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-

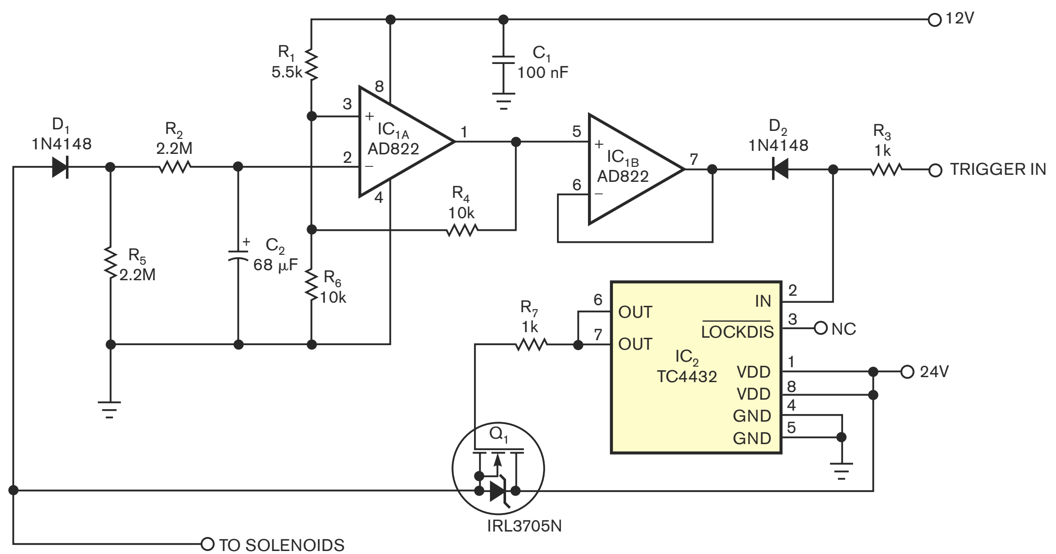

Figure 1 An externally triggered solenoid driver features an analog duty-cycle limiter.

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

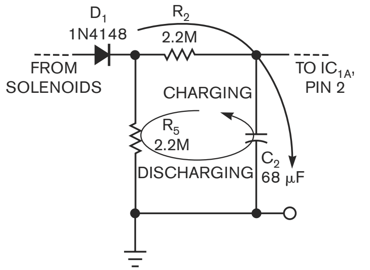

Figure 2 A resistance-capacitance circuit determines on- and off-time intervals.

Schmitt trigger's output rises to 12V, and the circuit awaits arrival of another external trigger pulse through resistor R_3. EDN