Precision capacitive-sensor interface suits miniature instruments

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In some applications of capacitive sensors, the instrument's front end must be small enough to fit into a narrow space. **Figure 1** shows a precision capacitive-sensor interface for such use. The square-wave output from a low-voltage 555 timer, IC_1, constantly triggers the precision one-shot, IC_2, to produce quasistable outputs for time periods T_1 and T_2, which are proportional to external timing capacitance: $T_1=KR_0(C_S+C_0)$, and $T_2=KR_0C_S$, where K is the multiplier factor. K is nearly independent of the external timing capacitance when that capacitance is more than 100 pF (**Reference 1**). So, a 150-pF capacitor, C_0, in shunt with the capacitive sensor, C_S, supplies an offset so that operation of the one-shot remains within a linear range even if the value of C_S is less than 100 pF.

To achieve good measurement accuracy, connect a reference channel with a fixed 150-pF capacitor. This method cancels the effects of both stray capacitance and transition time. A single 3.3V supply powers this interface circuit. The circuit's compact design permits flexibility, and you can easily

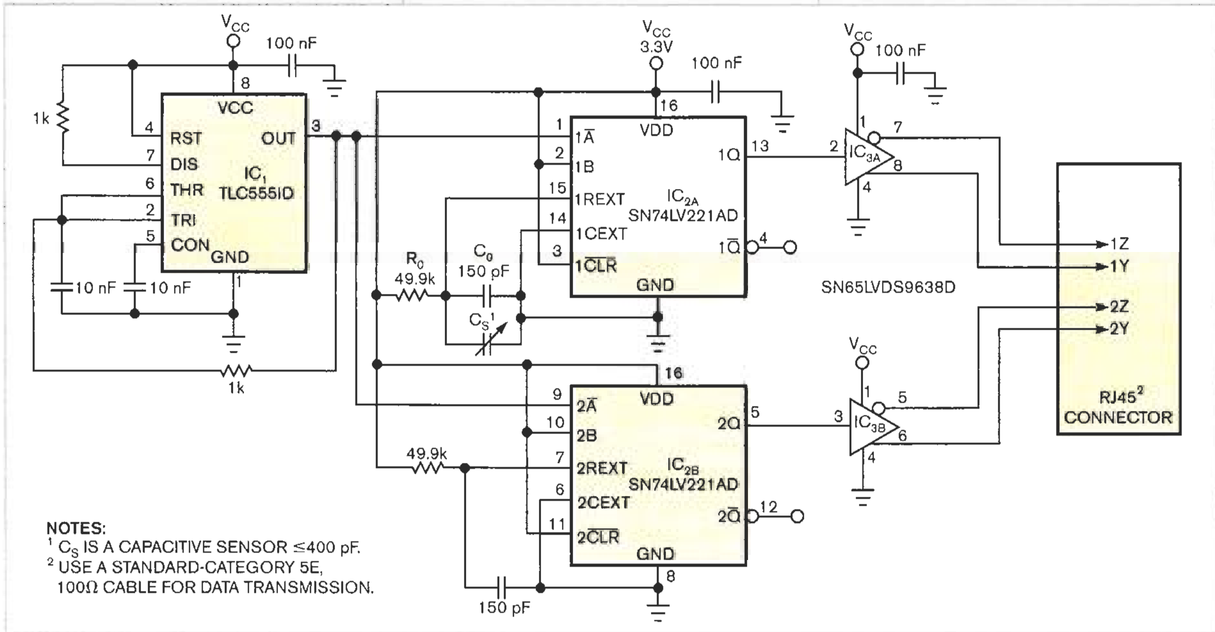

Figure 1 This compact capacitive-sensor-interface-circuit design permits great flexibility; you can easily integrate it into a miniature sensor head near the measurement point.

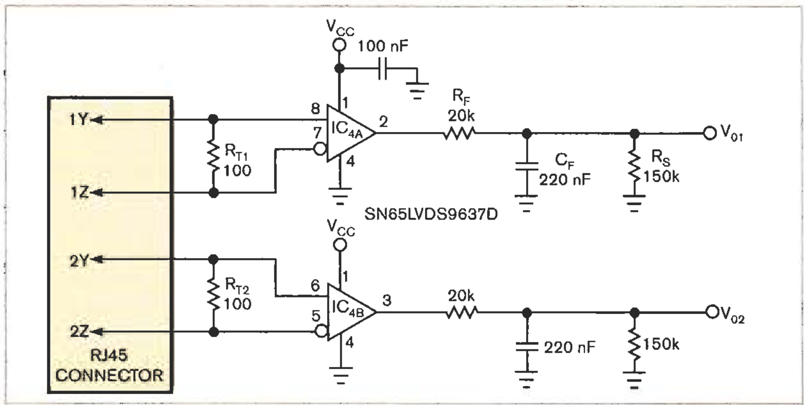

Figure 2 At the terminal, IC_4 converts the signals it receives from the interface to LVTTL levels and then feeds them to a set of passive filters.

integrate the circuit into a miniature sensor head near the measuring point. IC_3 converts the outputs to LVDS (low-voltage-differential-signaling) levels and then transmits these outputs using a standard Category 5e cable to the terminal, which may be some distance away. As long as the cable is shorter than 10m, the transmission bandwidth is adequate for ensuring acceptable measurement accuracy within several picofarads to hundreds of picofarads (**Reference 2**). In **Figure 2**, the terminal at IC_4 converts the signals it receives from the interface to LVTTL (low-voltage-transistor-to-transistor-logic) levels and then feeds them to a set of passive filters. Each dc output is proportional to the signal's duty cycle:

$$V_{O1} = V_H \times \frac{T_1}{T_P} \times \frac{R_s}{R_f + R_s},$$

and

$$V_{O2} = V_H \times \frac{T_2}{T_P} \times \frac{R_s}{R_f + R_s},$$

where V_H is the high-level output voltage of IC_4 and T_P is IC_1's oscillation period. By digitizing the two outputs, you can obtain a reading proportional to the sensor's capacitance, $V_{O1} - V_{O2}$. Be sure that $T_1 < T_P$—that is, $C_S < T_P/(K \times R_0) - C_0$; otherwise, the final output will be erroneous. For the sake of a wide measurement range, keep T_P as long as the target application permits. EDN

REFERENCES

1. "SN54LV221A, SN74LV221A: Dual Monostable Multivibrators With Schmitt-Trigger Inputs," Texas Instruments, April 2005, http://focus.ti.com/lit/ds/symlink/sn74lv221a.pdf.
2. High-performance linear products technical staff, *LVDS Application and Data Handbook*, Texas Instruments, November 2002, http://focus.ti.com/lit/ug/slld009/slld009.pdf.