

Using MMICAD as a Powerful General Purpose Mathematical Solver

Example 3: Numerical Integration, Numerical Differentiation & Custom Plots Using MMICAD's PARAM Mode

The combination of MMICAD's unique **PARAM**eter analysis mode and in-line **PROC**essor block allows the user to perform versatile mathematical operations. Several of these will be discussed in this application note.

Application #1: Numerical Integration

Figure 1 illustrates the integration of the following function:

$$I = \int_0^{\pi/2} \sin(2\cos(x)) \sin^2(x) dx$$

In the analysis file, the **MODE**, **PROC**, **PARAM**, and **OUT** blocks are set up as follows:

1-MODE Block: The Mode is set to **PARAM** which instructs MMICAD to sweep a **PARAM**eter

2-PROC Block: The integration argument X is set to **PARAM** and the equation is typed as shown in Figure 1.

3-PARAM Block: The integration argument X is swept from the lower to upper limit, and the interval is bisected to about 50 panels for numerical integration. The answer approaches the exact result for 50 or more panels.

4-OUT Block: The built-in Measurement function **INTGR** is used to integrate the **OUTVAR** expression as a function of the swept variable. The answer is obtained at the value of **PARAM** corresponding to the upper limit, **PARAM**=1.571.

In Figure 1, the tabular output of the integration frame is pasted between the **FREEZE ON** (Start Comments) and **FREEZE OFF** (End Comments) block. The answer obtained equals the analytical result.

```

FILE NAME: INTGR.CKT
NOTES: Numerical Integration With MMICAD's PARAM Mode

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MODE PARAM !Set analysis for PARAMeter Mode
PROC
I=SIN(2*COS(PARAM))*SIN(PARAM)*SIN(PARAM) !Integrate with respect to PARAM
PARAM !lower limit=0 upper limit= pi/2
SWEEP 0 1.5707963 0.0314159 ! # steps= 50
OUT ! Output Listing Pasted @ End of File
OUTVAR INTGR[I] INTGRATE !Integration Answer @ PARAM= pi/2

LABEL
Numerical Integration With MMICAD

FREEZE ON

! Tabular Listing of INTEGRATE Frame
! PARAM OUTVAR
! INTGR[I]
0.000 0.000 0.534 0.0463 1.068 0.306
0.031 1.4E-005 0.565 0.0548 1.100 0.326
0.063 8.5E-005 0.597 0.0642 1.131 0.345
0.094 2.7E-004 0.628 0.0746 1.162 0.364
0.126 6.2E-004 0.660 0.0859 1.194 0.383
0.157 0.00120 0.691 0.0982 1.225 0.401
0.188 0.00206 0.723 0.111 1.257 0.418
0.220 0.00327 0.754 0.126 1.288 0.434
0.251 0.00487 0.785 0.141 1.319 0.448
0.283 0.00692 0.817 0.157 1.351 0.462
0.314 0.00949 0.848 0.173 1.382 0.473
0.346 0.0126 0.880 0.191 1.414 0.484
0.377 0.0164 0.911 0.209 1.445 0.492
0.408 0.0208 0.942 0.228 1.477 0.499
0.440 0.0260 0.974 0.247 1.508 0.504
0.471 0.0319 1.005 0.266 1.539 0.507
0.503 0.0387 1.037 0.286 1.571 0.508 ←Answer

! Exact Answer=0.507968

FREEZE OFF
    
```

Figure 1: MMICAD analysis file for numerical integration

Application #2: Numerical Differentiation

Figure 2 illustrates the differentiation of the following function at X=1:

$$I = \frac{dY}{dX} = \sin(2\cos(X))\sin^2(X)$$

In the analysis file, the **MODE**, **PROC**, **PARAM**, and **OUT** blocks are set up as follows:

1-MODE Block: The Mode is set to **PARAM** which instructs MMICAD to sweep a **PARAMeter**.

2-PROC Block: The differentiation argument X is set up to **PARAM** and the equation is typed as shown in Figure 2.

3-PARAM Block: If the differentiation is to be found at X=a, then the **PARAM** has to be swept at three points a-δ, a, and a+δ where $\delta \leq 1e-3$.

4-OUT Block: The built-in Measurement function **SLOPE** is used to differentiate the function.

In Figure 2, the tabular output of the differentiation frame is pasted between the **FREEZE ON** and **FREEZE OFF** block, and the answer is indicated at **PARAM=1**.

```

FILE NAME: SLOPE.CKT
NOTES: Numerical Differentiation With MMICAD's PARAM Mode
-----
MODE PARAM

PROC
I=SIN(2*COS(PARAM))&          !Differentiate with respect to PARAM
*SIN(PARAM)*SIN(PARAM)

PARAM                          !Sweep about ±δ
STEP .999 1 1.001             !PARAM=1-δ, 1, 1+δ where δ=0.001

OUT                             ! Output Listing Pasted @ End of File
OUTVAR SLOPE[I] DIFFERENT      !Differentiation Answer @ PARAM=1

LABEL
Numerical Differentiation With MMICAD

FREEZE ON
! Listing of DIFFEREN Frame
! PARAM  OUTVAR
!      RE[I]
0.999  0.624
1.000  0.625 <===== Answer
1.001  0.625
FREEZE OFF

```

Figure 2: MMICAD analysis file for numerical differentiation

Application #3: Function Plots:

Figure 3 illustrates the procedure for plotting the following function from X=0 to X=10:

$$I = \sin(2\cos(X)) \sin^2(X)$$

In the analysis file, the **MODE**, **PROC**, **PARAM**, **MARKER**, **OUT**, **GRID**, and **LABEL** blocks are set up as follows:

1-MODE Block: The Mode is set to **PARAM** which instructs MMICAD to sweep a **PARAMeter**

2-PROC Block: The independent variable X is changed to **PARAM** and the equation is typed as shown in Figure 3.

```

FILE NAME: PLOT.CKT
NOTES: Function Plots With MMICAD's PARAM Mode
-----
MODE PARAM

PROC
I=SIN(2*COS(PARAM))*SIN(PARAM)*SIN(PARAM)

PARAM
SWEEP 0 10 .01

MARKER
SWEEP 0 10 1

OUT
OUTVAR RE[I] FUNCTION

GRID
PRANGE 0 10 1
FUNCTION -0.75 0.75 0.3

LABEL
Function Plots With MMICAD

```

Figure 3: MMICAD analysis file for Function Plotting

3-PARAM Block: The **PARAMeter** is set up to be swept from the starting point to the ending point with the desired number of steps.

4-MARKER Block: This is an optional block. The user can put markers at the points of interest.

5-OUT Block: The function is accessed by an **OUTVAR** statement in this block.

6-GRID Block: This is an optional block. In its absence, all plots are automatically autoscaled. Otherwise, the user can specify the minimum and maximum of each axis, the number of grids, and the type of axis (linear or logarithmic).

7-LABEL Block: This is an optional block. The user can specify a label for the plot. Figure 4 shows the plot of the function. Going further, it is possible to setup a three dimensional plot by using **FREQ** and **PARAM** sweeps together with **VARIATIONAL ANALYSIS**.

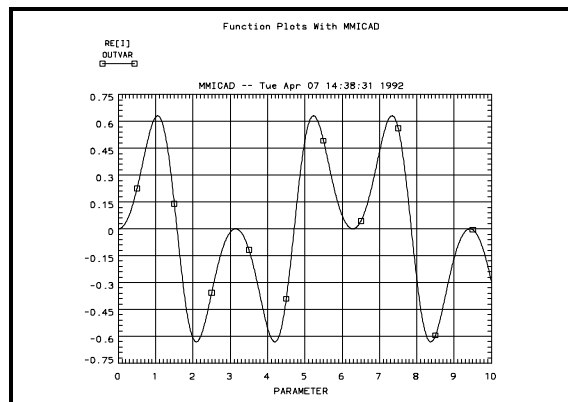


Figure 4: Function Plot in MMICAD