When the counter reaches this time, the count, $n_p$, determines the rotational speed, according to the **equation**. Finally, this value appears on the screen of the LCD.

In addition, a digital-to-analog conversion is necessary if the control system must measure the rotational speed. You can do this conversion without adding an expensive DAC by applying a PWM (pulse-width-modulation) output of the microcontroller to a lowpass filter comprising $R_2$, $R_3$, $C_4$, $C_6$, and $IC_3$. The frequency of the PWM signal is 20 kHz, and the cutoff frequency of the lowpass filter is 160 Hz, which is much lower than the PWM frequency. In this design, the maximum duty cycle of the PWM signal corresponds to a rotational speed of 1500 rpm.

You can download the source code for $IC_1$'s program from the online version of this Design Idea at www.edn.com/071108di1 and assemble the software with MPLab from www.microchip.com. You can alter constants within the software according to the encoder you use and your required resolution from the **equation**. EDN

## REFERENCE


1. Jain, Abhishek, "Versatile digital speedometer uses few components," *EDN*, May 12, 2005, pg 95, www.edn.com/article/CA529384.


# Battery monitor also enables constant-power-boost converter

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Some microcontrollers permit operation below a supply voltage of 3V. This feature allows powering directly from a 3V alkaline or lithium battery without the voltage drop and leakage current of a regulator. It is important to monitor the battery voltage to ensure system integrity, and you can also use this information for system purposes. The circuit in this Design Idea maintains constant power to a white-LED-display backlight by adjusting the duty cycle of a boost-power converter. However, an ADC normally needs a fixed voltage reference (**Figure 1**), which would require two input pins for this function. This Design Idea turns the ADC's architecture inside out, providing the voltage-reference function using no extra pins.

The monitor circuit in **Figure 2** integrates an ADC within the microcontroller. The converter uses the battery voltage as a reference voltage. The principle is the opposite of normal: You want to measure a fixed voltage using a variable-voltage reference (the battery). For an 8-bit converter, the result for this example is $(1.18V/V_{BAT})\times256$. Note that a high value indicates that the battery voltage is low. Also, you can use the microcomputer pin that connects to the reference for another purpose. This example normally uses Pin 6 as an output to the pulse-indicator LED, $LED_1$. However, by briefly changing the port direction to analog-input mode, you can complete the battery-measurement operation, including settling, sampling, and conversion, in less than 0.1 msec.

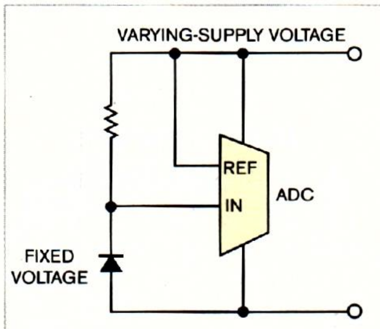


Figure 1 An ADC normally needs a fixed voltage reference, which would require two input pins for this function.

The example uses a PIC12F683 microcontroller and a voltage reference of 1.25V for the LM4041. $R_1$ biases the reference. $R_2$ ensures that the microcontroller output can rise to 3V to turn on transistor $Q_1$ without damag-

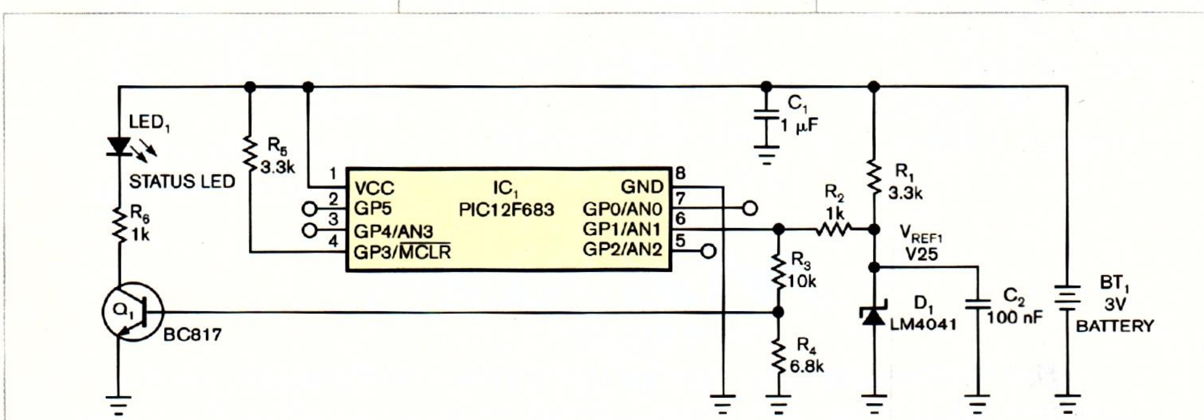


Figure 2 This monitor circuit integrates an ADC within the microcontroller. In this circuit, the converter uses the battery voltage as a reference voltage.

ing $D_1$. Resistors $R_3$ and $R_4$ ensure that the transistor is extinguished during the battery measurement. $R_2$, $R_3$, and $R_4$ introduce some attenuation, which you must take into account.

**Figure 3** shows the monitor with the addition of a constant-power voltage-booster circuit. The PWM (pulse-width-modulation) output of the microcontroller drives the converter. For constant power from the booster, the required duty cycle linearly relates to the ADC's converted value.

Battery technologies vary in their discharge characteristics. Alkaline batteries have high capacity but drop their open-circuit voltage as they operate. The open-circuit voltage can provide a good estimate of battery charge. However, alkaline batteries also have internal resistance and exhibit a recovery phase after supplying a heavy load. The resistance increases with low temperature and low battery charge. To determine the battery's state, you can take measurements before and immediately after a high-current load is active. This approach allows estimation of both internal resistance and battery charge. EDN

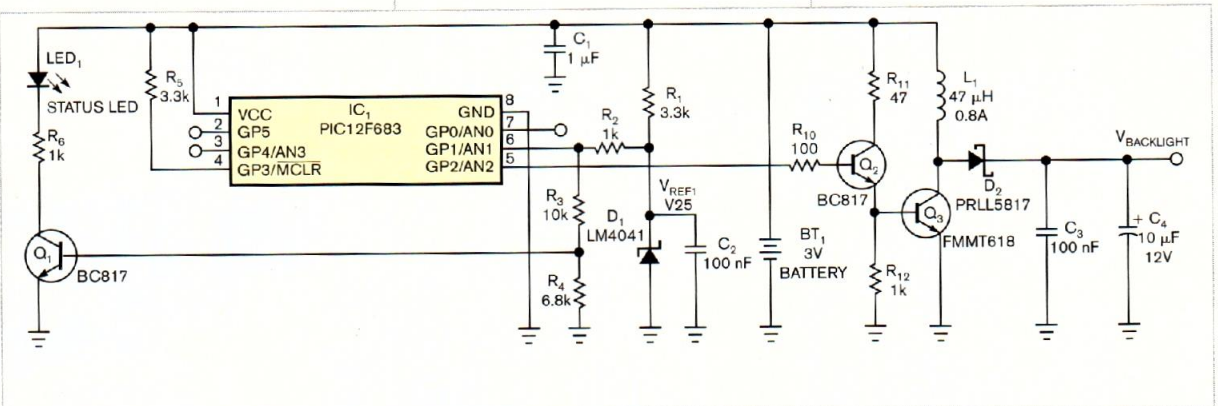


Figure 3 This monitor adds a constant-power voltage-booster circuit. The PWM output of the microcontroller drives the converter.