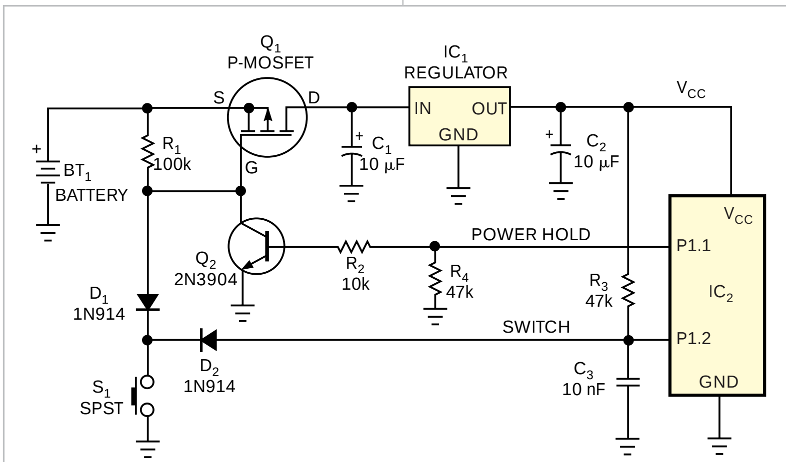

Figure 1 One switch can provide power control and user inputs to a microcontroller-based system.

and D_2 with a suitable common-cathode dual-diode array, such as the BAV70. Omit resistor R_3 if IC_2 includes built-in pullup resistors, as do many modern microcontrollers.EDN

REFERENCE

1 Hageman, Steve, "Single switch serves dual duty in small, microcontroller-based system," *EDN*, March 30, 2006, pg 96, www.edn.com/article/CA6317068.

Electronic circuit replaces mechanical push-push switch

Donald Schelle, Maxim Integrated Products Inc, Sunnyvale, CA

Mechanical push-pushbutton switches (also known as alternate-action or push-on/push-off switches) can be bulky and expensive. As an alternative, an electronic version uses a cheaper, NO (normally open), momentary-on switch (**Figure 1**). A supervisory microprocessor, IC_1, serves as a combination switch debouncer and intelligent controller. Applying power holds IC_1's $\overline{LBO}$ output (Pin 4) low, which in turn resets flip-flop IC_2's output to a logic-low state (off) (**Figure 2**). Pressing the NO momentary-contact switch, S_1, evokes a pulse from the $\overline{RESET}$ output (IC_1, Pin 5), which triggers IC_2's CK input (Pin 1) and toggles IC_2's output to a logic-high state (on). Pressing the switch a second time triggers another $\overline{RESET}$ pulse that toggles flip-flop IC_2's output to a logic-low state (off).

You can add an optional watchdog timer, IC_3, to reset IC_2's output to the logic-low state after a user-selectable interval as long as 60 sec. You can select shorter reset times using IC_3's programming pins: SET0, SET1, and SET2. The entire circuit costs about $2 (1000) and occupies a pc-board area that's no larger than its mechanical counterpart.EDN

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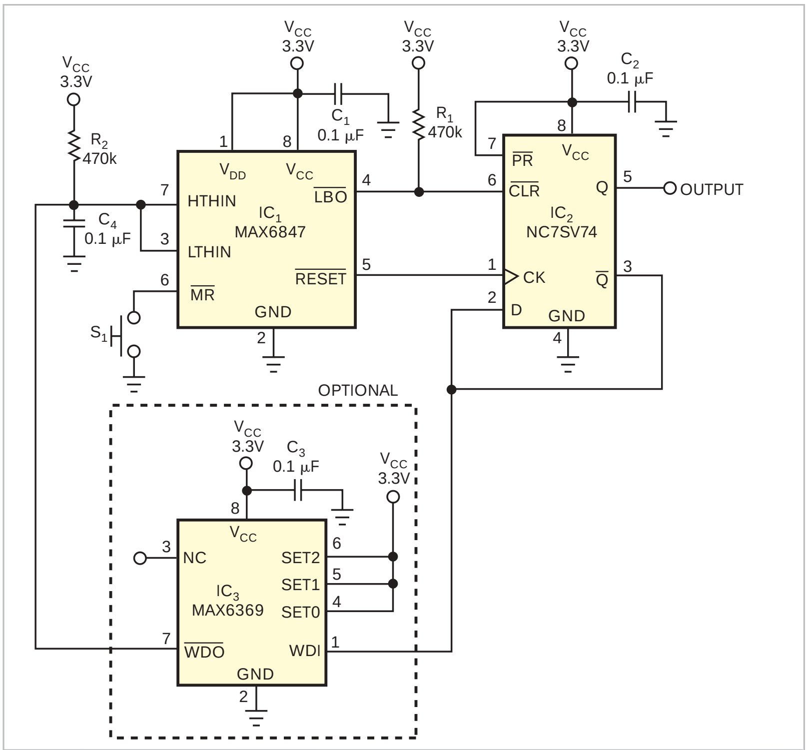

Figure 1 This simple electronic circuit uses a momentary-contact pushbutton switch, S_1, to replace a more expensive mechanical push-on/push-off switch.

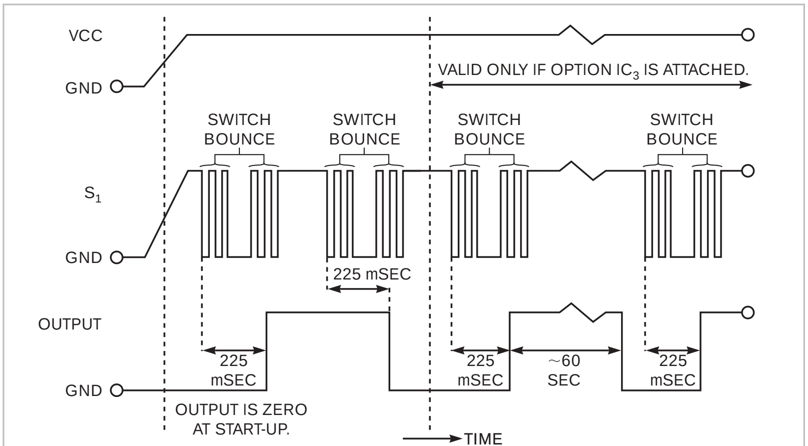

Figure 2 Repeatedly pressing the circuit's momentary-contact switch toggles the circuit's output on and off. After a preselected interval, an optional watchdog timer resets the output to the logic-low state.