

# SPAYN: Golden Device Search Algorithm, EKV MOSFET Model and Improved GUI

## Introduction

The addition of important features in the latest version of *SPAYN* (1.7.3.R) makes it an even more useful and versatile statistical parameter and yield analysis tool. The list of spice models available in *SPAYN* has been expanded to include the EKV MOSFET model. The new “Golden Device” function locates the observation in a particular database that is closest to the theoretical mean observation. This “Golden Device” is then considered to be the average observation that best characterizes that database. Several new plotting symbols have been added to the scattergram plotting facility allowing a clearer graphical representation of data. It is also now possible to locate the position of the minimum or maximum record in a given database without the need to manually sort through the complete data set.

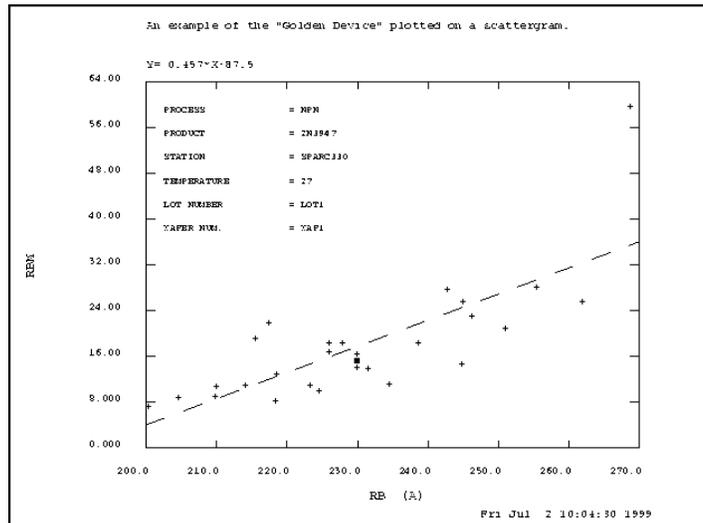


Figure 1. Scattergram: Golden device represented by a solid square

## EKV MOSFET model

The EKV MOSFET model has been added to the list of device levels currently available in *SPAYN*. An EKV SPICE model (level = 44) can be set up by selecting Setup→Spice→Edit Models from the main *SPAYN* window and then entering 44 for the model level. The other parameters are also selected accordingly (see [1] for more details).

Once the EKV SPICE model has been set up various device characteristics can be computed. This is accomplished by selecting Setup→Device Characteristic from the main *SPAYN* window. The user then selects the following options: Device Type = MOSFET, Device Level = EKV and Spice Model Setup = PMOD, where PMOD is the previously set up EKV SPICE model.

## Golden Device

The Golden Device facility allows the modeling engineer to calculate which observation (or observations) in a particular database most closely match the mean, based on some dissimilarity measure. This observation or record is referred to as the “Golden Device”. The name is derived from the fact that if the observations actually represent devices then the algorithm locates that measured device closest to the mean. This means the measured device that *on average* best describes the given database, hence the name “Golden Device”. The mean observation is constructed from individual parameter sample means and does not usually belong to the set of measured data.

In general, given a database of  $N$  measured observations or records, each described by  $p$  parameters, and a dissimilarity measure  $D$ , the algorithm [2] finds the  $m$  records closest to a query record (not necessarily in the database) with specified parameter values. The search algorithm uses the Euclidean distance, which is a special case of the Minkowski distance metric in equation (1) with  $q = 2$ .

$$D_{rs} = \left( \sum_{j=1}^p |x_{rj} - x_{sj}|^q \right)^{\frac{1}{q}} \quad (1)$$

where  $D_{rs}$  is the distance between 2 records  $r$  and  $s$  and  $x_{rj}$  is the value of the  $j^{\text{th}}$  parameter for the  $r^{\text{th}}$  observation. In fact since the mean is being used,  $x_{sj}$  is replaced in equation (1) by  $m_j$  the sample mean of parameter  $j$ .

The “Golden Device” window is opened by clicking on Analysis→Golden Device from the main *SPAYN* window.

- Select which parameters to include, the algorithm then uses the sample means of these parameters to locate the Golden Device i.e. the observation nearest the mean, based on the chosen dissimilarity measure.
- Enter the required number of neighbors (<15). The search algorithm then looks for that number of observations closest to the mean (rank 1 being the nearest). For example choosing 2 neighbors would return the two observations closest to the mean, based on the specified dissimilarity measure.

- iii. Choose a distance metric (1-8), the value 2 (default) corresponds to the Euclidean distance. This is equivalent to setting  $q=2$  in equation (1).
- iv. Press "Apply" to implement the search algorithm. The observations closest the mean will be displayed in the "Observation Number(s)" window. To view the parameter values for these observations click on Data Search->Search Results from the main menu, and then select "Statistics", "View Table" or "View Parameters". It is also possible to view the "Golden Device" graphically by using the "Golden Device" toggle in the "Scattergram" window (Figure 1).

### Scattergram Plotting Symbols

In addition to the existing scattergram plot symbols (markers), squares and triangles have also been added. Both of these symbols are available in outline or solid form e.g.  $\square$ ,  $\Delta$ ,  $\blacksquare$  and  $\blacktriangle$ . The scattergram plotting symbol can be changed by selecting Setup->Plots->Scattergram Palette, from the main menu. The user can then choose the marker type (plot symbol) from the pulldown menu. It is also possible to display different attributes in a scattergram with different plotting symbols. This is achieved by selecting Setup->Plots->Highlight by Attributes, from the main window. Figure 2 shows an example where data from each wafer is represented by a different plot symbol.

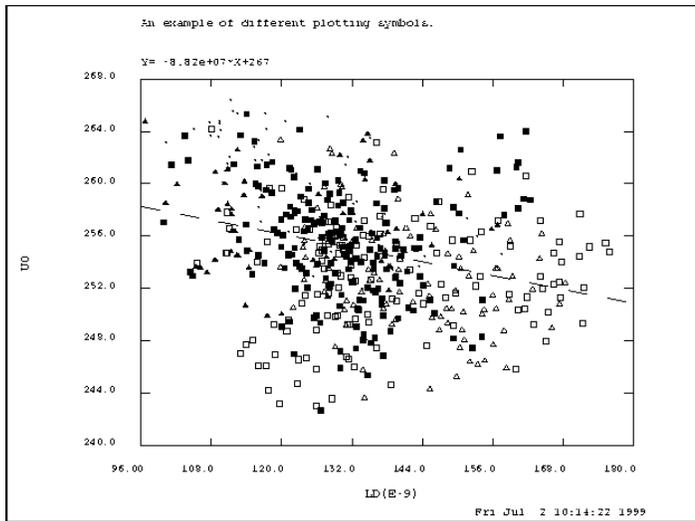


Figure 2. Scattergram: Each wafer is represented by a different plot symbol.

### Statistical Summary Parameter Information Display

One problem that occasionally confronts a modeling engineer is the necessity to locate the record in a database that corresponds to the maximum or minimum

value of a particular parameter. This option is now available in *SPAYN*, alleviating the need to sift through all the data points. In addition to providing the location of the required record, this facility also supplies attribute information for the selected parameter. It is accessed by clicking on the maximum or minimum value of a particular parameter in the "Statistical Summary" window. The "Statistical Summary" window is generated by selecting Data Search->Search Results->Statistics from the main menu. Figure 3 demonstrates the *SPAYN* Statistical Summary window, with the Parameter Information window inset. In this example the minimum value for the parameter U0 is located at observation/record number 539.

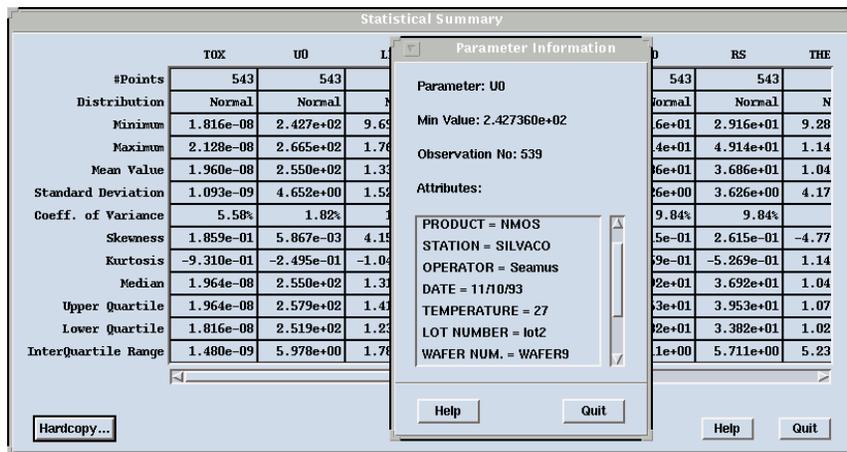


Figure 3. Parameter Information and minimum value displayed for variable U0. The minimum value is located at observation/record number 539.

### References

- [1] M Bucher, C Lallement, C. C Enz, and F Krummenacher. Accurate MOS Modeling for Analog Circuit Simulation using the EKV Model. In *Proceedings IEEE International Symposium on Circuits and Systems (ISCAS)*, pages 703-706, 1996.
- [2] J.H. Friedman, J. L Bentley, and R. A Finkel. An Algorithm for Finding Best Matches in Logarithmic Expected Time. *ACM Transactions on Mathematical Software*, 3:209-226, 1977.