Support Note

Contact debounce circuit for switches

WÜRTH ELEKTRONIK

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1 Introduction

Würth Elektronik offers a wide range of switch products. These products are used for many applications to simply open and close electronic circuits.

Figure 1: Part of the WE-switch portfolio

The switching function is mainly mechanical, but many switches are operating like an analog-digital interface for modern electronic circuits, with clearly defined voltage levels for logic 0 and logic 1. But anyone who has built an application with a tact or detector switch with a fast responding electronic circuit may be wondering why the circuit is not working properly. The reason may be what is called contact bouncing (also known as chattering). There are possibilities to eliminate the effects of this phenomena and this application note proposes a circuit to avoid this common issue.

2 What is contact bounce

2.1. Principle of switching mechanics

We naturally have the impression that the contact in a switch is immediate and firm.

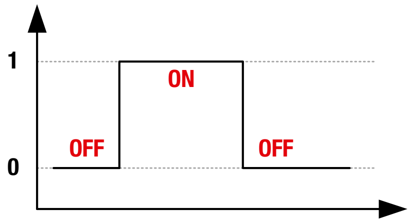


Figure 2: Idealized graph of a switched signal

However, the "reality" looks a little bit different.

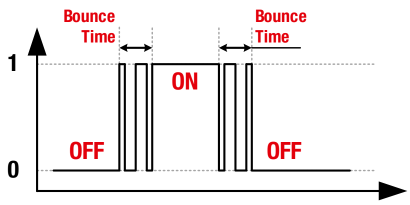


Figure 3: Idealized graph of a "real" switched signal

At each switch position, contact between electrically conductive points is established or separated by means of movable mechanical elements.

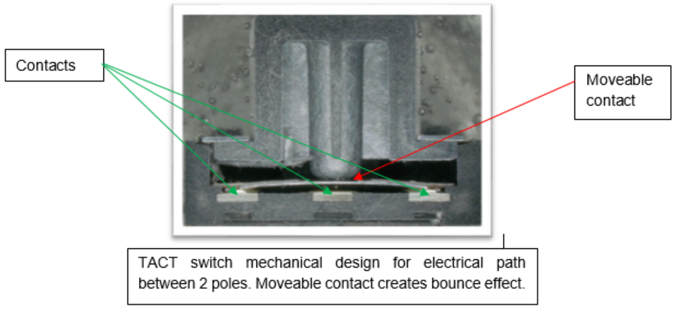


Figure 4: TACT switch design

Typically, spring components are used as transmitters of the nominal state, either as a metal plate or as a coiled spring, which have a certain mass and thus a certain moment of inertia. When these small components are set in motion for a change of state, they are accelerated until they have reached the desired position. There, they experience a reverse acceleration due to the principles of elastic shock and their spring characteristics. This effect occurs several times in succession until the movement is completely damped. As the damping factor is high and the moment of inertia is small, the effect itself typically only takes a few microseconds. This is not problematic for power circuits but this rebounding signal on status change creates bad transitions for a digital input. During the status change, the electronic signal has an unstable or better said undefined status. For a logic IC this can be really problematic, as it needs a clean defined signal. A microcontroller reading the port may miss the changed state if read at the wrong moment. Therefore a solution is needed to generate a clear output from the switch and we will take a look at a switch debounce circuit to solve this problem.

2.2. Applicable products

Debounce time is given in the product datasheet. Würth Elektronik defines bounce time as the time between when the product is mechanically switched and when it is fully electrically switched.

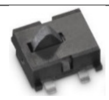
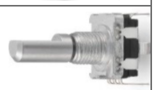
Series		Bounce Time
Tact switch		10 ms
Push button		
Detector		
Mechanical Encoder		

Table 1: Applicable products for debounce circuit

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3 Debounce circuit

In the following we will add some components to create a low pass filter circuit to see the influence on the signal output.

3.1. Adding a filter

The base switch circuit with no debounce compensation circuit looks like the following:

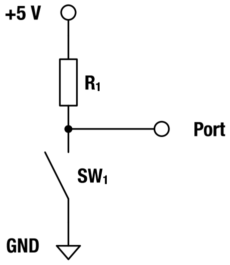

Figure 5: Switch circuit without debounce circuit

Classical values for resistor are R_1 = 1 kΩ to 10 kΩ and V_{CC} = 5 V.

Pushing the switch gives the following switching response that shows the bounce effect:

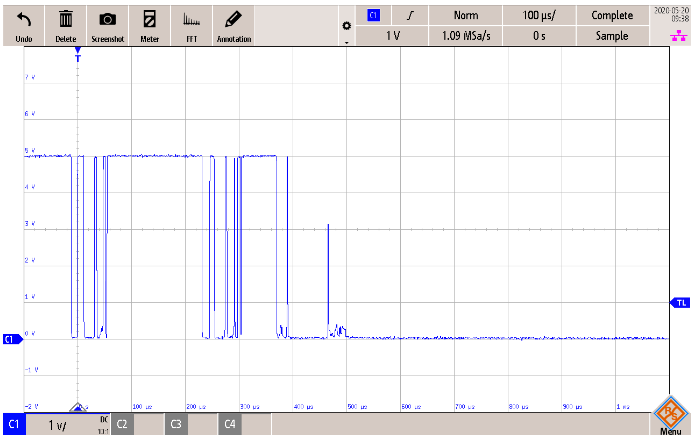

Figure 6: Output without debounce circuit during high to low transition

To solve this bounce in the V_{OUT} signal, a different electronic circuit is proposed. The following electronic circuit, a simple RC filter is one of the cheapest and simplest to realize. When the switch is open the capacitor charges through R_1+R_2 which causes the voltage to rise more slowly. When the switch is closed, the capacitor is discharged through R_2 at a controlled rate.

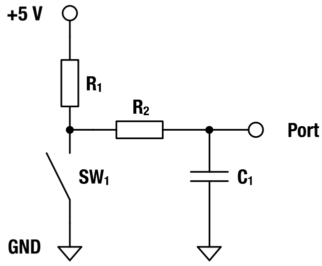

Figure 7: Switch circuit with a basic debounce circuit

When the components are selected carefully, the switch bouncing is absorbed during the charging or discharge period providing a smooth transition.

To calculate the value of capacitor and resistors, we need to know the following time constant formula applicable for this schematic:

$$\tau = (R_1 + R_2) \cdot C_1 \qquad \text{Eq.(1)}$$

τ : time constant in s

R : resistor value in Ω

C : capacitance value in F

The time constant is a balance between the needs to debounce the switch and the required response time of the circuit. During one time constant the voltage will rise to 63% of its final value or fall to 37% of its final value. In both cases, 99% is reached after five time constants.

3.2. Calculation example:

Fixed conditions

- Bounce time: specifications give 10 ms
- R_1 is chosen to limit current, we take the classical value of 1 kΩ.
- R_2: we choose two standard values for debouncing: 10 kΩ and 47 kΩ.
- Supply Voltage is 5 V_{DC}

Therefore, calculation gives two capacitance values:

$$C_1 = \frac{\tau}{R_1 + R_2} \qquad \text{Eq.(2)}$$

And then we propose two value ranges for this circuit:

- Solution 1 : R_1 = 1 kΩ, R_2 = 10 kΩ, C_1 = 1 µF
- Solution 2 : R_1 = 1 kΩ, R_2 = 47 kΩ, C_1 = 220 nF

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For both circuits, the answer becomes like following:

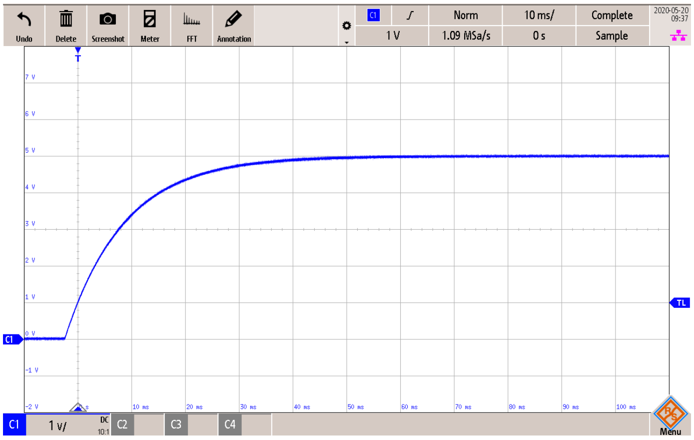

Figure 8: Output with debounce circuit during low to high transition

<u>Note:</u> Resistance and capacitance values, could vary according to customer circuit design

The value of U_{OUT} vs. time is given by the next formula

$$U_{OUT} = U_{IN} \cdot \left(1 - e^{\frac{t}{\tau}}\right) \qquad \text{Eq.(3)}$$

We see that at $t = \tau$, we reach a value of $U_{OUT} \approx 63\ \%\ U_{in}$.

In our example U_{OUT} is at 63 % (3.15 V) of its final value (5.0 V) after 10 ms.

3.3. Adding a diode

It is possible to control the charge time and discharge time separately by adding a diode across R_2. This allows for a faster transition time to charge the capacitor using R_1 and D_1 and a different discharge time using only R_2, as in this case the diode is blocking.

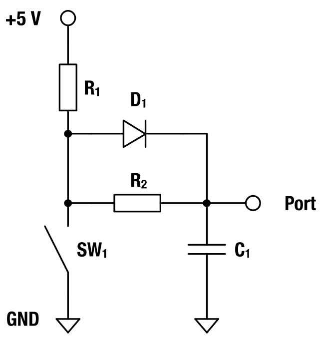

Figure 9: Adding a diode to the schematic

3.4. Adding a buffer

The user must also be aware the digitial logic is defined with zero being below a certain voltage (ie. 0.8 V) and one being above a certain voltage (ie. 2.5 V). The values between are undefined. If the application cannot support the undefined values a Schmitt trigger buffer with hysteresis may be required. A circuit with different switch-on and switch-off times and additional hysteresis is shown in figure 10. The response time of the circuit may have to be coordinated with the sampling time of the microcontroller.

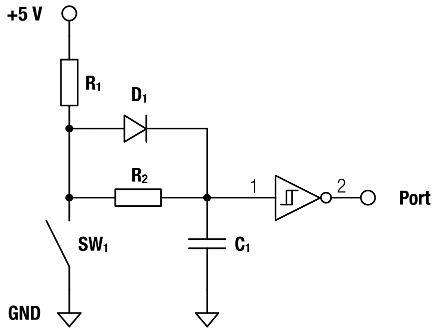

Figure 10: A schmitt trigger enures stable and defined voltage values

3.5. Transient protection

If the switch is located far away or at the end of a long wire, there will likely be a need for protection against overvoltage, ESD or other transients. This can be as simple as a ferrite bead and TVS diode in front of the input circuitry.

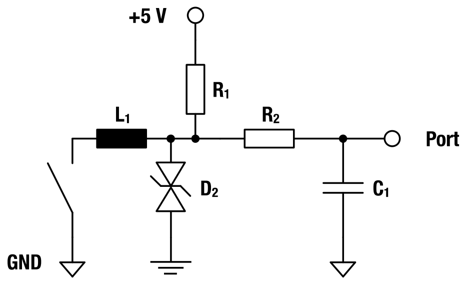

Figure 11: Adding a ferrite bead and TVS diode for overvoltage protection

4 Summary

Using mechanical switch products for signals gives a bounce effect that may cause short periods of unstable signal for an electronic circuit. Würth Elektronik switches have a bounce time of up to 10 ms, which should be considered, depending on the application. Therefore, the proposed filter in figure 7 can help to reduce this phenomena. The filter can also be upgraded with additional components for more refined signal conditioning and overvoltage protection.

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A. Appendix

A.1. References

- Brander, T., Gerfer, A., Rall, B., Zenkner, H., Trilogy of Magnetics, 5th ed., Waldenburg, 2018
- Gerfer, A., Jugy, R., Mroczkowski R., Robok, T., Trilogy of Connectors, 3th ed., Waldenburg, 2015

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