

EMAGE

Structure Evaluation Tool

- Data Driven Sweep Engine
- Dynamic Standard Test Sweeps
- Equation Support for Data Manipulation
- Data Graphing and Labeling Tools
- User Extensible Test Library
- Integrated Debugging of Test Conditions
- Pin-to-Pad De-Scramble Tables
- dBase IV Export Utility

EMAGE (Electrical Measurements for Analysis and Graphical Evaluation) is an automated digital-curve trace package. With EMAGE, one can quickly produce a graph of a structure's operation parameters, as with an analog curve tracer, to identify problems. In addition, complex data required for device characterization, device modeling, WLR stressing, and NVM evaluations can be gathered.

EMAGE test plans can also be executed in the Acquire application, allowing any desired sweep data to be gathered in an automated fashion. Acquire is used for:

- Executing complete test plan(s)
- Test chip layout
- Die pattern layout
- Operator interfacing and prober control
- Lot data printouts

Please refer to the Acquire data sheet for more details.

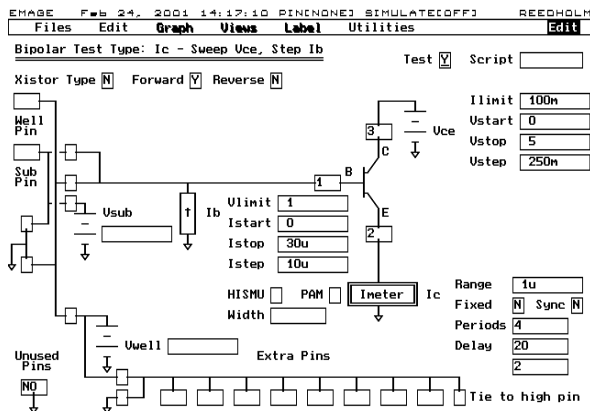


Figure 1 - I_C - Sweep V_{CE}, Step I_B Setup Screen

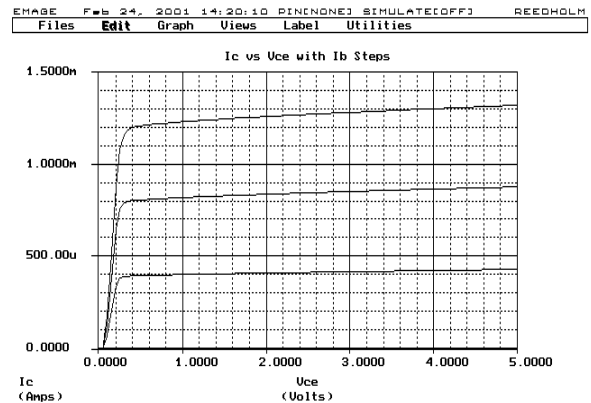


Figure 2 - I_C vs. V_{CE} with I_B Steps Output Screen

Data Driven Sweep Engine

Relying on a data-driven sweep engine makes EMAGE easy to use and durable. A data-driven engine performs tests based upon passed-in parameters, rather than hard-coded assignments. Every pin number, voltage step, current level, and connection scheme used per sweep is stored in an ASCII database file, instead of the source code. This allows the customer to upgrade software and computer platforms without having to port test code. Older test plans are automatically updated to work with the current sweep engine when they are invoked.

EMAGE sweeps are put together as a test plan, allowing what would be numerous separate files on a standard digital curve tracer to be stored and executed together. This ability to combine and save various sweep conditions for an indefinite period makes it easy to examine structures over time. In addition, all data taken can be saved indefinitely and later compared with new data, even if the comparison date is many years later.

Because test plans are data records linked in memory, the number of tests in a single plan is only limited to the amount of available memory. For example, EMAGE supports a test plan with about a 4,000 sweeps on a PC with 64MB of memory.

Editing Test Plans

Test plans are edited by filling in cells in an intuitive input grid. Compliance with system instrumentation is checked as each test is edited. EMAGE detects and prevents attempts to set impossible hookups such as, including pins greater than in the matrix, or setting voltages or currents that are greater than the span available using the instrumentation installed. Even when editing off-line, instrumentation is simulated enforcing test plan compliance.

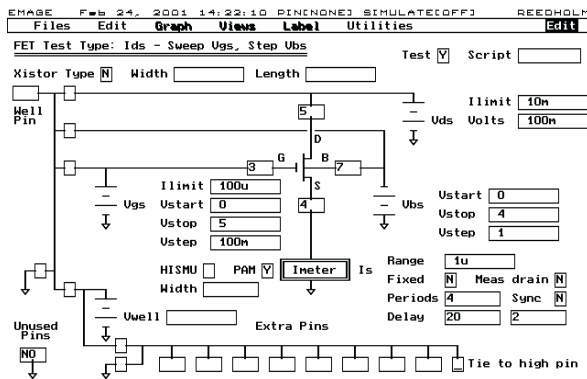


Figure 3 - I_{DS} vs. V_{GS} Sweep

Figure 3 is an input grid for an I_{DS} vs. V_{GS} sweep. To make the sweep setup easier, the grid layout is in schematic form.

Figure 4 represents a more exotic input grid used for NVM endurance testing. This sweep is one of several available for Flash and EEPROM reliability studies.

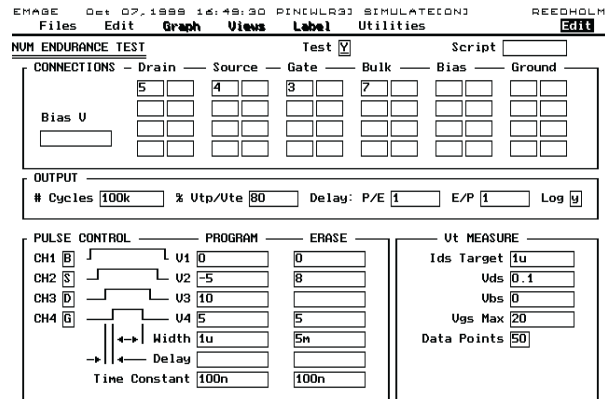


Figure 4 - NVM Endurance Testing

Graphing Data

EMAGE is really two programs in one: a test tool and a graphing tool. After completing data sweep(s), EMAGE plots the data for immediate examination. Data can then be saved to disk in an ASCII (*.PRN) file, which can be read in and graphed later. An overlay option reads in prior sweep data and overlays it on current graphs for comparison. Figure 5 shows six plotted data sets.

Other Reedholm applications output *.PRN files for EMAGE graphing, including:

- EMPAC - WLR and TCR Tests
- EMPAC - Force $V/Meas I (+1500V)$
- EMREL - Normal and CDF Plots
- EMREL - Raw Data vs. Log Time Plots

Besides exporting to dBase IV for portability, EMAGE is supported by leading SPICE modeling packages. Silvaco's Utmost has a built-in import for *.PRN files. EMAGE has a built-in export to TMA's Aurora file format.

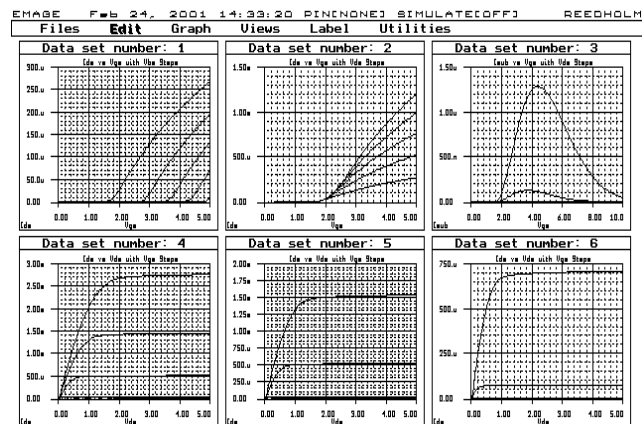


Figure 5 - Graphing Data

Graphing Tools

EMAGE has many tools to enhance graphed data:

- Scaling and grid settings
- Editing and adding labels to graphs
- Showing line and/or individual data points
- Showing tangent, inverse tangent, X & Y intercepts
- Overlaying multiple data sets
- Providing presentation-quality printouts of graphs

The scaling and grid tools allow separate selection of the X and Y scales. Graphs with left and right Y scales, can be controlled separately; however, they must be of the same scale type. Scale boundaries can be:

- Forced so that grids are on 1,2, or 5 point steps
- Set at the minimum and maximum points found
- Set by the user

EMAGE supports the following scale types: Linear, Log, Percentage, Normal, and CDF. Besides the scales, the number of ticks on the grid can be selected. This option allows the user to select the grid resolution needed to determine a data point's value.

The labeling tool includes options that allow a data point to move automatically upon scale changes, or to attach the label to a pixel point preventing movement.

Other labeling options include:

- Moving labels with the cursor
- Deleting and editing labels
- Selecting unit labels from a help list

The other graphing tools contain features similar to those of scaling and labeling. For example, the tangent tool can generate a label at the current cursor position consisting of the tangent, inverse tangent, and the X & Y intercepts. Figure 6 is an example graph enhanced with several EMAGE graphing tools, including the tangent feature.

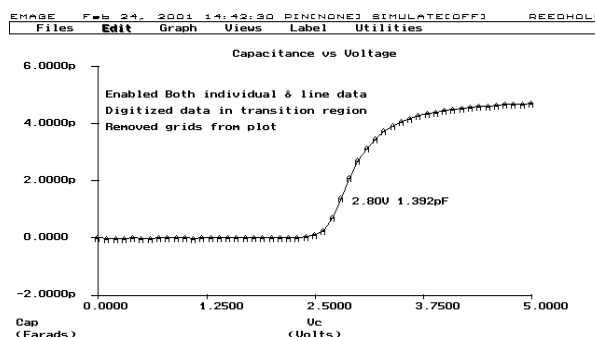


Figure 6 - EMAGE Graphing Tools

Numerical Manipulation Tools

EMAGE supports data manipulation via integrated or user-supplied equations. The integrated equations are quite specific to a test type. An example would be applying the sub-threshold equation to a gate transfer characteristic data set, creating a log-linear display for investigation of I_{off} or sub-threshold slope. Figure 7 shows a sub-threshold plot:

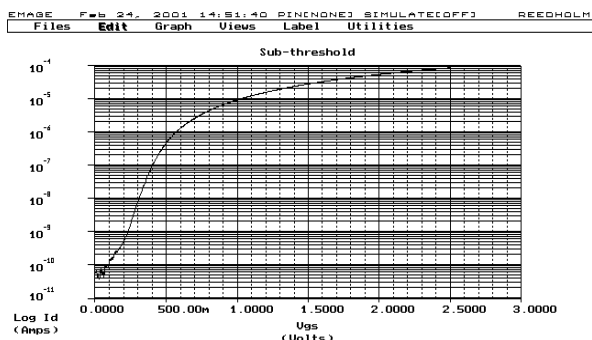


Figure 7 - Sub-threshold Plot

The integrated equations are:

- Conduction
- Gradient
- Linear Beta vs. Linear I_C
- Linear Beta vs. Log I_C
- Log Beta vs. Log I_C
- Normalized
- Sub-threshold
- Summation
- $1 / [C/C_{max}]^2$

The equation tool, with built-in error checking, allows the user to manipulate the data many ways. The equation editor utilizes the following operands:

- Arithmetic [$+$, $-$, $/$, x]
- Trigonometric [\sin , \cos , \tan]
- Logarithmic [\ln , \log_{10}]
- Power [x^n , e^n , \sqrt{x}]

Investigating Sweep Results

Normally, EMAGE is used to investigate an errant test condition or setup. During training classes, Reedholm instructs its users to characterize each structure using EMAGE before creating an EMPAC test plan. If the investigation tool produces meaningless results, EMAGE's internal test debugging can be enabled.

This investigation option shows the physical connections, status of all the instrumentation before and after each sweep, and any critical data taken during a sweep.

In addition, the sweep engine has built-in error checking that reports error conditions, including an over-ranged meter, and whether a power supply is in current limit.

```

EMAGE  Oct 20, 1998 16:44:00 PIN:NDNEJ SEMULATECONJ REEDHOLM
Files Edit Graph Views Labels Utilities
RT INSTRUMENTATION STATUS - ACTIVE STATION: 1
NODE 0 DMM1-
NODE 1 PS1 1
NODE 2
NODE 3 PS2 3
NODE 4 DMM1+ 2
NODE 5
SYSTEM FLAGS
DMMzero ON
LogicPin NONE
Safe YES
SelfCal OFF
CIC1 Base D800
CIC2 Base D900
Hz/Sample 60/151
Aborted NO
PAH1[INC] PAH2[INC] PAH3[INC]
Urange DMM1 PS1 PS2 PS3 PS4 PAH1 PAH2
Setting 400.00uV 2.5V 2.5V 100V 100V
Arange 1uA 10mA 10mA 1A 1.0000V 100nA 100nA
Setting 10.000nA 10.000nA 10.000nA 200.00nA
Reading -23.968nA 0.0000A 0.0000A
Ranging Auto Fixed Fixed Auto Auto
Uzero True True True True True
Ilimit False False False False False
OverRng
Type DMM-16 UFIF UFIF UFIF UF
    
```

Figure 8 - Test Status Screen

Test Coverage

EMAGE Sweep Coverage

EMAGE library choices cover almost all testing required for process development, characterization, and control. In addition, the library supports tools to aid in test structure design, including unique structures used for WLR and NVM testing. Table 1 shows the supported sweeps.

Capacitance—Sweep V_{CP}
Current—Sweep Time
Current—Sweep V_{test}
EEPROM—Hysteresis Curve
I_C & I_B —Sweep V_{BE}
I_C —Sweep V_{CE1} Step I_B
I_C —Sweep V_{CE1} Step V_{BE}
I_{DS} —Sweep V_{DS1} Step V_G & V_B
I_{DS} —Sweep V_{GS1} Step V_{BS}
I_{DS} —Sweep V_{GS1} Step V_{DS}
I_{SUB} —Sweep V_{GS1} Step V_{DS}
NVM Disturb Test
NVM Endurance Test
NVM V_T vs. Erase Pulse Width
NVM V_T vs. Write Pulse Width
Resistance—Sweep V_{test}
User-Written Tests
Voltage—Sweep Time

Table 1 - EMAGE Test Types

Extending the Sweep Library

Since its introduction in 1987, the majority of Reedholm customers have used EMPAC or EMAGE for test plan development. Out of hundreds of installed systems, 95% of the plans consist of tests from Reedholm's library. Those which are unique tests are usually proprietary and customers may not want them added to the EMAGE library. In these situations, the library is extended with user-written code.

This custom code can be written to conform with the EMAGE sweep engine so that all parameters are passed in, including pin numbers, voltages, delays, and sampling options. By conforming to the EMAGE

format, this new sweep can be accessed like other types and re-used in dozens of plans without the need to rewrite the source code. User functions can include debugging code, which is enabled when the EMAGE investigation flag is set.

We now provide several user examples, and we can provide training. For more complex needs, Reedholm Instruments may be contracted to write custom functions.

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