

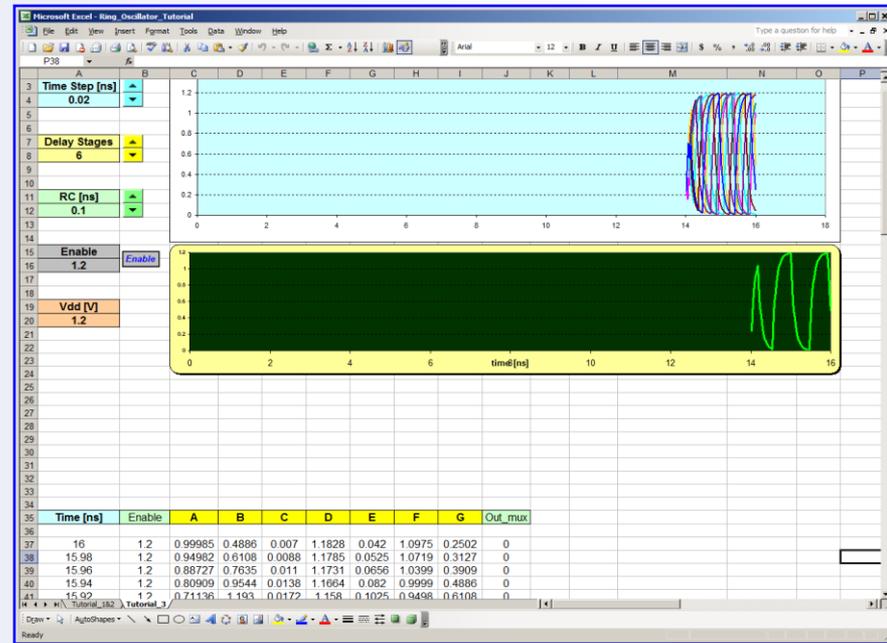
An Interactive Ring Oscillator Model - Part 3

by George Lungu

- This is the third section of the ring oscillator tutorial. In this section the previously created static model is being converted into a hybrid dynamic one by employing an infinite loop “copy-paste” macro.
- A static model is based on a table but in Excel 2003 can have at the most about 65000 rows (time steps). The static model however has the advantage of being the fastest.
- A dynamic model however is based on an infinite loop and despite the fact that it will degrade the simulation speed severely it can run the model for ever, hence it can simulate an infinite number of time steps.
- The best of the two worlds is a hybrid (static-dynamic) model which is a combination of the two models discussed previously. This model has a short table (50-1000 rows) in which the calculations are performed very fast (this table contains the “present” and “recent past” time steps) and once the results are available a macro will copy the results from present and paste them in the past.
- The process is actually like a FIFO stack where all the data in the stack (history) is based on a bunch of calculations happening always at the top of the stack.

Create a new worksheet:

- Copy the existing worksheet into a new one and rename the new worksheet "Tutorial_3":
- In the new worksheet delete everything under row 136 effectively leaving just 100 rows of calculation
- This table of 100 rows represents the simulation of our system over 100 time steps and it is calculated extremely fast because it contains only built-in functions. Let's call this the "present" or the "active calculation area".
- Later during this presentation we will show how to create a macro based on an infinite loop which will take all the calculated new data and paste it (as value) just below this active calculation area into what we call the "past" or the "historical data area".



Create a new relative time data series:

- This dynamic model will run as an infinite loop, therefore the sim. time can reach very large values.
- In order to be able to chart the waveform at any moment and still keep a good and uniform signal representation we will use an "oscilloscope" time display principle, which means that we will have a relative time scale (X) which will always start at zero against which we will plot the signal (Y). We will modify the formulas in column A to achieve this since column A is now used only for waveform display purposes (the data in this column is not used for calculations).
- Let's choose a fixed number of 3000 time steps to be simulated and plotted on the bottom chart (right now you can see 100 of them). The relative time series will be located in the range A37:A3037 => cell A37: "3000*time_step", cell A38 = "A37-time_step" => copy A38 down to cell A3037.

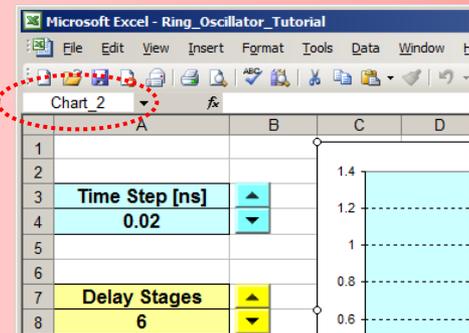
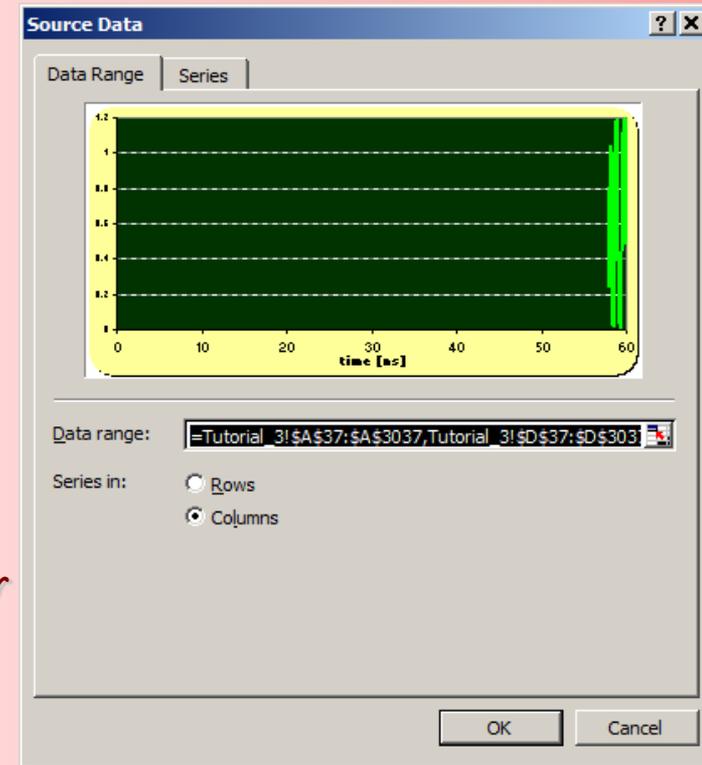
Upgrade the data range of the chart:

- Right click the first chart => Source Data => Data Range => modify the value so that the chart displays 3000 rows of data (=Tutorial_3!\$A\$37:\$A\$3037,Tutorial_3!\$D\$37:\$D\$3037).
- Repeat the same procedure for the second chart so that it displays 3000 time steps

Rename the charts:

- We have provided our model with an adjustable time step, which means that whereas we will keep the minimum X scale of the charts at a firm zero, the maximum X scale will need to change every time we change the time step to reflect the number $3000 * \text{time_step}$.
- If we set the X scale maximum to "Auto" we have no control on the maximum X scale value since Excel will often add some arbitrary blank zone after the maximum X if this maximum is not a round number. This is rather an annoyance and we need to set a firm maximum X scale value equal to $3000 * \text{time_step}$.
- We will first change the names of the charts so that we can use an upgraded "time_step" macro to change the maximum scale value of the X axis for both charts every time we change the time step.
- Bring up the drawing toolbar if you cannot see it at the bottom of the Excel window: View => => Toolbars => Drawing
- Click the white arrow (called Select Objects) in the drawing toolbar. The cursor will turn into a white arrow. Now click on the bottom chart and change its name by typing "Chart_1" in the Name Box situated at the top left of the page.
- Repeat the same procedure for the top chart by selecting it with the white arrow cursor and then typing "Chart_2" in the Name Box situated at the top left of the page. You can now exit Select Objects mode by double clicking any cell.

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Upgrading the “time_step” macro:

- Let's add two more lines of code to the “time_step” macro so that after the macro adjusts the value of the time step in cell [A4] it will also adjust the max X scale for both charts so that it has no “dead zone” after displaying 3000 pints of data.

```
Private Sub time_step_Change()  
    [A4] = time_step.Value / 50  
    ActiveSheet.ChartObjects("Chart_1").Chart.Axes(xlCategory).MaximumScale = 3000 * [A4]  
    ActiveSheet.ChartObjects("Chart_2").Chart.Axes(xlCategory).MaximumScale = 3000 * [A4]  
End Sub
```

The “Start-Pause” macro:

- 100 steps of static formulas will be combined with a macro which turns the model into a dynamic one based on a copy-paste infinite loop. Each loop iteration will shift the simulation result data 100 steps down (in the past) making room for new calculations.

- The Boolean variable “s” helps give the “Start_Pause” button a toggle effect. The value of this variable determines the conditional “Do” loop to either run (for s=True) or stop (for s=False) the macro. Whenever the button is clicked, variable “s” will toggle and so will the operation of the

macro, in other words if the macro runs, clicking this button will pause the macro and vice versa.

- The “Start_Pause” macro, once started, will copy 100 time steps of present and 2800 time steps of history information and paste it 100 cells down (in the past). It will do this operation repeatedly in a loop creating a time rolling simulation environment in which only the last 3000 time steps of information are stored in tabular form and can be plotted. The plot is dynamic and you can see the effect of any change in input parameters on the waveforms.

```
Public s As Boolean
```

```
-----  
Sub Start_Pause()
```

```
s = Not (s)
```

```
    Do Until s = False
```

```
        [B137:J3037] = [B37:J2937].Value
```

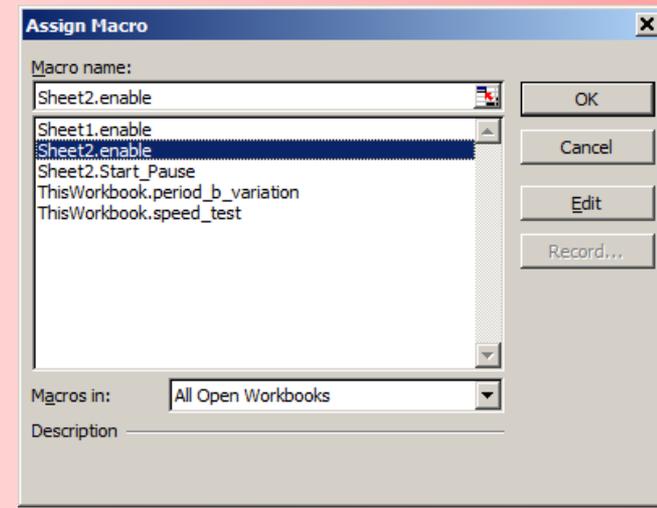
```
        DoEvents
```

```
    Loop
```

```
End Sub
```

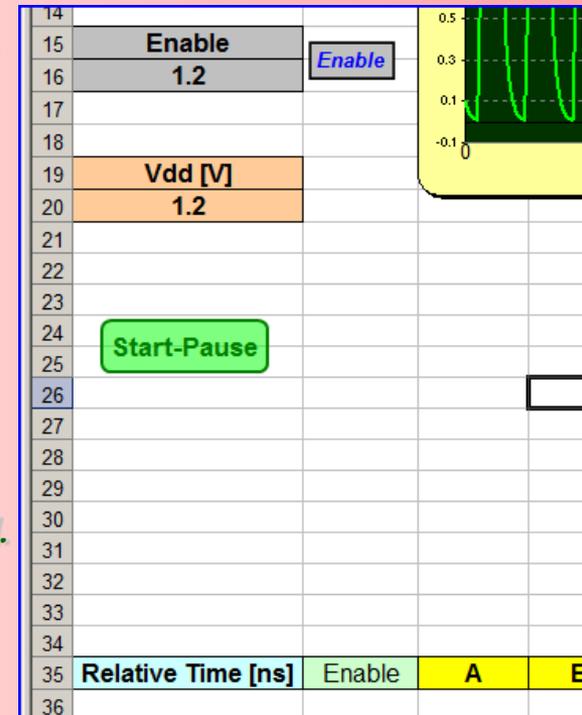
Assign the proper macro to the "Enable" button:

- When we copied the workbook, all the spin buttons were by default assigned with the new macros (which is great) but if in the old worksheet there is a shape (not a button) that was assigned a macro, the same shape in the copied worksheet will still have the old macro (belonging to the original worksheet) assigned to it.
- Because what was said before we need to reassign the "enable" macro from the new worksheet ("Tutorial_3") to the new "Enable" button.
- Right click the "Enable" button => Assign Macro => Sheet2.enable



Create a button and assign the "Start-Pause" macro to it:

- In the draw menu palette select Autoshapes => Basic Shapes => Rounded Rectangle.
- Format the button to your taste and make sure to add the following text: "Start-Pause" centered within the shape
- Right click the "Start_Pause" button => Assign Macro => Sheet2.Start-Pause

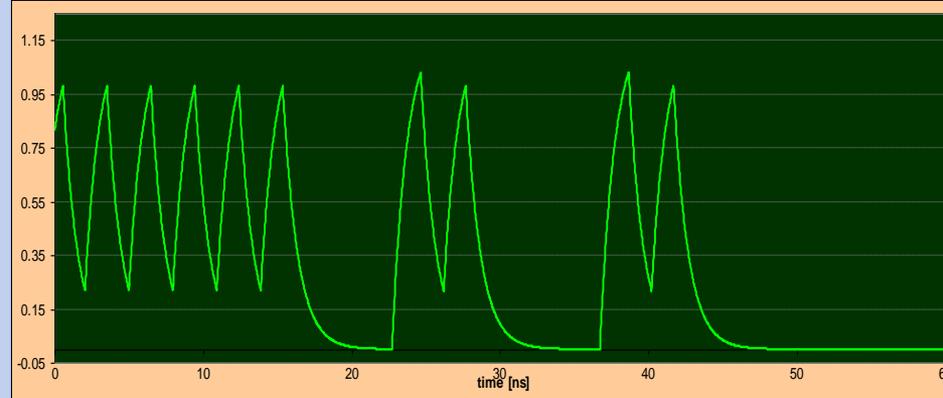
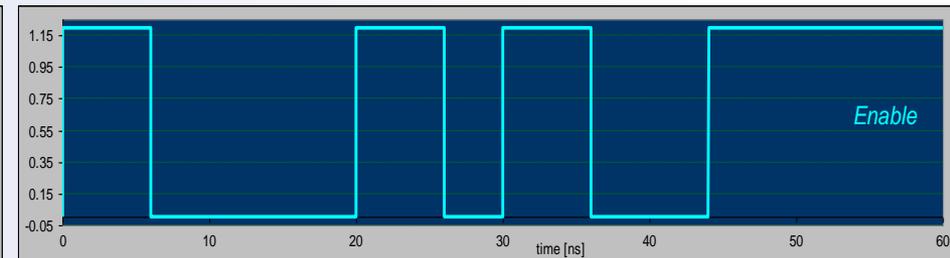
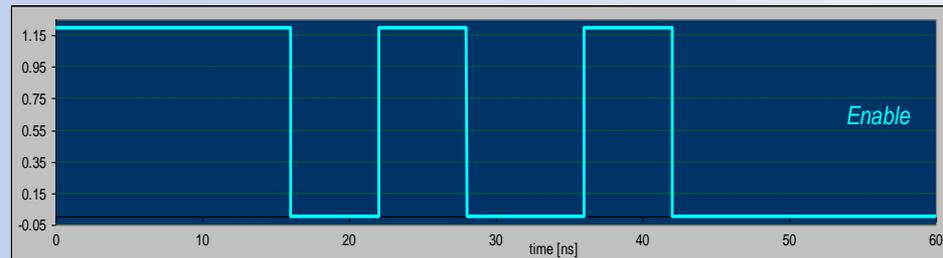


Readjust the charts:

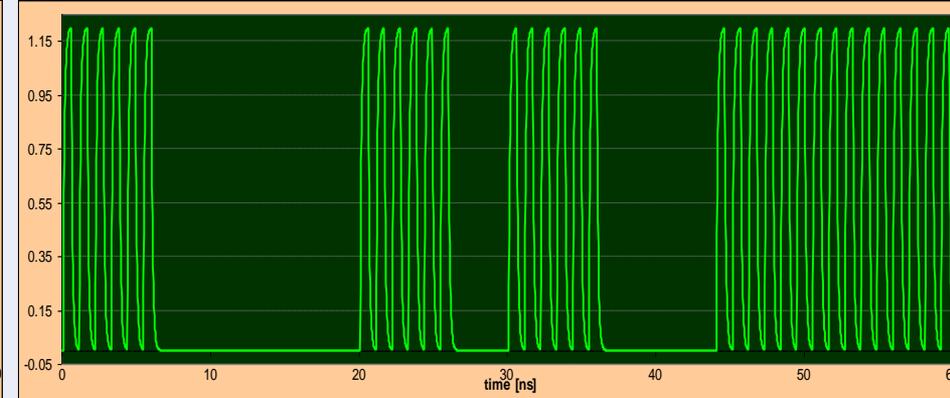
- Format both charts so that the vertical (Y) axes have scales ranging from -0.05 to 1.25V so we can see the extremes of the waveforms well.
- We are trying to make this model as fast as possible in case that we need to run the demo on a slow computer or in case we use a more recent (and slow) version of Excel. This being said let's replace all the series from the upper chart with a single one, the "Enable" series.

Test the model:

- We can start the model by clicking the "Start-Pause" button the quickly toggle the "Enable" button so we verify the functionality of the gating feature. Don't forget to change the number of stages and the RC constant to check the influence of these parameters on the oscillation period.



Delay stages = 3, RC = 1ns



Delay stages = 7, RC = 0.1ns

The next (and last) tutorial will create a virtual joystick control of the RC constant and the number of delay stages in the feedback loop.