Analog divider uses few components

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Although microprocessors may offer more-precise calculations, there's still room for analog-computation techniques in a designer's circuit collection. As a case in point, the analog-divider circuit in **Figure 1** offers reasonably good accuracy for the price of a few inexpensive components. Given two voltages, V_A and V_B, as its inputs, the circuit delivers an output of 5V multiplied by the ratio of V_A divided by V_B. In operation, a TLC555, the CMOS version of the ubiquitous 555 timer, serves as a free-running Schmitt-trigger RC oscillator, IC_2. Its output signal at Pin 3 drives resistor R_1 and capacitor C_1. The voltage at C_1 drives IC_2's trigger (Pin 2) and threshold (Pin 6) inputs, closing the timing loop and establishing oscillation. A low-impedance open-drain MOSFET at IC_2's discharge pin switches low whenever IC_2's output goes low.

Representing the calculation's denominator, an input voltage, V_B, drives IC_2's discharge pin through a resistive-voltage divider comprising R_3 and R_4. Regardless of IC_2's frequency of oscillation, a pulsed voltage appears at IC_2's Pin 7 with the same duty cycle as IC_2's output signal at Pin 3 and an amplitude of 0V to $V_B/2$. A voltage follower, IC_{1B}, buffers IC_2's discharge output and drives a lowpass filter comprising R_8 and C_3, yielding a voltage that equals $V_B/2$ multiplied by IC_2's duty cycle. A second resistive voltage divider, R_6 and R_7, halves the numerator-input voltage, V_A, and applies the signal to integrator IC_{1A}, along with the output from the lowpass filter, R_8 and C_3. The integrator's output voltage drives current through R_2 into C_1, creating a bias voltage that in turn controls IC_2's output pulse width and forming a feedback loop.

In operation, the feedback loop forces IC_2's duty cycle to equalize the voltages at IC_{1A}'s Pin 2 and Pin 3, such that V_B multiplied by the duty cycle equals V_A, or the duty cycle equals the ratio of V_A to V_B. IC_2's output at Pin 3 comprises a 0 to 5V pulse waveform. The feedback circuit controls this waveform and in turn drives a lowpass filter, R_5 and C_4, to generate a dc-output voltage equal to 5V multiplied by the pulse width, or $V_A \times 5V/V_B$.

Aside from the tolerances of the resistors in divider networks R_3 and R_4 and R_6 and R_7, the primary source for inaccuracy in the circuit arises from the nonzero on-resistance of IC_2's discharge switch and the inability of discharge-switch-voltage follower IC_{1A}'s output to reach 0V. Keeping the circuit's resistance values high tends to reduce this effect. A Spice simulation of this circuit indicates that, aside from the effects of resistor tolerances, the circuit achieves a worst-case accuracy of 0.5%. (Editor's note: For greatest accuracy, use a regulated, 5V power supply.) EDN

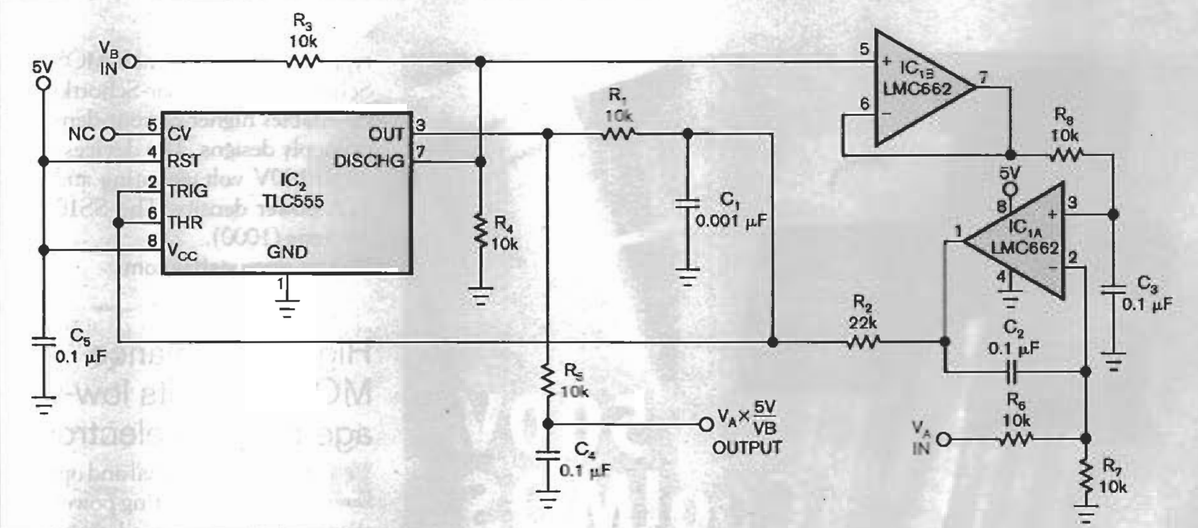

Figure 1 This low-cost pulse-width modulator performs analog division. Inputs V_A and V_B control this low-cost pulse-width modulator, and a lowpass filter follows it.

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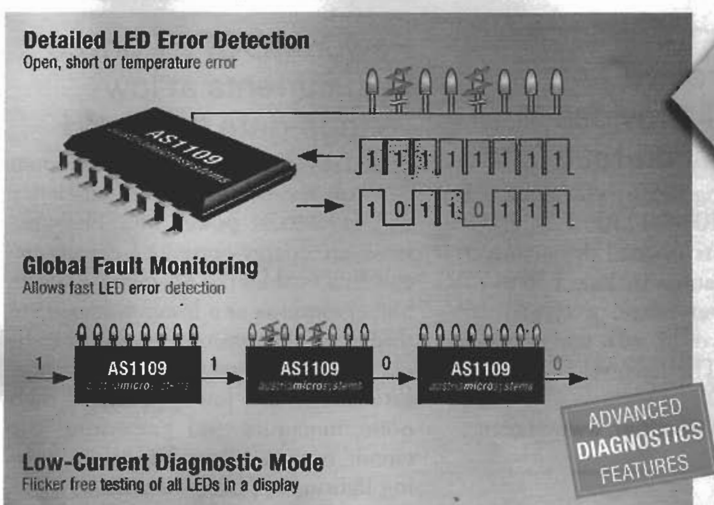

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