

Designing With the SN74LVC1G123 Monostable Multivibrator



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ABSTRACT

This document discusses the operation of and applications for monostable multivibrators. The SN74LVC1G123 was chosen as the example device, but Texas Instruments has a wide variety of other monostable multivibrator devices in other logic families that operate in practically the same manner. The applications here can be applied to almost any monostable multivibrator.

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1 Introduction

A “Monostable Multivibrator” is so named because its output is only stable in one state. When triggered, this device will switch the output to the so-called 'unstable state' for a set period of time and then return to the stable state. Note that "stable" in this context refers to an output state that will remain the same without an external input and "unstable" refers to a state which will change without external input. Since one input trigger event results in one output pulse, this device is also known as a “one-shot.” The SN74LVC1G123 will be used herein as an example because it is one of our most popular devices, but TI offers many other monostable multivibrators in different logic families to fit a wide variety of applications.

These devices can be used as debouncers, pulse extenders, delays, and edge detectors. They are very useful for cleaning up input signals to logic circuits of all types.

2 Terminology

- Stable State – The natural, resting, or ‘off’ state of a monostable multivibrator’s output; usually ‘low’
- Unstable State – The temporary, active, or ‘on’ state of a monostable multivibrator’s output; usually ‘high’
- Pulse Width – The amount of time for which the output is switched. Often referred to as ‘ t_w ’
- Trigger – The input signal edge which causes an output pulse to be generated. The trigger can be on a rising or falling edge depending on which input is used.
- Retrigger – The act of applying a trigger signal while the output of the system is already in the unstable state.
- Retriggerable - A monostable multivibrator that has the capability to retrigger.

3 Theory of Operation

3.1 Basic Concept

Any monostable multivibrator that has an external RC circuit for timing will operate on the same basic principle. The capacitor in an RC circuit will take a set amount of time, referred to as the ‘time constant,’ to charge up to 63.2% of its full charge from a fully discharged state. It takes 5 time constants to reach 99.3% of its full charge, which is generally accepted as a fully charged state. These two values are derived from the RC circuit step response characteristic equation, [Equation 1](#).

$$V_O = V_I e^{\frac{-t}{RC}} \quad (1)$$

A monostable multivibrator takes advantage of the consistency of RC circuit charge times to produce output pulses of set widths. Because external components are used, this consistency is reliant upon the thermal and manufacturing tolerances of those components in addition to the chosen semiconductor device.

3.2 Operation

1. Trigger event occurs. This can be a rising or falling edge depending on the configuration.
2. C_{ext} is discharged very quickly and is allowed to charge through the external RC network.
3. Output switches to the unstable state when the capacitor voltage drops below the designed threshold voltage. It returns to the stable state when the capacitor voltage charges back up above the threshold voltage.

The circuit representing this operation is shown in [Figure 3-1](#), and the capacitor voltage plotted with the output voltage is shown in [Figure 3-2](#). This plot is simulated from an ideal system designed to switch the output when the capacitor voltage is 63.2% of its full charge.

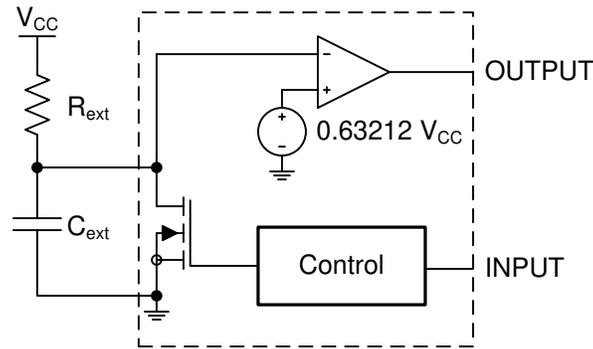


Figure 3-1. Functional Diagram of a Monostable Multivibrator

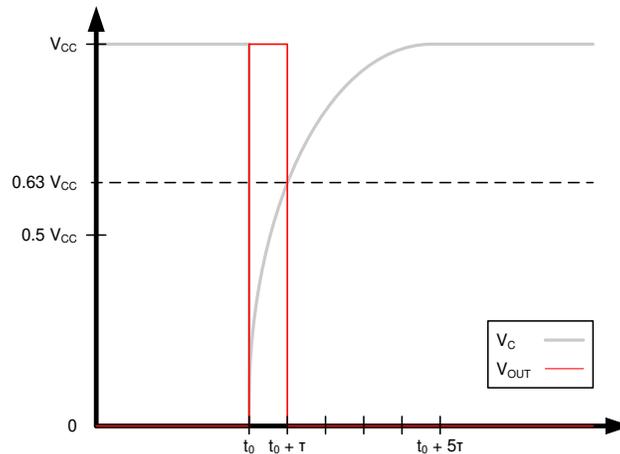


Figure 3-2. Capacitor Voltage With Aligned Output Pulse (Ideal)

The schematic shown in [Figure 3-1](#) is a simplified version of the internal operation of the SN74LVC1G123, but it does not capture all of the nuances of operating a monostable multivibrator. In this schematic, it is assumed that temperature and supply voltage will not change the output of the circuit, and that the RC circuit will always have a sufficient charge and discharge path for operation. It is additionally assumed that there is enough time for the system to recover between output pulses.

While the system is at rest, the capacitor is fully charged and the output voltage is LOW. When a trigger event occurs, the external capacitor, C_{ext} , is quickly discharged through the MOSFET, and then is allowed to charge through the external resistor, R_{ext} . When the capacitor voltage initially drops below the reference voltage, $0.63212 V_{CC}$, the comparator output immediately changes to HIGH. The output then remains HIGH until the capacitor charges up enough to surpass $0.63212 V_{CC}$, when it returns to its stable LOW state. Since it takes approximately one time constant to $0.63212 V_{CC}$, the output pulse will be very close to $\tau = R \times C$ in length. In a real monostable multivibrator, such as the SN74LVC1G123, the output pulse length will also be dependent on the supply voltage and the capacitor size. These two dependencies are usually represented as a multiplier, K . [Equation 2](#) shows the general pulse width (t_w) equation.

$$t_w = K \times \tau = K \times R \times C \quad (2)$$

The SN74LVC1G123 is a retriggering monostable multivibrator. This means that each trigger event produces an output of the chosen length. If the output is already outputting a pulse when the trigger occurs, then the output will continue to output as shown in [Figure 3-3](#). The timing diagram in [Figure 3-3](#) shows the difference between a retriggerable and non-retriggerable monostable multivibrator when both have the same pulse width.

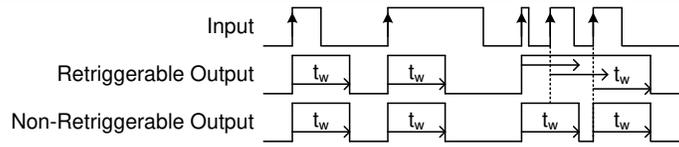


Figure 3-3. Difference Between Retriggerable and Non-Retriggerable Monostable Multivibrators

4 Applications

4.1 General Design Considerations

4.1.1 Pulse Length Determination

The output pulse length is the most important factor for the design of a monostable multivibrator circuit in most applications. Some systems might require only a few microseconds of output, while others might require seconds or even minutes. Any monostable multivibrator's datasheet should contain several useful graphics to help with this process. Since we are using SN74LVC1G123 as an example, the graphics from that datasheet are included here for reference.

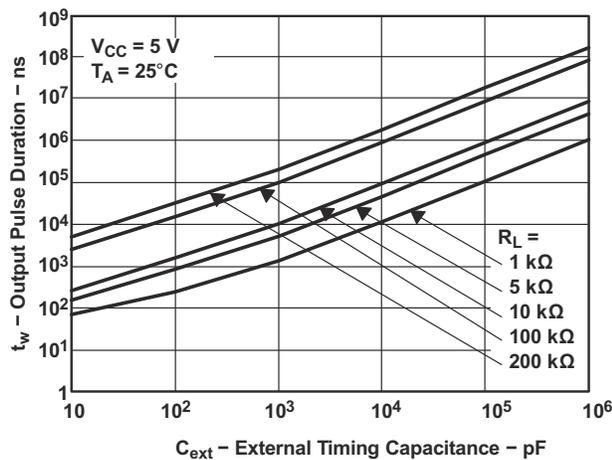


Figure 4-1. Output Pulse Duration vs External Timing Capacitance, SN74LVC1G123

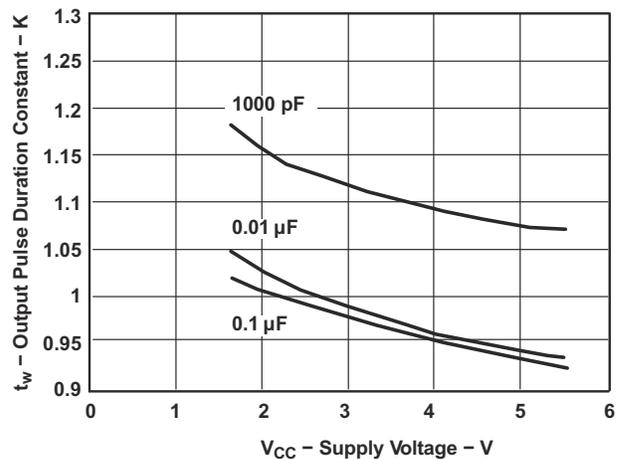


Figure 4-2. Output Pulse Duration Constant vs Supply Voltage

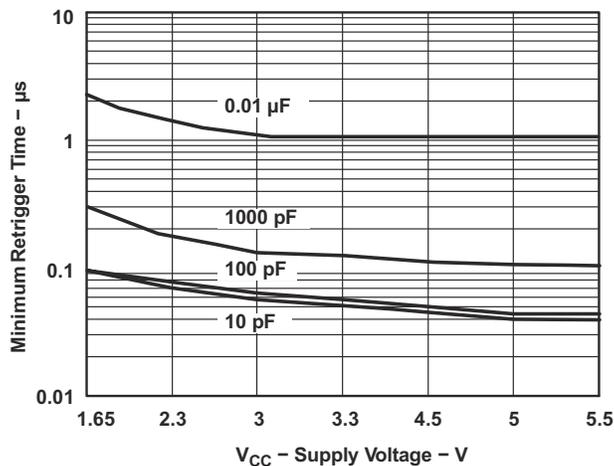


Figure 4-3. Minimum Retrigger Time vs Supply Voltage

One thing to notice on these plots is that only specific values of resistors and capacitors were tested for the datasheet. It is recommended to use one of the tested capacitor values to make calculations faster, easier, and more accurate. Several examples will be shown in [Section 4.2](#) using these graphics as reference.

4.1.1.1 Temperature Stability

The SN74LVC1G123 has surprising temperature stability characteristics. The following plots show the pulse length over temperature. The external resistor and capacitor were not exposed to the same temperature in order to test only the change due to the semiconductor device. Frost would form on the board near freezing temperatures because of the test environment, so only data above 10°C was used. Since there is a large variation in pulse length over supply voltage (as indicated by the V_{CC} vs K plots on the datasheet), the minimum and maximum recommended supply values are shown on each plot.

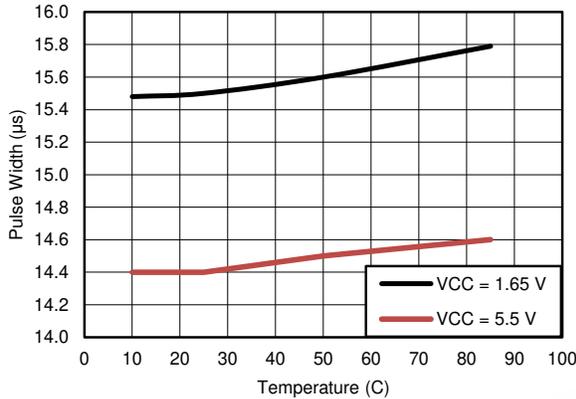


Figure 4-4. Pulse Width Over Temperature and Supply Voltage Range With $C_{ext} = 100$ pF and $R_{ext} = 100.7$ k Ω

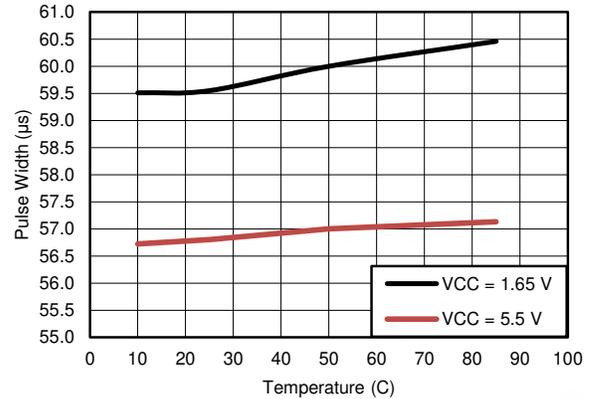


Figure 4-5. Pulse Width Over Temperature and Supply Voltage Range With $C_{ext} = 500$ pF and $R_{ext} = 100.7$ k Ω

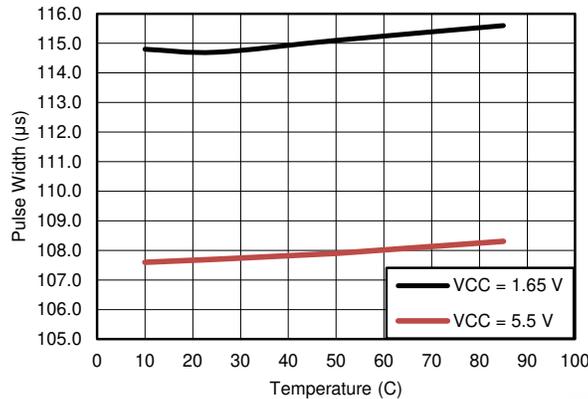


Figure 4-6. Pulse Width Over Temperature and Supply Voltage Range With $C_{ext} = 1$ nF and $R_{ext} = 100.7$ k Ω

4.2 SN74LVC1G123 Applications

These applications are designed specifically for the SN74LVC1G123, but could be implemented with other monostable multivibrators. The basic principles are the same.

4.2.1 Switch Debounce

When a human presses a button on a computer system, there is always the chance that the button press will be read incorrectly by the system. Most physical switches 'bounce' internally when pressed and can produce a large number of triggers to a computer system when the user only intended one. A system that changes multiple triggers into a single pulse is desirable in this situation.

The retriggerable functionality of the SN74LVC1G123 makes it an ideal choice for switch debouncing applications. By selecting a pulse length longer than the bounce length but shorter than a human would notice, the monostable multivibrator will change an unpredictable button press from a human into a predictable pulse of a selected width.

4.2.1.1 Requirements

- $V_{CC} = 5\text{ V}$
- Bounces are less than 1 ms
- Output pulse length of less than 25 ms
- Low power consumption (< 1 mA total current)
- Operation at room temperature

4.2.1.2 Schematic

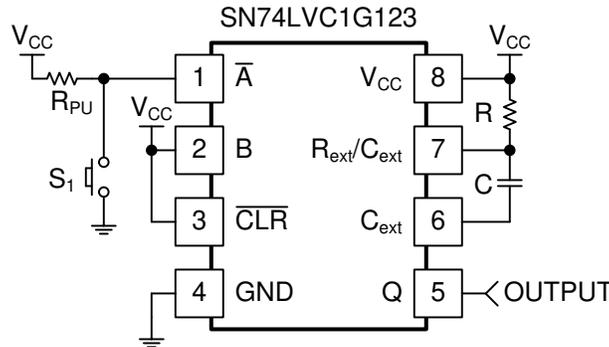


Figure 4-7. Debounce Application Schematic

The input from the user is a push-button momentary switch, S_1 . Since the input is normally HIGH and is pulled LOW by the switch, a falling edge trigger is required. This is selected by holding B and $\overline{\text{CLR}}$ HIGH while applying the input to $\overline{\text{A}}$.

4.2.1.3 Component Selection

- R_{PU} is selected by two criteria: power consumption and timing.
 - Power consumption in this circuit is desired to be less than 1 mA at 5-V V_{CC} . Since the SN74LVC1G123 has a maximum ICC of 812.5 μA at 5-V V_{CC} , the pull-up resistor must draw less than 187.5 μA . This means that the minimum resistance must be 26.7 k Ω .
 - For the second criteria, it is reasonable to assume a 15-pF input capacitance and a 5-pF trace capacitance, resulting in a total capacitance of 20 pF. The recovery period for an RC circuit is $5 \times R \times C$. For the case of a 26.7-k Ω resistor, 2 μs is the expected recovery time. Increasing this to 100 k Ω still maintains a very fast recovery time of approximately 8 μs and allows the usage of a standard 5% tolerance resistor. Maintaining a recovery period of less than 1 ms is more than reasonable for this system.
- R and C are selected by using the datasheet's graphics and the pulse length equation, $t_w = K \times R \times C$.
 - The capacitor value is selected first because there are fewer capacitor values available on the market and this simplifies other calculations. By looking at the figures on the datasheet (some of which are in [Section 4.1.1](#)), it can be seen that 0.1 μF was a tested capacitor value that will meet our timing requirement.
 - The resistor value is calculated from the pulse length equation, $t_w = K \times R \times C$. By rearranging terms, $R = t_w / (K \times C)$. K is found in [Figure 4-2](#) to be 0.925 for $C = 0.1\ \mu\text{F}$ and $V_{CC} = 5\text{ V}$. Since the pulse width is a range from 1 ms to 25 ms, a range of R values will be given to match. $10.8\ \text{k}\Omega < R < 270\ \text{k}\Omega$. 100 k Ω is selected because it is already on our bill of materials from the pull-up resistor and will result in an output pulse of 9.25 ms.

Table 4-1. Debounce Circuit Component Values

Component	Value
R_{PU}	100 k Ω
R	100 k Ω
C	0.1 μF

4.2.2 Leading and Trailing Edge Detector

It is sometimes preferable to have a short pulse when an edge is detected rather than sending the original waveform to a microcontroller. This application shows how to output a pulse on one output when a leading edge is detected, and a second pulse on a different output when a falling edge is detected. The leading and falling edge detector circuits are identical in design and only have different input configurations. These two circuits use the same input in this example, but they could be used individually.

One example of when this might be useful is when a switch is toggled relatively rarely. A microcontroller would have to poll an input regularly in order to know the state of that switch. By adding a leading/trailing edge detector circuit, the microcontroller can just have an interrupt for each event and action would only be taken when the switch is actually toggled.

4.2.2.1 Requirements

- $V_{CC} = 5\text{ V}$
- Output pulse length between 1 and 2 ms
- Outputs are rising edge triggered
- Input is transitions from logic LOW to HIGH and back again over some unknown period of time
- Operation at room temperature

4.2.2.2 Schematic

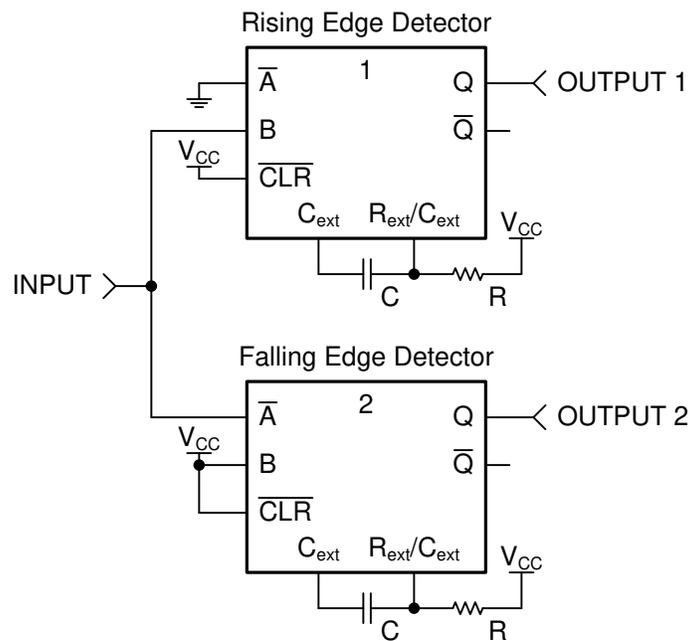


Figure 4-8. Rising and Falling Edge Detector Application Schematic

4.2.2.3 Component Selection

- R and C are selected by using the datasheet's graphics and the pulse length equation, $t_w = K \times R \times C$. Because both edge detector circuits are outputting to the same system, the output pulse lengths are the same.
 - The capacitor value is selected first because there are fewer capacitor values available on the market and this simplifies other calculations. By looking at the figures on the datasheet (some of which are in [Section 4.1.1](#)), it can be seen that 0.1 μF was a tested capacitor value that will meet our timing requirement.
 - The resistor value is calculated from the pulse length equation, $t_w = K \times R \times C$. By rearranging terms, $R = t_w / (K \times C)$. K is found in [Figure 4-2](#) to be 0.925 for $C = 0.1 \mu\text{F}$ and $V_{CC} = 5 \text{ V}$. Since the pulse width is a range from 1 ms to 2 ms, a range of R values will be given to match. $10.8 \text{ k}\Omega < R < 21.6 \text{ k}\Omega$. 12 k Ω is selected because it is a standard 5% resistor value and yield a pulse length of 1.11 ms.

**Table 4-2. Leading and Trailed Edge Detector
Component Values**

Component	Value
R	12 k Ω
C	0.1 μF

5 Frequently Asked Questions

5.1 How do I calculate the output pulse length?

$$t_w = K \times R_{ext} \times C_{ext}$$

The external resistor and capacitor names will be different from one device to another, but this equation will always work. If a plot for K is not given, assume it to be 1.

5.2 How do I configure the SN74LVC1G123's inputs for _____ edge triggering?

Table 5-1. Trigger Method Selection

Desired Trigger Method	\bar{A}	B	\overline{CLR}
Falling Edge	INPUT	HIGH	HIGH
Rising Edge	LOW	INPUT	HIGH
Rising Edge with output pulse interrupt when LOW	LOW	HIGH	INPUT

5.3 How stable is the output pulse length over V_{CC} changes?

The output pulse length does change with V_{CC} . The amount of change is reflected in K and can be found in the plots on the part's datasheet.

5.4 How stable is the output pulse length over temperature changes?

The output pulse length changes with temperature, but as can be seen in [Section 4.1.1.1](#), the difference is minimal over the operating temperature range of the device for the SN74LVC1G123. Most monostable multivibrators are designed to have good temperature stability over their operating range.

5.5 Which inputs of the SN74LVC1G123 have Schmitt-triggers?

\bar{A} , B, and \overline{CLR} all have Schmitt-triggers. This means that they can all handle slow or noisy inputs without creating multiple trigger events.

5.6 Can I connect the C_{ext} pin to ground?

It is best to follow the datasheet recommendations. If your monostable multivibrator recommends not connecting C_{ext} to ground, then do not connect it to ground.

In some monostable multivibrators the C_{ext} pin is internally tied to ground, but in some it is not. If the datasheet is unclear and the information is required, use an ohmmeter to check the resistance between the two pins. If the resistance reads less than 1 Ω , it is safe to connect both to ground.

6 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision * (July 2015) to Revision A (October 2020)	Page
• Updated the numbering format for tables, figures, and cross-references throughout the document.....	2
• Switched images in Figure 4-4 and Figure 4-5	5

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