



Edited by Brad Thompson

Versatile digital speedometer uses few components

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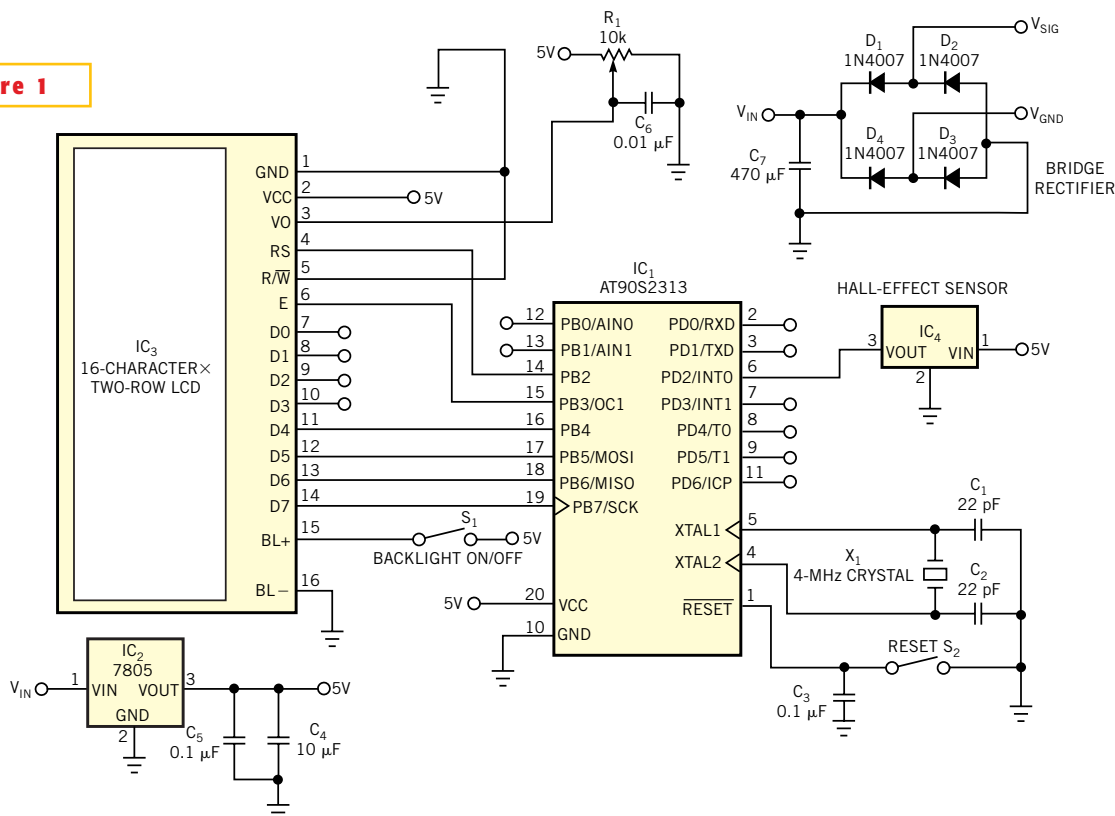
A SPEEDOMETER measures a wheel's rotational speed. Unlike conventional mechanical and moving-magnet designs that use analog moving-pointer displays, the electronic speedometer in this Design Idea features a digital readout and a power-saving device that uses few components. **Figure 1** shows the digital speedometer's circuit design. An Atmel AVR AT90S2313 microcontroller, IC₁, drives IC₃, a 16-character, two-row LCD. All components except IC₄, an Allegro A3121 Hall-effect sensor reside on a pc board within the reach and view of the vehicle's operator.

The Hall-effect sensor attaches to the vehicle near its periphery and a fixed distance from the wheel's axle. When the wheel rotates, a permanent magnet attached to the wheel passes the sensor, activating it and generating one short pulse for each revolution of the wheel.

After you apply the pulse's rising edge to the IC₁'s INT0 input, the rising edge generates a high-priority interrupt. The AVR calculates the elapsed time between two interrupts, computes the speed and distance traveled, and displays the results on the LCD. One of IC₁'s internal timers, Timer₀, increments after every N clock

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Figure 1



Three ICs and an LCD form a versatile digital speedometer.

pulses. Distance traveled equals $2\pi R$, where R is the wheel's radius. To calculate speed, IC_1 divides the distance the elapsed time travels. In this application, the display shows speed in kilometers per hour.

In addition, IC_1 keeps the track of distance traveled by incrementing a register every time a sensor interrupt occurs. It compares this register value with a number that's equivalent to a 100m distance traveled, and, when the register value exceeds the 100m constant, IC_1 increments the distance register. The display shows the distance traveled in kilometers, and a location in IC_1 's EEPROM retains

the distance even when a users switches off power to the speedometer. Maximum values of the design include speeds of 0 to 255 km/hour and distances as far as 9999.9 km.

The design requires a 5V-dc power supply to work properly. To accommodate higher power-supply voltages, a bridge rectifier and a 7805 voltage regulator, IC_2 , accept power supplies ranging from 6 to 24V dc or ac for indoor applications. At 12V-dc input, the speedometer draws approximately 43 mA, or approximately 500 mW, under normal conditions. Switching on the LCD's backlight for night operation increases cur-

rent drain by approximately 11 mA for a power consumption of approximately 730 mW.

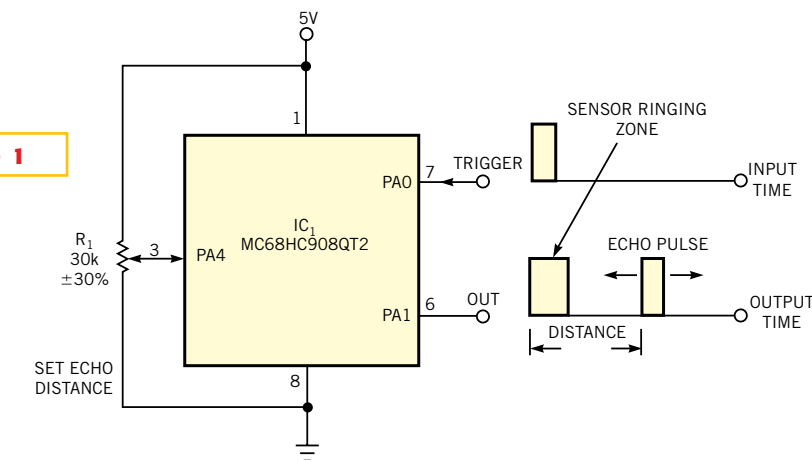
You can download the source code for IC_1 's program from the online version of this Design Idea at www.edn.com and assemble the software with Atmel's AVR Studio 4 software. You can alter constants within the software to accommodate wheels of various radii for other applications. Future enhancements to the software would allow measurement and display of a rotating object's speed in revolutions per minute or show elapsed distances when you use the device as a trip meter. □

Microprocessor, linear potentiometer deliver echo pulses

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FOR DESIGNERS of radar or sonar echo-ranging systems, an echo imitator can ease development and adjustment chores by generating a controllable pulse that's similar to an incoming echo signal. A decade ago, you'd probably use several 555 timers and their associated RC circuits to design an echo imitator. As **Figure 1** shows, today's version uses only two components: linear potentiometer R_1 and a small, low-end microcontroller, IC_1 . An external trigger pulse applied to IC_1 's pA0 input pin triggers the first of two pulses delivered to output pin pA1. For ultrasonic-receiver testing, the optional first pulse imitates 2 msec of post-trigger sensor ringing that limits the minimum reception distance. You can also use this pulse to synchronize an oscilloscope.

Linear potentiometer R_1 , a Panasonic model EVA-JGTJ20B14, sets the echo pulse's delay time. Microcontroller IC_1 , a Freescale MC68HC908QT2 8-bit flash-memory device, includes four 8-bit successive-approximation ADCs, one of which digitizes the voltage at R_1 's sliding



The firmware's features determine the characteristics of this radar and sonar echo simulator.

contact. For this application, the firmware divides the digitized potentiometer readings by four to match the system's reception range. Every 0.5 msec, the firmware also generates internal timer-overflow interrupts that determine the resolution of the simulated target's return echo. The interrupt-service routine increments the distance counter, and, when the counter's value equals the distance

setting that R_1 supplies, output pin pA1 produces a 0.5-msec-wide echo pulse. Thus, the echo's delay time tracks the potentiometer's sliding-contact position. Although this Design Idea features a Freescale microcontroller, you can use others that include an ADC. To download the firmware's assembler code, view the online version of this Design Idea at www.edn.com. □

Passive-detector receiver keeps you informed, entertained during flights

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FAA (Federal Aviation Administration) regulations generally forbid the use of receivers onboard commercial aircraft because a superheterodyne receiver's local oscillator can radiate signals that could interfere with aircraft communication and navigation systems. The crystal radio in **Figure 1** directly detects nearby AM signals in the very-high-frequency aircraft band, 118 to 137 MHz, and thus cannot interfere with aircraft equipment. Communications between the pilot and the flight controllers are brief and infrequent, and listening to the aircraft band as a passenger can get boring. However, the circuit in this Design Idea improves on an earlier passive aircraft-band receiver by allowing you to en-

joy an aircraft's in-flight-entertainment system while monitoring pilot-to-ground communications (**Reference 1**).

In **Figure 1**, the shields of the headphone's wires double as an antenna. A series network comprising L_2 and C_3 couples RF energy into a resonant LC tank circuit comprising L_1 and trimmer capacitor C_1 . You adjust C_1 to peak the tank circuit's resonant frequency within the 118- to 137-MHz aircraft band. The crystal detector comprises Schottky diode D_1 that is forward-biased through R_1 and R_2 . Depending on the diode's characteristics, you may have to adjust R_1 to optimize the diode's bias current.

Both sections of IC_1 , a Maxim MAX474 single-supply, 2.7 to 5.25V, rail-

to-rail, dual op amp, boost the level of demodulated audio that D_1 and C_4 recover. Lowpass filters R_5 and C_{12} and R_7 and C_{13} limit audio bandwidth to voice-range frequencies to improve intelligibility and reduce power consumption. Capacitors C_{10} and C_{11} split the amplified audio signal into two channels to drive stereo-headphone amplifier IC_2 , a Texas Instruments TPA4411. Capacitors C_8 and C_9 drive IC_2 's inputs with stereophonic audio signals from the aircraft's entertainment system or a portable CD/DVD player. The TPA4411 headphone amplifier provides a fixed gain of -1.5 , which allows you to maintain a comfortable listening level by adjusting the aircraft-entertainment device's volume control. Potentiometer R_6

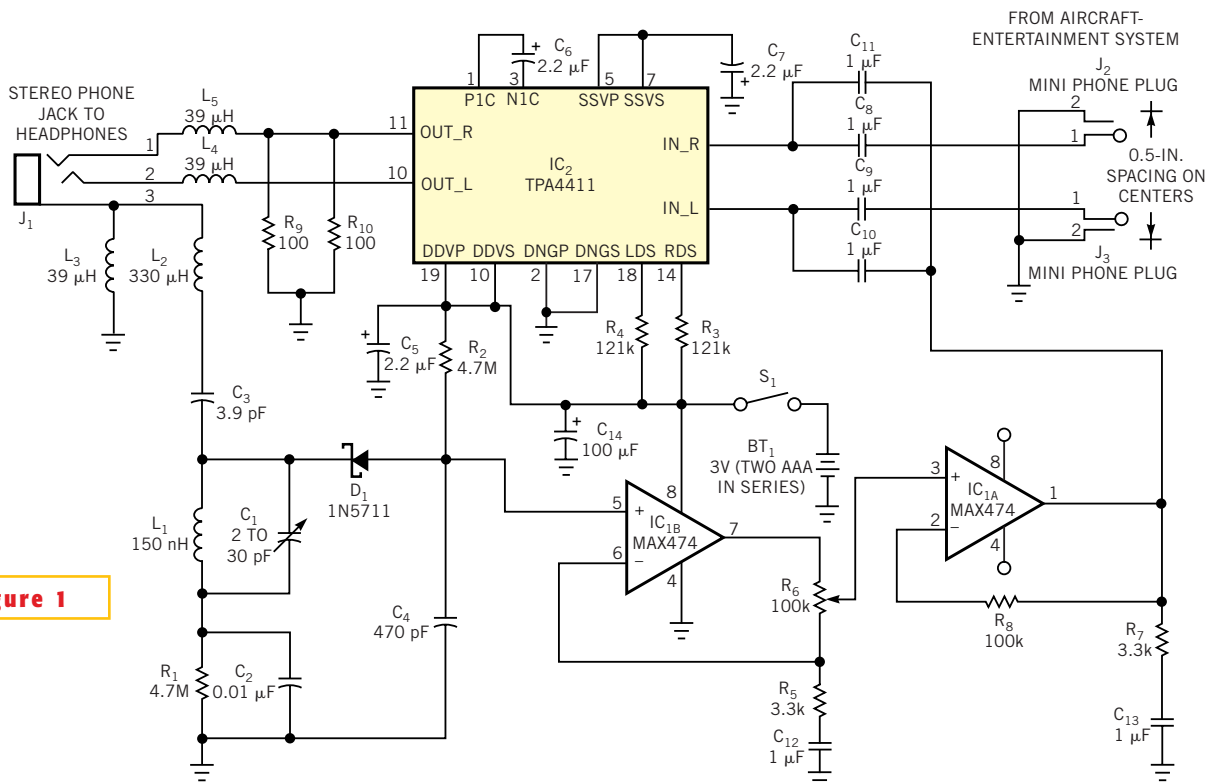


Figure 1

NOTE: MOUNT PHONE PLUGS J_2 AND J_3 ON 0.5-IN. CENTERS TO MATCH AIRCRAFT-ENTERTAINMENT SYSTEM'S AUDIO-JACK SPACING. SELECT R_1 TO BIAS DIODE.

This modern version of the crystal radio allows you to monitor aircraft communications while listening to in-flight-entertainment programs.

controls the aircraft-band audio level, and the user should adjust it during quiet radio periods to minimize noise introduced into the entertainment audio program.

The TPA4411 integrates pop-noise-reduction circuitry, can drive as much as 80 mW into a typical headphone's 8 to 16Ω load, and operates over a power-supply range of 1.8 to 4.5V. Inductors L_3 , L_4 , and L_5 allow audio to pass unimpeded to the headphones and prevents the amplifier's outputs from shunting RF signals meant to be coupled to the receiver's resonant LC tank circuit.

To use the receiver, slowly adjust C_1 until you hear a pilot's communication in progress. Then, quickly tune C_1 to maximize the signal. The tuned circuit's selectivity is low enough such that, once you adjust C_1 , it doesn't require retuning. Although you can use this receiver while awaiting your flight's boarding call, always ask permission from the flight crew before using the receiver aboard an aircraft. You can explain that the circuit does not interfere with the aircraft's navigation and communication systems. Air-

port-security personnel may regard any user-constructed electronic device with suspicion, however.

This receiver's sensitivity is low, and you generally hear only the pilot-to-ground side of two-way traffic. Fortunately, in controlled airspace, a pilot must repeat all commands so that air-traffic controllers can verify that the pilot clearly understood their instructions. Although a comprehensive survey of aircraft-band communications procedures is beyond the scope of this Design Idea, the following example explains certain terms.

While the aircraft remains at the departure gate, you typically hear a pilot repeating flight clearance, altitude restrictions, and other instructions—for example, "KLM 657 heavy, cleared for Amsterdam ... FL320 five minutes after departure. Departure frequency is 127.4, squawk 4312." "Heavy" means that the aircraft is a large jet, "FL320" means that the aircraft is cleared to fly at 32,000 feet, and "squawk" is the aircraft's four-digit identification number. To contact departure control, the pilot retunes the aircraft

radio to 127.4 MHz. When the pilot enters the squawk into the aircraft's transponder, the flight controllers can identify the aircraft on-radar screens as KLM flight 657. Each time the aircraft enters a new segment of the taxiway on its way to the runway and again for take-off clearance, the pilot contacts ground control to get taxi clearances.

Shortly after takeoff, the pilot contacts departure control: "KLM 657, radar contact, climb and maintain FL320, turn right heading 120, proceed on course." From then on, the pilot contacts flight controllers upon reaching predefined altitudes or when entering a different flight-control center's airspace. Approximately 30 minutes before reaching its destination, the aircraft begins its descent, and the pilot contacts approach control. Just before landing, you hear the final clearance: "KLM 657 heavy, winds 030 at 12, cleared to land runway 31." □

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Quickly estimate an electronic system's cooling requirements

James Gabel, Thermo Electron Corp, San Jose, CA

DURING NORMAL OPERATION, an electronic system generates wasted heat that can cause malfunctions and damage components unless you remove it. In an ideal world, you would have the time and resources to perform a rigorous evaluation of an electronic system's cooling requirements early in the design phase and thus avoid the cooling errors others have made in the past (Reference 1). However, circumstances often demand a diagnostic evaluation of a system's cooling methods or a rapid estimate of a proposed system's cooling requirements. For these purposes, you don't need an advanced degree in computational fluid dynamics; this Design Idea outlines a method that may be all that's necessary.

Figure 1 shows a typical cabinet-mounted electronic system that includes

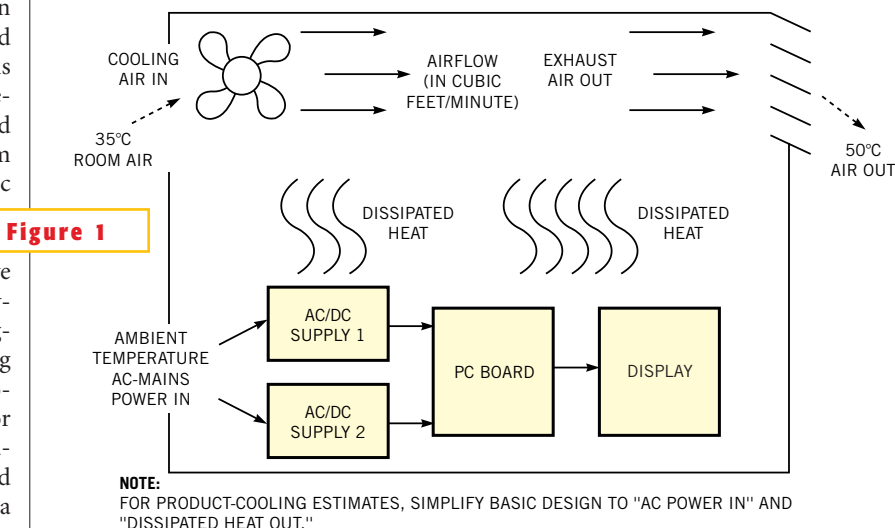


Figure 1

NOTE: FOR PRODUCT-COOLING ESTIMATES, SIMPLIFY BASIC DESIGN TO "AC POWER IN" AND "DISSIPATED HEAT OUT."

To estimate a system's cooling requirements, you can simplify the thermal model to comprise an ac-power input and a dissipated-heat output.

two power supplies, a pc board, and a display. For simple products, you can assume that all of the power entering the cabinet from the ac power line ultimately converts into heat that dissipates within the cabinet. After you calculate the system's ac and dc power requirements, you can estimate the amount of power that the cooling method must dissipate. As a rule of thumb, the thermal capacity of air is $0.569W\text{-minute}/^{\circ}\text{C}/\text{ft}^3$ (Reference 2). That is, one cubic foot per minute of moving air can transfer 0.569W of dissipated heat for a 1°C temperature change. You can also express this rule as its reciprocal: To dissipate the heat 1W of power produces and maintain a 1°C temperature change, you need to provide an air

stream of 1.757 cfm (cubic feet/minute). Thus, once you determine the wattage dissipated within a system and specify an allowable internal temperature rise, you can estimate a cooling fan's required air-movement capacity rating in cubic feet/minute.

However, a cooling fan's maximum rating in cubic feet/minute occurs only at zero static pressure, or back pressure, an operating condition that you don't realize in practice. You derate the fan's air-movement ability based on either measurements or estimates of the back pressure in the system's cabinet. (A manometer-style gauge measures air-pressure differentials in units of inches of water—that is, the height in inches of a

column of water supported by the difference between ambient air and pressurized air within an enclosure.) For example, a manometer might display a pressure differential of 0.10 to 0.15 in. of water across a mostly clogged dust filter. When you plot the pressure versus airflow-volume curve for a typical 100-cfm fan, this pressure differential might reduce the fan's airflow volume to only 50 cfm.

In a sample calculation, a system uses 70% of a single ac/dc 400W power supply's output that

operates at 75% efficiency—that is, the supply contributes 25% of its output as heat. The system's fan or fans must remove all of the resultant waste heat, as follows: $P_{\text{DISS}} = 125\% \times 400W = 500W$; $70\% \times 500W = 350W$. Design the system for operation in ambient air that's no hotter than 35°C (95°F). The system's heated exhaust air must not exceed a worst-case temperature of 50°C (122°F), producing a temperature difference, T_D , of 15°C . Next, calculate n, the effective airflow required, in units of cubic feet/minute: $n(\text{cfm}) = k \times P_{\text{DISS}}/T_D$, where $k = 1.757 \text{ cfm} \times ^{\circ}\text{C}/W$. Solving for n yields: $n = 1.757 \text{ cfm} \times ^{\circ}\text{C}/W \times 350W/15^{\circ}\text{C} = 40.99 \text{ cfm}$.

Select a fan and examine its pressure versus-airflow-volume curve (Figure 2). At an airflow of 41 cfm, the fan's static pressure curve shows 0.1 in. of water within the fan's normal operating range. (For additional information on fans and their characteristics, see Reference 3.) □

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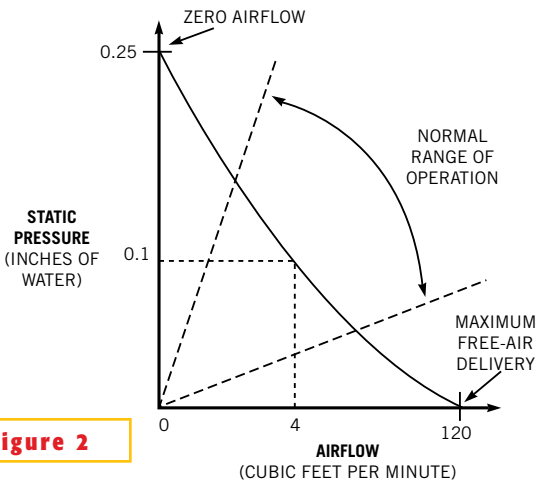


Figure 2

You can use a fan's airflow-versus-pressure difference curve to determine whether the fan will provide adequate cooling in your application.

Spreadsheet converts sound levels

Dan O'Brien, Mallory Sonalert Products Inc, Indianapolis, IN

AS EVERYONE who attempts to get someone's attention from a distance intuitively knows, sound level decreases as the distance between the source and the detector increases. For distances less than 50 ft, the rule of thumb states that sound level drops 6 dB for every doubling of the distance between the sound source and the detector.

If your work involves generation of audible signals, the rule of thumb may appear simple, but putting it into prac-

tice takes valuable time to ensure that you correctly calculate the conversion. To complicate matters, there's no standard single distance for measuring sound level, and thus conversion of sound levels for different separations or between metric- and nonmetric-measurement units requires rethinking and recalculation.

For example, if an audible signal source measures 90 dBA at a distance of two feet, what's the equivalent sound

level at a distance of 10 cm? If you can perform this conversion without putting pencil to paper, you're several steps ahead of your competition. To ease sound-level conversions, you can use an Excel spreadsheet (available for downloading at the online version of this Design Idea at www.edn.com). You enter a sound level in decibels acoustic, and the calculation returns sound levels for various commonly used measurement distances. □