Designing With the SN54/74LS123

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TEXAS INSTRUMENTS

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Contents

Title *Page*

List of Illustrations

Introduction

The Texas Instruments (TI) SN54/74LS123 dual retriggerable monostable multivibrator is a one-shot device capable of very long output pulses and up to 100% duty cycle. The ’LS123 also features dc triggering from gated low-level active A and high-level active B inputs and provides a clear input that terminates the output pulse of any predetermined time independent of timing components, R_{ext} and C_{ext}. The output pulse duration can also be extended by retriggering the input prior to the termination of an existing output pulse. Retrigger pulses starting before 0.22 C_{ext} (in pF) ns after the initial trigger pulse will be ignored and the output duration will remain unchanged.

The B input on an ’LS123 is designed to handle pulses with a transition rate as slow as 0.1 mV/ns, (Schmitt-trigger input) with jitter-free one-shot action. This capability allows the ’LS123 to be used as an interface element between circuits with very slow-rising output pulses and circuits that require fast-rising input pulses.

Features

- 100% maximum duty cycle
- Dc triggered from active-high or active-low logic inputs
- Input clamp diodes
- Low power dissipation
- Compensated for V_{CC} and temperature variations

Figure 1 is a functional block diagram of the ’LS123. Each one-shot has two inputs, one active-low and one active-high, which allow both leading or trailing edge triggering. When triggered, the basic pulse duration can be extended by retriggering the gated low-level active A or high-level active B inputs, or the pulse duration can be reduced by use of the overriding clear. Therefore, an input cycle time shorter than the output cycle time will retrigger the ’LS123 and result in a continuously high Q output.

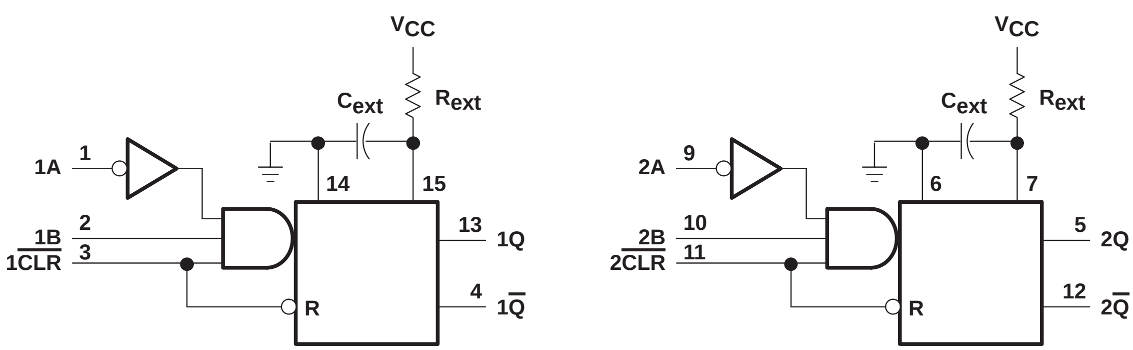


Figure 1. ’LS123 Logic Diagram

FUNCTION TABLE

CLEAR	A INPUT	B INPUT	Q	$\overline{Q}$
L	X	X	L	H
X	H	X	L†	H†
X	X	L	L†	H†
H	L	↑	LHL‡	HLH§
H	↓	H	LHL‡	HLH§
↑	L	H	LHL‡	HLH§

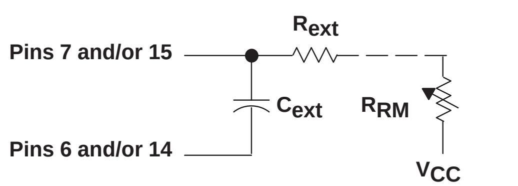
† These lines of the functional tables assume that the indicated steady-state conditions at the A and B inputs have been set up long enough to complete any pulse started before the setup.
‡ This is a low-to-high-to-low pulse.
§ This is a high-to-low-to-high pulse.

Rules for Operation

1. An external resistor (R_{ext}) and an external capacitor (C_{ext}) are required, as shown in Figure 1, for proper circuit operation.

NOTE:
For best results, system ground should be applied to the C_{ext} terminals.

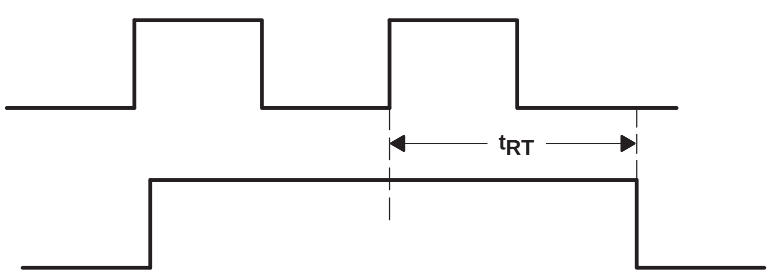
2. This value of R_{ext} may vary from 5 kΩ to 180 kΩ between –55°C and 125°C.
3. C_{ext} may vary from 0 pF to any necessary value.
4. The input may have a minimum amplitude of –0.5 V and a maximum of 5.5 V.
5. When an electrolytic capacitor is used as C_{ext}, the switching diode required by most one-shots is *not needed* for ’LS123 operation.
6. For remote trimming, the circuit shown in Figure 2 is recommended.



NOTE: R_{RM} is placed as close as possible to the ’LS123.

Figure 2. Remote Trimming Circuit

7. The retrigger pulse duration is calculated as shown in Figure 3.



$t_{RT} = t_W + t_{PLH} = K \bullet R_{ext} \bullet C_{ext} + t_{PHL}$

Figure 3. Retrigger Pulse-Duration Calculation

8. A 0.001-µF to 0.1-µF bypass capacitor between V_{CC} and GND as close as possible to the ’LS123 is recommended (see Figure 4).

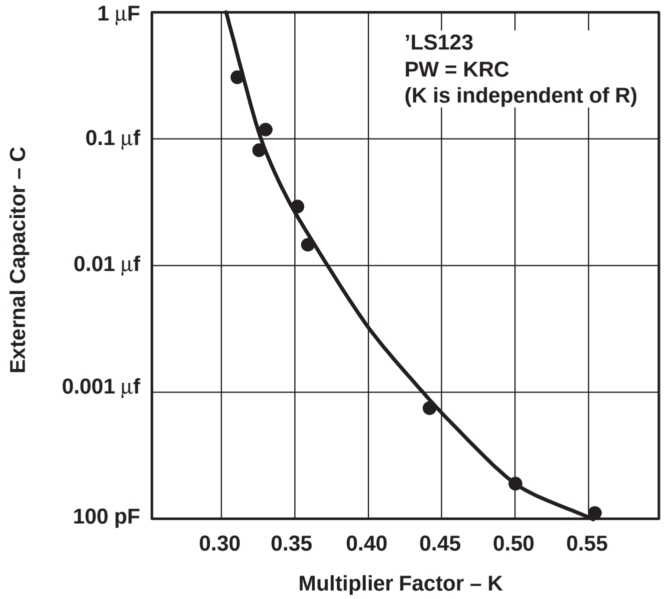


Figure 4. Multiplier Factor Versus External Capacitor (C_{ext})

Output Pulse Duration

The basic output pulse duration is essentially determined by the values of external capacitance and timing resistance. For pulse durations when C_{ext} is < 1 µF, use the following formula:

$$t_w = K \cdot R_t \cdot C_{ext} \text{ (also see Figure 5)} \quad (1)$$

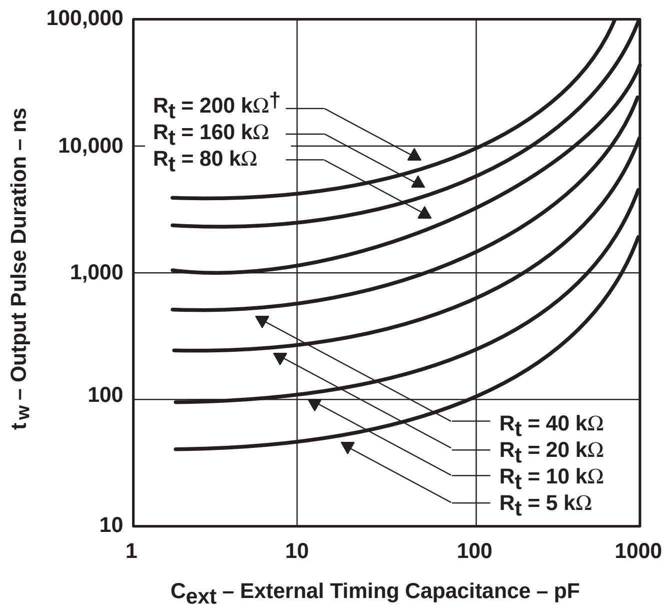
When C_{ext} is > 1 µF, the output pulse duration is defined as:

$$t_w = 0.33 \cdot R_t \cdot C_{ext} \quad (2)$$

Where, for the two previous equations, as applicable:

K = multiplier factor
R_t = given in kΩ (Internal or External Timing Resistance)
C_{ext} = in pF
t_w = in ns

For capacitor values of less than 1000 pF, the typical curves in Figure 5 can be used.



† This value of resistance exceeds the maximum recommended for use over the full temperature range of the SN54LS circuits.

Figure 5. Output Pulse Duration Versus External Timing Capacitance

Output Pulse Duration Versus Supply Voltage

Figure 6 shows the relationship between the output pulse duration and V_{CC} at specific temperatures.

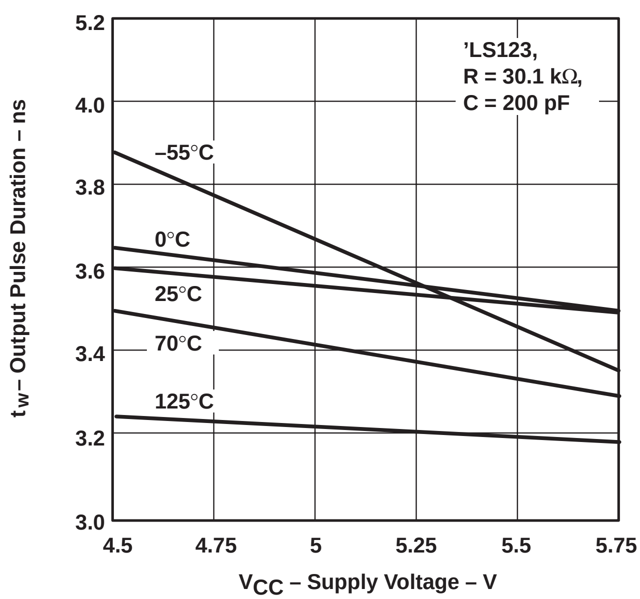


Figure 6. Output Pulse Duration Versus Supply Voltage

Special Considerations

Because these monostable multivibrators are half analog and half digital, they inherently are more sensitive to noise on the analog portion (timing leads) than standard digital circuits. They should not be located near noise-producing souces or transient-carrying conductors and liberal power-supply bypassing is recommended for greater reliability and repeatibility. Also, a monostable should not be used as a fix for asynchronous systems; synchronous design techniques always provide better performance. For time delays over 1.5 s or timing capacitors over 100 μF, it is usually better to use a free-running astable multivibrator and a couple of inexpensive decade counters (such as a 7490A) to generate the equivalent of a long-delay one-shot. Astable oscillators made with monostable building blocks have stabilities approaching five parts in 100 and should not be used if system timing is critical. Crystal oscillators provide better stability.

In all one-shot applications, follow these guidelines:

- Use good high-frequency 0.1-μF (ceramic disk) capacitors, located 1 to 2 inches from the monostable package, to bypass V_{CC} to ground.
- Keep timing components (R_t, C_t) close to the package and away from high transient voltage or current-carrying conductors.
- Keep the Q-output trace away from the $\overline{CLR}$ lead; the negative-going edge when the one-shot times out may cause the C lead to be pulled down, which may restart the cycle. If this happens, constantly high (Q = H, $\overline{Q}$ = L) outputs with 50-ns low spikes will occur at the repetition rate determined by R_t and C_t. If sufficient trace isolation cannot be obtained, a 50-pF capacitor bypassing the C lead to ground usually eliminates the problem.
- Beware of using the diode or transistor protective arrangement when retriggerable operation is required; the second output pulse may be shorter due to excess charge left on the capacitor. This may result in early time out and apparent failure of retriggerable operation. Use a good capacitor, one that is able to withstand 1 V in reverse and meet the leakage current requirements of the particular one-shot.
- Remember that the timing equation associated with each device has a prediction accuracy. Generally, for applications requiring better than ±10% accuracy, trimming to pulse duration is necessary.

Variations in performance versus applicable parameters are shown in Figures 7 through 10.

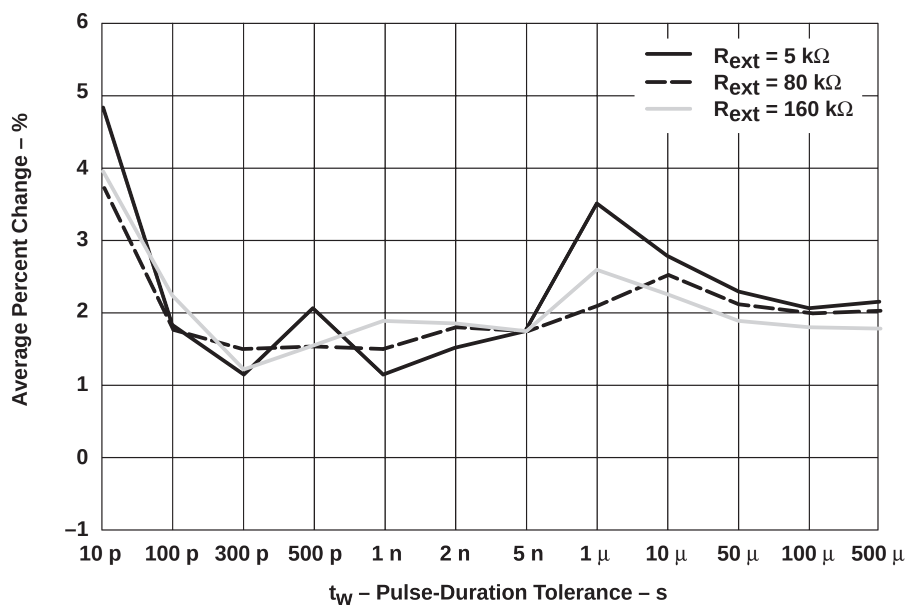


Figure 7. Average Percent Change Versus Pulse-Duration Tolerance

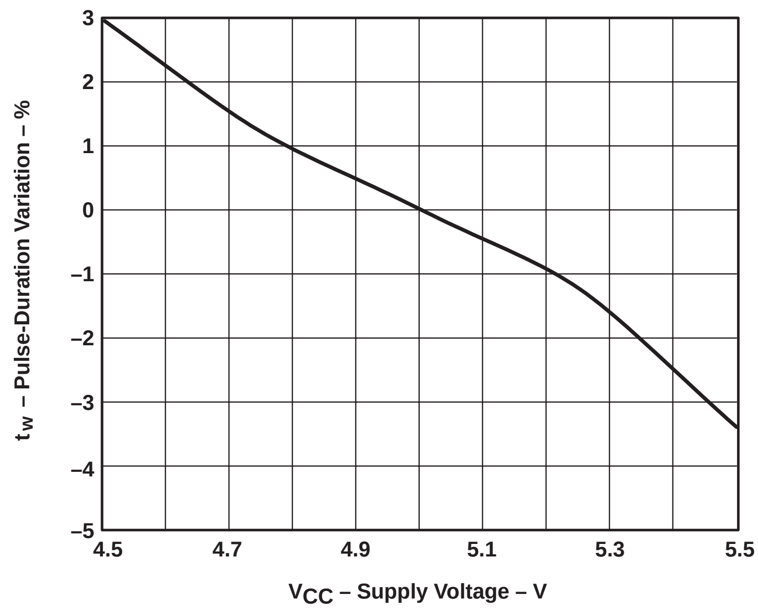


Figure 8. Pulse-Duration Variation Versus Supply Voltage

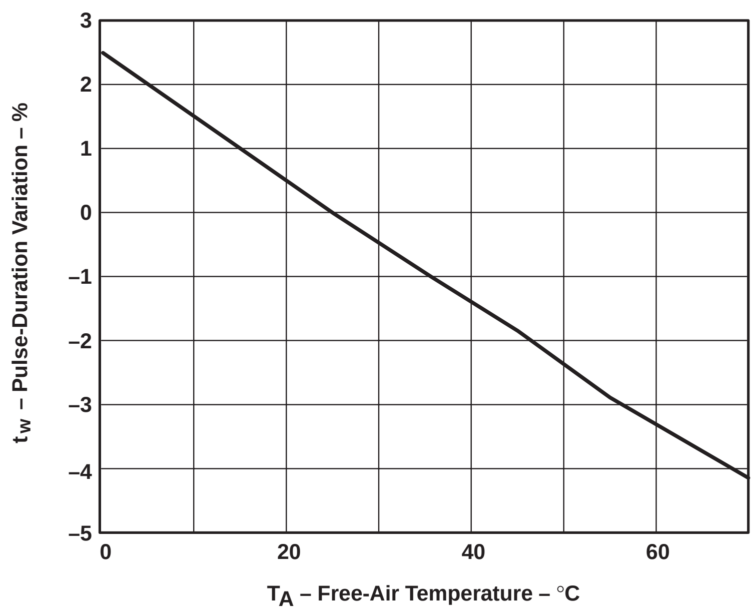


Figure 9. Pulse-Duration Variation Versus Free-Air Temperature

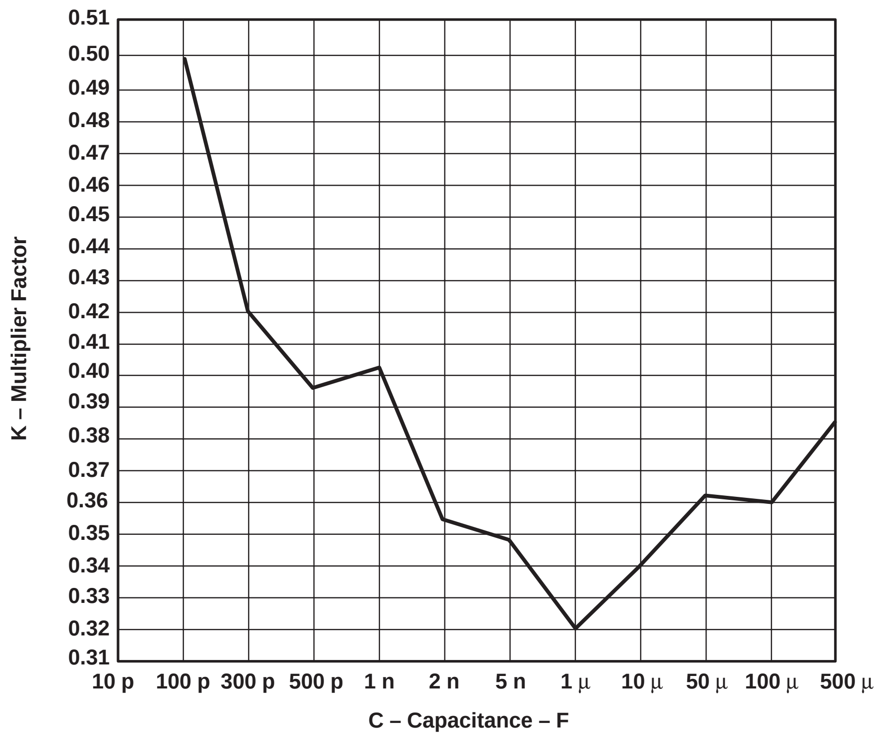


Figure 10. Multiplier Factor Versus Capacitance

Device-to-Device Variation

Device-to-device variation is always a concern with designers when using a part such as the ’LS123. The data in Table 1 were taken in the laboratory using three external-resistor (R_{ext}) values. Ten devices were tested, using three different date codes, and using 12 different external capacitor (C_{ext}) values. Each column was averaged and that number considered a target value, and the high and low values considered the + and – percentage change from that value. These results indicate that the average percentage change from the target value probably should not exceed ±5%. This should not, however, be interpreted as an ensured parameter. This parameter is not tested by TI.

Table 1. 74LS123N/J Device-to-Device Variation

Example 1. Conditions: T_A = 25°C, Ten units, R_{ext} = 5 kΩ (4.96 kΩ), Capacitances (as listed)

. . . . ns . . . . X . . . . ms

C_{ext} UNIT		10 pF	100 pF	300 pF	500 pF	1000 pF	2000 pF	5000 pF	1 µF	10 µF	50 µF	100 µF	500 µF
	1.	80	250	615	960	2100	3450	8400	1.88	19.8	95.4	213	851
	2.	83	255	615	960	2100	3400	8500	1.94	20.2	97.2	217	866
	3.	84	255	625	970	2150	3450	8400	1.86	19.7	95.2	213	848
	4.	88	260	630	980	2150	3500	8600	1.88	20	96.6	216	860
	5.	88	255	620	970	2100	3450	8400	1.88	19.9	95.8	214	853
	6.	86	260	620	970	2100	3450	8500	1.9	20	96.4	215	856
	7.	82	255	620	970	2100	3450	8400	1.87	19.6	95.2	213	850
	8.	83	260	615	940	2100	3450	8500	1.95	20.4	97.7	218	867
	9.	82	250	615	960	2100	3400	8300	1.82	19.3	93.2	209	830
	10.	87	260	630	980	2150	3500	8500	1.89	20	96.5	216	859
AVG		83.7	255	620.5	965	2115	3450	8450	1.888	19.89	95.92	214.4	854
MAX		88	260	630	980	2150	3500	8600	1.95	20.4	97.7	218	867
MIN		80	250	615	940	2100	3400	8300	1.82	19.3	93.2	209	830
%CHG+		5.14	1.96	1.53	1.55	1.65	1.45	1.78	3.28	2.56	1.86	1.68	1.52
%CHG–		4.12	1.96	0.89	2.59	0.71	1.45	1.78	3.60	2.97	2.84	2.25	2.81

Example 2. Conditions: T_A = 25°C, Ten units, R_{ext} = 80 kΩ (80.2 kΩ), Capacitances (as listed)

. . . . µs . . . . X . . . . ms . . . . X . . . . . . s X

C_{ext} UNIT		10 pF	100 pF	300 pF	500 pF	1000 pF	2000 pF	5000 pF	1 µF	10 µF	50 µF	100 µF	500 µF
	1.	0.91	3.9	10	16	33.5	53.5	140	34	325	1.61	3.54	14.7
	2.	0.92	3.9	10	16	33.5	58.5	141	35	334	1.64	3.59	14.9
	3.	0.9	3.9	10.1	16.2	34	59	141	34	329	1.62	3.56	14.8
	4.	0.94	3.95	10.3	16.4	34.5	60	143	34.5	334	1.64	3.61	15
	5.	0.89	3.9	10	16.1	34	58.5	141	34.5	331	1.62	3.57	14.8
	6.	0.915	3.9	10.1	16.2	34	59	142	34.5	333	1.63	3.59	14.9
	7.	0.92	3.9	10.1	16.2	34	58.5	140	34	328	1.61	3.54	14.7
	8.	0.91	3.9	10	15.9	33.5	58.5	141	35	328	1.65	3.62	15
	9.	0.87	3.8	10	15.9	33.5	58	138	33.5	322	1.58	3.48	14.4
	10.	0.91	3.9	10.2	16.3	34.5	59.5	143	34.5	334	1.64	3.61	15
AVG		0.9085	3.895	10.08	16.12	33.9	58.8	141	34.35	331.1	1.624	3.571	14.82
MAX		0.94	3.95	10.3	16.4	34.5	60	143	35	338	1.65	3.62	15
MIN		0.87	3.8	10	15.9	33.5	58	138	33.5	322	1.58	3.48	14.4
%CHG+		3.47	1.41	2.18	1.74	1.77	2.04	1.42	1.89	2.08	1.60	1.37	1.21
%CHG–		4.24	2.44	0.79	1.36	1.18	1.36	2.13	2.47	2.75	2.71	2.55	2.83

Table 1. 74LS123N/J Device-to-Device Variation (Continued)

Example 3. Conditions: T_A = 25°C, Ten units, R_{ext} = 160 kΩ (159.7 kΩ), Capacitances (as listed)

. . . . µs . . . . X ms X . . . . s X

C_{ext} UNIT		10 pF	100 pF	300 pF	500 pF	1000 pF	2000 pF	5000 pF	1 µF	10 µF	50 µF	100 µF	500 µF
	1.	1.79	7.8	20	32	67	117	280	68.9	658	3.23	7.1	29.6
	2.	1.8	7.8	20	32	67	118	280	70.5	672	3.29	7.21	30
	3.	1.78	7.8	20	32.5	68	119	280	69.5	662	3.25	7.16	29.8
	4.	1.85	7.9	20.5	33	69	120	285	70.4	672	3.3	7.26	30.2
	5.	1.76	7.75	20	32	67.5	118	285	70	667	3.27	7.17	29.9
	6.	1.8	7.8	20	32.5	68	119	285	70.4	670	3.28	7.21	30.1
	7.	1.8	7.85	20	32.5	67.5	118	280	68.9	658	3.23	7.12	29.6
	8.	1.79	7.8	20	32	66.5	118	285	71.5	678	3.31	7.26	30.2
	9.	1.71	7.55	20	32	66.5	116	275	67.9	648	3.19	7	29.2
	10.	1.78	7.8	20.5	33	68.5	120	285	70.5	672	3.3	7.26	30.2
AVG		1.786	7.785	20.1	32.35	67.55	118.3	282	69.86	665.7	3.265	7.175	29.88
MAX		1.85	7.9	20.5	33	69	120	285	71.5	678	3.31	7.26	30.2
MIN		1.71	7.55	20	32	66.5	116	275	67.9	648	3.19	7	29.2
%CHG+		3.58	1.48	1.99	2.01	2.15	1.44	1.06	2.35	1.85	1.38	1.18	1.07
%CHG–		4.26	3.02	0.5	1.08	1.55	1.94	2.48	2.81	2.66	2.30	2.44	2.28

Applications

Delayed-Pulse Generator With Override

In Figure 11, the first one-shot (OS_1) determines the delay time by preselected values of $R_{ext}1$ and $C_{ext}1$. The second one-shot (OS_2) determines the output pulse duration by preselected values of R_{ext} and C_{ext}. The output pulse can be terminated at any time by a positive rising pulse into the override input.

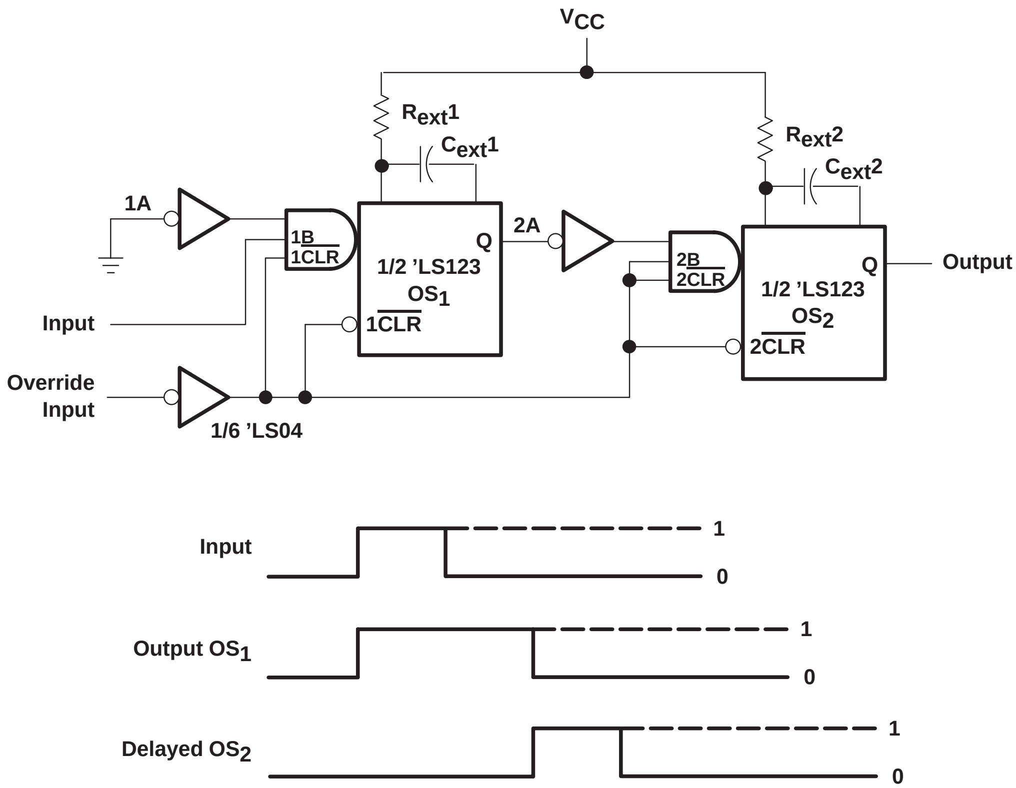


Figure 11. Delayed-Pulse Generator with Override

Missing-Pulse Detector

The pulse duration of OS_1, determined by $C_{ext}1$ and $R_{ext}1$, is set to at least one half the incoming pulse period. The rise of the incoming pulse fires OS_1, producing a high on the Q output. The output of OS_1 remains high as long as there is no missing pulse in the pulse train. Therefore, the one-shot is being retriggered. However, if a pulse is missing from the pulse train, the output of OS_1 falls and OS_2 fires.

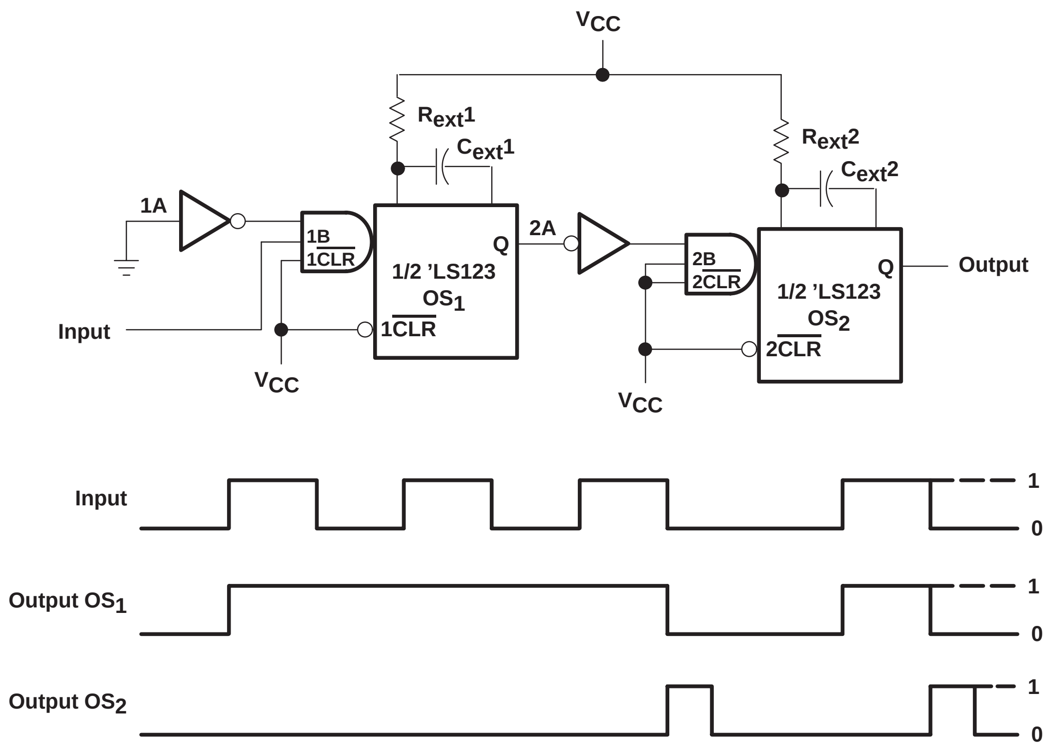
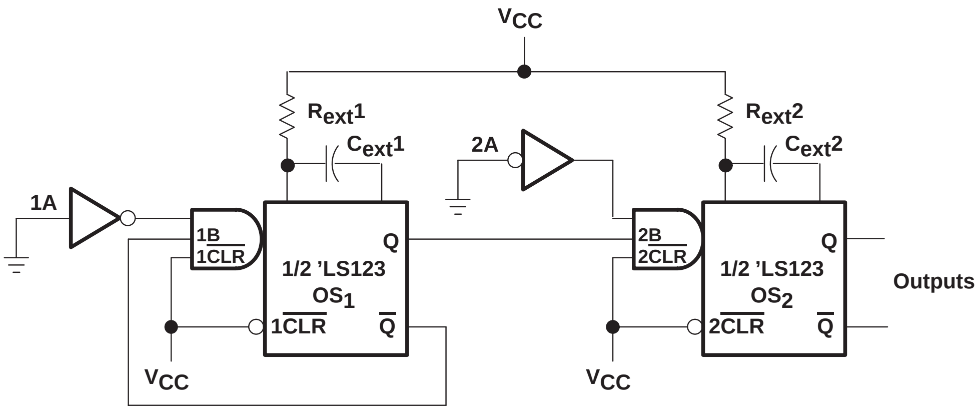
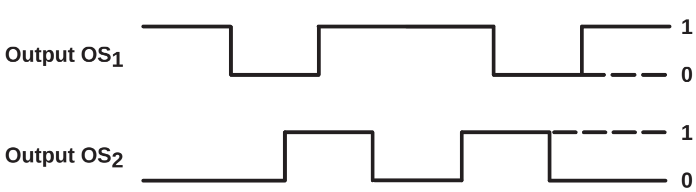


Figure 12. Missing-Pulse Detector

Low-Power Pulse Generator

The output frequency developed by the OS_1 configuration is determined by $R_{ext}1$ and $C_{ext}1$, while the output pulse duration of OS_2 is determined by $R_{ext}2$ and $C_{ext}2$. A low-power pulse generator is shown in Figure 13.





1. Duty cycle of output pulse $= \dfrac{R_{ext}2 \; C_{ext}2}{R_{ext}1 \; C_{ext}1}$

2. $f = \dfrac{1}{K \; R_{ext}1 \; C_{ext}1}$ MHz

   where R_{ext} is in kΩ and C_{ext} in pF.

NOTE: See Figure 4 or 10, as appropriate, for values of K.

Figure 13. Low-Power Pulse Generator

Negative/Positive Edge-Triggered One-Shot

Monostable multivibrators OS_1 and OS_2 arranged in a circuit such that a negative-going input pulse or a positive-going input pulse causes OS_1 (OS_2 disabled) to change states (see Figure 14). The outputs of OS_1 and OS_2 are connected to an OR gate, which outputs a pulse when OS_1 or OS_2 switches. This circuit can also be utilized as a frequency doubler.

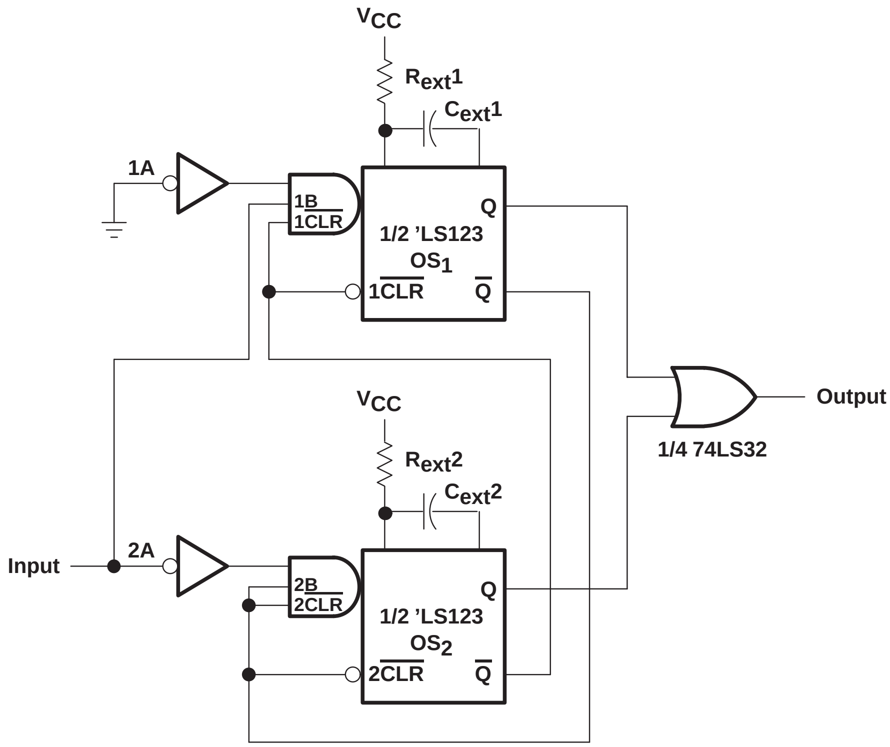


Figure 14. Negative/Positive Edge-Triggered One-Shot

Pulse-Duration Detector

The circuit shown in Figure 15 generates an output pulse (t_3) only if the trigger pulse duration (t_2) is wider than the programmed pulse ($t_w = K \bullet R_{ext} \bullet C_{ext}$) of the ’LS123.

Q_1 is normally off and the A input of the ’LS123 is approximately V_{CC}. The normal Q output of the ’LS123 is low and the Q_2 output is off (the output is normally low because no pullup exists). A trigger of duration t_1 applied at the input is differentiated by the R_1C_1 combination and turns Q_1 on. The result of that momentary condition at the base of Q_1 is a negative-going pulse at point 1 (the A input of the ’LS123), which triggers ’LS123. The ’LS123 remains on for the time $t_w = K \bullet R_{ext} \bullet C_{ext}$, which is waveform t_2. The output of the ’LS123 turns on Q_2 for a time equal to t_2. At the end of t_2, Q_2 turns off. If the input pulse is still high, it appears at the output. The circuit output pulse duration (t_3) equals the input pulse duration minus the pulse duration of the ’LS123.

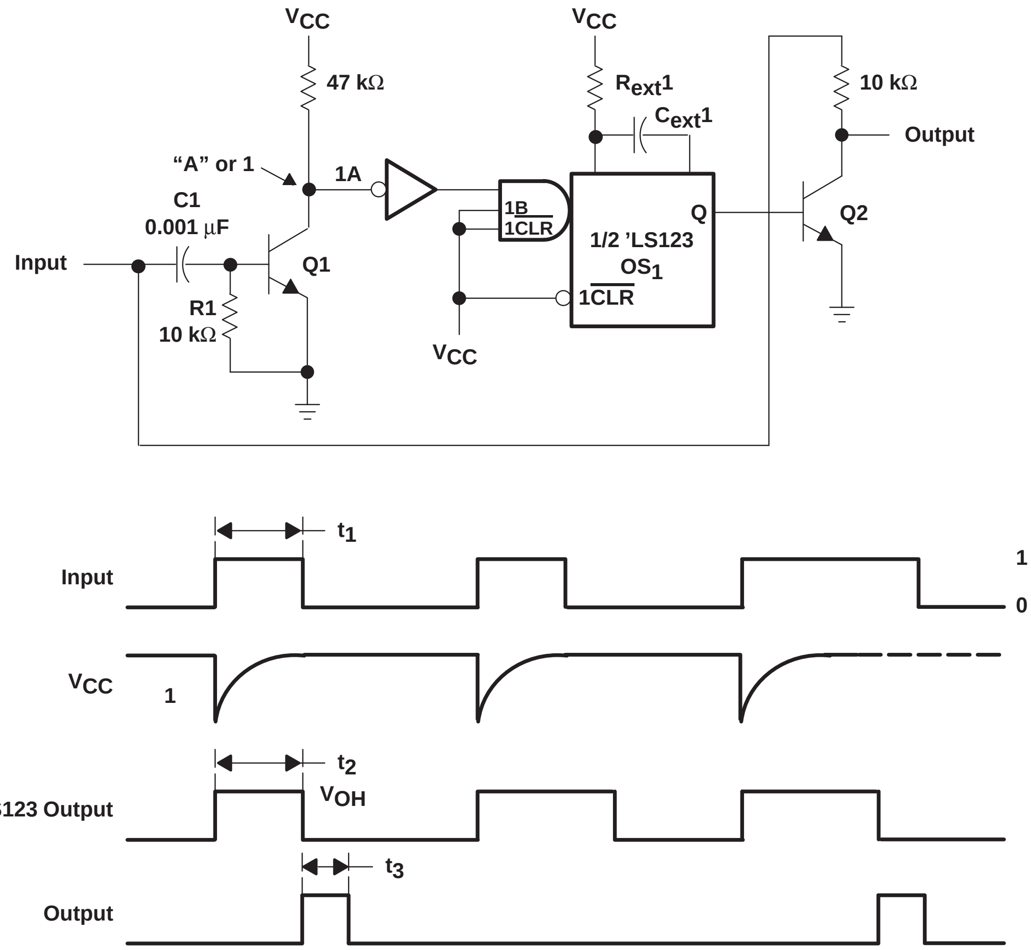


Figure 15. Pulse-Duration Detector

Frequency Discriminator

In Figure 16, R_1 and C_1 form a resistor-capacitor integration network that produces a linear output-voltage curve proportional to frequency over a limited range.

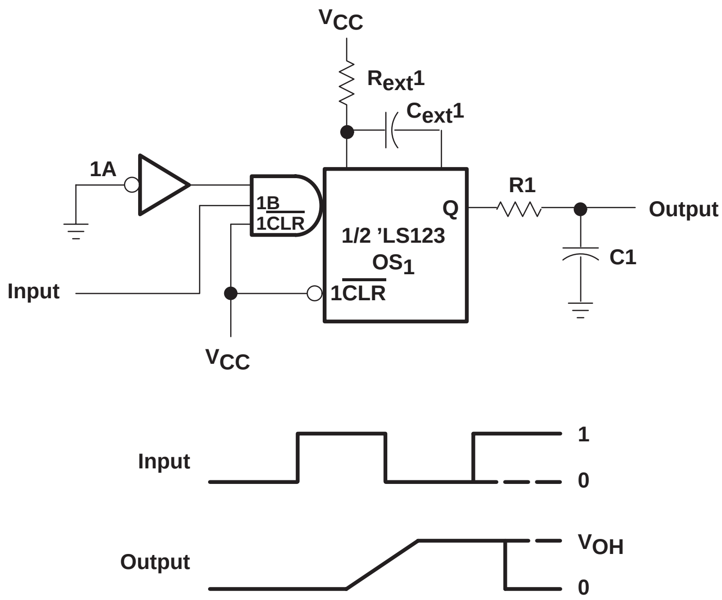
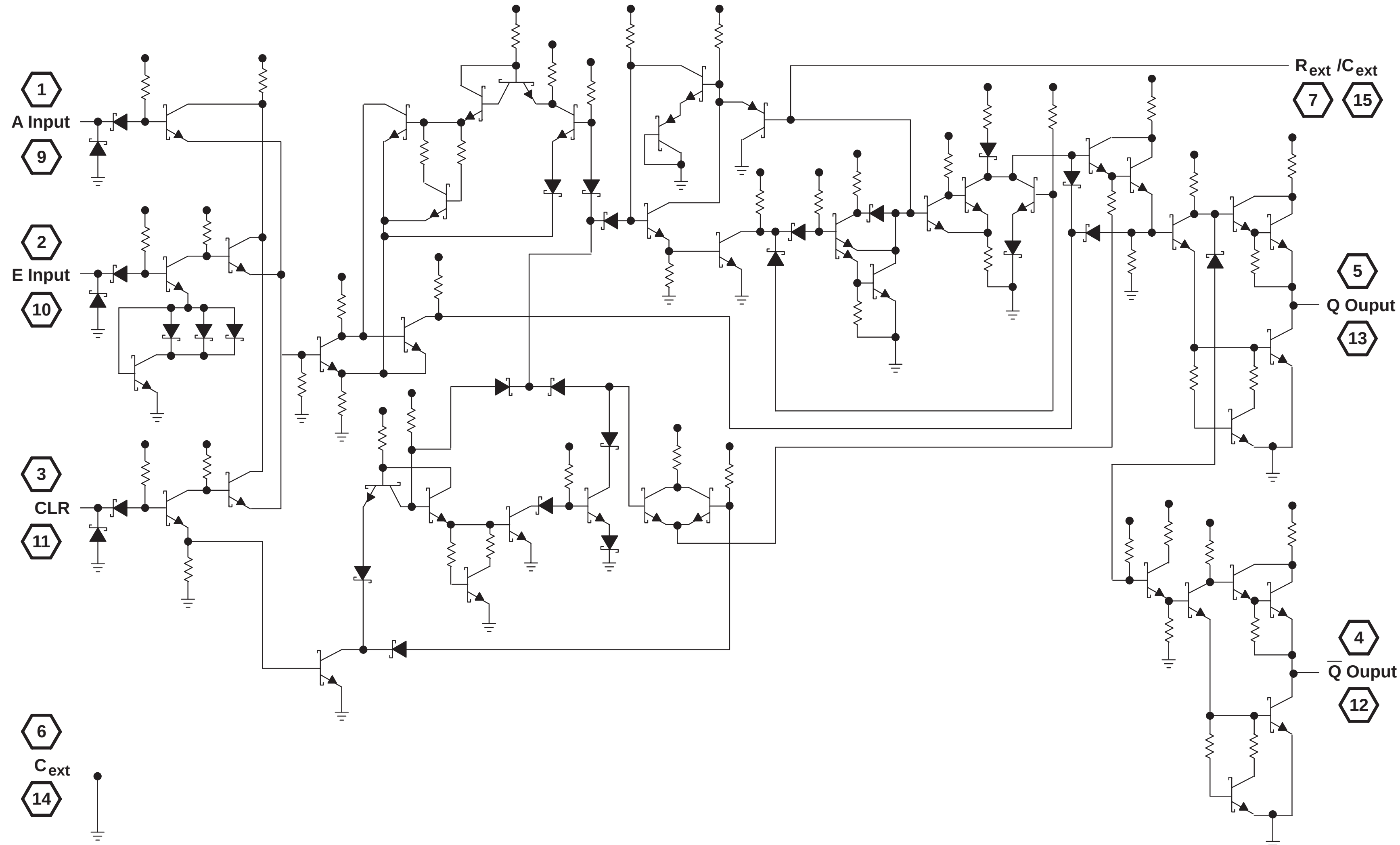


Figure 16. Frequency-Discriminator Circuit



NOTE: For clarity, only one-half of the device is shown.

Figure 17. ’LS123 Schematic