

Flyback Design with TPS7H500X-SP family of controllers

Agenda

- Basic Overview
- Getting Started on Converter Design
 - Utilizing Power Stage Designer
- Starting with SIMPLIS Models
 - Basics
 - Worst Case Analysis
 - Radiation Effects

Basic overview

- Basic converter schematics are available on ti.com
- Too many to fit on single page
- Can be used as a starting point for designs
- All models come with a basic schematic, with the default being a push-pull converter

Design tools & simulation



SIMULATION MODEL

[TPS7H5001-SP SIMPLIS Transient Model](#)

SLVMDM7.ZIP (30 KB) - SIMPLIS Model

[Download](#)

SIMULATION MODEL

[TPS7H5001-SP PSpice Transient Model \(Rev. A\)](#)

SLVMDN1A.ZIP (53 KB) - PSpice Model

[Download](#)

SIMULATION MODEL

[TPS7H5001-SP SIMPLIS Model \(Flyback Reference Schematic\)](#)

SLVMDP9.ZIP (28 KB) - SIMPLIS Model

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SIMULATION MODEL

[TPS7H5001-SP PSpice Transient Reference Design \(Flyback Reference Schematic\)](#)

SLVMDQ0.ZIP (27 KB) - PSpice Model

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SIMULATION MODEL

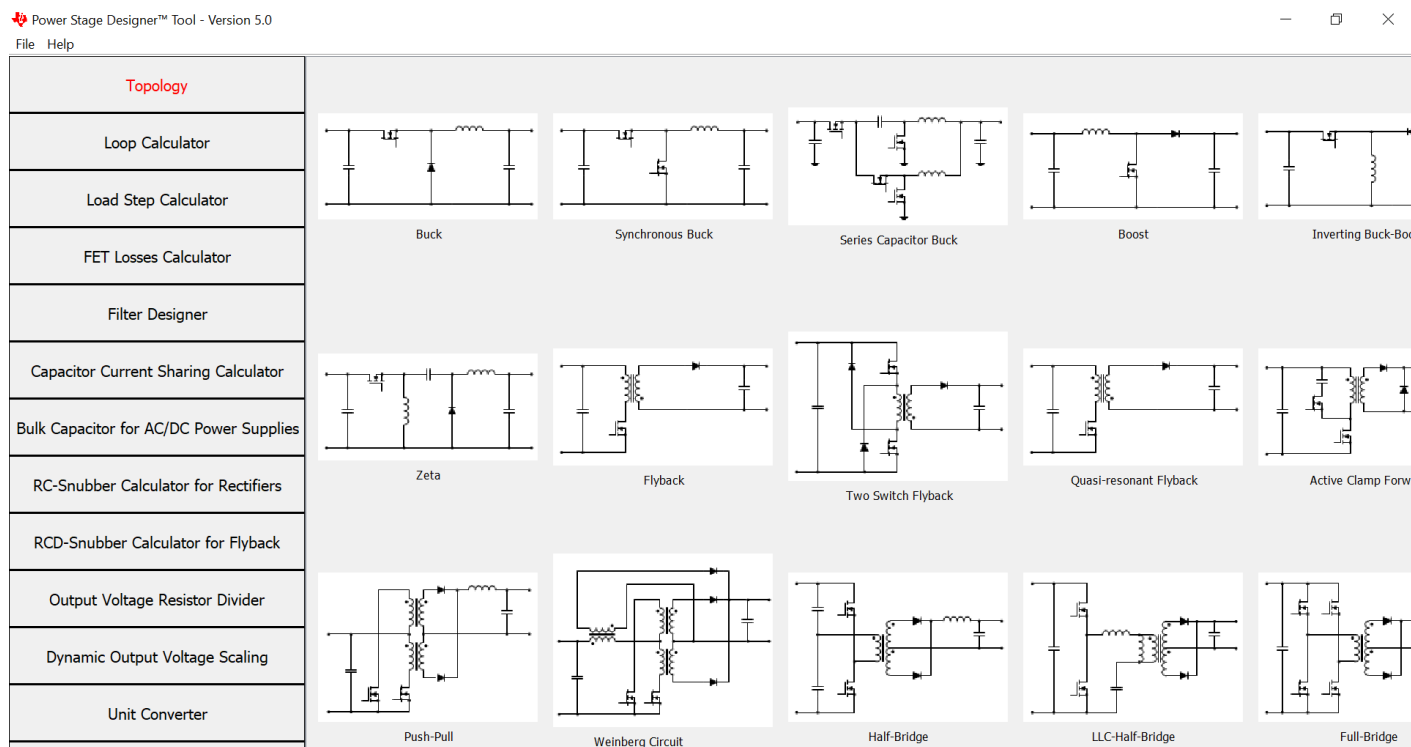
[TPS7H5001-SP SIMPLIS Model \(Buck Schematic\)](#)

SLVMDU0.ZIP (29 KB) - SIMPLIS Model

[Download](#)

Getting started on Converter Design

- Power stage designer is a great tool to look at the basics of the converter
- Works for multiple different topologies
- Has many different calculators to help with different aspects of the design



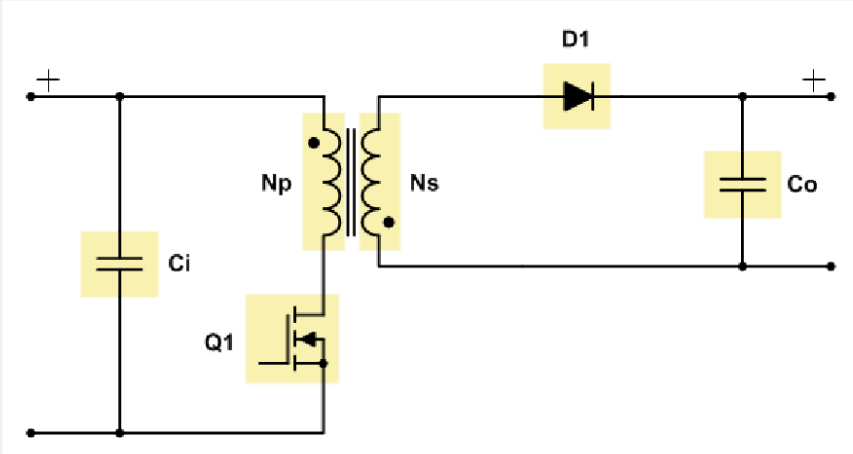
Getting started on Converter Design

- Looking at each converter you can see suggestions on transformer design as well as inductor design
- Basic calculations are listed at the bottom
- Information on the equations are listed under the help tab at the top (not shown here)

Design Values

Minimum Input Voltage:	<input type="text" value="28"/> V
Maximum Input Voltage:	<input type="text" value="28"/> V
Output Voltage:	<input type="text" value="5"/> V
Output Current:	<input type="text" value="10"/> A
Switching Frequency:	<input type="text" value="500"/> kHz
Diode Voltage Drop:	<input type="text" value="0.7"/> V
Current Ripple:	<input type="text" value="30"/> %
Maximum Duty Cycle:	<input type="text" value="30"/> %

☐ Discontinuous Conduction Mode
☐ Boundary Mode
☒ Continuous Conduction Mode
☐ Transition Mode



Recommended Values

Turns Ratio:	2.11 : 1
Inductance:	8.25 μ H

Choose Values

Turns Ratio:	<input type="text" value="2"/> : 1
Inductance:	<input type="text" value="9"/> μ H

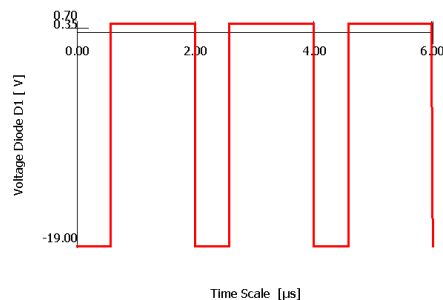
Calculated Values at Input Voltage: 28.00 V Load Current: 10.00 A

Switch. Freq.:	500.00 kHz	Input Power:	57.00 W	L_{sec} :	2.25 μ H
Period:	2.00 μ s	Output Power:	50.00 W	Input Current:	2.04 A
Duty Cycle:	28.93 %	Diode Losses:	7.00 W	Current Ripple:	1.80 A
On-Time:	0.58 μ s				25.59 %
Off-Time:	1.42 μ s				
Zero-Time:	0.00 μ s				
RHPZ:	61.73 kHz				

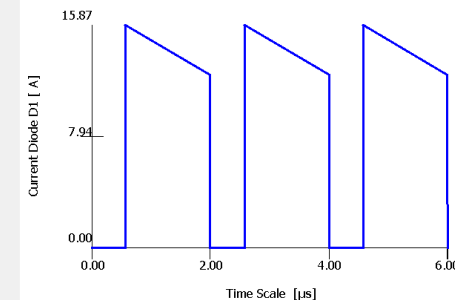
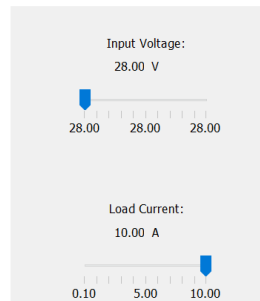
Getting started on Converter Design

- Clicking on the yellow sections shows basic current and voltage stresses on the parts
- This does not include spikes from parasitics or increases in current from efficiency
- This can be looked at for different output currents and input voltages

Graph - Diode D1

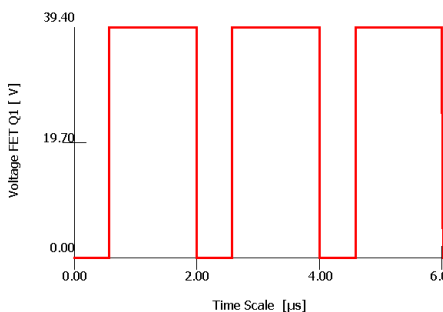


Min. Voltage Diode D1: -19.00 V
Max. Voltage Diode D1: 0.70 V

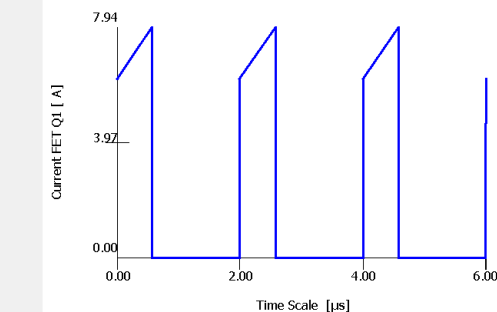
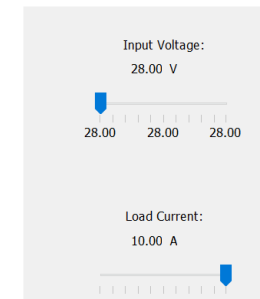


Min. Current Diode D1: 12.27 A
Max. Current Diode D1: 15.87 A
RMS Current Diode D1: 11.89 A
Avg. Current Diode D1: 10.00 A
AC Current Diode D1: 6.44 A

Graph - FET Q1



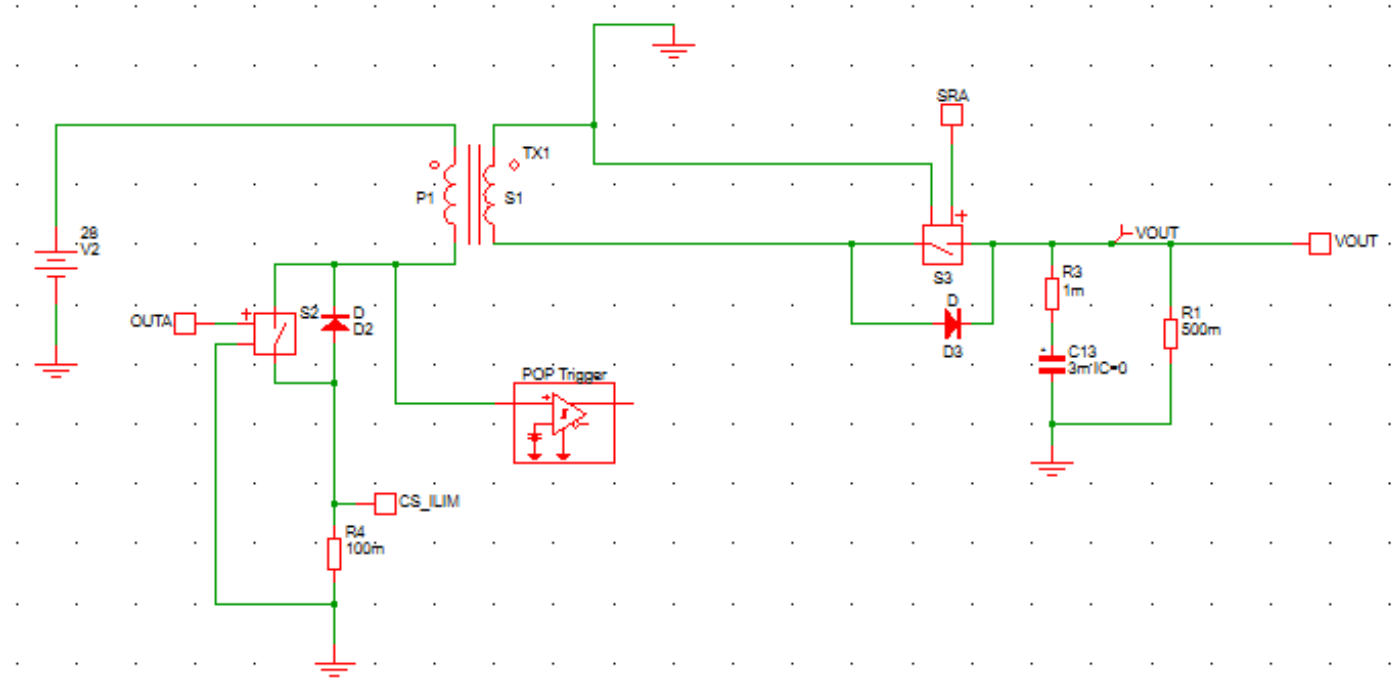
Min. Voltage FET Q1: 0.00 V
Max. Voltage FET Q1: 39.40 V



Min. Current FET Q1: 6.14 A
Max. Current FET Q1: 7.94 A
RMS Current FET Q1: 3.79 A
Avg. Current FET Q1: 2.04 A
AC Current FET Q1: 3.20 A

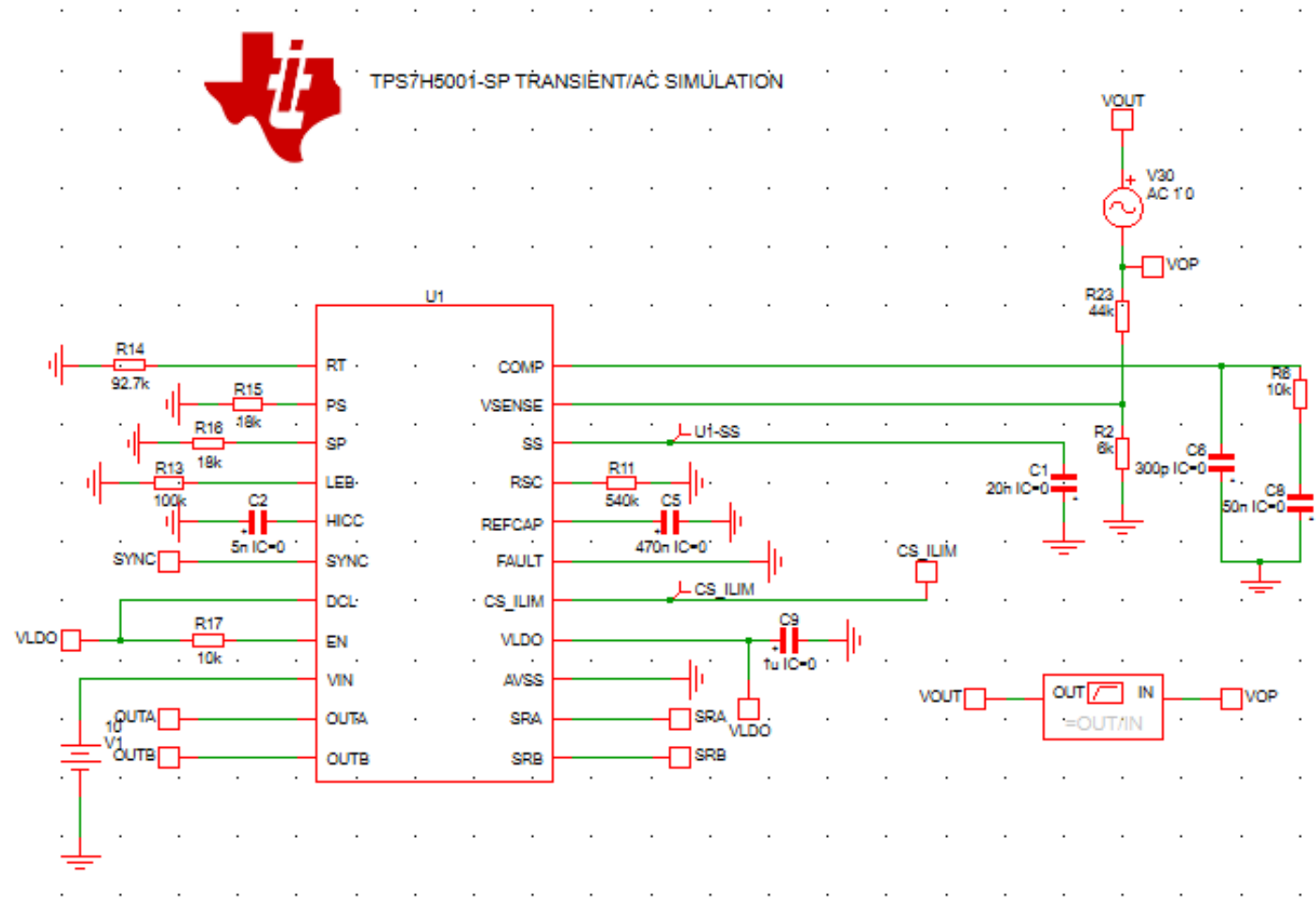
Starting with SIMPLIS models

- Can be used as a starting point for designs
- POP trigger is important for AC analysis and will be gone over more later
- Basic models are used by default, can be replaced with more complicated models



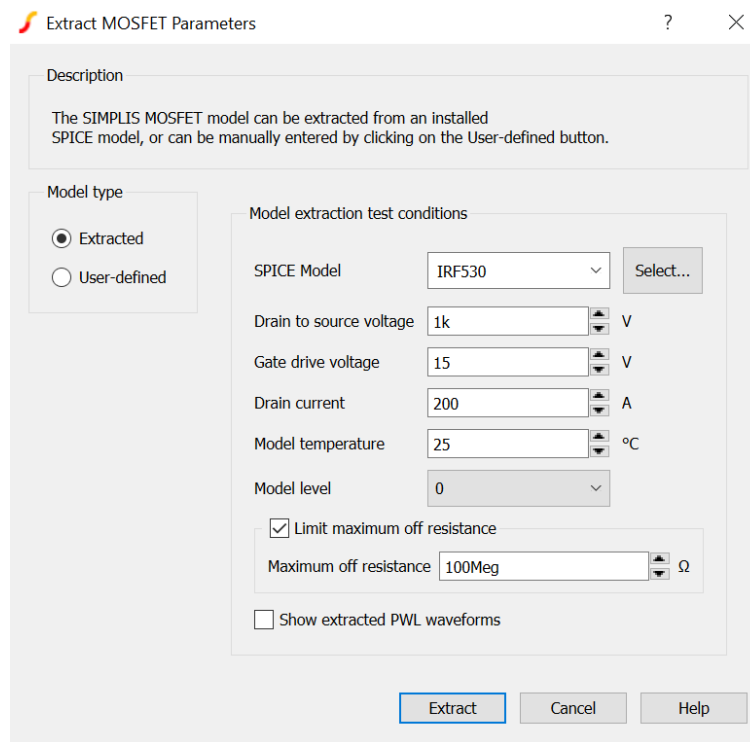
Starting with SIMPLIS models

- This is the TPS7H5001-SP model that was developed
- V30 and OUT/IN block are used for AC analysis and don't affect transient analysis
- Note that no driver is included in supplied schematics, but is needed in final design.
- Note SS value is generally placed lower during debug



Starting with SIMPLIS models

- Switches in design can be replaced
- Both imported models and user defined models are supported
- Note that some non-linearities and a slow down of simulation is to be expected



Extract MOSFET Parameters

Description

The SIMPLIS MOSFET model can be extracted from an installed SPICE model, or can be manually entered by clicking on the User-defined button.

Model type

☒ Extracted
☐ User-defined

Model extraction test conditions

SPICE Model: IRF530 [Select...]

Drain to source voltage: 1k V

Gate drive voltage: 15 V

Drain current: 200 A

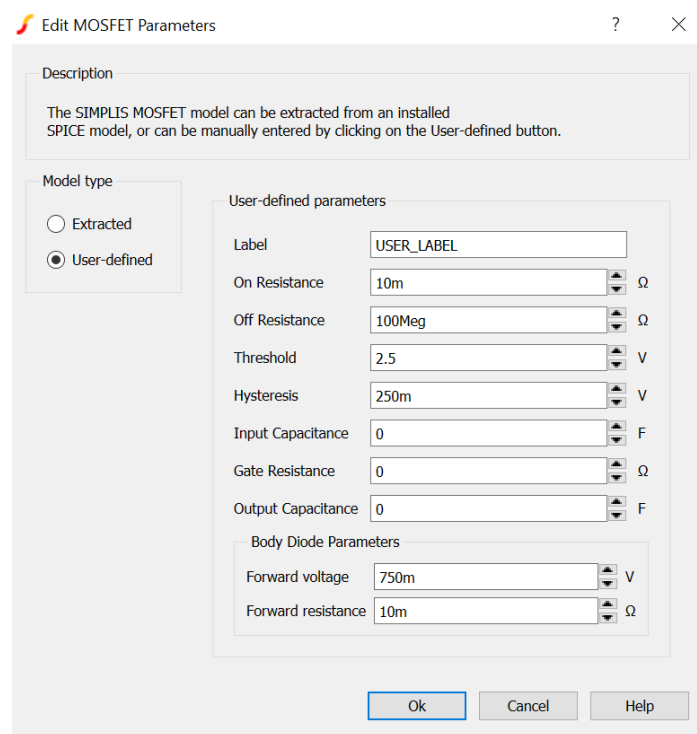
Model temperature: 25 °C

Model level: 0

☒ Limit maximum off resistance
Maximum off resistance: 100Meg Ω

☐ Show extracted PWL waveforms

Extract Cancel Help



Edit MOSFET Parameters

Description

The SIMPLIS MOSFET model can be extracted from an installed SPICE model, or can be manually entered by clicking on the User-defined button.

Model type

☐ Extracted
☒ User-defined

User-defined parameters

Label: USER_LABEL

On Resistance: 10m Ω

Off Resistance: 100Meg Ω

Threshold: 2.5 V

Hysteresis: 250m V

Input Capacitance: 0 F

Gate Resistance: 0 Ω

Output Capacitance: 0 F

Body Diode Parameters

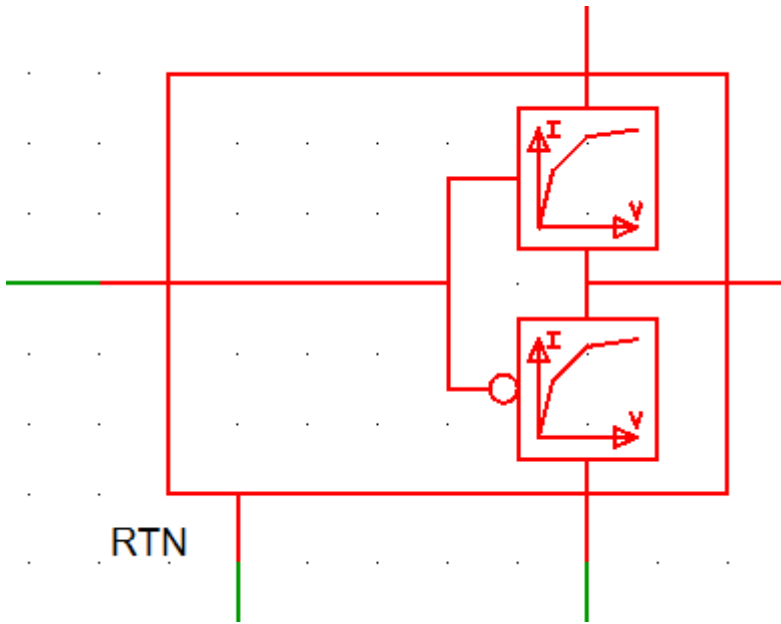
Forward voltage: 750m V

Forward resistance: 10m Ω

Ok Cancel Help

Starting with SIMPLIS models

- A driver model is required in order to use the MOSFET models properly
- Refer to SIMPLIS website



Edit Multi-Level MOSFET Driver: U44

Multi-Level MOSFET Driver (Version 8.0+)

Model level

- ☐ Level 0
- ☐ Level 1
- ☒ Level 2

Parameters Additional Parameters

Input parameters

Threshold V

Hysteresis V

☐ Use inverted logic

☐ Use delay

Rising-edge delay s

Falling-edge delay s

Upper switch PWL model

V1 V R0N1 Ω

R0N2 Ω

I3 A R3 Ω

Lower switch PWL model

V1 V R0N1 Ω

R0N2 Ω

I3 A R3 Ω

Ok Cancel Help

Starting with SIMPLIS models

- Ideal transformers are suggested to be used
- Putting the number of turns as well as the primary inductance auto fills the secondary inductance
- Coupling can be changed as well as number of turns on each side

Define Ideal Transformer

Configuration

Primaries # Secondaries

Coupling

Inter-primary coupling Primary-secondary coupling Inter-secondary coupling

	Winding	Number of turns	Polarity	Inductance
1	Primary 1	<input type="text" value="1"/>	+ <input type="text" value="v"/>	<input type="text" value="10u"/>
2	Secondary 1	<input type="text" value="1"/>	+ <input type="text" value="v"/>	<input type="text" value="10uH"/>

Ok Cancel Help

Starting with SIMPLIS models

- WCA modeling can be done when model is released with F11 window
- Parameters GMEA, VREF, and CCSR can be varied using the SIMPLIS functions
- SIMPLIS has different variations based on 6 sigma, or even just looking at corners
- Monte Carlo -> Set-up brings up the window to the right
- Monte Carlo will be ran on whatever simulation you have prepared.

```
25 .GLOBALVAR gmea = 1.825m*WC(0.37)
26 .GLOBALVAR Vr = 0.613*WC(0.01)
27 .GLOBALVAR Rtt = (1.23-Vr)*1000/Vr
28 .GLOBALVAR IDComp = 1/(2.06*WC(0.029))
```

Define SIMPLIS Monte Carlo Analysis

Number of Monte Carlo steps: 50

Monte Carlo seed: 0 ☐ Enable

Multi-core

Number of cores: 1 ☐ Show console for each process

Number of physical cores: 4 Number of cores allowed by license: 1

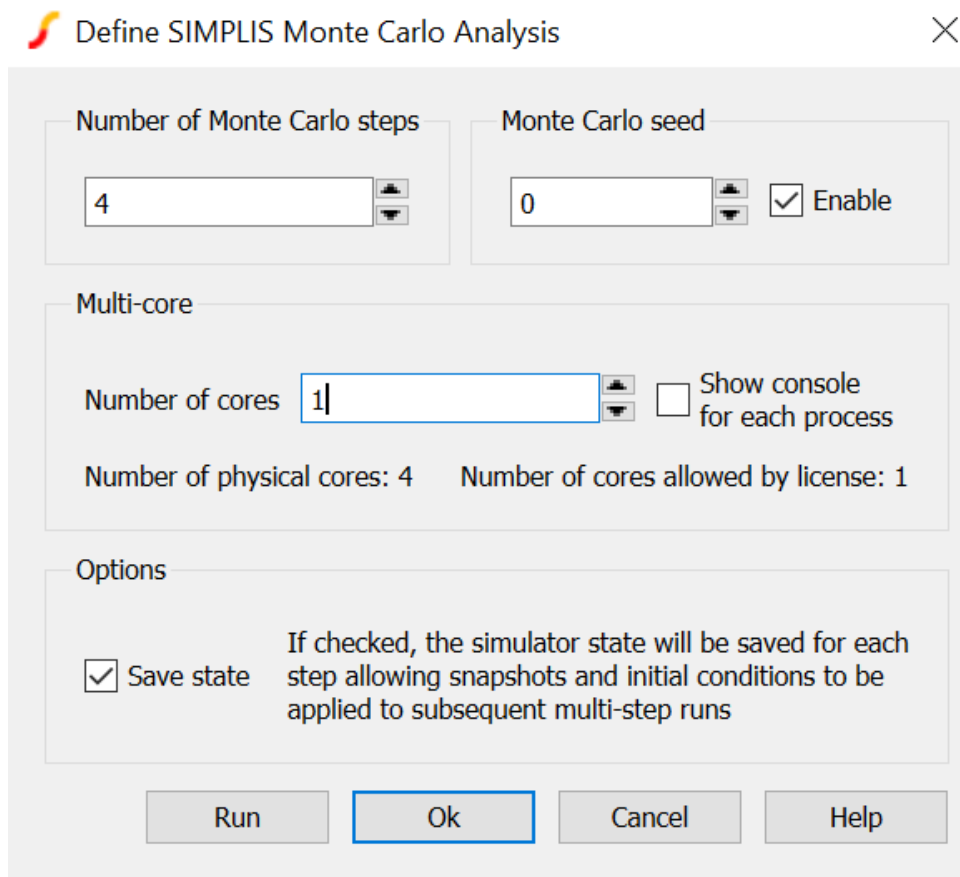
Options

☐ Save state If checked, the simulator state will be saved for each step allowing snapshots and initial conditions to be applied to subsequent multi-step runs

Run **Ok** Cancel Help

Starting with SIMPLIS models

- Monte Carlo analysis will be run with a number of runs equal to the number of steps you provide
- To look at a specific run that was previously looked at, the Monte Carlo seed can be put in to re-run those specific parameters



The dialog box is titled "Define SIMPLIS Monte Carlo Analysis" and features a close button (X) in the top right corner. It is organized into three main sections: "Number of Monte Carlo steps" and "Monte Carlo seed" at the top, "Multi-core" in the middle, and "Options" at the bottom. The "Number of Monte Carlo steps" section contains a text box with the value "4" and a spinner control. The "Monte Carlo seed" section contains a text box with the value "0", a spinner control, and a checked checkbox labeled "Enable". The "Multi-core" section includes a "Number of cores" text box with the value "1" and a spinner control, followed by an unchecked checkbox labeled "Show console for each process". Below these are two status labels: "Number of physical cores: 4" and "Number of cores allowed by license: 1". The "Options" section features a checked checkbox labeled "Save state" and a descriptive text: "If checked, the simulator state will be saved for each step allowing snapshots and initial conditions to be applied to subsequent multi-step runs". At the bottom of the dialog are four buttons: "Run", "Ok" (which is highlighted with a blue border), "Cancel", and "Help".

Define SIMPLIS Monte Carlo Analysis

Number of Monte Carlo steps: 4

Monte Carlo seed: 0 ☒ Enable

Multi-core

Number of cores: 1 ☐ Show console for each process

Number of physical cores: 4 Number of cores allowed by license: 1

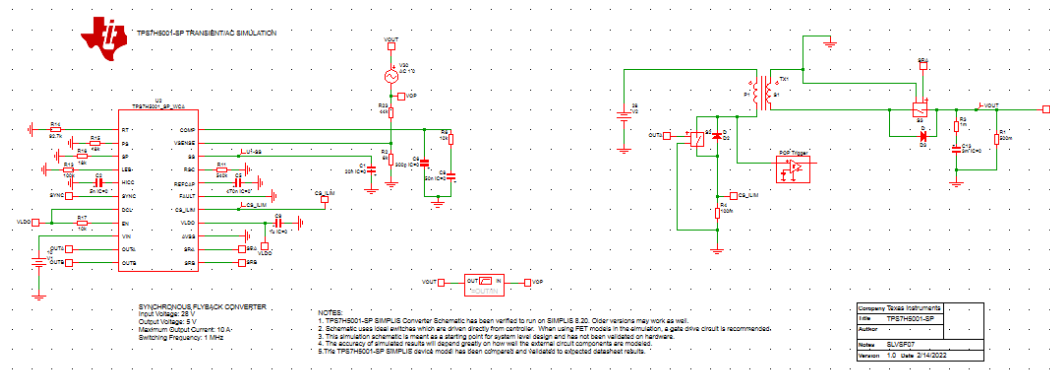
Options

☒ Save state If checked, the simulator state will be saved for each step allowing snapshots and initial conditions to be applied to subsequent multi-step runs

Run Ok Cancel Help

Starting with SIMPLIS models

- Worst Case Analysis can be ran on 3 different internal parameters
- These parameters were determined to be most influential on transient performance
- The default schematic provided is a flyback



Parameter	Description	Default Mean Value	Default Tol- Value
gmea	Model variable for the error amplifier transconductance	1825 μ S	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%

Starting with SIMPLIS models

- By pressing F11 in SIMPLIS simulator you can access the variables
- Changing the names of the variables can cause issues with the model
- By default the simulator only considers the edges of the ranges
- If a typical run is wanted, simply comment out the range the value is being multiplied by with a *.

```
1 .simulator SIMPLIS
2 .ac DEC 25 100m 1Meg
3 .print
4 + ALL
5 .options
6 + PSP_NPT=1001
7 + POP_ITRMAX=20
8 + POP_USE_TRAN_SNAPSHOT
9 + POP_OUTPUT_CYCLES=5
10 + POP_SHOWDATA
11 + SNAPSHOT_INTVL=0
12 + SNAPSHOT_NPT=11
13 + NEW_ANALYSIS
14 + MIN_AVG_TOPOLOGY_DUR=1a
15 + AVG_TOPOLOGY_DUR_MEASUREMENT_WINDOW=128
16 .pop
17 + TRIG_GATE={TRIG_GATE}
18 + TRIG_COND=0_TO_1
19 + MAX_PERIOD=2u
20 + CONVERGENCE=10p
21 + CYCLES_BEFORE_LAUNCH=4000
22 + TD_RUN_AFTER_POP_FAILS=-1
23 *.tran 30m 0
24
25 *.Do not change the names of these global variables or the model will not work
26 .GLOBALVAR gmea = 1.825m*WC(0.37)
27 .GLOBALVAR Vr = 0.613*WC(0.01)
28 .GLOBALVAR Rtt = (1.23-Vr)*1000/Vr
29 .GLOBALVAR IDComp = 1/(2.06*WC(0.029))
30 .simulator DEFAULT
31
```

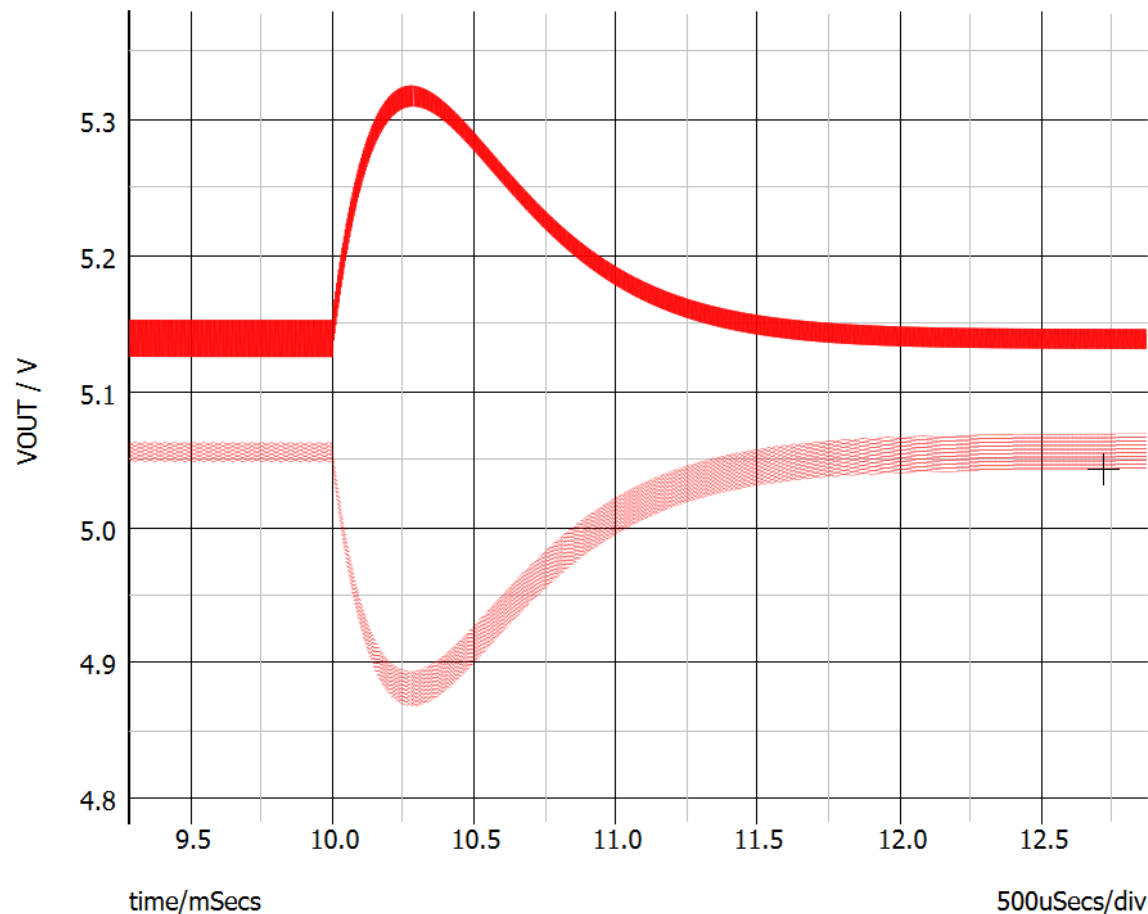
Starting with SIMPLIS models

- What values can be picked in worst case analysis can be changed depending on what is needed for your design
- Values in-between the two extremes can be picked with any of the other distributions

Distribution Name	Definition
WC(tol)	Worst-Case. Returns either $1.0 - \text{tol}$ or $1.0 + \text{tol}$ chosen at random.
Unif(tol)	Uniform. Returns a random value in the range $1.0 \pm \text{tol}$ with a uniform distribution.
GaussTrunc(tol)	Truncated Gaussian. As with Gauss() but values greater than $(1 + \text{tol})$ and less than $(1 - \text{tol})$ 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 $\text{tol}/3$. Random values have a Gaussian or Normal distribution.

Starting with SIMPLIS models

- Changing the values in the WCA model also allow for looking at worst case transients due to the selected parameters
- Here the slowest/lowest value of GMPS is used as well as changing the VREF value in order to get the worst case transient range
- Very useful for looking at how much room there is for tolerances



Starting with SIMPLIS models

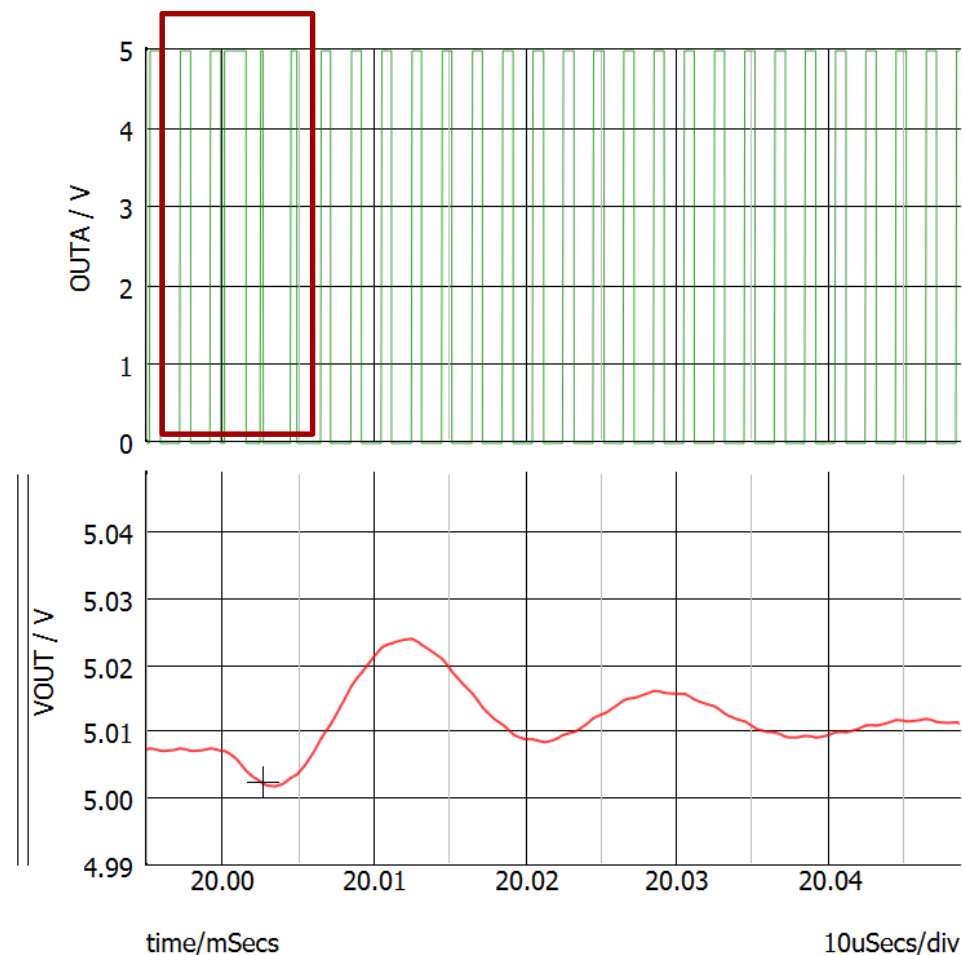
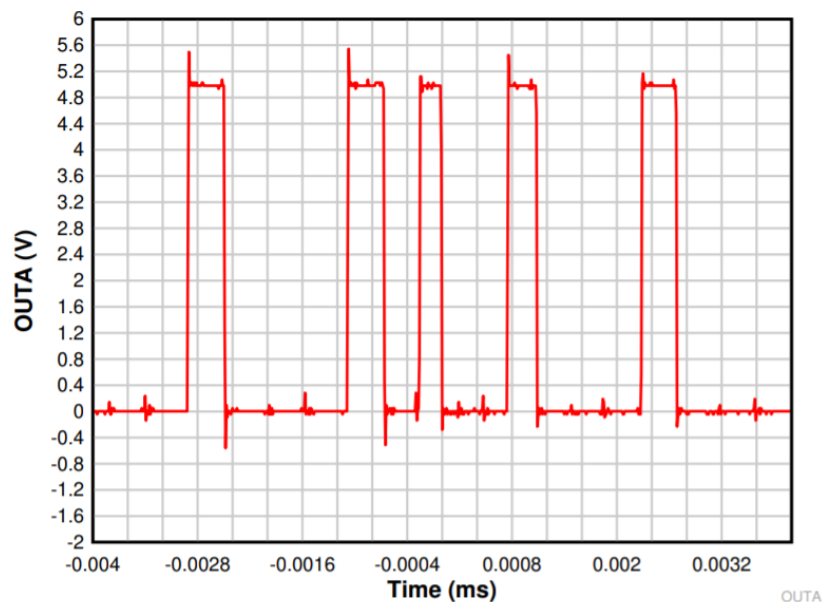
- If SIMPLIS is not your simulator of choice for worst case analysis all information used to create the model is in the Worst Case Analysis model user guide
- This allows users to change values in both the SIMPLIS model as well as any model they plan to make to fit their exact needs.

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

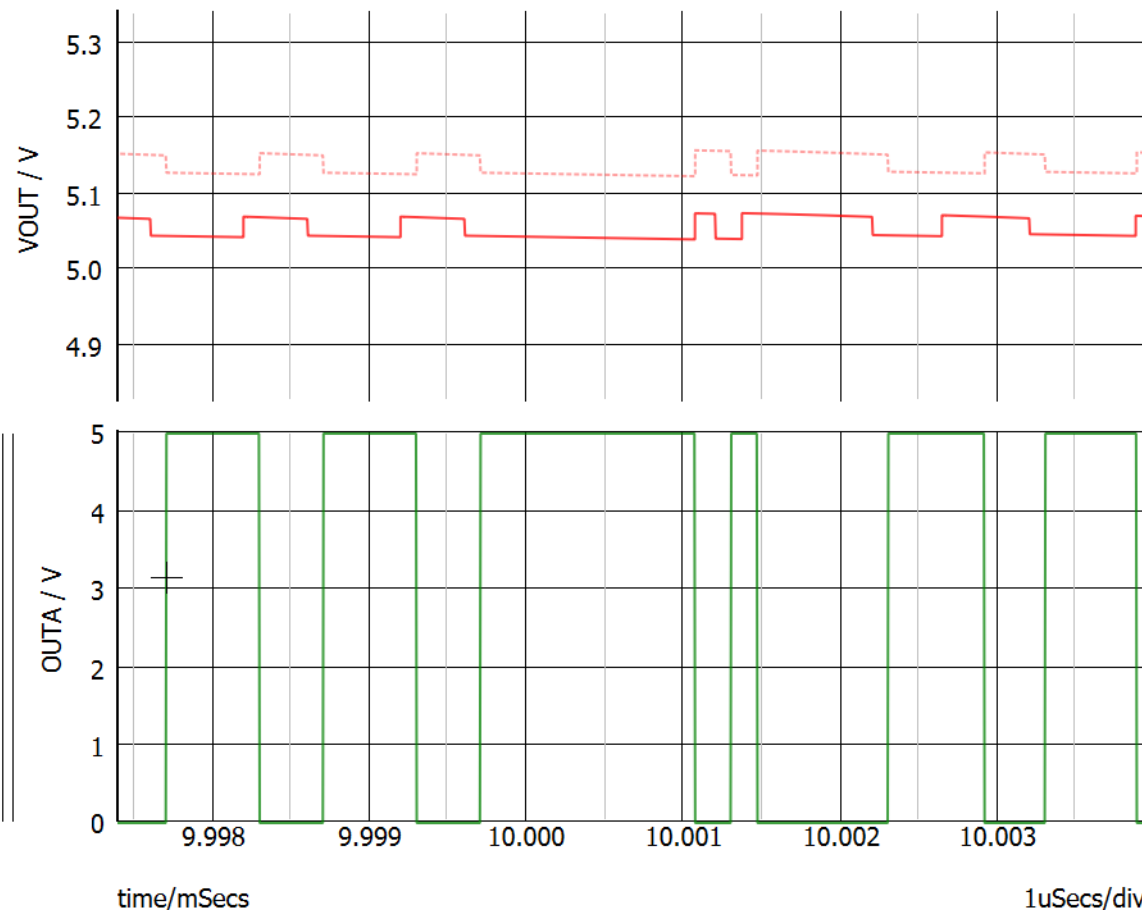
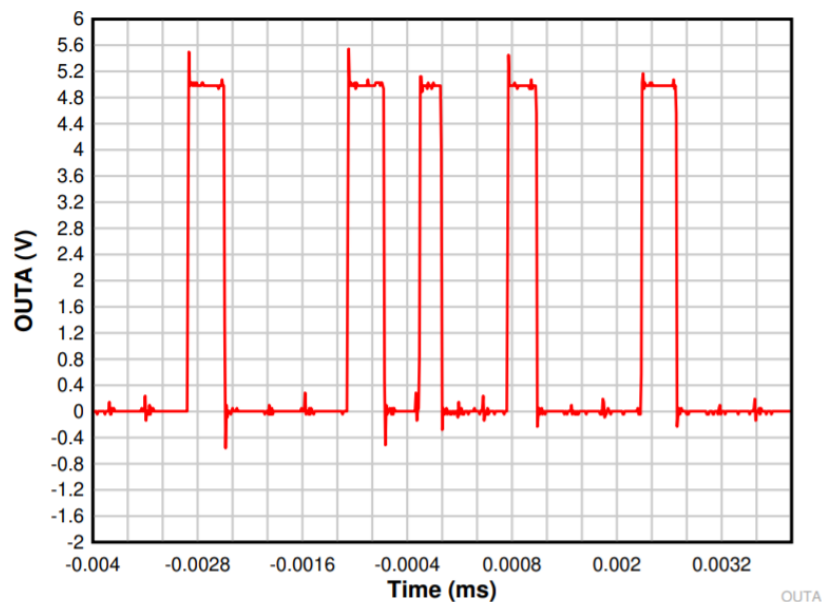
Starting with SIMPLIS models

- SET performance can be simulated by pulling current out of the RT pin
- 1 mA of current was pulled out of RT pin for 1 μ s in order to cause event



Starting with SIMPLIS models

- This can be combined with WCA in order to look at multiple different parameters or even different radiation effects



Questions?



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