# Coupled Bicores, first experiments

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In the following I will describe a couple of the first results from experiments with coupled bicore oscillators. Except for ‘educational purposes’ (maybe you will learn something like I did) I offer this to you mainly to get some comments: my reasoning and conclusions might not be totally correct everywhere so I hope you will read it carefully and email your questions, comments and suggestions to me at W.J.M.Brok@stud.tue.nl .

The experiments I plan to do involve coupling of a number of suspended bicore oscillators, for example in a linear structure (every oscillator is coupled to two neighbouring oscillators), and see which stable states the system will converge to, or how ‘phase-waves’ will propagate through it. A possible application for this would be an artificial spinal column. Before these rather complex experiments can be done it is useful to have a look at how one oscillator reacts on influences from its environment (another oscillator).

When examining such systems a couple of variables and constants are important: the frequencies of the different oscillators and the phase-differences between the oscillators. Of course specific features of the oscillator are important as well.

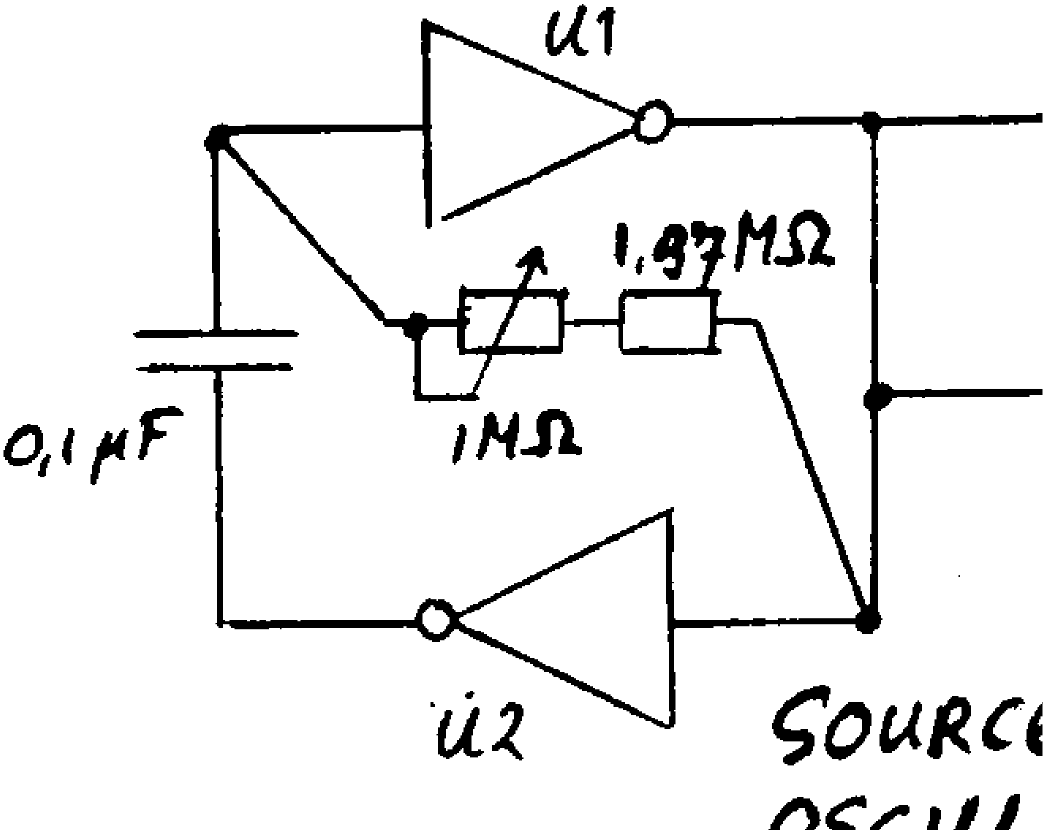
Frequency is a quantity which does not need further explanation. About phase however something more needs to be said, since the way it is defined in this text it is very relevant for the results that are shown later. Phase is defined here as a cyclic quantity that rises from 0 to 1 in one period of oscillation. So at the beginning of a period (the definition of ‘beginning’ will mentioned later) the phase is 0 and at the end of the period it will be 1. The end of a period is the beginning of a new period, so phase 1 equals phase 0. How the phase rises during the period is in general dependent on external influences on the oscillator. For an oscillator which does not experience influences from the outside one can define the rate of change of phase to be constant (the time-derivative of the phase is constant), so the phase then rises in a linear fashion from 0 to 1 during a period of oscillation.

In general one can take the lowest frequency sine-component of the Fourier-series of the waveform to determine phase 0. Phase 0 for the waveform is that moment in time where this sine rises through 0. The argument of the sine is equivalent to argument 0 at that point in time. For the suspended bicore oscillator, which outputs a block-wave, the phase is defined like this to be 0 when the voltage rises from low to high at the output of inverter 1 (which one is inverter 1 and which one inverted 2 is subject to definition, but that does not matter for the rest of the text). So the beginning of a period of oscillation is defined to be the low-high transition.

The graphs shown below are made with a computer program written in Turbo Pascal 7 for DOS to record the experiments. Via a buffer (74HC245) and a MPX (74HC157) the blockwave of the bicore is offered to the parallel port of the computer. The program is configured to read the parallel port every 10 ms and to store that data in an array. When the measurement is finished it calculates the phases of the measured oscillations, stores them in another array, draws a graph of phase or phase-difference as a function of time and stores everything on the harddisk.

In order to calculate the phases an assumption has to be made, since only two phases in every period of oscillation are known precisely: phase 0 at the beginning of the period and phase 1 at the end of it. More information is not available to the program so it has to interpolate between those two phases. The most logical way is to do this in a linear way, but this is not per definition correct: as mentioned before the rate of change of phase does not need to be constant if the oscillator experiences influences.

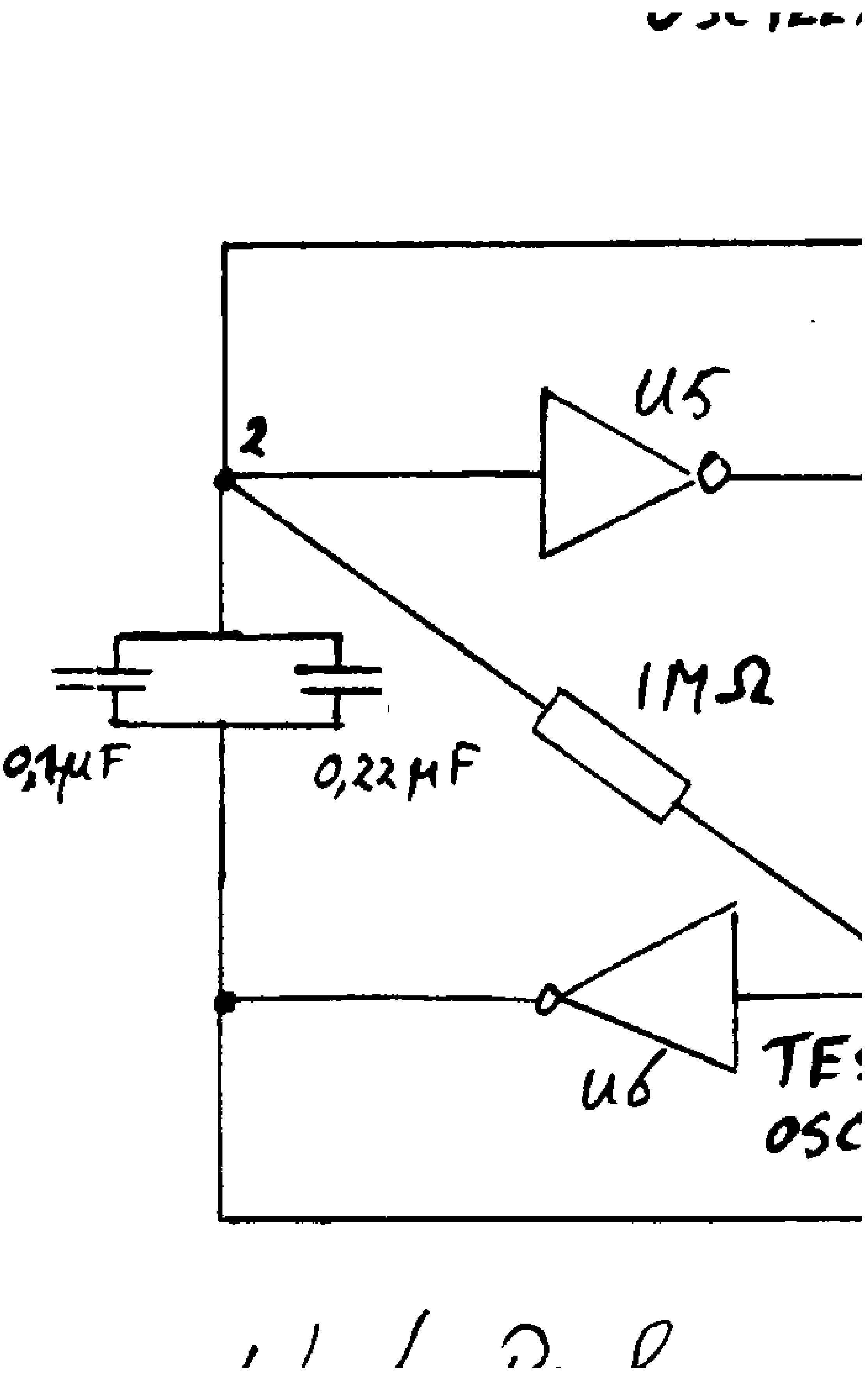
In fig. 1 a drawing of the circuit used for the experiments discussed later is shown. One can see a suspended bicore with only one capacitor: B1. This oscillator is used as a source of blockwaves and can be coupled to the other oscillator via a resistor. The second oscillator, B2, is the one that is subject to the experiments. As one can see the two capacitors are not equal. This is done for two reasons: Like this the oscillator is less sensitive to noise, which undoubtedly is there because of the computer and hobby-powersupply. The fact that the two capacitors are not equal makes the



**Figur**

suspended bicore asymmetric. Because of this asymme
unequal capacitors you can have a look at the suspende

The first graph (graph 1) shown is the graph of the pha
interpolation of it, as explained before. Nothing special
shown just above the horizontal axis.



In the graphs shown in this paper some weird things ar

A note about the vertical axis: it ranges from -1 to 1. Tl
etc.

In graph 2 the phase difference between the source-osc
linearly because the frequencies of the oscillators are n
impression of the difference in frequencies of the oscill

Note that the graph now extends from phase-difference

The first five seconds of graph 3 show what happens if
should be mentioned that the coupling resistor is conne
frequency again. At time t ∪ 15 s the coupling is re-est

There are actually two ways B2 can adjust its phase rel
down is dependent on the phase-difference at the mom

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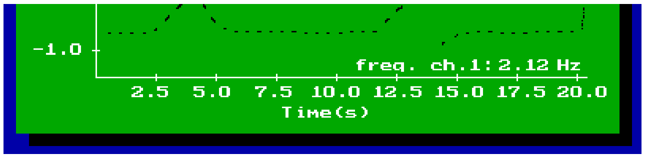
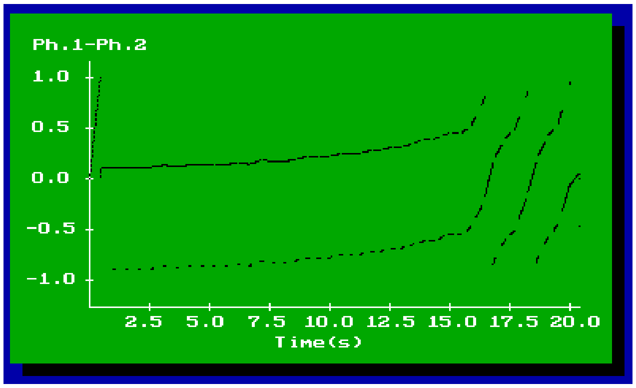


**Graph 4:** **Slowing down and speeding up of B2 when coupling is established.**

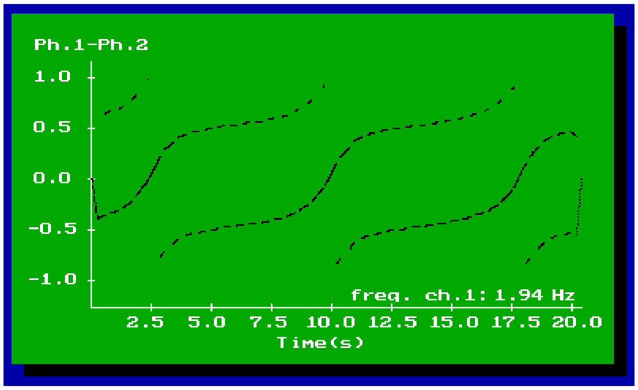
is a specific phase-difference at which it can either speed up or slow down: this also is an equilibrium position, be it an unstable one.

Nothing has been mentioned about the stable equilibrium phase-difference yet: this is dependent on the coupling resistor and the difference in frequencies of the oscillators. An example of the last is shown in graph 5 in which the frequency of the source-oscillator B1 is increased by turning the potmeter (see fig. 1). When the frequency of B1 becomes too large for B2 to follow the phase-difference will do what it does in the last seconds of graph 5: get larger and larger.



**Graph 5:** **Effect on the phase-difference of increasing the frequency of B1.**

A last graph (graph 6) to show even better how complex a coupled suspended bicore oscillator can behave. In this experiment the coupling was connected to biaspoint 2 of the test-oscillator B2: the side of the larger capacitor. Remember that the natural frequency of B1 (determined with graph 1) is 1.88 Hz. As one see the phase of B2 is affected by B1 only significantly when the phase-difference between the oscillators is around 0. This means that rate of change in phase of



**Graph 6:** **Coupling to the biaspoint with larger capacitor.**

B2 under the influence of B1 is a function of the phase-difference of the two oscillators or actually even of the phase of B2: only near those points in time where B2 is about to change inverter-states it is influenced by B1.

At this point I am very curious what you think about the experiments presented to you; please let me know via the email-address shown at the beginning of this document.

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