CMOS Reliability Validation with RealCAS

Manual Ver.201707

A tool for fast design verification of highly reliable CMOS integrated circuit named as RealCAS (Real-time Circuit Aging Simulations) is developed with support by Innovation and Technology Fund GHP/055/14SZ. Descriptions to this tool and guidelines for its usage is provided with this user manual. RealCAS is a simulator written based on the DTEM (Dynamic Time Evolution Method) developed within the project. It can simulate the HCI (Hot Carrier Injection) and NBTI (Negative Bias Temperature Instability) induced aging of transistors, and EM (Electro Migration) induced aging of interconnects. There are four steps to perform CMOS reliability validations with RealCAS: (1) user library construction; (2) inputting the netlist; (3) setting up of reliability simulation; and (4) viewing the returned data

1.1 Constructing the User Library

Reliability simulation uses the same user library as regular simulation of *i*-MOS. User can follow the instructions for regular simulation to construct the user library.

1.2 Entering Netlist

In order to perform reliability simulation for a circuit, a netlist has to be constructed. Different from regular simulation there are only one mode to enter the netlist, which is the Netlist mode.

1.2.1 The Netlist Mode

The Netlist mode provides a simple user interface for user to construct the netlist and set up the preferred reliability simulation. The netlist page consists of 3 different sections and an aging simulation setup card as shown in Fig. 1.1 that need to be completed before simulation can be executed.

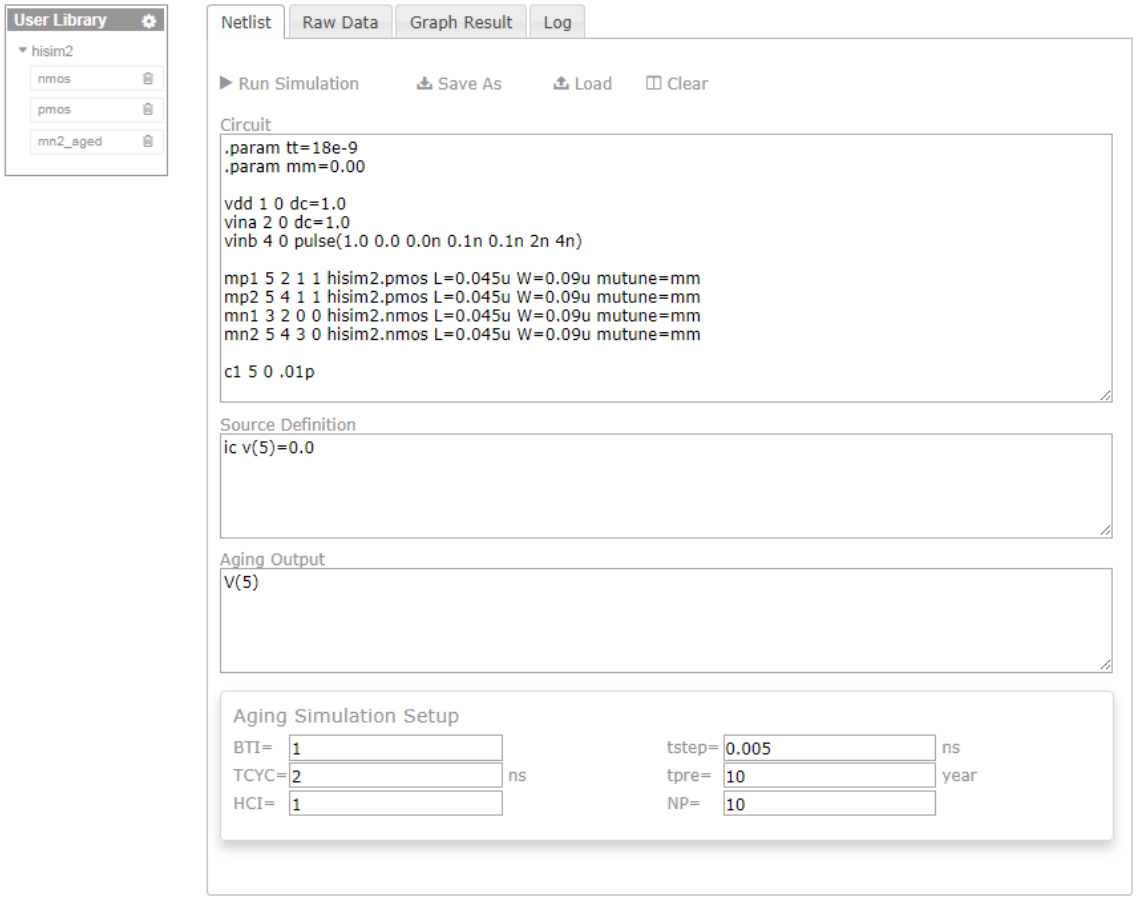


Fig. 1.1: The netlist page showing the three sections of a 2-nand gate: (1) Circuit; (2) Source definition; (3) Output variables, together with the aging simulation setup card.

The Circuit section is where you enter the netlist. Same as regular simulation, the format follows what is specified in the NGSpice manual.

The Source Definition section is same as that in the regular simulation. To be noted that a transient simulation is assumed in RealCAS, therefore appropriate sources that can represent the circuit operation have to be specified.

The Aging Output section defines the output data to be collected and plotted. Please refer to the regular simulation for more information.

The Aging Simulation Setup is where you specify the requirements for reliability simulation of circuit. In current version, six parameters control all possible requirements, including effect flags (BTI, HCI), extrapolation cycle (TCYC), time step (tstep), total operation time (tpre), and extrapolation cycles (NP). *'BTI/HCI' equaling to 1 means 'NBTI/HCI' effect is considered. 'TCYC' should be the integer multiple of period of input signal. 'tstep' is the time step used in simulation. 'tpre' is the interested time when the degraded circuit performance is required. 'NP' is the total extrapolation cycles, which equals to the output time points in simulation.*

When you are done with editing, you may submit the job to the simulator using the Run Simulation function on the top and view the result in the Raw Data page or Graph Result page to be described later.

If you are going to stop editing your input for some time and return later, you may save the netlist in the netlist mode using the save function on the page. A file with an .isp extension will be saved in the default location set by your browser.

1.2.2 Running Simulation

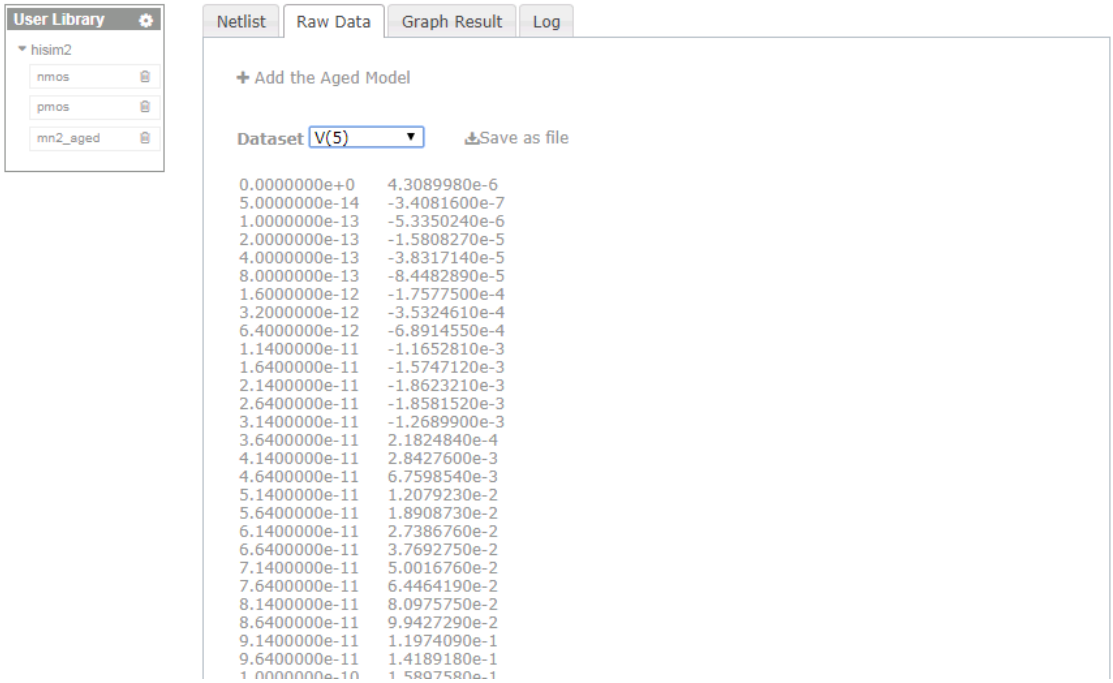
After you select the Run Simulation option, the input file will be sent to the simulator. If there are errors, the error messages will be displayed in the Log page where you can check to correct your input. If you find the simulation is running for a long time without response, you may also abort the simulation by pressing the Abort option. If everything runs smoothly, the output will be ready as raw data or graphical output.

1.3 Obtaining Results

1.3.1 Viewing Raw Data

When simulation is completed, the numeric data is listed in the Raw Data page as shown in Fig. 1.2. In Fig. 1.2 (a), the node voltage 'V(5) against time' is displayed where the first column is the time in unit of second. In Fig. 1.2 (b), the degraded threshold voltage of transistor 'mn2' is displayed where the first column is the time in unit of year.

a)



b)

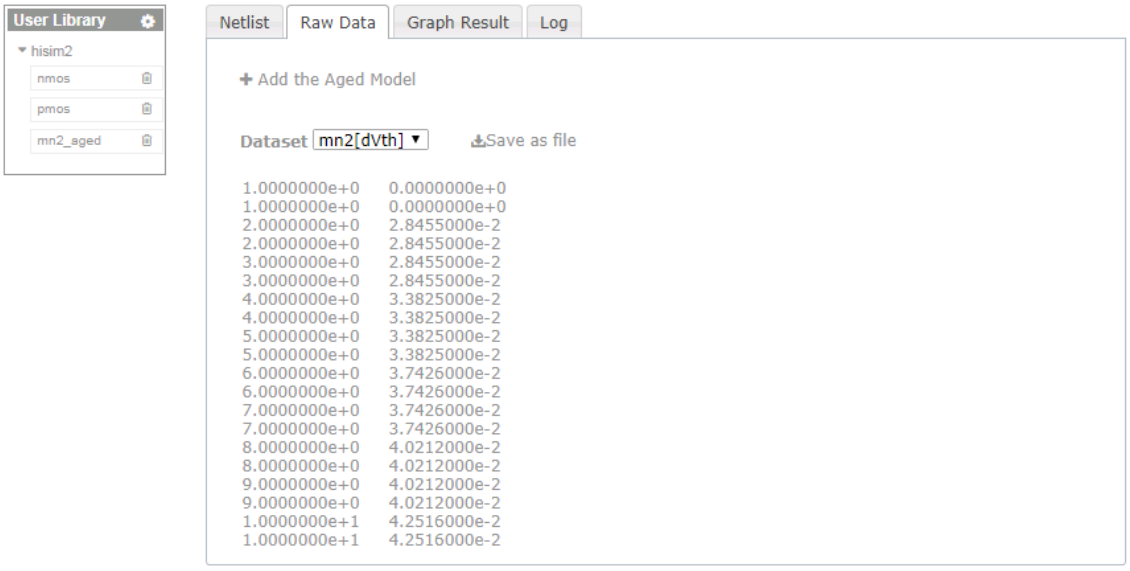


Fig. 1.2: The Raw Data output. Different variables can be selected from the Dataset drop down menu. (a) Output circuit signal, (b) degraded parameter.

The degraded threshold voltages of transistors are automatically displayed in raw data page. Other interested outputs regarding circuit need to be listed in the 'Aging output section' in the netlist input to be displayed. If you list the output variables on the same line in the netlist input, they will be displayed in the same table. If they are listed in different lines, they will be displayed in different tables to be selected with the Dataset drop down menu. You may download the numerical data from the simulation to default location of your computer as defined by the browser and plot them using other graph-plotting utilities of your preference.

1.3.2 Viewing Graphical Data

RealCAS provides a simple graphical interface for you to view the data. To see the graphical output, select the Graph Result tag on top, and the raw data will be displayed as shown in Fig. 1.3.

The y-axis of the plot displays the output variables without explicit labels. As a reminder, the legends tell you what the corresponding units should be. Different data set (or tables in the Raw Data) can be selected using the Graph drop down menu. The degraded threshold voltages of transistors are automatically displayed in raw data page. Other interested outputs regarding circuit need to be listed in the 'Aging output section' in the netlist input to be displayed. You may also plot the y-axis in log scale if it is desired. By clicking on the graph, you may magnify the figure. Further more, you may save the graph in .png format if you want to save it for recording purpose.

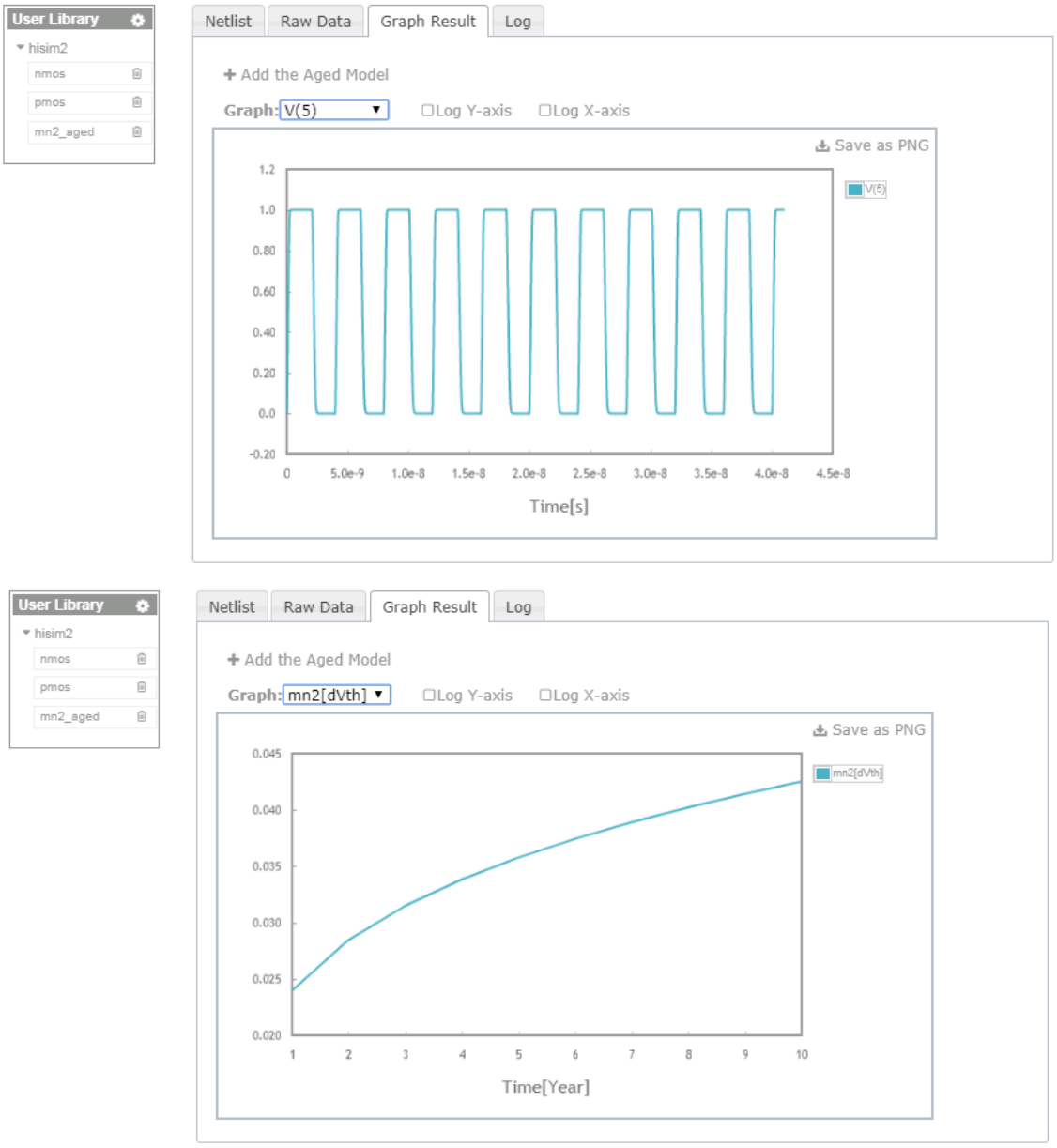


Fig. 1.3: Graphical output of simulation results. (a) Output circuit signal, (b) degraded parameter.

1.3.3 Adding Aged Model

Simulating the degraded circuit in detail requires the aged models of each device. RealCAS provides a simple way to add the aged model into user library. With the aged model in user library, user can run simulation for aged circuit in regular simulation.

To add the aged model, user first need to choose the right degraded parameter of one device in raw data page. Then click the ‘Add the Aged Model’ above the data, and specify the original model name and new aged model name in the prompt. Then click

confirm, the mn2_aged will show in the user library. Fig. 1.4 shows an example in which the device ‘mn2’ is chosen.

Afterwards, user can go to regular simulation to simulate the aged circuit with ‘mn2_aged’ that is just created.

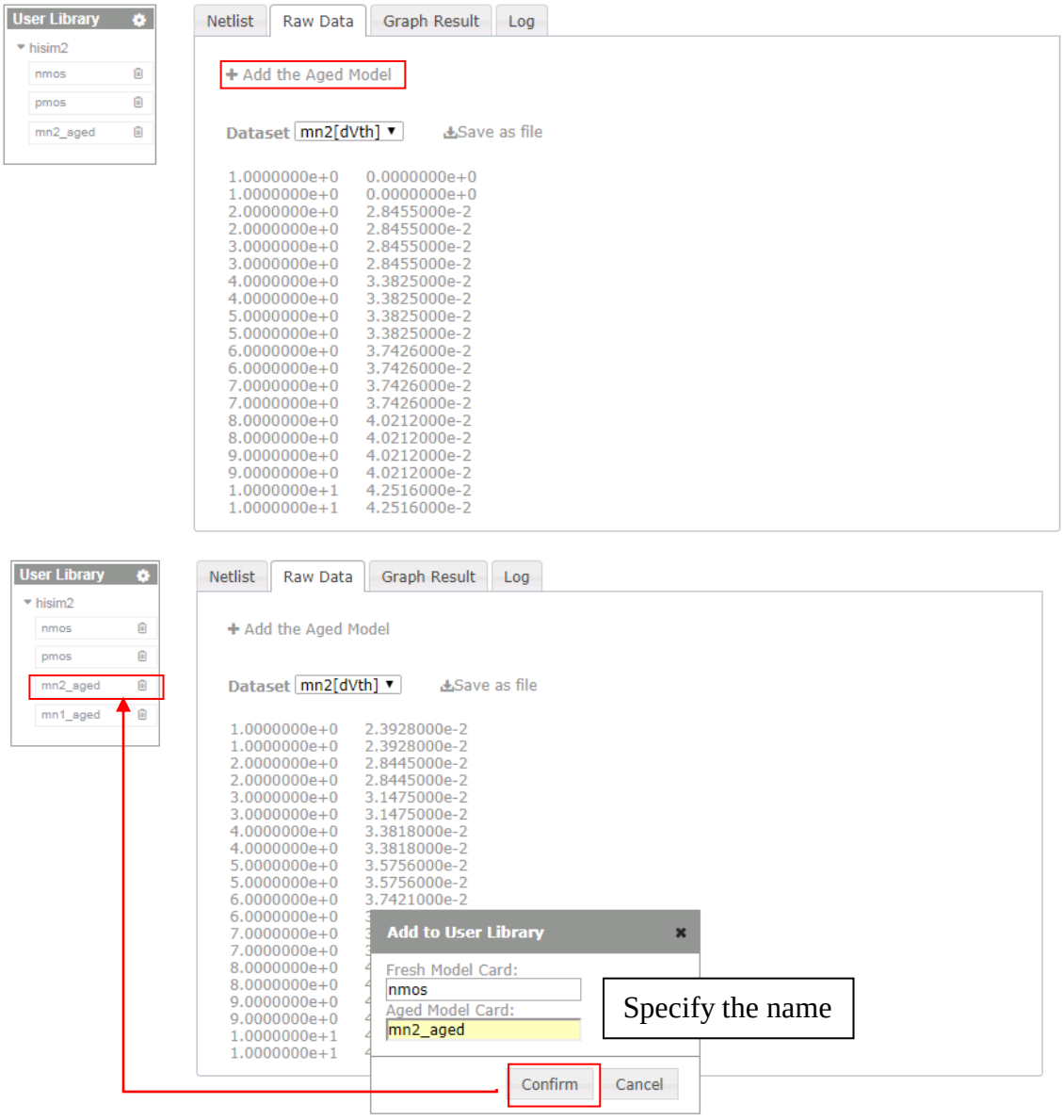


Fig. 1.4: An example showing how to add aged model for device mn2.

1.4 The Log File

The log file tag keeps track of all messages that the simulator returns during simulation. If there is any problem with the simulation, you should check the log file to make sure all the problem listed are solved before re-submitting the next simulation.