Gated Oscillator has Independently Variable t_{on} and t_{off}

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A clock source is a very important circuit, because it finds applications in almost any digital circuit, whether in communications, computation or system timing. Generally, clock oscillator design does not present any particular difficulty, and suitable circuits are mainly of two types: Crystal-based if frequency accuracy and stability is a necessary requirement, and some form of RC free-running multivibrator in most other cases.

The design can become quite another story if the oscillator has the following unusual requirements:

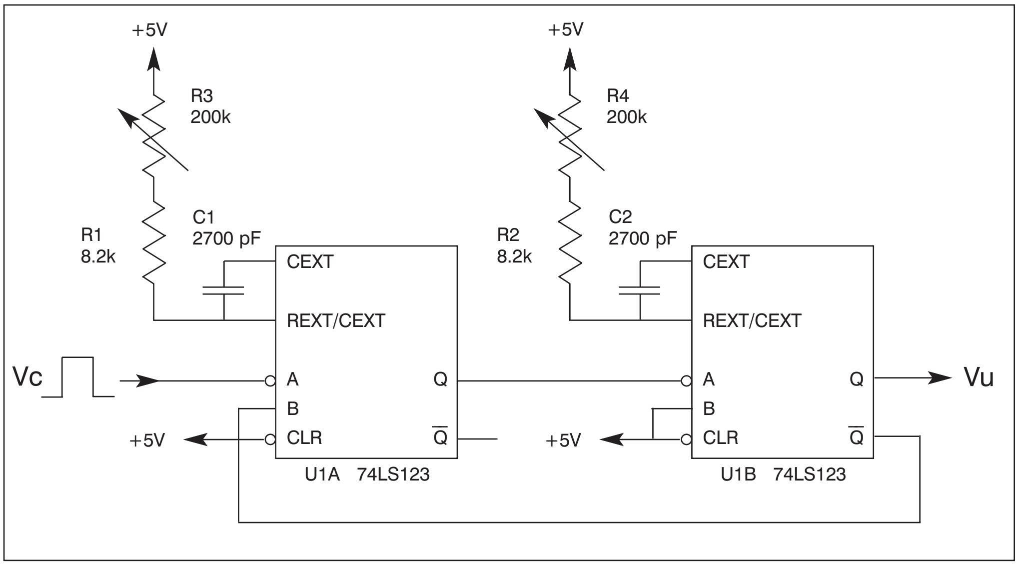


Figure 1. Circuit diagram of the gated oscillator.

- Wide frequency range
- Variable duty cycle with t_{on} and t_{off} adjustable independently of one another
- The capability for synchronization with an external signal

The number of references available for the design of an astable multivibrator are is considerable, but rarely are the above requirements achievable in a single circuit.

One very simple solution is proposed here in Figure 1. As shown, the circuit is built with only one 74LS123, two capacitors and two resistors. This basic design assumes that a final design will combine the potentiometers' resistance values with resistors R_1 and R_2.

To analyze this circuit, let the A input of the first monostable U1A be momentarily connected to ground. U1B's positive-going output of $\overline{Q}$ triggers the B input of U1A, whose Q negative-going output triggers the A input of U1B, establishing a DC positive feedback that will always self-start the circuit.

t_{on} is determined by the time constant $(R_2+R_4) \times C_2$, and t_{off} by $(R_1+R_3) \times C_1$. For the 74LS123, the output pulse width is essentially determined by the value of the external components R_{ext} and C_{ext}:

$$t_w = k \cdot R_{ext} \cdot C_{ext}$$

where $k = 0.45$ for $C_{ext} > 1000$ pF [1].

Assuming $R_A = R_1 + R_3$ and $R_B = R_2 + R_4$, the period and the duty cycle are given by:

$$DuCy = \frac{t_{on}}{t_{on} + t_{off}} = \frac{K \cdot R_B \cdot C_2}{K \cdot R_A \cdot C_1 + K \cdot R_B \cdot C_2}$$

$$= \frac{R_B \cdot C_2}{R_A \cdot C_1 + R_B \cdot C_2}$$

If $C_1 = C_2$, then:

$$DuCy = \frac{R_B}{R_A + R_B}$$

and the circuit oscillates at the frequency:

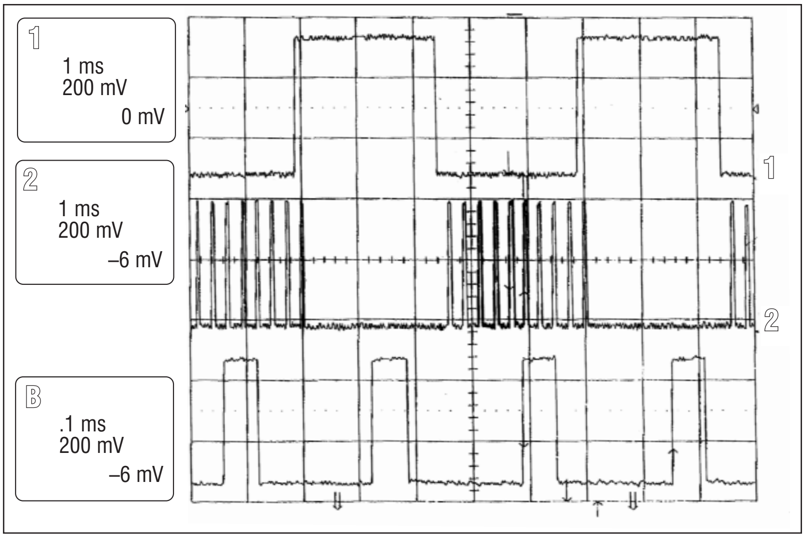
$$f = \frac{1}{t_{on} + t_{off}} = \frac{1}{K \cdot R_A \cdot C_1 + K \cdot R_B \cdot C_2}$$

In the 74LS123 operating range (5 kΩ ≤ 200 kΩ and no limits for C_{ext}) we have:

- For R_A = 5 kΩ and R_B = 200 kΩ, *DuCy* = 100%
- For R_A = 200 kΩ and R_B = 5 kΩ, *DuCy* = 0

That is, the duty cycle can change from the minimum to the maximum possible. What is more, since t_{on} and t_{off} are completely independent, it is also possible to vary frequency without affecting the duty cycle. The oscillator frequency is adjustable from approximately a few Hz to 15 MHz.

Another important property of the circuit is the fact that it can easily become a gated oscillator simply by applying to the A input of U1A a square wave vc whose frequency is less than that defined by *f*. In this case, the oscillator is gated by vc, with the oscillator output low when the gating signal is high, and free-running when the gating signal is low.



▲ **Figure 2. Waveforms of the gating signal (top), the oscillator output (center) and its expanded waveform (bottom).**

Figure 2 shows the 200 Hz gating signal, the oscillator output and its expanded waveform when R_A = 170 kΩ, R_B = 50 kΩ and C_{ext} = 2700 pF. In this case, using the above formulas we have $t_{on} \cong 60\ \mu s$, $t_{off} \cong 206\ \mu s$ and $f \cong 3741$ Hz. These calculations are in good agreement with the oscilloscope waveform. ■

Reference

1. *The TTL Data Book for Design Engineers*, Texas Instruments.

Author information

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