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“Chipiplexing” efficiently drives multiple LEDs using few microcontroller ports

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Actual microcontrollers have powerful bidirectional I/O ports, and you can use different techniques to fully exploit such capabilities. Recent Design Ideas described the “Charlieplexing” method as an effective way to drive $M=N\times(N-1)$ LEDs using only N bidirectional I/O ports and N resistors (**references 1** and **2**). Unfortunately, using Charlieplexing allows you to drive only one LED at a time, so, when using a large number of LEDs, only a tiny slice of time is available to multiplex each LED: $T_{DRIVE}=T/M$, where T is the PWM excitation period. As a consequence, to obtain a given average current and bright LEDs, you must excite them with a current M times higher, and you can’t usually obtain such peak currents from the microcontroller port.

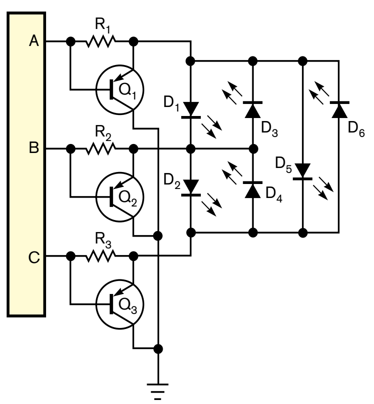

Figure 1 With Chipiplexing, you need to add only N cheap, bipolar transistors to simultaneously drive two LEDs.

This Design Idea describes “Chipiplexing,” a method in which you need to add only N cheap, bipolar transistors. This circuit uses PNP types, but you can also use NPN devices. (The term *Chipiplexing* comes from my nickname, Chipi.) The benefits pay the additional cost because you can simultaneously drive $N-1$ LEDs, thereby reducing peak currents $N-1$ times.

Figure 1 shows the approach for $N=3$ and $M=6$, but you can use the same criteria for different values of N; in this case, you can simultaneously drive two LEDs. The current-limiting resistors connect in parallel with the base and emitter of the added PNP transistors, and all the collectors connect to ground. If you set one of the microcontroller ports to zero, or ground, the respective PNP transistor has a grounded base, and its emitter is at a fixed voltage—typically, 0.7V. You can excite every LED whose cathode connects to this emitter through the remaining ports. If you set the port to one, the battery voltage, the LED turns on; if you set the port to high impedance, the LED turns off.

Table 1 shows how there are now nine possible combinations of the

TABLE 1 NINE POSSIBLE USEFUL PORT COMBINATIONS TO DRIVE LEDS

A	B	C	D_1	D_2	D_3	D_4	D_5	D_6
V_{BAT}	Ground	High impedance	Yes	No	No	No	No	No
High impedance	V_{BAT}	Ground	No	Yes	No	No	No	No
Ground	V_{BAT}	High impedance	No	No	Yes	No	No	No
High impedance	Ground	V_{BAT}	No	No	No	Yes	No	No
V_{BAT}	High impedance	Ground	No	No	No	No	Yes	No
Ground	High impedance	V_{BAT}	No	No	No	No	No	Yes
Ground	V_{BAT}	V_{BAT}	No	No	Yes	No	No	Yes
V_{BAT}	V_{BAT}	Ground	No	Yes	No	No	Yes	No
V_{BAT}	Ground	V_{BAT}	Yes	No	No	Yes	No	No

three microcontroller ports: the six available when using Charlieplexing to drive one LED at a time and three new combinations to drive two LEDs at a time. The microcontroller port grounds the transistor's base. This action fixes a junction-drop voltage at the emitter and collects and sinks all the LED currents to ground without overconstraining the microcontroller port, which has to sink only the transistor's base current plus 0.7V per resistor. Each of the other ports set to the battery voltage needs to source only one LED current.

With Charlieplexing, two resistors are in the LED-current path; in this case, however, you can easily compute the limiting resistors as $R=(V_{BAT}-V_{LED}-0.7)/I_{LED}$, where V_{BAT} is the battery voltage, V_{LED} is the LED voltage, and I_{LED} is the desired LED current. The benefits are more noticeable as the number of LEDs increases. For N=5, with 20 LEDs, this approach gives 20% of the total time to drive each LED, instead of only 5% of the time using Charlieplexing.**EDN**

REFERENCES

[1] Gadre, Dhananjay V, "Microcontroller drives 20 LEDs," *EDN*, Sept 27, 2007, www.edn.com/article/CA6483826.

[2] Gadre, Dhananjay V, and Anurag Chugh, "Microcontroller drives logarithmic/linear dot/bar 20-LED display," *EDN*, Jan 18, 2007, pg 83, www.edn.com/article/CA6406730.

Achieve precision temperature control with TEC Seebeck-voltage sampling

W Stephen Woodward, Chapel Hill, NC

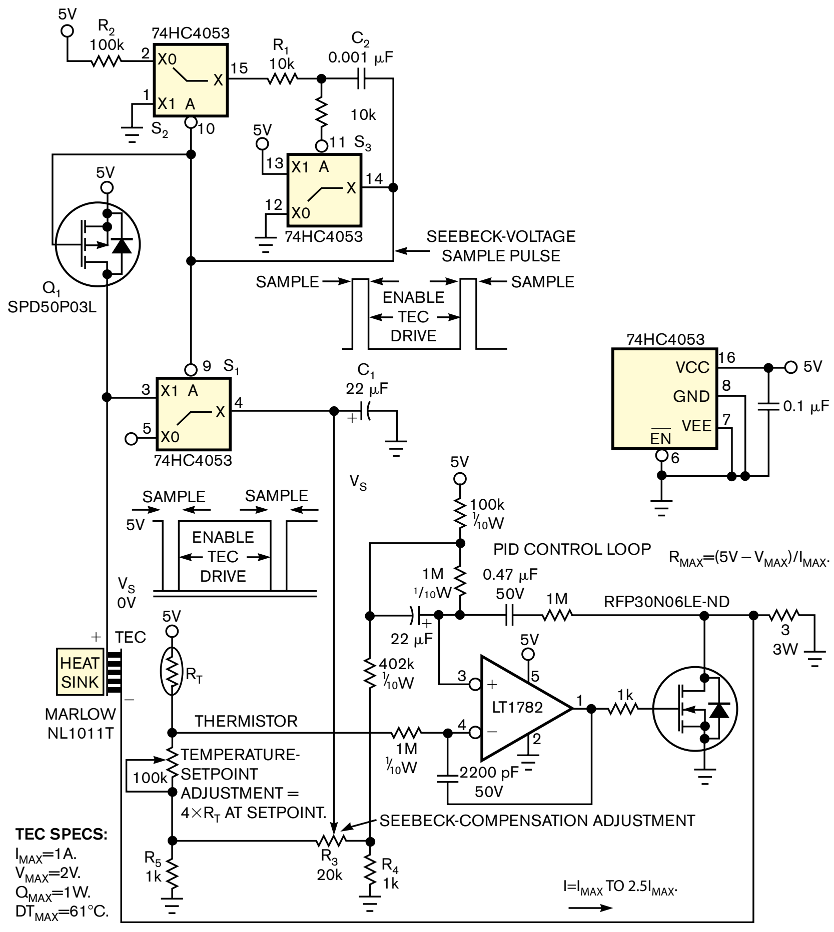

Figure 1 This circuit periodically sets the thermoelectric cooler's drive current to zero, sampling the Seebeck voltage and holding it in a storage capacitor to achieve stable temperature control with real-world heat sinks and thermocouples.

TEC (thermoelectric-cooler) temperature-control systems often have limited stability. The causes of these limitations are the thermal properties of the system, not the performance of the control electronics. Real-world thermal-control systems incur nonzero thermal impedances in the heat-transfer paths between the TEC; the thermal load, which is the object of thermostasis; the temperature sensor—for example, a thermistor; and the ambient temperature.

If the ratios of these impedances don't balance, then even perfect thermostasis of the sensor's temperature doesn't equate to adequate stability of the load's temperature. The circuit in **Figure 1** provides a thermoelectronic design that directly measures the heat flux through the TEC and then uses the measurement to better estimate and cancel the effects of thermal impedances. Its operation is based on the fact that the total voltage that every TEC develops is the sum of two components: an ohmic component proportional to drive current and the Seebeck voltage, V_S, which is proportional to the temperature difference across the TEC and, therefore, to heat flux.

In this circuit, however, the drive current switches to zero approximately every 100 µsec because of the asymmetrical sample-pulse waveform that multivibrator S_2/S_3 generates. Each sample pulse turns off 5V transistor Q_1, which isolates the Seebeck voltage and allows its sampling through S_1 and storage capacitor C_1 to hold it. The duty factor of the sampling pulse, which the

R_1-to-R_2 ratio sets, is less than 10% to avoid significantly reducing the TEC-drive capability of the circuit.

You apply the acquired Seebeck signal to the $R_3/R_4/R_5$ adjustable-bridge circuit, which empirically determines the feedback ratio for both polarity and amplitude to provide best stability. With proper bridge adjustment, you can make gradient cancellation nearly perfect over a wide range of ambient temperatures. The TEC-control circuit in **Figure 1** derives from a previous Design Idea because it eases the incorporation of Seebeck sampling (**Reference 1**). You can, however, adapt Seebeck sampling to virtually any TEC-drive topology. You can further enhance the circuit in **Figure 1** by using nonvolatile, in-circuit-programmable resistors for the $R_3/R_4/R_5$ bridge, automatically optimizing gradient cancellation. One attractive choice is the Rejustor family of monolithic resistors from Microbridge Technologies (www.mbridgetech.com). **EDN**

REFERENCE

1 Woodward, W Stephen, "Thermo-electric-cooler unipolar drive achieves stable temperatures," *EDN*, Dec 3, 2007, pg 98, www.edn.com/article/CA6505571.

Instrumentation-amplifier-based current shunt exhibits 0V drop

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Passive current shunts for measuring the value of current flowing through a relatively small-value resistor often have a full-scale voltage drop of 60 mV for higher-power equipment and 200 mV for electronic instruments. Similarly, simple current-to-voltage converters, in which the measured current flows through a sensing resistor, often have even higher voltage drops. In some cases, however, the voltage drop between the input terminal and the ground must be as low as possible; 0V—independent of the value of measured current—is ideal. If your application requires this feature, you can use the current-to-voltage converter in **Figure 1**. In this circuit, resistor R_1 serves as a classic current-sensing resistor, on which the instrumentation amplifier senses the measured current, resulting in the voltage drop. The instrumentation amplifier, along with R_1, not only serves as an inverting current-to-voltage converter, but also creates a voltage through a resistive network at Point B. This voltage is equal in magnitude to a voltage drop on R_1 and has the opposite polarity to ΔV_{R1}. The net result is that the value of voltage at Input A is theoretically 0V, regardless of the magnitude and polarity of the current flowing into the input.

The design uses the Analog Devices (www.analog.com) AD8223 instrumentation amplifier because it has a default voltage gain of five; this value remains close to the ideal one with high precision. The typical gain error at the default value of gain is 0.03%, and the worst-case error is 0.1% for the B-grade IC (**Reference 1**). For gain of five and R_1 and R_2 having the same value, you can derive that the value of R_3 is two times that of R_2 for a 0V drop at Input A (**Figure 2**). Resistors R_1, R_2, and R_3 in **Figure 1** should be high-precision, low-temperature-coefficient types. In the experimental circuit with a value of 20Ω for R_1 and R_2, there is an input-referred-current zero shift of 0.8 μA, and the voltage drop at Input A varies by 0.27 mV at a 1-mA input current. Similar slope of negative-voltage variations occurs at Input A for negative-input current. The transfer constant, or transresistance, of the circuit is: $(\Delta V_{OUT})/(\Delta I_{IN})=-5R$.

Thus, for instance, an input current of 1 mA causes the voltage of −100 mV to appear at the output. Because the output-current capability of the AD8223 is approximately 2.5 times higher for sinking output current than for sourcing current, the input scale can be higher for positive currents by a factor of 2.5. You can further increase the scales for both positive and negative currents by increasing the supply voltages from ±5V to ±12V; you can also use 12V and −5V. If your design requires an even higher input current, place a precision voltage buffer, having appropriately high

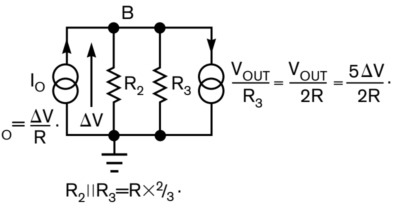

Figure 2 The value of R_3 is two times that of R_2 for a 0V drop at Input A in Figure 1.

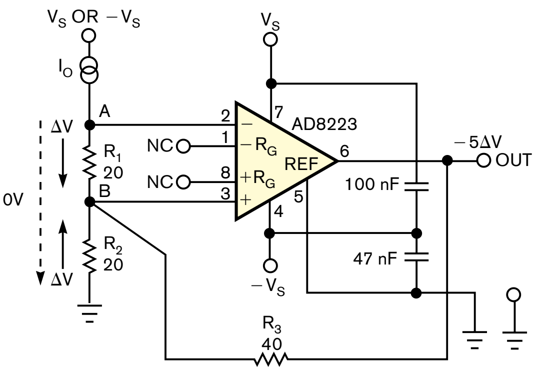

Figure 1 This instrumentation amplifier serves two purposes: It forms a current-to-voltage converter having a transresistance of −5R, and it exerts a voltage drop of opposite polarity at point B, resulting in a zero potential at Input A, regardless of input-current I/0.

output-current capability, between the output of the instrumentation amplifier and resistor R_3. **EDN**

REFERENCE

[1] "Single-Supply, Low-Cost Instrumentation Amplifier, AD8223," Analog Devices Inc, 2008, www.analog.com/en/prod/0,2877,AD8223,00.html.

Spark detector uses proximity

Robert Most, Ferris State University, Big Rapids, MI

Hall-effect ICs find use as proximity sensors in applications such as proximity detection and angular-velocity measurement on rotating machinery. Hall-effect devices can detect mechanical motion without mechanical contact. This noninvasive detection is due to the magnetic nature of the Hall effect. A current flowing through a semiconductor in the Y direction produces a negligible potential difference in the X direction (**Figure 1**). In the presence of a magnetic field at a right angle to the current flow, the Z direction, a displacement voltage appears across the semiconductor in the X direction. This effect is the Hall voltage, V_H.

Hall-effect ICs detect, signal-condition, and add hysteresis to the electrical displacement. In essence, the devices measure the electric field, which the magnetic field causes, across the semiconductor in the X direction. Therefore, if you subject the semiconductor to an electric field of sufficient magnitude in the X direction, the Hall-effect device would detect the electric field, as well.

Internal-combustion-engine designs require precise control of spark timing. The microcontroller that controls engine parameters not only changes the spark relation relative to the piston position, but also, in more advanced engines, requires feedback for variable valve timing. In addition, diagnostic aids and engine-troubleshooting hardware can benefit from an easy way to measure spark timing using this novel approach. Even the most basic carburetor adjustments on a lawnmower require a method to measure an engine's revolutions per minute. Four-stroke small engines create a spark on every engine revolution. Therefore, the detection of this spark is a direct indication of engine revolutions per minute.

By simply placing the Hall-effect IC against the spark-plug wire using the correct orientation, you can detect a spark-plug pulse using its electric field. Simply attach the device with electrical tape to the spark-plug wire's insulation. Because the Hall-effect IC incorporates internal signal conditioning and hysteresis, no additional components are necessary to read a basic frequency from the device, unlike with the traditional current-transformer method.

The circuit in **Figure 2** converts the pulses from the Hall-effect IC into a dc voltage that the most basic voltmeter can read. The Hall-effect IC provides an open-collector output. You need only a pullup resistor. The sensor converts the series of generated pulses, which the LM2917 frequency-to-voltage converter from National Semiconductor (www.national.com) converts to a voltage. The selection of C_1 and R_1 scales the output voltage in relation to the range of frequencies that the charge-pump section of this device will encounter. In the case of a four-stroke, single-cylinder engine, a range to 5000 rpm is more than sufficient.

The circuit provides an output voltage as high as 5V and requires a battery-supply voltage of 9V. Operation is straightforward: By pressing the Hall-effect IC against the spark-plug wire, the voltage on the DVM (digital volt-

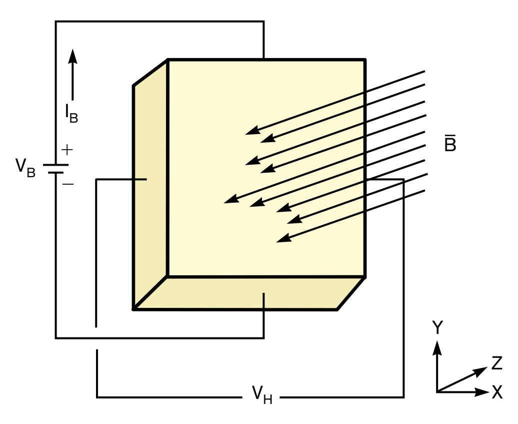

Figure 1 A current flowing through a semiconductor in the Y direction produces a negligible potential difference in the X direction.

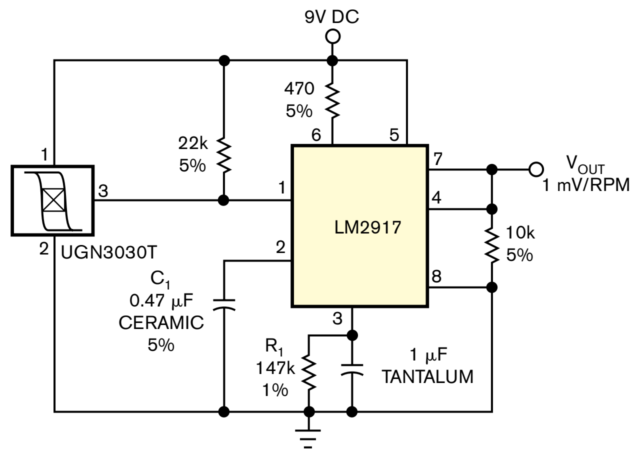

Figure 2 This circuit converts the pulses from the Hall-effect IC into a dc voltage that the most basic voltmeter can read.

meter) can readily interpret the revolutions per minute. Because the measurement is noninvasive, this method can easily perform repeated measurements or analysis of multicylinder engines. Measurement of automobile engines differs slightly. Automobile engines have mechanical distributors that spark on every other engine revolution. Ignition systems without distributors and with one ignition coil per cylinder also spark on every other engine revolution.

Because there is no electrical contact with the ignition system, this circuit intrinsically provides isolation from the high voltage. Interfacing to microprocessors and microcontrollers thus becomes a matter of compatible logic levels. The Hall-effect IC's power-supply voltage is 4.5 to 24V dc, which enables it to work with standard 5V processors as well as automotive voltages. You can interface multiple sensors to provide ignition diagnosis and timing analysis in automotive applications.EDN

Configure a low-cost, 9V battery-voltage monitor

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This Design Idea describes a 9V battery-voltage monitor whose total parts cost less than 34 cents (**Figure 1**). You configure transistor Q_1 as a 10-mA current sink. LED_1, a Kingbright (www.kingbrightusa.com) WP7104IT, is on when the battery voltage is good. When the battery voltage nears the threshold voltage, the LED gradually dims. It goes out once it reaches the threshold voltage. The threshold voltage for this design is 7.2V, which the values of D_3, LED_1, and R_1 determine. If your application requires a different threshold voltage, you can change these three components' values. You can reduce the PCB (printed-circuit-board) space this circuit requires by using equivalent surface-mount components.EDN

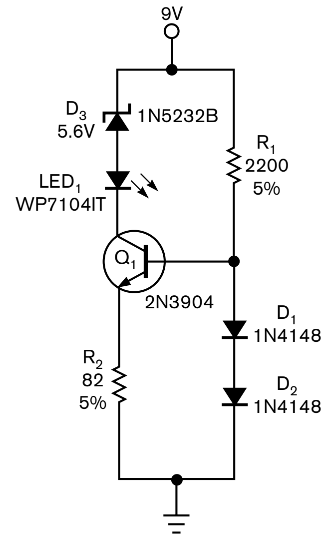

Figure 1 The parts for this 9V battery-voltage monitor cost less than 34 cents.