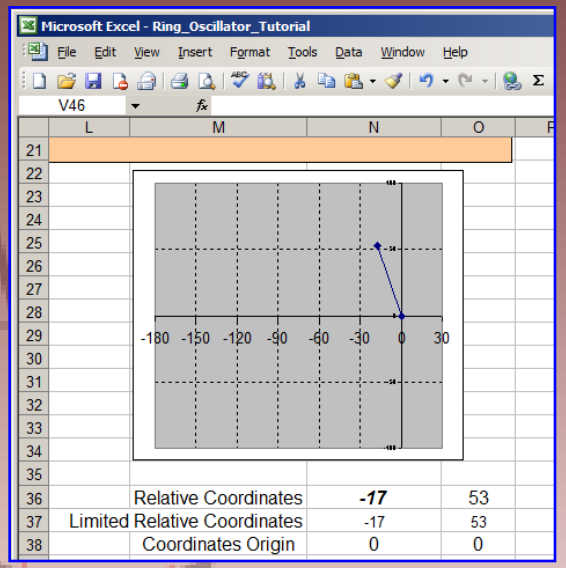
An Interactive Ring Oscillator Model – Part 4

by George Lungu

– In this fourth and last section of the ring oscillator tutorial a joystick is introduced to control the RC equivalent constant and the number of delay stages of the model.

The virtual joystick – the chart:

– We will use elements of a previously created virtual joystick model.
– In the original file copy the second worksheet "Tutorial_3" and rename the new worksheet "Tutorial_4". Also don't forget to reassign the new "enable" and "Start-Pause" macros to the new buttons.
– The joystick will be implemented as a 2D scatter chart and a macro.
– Once the joystick chart will be created and the "joystick" macro assigned to it, clicking the chart will start the "JoyStick" macro which will continuously update (in range N50:O50) the mouse coordinates relative to the initial click point on the screen which was initially clicked (when the macro was triggered).



– Range M35:M37 contains labels. Range N36:O36 contains the relative x-y coordinates of the mouse relative to the initial click point.
– Range N37:O37 contains the previously mentioned x-y coordinates (from range N36:O36) but limited to [-180, +30] for X and +/- 100 for Y.
– Range N38:O38 is the origin of the joystick on the chart and this range is filled with two zeros but it could be later adjusted if needed. The 2D scatter chart has both axes scaled accordingly (see the previous paragraph) and the data charted is from range N37:O38. Let's now see the macro which retrieve the relative mouse coordinates (turn to next page) => => => => => => =>

A few explanations about the "JoyStick()" macro – place it in a module:

The following are declarations:

```
Public Declare Function GetCursorPos _
      Lib "user32" (Some_String As POINTAPI) As Long
```

Declaration of a special API (Application Programming Interface) function which retrieves the cursor position

```
Type POINTAPI
   X  As Long
   Y  As Long
End Type
```

Declaration of a special structure (Point API) used as the output type of the previous API function. It is essentially the pair of coordinates (as long integers) of the cursor on the screen started to be measured from the upper left corner of the screen.

```
Dim RunPause As Boolean
```

Boolean variable declaration which has the role of a "switch", keeping track if the macro is running or is stopped. This will allow the macro to be started or stopped using the same button

```
Sub JoyStick()
```
Declaration of the macro

```
Dim Pt0 As POINTAPI
Dim Pt1 As POINTAPI
```
Declaration two Point API type structures, one as initial click coordinates and the second as the current (dynamic) cursor coordinates

```
RunPause = Not RunPause
```
Boolean "flip", if the macro is stopped this will start it and vice versa

```
GetCursorPos Pt0
```
Assigns variable "Pt0" the initial click coordinates

```
  Do While RunPause = True
```
Conditional "Do" loop declaration (start)

```
  DoEvents
```
Always add this statement if you ever need to stop the loop manually or update a chart while the loop is running

```
   GetCursorPos Pt1
```
Every loop cycle assigns "Pt1" the cursor coordinates

```
   [N36] = Pt1.X - Pt0.X
   [O36] = -Pt1.Y + Pt0.Y
```
Every loop cycle calculate the relative coordinates and display them in the range "N36:O36" (figure out why I wrote those formulas the way I wrote them)

```
   Loop
```
End of "Do" loop

```
End Sub
```
End of macro declaration

A review of the joystick spreadsheet formulas and the joystick chart:

-Let's update the joystick chart with the following features:

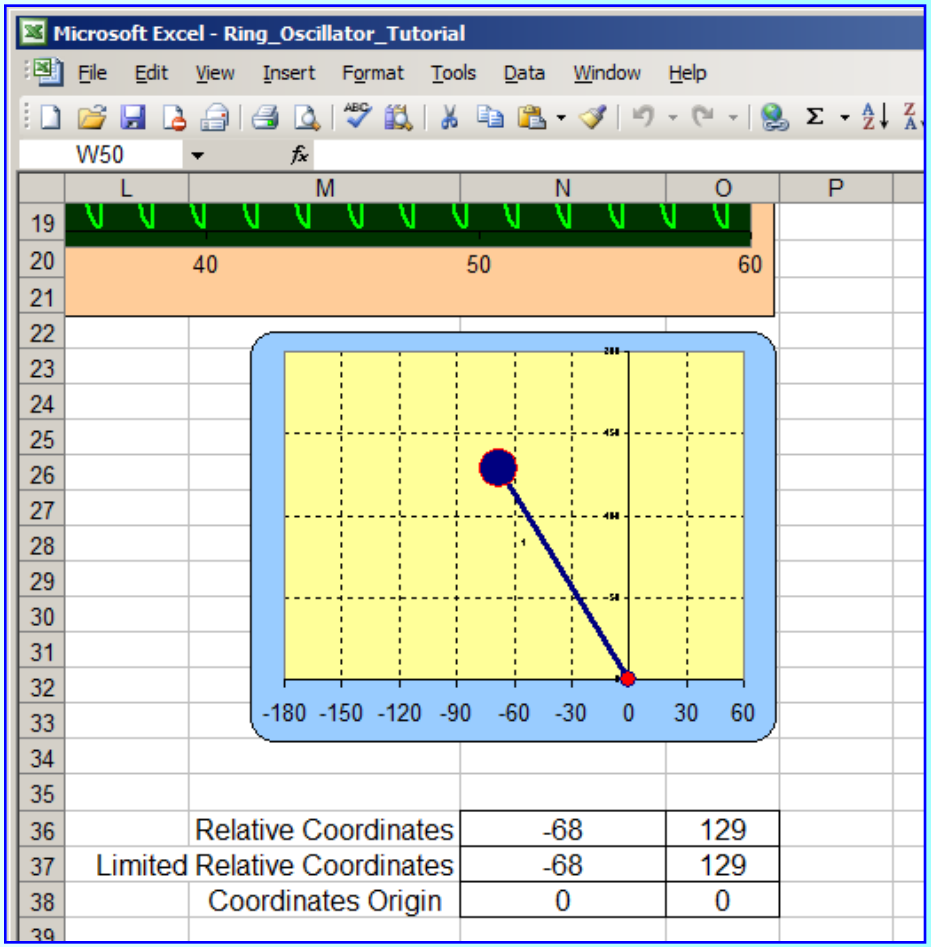
-the horizontal movement of the joystick head to the left will change the number of delay stages within the ring from 2 (extreme left) to 7 (near the vertical axis)
- the horizontal movement to the right will keep 7 delay stages within the chain but will also introduce a chopping of the signal "Enable" with a period between 50 ns and 5ns
- the vertical movement of the joystick will change the RC constant of the delay stages with a very large (5ns) time constant at the bottom and a very low (0.05ns) at the top. This needs to be a nonlinear exponential function since we are talking about two decades of variation or RC and a linear over 200 pixel variation of the mouse coordinate.

Final implementation of the joystick spreadsheet formulas and the joystick chart:

- A preliminary joystick chart was described on the first page of this presentation, however because of the new requirements, let's describe a new procedure for creating an upgraded chart version.
- Cell N36: "-100", Cell O36: "100" (these are not important since the macro will change them a lot during the joystick operation).
- Cell N37: "=IF(N36<0,MAX(-180,N36),MIN(N36,60))", CellO37: "=IF(O36<0,0,MIN(O36,200))" (limiting movement effects of the mouse cursor on the joystick head)
- Cell N38: "0", Cell O38: "0" (these are offset correction values and could later be used to shift the origin of the joystick to a different position on the chart if necessary).
- The chart has the X axis scaled between -180 and +60 with tick marks and grid lines at 30 units
- The chart has the Y axis scaled between 0 and +200 with tick marks and grid lines at 50 units
- Format the chart to your taste and after you finish, right click the chart => Assign Macro => JoyStick

The virtual joystick – a final snapshot:

- For additional insight, the reader is advised to read the Joystick tutorial from January 2011.



The formula for the number of stages:

- We would like to have 2 delay stages for:
  -180 <= X_joystick < -150
- We would like to have 3 delay stages for:
  -150 <=X_joystick < -120
- We would like to have 4 delay stages for:
  -120 <=X_joystick < -90
- We would like to have 5 delay stages for:
  -90 <=X_joystick < -60
- We would like to have 6 delay stages for:
  -60 <=X_joystick < -30
- We would like to have 7 delay stages for:
  -30 <=X_joystick < +60
- The final spreadsheet formula: Cell N40: "=IF(AND(-180<=N37,N37<-150),2,0)+IF(AND(-150<=N37,N37<-120),3,0)+IF(AND(-120<=N37,N37<-90),4,0)+IF(AND(-90<=N37,N37<-60),5,0)+IF(AND(-60<=N37,N37<-30),6,0)+IF(AND(-30<=N37,N37<=60),7,0)"
- Let's now give an exponential value to the RC constant controlled by the vertical movement of the joystick: Cell N41: "=5/10^(O37/100)" – the RC range given by this formula will be between RC=5ns when the joystick head is on the bottom of the joystick chart and RC=0.05ns when the joystick head is on the top of the joystick chart.

- We decided that the horizontal movement to the right of the joystick head will keep 7 delay stages within the chain but will also introduce a chopping of the signal "Enable" with a period between 5 ns (to the extreme right where x=60) and 50ns (for very small but positive x-coordinates)
- Let's write the formula for the period of the "Enable" chopping signal:

Cell N42: "=IF(N37>0,50*10^(-N37/60),"NA")

- Also make sure to delete the "Enable" button since now, the enable signal status will be decided by the position of the joystick head.

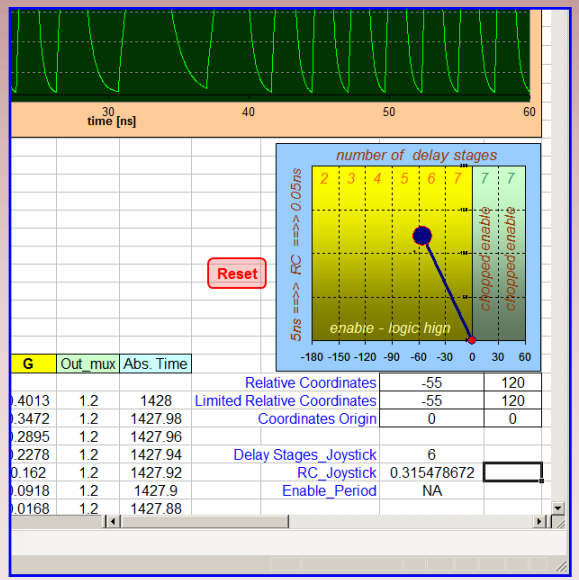
Create an "enable" data series based on a periodic signal:

- We will create this series in column K: Cell K37: "=K38+time_step" and auto-fill down to K136
- Also we need to change the formulas in the "enable" (B) column: Cell B37: "=IF(N42="NA",vdd,vdd*(1+SIGN(SIN(2*PI()*K37/N42)))/2)" – this formula will keep the signal logic high if the value in cell N42 is "NA" (Not Applicable) and will generate a rectangular signal with the period equal to the value in cell N42 if the value in cell N42 is different than the string "NA". Drag copy cell B37 down to cell B136.

Create an "Reset" macro:

- The macro code below is necessary in case the oscillator reaches unreasonable states (very large values in mis-converged simulations) especially now that we have a joystick controlling several aspects of the simulation.
- We place this macro in Module1 and assign it to the Start-Pause button after changing its color to red and replacing the text inside with "Reset".
-We will later see that we don't need the -"start_pause" macro anymore.

```
Sub Reset()
[B137:K3037].Clear
End Sub
```

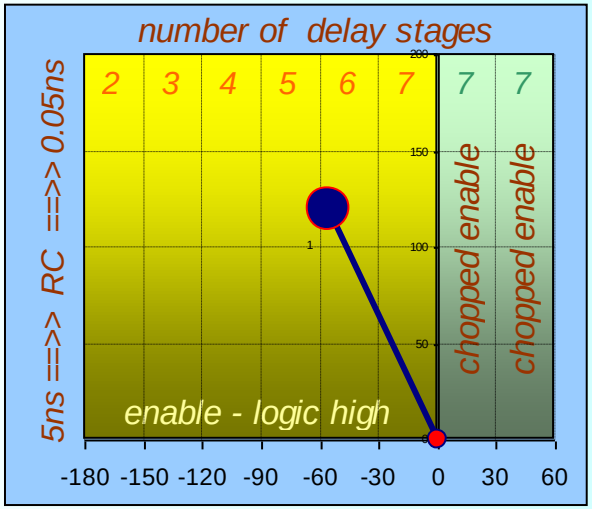


Update the "Joystick" macro:

- We recycled the "Start_Pause" button and turned it into a "Reset" button since we won't need the "start_pause" macro.
- This is because we incorporated the "start-pause" macro functionality in the "JoyStick" macro. See the new code here => =>

Update the joystick chart:

- The joystick chart as seen in page #4 is perfectly functional, however it would be nice to add various shapes and text in the background which would suggest functionality associated with the chart.
- You can create any assemble of shapes and text as long as they are properly sized with respect to the chart and are grouped together.
-The chart area together with the plot area of the chart need to be transparent (select the option "None" while formatting them)



-Move the chart on top of the group of shapes but make sure the chart is on top (use the "Order" option in the "Draw menu").
-At the end, group the chart with the original assemble of shapes (use the Group feature in the Draw menu) and assign the proper macro ("JoyStick" in this case) to the final group.

```
Public Declare Function GetCursorPos _
        Lib "user32" (Some_String As
POINTAPI) As Long

Type POINTAPI
    X  As Long
    Y  As Long
End Type

Dim RunPause As Boolean

Sub JoyStick()
Dim Pt0 As POINTAPI
Dim Pt1 As POINTAPI
RunPause = Not RunPause
GetCursorPos Pt0
   Do While RunPause = True
   DoEvents
    GetCursorPos Pt1
    [N36] = Pt1.X - Pt0.X
    DoEvents
    [O36] = -Pt1.Y + Pt0.Y
    DoEvents
    [B137:K3037] = [B37:K2937].Value
    DoEvents
    Loop
End Sub
```