PLECS

DEMO MODEL

Flyback Converter with Magnetics

Last updated in PLECS 4.4.2

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1   Overview

This demonstration shows a DC-DC flyback converter operating in discontinuous conduction mode with two outputs. The converter has been designed for a DC input voltage between $20\,\mathrm{V}$ and $30\,\mathrm{V}$, however an average value of $25\,\mathrm{V}$ is used. The requirements for the two outputs are $12\,\mathrm{V}$, $0.2\,\mathrm{A}$ peak and $5\,\mathrm{V}$, $2\,\mathrm{A}$ peak, where the $12\,\mathrm{V}$ output is regulated with a control feedback loop. The model combines the electrical power circuit with a special magnetic circuit for the flyback transformer and the discrete controller.
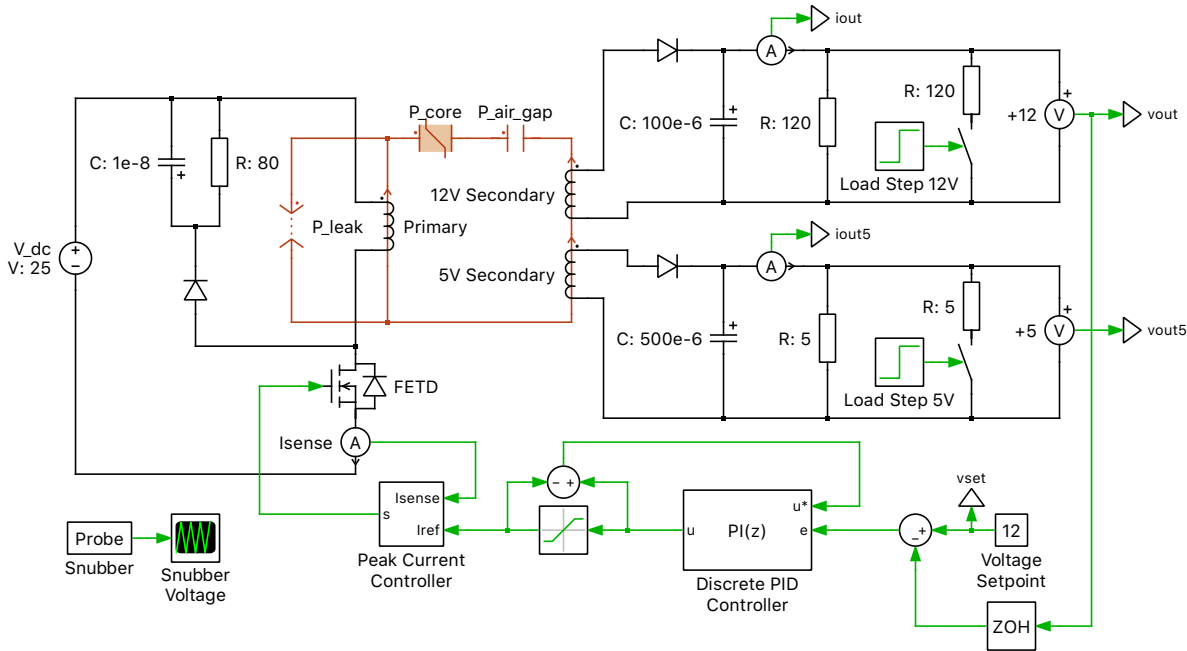

Figure 1: Schematic of the three-output flyback converter with magnetics

2   Model

2.1   Electrical system

The power circuit is based on a standard flyback topology with two outputs. Rather than modeling the flyback transformer with an ideal transformer and magnetizing inductance in the electrical domain, primitive components from the PLECS Magnetic component library are used to model the saturable core, input and output windings, air gap, and leakage inductance.

Fig. 1 depicts the electrical-equivalent and magnetic circuit designs for the transformer as implemented in PLECS.

The transformer core was chosen to be a Ferroxcube 2616 pot-core made of 3C91 material with the key parameters being: core magnetic path length, $37.6\,\mathrm{mm}$, and core cross-sectional area, $93.9\,\mathrm{mm}^2$. Using these values, information from the core material datasheet, and the target output specifications, values were then calculated for saturation characteristics, the length of the air gap, leakage inductance, and the number of primary and secondary side windings. A coth (hyperbolic cotangent) fitting function was used for the saturated core component as this was found to show a better approximation of the saturation curve than the arctangent fitting function. A flux density saturation of $0.47\,\mathrm{T}$ and unsaturated relative permeability of 9550 were used as parameters for the fitting function. A plot of the saturation curve is shown in Fig. 2. For further information regarding the Ferroxcube core set chosen (2616), see their website [1]. The datasheet for the core material (3C91) can also be found there.

An RCD snubber is used in the circuit to protect the switch during turn-off in from excessive voltage spikes. The snubber will dissipate the energy stored in the leakage inductance of the transformer and
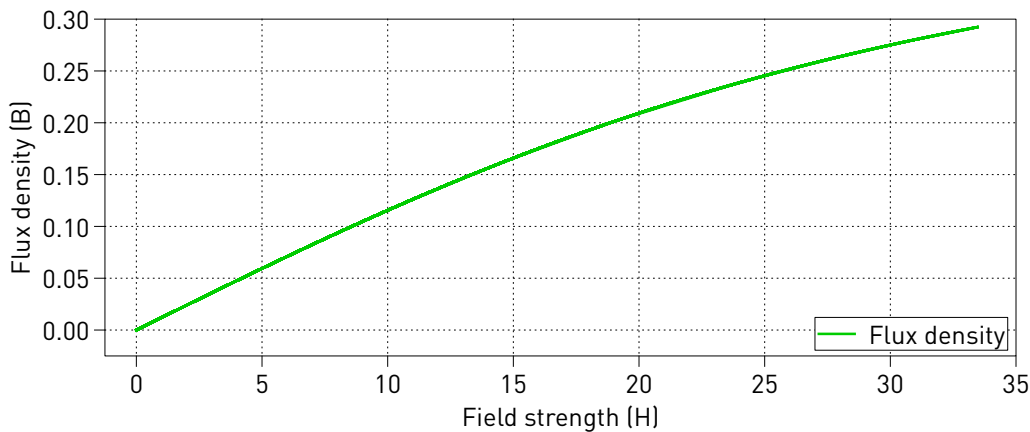
Figure 2: Saturation curve of the Ferroxcube 2616 pot-core made of 3C91 material

the capacitance on the switch (which has not been modeled in this example). Design guidelines for RCD snubbers in flyback converters can be found in the Fairchild Semiconductor AN-4147 application note [2].

2.2 Controls

The controller is cascaded and consists of an outer voltage control loop, using digital PI control, and an inner current control loop operating in peak current mode. The voltage setpoint is $12\,\text{V}$ for the high side output and the reference voltage for the PI controller is taken from this output. A current measurement is made using an ideal current sensor at the output of the switch, although in practice a small shunt resistance would likely be used.

3 Simulation

The simulation shows a start-up of the power supply under rated load conditions for both outputs. At $0.1\,\text{s}$, the $12\,\text{V}$ output has a load step to reach peak current conditions, and at $0.2\,\text{s}$ the $5\,\text{V}$ output has a load step to reach peak current conditions. A Scope displays the output voltages and currents and another shows the output power of each winding as well as the total. At start-up and after each load step the ramp-up of the voltage and currents to their target values is shown.

An XY Plot is also provided to show the BH loop for the saturation effect of the core. From the material datasheet, it is decided to not operate the core beyond $0.33\,\text{T}$ and the XY plot shows that the core is driven close to this value without exceeding it. In order to accurately show the saturation curve the Refine Factor of the solver must be increased to improve the rendering in the plot.

References

[1] Ferroxcube website.

[2] Fairchild Semiconductor AN-4147 application note.

Revision History:

PLECS 4.3.1	First release
PLECS 4.4.2	Update PI controller component

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