User's Guide

TPS7H5001-SP Worst-Case Analysis Model

ABSTRACT

This user's guide is intended to define the Worst Case Analysis (WCA) PSpice model for the TPS7H5001-SP. Instructions on setting up the unencrypted model for simulationSIMPLIS® are also provided. The first section of the guide outlines the model parameters and development. The second section covers different options for setting the model up to run simulations. Finally, the third section addresses how to run different types of simulations.

Table of Contents

List of Figures

Trademarks

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1 TPS7H5001-SP WCA Model Specification

The TPS7H5001-SP WCA model takes the TPS7H5001-SP SIMPLIS Model and allows users to edit specific parameters related to the frequency response of a power converter. Monte Carlo analysis can also be performed to observe the distribution of behavior across a specified sample size of devices. The following tests/device characteristics have provided data in order to find worst case conditions for parameters associated with frequency response analysis.

Process Variation Characteristics
: Device-to-device manufacturing differences;

Data characteristics provided comes from an internal statistical model of variation due to the manufactering process.

LDR Radiation Test
: Data characteristics provided after devices exposed up to the maximum rated Total Ionizing Dose (TID) of the device: 100 krad at a does rate of 0.01 rads(Si)/s

HDR Radiation Test
: Data characteristics provided after devices exposed up to the maximum rated Total Ionizing Dose (TID) of the device: 100 krad at a does rate of 72.28 rads(Si)/s

Life Test
: Data characteristics provided at 25°C after 1,000 hours of testing at 125°C, and meant to emulate 15 years operating at 65-95°C as defined by Group C specifications in MIL-PRF-38535. Additional data provided at -55°C and 125°C for the same devices.

In the model, the specific device parameters influenced by the above variation include:

gm_{ea} Error amplifier transconductance

COMP to CS_ILIM ratio (CCSR) Power stage transconductance

V_{REF} Reference voltage

1.1 Parameter Variation

Parameter Variation

Each parameter in the table below had initial data taken on a population of TSP7H5001-SP devices. A population of devices underwent a life test, a separate population of devices went through a HDR radiation test and a different population of devices underwent an LDR test. The information gained from those tests are provided in the tables below.

Table 1-1. GM_{EA} Variation Information (A/µV)

Test	Temperature	VIN	Min	Mean	Max	Standard Deviation	Population
Process Variation	-55-125°C	4-14 V	N/A	N/A	N/A	7%*	N/A
Pre-Life/Pre-Radiation	-55°C	4	1814	2105	2362	109	87
Pre-Life/Pre-Radiation	-55°C	5	1834	2109	2333	110	87
Pre-Life/Pre-Radiation	-55°C	12	1849	2106	2351	105	87
Pre-Life/Pre-Radiation	-55°C	14	1855	2126	2389	108	87
Pre-Life/Pre-Radiation	25°C	4	1605	1789	1941	71.0	87
Pre-Life/Pre-Radiation	25°C	5	1616	1808	1950	71.1	87

Table 1-1. GM_{EA} Variation Information (A/µV) (continued)

Pre-Life/Pre-Radiation	25°C	12	1650	1808	1957	67.4	87
Pre-Life/Pre-Radiation	25°C	14	1647	1807	1954	68.1	87
Pre-Life/Pre-Radiation	125°C	4	1312	1405	1492	38.0	87
Pre-Life/Pre-Radiation	125°C	5	1329	1422	1509	39.2	87
Pre-Life/Pre-Radiation	125°C	12	1334	1425	37.8	1508	87
Pre-Life/Pre-Radiation	125°C	14	1330	1424	1506	38.8	87
Post-Life Test	-55°C	4	1817	2084	2318	109	87
Post-Life Test	-55°C	5	1834	2108	2333	109	87
Post-Life Test	-55°C	12	1849	2106	2351	105	87
Post-Life Test	-55°C	14	1855	2126	2389	108	87
Post-Life Test	25°C	4	1605	1789	1941	71.0	87
Post-Life Test	25°C	5	1616	1808	1950	71.2	87
Post-Life Test	25°C	12	1650	1808	1957	67.4	87
Post-Life Test	25°C	14	1647	1807	1954	68.1	87
Post-Life Test	125°C	4	1312	1405	1492	38.0	87
Post-Life Test	125°C	5	1329	1422	1509	39.2	87
Post-Life Test	125°C	12	1334	1425	1508	37.8	87
Post-Life Test	125°C	14	1330	1424	1505	38.9	87
Post LDR Radiation	25°C	4	1667	1787	1925	60.1	80
Post LDR Radiation	25°C	5	1692	1805	1950	59.2	80
Post LDR Radiation	25°C	12	1698	1804	1938	59.6	80
Post LDR Radiation	25°C	14	1681	1801	1950	60.0	80
Post HDR Radiation	25°C	4	1641	1804	1937	66.6	70
Post HDR Radiation	25°C	5	1645	1821	1982	71.2	70
Post HDR Radiation	25°C	12	1646	1821	1992	71.3	70
Post HDR Radiation	25°C	14	1630	1820	1988	71.2	70

*Standard deviation value is the largest at a single temperature and VIN operating point when considering all temperatures and VIN values. It is not the standard deviation when the population includes all VIN and temperatures.

Table 1-2. VREF Variation Information (mV)

Test	Temperature	VIN	Min	Mean	Max	Standard Deviation	Population
Pre-Life/Pre-Radiation	-55°C	4	607.7	609.2	610.6	0.619	87
Pre-Life/Pre-Radiation	-55°C	5	607.8	609.1	610.6	0.615	87
Pre-Life/Pre-Radiation	-55°C	12	607.8	609.3	610.7	0.611	87
Pre-Life/Pre-Radiation	-55°C	14	607.9	609.3	610.8	0.607	87
Pre-Life/Pre-Radiation	25°C	4	611.6	613.1	614.0	0.438	87
Pre-Life/Pre-Radiation	25°C	5	611.7	613.2	614.1	0.435	87
Pre-Life/Pre-Radiation	25°C	12	611.7	613.2	614.1	0.437	87
Pre-Life/Pre-Radiation	25°C	14	611.7	613.2	614.1	0.436	87
Pre-Life/Pre-Radiation	125°C	4	612.6	614.0	615.1	0.511	87
Pre-Life/Pre-Radiation	125°C	5	612.7	614.3	615.2	0.512	87
Pre-Life/Pre-Radiation	125°C	12	612.8	614.1	615.2	0.511	87
Pre-Life/Pre-Radiation	125°C	14	612.8	614.1	615.2	0.505	87
Post-Life	-55°C	4	607.7	609.0	610.3	0.638	87
Post-Life	-55°C	5	607.8	609.0	610.4	0.645	87
Post-Life	-55°C	12	607.8	609.1	610.4	0.640	87
Post-Life	-55°C	14	607.9	609.1	610.4	0.627	87
Post-Life	25°C	4	611.5	613.0	613.8	0.435	87
Post-Life	25°C	5	611.7	613.1	613.8	0.425	87
Post-Life	25°C	12	611.3	613.0	613.9	0.426	87
Post-Life	25°C	14	611.6	613.8	613.9	0.425	87
Post-Life	125°C	4	612.6	614.0	615.1	0.503	87
Post-Life	125°C	5	612.8	614.1	615.2	0.501	87
Post-Life	125°C	12	612.8	614.1	615.2	0.506	87
Post-Life	125°C	14	612.8	614.1	615.2	0.503	87
Post LDR Radiation	25°C	4	611.1	612.5	613.6	0.555	80
Post LDR Radiation	25°C	5	611.2	612.5	613.6	0.560	80
Post LDR Radiation	25°C	12	611.2	612.5	613.6	0.558	80

Table 1-2. VREF Variation Information (mV) (continued)

Post LDR Radiation	25°C	14	611.2	612.5	613.7	0.561	80
Post HDR Radiation	25°C	4	610.5	612.2	613.6	0.698	70
Post HDR Radiation	25°C	5	610.5	612.2	613.6	0.704	70
Post HDR Radiation	25°C	12	610.5	612.2	613.6	0.699	70
Post HDR Radiation	25°C	14	610.5	612.2	613.6	0.708	70

*Standard deviation value is the largest at a single temperature and VIN operating point when considering all temperatures and VIN values. It is not the standard deviation when the population includes all VIN and temperatures.

Table 1-3. COMP to CS_ILIM Ratio Variation

Test	Temperature	Min	Mean	Max	Standard Deviation	Population
Pre-Life/Pre-Radiation	-55°C	2.030	2.048	2.072	0.00956	30
Pre-Life/Pre-Radiation	25°C	2.030	2.047	2.083	0.0121	30
Pre-Life/Pre-Radiation	125°C	2.041	2.055	2.083	0.0116	30
Post-Life	-55°C	2.030	2.048	2.083	0.00992	87
Post-Life	25°C	2.025	2.049	2.089	0.0137	87
Post-Life	125°C	2.036	2.057	2.094	0.0133	87
Post-LDR Radiation	25°C	2.030	2.049	2.089	0.0102	80
Post-HDR Radiation	25°C	2.025	2.053	2.117	0.0162	70

1.2 Global Variables

The following global variables are used within the F11 window of SIMPLIS. Global variables are used by the TPS7H5001-SP WCA device and changing the names in the F11 window, will cause the model not to work. Default values are placed so that the minimum and maximum values are the minimum and maximum values of the data sheet.

Parameter	Description	Default Mean Value	Default Tol- Value
gmea	Model variable for the error amplifier transconductance	1825 µS	37 %
Vr	Model variable for the reference voltage	0.613 V	1 %
Rtt	Internal variable related to the voltage reference. Changing the equation will cause model to work improperly.	N/A	N/A
IDCOMP	Model variable for CCSR parameter	2.06	2.9%

In addition to the listed model parameters, external component selection will also influence device behavior. The external components used in the default schematic take nominal values and, as such, users may see fit to add tolerances to them to model real-world variation.

1.3 Editing Model Parameters

The TPS7H5001-SP WCA Model allows for editing internal parameters through the use of the F11 window in SIMPLIS. After opening the schematic file "TPS7H5001_SP_SIMPLIS_Flyback.sxsch" simply pressing F11, or sometimes CTRL + F11 will open up the F11 window.

```
.simulator SIMPLIS
.ac DEC 25 100m 1Meg
.print
+ ALL
.options
+ PSP_NPT=1001
+ POP_ITRMAX=20
+ POP_USE_TRAN_SNAPSHOT
+ POP_OUTPUT_CYCLES=5
+ POP_SHOWDATA
+ SNAPSHOT_INTVL=0
+ SNAPSHOT_NPT=11
+ NEW_ANALYSIS
+ MIN_AVG_TOPOLOGY_DUR=1a
+ AVG_TOPOLOGY_DUR_MEASUREMENT_WINDOW=128
.pop
+ TRIG_GATE={TRIG_GATE}
+ TRIG_COND=0_TO_1
+ MAX_PERIOD=2u
+ CONVERGENCE=10p
+ CYCLES_BEFORE_LAUNCH=4000
+ TD_RUN_AFTER_POP_FAILS=-1
*.tran 30m 0

*.Do not change the names of these global variables or the model will not work
.GLOBALVAR gmea = 1.825m*WC(0.37)
.GLOBALVAR Vr = 0.613*WC(0.01)
.GLOBALVAR Rtt = (1.23-Vr)*1000/Vr
.GLOBALVAR IDComp = 1/(2.06*WC(0.029))
.simulator DEFAULT
```

Figure 1-1. F11 Window in SIMPLIS

Editing the tolerances can be done in this window by changing the tol parameter for the specific distribution chosen. WC(tol) is used by default, but there are different distributions that can be chosen.

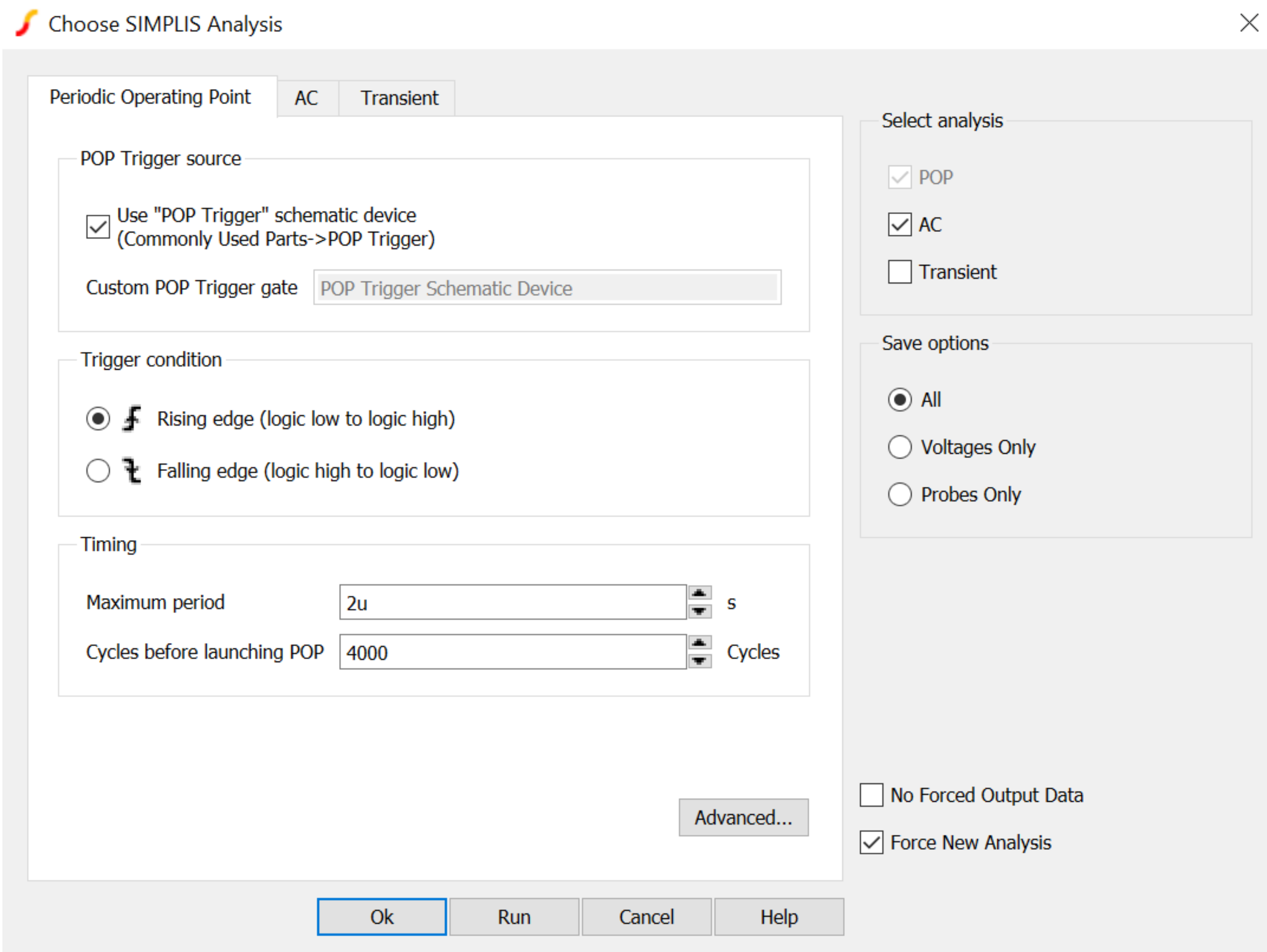
Distribution Name	Definition
WC(tol)	Worst-Case. Returns either 1.0-**tol** or 1.0+**tol** chosen at random.
Unif(tol)	Uniform. Returns a random value in the range 1.0 +/- **tol** with a uniform distribution.
GaussTrunc(tol)	Truncated Gaussian. As with Gauss() but values greater than (1 + **tol**) and less than (1 - **tol**) are rejected, and the program picks another random number inside the Gaussian distribution.
Gauss(tol)	Gaussian. Returns a random number with a mean of 1.0 and a standard deviation of **tol**/3. Random values have a Gaussian or Normal distribution.

2 Model Setup

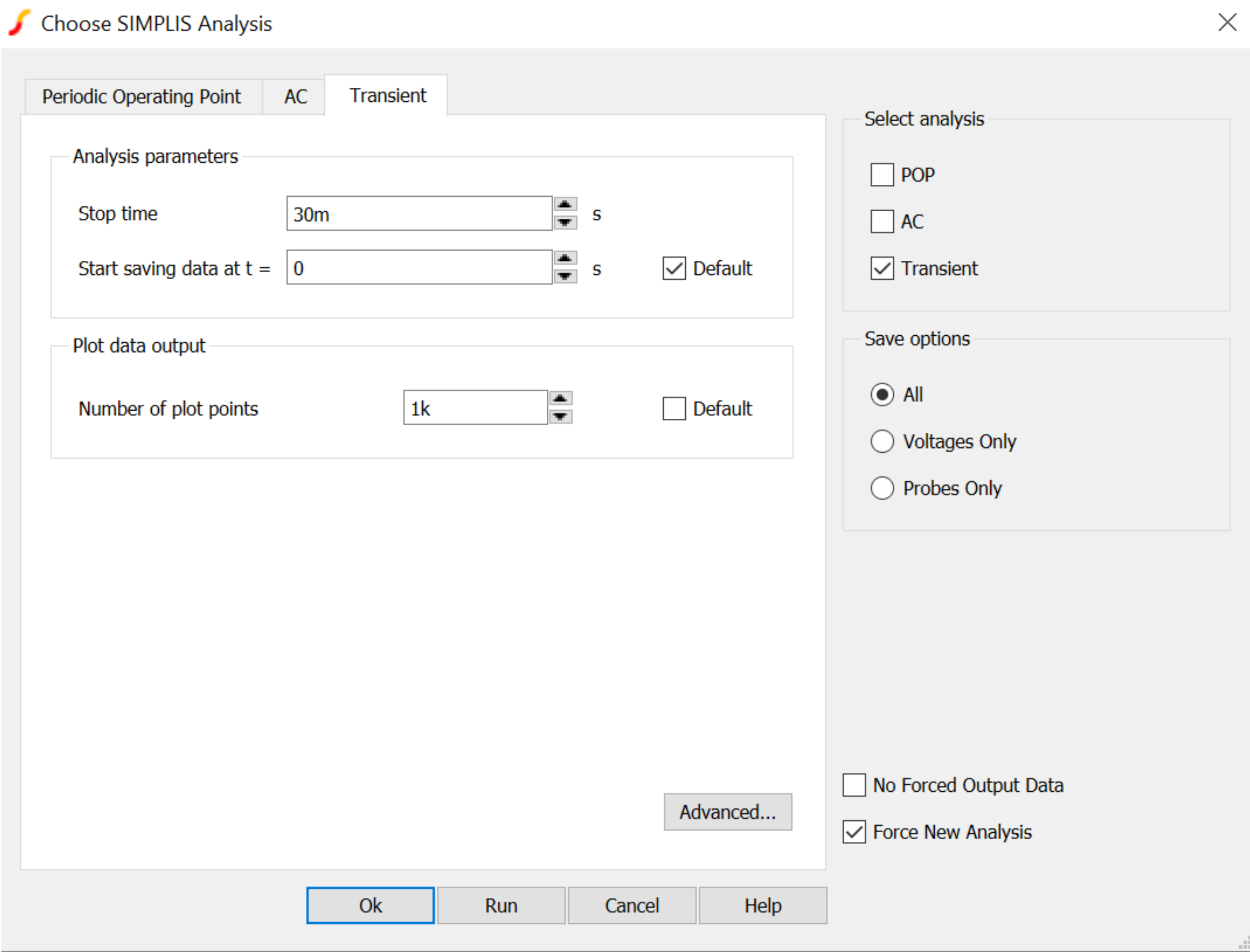
The TPS7H5001-SP WCA model comes with a default schematic file (TPS7H5001_SP_SIMPLIS_Flyback.sxsch) that can be used to run simulations with minimal effort needed to set up the model. Users will need to set up their own Simulation Profiles in order to run simulations. Instructions for doing so are provided in Section 3.

2.1 Running Transient Simulation

1. Open TPS7H5001_SP_SIMPLIS_Flyback.sxsch
2. Click **Simulator → Choose Analysis**.



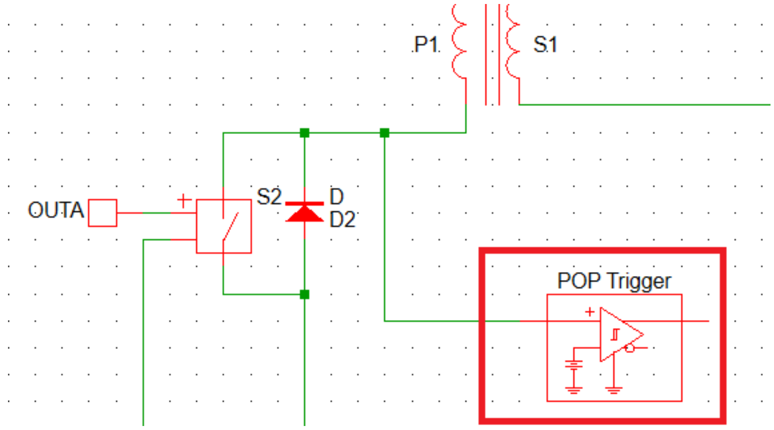
3. Open the **Transient** tab



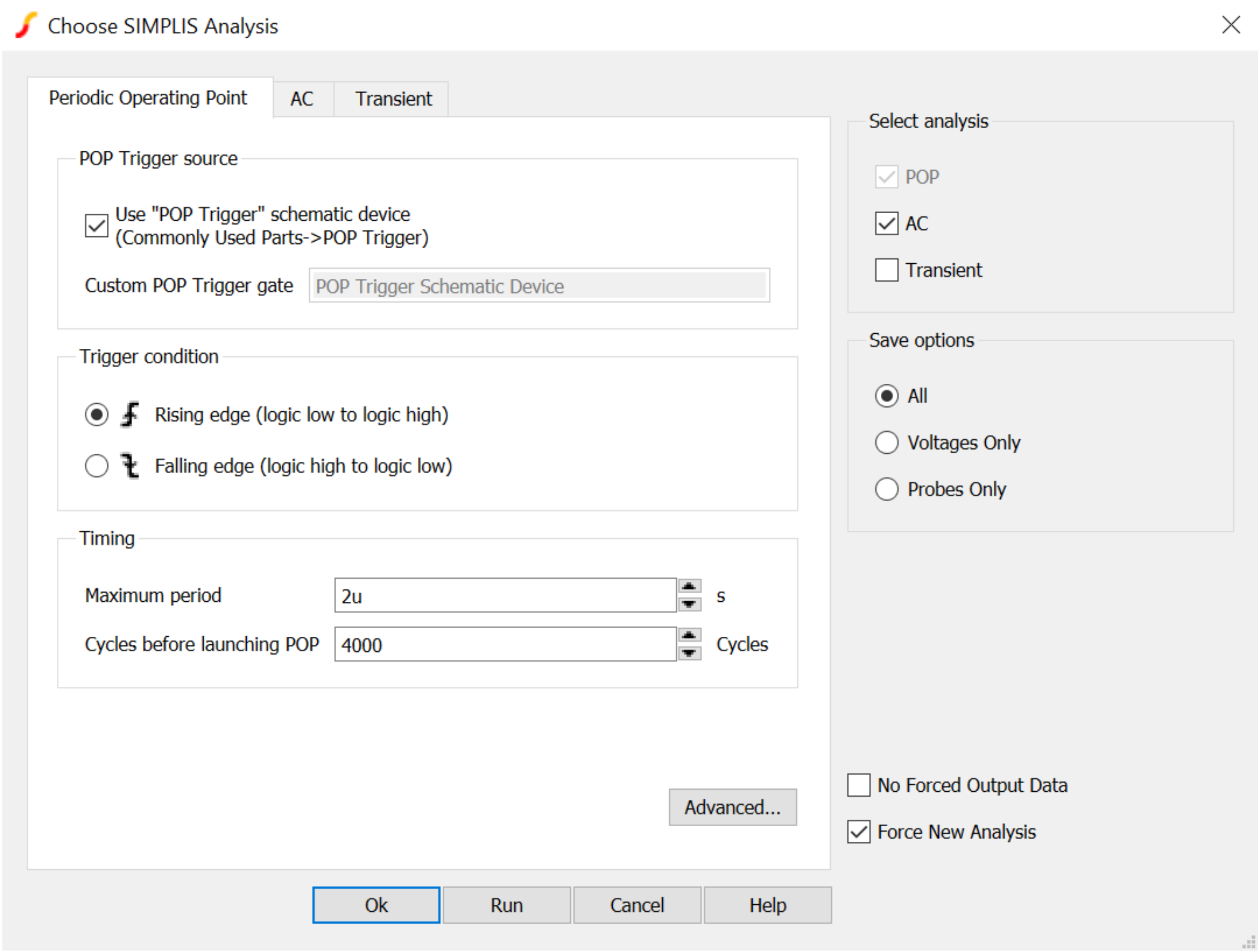
4. Edit **Stop Time** for desired run length. **Start saving data at t =** will start saving the data at the inputted time. **Number of plot points** is used to change the amount of plot points for the data saved in the simulation.
5. In **Select Analysis** on the right, select **Transient** and press run at the bottom

2.2 Running POP Analysis and AC Simulation

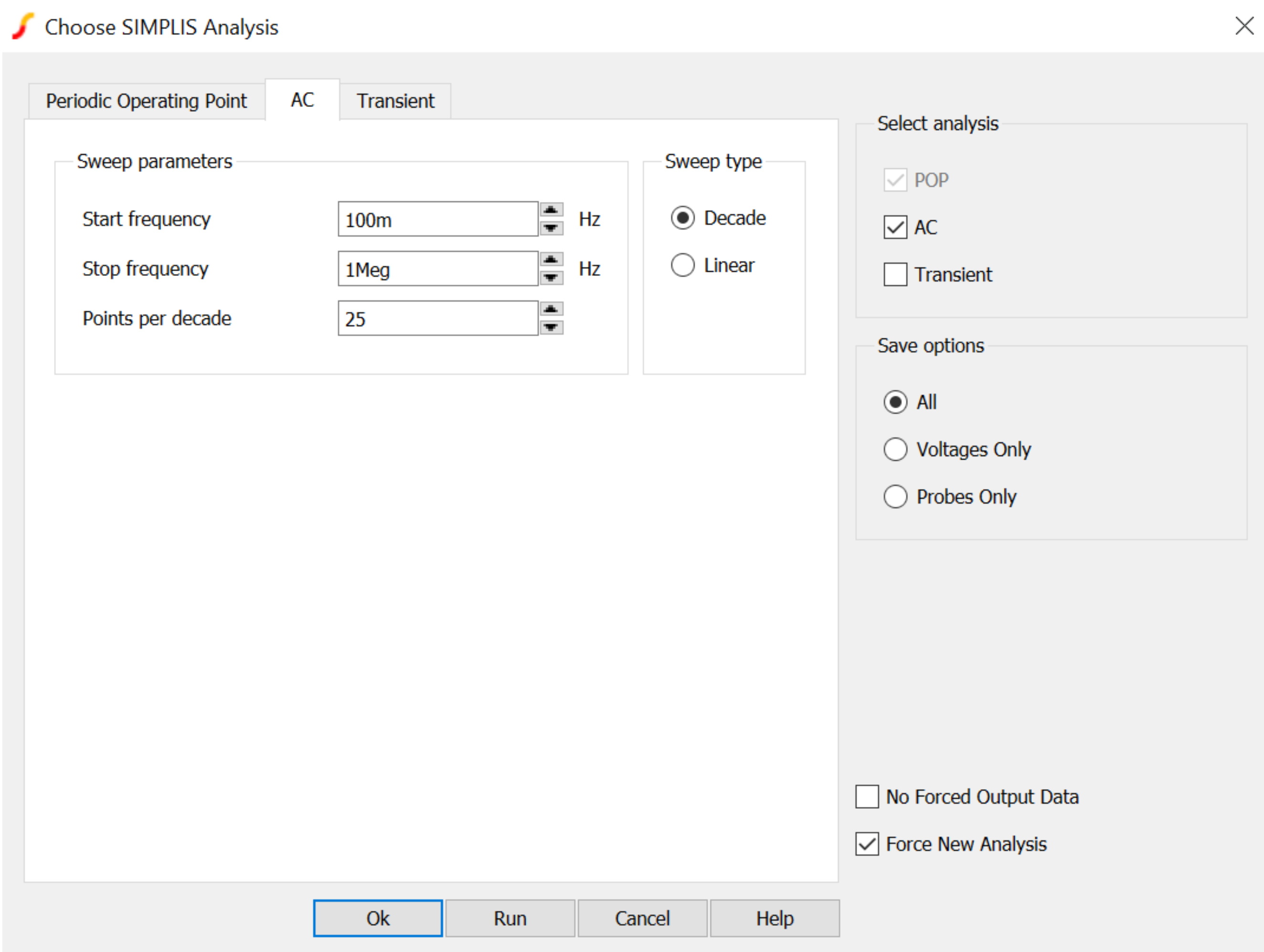
1. Open TPS7H5001_SP_SIMPLIS_Flyback.sxsch
2. **POP Trigger** in the provided schematic should be connected to the primary side switch node of the converter for single frequency converters. Note that the POP Trigger requires the user to designate a switching node which is the least common multiple of the periodic frequencies present in the circuit. This can be an issue in power converters such as a full-bridge where some of the switch nodes are running at twice the frequency of the outputs of the device.



3. Click **Simulator** → **Choose Analysis**.
4. **Periodic Operating Point (POP)** tab should be open



5. Default values for the schematic are 2us for the **Maximum Period** and 4000 **Cycles before launching POP**.
6. **Maximum Period** should be increased if the frequency of the converter decreases such that the **Maximum Period** is larger than the maximum period of the converter.
7. **Cycles before launching POP** needs to be larger such that the output of the converter reaches steady state by the time POP analysis starts. If this number is not large enough POP analysis will fail. There is a maximum of 8192 cycles. If the maximum amount of cycles is not large enough, the soft start capacitance of the converter may need to be decreased in order to allow the converter to start up faster and have the POP analysis converge. The POP analysis will try and start up the converter faster than normal, so the soft start function is not valid during this test.
8. Open the **AC** tab



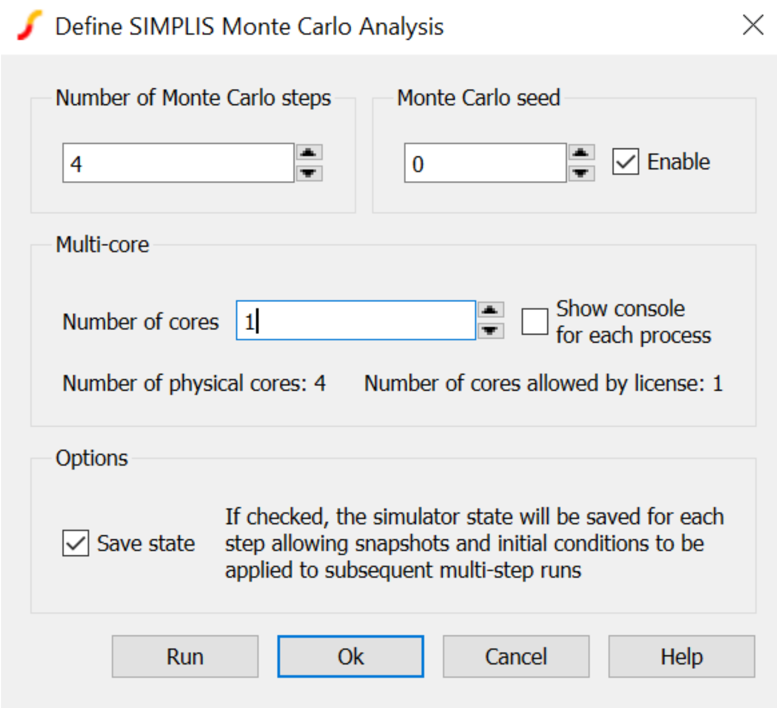
9. **Start frequency** is where the data will start to be taken for the frequency response and the **stop frequency** is where the data will stop being taken. **Points per decade** will simply effect how much data is taken for the test.
10. In **Select Analysis** on the right, select **POP** and **AC** and press run at the bottom

3 Monte Carlo

3.1 Monte Carlo Simulation

1. Click

   Monte Carlo→ Setup Monte Carlo



2. **Number of Monte Carlo steps** is the amount of times a Monte Carlo simulation will run. **Monte Carlo Seed** can be used to to the same seed as a previous Monte Carlo simulation. **Number of Cores** will be how many cores of your computer is used for processing.
3. Click

   Monte Carlo→ Run Monte Carlo
4. The Monte Carlo analysis will run whichever analysis is chosen under **Simulator → Choose Analysis**. If transient Monte Carlo analysis is required, choose **Transient** on the right. If AC Monte Carlo analysis is required choose **AC** and **POP**.

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision * (March 2022) to Revision A (February 2023)	Page
• Updated TPS7H5001-SP WCA Model Specification section	2