Dual-feedback amplifier zeros comparator hysteresis

by Svein Olsen
Royal Institute of Technology, Stockholm, Sweden

Amplifiers with positive feedback may be combined to create voltage comparators and zero-crossing detectors devoid of hysteresis. Alternatively, the amount of hysteresis, either positive or negative, may be selected. In both cases, feedback ensures that true bistable (switching) operation is achieved without undue sacrifice of noise immunity—a necessary condition for optimum comparator and zero-detector performance.

The ideal voltage comparator cannot be realized with a single amplifier because bistable operation does not occur until hysteresis starts. Witness today's typical comparator—a fast differential amp and a transistor-switch output stage that actually operates as a linear amplifier within a small region about the transition level. Achieving a step transition for slowly varying input signals is difficult with these high-gain, wideband devices, too, because of the radio-frequency oscillations and multiple transitions that occur in association with very small noise signals.

Introducing positive feedback to increase loop gain and thus ensure bistable operation, as some have tried, will yield clean switching independent of input slope. But hysteresis also is introduced, and, worst of all, Δt, a varying input/output delay—which depends on the slope of the input signal and the instantaneous value of hysteresis—comes into play.

The block diagram (a) shows how to achieve bistable operation while eliminating all of these problems. Amplifiers 1 and 2, each having positive feedback (α, β, respectively), are applied to their individual summing junctions, where they are combined with the input signal. Amplifier 1 also drives the second summing junction with a dc-level shift signal ($\pm k$) that is a function of the amp's hysteresis. Note that this feedback signal can be derived by either a switching or a linear stage.

Depending upon its polarity, the signal may add to or subtract from the amount of hysteresis inherent in amplifier 2. In the special case, total circuit hysteresis may be eliminated with little loss of noise immunity. At the same time, the circuit will retain high gain for true bistable operation. (The lengthy mathematical analysis of the circuit may be found elsewhere.[1])

A practical circuit having TTL-compatible outputs is shown in (b). Feedback in both amplifiers is determined by resistors r and R. In this application, r is 150 ohms and R is 15 kilohms, so that V_{H1} = 40 millivolts ($V_{in\,min}$ = 15 mV root mean square) and V_x = 20 mV, where V_{H1} is the hysteresis for amplifier 1 and V_x is the noise immunity.

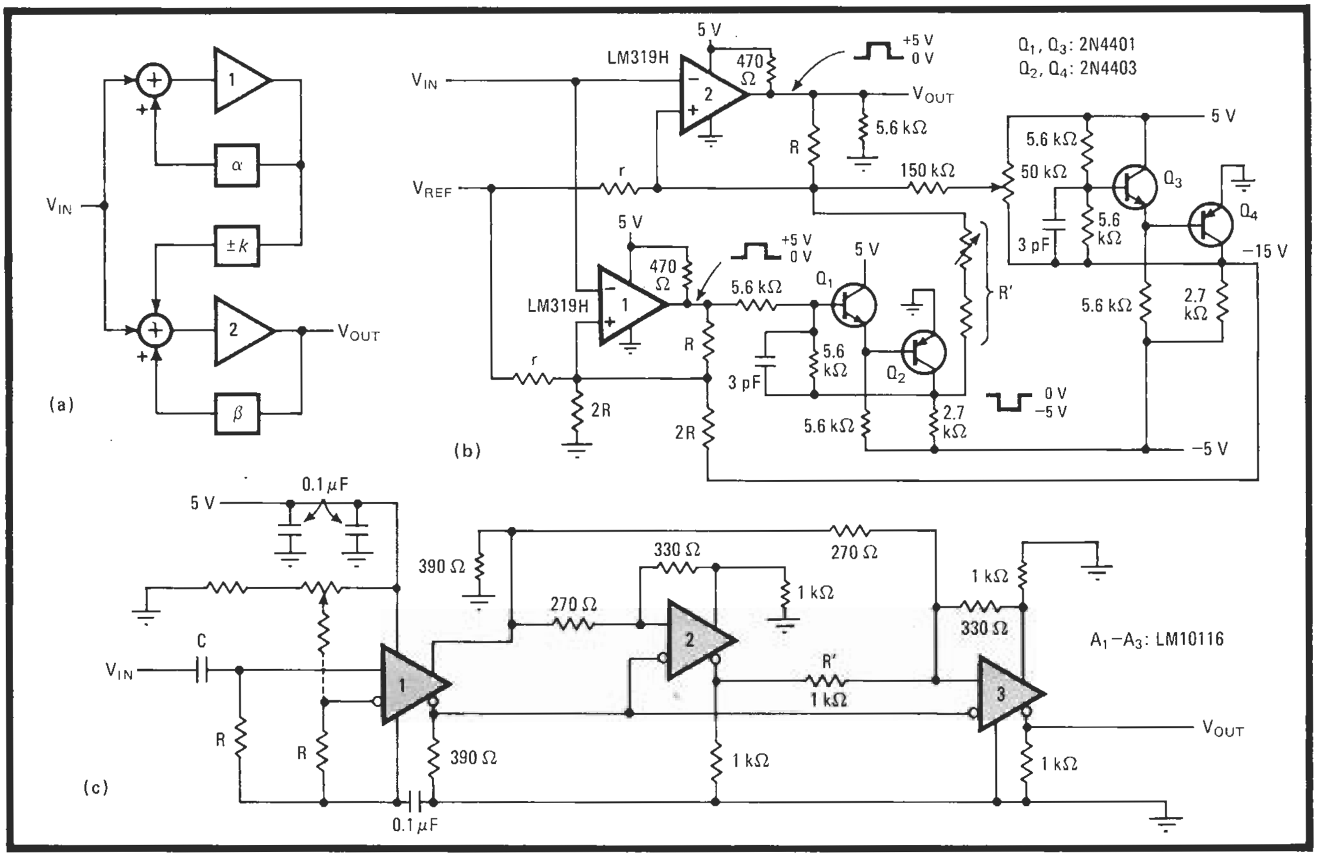
Amplifier Q_1–Q_2 provides an inverted feedback signal to the second summing junction, with the magnitude of the signal set by potentiometer R′. The negative voltage at the junction of amplifier 1 required to establish a level-shift voltage at amplifier 2 is provided by Q_3–Q_4. The output hysteresis is adjustable to zero.

A fast (3-nanosecond) zero-crossing detector with zero hysteresis is shown in (c). This application requires an LM10116 emitter-coupled-logic receiver to be used, and although its low amplification factor makes it a little more difficult to achieve high loop gain, three sections are used to make up for the shortcoming.

Amplifier 1 is the input stage biased for Class A amplification. The input RC values are selected according to the impedance-matching requirements and to provide the required low-frequency response. Amplifiers 2 and 3 serve the functions previously mentioned. □

References

1. Svein Olsen, "The Zero Hysteresis Comparator," RVK-78 Conference Notes, Stockholm, March 29, 1978.



Ideal. Amplifiers with high loop gain work as nearly perfect comparators and zero-crossing detectors when they are suitably combined to cancel hysteresis (a). The implementation of a practical comparator (b) and a zero-crossing element (c) are relatively simple.