What's New with LTspice?

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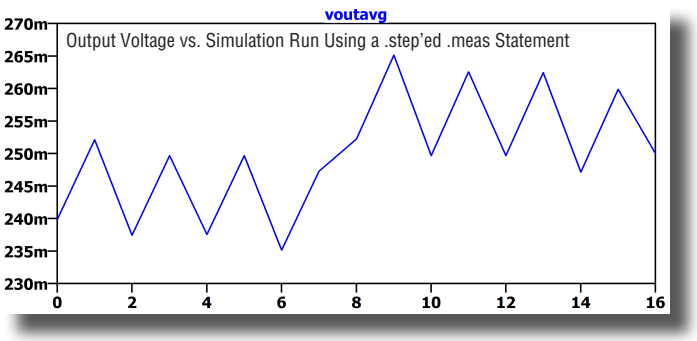
WORST-CASE CIRCUIT ANALYSIS WITH MINIMAL SIMULATIONS RUNS

www.linear.com/solutions/7852

When designing in LTspice®, you may want to assess the impact of component tolerances. For example: what is the gain error introduced by non-ideal resistors in an op amp circuit? LTspice offers several tools to vary parameters and examine circuit performance over parameter ranges, including use of the functions: .step param, gauss(x), flat(x), and mc(x,y). These functions are powerful, for instance, revealing design performance in terms of component value distributions. Nevertheless, they may not be the quickest way to zero in on worst-case performance.

Using gauss(x), flat(x) and mc(x,y), for example, to produce worst-case results requires a simulation to run a statistically significant number of times. From there, a distribution can be looked at and worst-case values calculated in terms of standard deviations. As the number of parameters multiplies, this can be a data heavy project. In many designs, the worst-case scenarios are often found by focusing on components' maximum deviations from nominal. This article shows how to quickly zero in on circuit performance by exploring circuit performance at the nominal component values and their tolerance limits.



Use LTspice to zero in on worst-case performance by exploring the tolerance limits of components. Here, 16 possible parameter combinations of four resistor values—at their tolerance limits—are simulated and graphed. The effects of tolerance are clearly shown.

SELECTED DEMO CIRCUITS

For a complete list of example simulations, please visit www.linear.com/democircuits.

Buck Regulators

- **LT8607:** 2MHz low EMI high voltage synchronous buck regulator (5.5V–42V to 5V at 750mA) www.linear.com/solutions/7864
- **LT8609S:** 2MHz low EMI high voltage synchronous buck regulator (5.5V–42V to 5V at 2A) www.linear.com/solutions/7876
- **LTC3810-5:** High efficiency high voltage buck converter (12V–60V to 5V at 6A) www.linear.com/solutions/4900
- **LTM®4631:** High efficiency, high density, dual 10A buck regulator (4.5V–15V to 1V & 1.2V 10A) www.linear.com/solutions/7377

Operational Amplifiers

- **LT1997-3:** Conversion of single ended pulse to differential output www.linear.com/solutions/7898
- **LT5400/LTC2063:** RTD sensor circuit with ±1°C precision www.linear.com/solutions/7945
- **LT6200/LTC2050:** Low noise, low power photodiode transimpedance amplifier with DC precision www.linear.com/solutions/1205
- **LTC®6258/LTC6992:** Low power sine wave generator www.linear.com/solutions/7971

SELECT MODELS

To search the LTspice library for a particular device model, press F2. To update to the current version, choose Sync Release from the Tools menu.

Buck Regulators

- **ADP2443:** 3A, 36V synchronous step-down DC-to-DC regulator www.analog.com/adp2443
- **LT8606:** 42V, 350mA synchronous step-down regulator with 2.5µA quiescent current www.linear.com/LT8606
- **LT8645S:** 65V, 8A synchronous step-down Silent Switcher 2 with 2.5µA quiescent current www.linear.com/LT8645S
- **LTC3886:** 60V dual output step-down controller with digital power system management www.linear.com/LTC3886
- **LTM4650A:** Dual 25A or single 50A DC/DC µModule® buck regulator with 1% DC accuracy www.linear.com/LTM4650A

Multi-Topology Regulators

- **LTC3589:** 8-output regulator with sequencing and I²C www.linear.com/LTC3589

Buck-Boost, Boost, SEPIC & Inverting Regulators

- **LT8362:** Low I_Q boost/SEPIC/inverting converter with 2A, 60V switch www.linear.com/LT8362
- **LT8390A:** 60V synchronous 4-switch buck-boost controller with spread spectrum www.linear.com/LT8390A
- **LTC3106:** 300mA low voltage buck-boost converter with PowerPath™ and 1.6µA quiescent current www.linear.com/LTC3106

MOSFET Drivers

- **LTC7000:** Fast 150V protected high side NMOS static switch driver www.linear.com/LTC7000
- **LTC7003:** Fast 60V protected high side NMOS static switch driver www.linear.com/LTC7003

Operational Amplifiers

- **LTC2063:** 2µA supply current, low I_B, zero-drift operational amplifier www.linear.com/LTC2063
- **LTC6259:** Dual 1.3MHz, 20µA power efficient rail-to-rail I/O op amps www.linear.com/LTC6259

Voltage Monitors

LTC2965: 100V micropower single voltage monitor www.linear.com/LTC2965 ■

Power User Tip

ARBITRARY STATE MACHINE

LTspice now includes an arbitrary state machine, which operates on data structures with rules and functions. State machine models are arbitrary in their levels of abstraction, so they can provide encapsulation of any design with states, from hardware to software. Let's explore the classic "divide-by-two counter" with a reset as an example of a state machine in LTspice.

The state machine is encapsulated by its .machine and .endmachine statements in the schematic as a SPICE directive.

Each state of the state machine is defined using a .state command. The first state listed is the initial state, otherwise the order of the states makes no difference. The name of the state can be anything and the output of the state is defined by a value.

```
.state <name> <value>
```

The .rule command defines the transition between the old state to the new state using a condition statement.

In our case it is a set of expressions that evaluates if V(IN) is greater than or less than 0.5V.

There is no limit to the number of rules, but they are checked in order, with only one rule executing per time step.

```
.rule <old state> <new state> <condition>
```

The last command in the set of .rule expressions is the reset condition that uses a wildcard character '*' to match any of the old states. Using the wildcard character implies that this rule will be checked first and if true, trumps the next rule in the sequence.

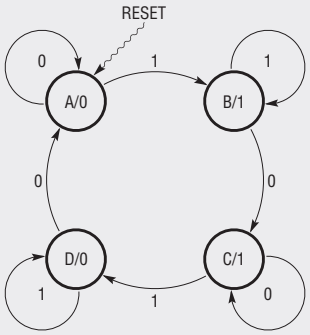
```
.rule * <new state> <condition>
```

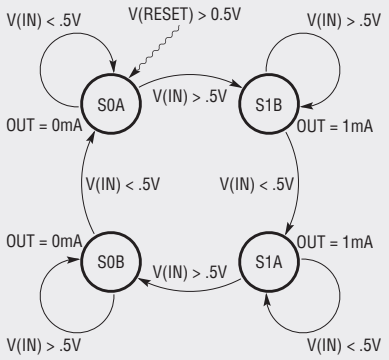
The .output statement is implemented as a current source and requires an external device, such as a resistor, to read out the current. As shown in the example, a 1k ground-referenced resistor is used; and if needed to slow transitions, add some parallel capacitance. The expression can be a combination of logic or state. Even though the .output statement is implemented as a current source, it is not designed to directly connect to a device pin as in a current monitoring application.

```
.output (node) <expression>
```

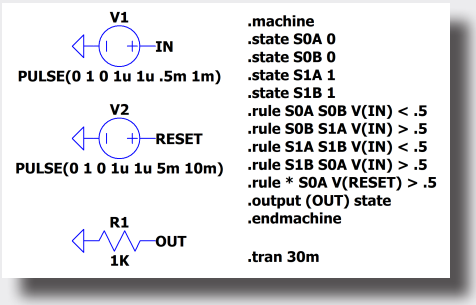
Happy simulations!

Simplified state diagram of divide-by-two counter; and state diagram showing the values in LTspice





LTspice schematic of state machine: divide-by-two counter with reset



LTspice waveform shows results of divide-by-two counter with reset