EDITED BY BRAD THOMPSON
AND FRAN GRANVILLE

designideas

READERS SOLVE DESIGN PROBLEMS

Current mirror improves PWM regulator's performance

Grant Smith, National Semiconductor, Phoenix, AZ

Power-supply designs requiring high-performance isolated feedback often use an error amplifier similar to the one in **Figure 1**, which relies on a second amplifier, IC_{1B}, to provide the necessary inversion to keep the optocoupler, IC_2, referenced to ground. To prevent bias-supply noise from entering the feedback path and causing oscillations, the amplifier relies on its ground reference and power-supply-rejection characteristics. The power supply's output drives a voltage divider comprising R_1 and R_2 that maintains the amplifier's inverting input at the same voltage as the reference voltage that IC_3 provides. C_2, R_3, and C_3 comprise frequency-compensation components for the power supply's stable operation. This component-intensive error-amplifier configuration requires two operational amplifiers, one precision shunt-voltage reference, four capacitors and often a fifth in parallel with R_6, and seven resistors.

Figure 2 shows an alternative single-amplifier design in which IC_3, an LM4040 precision-voltage reference, drives optocoupler IC_2 with a "stiff" positive-voltage source over a wide current range. The voltage reference suppresses any noise present on the bias-supply rail. Variations in the reference and power-supply voltages appear in common mode at the amplifier's inputs and thus provide additional noise immunity. A resistive-voltage divider comprising R_2 and R_3 reduces the reference voltage to equal the power supply's regulated output voltage, which drives IC_1's inverting input through R_1. Given its single voltage divider, the error-amplifier circuit of **Figure 2** provides the same output voltage as the circuit of **Figure 1** and requires a single operational amplifier and precision shunt reference, four capacitors, and six resistors.

Miller-effect coupling of collector-emitter-voltage transitions into a typical phototransistor-based optocoupler's high-impedance, optically sensitive

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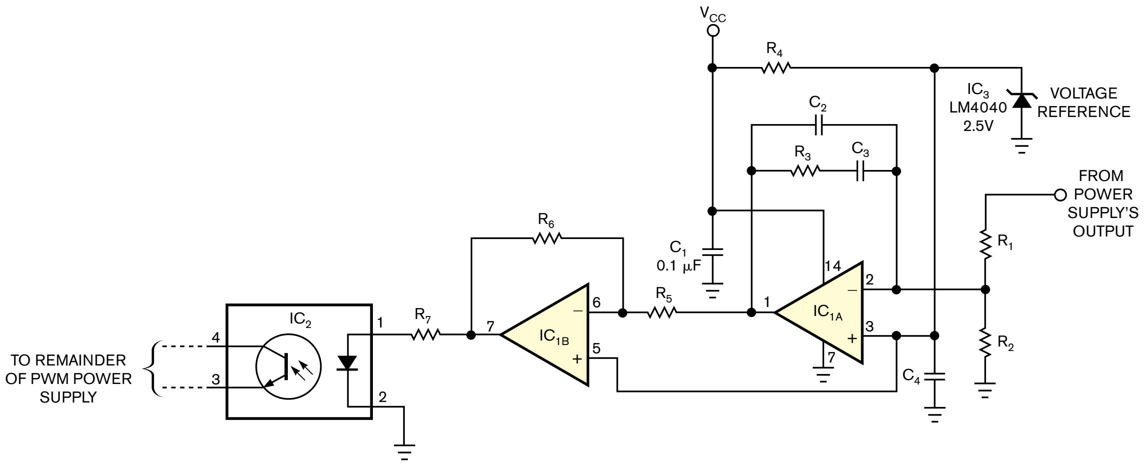

Figure 1 A conventional isolated-feedback circuit requires an extra operational amplifier and adds several passive components to a representative pulse-width-modulated power-supply design.

base region introduces a bandwidth-limiting pole, which dramatically slows the device's response time. Holding the phototransistor's collector-emitter voltage constant and allowing only its collector-emitter current to change provide an order-of-magnitude switching-speed improvement.

National Semiconductor's (www.national.com) LM5026 active-clamp current-mode PWM controller, IC_4, provides a convenient method of reducing an optocoupler's Miller-effect-induced slowdown. **Figure 2** shows the LM5026's internal current mirror driving what would normally serve as a frequency-compensation pin. Optocoupler IC_2 connects directly between two constant-voltage sources comprising the current mirror and a voltage reference. The resultant decrease in response time relocates the bandwidth-limiting pole and improves the circuit's transient response.

The values of C_2, C_3, R_3, and R_1 apply only to this design and may require modification for other applications. Select R_1 to provide equal impedances at both of the op amp's inputs. C_2 forms a high-frequency noise filter. After you measure the converter's overall gain, calculate values for C_3 and R_3 that will provide proper gain and phase response. Several methods of calculation are available, most of which will provide adequate results.EDN

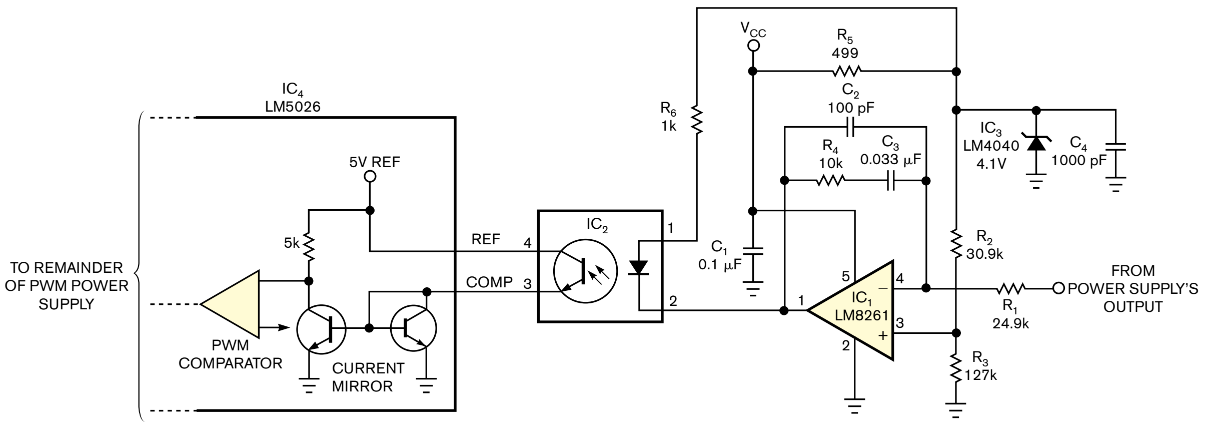

Figure 2 Clamping an optoisolator's voltage excursion improves the PWM-regulator loop's transient response.

Low-cost current monitor tracks high dc currents

Susanne Nell, Breitenfurt, Austria

To measure high levels of direct current for overload detection and protection, designers frequently use either a current-shunt resistor or a toroidal core and Hall-effect magnetic-field sensor. Both methods suffer from drawbacks. For example, measuring 20A with a 10-mΩ resistor dissipates 4W of power as waste heat. The Hall-effect sensor delivers accurate measurements and wastes little power, but it's

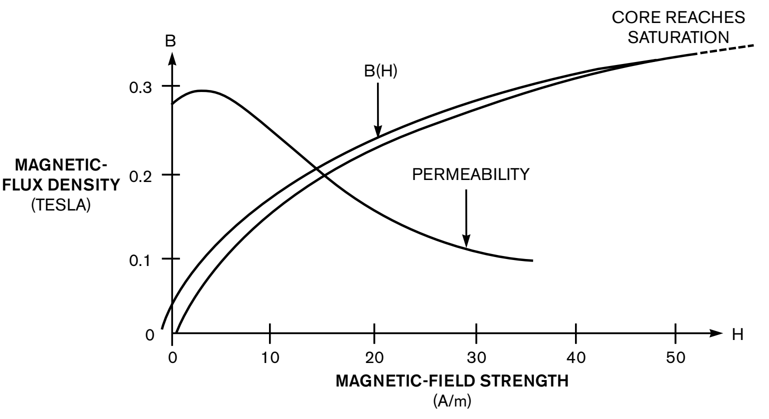

Figure 1 This representative magnetization (BH) curve shows that, as current through an inductor's winding increases, so does magnetizing-field strength, H. When magnetic-flux density, B, can no longer increase, the core's magnetic material has reached saturation.

an expensive approach to simple current monitoring.

This Design Idea describes an inexpensive, low-power current-measurement circuit that's useful for measurements of modest accuracy. As a bonus, a filter inductor in a dc/dc converter's input line can double as a current sensor for the measurement circuit. A representative ferrite core's permeability decreases as the core nears saturation (**Figure 1**). The curve's shape and values depend on the core material's characteristics and whether the core includes an air gap.

The core's permeability depends on the magnetic-flux level in the ferrite material, which in turn depends on the amount of current flowing through the core's windings. This circuit uses a simple LC oscillator to measure the core's permeability. A primary winding comprising one or more turns wound on the core carries the measurement current. A multiturn secondary winding on the core forms an inductor, L, that determines the oscillator's resonant frequency.

A FILTER INDUCTOR IN A DC/DC CONVERTER'S INPUT LINE CAN DOUBLE AS A CURRENT SENSOR FOR THE MEASUREMENT CIRCUIT.

In theory, any LC oscillator circuit will serve in this application, but, in practice, the current-measurement winding presents a low impedance that damps the LC-tank circuit and causes start-up and stability problems in some oscillator circuits. Of a variety of tested oscillator circuits, the design in **Figure 2** offers the best performance. A number of factors affect the core's permeability, which in turn impacts the circuit's frequency stability and limits its applications to current-overload detection and low-accuracy current measurements.

Figure 3 illustrates the circuit's output-frequency-versus-current characteristics for three vendors' ferrite cores of identical dimensions and number of secondary turns. For best linearity, use a low-hysteresis core material. Cores of virtually any dimensions and materials work in the circuit but require optimization of the number of turns on the oscillator tank and primary windings. Increase the core's air gap, if present, when the current you apply to the core causes saturation before reaching the overload value. For improved performance and linear measurements, use the circuit in a closed-loop configuration (**Reference 1**).**EDN**

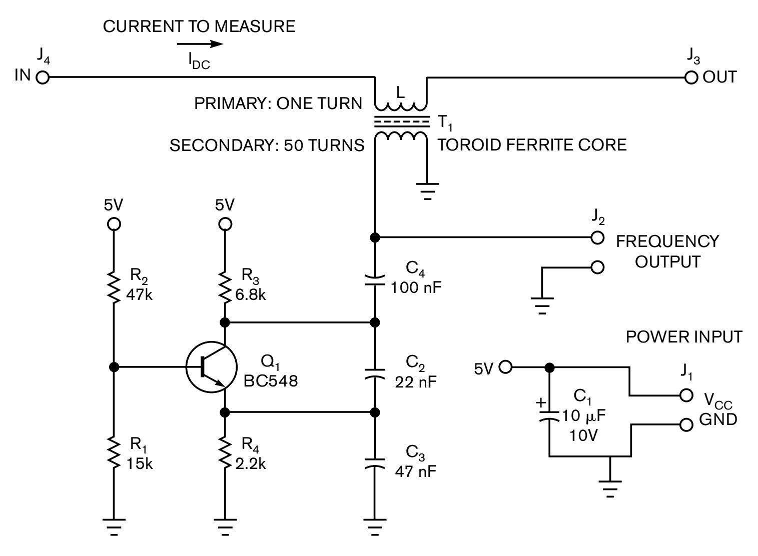

Figure 2 Varying the direct current flowing through the single-turn primary winding alters T_1's secondary winding's inductance, which in turn varies the oscillator's output frequency.

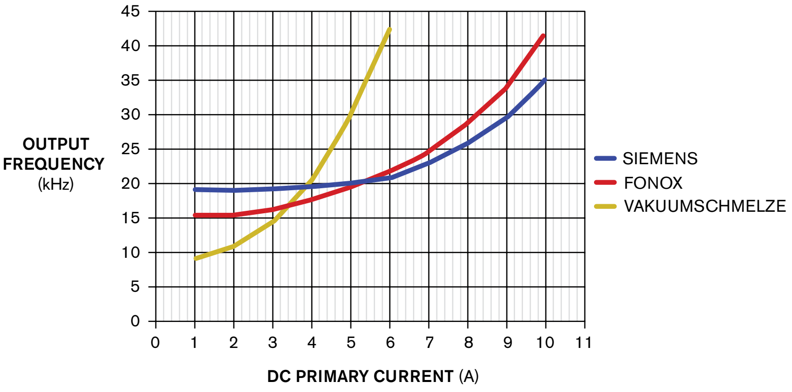

Figure 3 Current-versus-output-frequency plots for three manufacturers' toroidal cores show the influence of the cores' characteristics on frequency linearity and relative sensitivity.

REFERENCE

1 Nell, Susanne, "Improved current monitor delivers proportional-voltage output," *EDN*, Jan 19, 2006, pg 84, www.edn.com/article/CA6298271.

Digital-I/O circuit adapts to many interface voltages

Steve Hageman, Windsor, CA

To test products in my R&D lab, I build many universal data-acquisition systems that connect to a PC or another controller through RS-232 links or LANs. These small systems typically include multiple ADC, DAC, and digital-I/O channels to control various hardware functions during product design and development. Over the years, I have established a simplified analog-interface standard that spans a 0 to 5V range. On the digital side, many of the newer logic families no longer tolerate 5V inputs and have rendered 5V-only digital-I/O ports obsolescent.

To solve the problem, I designed a flexible digital-interface circuit around a MAX7301 I/O expander from Maxim Integrated Products (www.maxim-ic.com) and a programmable linear-power supply comprising a MAX1658 adjustable linear-voltage regulator under the control of a MAX5400 256-position, digitally programmable potentiometer. This circuit provides a programmable interface matching the logic levels of ICs that require 2.5, 3, 3.3, and 5V power supplies.

Two SPIs (serial-peripheral inter-

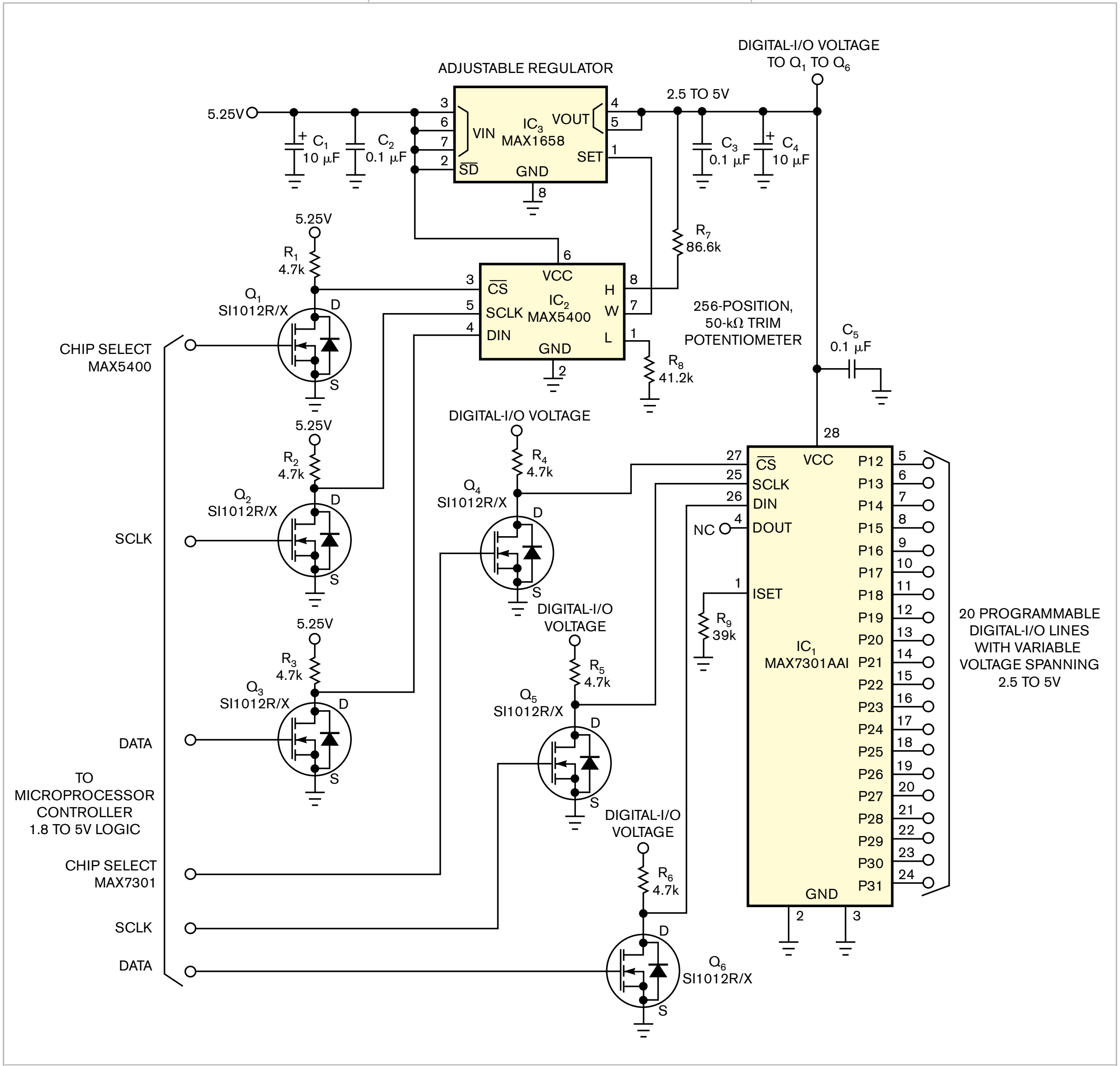

Figure 1 A programmable power supply sets voltage thresholds for a universal digital-I/O device.

faces) control all 20 of the MAX7301AAI's input and output pins and voltage thresholds (**Figure 1**). Unlike some SPI-port expanders that include weak, resistor-only pullups, the MAX7301, IC_1, features true, active-pullup, "totem-pole" outputs that can source higher currents. When powered by the SPI-programmable linear regulator, the MAX7301's outputs can deliver logic levels of 2.5 to 5V. The programming interfaces for both devices comprise two three-wire (plus ground) SPI connections that use only six of the controller's signal lines.

Six Vishay (www.vishay.com) Si1012R low-gate-voltage-threshold N-channel MOSFETs, Q_1 through Q_6, isolate the controllers' fixed-output-voltage levels from IC_1's variable-input-threshold voltages. Although any of several IC-level-translator ICs work equally well, the inexpensive MOSFET buffers occupy small footprints on the interface's PCB (printed-circuit board). For operation at serial-interface clock rates approaching IC_1's 26-MHz maximum, optimize the values of resistors R_1 through R_6 to provide adequate rise times at the selected clock rate. These values are adequate for operation at the 1-MHz SPI clock rate that a low-power microcontroller produces.

UNLIKE SOME SPI-PORT EXPANDERS THAT INCLUDE WEAK, RESISTOR-ONLY PULLUPS, THE MAX7301, IC_1, FEATURES TRUE ACTIVE-PULLUP, "TOTEM-POLE" OUTPUTS THAT CAN SOURCE HIGHER CURRENTS.

To alter the circuit's output-voltage level, IC_2, a 256-step Maxim MAX5400 digital potentiometer, controls IC_3, a Maxim MAX1658 adjustable-voltage linear regulator. Writing all zeros to IC_2 sets IC_3's output voltage to slightly more than 5V, and writing all ones (255 decimal) to IC_2 reduces IC_3's output voltage to slightly less than 2.5V. To compensate for component tolerances, the circuit provides enough voltage overrange to cover the full 2.5 to 5V range. Writing 128 (decimal) to IC_2 should produce a nominal 3.25V output. Measure IC_3's actual output voltage and subtract it from the nominal voltage to produce an offset count for calibration correction.

In operation, the host controller sets IC_3's regulated output voltage through IC_2 and determines the maximum voltages of IC_1's logic inputs and outputs. Next, the controller configures IC_1's inputs and outputs as necessary for the interface task at hand. The MAX7301's standard CMOS logic-threshold voltages of 0.3 to 0.7 times its supply voltage for low and high inputs, respectively, interface with other CMOS parts.**EDN**