

ON Semiconductor

Is Now



To learn more about onsemi™, please visit our website at
www.onsemi.com

onsemi and onsemi. and other names, marks, and brands are registered and/or common law trademarks of Semiconductor Components Industries, LLC dba "onsemi" or its affiliates and/or subsidiaries in the United States and/or other countries. onsemi owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of onsemi product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent-Marking.pdf. onsemi reserves the right to make changes at any time to any products or information herein, without notice. The information herein is provided "as-is" and onsemi makes no warranty, representation or guarantee regarding the accuracy of the information, product features, availability, functionality, or suitability of its products for any particular purpose, nor does onsemi assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using onsemi products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by onsemi. "Typical" parameters which may be provided in onsemi data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. onsemi does not convey any license under any of its intellectual property rights nor the rights of others. onsemi products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use onsemi products for any such unintended or unauthorized application, Buyer shall indemnify and hold onsemi and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that onsemi was negligent regarding the design or manufacture of the part. onsemi is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner. Other names and brands may be claimed as the property of others.

Characterization of Retrigger Time in the HC4538A Dual Precision Monostable Multivibrator



ON Semiconductor
Formerly a Division of Motorola
<http://onsemi.com>

Prepared by: Douglas M. Buzard, Rodolfo E. Soto

Introduction

The MC74HC4538A is a monostable multivibrator commonly used as a one-shot, or in applications that require a pulse width of reliable dimensions. The pulse width and the minimum retrigger time are usually well behaved over the suggested pulse-width range of 1 μ s to 1 second. However, some customers have found that in using shorter than recommended pulse widths the retrigger time did not behave as it had at longer pulse widths. ON Semiconductor has done an overall characterization of the minimum retrigger time in an investigation of this phenomenon.

The retrigger time is applicable when the device is triggered a second time within the period of the output pulse. When this happens, the output pulse remains high for a period of $\tau + T_{rr}$. The earliest the part can be retriggered, or the minimum retrigger time, is the focus of this characterization. A trigger pulse on A or B inputs before this minimum retrigger time would be ignored.

Analysis and Data

When used in the retriggerable mode (Figure 1), the MC74HC4538A uses an external R_X & C_X to regulate the output pulse width, and the minimum retrigger time (T_{rr}). The minimum retrigger time depends on:

- 1) Time to discharge $R_X C_X$ from V_{CC} to ($V_{ref\ lower} = 1/3 V_{CC}$) $T_{discharge}$. This discharge occurs quickly because external resistance, R_X , does not have any effect on the R_C time constant. The resistance in the discharge path, as seen in Figure 2, is the on-resistance of M3, and the interconnect resistance. The interconnection resistance is dependent on the polysilicon sheet resistance, the metal sheet

resistance, and the contact resistance. The interconnection resistance is heavily process dependent, but fortunately it is small overall and doesn't vary significantly from lot to lot. The discharge time can be computed from:

$$T_{discharge} = \left(\ln \frac{3}{2} \right) \cdot R_i \cdot C_X$$

(Equation 1)

Typically the value of R_i would be near 300 Ω .

- 2) Loop delay ($T_{delay} = \text{constant}$) ranges from 20–60ns, and is strongly correlated to V_{CC} . This is the time for the signal coming from the lower reference circuit to reset the flip-flop, and turn off M3. The amount of the undershoot voltage is a function of the loop delay, and for small values of capacitance the undershoot voltage is well below the lower reference voltage.
- 3) The time to charge $R_X C_X$ from the undershoot voltage back to the lower reference voltage ($V_{ref\ lower}$). This time is given by the $R_X C_X$ transient equation:

$$T_{charge} = R_X \cdot C_X \cdot \ln \left(1 + \frac{3 \cdot V_{undershoot}}{2 \cdot V_{CC}} \right)$$

(Equation 2)

where $V_{undershoot} = (V_{ref\ lower}) - Gnd$. Hence the retrigger time is given by:

$$T_{rr} = T_{discharge} + T_{delay} + T_{charge}$$

(Equation 3)

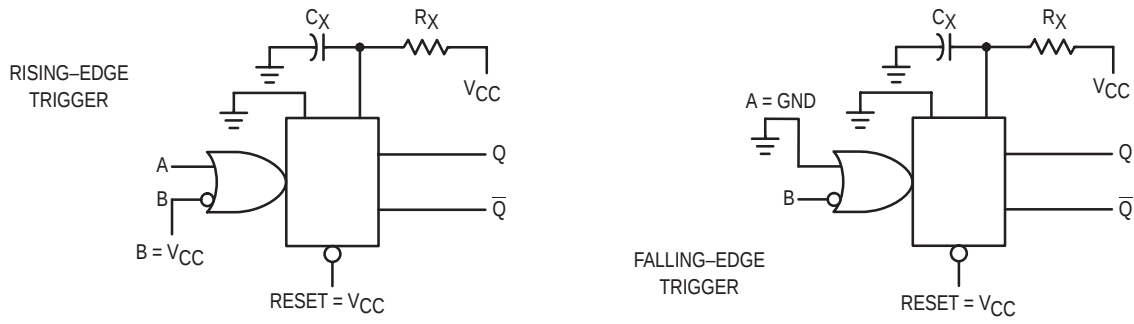


Figure 1. Retriggerable Monostable Circuitry

**LOGIC DETAIL
(1/2 THE DEVICE)**

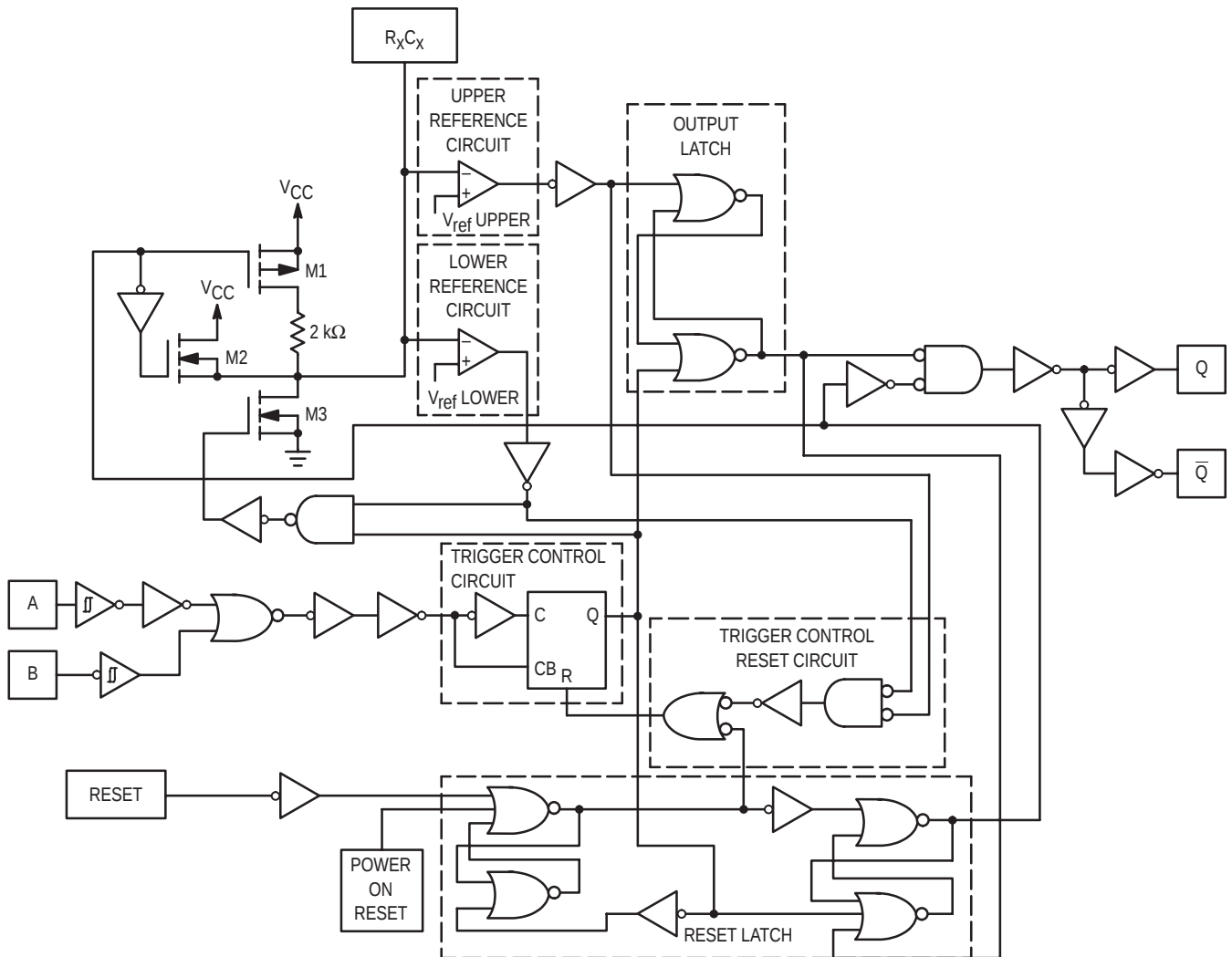


Figure 2. MC74HC4538A Logic Circuit Detail

AN1558/D

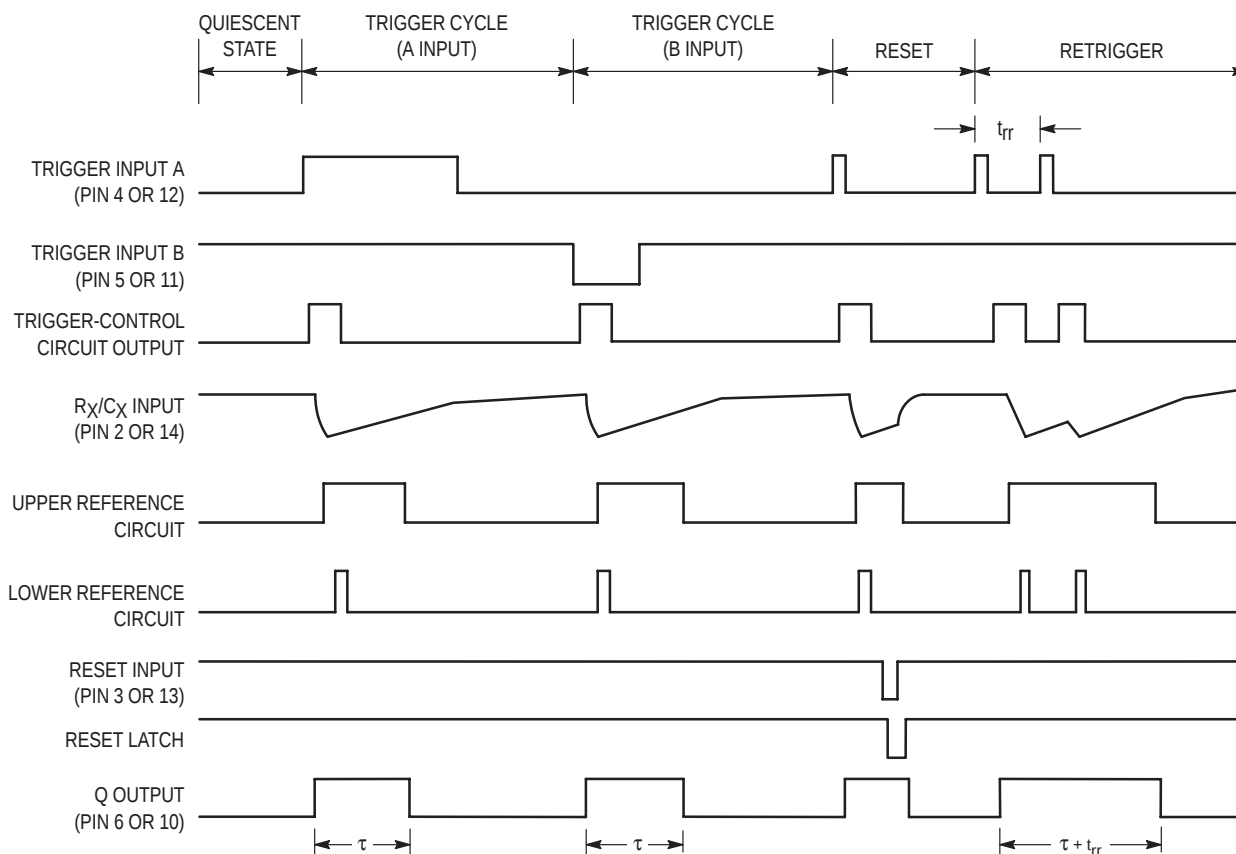


Figure 3. Timing Diagram

Design and Applications

The output pulse width of the HC4538A is determined by the external timing components, R_X and C_X , and can be represented linearly as shown in Figure 10.

The array in Table 1 was generated to make a concise study of the behavior for the retrigger time for short pulse widths. A sample of 10 pieces from each of 7 non-consecutive wafer lots were tested at each condition.

The retrigger time for external capacitance that ranges from $3000\text{pF} < C_X < 4.7\mu\text{F}$, Region 3 on the graphs, can be computed by making use of the following linear equation (Equation 4).

$$T_{rr} = 10^z,$$

$$\begin{aligned} \text{where } z = & \left[-1062.41 - (0.1236764 \cdot V_{CC}) + (1.13509292 \cdot (\log C_X)^3) - (2.875 \times 10^{-17} \cdot R_X^3) + \right. \\ & (3.5256 \times 10^{-16} \cdot (\log C_X)^2 \cdot R_X) + (5.9621 \times 10^{-12} \cdot (\log C_X) \cdot R_X^2) + (4.03306325 \cdot (\log C_X)^2) + \\ & (7.9452 \times 10^{-11} \cdot R_X^2) + (5.1513 \times 10^{-5} \cdot (\log C_X) \cdot R_X) + (0.02312176 \cdot \log R_X) + \\ & \left. (1.8339 \times 10^{-4} \cdot R_X) - (171.91718 \cdot \log C_X) + (4.64784302 \times 10^8 \cdot C_X) \right] \end{aligned}$$

Equation 4. Retrigger Time for $4.7\mu\text{F} > C_X > 3000\text{pF}$

Table 1. Test Matrix

C_X/R_X	10pF	100pF	220pF	1000pF
2K Ω	4.5V	4.5V	4.5V	4.5V
10K Ω	3.0V 4.5V	3.0V 4.5V	3.0V 4.5V	3.0V 4.5V
100K Ω	3.0V 4.5V	3.0V 4.5V	3.0V 4.5V	3.0V 4.5V
1M Ω	3.0V 4.5V	3.0V 4.5V	3.0V 4.5V	3.0V 4.5V

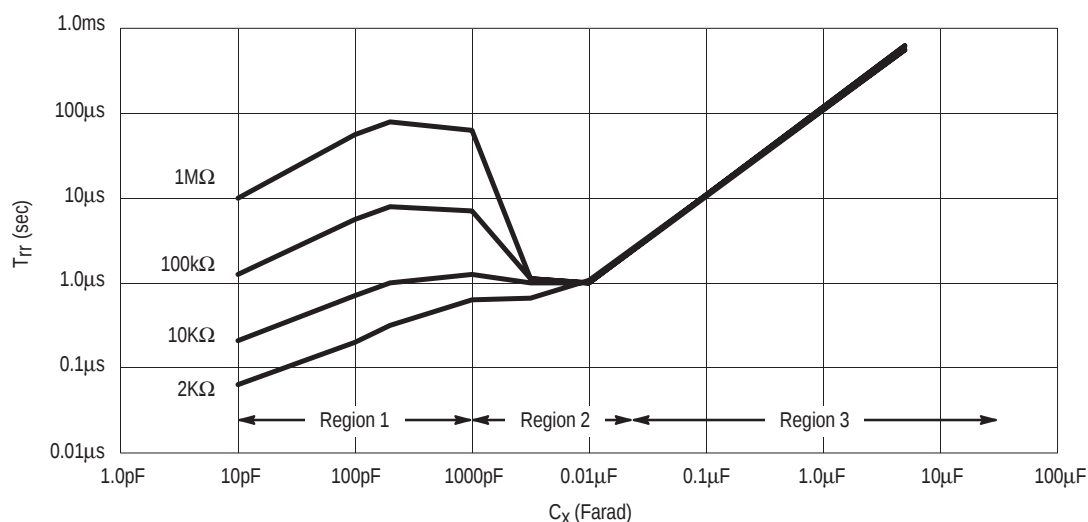


Figure 4. Retrigger Time versus Timing Capacitance at $V_{CC} = 4.5V$

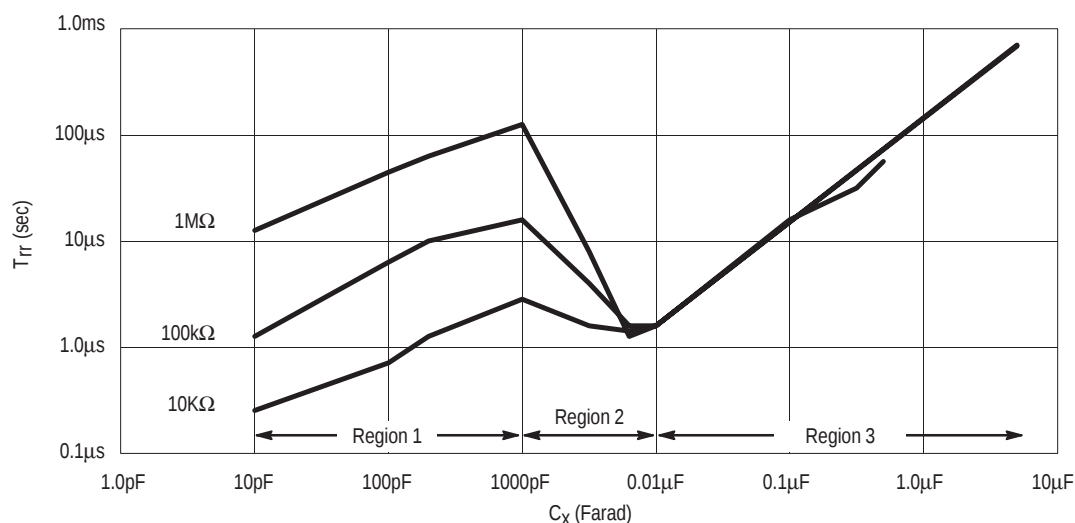


Figure 5. Retrigger Time versus Timing Capacitance at $V_{CC} = 3.0V$

For values of $1000pF < C_X < 3000pF$, the non-linear portion of the curves are converging. In this region, Region 2, the equation was represented by too few measurements to generate a reasonably accurate equation. Therefore, the equation in Region 2 will remain underived. A value may be approximated from the graphs in Figure 4 and Figure 5.

It was determined from experiment and statistical analysis of the data that the retrigger time for small values of external capacitance within the range of $10pF < C_X < 1000pF$, Region 1, can be characterized with the following linear equation (Equation 5).

$$T_{rr} = 10^z,$$

$$\text{where } z = \left[-315.29624 - (0.082881 \cdot V_{CC}) - (0.3146338 \cdot (\log C_X)^3) + 4.3277 \times 10^{-16} \cdot R_X^3 \right] - \\ (3.984 \times 10^{-7} \cdot (\log C_X)^2 \cdot R_X) + (3.0657 \times 10^{-12} \cdot (\log C_X) \cdot R_X^2) - (9.467093 \cdot (\log C_X)^2) - \\ (4.575 \times 10^{-10} \cdot R_X^2) - (1.124 \times 10^{-5} \cdot (\log C_X) \cdot R_X) - (94.092747 \cdot \log C_X) + \\ (1.36599588 \times 10^8 \cdot C_X) - (1.423 \times 10^{-5} \cdot R_X) \]$$

Equation 5. Retrigger Time for 10pF < C_X < 1000pF

Here, the same components of:

$$T_{rr} = T_{\text{discharge}} + T_{\text{delay}} + T_{\text{charge}}$$

(Equation 3)

are still represented, but have become combined by the linear regression. The constant and V_{CC} dependent term still derive from the loop delay, and serve to shift the components along the vertical axis. The major difference between this and the larger values of C_X is twofold.

First, over all of Region 3 the undershoot is effectively 0 volts. This results in T_{charge} not contributing to T_{rr} and the predictable minimum T_{rr} occurring in Region 2.

Second, as we progress to smaller values of capacitance in Region 1, C_X is too small to support V_{reflower} as the charge is drained through M3. This is why the resistance of R_X now plays a role in T_{rr}. This condition creates the undershoot of V_{reflower} and the time of T_{charge} is then controlled by the current through R_X. This is also why as the

value of C_X increases for the same resistance, T_{rr} increases as it takes longer to charge the larger capacitor. For values of R_X > 10kΩ, this increasing undershoot of V_{reflower} and the resultant increase in T_{charge} negates any improvement in T_{rr}.

At small values of C_X, the circuit capacitance will also come into play. The size of the undershoot of V_{reflower} can vary as a function of normal process variance. This will also introduce an uncertainty into T_{rr} for these smaller values. The curves and regression equations here were derived statistically and only represent the mean of the variance in 7 non-consecutive production lots.

This difference in the non-zero value of T_{charge} in Region 1 can also be seen in Figure 6 and Figure 7 as the slope of T_{rr} becomes zero as the undershoot becomes zero.

Also, note that in Figure 8 through Figure 11, this effect has no influence on the Output Pulse Width as the Pulse Width is controlled by R_XC_X and V_{refupper}.

$$\tau = 10^z,$$

$$\text{where } z = \left[-1.0059363 - (7.6336 \times 10^{-3} \cdot V_{CC}) + (0.87653815 \cdot \log R_X) + \right. \\ \left. (0.8635535 \cdot \log C_X) - (9.3203 \times 10^{-3} \cdot \log R_X \cdot \log C_X) \right]$$

Equation 6. Pulse Width

Equation 6 is a linear regression equation for calculating the pulse width and is also made from the data means. From the logarithmic plots in Figure 8 through Figure 11, it can be seen that there is no cubic dependency similar to T_{rr}, even at the small values of capacitance. The pulse width is completely controlled by the relationship between R_XC_X and V_{refupper}. This predictability of the pulse width has tempted some customers into trying to use the part for very short pulse widths. Unfortunately it has also resulted in inconsistent performance for T_{rr}.

Summary

While smaller pulse widths and T_{rr} values can be achieved, selection of the external components must take into account the introduction of undershoot of V_{reflower}.

Also, as we have stated above, as the value of C_X decreases in the non-linear region, the total capacitance becomes more dependent upon internal circuit capacitance. Since the internal circuit capacitance is process dependent, it can vary from lot to lot, and from manufacturing site to manufacturing site. It is for this reason that the device is not recommended to be used in this range, as doing so would potentially result in inconsistent performance over large production runs. The curves represented in this applications note were made using linear regression on a number of lots widely separated in time, but all from the same manufacturing site. As a result, the curves can only be regarded as statistical means, and may not represent the performance of any particular device the customer may encounter.

AN1558/D

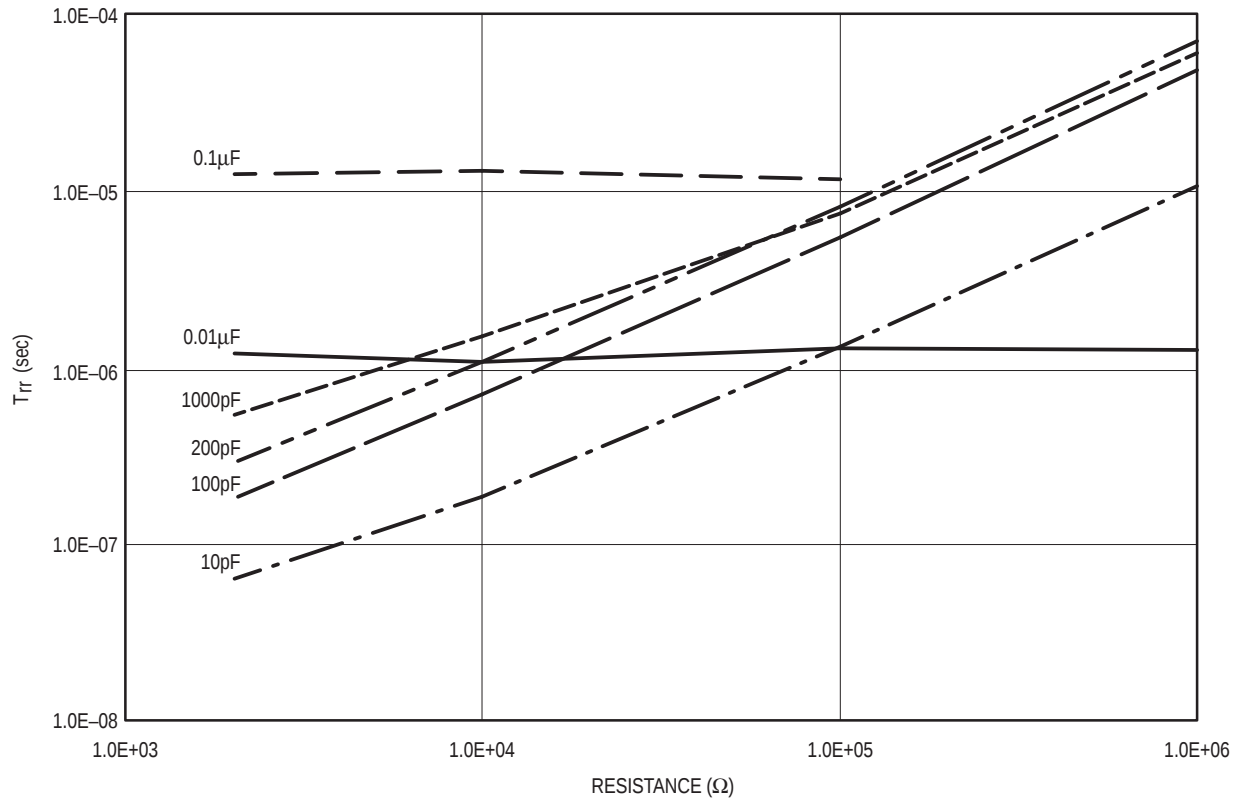


Figure 6. Retrigger Time vs Resistance at $V_{CC} = 4.5V$

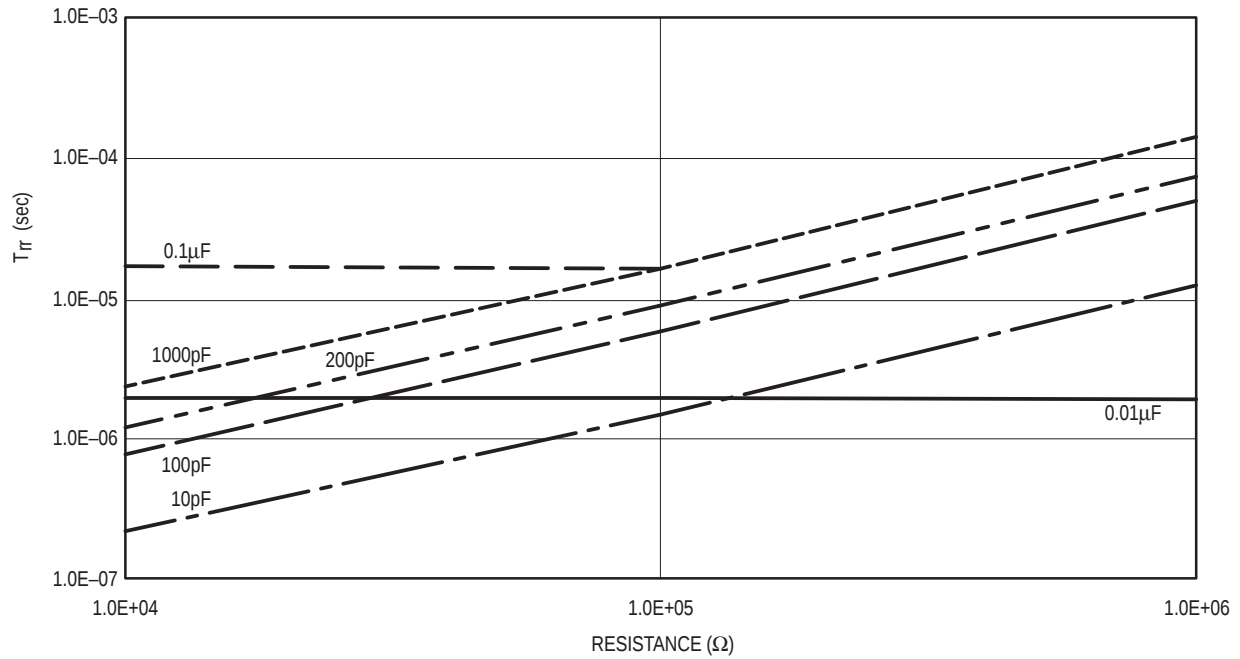


Figure 7. Retrigger Time vs Resistance at $V_{CC} = 3.0V$

AN1558/D

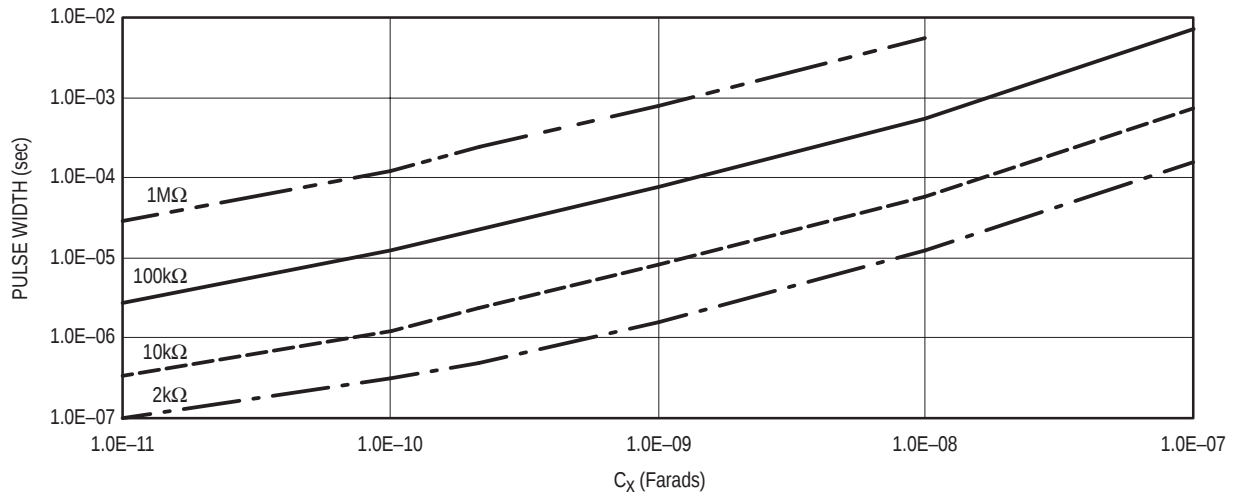


Figure 8. Pulse Width vs Timing Capacitance at $V_{CC} = 4.5V$

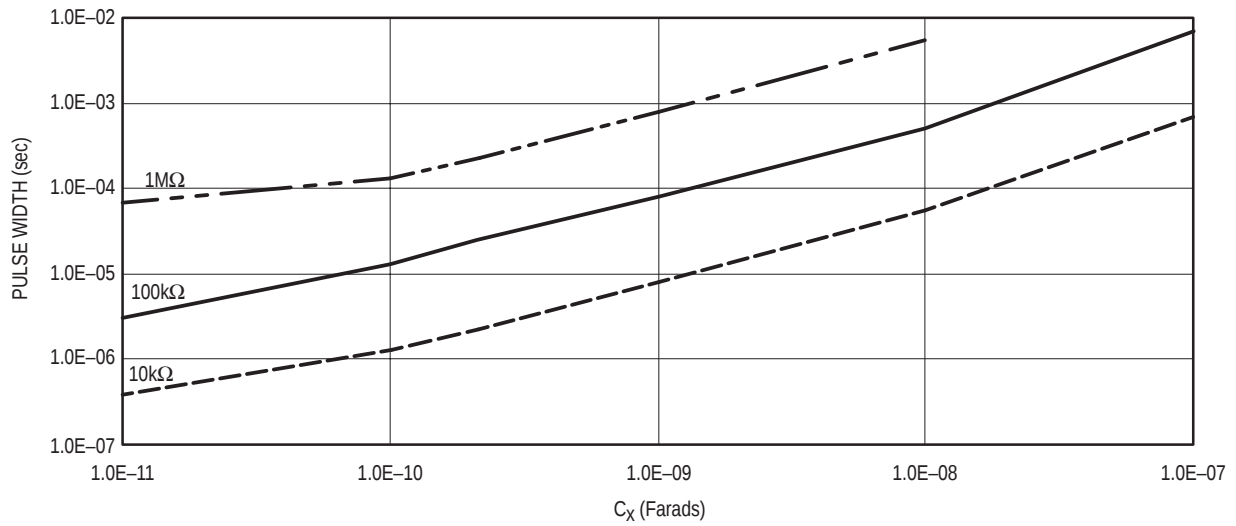


Figure 9. Pulse Width vs Timing Capacitance at $V_{CC} = 3.0V$

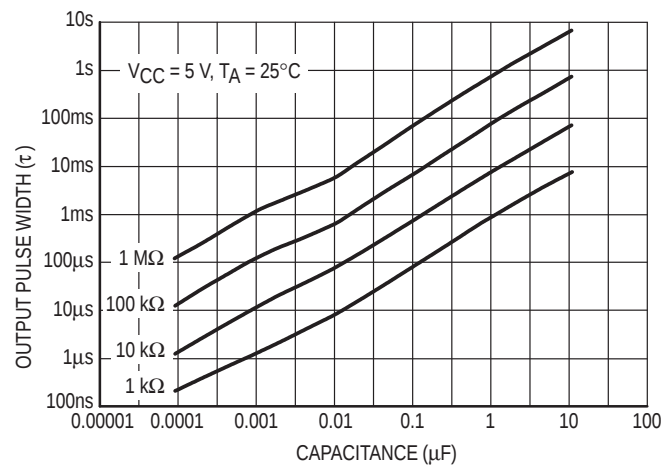


Figure 10. Output Pulse Width vs Timing Capacitance

AN1558/D

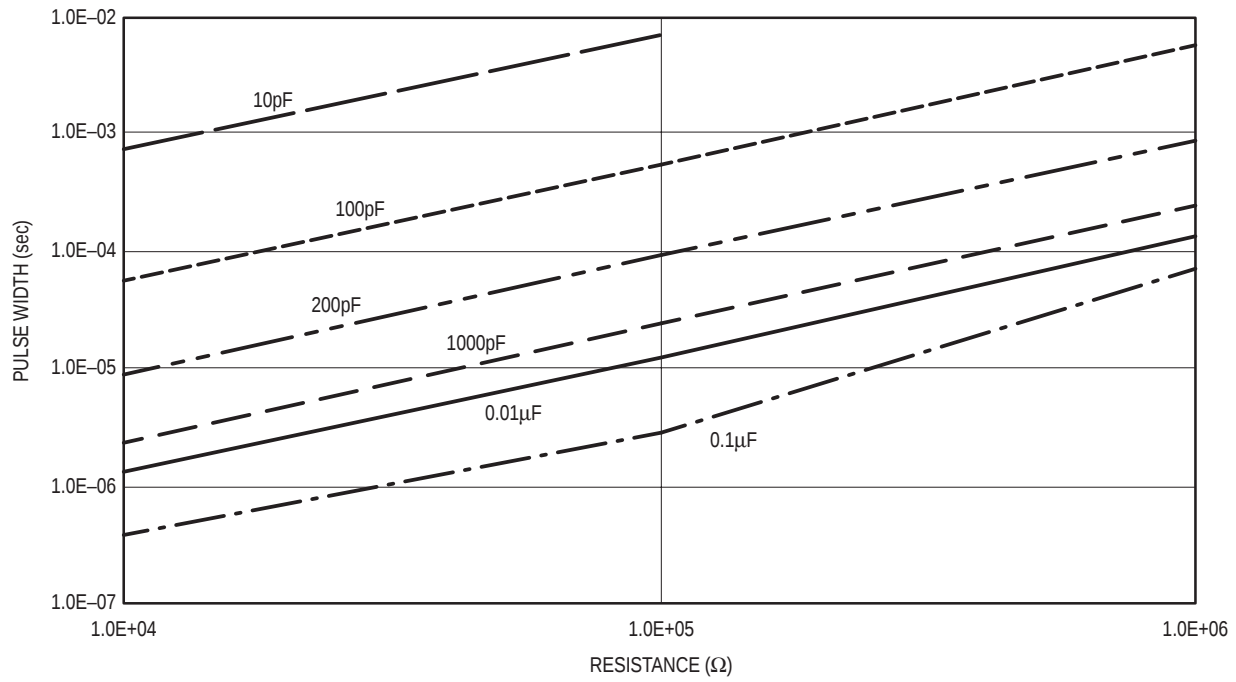


Figure 11. Pulse Width versus Resistance at $V_{CC} = 3.0V$

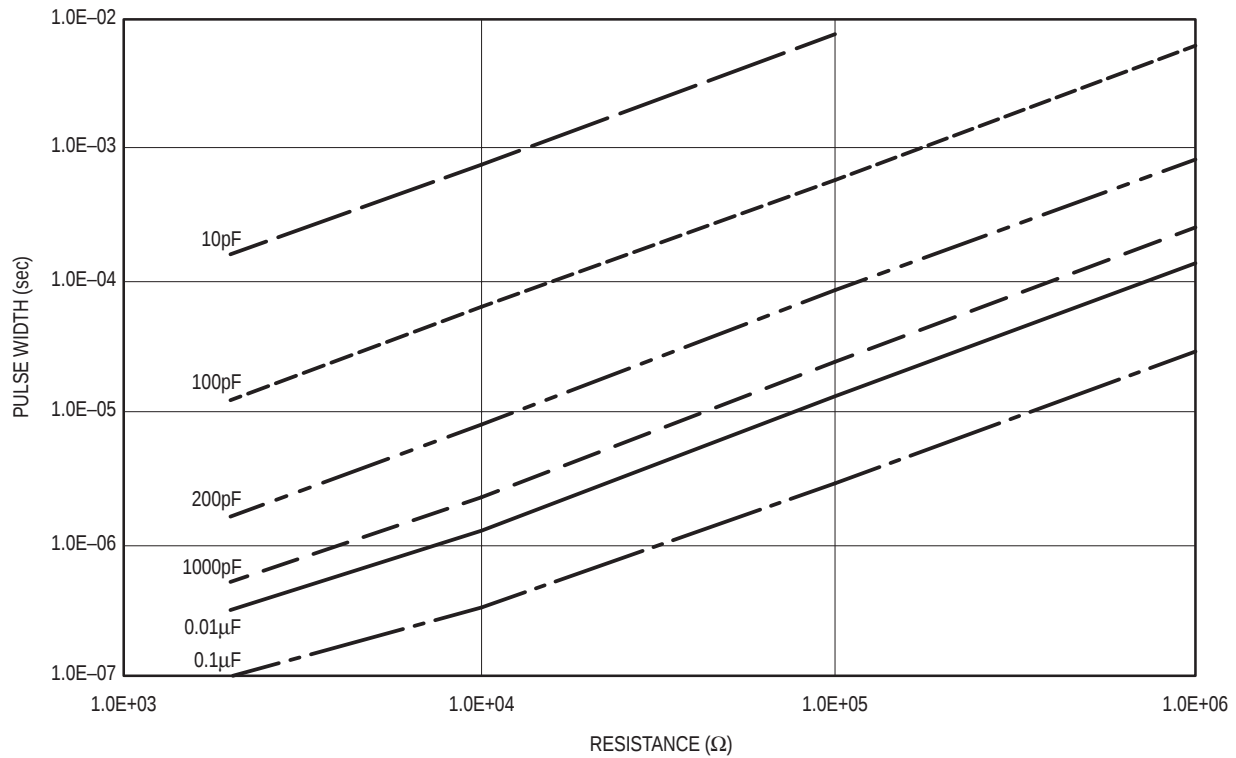


Figure 12. Pulse Width versus Resistance at $V_{CC} = 4.5V$

Notes

Notes

Notes

ON Semiconductor and  are trademarks of Semiconductor Components Industries, LLC (SCILLC). SCILLC reserves the right to make changes without further notice to any products herein. SCILLC makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does SCILLC assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. "Typical" parameters which may be provided in SCILLC data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. SCILLC does not convey any license under its patent rights nor the rights of others. SCILLC products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the SCILLC product could create a situation where personal injury or death may occur. Should Buyer purchase or use SCILLC products for any such unintended or unauthorized application, Buyer shall indemnify and hold SCILLC and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that SCILLC was negligent regarding the design or manufacture of the part. SCILLC is an Equal Opportunity/Affirmative Action Employer.

PUBLICATION ORDERING INFORMATION

NORTH AMERICA Literature Fulfillment:

Literature Distribution Center for ON Semiconductor
P.O. Box 5163, Denver, Colorado 80217 USA
Phone: 303-675-2175 or 800-344-3860 Toll Free USA/Canada
Fax: 303-675-2176 or 800-344-3867 Toll Free USA/Canada
Email: ONlit@hibbertco.com
Fax Response Line: 303-675-2167 or 800-344-3810 Toll Free USA/Canada

N. American Technical Support: 800-282-9855 Toll Free USA/Canada

EUROPE: LDC for ON Semiconductor – European Support

German Phone: (+1) 303-308-7140 (M–F 1:00pm to 5:00pm Munich Time)
Email: ONlit-german@hibbertco.com
French Phone: (+1) 303-308-7141 (M–F 1:00pm to 5:00pm Toulouse Time)
Email: ONlit-french@hibbertco.com
English Phone: (+1) 303-308-7142 (M–F 12:00pm to 5:00pm UK Time)
Email: ONlit@hibbertco.com

EUROPEAN TOLL-FREE ACCESS*: 00-800-4422-3781

*Available from Germany, France, Italy, England, Ireland

CENTRAL/SOUTH AMERICA:

Spanish Phone: 303-308-7143 (Mon–Fri 8:00am to 5:00pm MST)
Email: ONlit-spanish@hibbertco.com

ASIA/PACIFIC: LDC for ON Semiconductor – Asia Support

Phone: 303-675-2121 (Tue–Fri 9:00am to 1:00pm, Hong Kong Time)
Toll Free from Hong Kong & Singapore:
001-800-4422-3781
Email: ONlit-asia@hibbertco.com

JAPAN: ON Semiconductor, Japan Customer Focus Center
4-32-1 Nishi-Gotanda, Shinagawa-ku, Tokyo, Japan 141-8549
Phone: 81-3-5740-2745
Email: r14525@onsemi.com

ON Semiconductor Website: <http://onsemi.com>

For additional information, please contact your local Sales Representative.