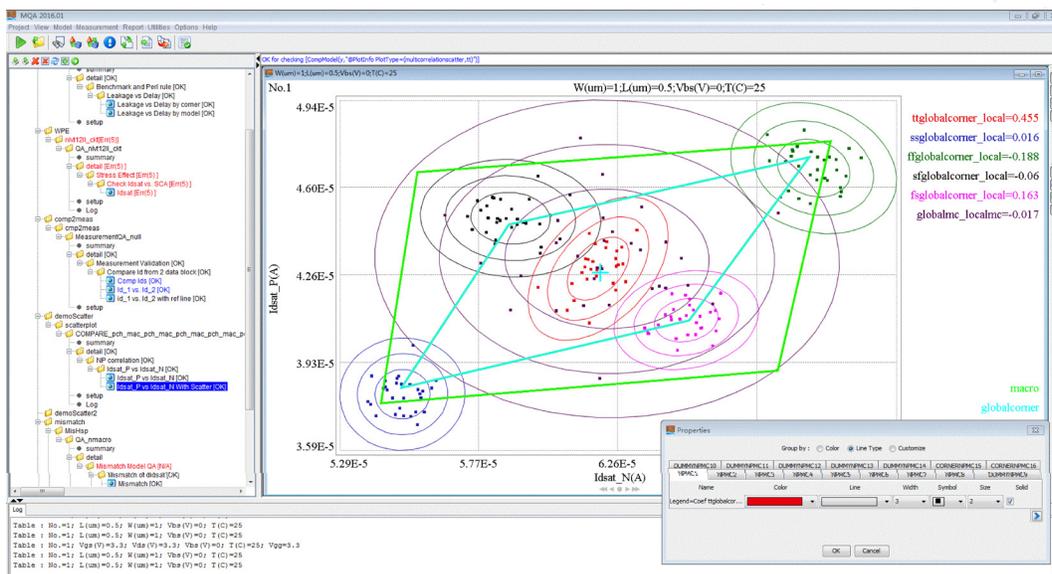


Model Quality Assurance (MQA)

Industry Standard SPICE Model Validation Software



Introduction

Model Quality Assurance (MQA) is a collection of comprehensive SPICE model validation procedures, interfaces and utilities that provide the ability to thoroughly check SPICE model quality and automate QA and reporting procedures for both silicon and III-V technologies. Given today's nanoscale process technologies and increasing model complexities, validating SPICE models is a significant challenge and can be very time consuming. However, SPICE modeling engineers and model users still want the models to be thoroughly checked and the model characteristics to be easily obtained. MQA satisfies this critical industry requirement by rigorously checking the model quality, plotting model characteristics, and customizing the output targets with its comprehensive checking rules while employing easy-to-use interfaces and utilities.

Key features

- Integrates a comprehensive set of rules to ensure SPICE model quality while overlaying measurements and simulation results
- Support for commercial simulators. Equipped with internal SPICE engine for fast simulation
- Rules and checking functions are flexible and fully customizable
- Customize user defined plots and/or tables with Python script
- Measurement QA, model comparison, corner model QA and Monte Carlo analysis
- Powerful plotting functions and utilities
- Open interface enables flexible support of models, simulators and checking routines
- Automatic QA report generation and customization
- Complete parallelism support on different levels: simulator level, rule level and project level
- Native support of IC-CAP mdm data and MySQL/SQLite database

MQA

MQA is a unique software product developed to solve the following problems:

<p>1 SPICE model validation is becoming increasingly important and significantly more difficult. This is because:</p>	<p>2 Model validation involves much more than just overlaying the measurement results to simulation results of the model.</p>	<p>3 Model validation should be automatic and customizable.</p>
<ul style="list-style-type: none"> - As the channel scales down, second-order physical effects make device modeling more complex. - Macro models and binning models have been used extensively. Validating these models is much trickier than global models. - A natural consequence of foundry business requires a better way of communicating between modeling engineers and designers. Designers often need to check whether the models satisfy their requirements for some specific circuit design needs. - What appears to be a good model for certain application can turn out to be a terrible one for other applications. 	<ul style="list-style-type: none"> - After all, measurement is limited to the number of physical devices in the test structure and the resolution of instruments. - Model validation should include the following checks: <ul style="list-style-type: none"> - Accuracy of the model (compare with measurement). - Completeness of the model (have all the major physical effects important to the design been modeled?). - Mathematical robustness of the model (no kink in first and second derivative). - Capability of the model to predict physical trends (very important in design optimization). - Model simulation results using benchmark circuits. 	<ul style="list-style-type: none"> - The quality can only be guaranteed after fixed QA procedures are in place. - Manually validating a model is nearly impossible considering the large number of checks for different device sizes, temperatures, and bias conditions. - Model reporting is often time-consuming and should be expedited. - Model QA routines often change with model modifications; a customizable QA platform is needed. - QA tools should help users debug model issues and point out potential problems.

Model QA

Check model completeness

- Are I_{sub} , I_{gate} , $1/f$ noise, etc. covered in the model?

Model parameter range check

Check the trend of model characteristics

- Verify that the trends of I_{dsat} , V_{th} , G_m , G_{ds} , vs $W/L/T$ are correct

Check numerical robustness of the model

- Any kinks in G_m or G_{ds} curves?

Check bin continuity

Check benchmark circuit performance

- Ring Oscillators for example
- Users can input their own circuits

Calculate point simulation value according to user's specification

Check model accuracy with the measurements

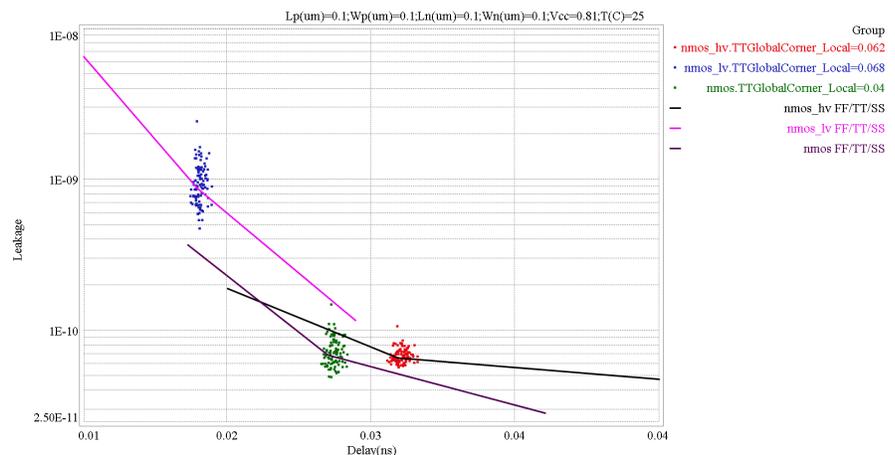
Compare model performance of different models, such as:

- HSPICE model with Spectre model
- BSIM3v3 model with BSIM4 model
- Macro model with its core model

Check and compare different process corners

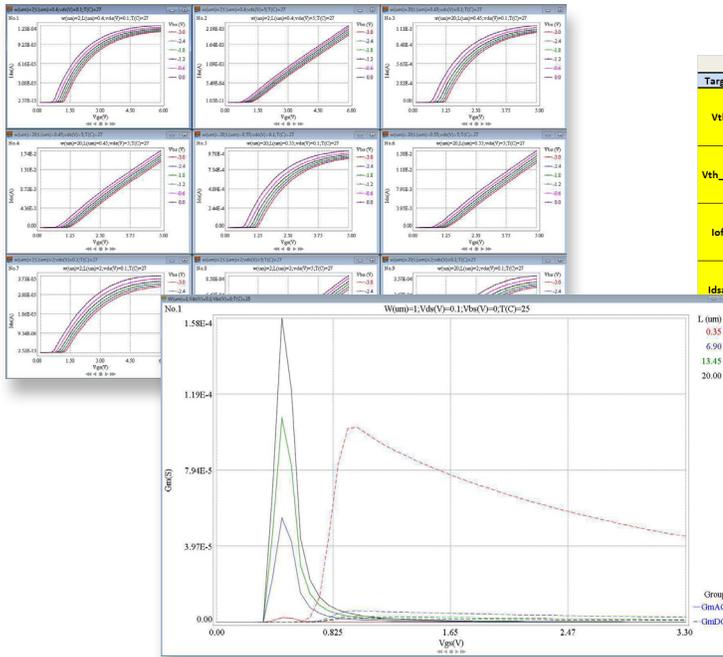
Check analog/RF design targets

- Smith and polar chart plotting
- Check the trend of network parameters
- Load-pull and harmonic balance simulation and plotting
- Thermal noise characterization
- Support for multi-port QA



Measurement QA

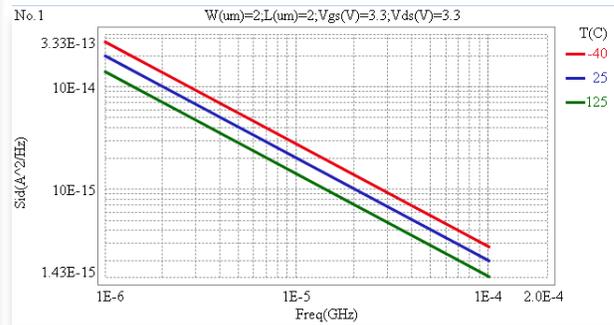
- Quick display of measured device geometry and bias condition
- Plot measured device characteristics
- Check the trend of $I_{dsat} \cdot L$, I_{dsat} / W and V_{th} to detect bad measurements



Customizable checking rules

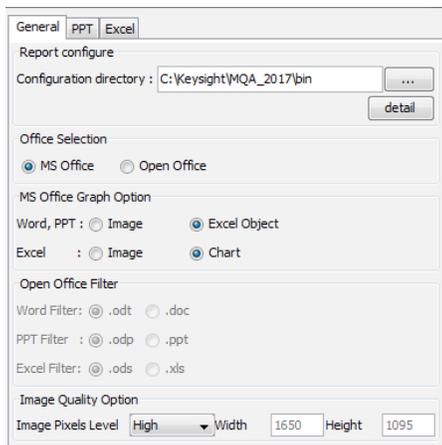
- Customize checking criteria and define sweeping range
- Add your own rules and check new targets

Device Table		NCH					PCH						
Target	Unit	W(um)	L(um)	TT	FF	SS	FS	SF	TT	FF	SS	FS	SF
Vth	V	0.4	0.38	0.5219	0.4234	0.6232	0.4228	0.6232	-0.7490	-0.6357	-0.8604	-0.8507	-0.6478
		0.4	20.01	0.4970	0.3966	0.5995	0.3980	0.5989	-0.7413	-0.6212	-0.8650	-0.8428	-0.6394
		200.1	0.38	0.5761	0.4738	0.6813	0.4772	0.6778	-0.7225	-0.6041	-0.8207	-0.8146	-0.6107
Vth_sat	V	0.4	0.38	0.4817	0.3813	0.5845	0.3824	0.5829	-0.6292	-0.5254	-0.7225	-0.7212	-0.5270
		0.4	20.01	0.4926	0.3923	0.5952	0.3937	0.5946	-0.7340	-0.6149	-0.8568	-0.8356	-0.6323
		200.1	0.38	0.5264	0.4200	0.6363	0.4282	0.6288	-0.6145	-0.4967	-0.7306	-0.7164	-0.5128
Ioff	nA	0.4	0.38	6.74E-03	8.90E-03	6.62E-03	9.48E-03	6.62E-03	-6.63E-03	-6.84E-03	-6.61E-03	-6.61E-03	-6.62E-03
		0.4	20.01	6.61E-03	6.65E-03	6.61E-03	6.66E-03	6.61E-03	-6.61E-03	-6.62E-03	-6.61E-03	-6.61E-03	-6.62E-03
		200.1	0.38	2.96E-02	4.99E-02	8.47E-03	5.08E-01	8.19E-03	-2.43E-02	-3.66E-01	-7.62E-03	-7.84E-03	-2.81E-01
Idsat	A	0.4	0.38	7.18E-03	1.78E-02	6.65E-03	1.95E-02	6.59E-03	-7.50E-03	-1.64E-02	-6.71E-03	-6.59E-03	-1.84E-02
		0.4	20.01	3.02E-04	3.60E-04	2.27E-04	3.01E-04	2.75E-04	-1.34E-04	-1.44E-04	-8.85E-05	-1.05E-04	-1.23E-04
		200.1	0.38	8.86E-06	1.09E-05	6.61E-06	9.32E-06	7.88E-06	-1.64E-06	-1.36E-06	-2.03E-06	-2.41E-06	-2.80E-06
Idsat	A	0.4	0.38	1.02E-01	1.11E-01	8.80E-02	1.05E-01	9.34E-02	-4.87E-02	-5.59E-02	-4.22E-02	-4.48E-02	-5.28E-02
		0.4	20.01	4.71E-03	5.16E-03	4.12E-03	5.04E-03	4.21E-03	-1.51E-03	-1.70E-03	-1.34E-03	-1.38E-03	-1.65E-03
		200.1	20.01										



Powerful model reporting

- MQA is equipped with a powerful report module:
- Easily output all desired tables and plots to a report format of the user's choice (i.e. Word, Excel, PowerPoint, HTML, PDF or OpenOffice)
 - Easily output all existing MQA plots to a report
 - Report content is rule driven and user customizable

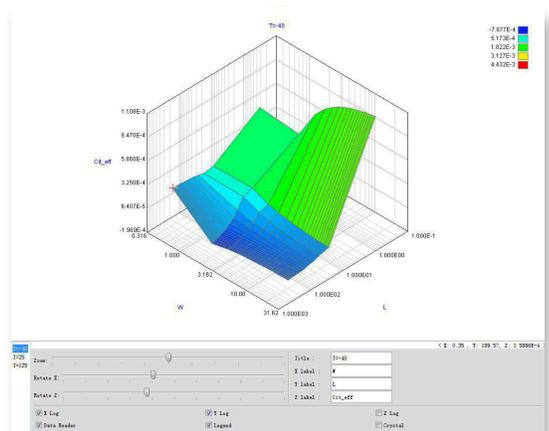


Open interface

- MQA provides an open interface for advanced users to utilize their own math functions and data process functions.
- Implement more math functions with little programming
 - Customize/add RMS functions of your preference
 - MQA's Java interface has its own engine that enables users to edit, compile and debug their own programs

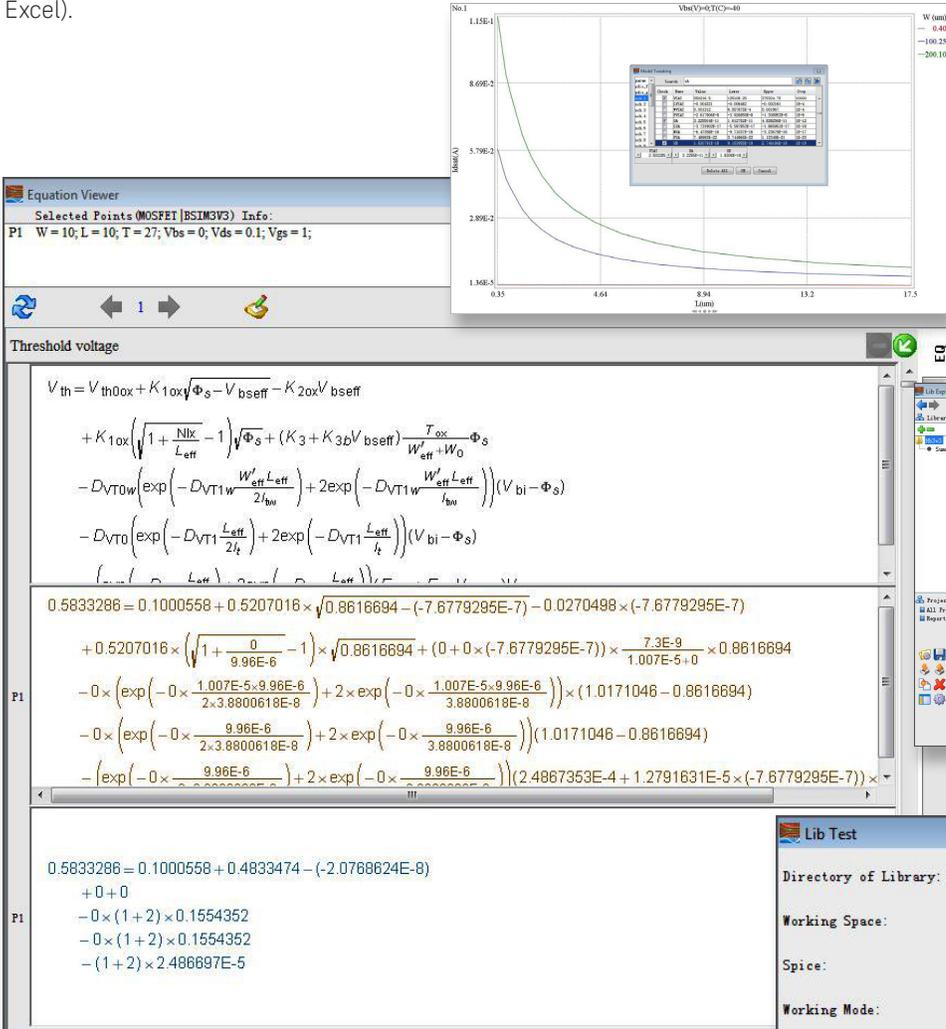
Powerful plotting

- Check scale, zoom in/out and digitalize the plots and apply math functions
- All plots can be saved to a graphic file
- The curves can also be displayed in a table
- Plot Smith Chart, polar chart and noise figure
- Easily view the previously generated results
- Generate 3D plots



Equation viewer

This feature outputs model equations and automatically calculates the parameter values, OP values and intermediate variable values in the equations. This helps users to easily debug model issues and saves effort compared to calculating these values using other means (such as Excel).

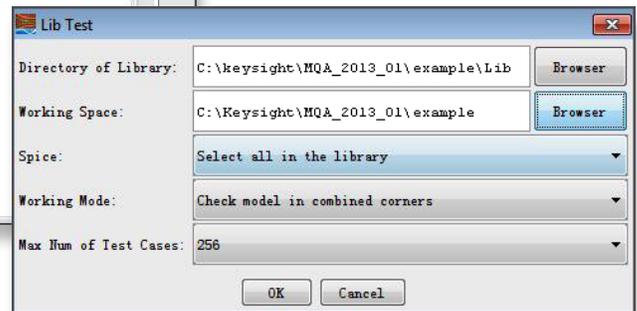
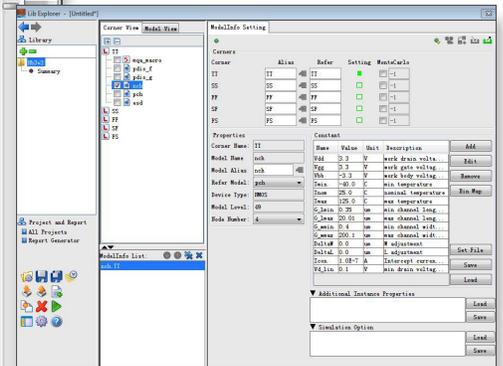


Model tweaking

MQA enables you to tweak the model parameters and see the impact on the model performance. This allows for model adjustment in order to adapt to a specific use.

Lib explorer

Lib Explorer is an efficient way to clearly present and setup model libraries. Within Lib Explorer, libraries are presented in a tree hierarchy, model configuration and settings can be done quickly, QA and Report projects are globally organized, and all effort can be saved, reused and accumulated.



Support ET

MQA enables you to load ET/PCM data and compare it with your simulation. The ET data can be overlaid with many simulation results in MQA.

Lib test

The Lib Test option in MQA provides you with a convenient method to do the quick checking on model libraries in batch. You can easily find the errors in the library file such as syntax errors, undefined parameters, incorrect links, etc. Lib Test supports all types of device models and can recognize HSPICE and Spectre libraries automatically.

Integrated data flow

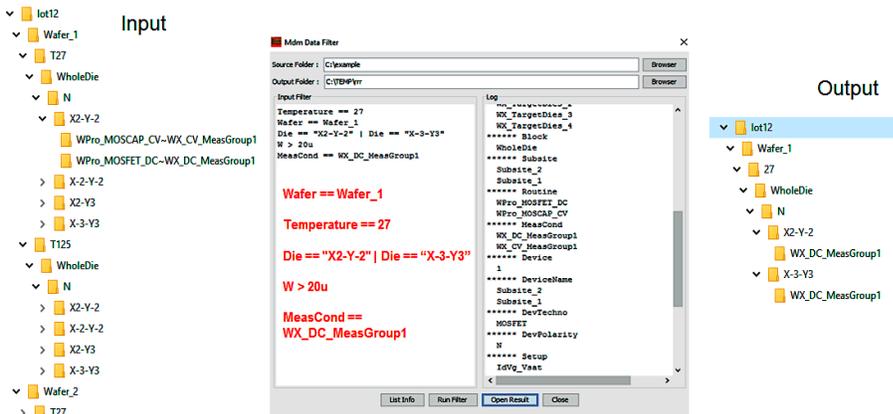
MQA supports IC-CAP mdm data files and MySQL/SQLite database natively. It enables a seamless data flow across Keysight's device modeling platform.

Mdm data filter

The new mdm data filter utility can select mdm data which is measured by IC-CAP WaferPro (WPRO) or WaferPro Express (WPE) for specific conditions. For example, you can easily select the data at a specific temperature; Temp=25C, a specific device type such as NMOS, L >1.8um, a specific measurement condition; Meas-Cond = xxx and specific lot numbers (A, B, etc). The output will then be an mdm directory with the same hierarchical structure as the original directory but contain only the subset of data you selected.

Speedup by parallelism support on multiple levels

MQA supports multiple level parallelism including simulator level, rule level and project level. It maximizes the model QA speed by allowing the user to efficiently utilize the hardware and license resources.

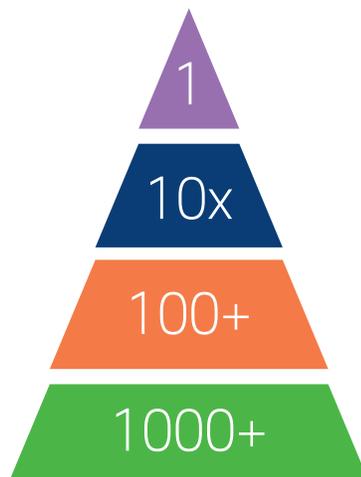


MQA's value proposition

Quality guarantee	Productivity improvement	Cost savings
Complete QA flow on one unified platform	Fully automated model QA and documentation	Quickly qualify second source foundries thereby optimizing manufacturing prices
Comprehensive understanding of model behavior	Quickly bring libraries into compliance	Reduced resources spent on the lengthy and repetitive model QA job and report generation
Avoid costly errors from undetected model imperfections	Rule driven methodology, ideal for flexibility and team sharing	Save human cost

Supported Model Formats and Platforms

- Global model, binning model, and macro (sub-circuit) model
- III-V FETs, HEMTs and HBTs
- MOSFETs (BSIM3v3, BSIM4, BSIM-BULK, BSIMSOI, PSP, HiSIM2, HiSIM_HV), MGFETs (BSIM-CMG and BSIM-IMG), diodes, BJTs (Gummel-Poon, VBIC, HICUM, and Mextram), and passive devices (resistors, capacitors and inductors)
- Support platforms: Windows and Linux
- Supported simulators includes ADS, GoldenGate, HSPICE, Spectre, Eldo, FineSim, SmartSpice, AFS, SPICE3, and the internal engine.



The de-facto industry standard SPICE model signoff and acceptance platform

Productivity improvement comparing with traditional manual script solutions

Customer base worldwide including the leading IDMs, foundries and design houses

Comprehensive checking routines enablement to reassure yourself and your customers

Product Structure

Model Quality Assurance (MQA)

Provides the complete solution and framework to fabless design companies, IDMs, and foundries for SPICE model library validation, comparison, and documentation.

Core environment

The MQA core environment software includes the basic components, simulator interfaces and utilities that allows you to check SPICE model quality and generate reports automatically. By default, the core environment supports the validation of BSIM3, BSIM4, Gummel-Poon, Mextram, HICUM, diodes, resistors, capacitors and inductors.

- W8644BP/BT Model Quality Assurance Core Environment

Models	Description	Modules
CMOS model validation	The products listed below enable BSIMSOI, PSP, HiSIM2, HiSIM_HV, BSIM-BULK (formerly known as BSIM6), BSIM-CMG, BSIM-IMG model verification.	W8632EP/ET MQA BSIMSOI model support
		W8633EP/ET MQA PSP model support software
		W8634EP/ET MQA HiSIM2 model support software
		W8635EP/ET MQA HiSIM_HV model support software
		W8637EP/ET MQA BSIM6 model support software
		W8638EP/ET MQA BSIM-CMG model support software
BJT model validation	The product listed below enables VBIC model verification.	W8639EP/ET MQA BSIM-IMG model support software
		W8636EP/ET MQA VBIC model support software
Script interface	The products listed below supports TCL & Perl script-based rule files.	W8641EP/ET MQA TCL support software
		W8642EP/ET MQA Perl support software
Viewer module	The product listed below enables results viewing and report generation of plots and tables generated by MQA.	W8640EP/ET MQA viewer site software

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