SmartCtrl Tutorial

Resonant Converter Control Loop Design

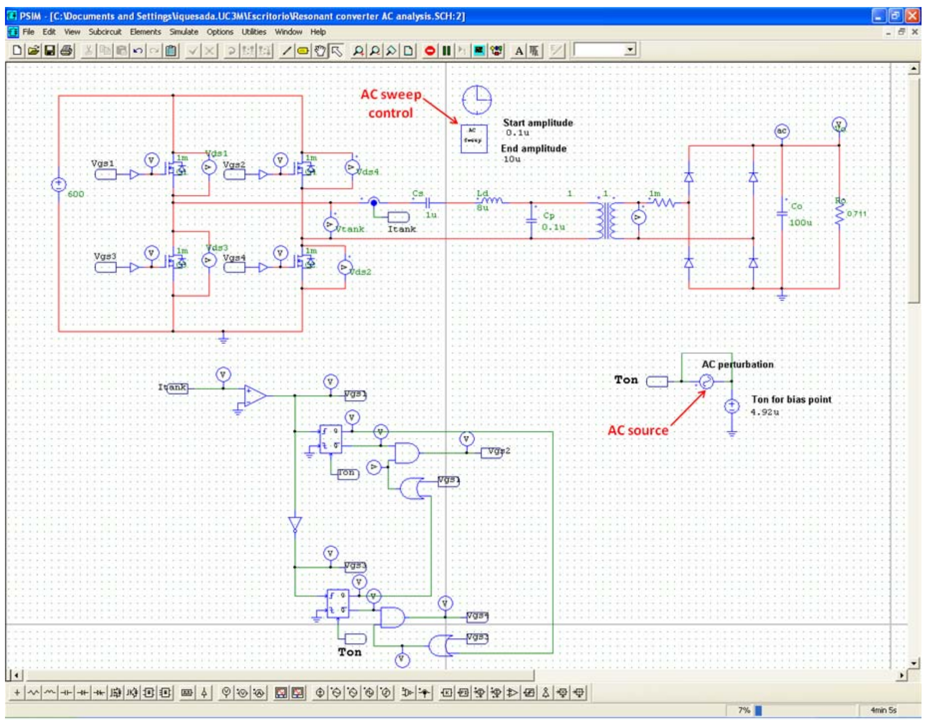
SmartCtrl[1] is a general-purpose controller design software specifically for power electronics application. This tutorial is intended to guide you, step by step, to design the control loop of a resonant converter.

Since the transfer function of a resonant converter is difficult to derive, one of the main purposes of this example is to illustrate that the resonant converter can be represented by the imported ac sweep results from PSIM, and the control loop of the resonant converter can be designed using SmartCtrl. This example demonstrates the power and flexibility of using SmartCtrl in combination with PSIM to design the control loop of any power converters.

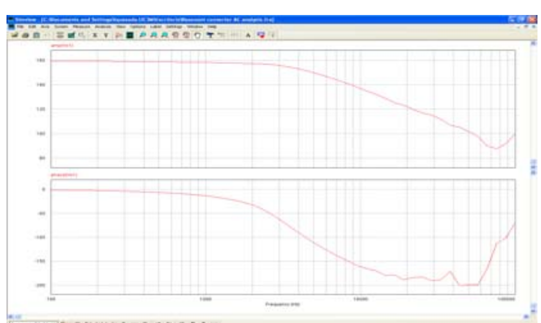
The first step is to obtain the resonant converter frequency response by means of the PSIM ac analysis.

1. Perform ac analysis in PSIM

   The frequency response of the plant is obtained from the switchmode form of the resonant converter using PSIM's ac analysis. The converter circuit is shown in the figure below. To perform the ac analysis, the ac sweep block and the ac source for signal injection are needed in the circuit.



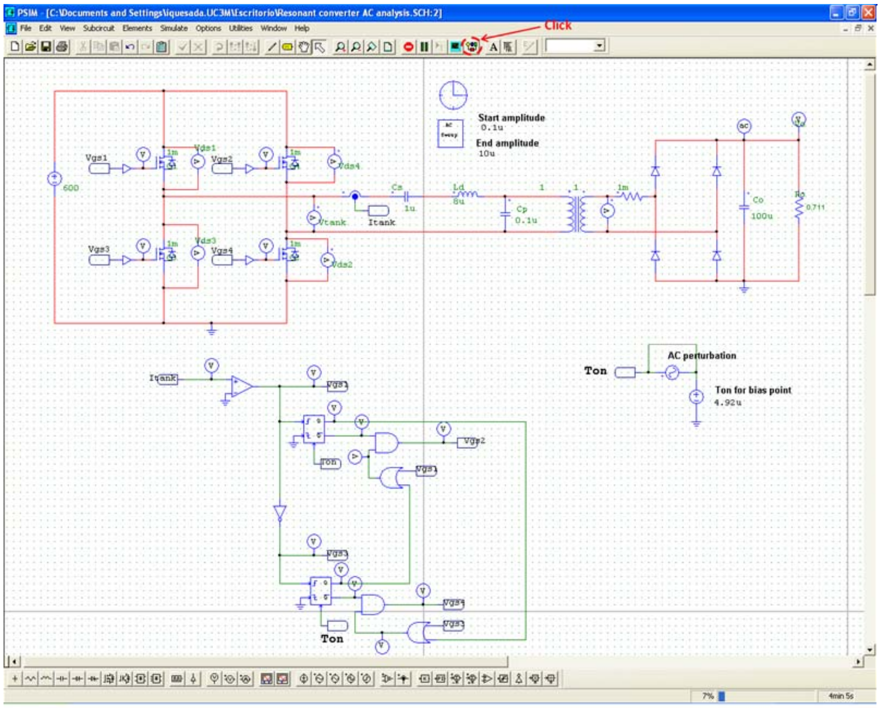
   After the simulation, the frequency response of the output voltage versus the control variable Ton is obtained, as shown below, and it can be exported to SmartCtrl.



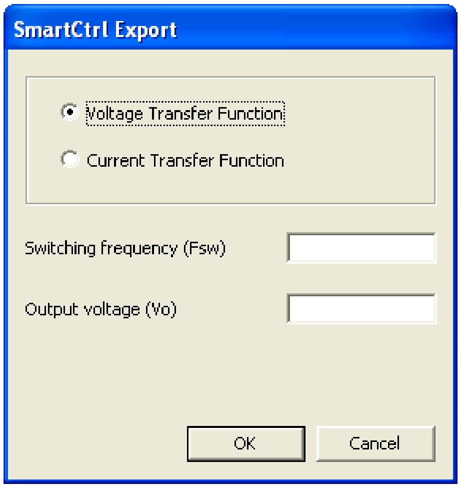
[1] SmartCtrl is copyright in 2010 by Carlos III University of Madrid, GSEP Power Electronics Systems Group, Spain

2. Import the frequency response data into SmartCtrl

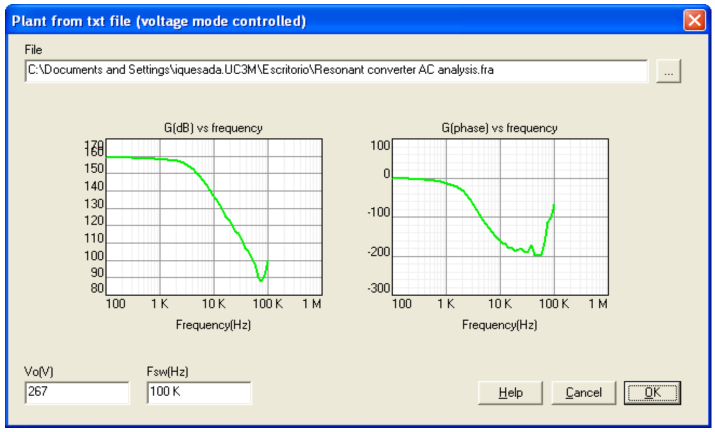
   Click the SmartCtrl button to open SmartCtrl. This action send a text file with the frequency response data from the PSIM ac analysis.



   Enter the output voltage and the switching frequency and click OK to continue.

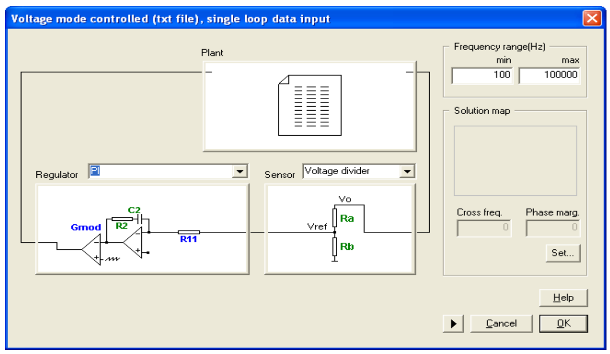


The loaded transfer function is automatically plotted as shown below:

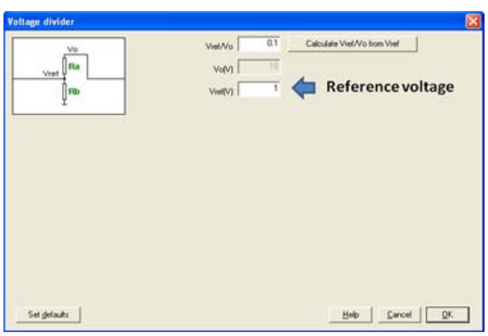


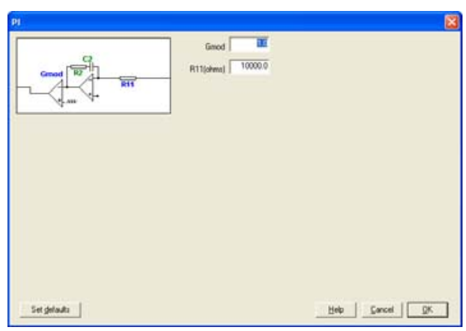
3. Design the control loop in SmartCtrl

After the plant is defined, the next step is to select the sensor and the regulator types.



Note that the reference voltage needs to be entered in the voltage divider input data window and the modulator gain in the regulator input data window, as shown below.

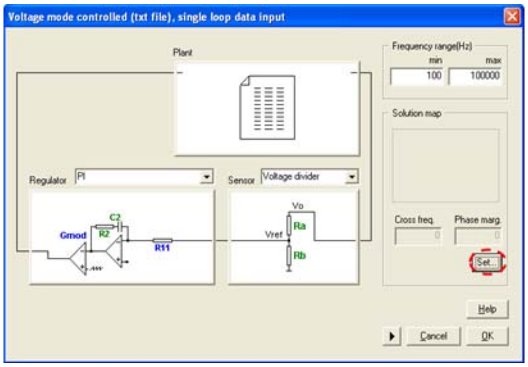


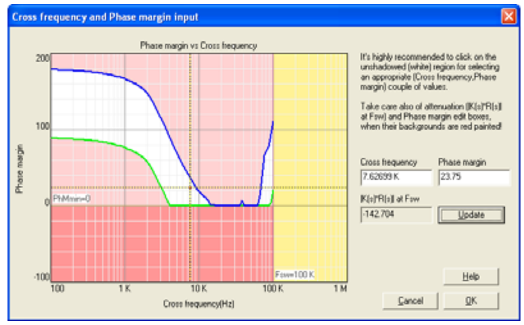


Once all the control loop transfer functions are defined, the crossover frequency and the phase margin can be selected.

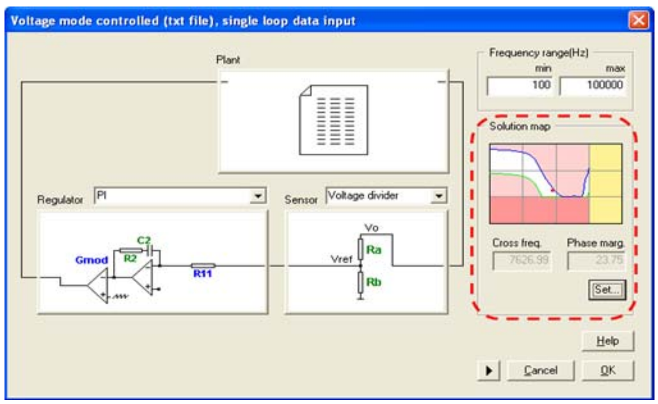
SmartCtrl provides a guideline and an easy way of selecting the crossover frequency and the phase margin through the ***Solution Map***. Each point within the white area corresponds to a combination of cross freq. and phase margin that lead to a stable solution. In addition, when a point is selected, the attenuation given by the sensor and the regulator at the switching frequency is provided. Note that not enough attenuation at the switching frequency could provoke high frequency oscillations.

To carry out the selection, click on the **Set** button and SmartCtrl will display the solutions map. Then left click a point within the white area, and click OK to continue.

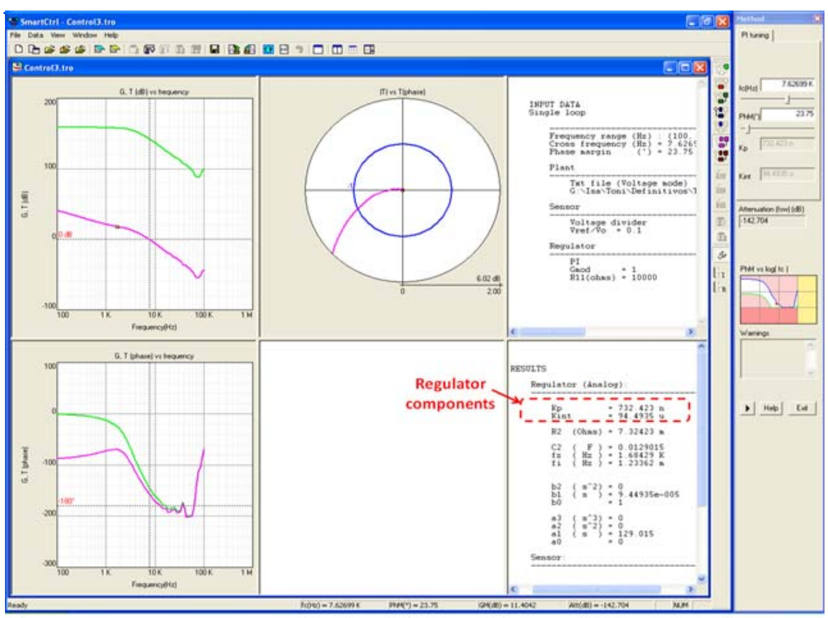




Once the crossover frequency and the phase margin are selected, the solution map will be shown on the right side of the input data window. If, at any time, these two parameters need to be changed, just click on the shown solution map as shown below.



Now accept the selected configuration and confirm the design, the program will automatically show the system performance in terms of the frequency response and transient response.



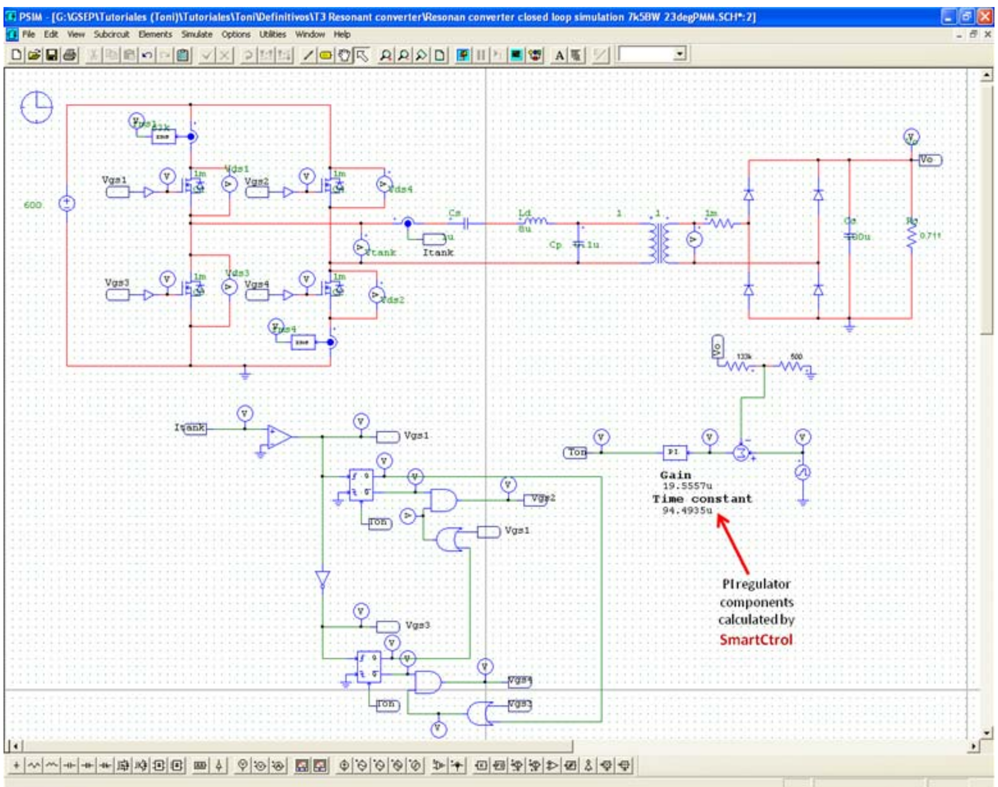
4. Validate the control loop design

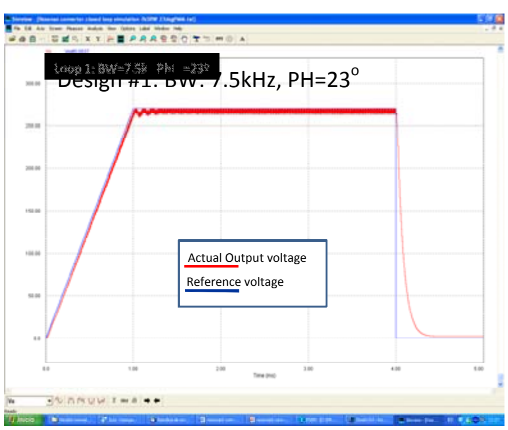
In order to check the closed loop performance of the regulator designed by SmartCtrl, a closed loop time-domain simulation is carried out in PSIM.

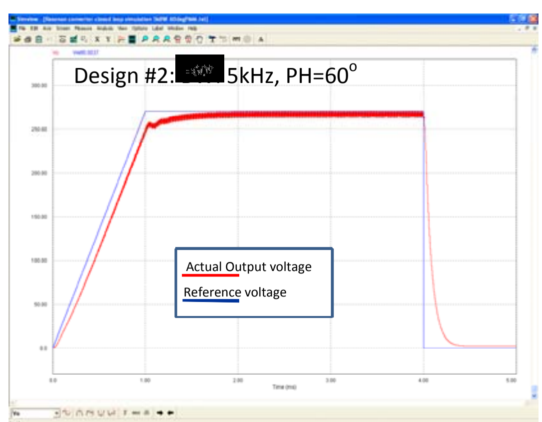
Two different designs are obtained from SmartCtrl. The following table shows the control loop bandwidth (BW) and the phase margin (PM) of these two designs, as well as the regulator parameters.

Design #1	Design #2
Bandwidth = 7.5kHz Phase Margin = 23º	Bandwidth = 5kHz Phase Margin = 60º
Kp = 19.557µ Kint = 94.4935µ	Kp = 8.55987µ Kint = 201.726µ

Using the two regulators from the table above, the corresponding closed loop responses are simulated in PSIM. Both the PSIM schematic and the simulation results are included below.







It can be observed from the waveforms that the first design (Design #1) tracks the reference signal more accurately than the second design (Design #2). Although Design #1 has a lower phase margin with under-damped oscillations, its higher bandwidth and higher low-frequency gain leads to a faster response.

This example shows that, ***SmartCtrl in combination with PSIM,*** with the capability to import frequency response results from PSIM, provide a fast and powerful platform for control loop design and optimization of any power converters.