EMBEDIX: Embedded Computer systems

The Mærsk Mc-Kinney Møller Institute
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Robotronix: Fall 2018

Lab assignment 2: Expand the oscillator with adjustable skew and use it to expose a faulty circuit

Abstract

When experimenting with electronics, it is very useful to trigger two events almost simultaneously or with a known delay. This can be achieved by splitting the output of an oscillator in two strands, with slightly different (adjustable) delay.

In this exercise, you will expand your oscillator to produce two almost identical outputs, with the ability to adjust the delay between them with a resolution of +/- a few nanoseconds.

Assignment

Part 1:

Expand, experiment and test you oscillator as follows:

1. Recreate your 1MHz schmitt trigger oscillator using the best possible design learned from last week. Remember proper decoupling, tie unused inputs etc.
2. To support later activities, the oscillator should be equipped with two separate outputs, and allow the phase (time difference) between the two outputs to be adjusted in the range of +/- 10ns, using e.g. a potentiometer (see design tip below).
3. The 'product' of the assignment is:
   - The 2-phase oscillator itself, which will be used next time. TIP: Build it nicely in one corner of the breadboard, using short well ordered wires.
   - A journal that express your work and what you have learned from doing it
   - Compare the real RC step response with the theoretical, and document how the RC response combined with the schmitt trigger levels produce the delay.

Part 2:

The EXOR function is true if the two inputs: A and B are different, else false. Build an EXOR function of the 4 NAND gates in a 74HC/HCT00. Remember a decoupling capacitor of 10-100nF.

Use the 2-phase oscillator to test the 4xNAND gate implementation of an EXOR gate, in order to expose an inherent design flaw that affect the EXOR function when the 2 inputs change (almost) simultaneous:

4. Use a 74HC/HCT00 quad NAND gate to implement an EXOR gate with 2 inputs: A and B, and one output Q.
5. Connect the 2 oscillator outputs to A and B respectively.
6. Show that the circuit is in fact operating as an EXOR gate when the inputs do not change simultaneously … Tip: Choose capacitors for the skew delay, to cause a skew of more than 100ns, in order to create time intervals of 100ns or more, where A and B are clearly different.
7. When A and B switch simultaneous, then A=B, and Q should remain : Q=0. Show that when you adjust the skew within a few (fractions of) ns, you can obtain a situation where this is not the case … the EXOR fails and create short pulses on Q rather than staying at Q=0.
8. The interval of skew where you can provoke the error is quite narrow, from skew_min to skew_max. Ideally, it should be symmetrical around 0ns, but in practice it may be offset. Document the interval width and offset. Speculate on the cause of the offset. If you have time, see if you can change the offset by changing details in your design, e.g. wire length and wire placement.
9. The flaw is due to a “race condition” which is taken care of in commercially available EXOR gates, such as the 74HC/HCT86. Find a 74HC/HCT86 datasheet and compare the designs. If you have time, use the oscillator to test a 74HC/HCT86 and compare.

Reading … a lot is the same as last time

The following is compulsory reading before this lab assignment:

• AN-77	CMOS, The ideal logic family
• AN-88	CMOS linear applications
• AN-118	CMOS oscillators
• AN-140	CMOS Schmitt trigger
• 74HC04	HEX CMOS inverter
• 74HC14	HEX CMOS schmitt trigger inverter
• 74HC00	QUAD CMOS NAND gate
• 74HC86	QUAD CMOS EXOR gate
• Scope-manual	Manual for whatever scope you use

If you are not used to prototyping, please read:

• Wikipedia/breadboard	About Breadboard prototyping
• Wikipedia/perfboard	About Perfboard prototyping
• Wikipedia/soldering	About soldering

There is only time for using breadboards for this exercise, but at some later point you may want to use more rugged techniques for prototyping, such as perfboard, deadbug or PCB's

The following is suggested reading – it may interest you:

• AN-340	HCMOS crystal oscillators
• AP-155	Oscillators for microcontrollers

- https://www.dartmouth.edu/~sullivan/prototyping.pdf

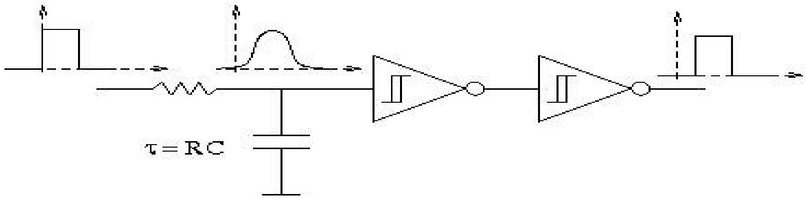
Groups:
You will be divided into a number of groups, by the teachers choice. Each group will perform the assignment together, and hand in the documentation in common, as a group.

Appendix A: Design tips

Here are a few tips:

Creating a delay using a Schmitt trigger.

One of the primary uses of a Schmitt trigger, is it's ability to accept slowly rising input voltages, without risking unwarranted pulses on the output. This feature can be utilized to delay a digital signal, e.g. a clock signal, using a RC low-pass filter.

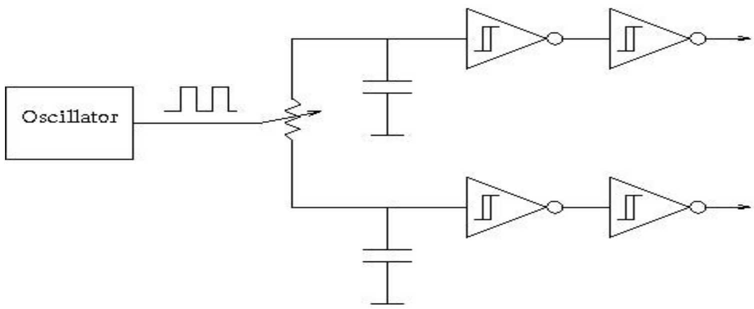


As the low-pass filter will “soften up” the edges of the original square-wave, it will take some time from the square-wave changes between high and low, until the Schmitt trigger input reaches its threshold. This delay will be related to the time-constant of the filter, and can be controlled by the chosen values of R and C.

Adjustable skew

When experimenting and testing digital electronics, it can be very useful to be able to generate two identical clock signals, with adjustable skew. The 'skew” is the difference in timing between two otherwise identical clock signals. In practice, skew can arise because one signal travels a longer distance than the other, or because two signals have different load.

An ordinary clock generator with a single output can easily be upgraded to output two clock signals with adjustable skew, using the following circuit.



Two separate RC delay circuits is connected in parallel, using a potentiometer to form the resistors for the two circuits. The potentiometer is coupled so one resistor increases, as the other decreases. If the potentiometer is set to the middle position, the two circuits are identical, and there will be no skew between the outputs. If the potentiometer is moved, one signal will be delayed more, while the other is delayed less, creating a skew between the two outputs. The adjustable range is controlled by the choice of capacitor and potentiometer values.

Having 2 inverters in series make sure that the output pulses have the same polarity as the original oscillator. In most cases this is irellevant, and 1 inverter to re form a square shape will suffice.

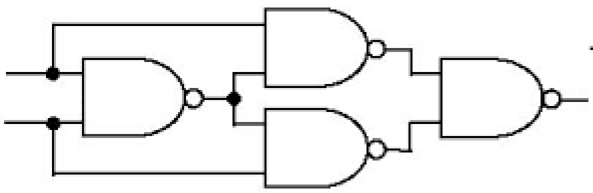
EXOR with 4 NAND gates

This is a classical textbook design of an XOR gate. It is easy to understand how NAND gates can be connected to form the correct logical function.

The circuit is correct from a statical point of wiev, but a dynamic analysis will reveal that it has a design flaw, that will cause it to fail when A and B change state simultaneous.

… So most textbooks will quicly move on to tell you how to use Karnough analysis to identify and deal with race conditions, but you already did that in previous courses, and that is not the point of this exercise. The point is to get experience with experiments that require (almost) simultaneous signal changes.

Exclusive OR (XOR)



A	B	Output
0	0	0
0	1	1
1	0	1
1	1	0