Dual flip-flop forms simple delayed-pulse generator

Luca Bruno - April 17, 2008

Some applications require clock-timing adjustments, such as generating precision clocks for time-interleaved ADCs, or delay adjustments in a variety of precision-timing and pulse-delay applications. This Design Idea describes a delayed-pulse generator using a dual-CMOS D-type flip-flop (Figure 1). The circuit provides precision time delays of a trigger-input pulse. A dc-control voltage selects a time delay within the full-scale range. When the rising edge of a pulse triggers the input, the circuit’s output generates a pulse with its rising edge delayed by an amount equal to the selected time delay, \( T_D \), plus a fixed inherent propagation delay \( T_{PD} \). Also, a time constant, \( R_4C_2 \), determines the output pulse’s width.

A precision dc source, \( I_{O} \), and capacitor \( C_1 \) set the full-scale delay range. When \( Q_3 \) is off, the current source charges capacitor \( C_1 \), generating a linear-ramp voltage with slope equal to \( I_O/C_1 \). The delay is the time it takes for the ramp to rise from its initial voltage to the control-voltage value.

In this application, the ramp slope is 10 mV/1 \( \mu \)sec, so that the full-scale delay range is 256 \( \mu \)sec for a control voltage of 0 to 2.56V. You can set the full-scale delay by changing \( I_O \) through either \( R_1+R_2 \) or capacitor \( C_1 \). For best accuracy, the current source can range from 10 \( \mu \)A to 1 mA, the capacitor’s value can range from 1 nF to 1 \( \mu \)F, and the corresponding full-scale delay can range from 2.56 \( \mu \)sec to 256 msec. Use a precision film capacitor for \( C_1 \).

The basis of the current source is a shunt precision-micropower-voltage-reference, \( IC_{3} \), producing a reference voltage of 1.233V with an initial accuracy of 0.2%. A Texas Instruments LM4041, through precision resistors \( R_1 \) and \( R_2 \), biases the Darlington-coupled transistors \( Q_1 \) and \( Q_2 \) with a reference current \( I_O=V_{REF}/(R_1+R_2)=100 \mu \)A. The Darlington configuration ensures that base current is negligible and that the output collector current can achieve a worst-case accuracy of 0.3%. You can use any small-signal transistor, but, for best accuracy, use high-gain, low-level, low-noise BJTs, (bipolar-junction transistors) such as a 2N5087 or a BC557C.

\( IC_{1A} \) is a one-shot circuit (Reference 1). The output pulse’s width, \( T_W \), is \( R_4C_2\times\ln(V_{DD}/V_{TH}) \), where \( V_{TH} \) is the threshold voltage of the digital CMOS. Because \( V_{TH}=V_{DD}/2 \), then \( T_W=R_4C_2\times0.69 \). Diode \( D_1 \) reduces recovery time. After power-up, \( Q_3 \) is in saturation, absorbing the current source’s output, and, as soon as an input pulse triggers the circuit, \( IC_{1B} \)’s Q output goes low, switching off \( Q_3 \), starting a ramp. When the ramp exceeds the control voltage, then the \( IC_{2A} \) comparator’s output goes high, and the rising edge triggers one-shot \( IC_{1A} \) and switches on \( Q_3 \) through \( IC_{1B} \), allowing the discharge of the capacitor \( C_1 \). When an input pulse triggers the circuit, any other trigger pulse that occurs before the falling edge of the delayed output pulse does not produce an output pulse; in other words, the circuit is not retriggerable. This feature permits you, at the same time, to divide and delay an input-trigger clock.
Although IC₁ and IC₂ can operate from a 3 to 16V supply, the minimum supply voltage of the circuit is 5V; otherwise, Q₁ and Q₂ approach saturation, generating a less linear ramp voltage. Voltage comparator IC₂A, an STMicroelectronics TS3702, has an input-common-mode-voltage range that includes ground, permitting you to monitor input voltages as low as 0V.

However, for correct operation of the circuit, the minimum control voltage must be greater than the saturation voltage of Q₃. For the components in Figure 1, the measured value is 12 mV. If you want to reduce this voltage, you can use a digital N-channel MOSFET with low on-resistance. The optional input lowpass filter, comprising R₆ and C₄, helps to clean noise from the dc-control voltage.

If a DAC drives the control input, you can build a digitally programmable delay generator. A suitable low-cost, 8-bit DAC is the AD558 from Analog Devices, which features an internal precision bandgap reference to provide an output voltage of 0 to 2.56V, making 1 LSB equal to 1 µsec. It operates from 5 to 16V, with a 1-µsec settling time. The circuit’s quiescent current, I_DD, is less than 300 µA because all ICs are micropower.

Reference