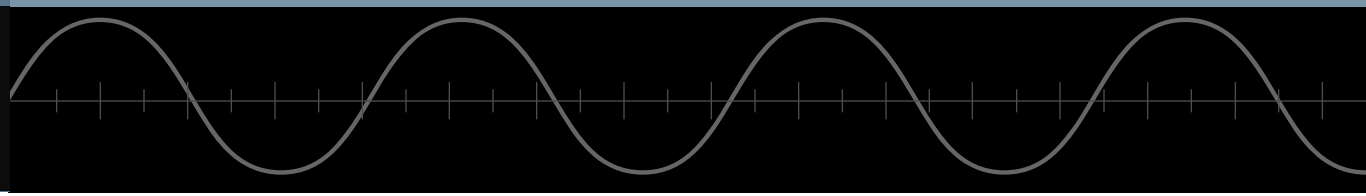
Voltage & Current Controlled Switches

Presented by Thomas Mosteller



LINEAR TECHNOLOGY

NOW PART OF ANALOG DEVICES

Voltage Controlled Switch – Model

- A voltage controlled switch must have a model defined.
  - Typically done as a SPICE directive placed directly on the schematic
- The V-switch .model syntax:

  .model <ModelName> SW(Ron=<Ω> Roff=<Ω> Vt=<V> Vh=<V> Lser=<H> Vser=<V> Ilimit=<A>)

  where

  Vt: Threshold voltage

  Vh: Hysteresis voltage

  Ron: On resistance

  Roff: Off resistance

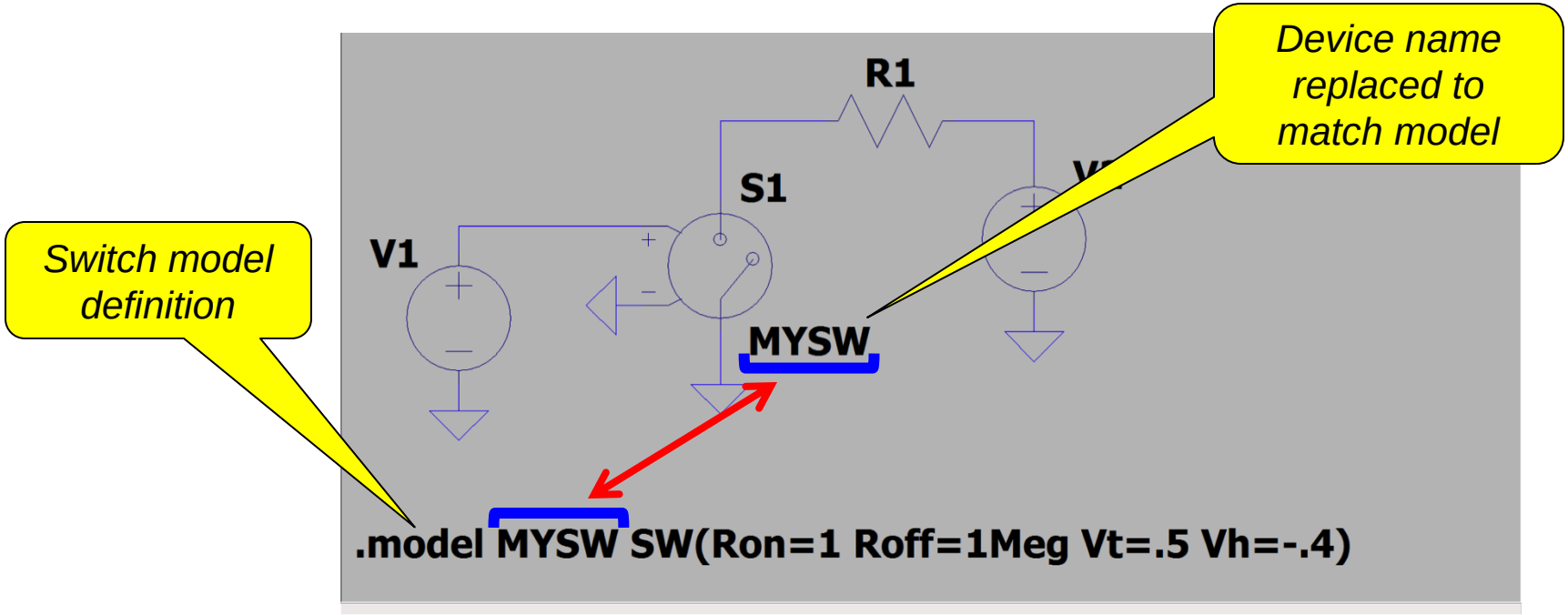
  Lser: Series inductance

  Vser: Series voltage

  Ilimit: Current limit.

Voltage Controlled Switch – Model

- As for other intrinsic Spice models, the device name of the schematic component must be changed to correspond to the switch model name.
- Schematic example of a voltage controlled switch:



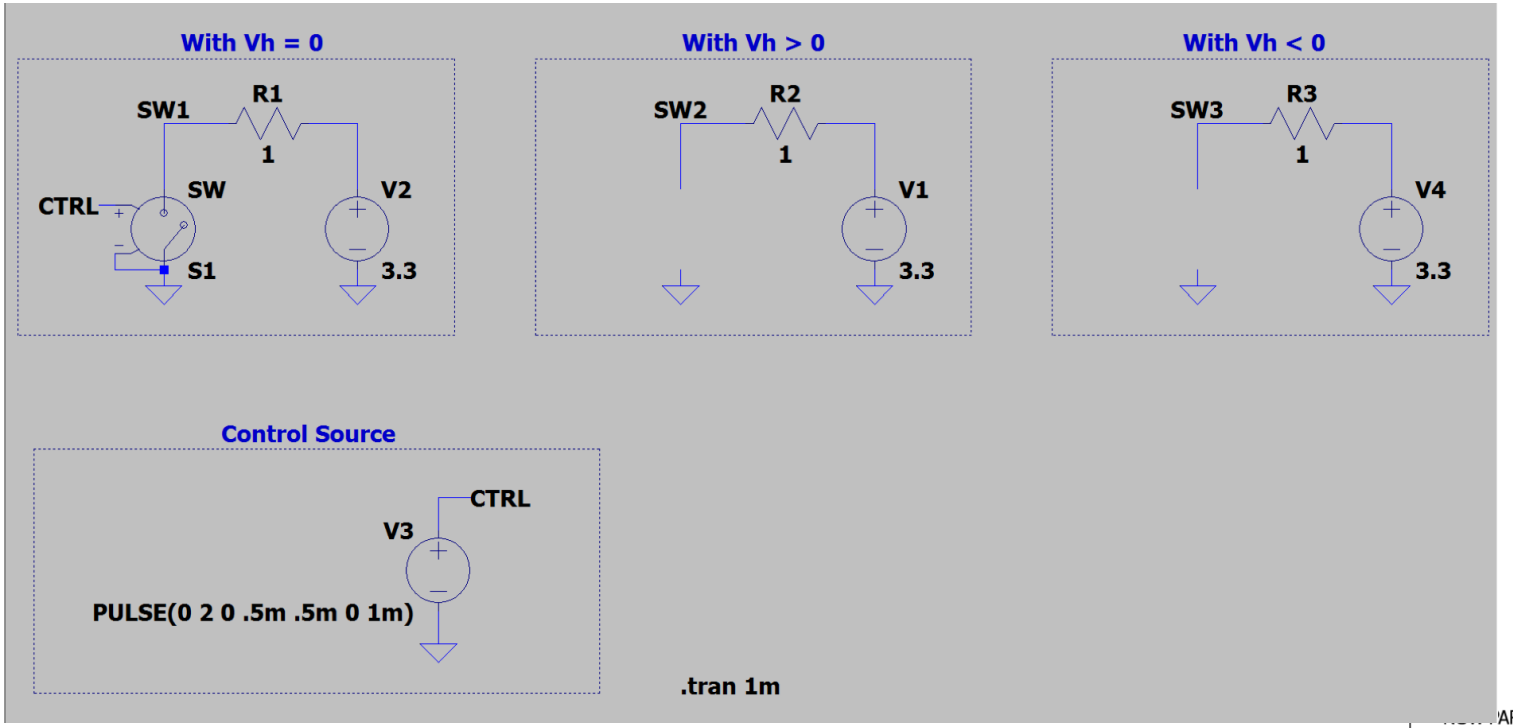
Voltage Controlled Switch – Modes of Operation

- The switch has three distinct modes of voltage control depending on the value of the hysteresis voltage, Vh:
  - Vh = 0V: Switch is always completely on or off depending upon whether the input voltage is above the threshold.
  - Vh > 0V: it shows hysteresis, as if it was controlled by a Schmitt trigger with trip points at Vt - Vh and Vt + Vh.
    - Note that Vh is half the voltage between trip points which is different than the common laboratory nomenclature.
  - Vh < 0V: it will smoothly transition between the on and off impedances. The transition occurs between the control voltages of Vt - Vh and Vt + Vh. The smooth transition follows a low order polynomial fit to the logarithm of the switch's conduction.

Voltage Controlled Switch

Hands-on Exercise:

- Define and use voltage controlled switches.
- Learn to differentiate the different modes of operation of the V-switch.



VswitchLab.asc

Current Controlled Switch – Model

- Like the V-switch, the current controlled switch must have a model defined.
  - Typically done as a SPICE directive placed directly on the schematic
- The C-switch .model syntax:
  - *.model <ModelName> CSW(Ron=<Ω> Roff=<Ω> It=<A> Ih=<A>)*
    - The parameters are:

      It: Threshold current

      Ih: Hysteresis current

      Ron: On resistance

      Roff: Off resistance

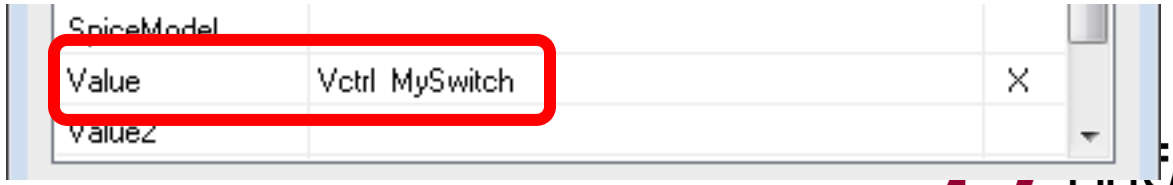
Current Controlled Switch – Model

- The name of the schematic component must be changed to correspond to the switch model name.
- Contrary to the V-switch, the stimulus is not wired to the switch symbol:
  - The C-switch symbol has only two terminals: the switch's input and output terminals. No control terminal.
  - The control source is defined by setting the content of the *Value* attribute to read <*Vcontrol*> <*ModelName*> where

    <*Vcontrol*> : name of the **voltage** source whose current controls the switch. **Important: Must be a voltage source**.

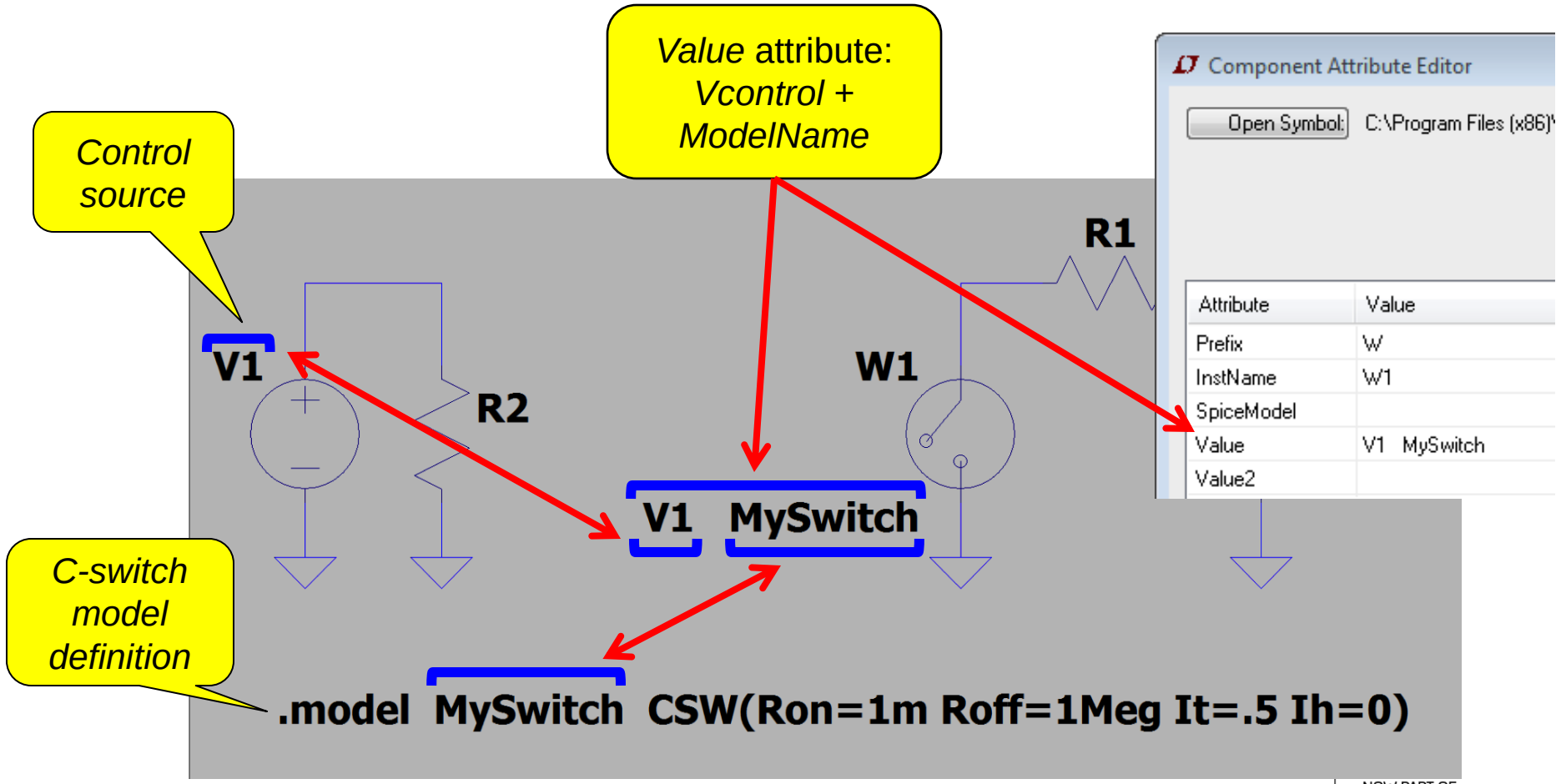
    <*ModelName*> : name given to the controlled switch (model name)

    - As an example:



Current Controlled Switch – Model

- Schematic example of a current controlled switch:



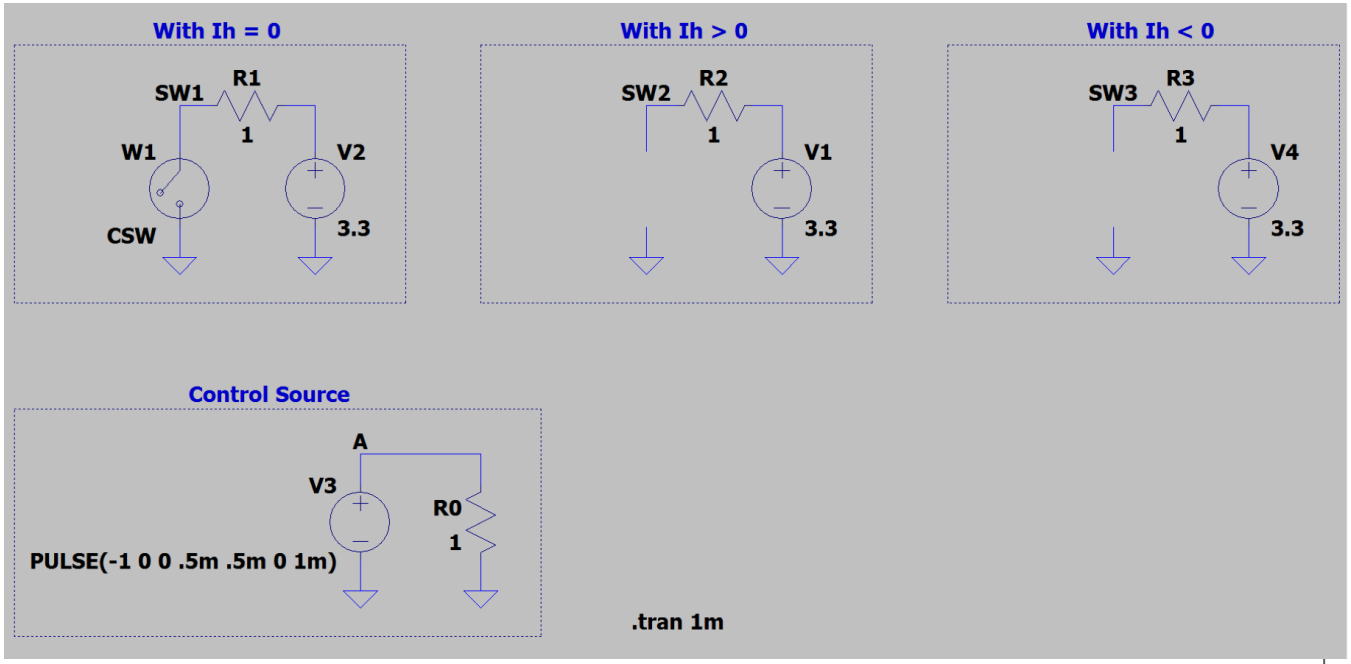
Current Controlled Switch – Modes of Operation

- Like the voltage switch, the CC-switch has three distinct modes of current control depending on the value of the hysteresis current, Ih:
  - Ih = 0A: Switch is always completely on or off depending upon whether the control current is above the threshold.
  - Ih > 0A: it shows hysteresis with trip points at It - Ih and It + Ih.
  - Ih < 0A: it will smoothly transition between the on and off impedances. The transition occurs between the control currents of It - Ih and It + Ih. The smooth transition follows a low order polynomial fit to the logarithm of the switch's conduction.

Current Controlled Switch

Hands-on Exercise:

- Define and use current controlled switches including their control source.
- Learn to differentiate the different modes of operation of the C-switch.



CswitchLab.asc

Switches - Application Circuit Examples

- LT3081 - Linear Regulator current limit
  - Test the circuit current limiter


LT3081LDO.asc

- LTC2954 - Push-Button controller
  - Replicate the push-button function
  - Implement a kill switch function


LTC2954PBController.asc

- LT3954 - LED driver
  - Open LED circuit response
  - Emulate a LED cathode short to GND (no dimming)

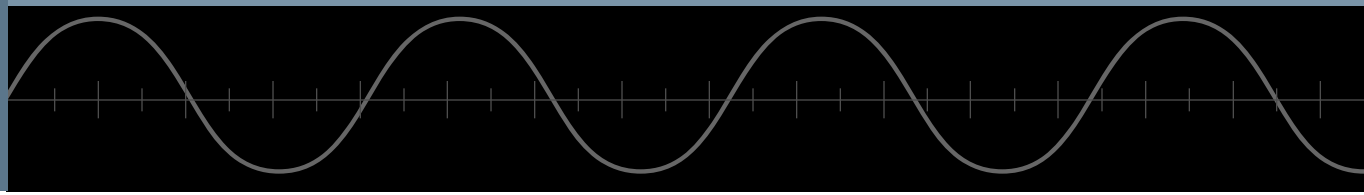

LT3954LEDDriver.asc

- LTC4227 - Dual ideal diode and hot-swap
  - Check the Ideal diode response to input disconnect
  - Verify the hot-swap current limiting function


LTC4227IdealORingAndHotSwap.asc

ADVANCED TOPICS

To consult at your leisure.



Voltage Controlled Switch – Level 2 Model

- The level 2 V-switch model is an advanced version of the level 1 switch with negative hysteresis.
  - The level 2 switch is never completely on or off.
- The conduction as a function of control voltage Vc is

  $$g(Vc) = \exp(A * \operatorname{atan}((Vc - Vt)/\operatorname{abs}(Vh)) + B)$$

  where
  - A = log(Roff / Ron) / π
  - B = log(1 / (Roff * Ron)) / 2
- The transition of the level 2 switch to current limit is gradual instead of abrupt. At a fixed control voltage, the I-V curve is given by the equation

  $$I(V) = Ilimit * \tanh(g(Vc) * V)$$

  where Ilimit defaults to 10 amperes for the level 2 switch.

Voltage Controlled Switch – Level 2 Model

- The level 2 switch supports the option to conduct in only one direction by specifying either the flag "oneway" or a voltage drop with parameter Vser.
  - The transition between forward conduction and reverse open circuit can be specified to be a smooth transition by specifying the parameter epsilon to be non-zero.
- Syntax

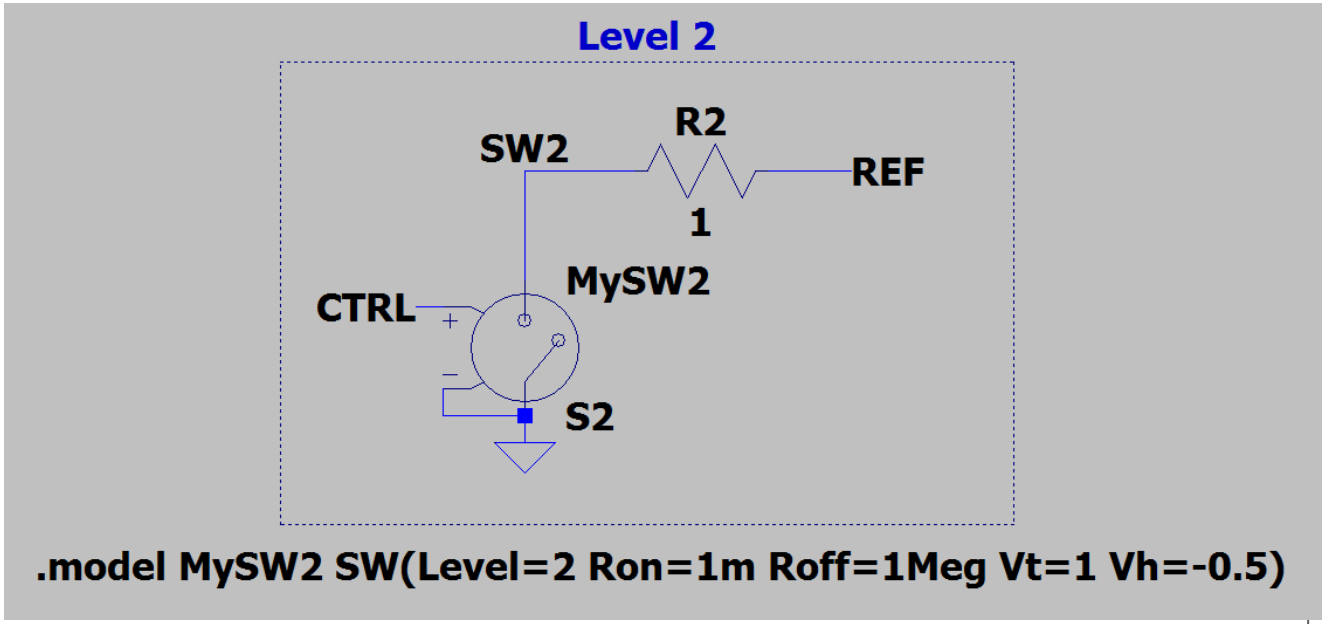
  .model <ModelName> SW(level=2 Ron=<Ω> Roff=<Ω> Vt=<V> Vh=<V> Lser=<H> Vser=<V> Ilimit=<A> oneway)

  - Vh is always negative
- The C-Switch does not have a level 2 model.

Voltage Controlled Switch – Level 2 Model

Lab to consult at your leisure:

- Shows how to define and use level 2 voltage controlled switches.
- Demonstrates the differences between a level 2 and a level 1 with negative hysteresis V-switch.



VswitchLevel2Solution.asc