

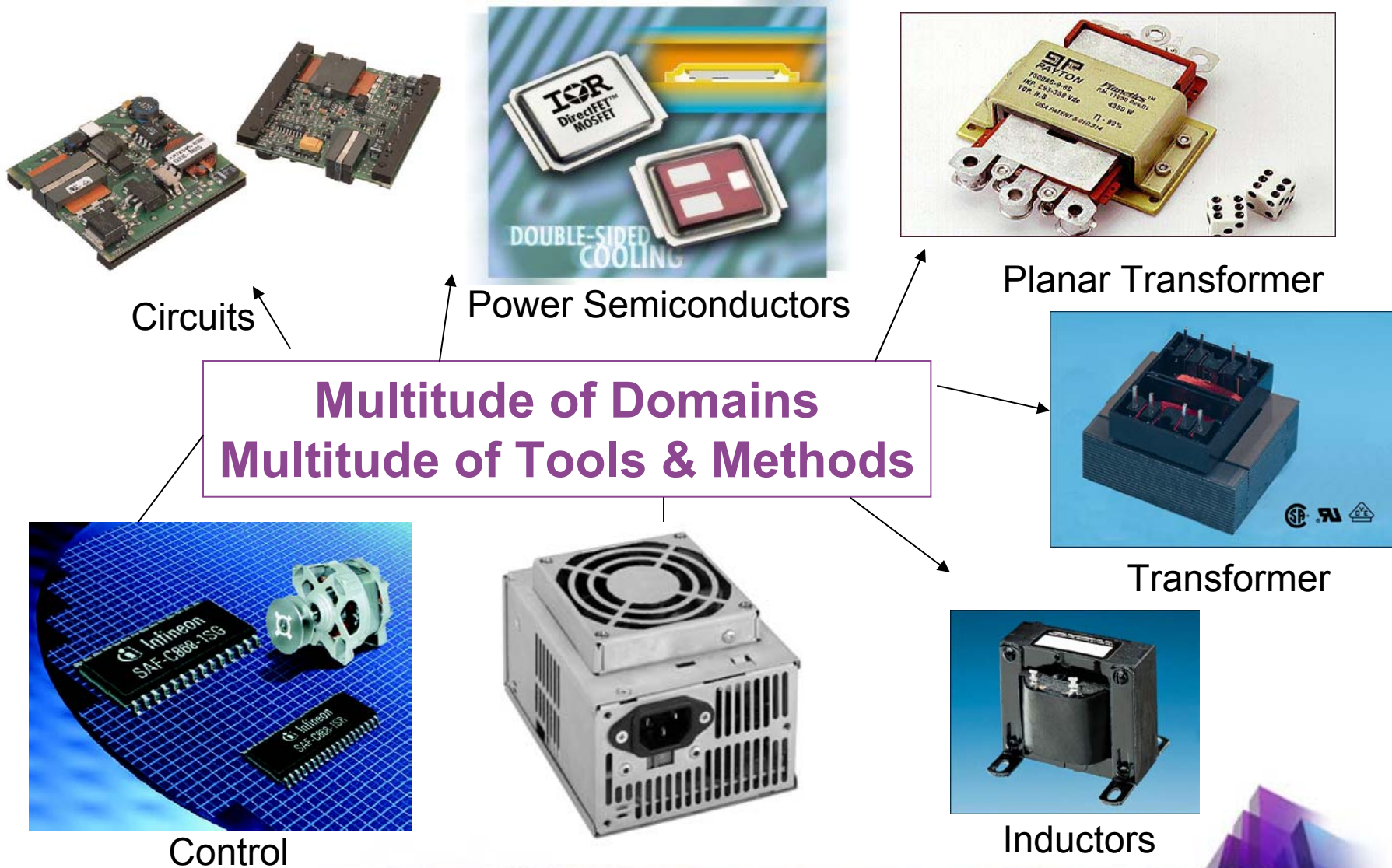
Behavioral Modeling of a 4 Phase Buck Converter Design

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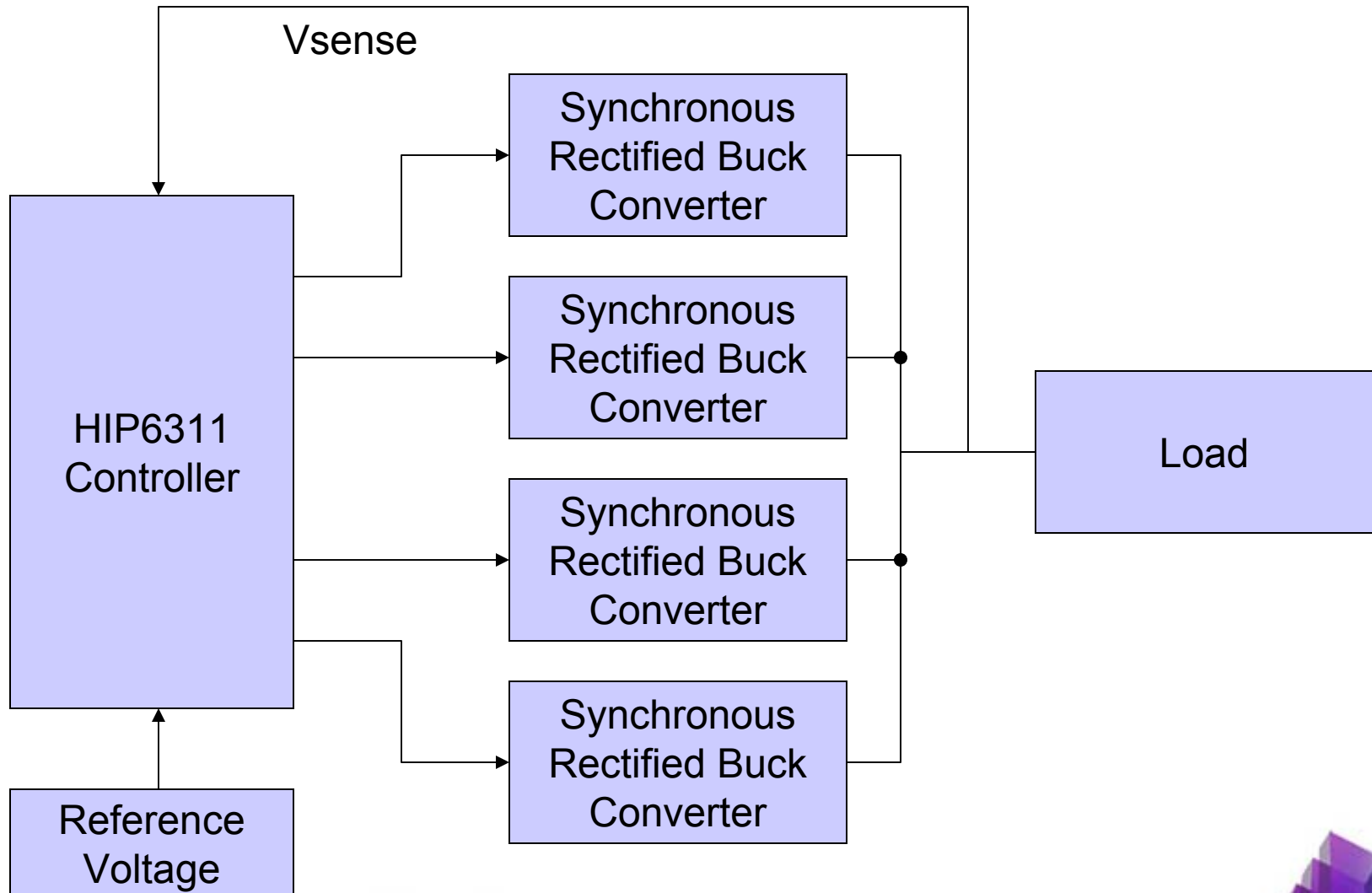
4 Phase Buck Converter

- ▶ Voltage regulation modules (VRM)
- ▶ High current low voltage applications, e.g. power supplies for micro processors
- ▶ Distributing power in multiple phases
- ▶ Advantages vs. single phase design
 - ▶ Smaller and lower cost transistors
 - ▶ Fewer input and output capacitors due to higher effective conversion frequency
 - ▶ Higher frequency ripple current due to phase interleaving
 - ▶ Faster response time

Multi Domain Design



System Structure

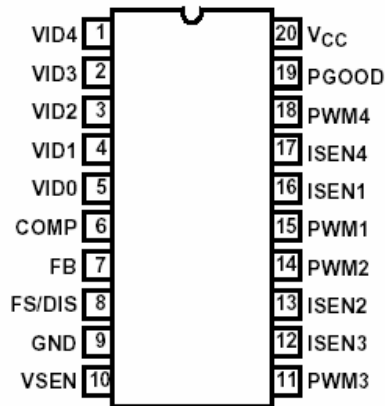


Advanced Components



- ▶ Integrated buck phase building block
- ▶ Integrated Protection Functionality
- ▶ Rated a 20 A
- ▶ Replaces up to 11 discrete components
- ▶ Reduced footprint
- ▶ Reduced design time
- ▶ Only multiphase controller, input and output capacitances required

Models?



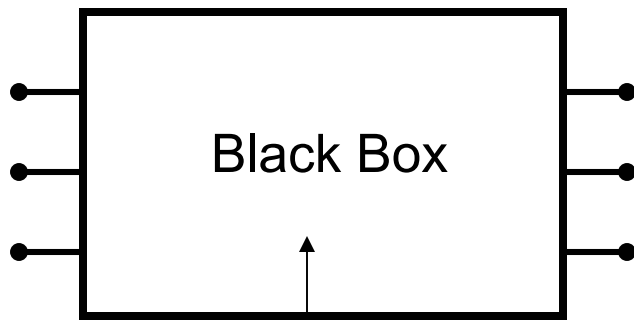
iP2001 Power Block

- Usually component providers models are not available when the designer needs them
- SPICE based circuit models are frequently too detailed and slow computing
- SPICE based behavioral models tend to be numerically unstable

Solution

Behavioral Modeling:

Represent the functionality of the IC rather than the actual circuit using more efficient and faster modeling levels!



Electrical Connectivity

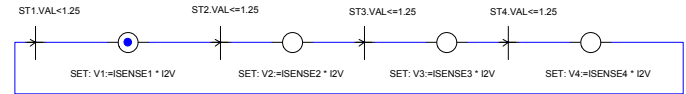
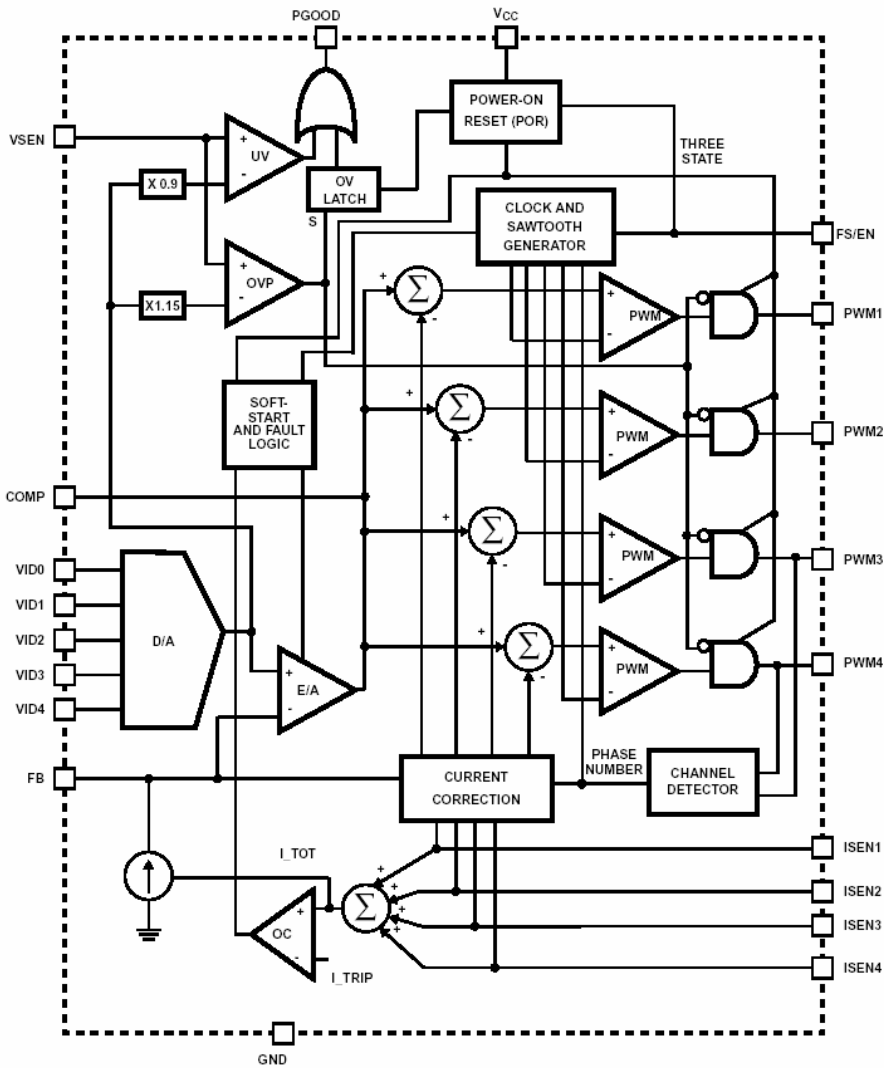
Model Behavior using:

- Block Diagrams
- State Machines
- C/C++ Code
- Coming soon VHDL-AMS

Advantages:

- Fast
- Easy
- Available

HIP6311



EQU

$$VAVG = 0.25 * (V1 + V2 + V3 + V4)$$

$$VCOR1 = 0.5 * (V1 + VAVG)$$

$$VCOR2 = 0.5 * (V2 + VAVG)$$

$$VCOR3 = 0.5 * (V3 + VAVG)$$

$$VCOR4 = 0.5 * (V4 + VAVG)$$

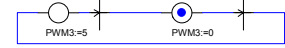
$$VM_ERROR.V - VCOR1 \leq ST1.VAL \quad VM_ERROR.V - VCOR1 > ST1.VAL$$



$$(VM_ERROR.V - VCOR2) \leq ST2.VAL \quad (VM_ERROR.V - VCOR2) > ST2.VAL$$



$$(VM_ERROR.V - VCOR3) \leq ST3.VAL \quad (VM_ERROR.V - VCOR3) > ST3.VAL$$



$$(VM_ERROR.V - VCOR4) \leq ST4.VAL \quad (VM_ERROR.V - VCOR4) > ST4.VAL$$



ICA

$$I2V = 4.1 / 20$$

$$V1 = 0$$

$$V2 = 0$$

$$V3 = 0$$

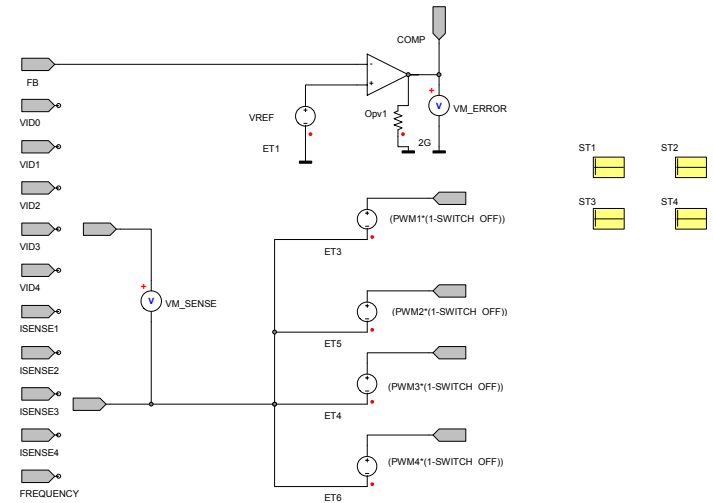
$$V4 = 0$$

EQU

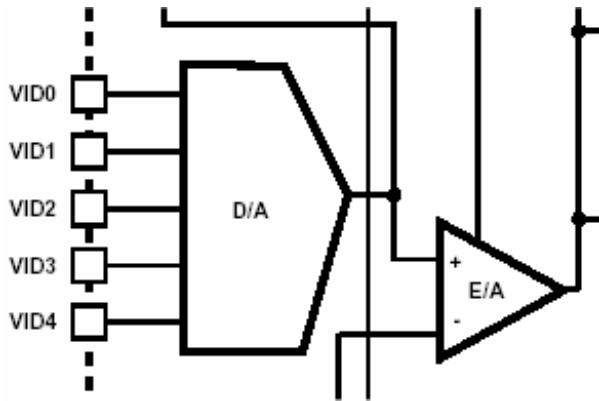
$$DAC = VID0 + VID1 * 2 + VID2 * 4 + VID3 * 8 + VID4 * 16$$

$$SWITCH_OFF = (DAC = 31)$$

$$VREF = (1 - SWITCH_OFF) * (1.85 - 25m * DAC)$$



HIP6311 – DAC



EQU

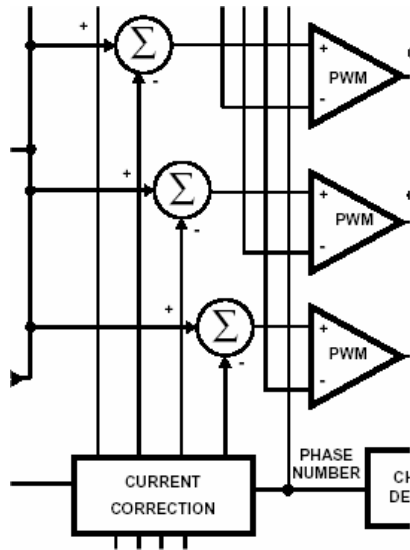
$DAC := VID0 + VID1 * 2 + VID2 * 4 + VID3 * 8 + VID4 * 16$

$SWITCH_OFF := (DAC = 31)$

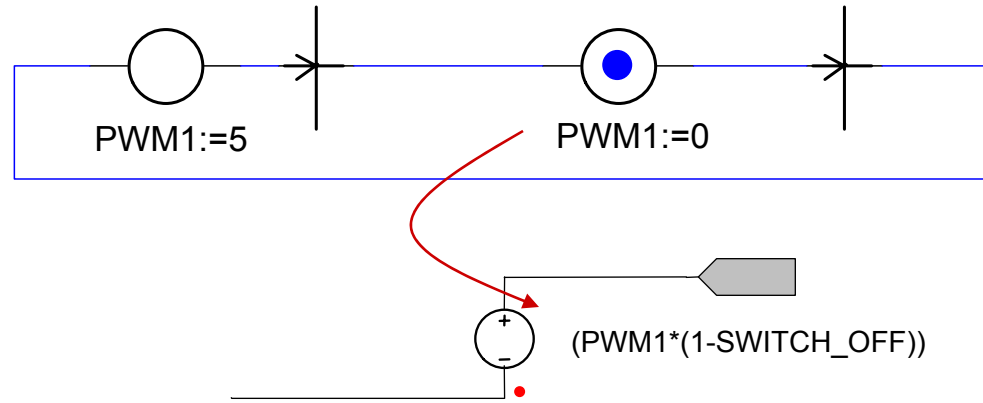
$VREF := (1 - SWITCH_OFF) * (1.85 - 25m * DAC)$

- ▶ Translates digital reference voltage settings into analog reference voltage signal
- ▶ Internally complex electrical circuit
- ▶ Modeling using SIMPLORER's built in math engine

HIP6311 – PWM



$VM_ERROR.V - VCOR1 \leq ST1.VAL$ $VM_ERROR.V - VCOR1 > ST1.VAL$



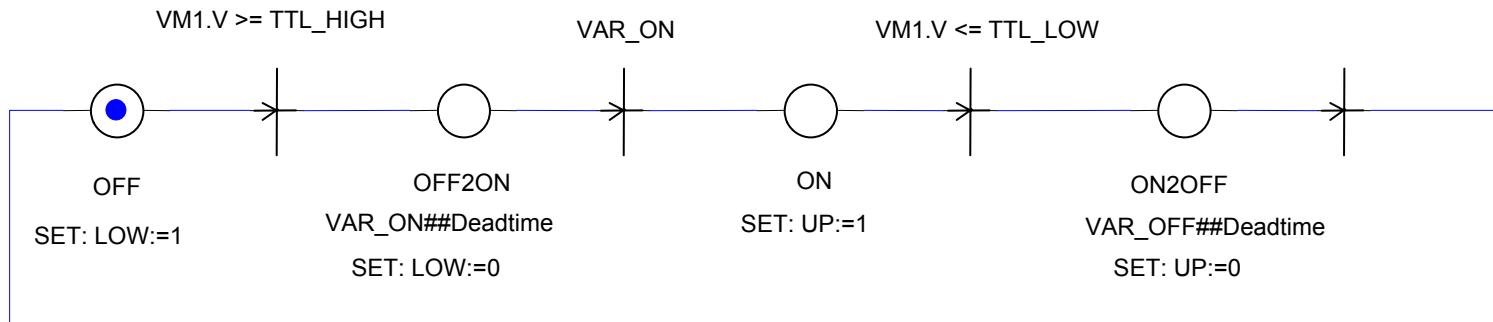
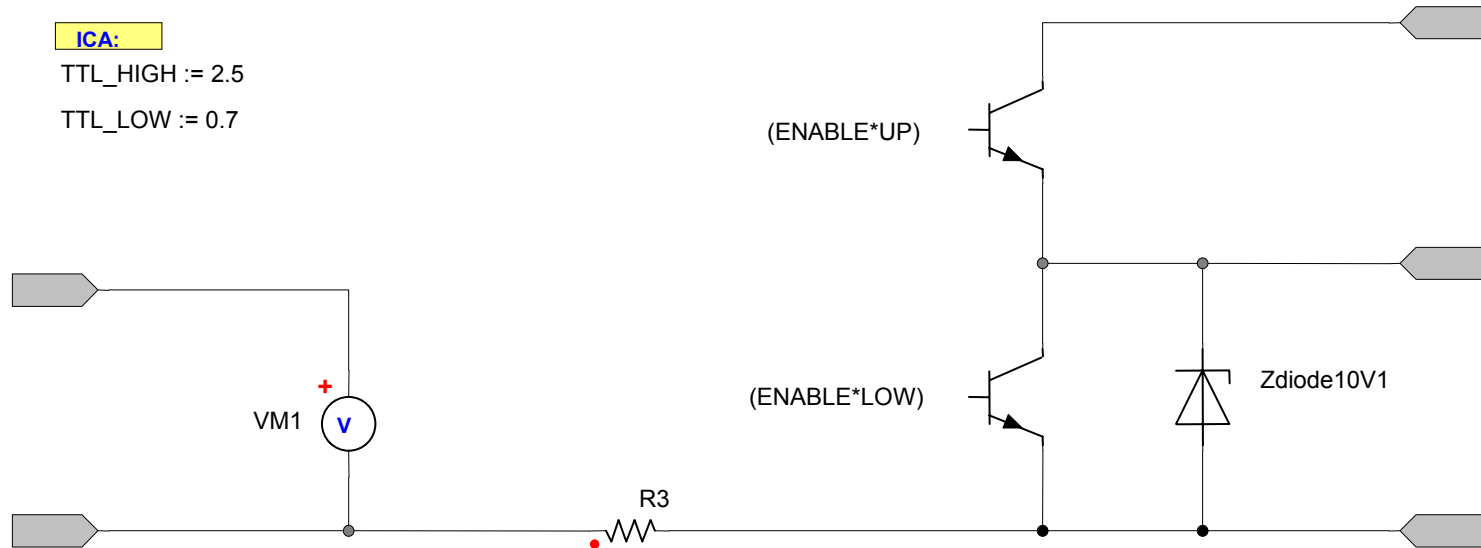
- ▶ PWM is usually realized with a comparator, adding a variety of electrical components
- ▶ State machines provide an easy way to model PWM behavior
- ▶ Externally controlled voltage source as electrical connection for the circuit

IP2001 – Behavioral Model

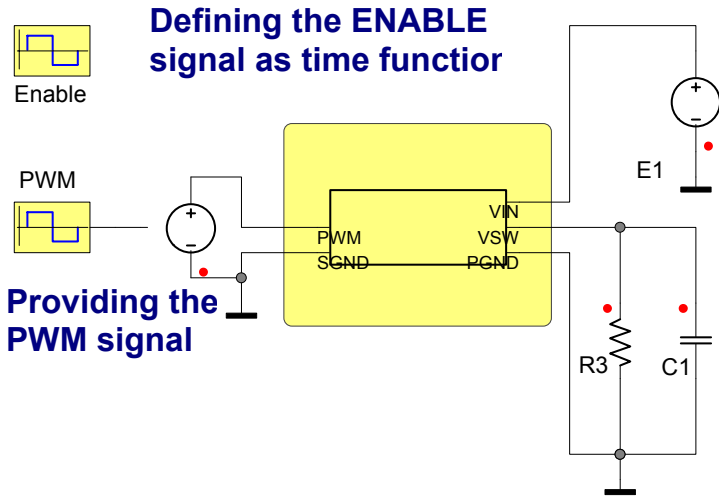
ICA:

TTL_HIGH := 2.5

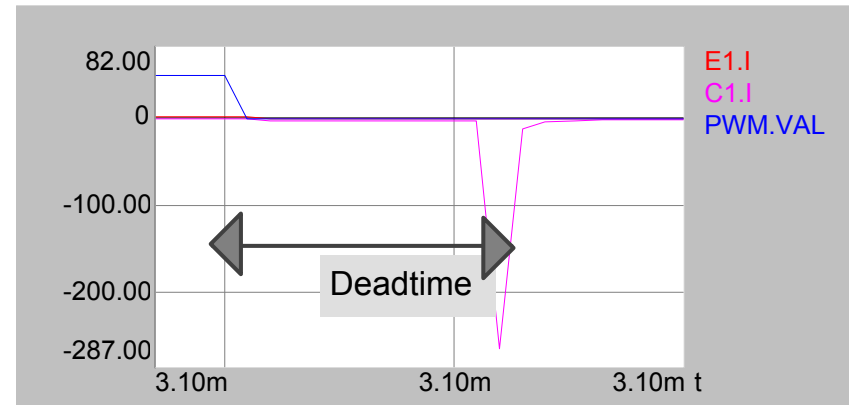
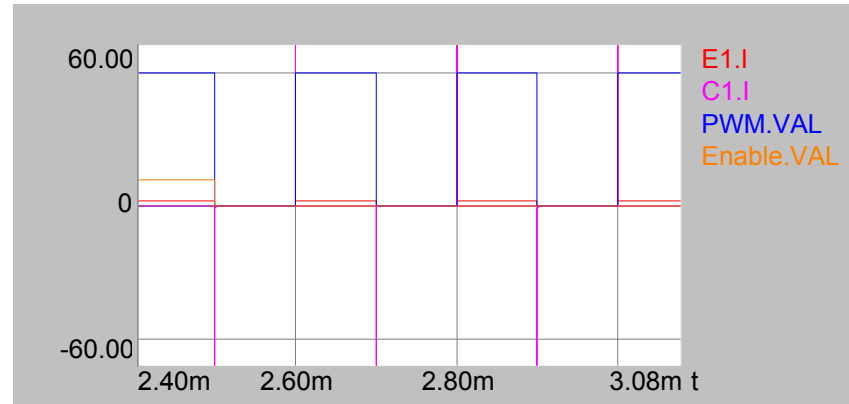
TTL_LOW := 0.7



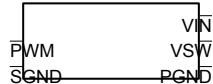
IP2001 – Test Circuit



SIM  **plorer**[®]
systems simulation



Symbol Editor & Library



- Open
- Edit Symbol**
- Probe
- Cut
- Copy
- Delete
- Copy Data From...
- Flip Horizontal F
- Rotate (90°) R
- Align
- Synchronize
- Move Pin
- Pins
- Show Name
- Don't Add To SML
- Properties...

Symbol Editor - [iP2001]

File Edit View Draw Object Window Help

0 1 2 3 4 5 6 7 All None Default

English (United States)

English (United States)

Ready; F1 for working sheet at level 0, 12.5 x 15.0 (12.5, 10.2)

ModelTree

Basics Displays Add Ons

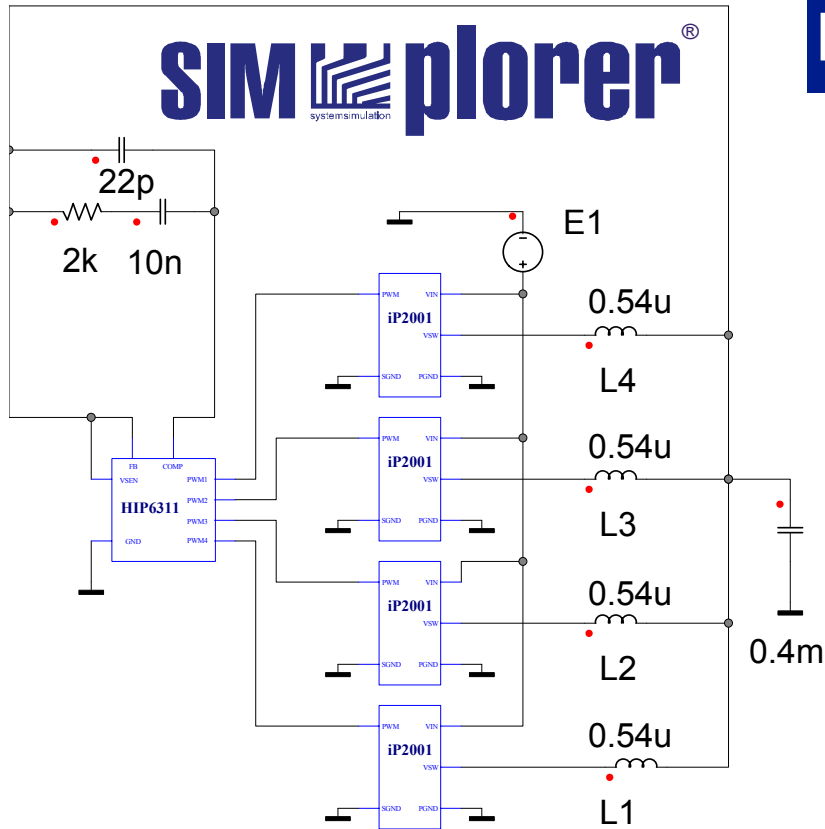
Manufacturers

Users Projects

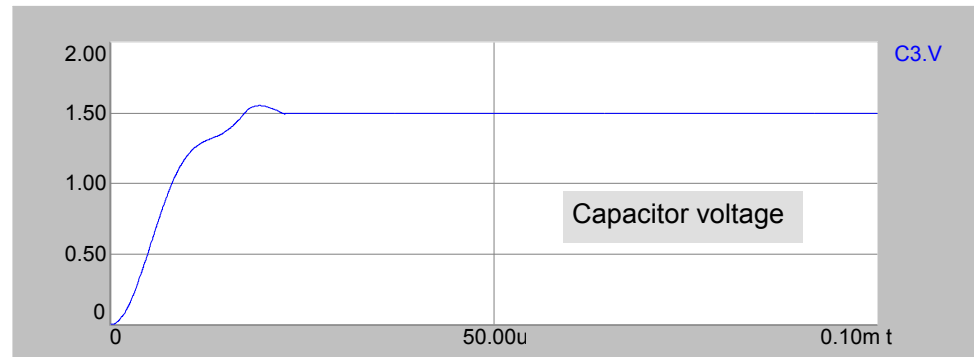
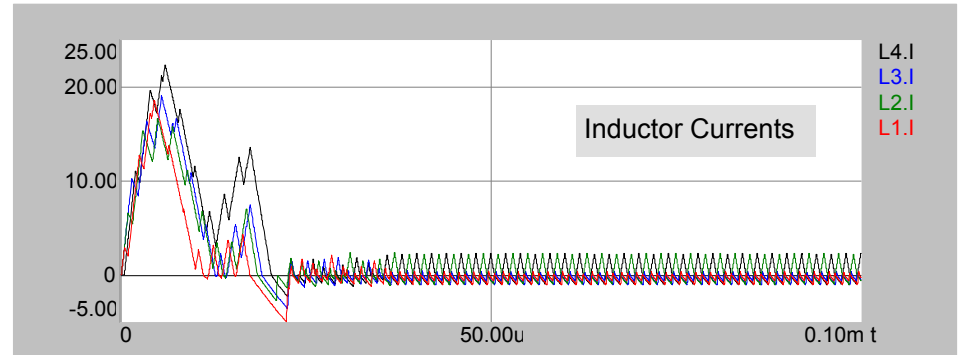
COMPATIBILITY4X
IRDCIP20015
PLEXUS

HIP6311
IP2001

Complete System



Reference Design IRDCi2001-C



Conclusion

- ▶ Behavioral Modeling can help to generate quick and easy models of complex components
- ▶ SIMPLORER state machines and math engine are extremely flexible modeling tools
- ▶ Using math engine and event driven state machines simulation is accelerated considerably
- ▶ Easy to use macro feature
- ▶ Easy to use library management and symbol editor