Pulse-Width Modulator Features Versatile Operating Parameters

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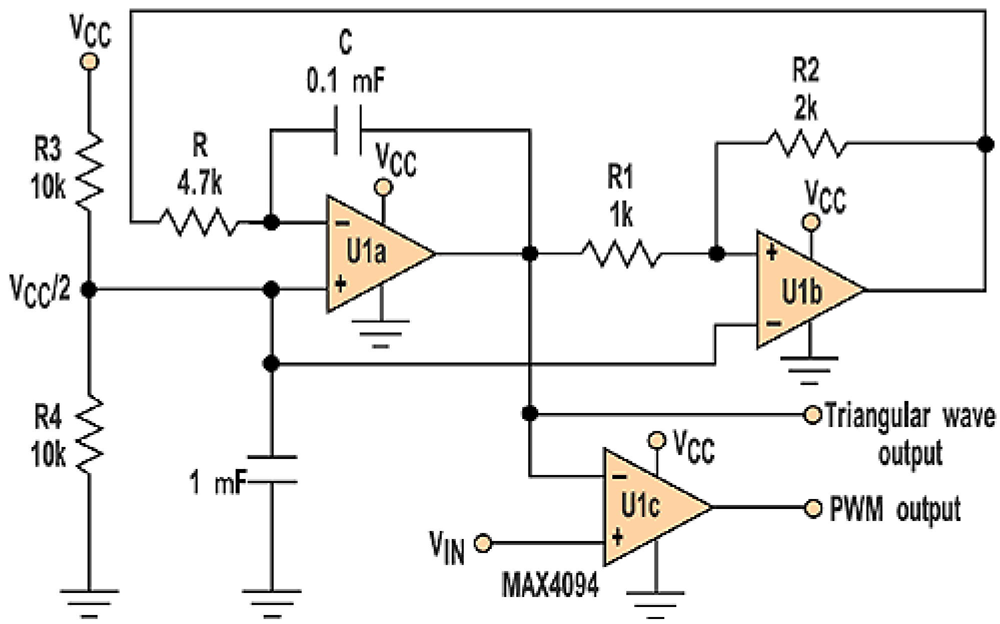
ED Online ID #7380
March 1, 2004

Included among the many applications for pulse-width modulation (PWM) are voltage regulation, power-level control, and fan-speed control. A PWM circuit for such systems can be implemented with three op amps on a single quad-op-amp chip (Fig. 1).



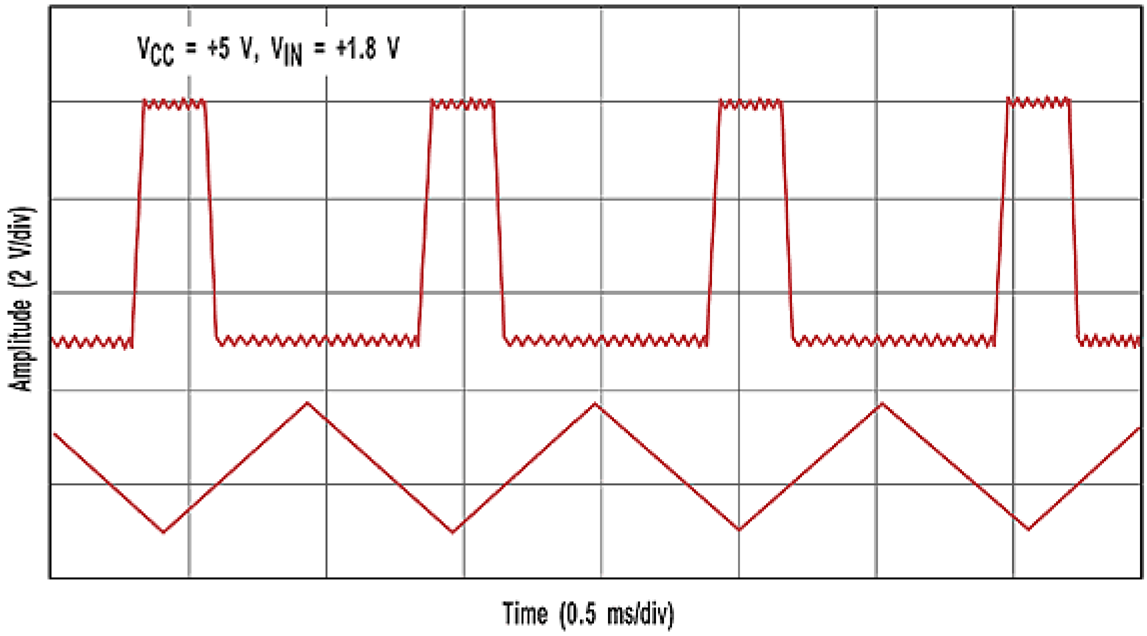
1. This three-op-amp circuit produces both a triangular wave and a variable-pulse-width output.

Because op amps are used for the modulator, it's suited for a wide variety of applications. For example, low-power op amps can be used in a low-power system, and high-frequency op amps can be used for a high-frequency PWM. The circuit in Figure 1 also generates a triangular wave.

The circuit consists of a triangular-wave generator (U1a and U1b) and a comparator (U1c). U1a is configured as an integrator (or de-integrator) and U1b as a comparator with hysteresis. At power-up, the comparator's output voltage is assumed to be zero.

U1a's noninverting input is biased at $V_{CC}/2$. A virtual connection between the inverting and noninverting inputs allows a constant current through R equal to $I = V_{CC}/2R$, which charges capacitor C. Thus, the U1A integrator output increases linearly with time. When it reaches 0.75 V_{CC}, the comparator output (U1b) changes to its maximum output voltage (V_{CC}). At that point, the integrator begins to de-integrate, causing the output voltage to decrease linearly. When it reaches 0.25 V_{CC}, the comparator output voltage changes to zero, and the cycle repeats. Thus, the integrator output is a triangular wave that swings between the levels of 0.25 V_{CC} and 0.75 V_{CC}.

U1c compares the triangular wave against the dc level V_{IN}. Its output is a square wave, with a duty cycle that varies from 0 to 100% as V_{IN} varies from 0.25 V_{CC} to 0.75 V_{CC} (Fig. 2).



2. These waveforms show the circuit's PWM and triangular-wave outputs.

Frequency is determined by R, C, R1, and R2:

$f = R2/(4RCR1)$

where R2 > R1.

The ratio of R2 and R1 affects the operating frequency and the amplitude of the triangular wave. Given that V_{TH} is the triangular wave's maximum voltage and V_{TL} is its minimum voltage, the amplitude swing is:

$V_{TH} = V_{CC}(R1 + R2)/2R2$, and

$V_{TL} = V_{CC}(R2 - R1)/2R2$,

where R2 > R1. Therefore:

$V_{TH} - V_{TL} = (R1/R2)V_{CC}$ (R2 > R1).

The triangular wave's peak-to-peak voltage is centered at the $V_{CC}/2$ bias voltage generated by R3 and R4. With the circuit configuration shown, the PWM operates on a single supply. Use micropower op amps and larger resistors (R and R1 to R4) for low-power applications and high-frequency op amps for higher-frequency applications. (The quad op amp shown comes in a single package.)