smart ctrl

control design for power electronics

Peak Current Control with AC Sweep model

Tutorial –December 2018-

How to Contact:

info@powersmartcontrol.com

www.powersmartcontrol.com

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Power Smart Control SL

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1. Introduction

SmartCtrl is a design software specifically designed for power electronics applications. There are many predefined topologies, compensators and control types in SmartCtrl that allow a straightforward design of the control loop.

Moreover, if the model of the converter is not included into the program database, SmartCtrl proposes an alternative: the design of the compensator considering the frequency response of the plant directly introduced by the user. Thanks to this feature, the designer is able to carry out the control loop design and optimization for almost any plant.

This tutorial is intended to guide you, step by step, to design the peak-current control of a DC/DC converter using the SmartCtrl Software.

Although the model of this converter is included (among many others) into the database of the program, it has been considered interesting to give the user an alternative workflow.

2. Plant frequency response and SmartCtrl exporting

1. To obtain the AC response of a plant, an AC sweep has been done using PSIM. The PSIM required schematic is shown in Figure 1. It includes the compensating ramp that avoids the sub-harmonic oscillation.

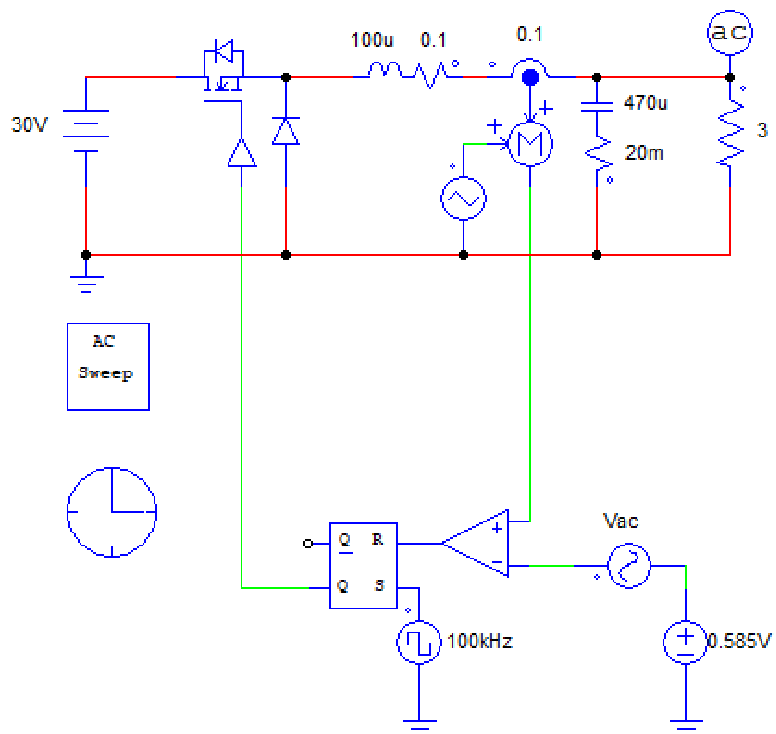

Figure 1: Psim schematic for creating an AC sweep

2. The result of the AC sweep performed in Psim is shown in Figure 2.

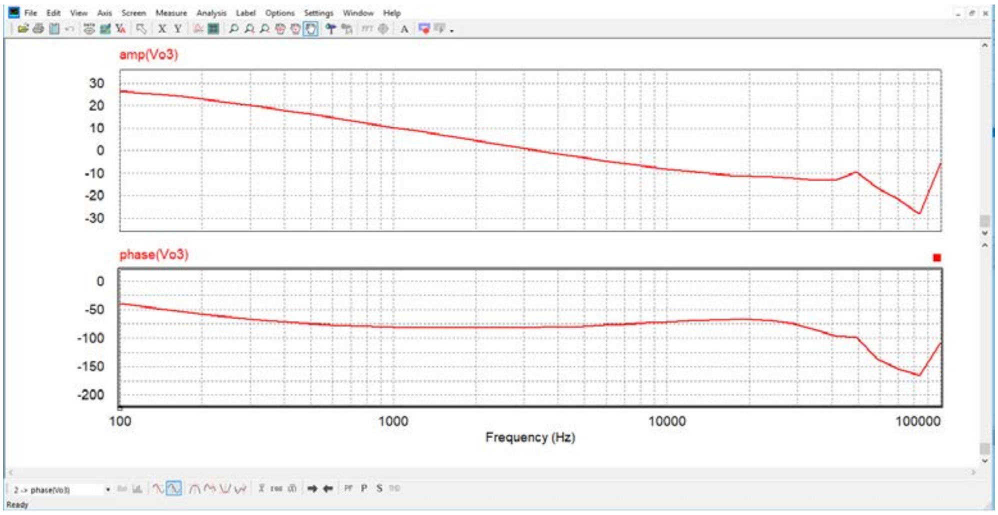

Figure 2: AC sweep performed in Psim

3. Exporting the plant to SmartCtrl

This result can be automatically exported to SmartCtrl by using the link between the two programs. The PSIM provides a special button (See Figure 3) that automatically exports the frequency response to SmartCtrl. This process is completely transparent for the user.

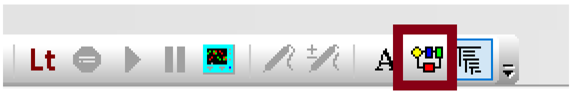

Figure 3: Psim export to SmartCtrl button

To configure SmartCtrl data importation, it is necessary to indicate if the transfer function is a “Voltage Transfer Function” or a “Current Transfer Function”. In this tutorial, the converter is voltage controlled. Figure 4 shows how to configure the AC data importation.

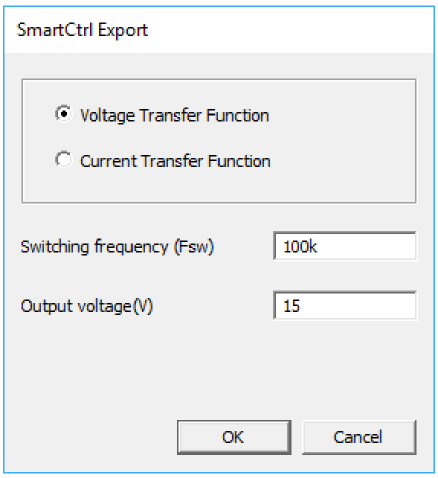

Figure 4: SmartCtrl AC data importing parameters

Other required parameters are the switching frequency and the output voltage. In this tutorial, those parameters are 100 kHz and 15 V respectively. Type these parameters and click OK. See Figure 4.

4. Control loop design in SmartCtrl

SmartCtrl will open automatically showing the imported data, click OK. See Figure 5.

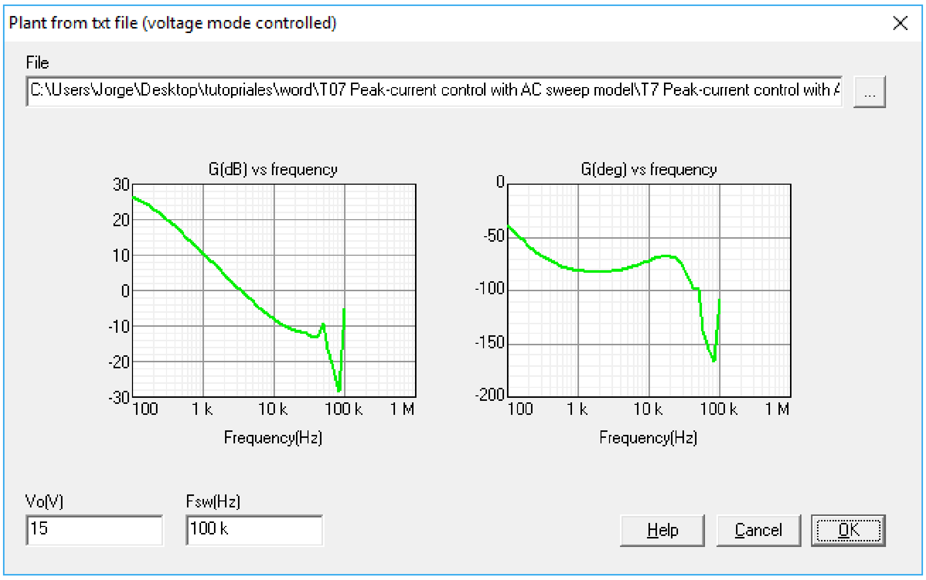

Figure 5: SmartCtrl imported data

The next step is to select the sensor to measure the output voltage. Select the "Regulator embedded voltage divider" as shown in Figure 6. With this sensor topology, there is no need to parametrize anything.

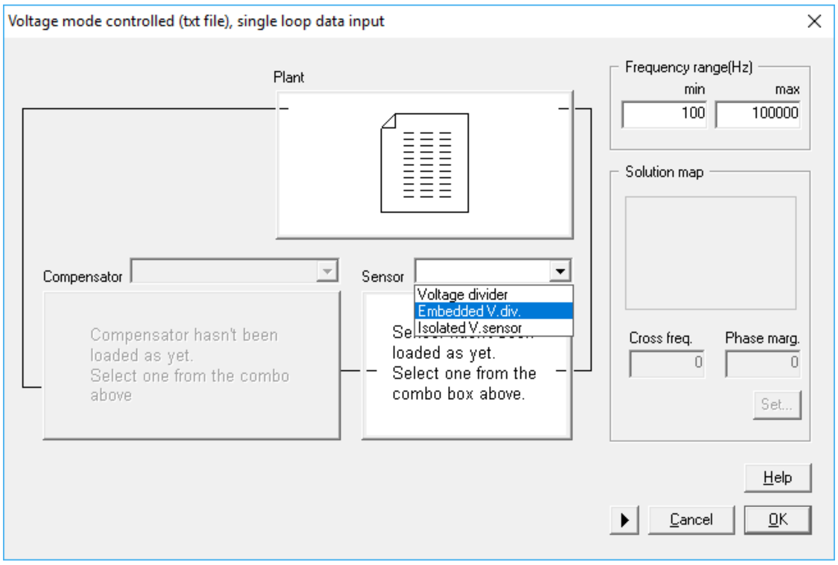

Figure 6: Embedded voltage sensor

Note: for a fixed voltage reference and a peak-current control, it is good selection to use an embedded voltage divider and an Unattenuated Type 2 compensator.

To define the compensator, select an Unattenuated Type 2 as shown in Figure 7 and parametrize it as it has been done in Figure 8.

Notice that the modulator behaviour is already included in the compensator block. In this case, the parameters Vp, Vv and tr will define the gain of the modulator. These parameters have been modified in such a way that the carrier signal is a ramp with a voltage ripple equal to one and a duty cycle also equal to one (rising time equal to the switching period).

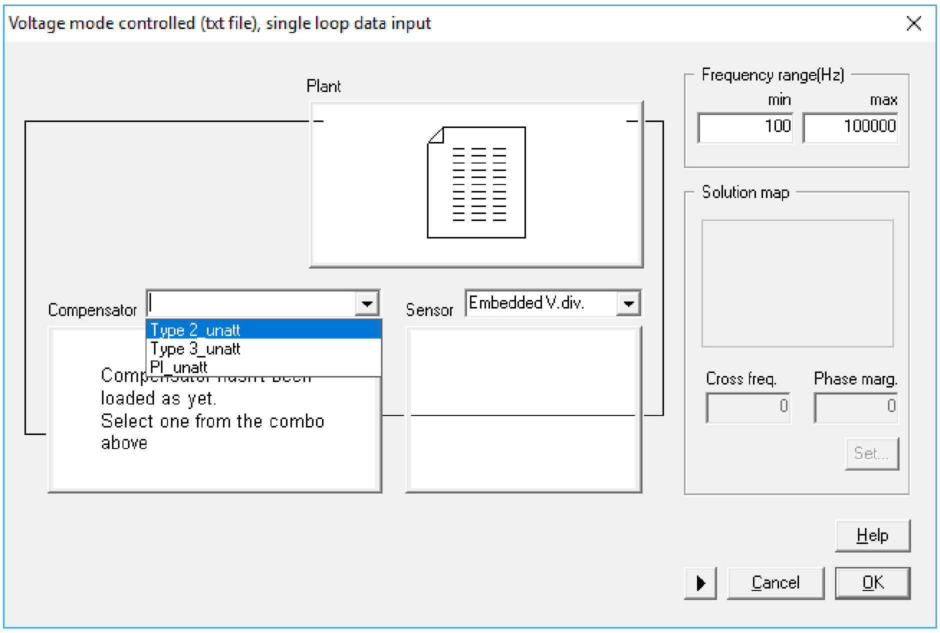

Figure 7: compensator available topologies

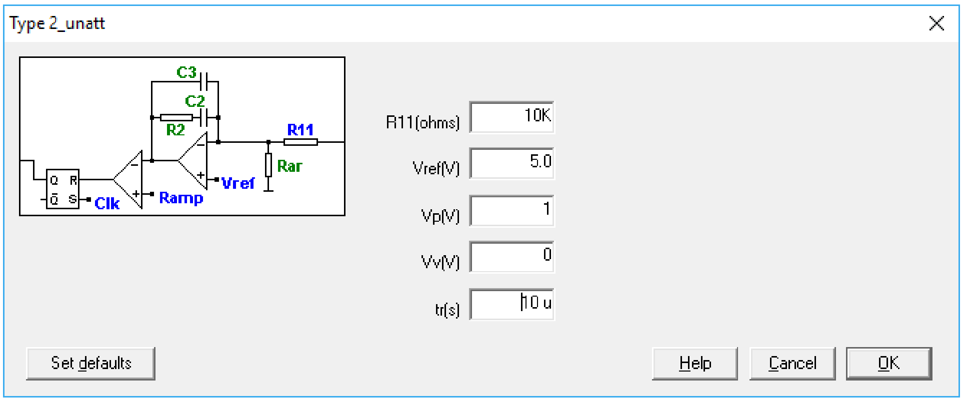

Figure 8: Unattenuated Type 2 compensator parameters

Once all the components of the control loop have been selected, it is necessary to specify the dynamic requirements. To do so, SmartCtrl provides the Solution Map. Click in set to access it, see Figure 9.

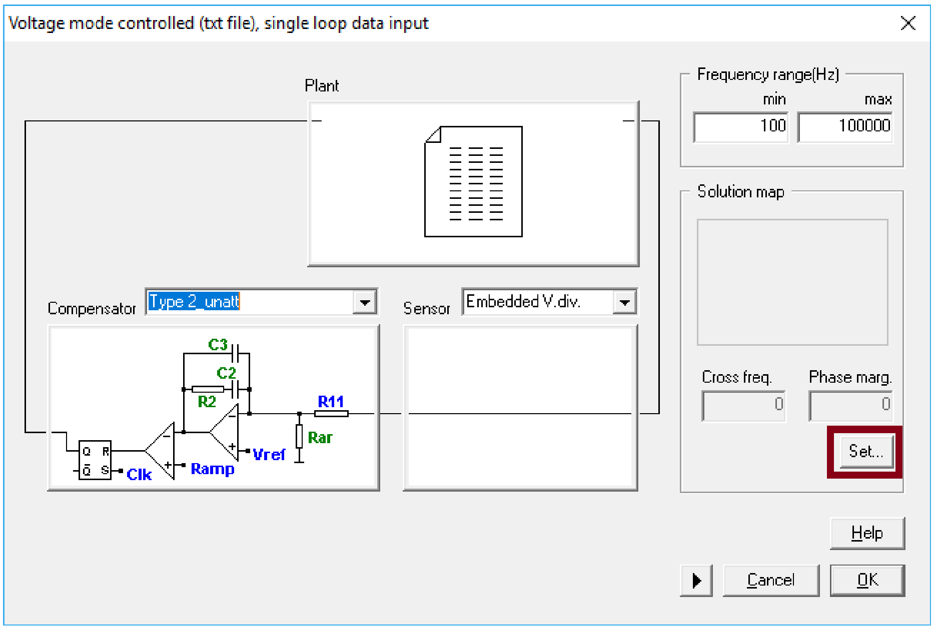

Figure 9: Access to the solution map

Solution Map is a graphical plot that represent the margin phase versus the cross-over frequency and gives the user a white zone. This white area is the one that contains stable phase margin – cross frequency pairs; so the design should be done in this area.

In this tutorial it has been chosen a cross frequency of 10 kHz and a phase margin of 60 degrees. See Figure 10.

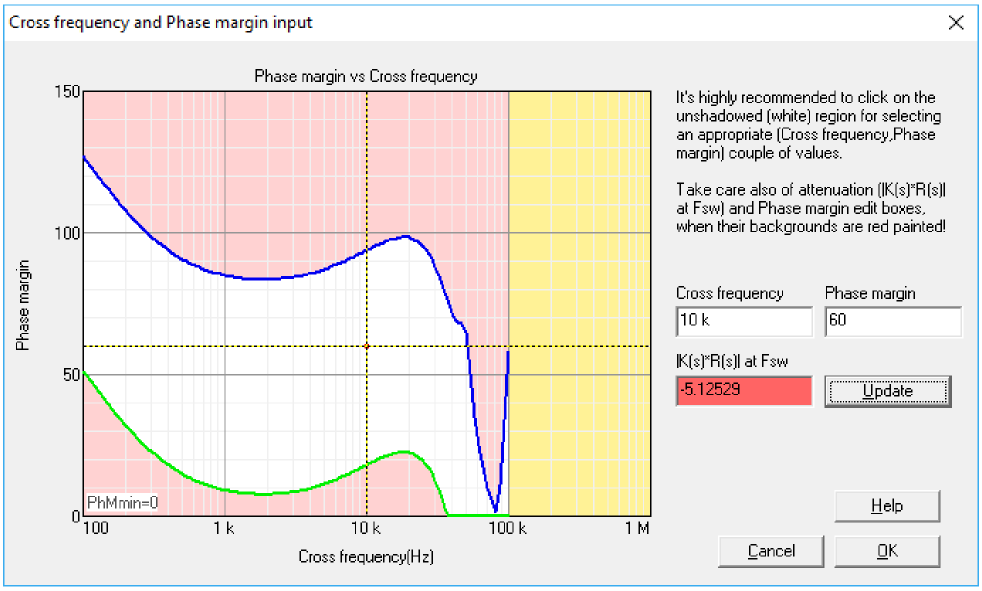

Figure 10: Solution map already configured

Note that the red field gives the user the attenuation of the loop at switching frequency. SmartCtrl warns the user that -5dB of attenuation may not be enough.

At this point the loop design is fully done as can be seen in Figure 11. Click OK and SmartCtrl will automatically show the dynamic performance of the system by means of the Bode plots, the Nyquist plot and the transient response, see Figure 12.

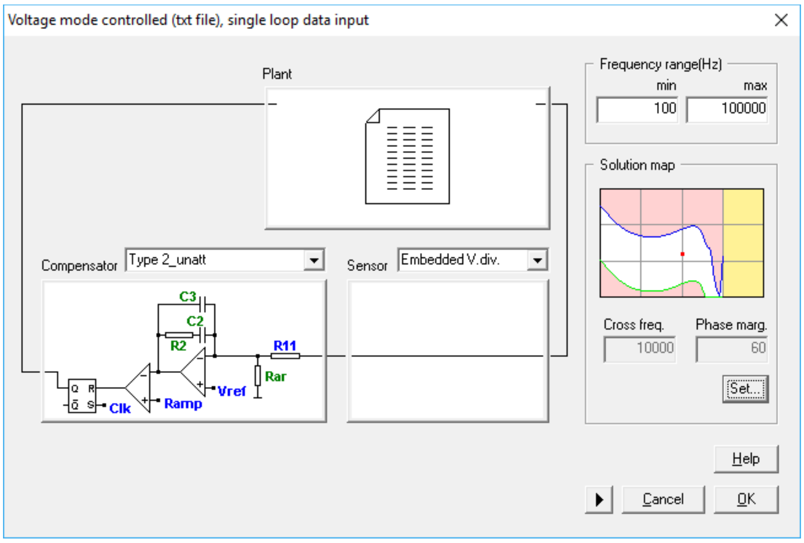

Figure 11: loop fully defined in SmartCtrl

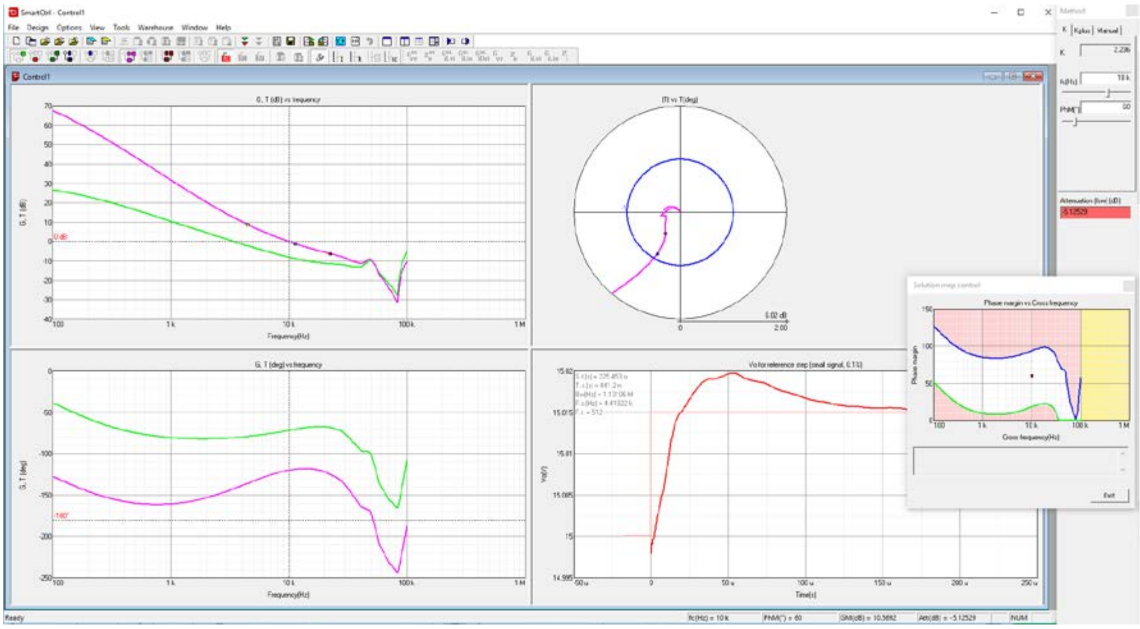

Figure 12: SmartCtrl analysis view

SmartCtrl also provides detailed reports about the input and output data where all the design parameters are collected and ordered. To access those reports it is only required to press the bottoms of Figure 13.

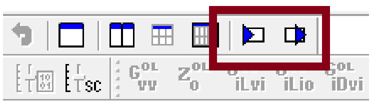

Figure 13: SmartCtrl input/output report buttons

3. Design simulation in PSIM

SmartCtrl has a link with PSIM that allows the exportation of the compensator designed to PSIM. To export it just click on the button shown in Figure 14 and configure the exportation according to Figure 15.

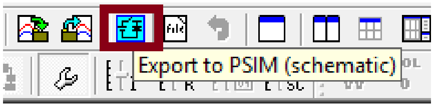

Figure 14: Exporting to Psim button

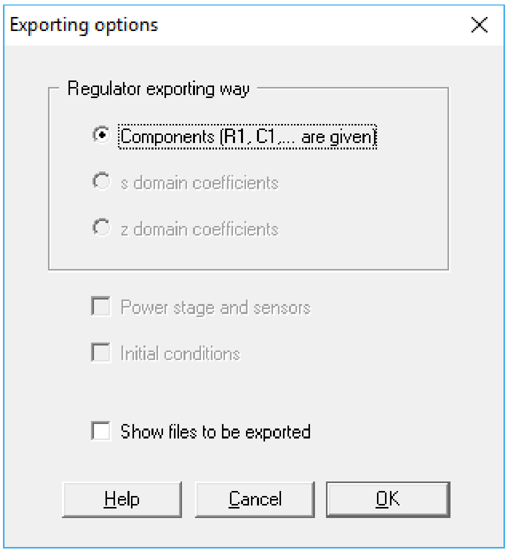

Figure 15: SmartCtrl exporting options

In this tutorial, the components of the regulator have been exported to a PSIM schematic with the original plant shown Figure 1. The control stage exported by SmartCtrl is shown in Figure 16.

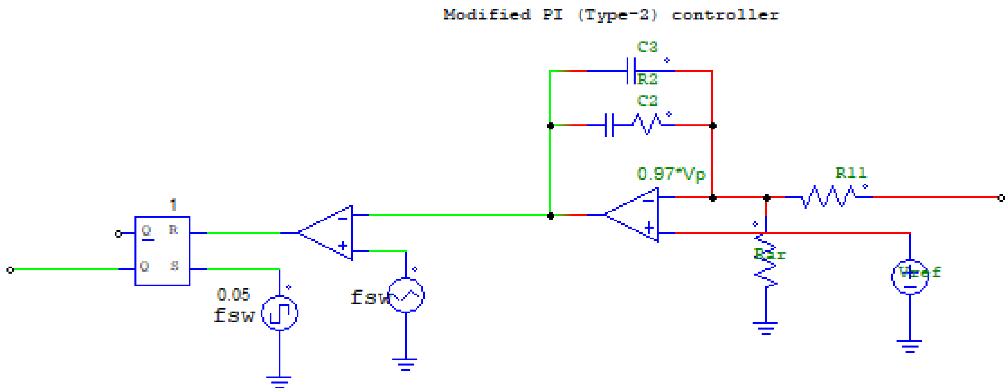

Figure 16: SmartCtrl exported control stage

The designer has to properly connect the compensator to the original power stage. It is important to highlight that the modulator proposed by SmartCtrl must not be considered (since the original design has its own modulator).

This stage can be easily modified so it can be successfully integrates with the initial plant of Figure 1. See Figure 17.

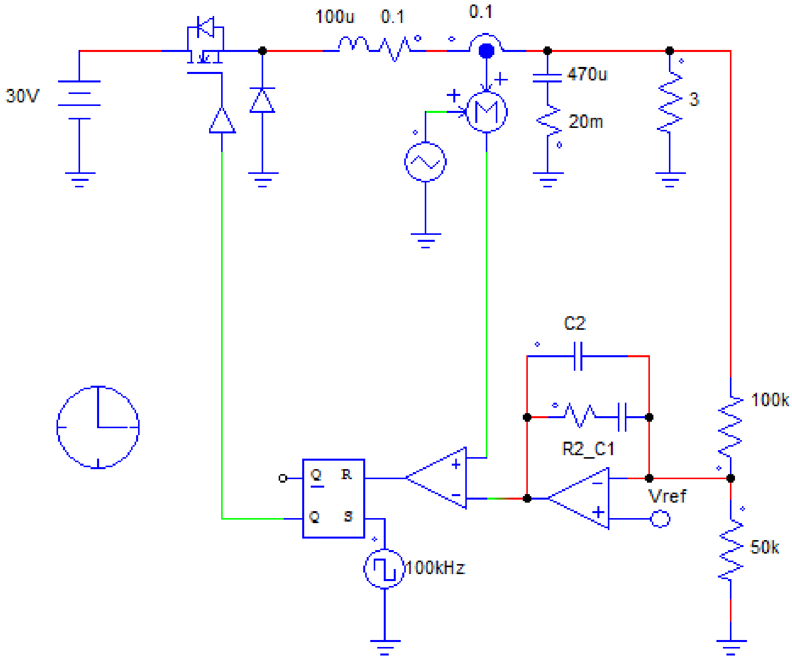

Figure 17: Psim schematic with SmartCtrl control stage connected

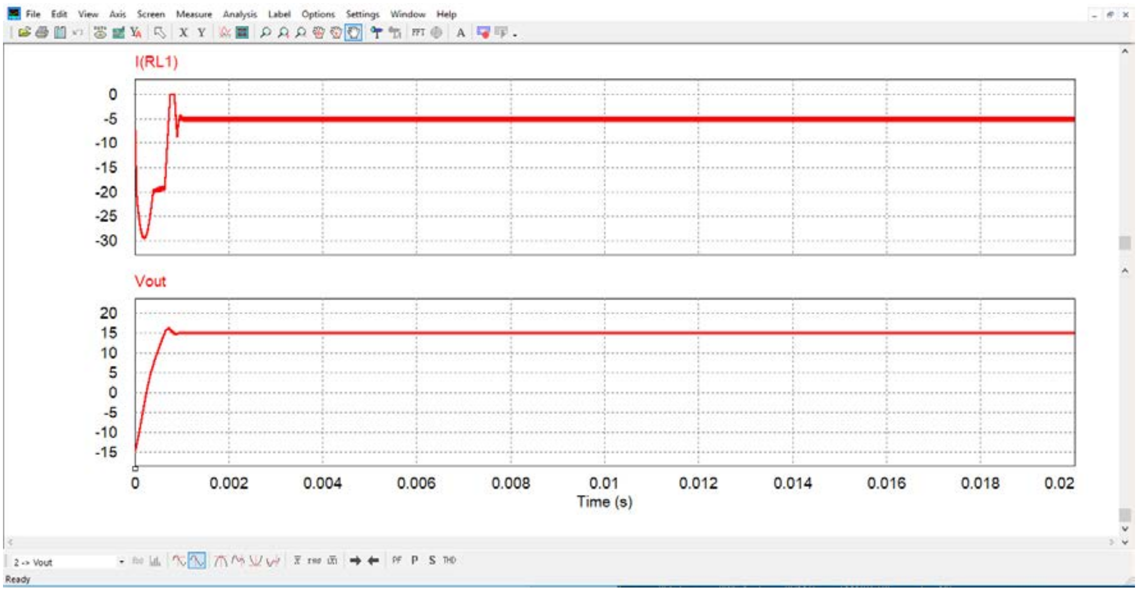

Figure 18: Psim simulated output voltage and inductor current

4. Comparison of SmartCtrl response with Psim

It is interesting to obtain the bode plot of open loop gain in Psim in order to compare it with the one provided by SmartCtrl. To do this, it is necessary to follow some steps:

1. Perform an AC sweep analysis to obtain the open loop gain with PSIM. It is quite important to understand that open loop gain must be measured with the converter working in closed loop; in other case, the control stage will saturate. To do so, Psim provides a special AC probe with two leads.
   To measure the open loop gain of the converter, the schematic of Figure 19 is required.

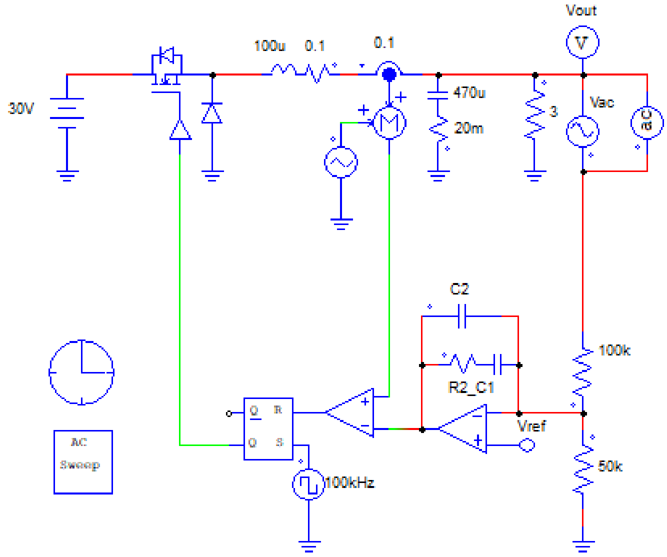

Figure 19: schematic required to measure the open loop gain

2. The result of the simulation is the one shown by Figure 20.

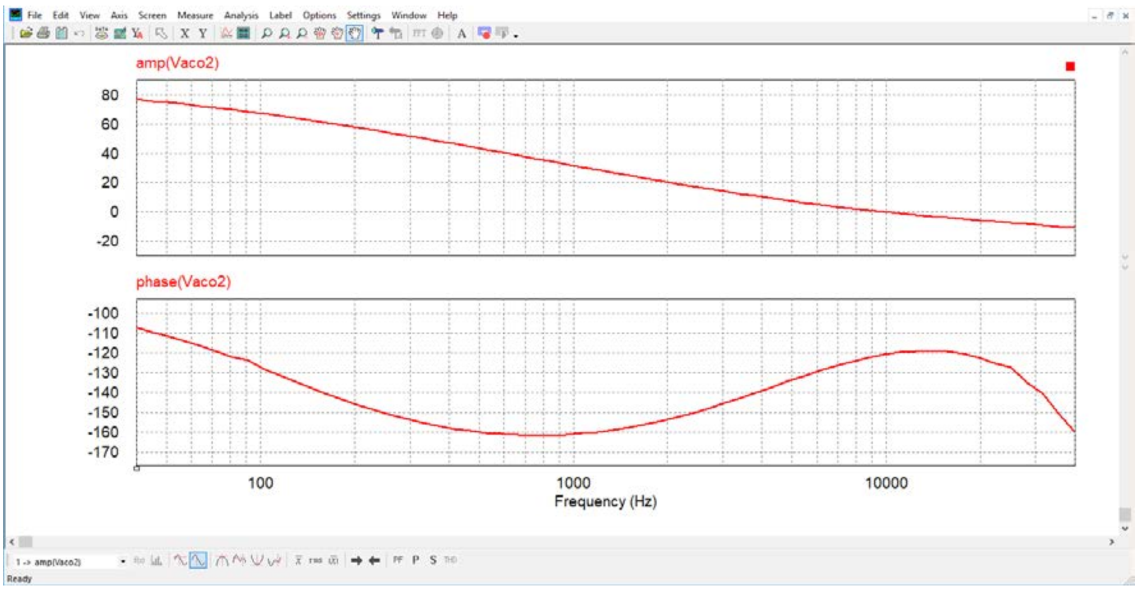

Figure 20: open loop gain measured in Psim

3. Save the Psim AC simulation with **File** -> **Save as** -> Psim_open_loop_gain**.txt**
4. In SmartCtrl merge the new transfer function with File -> merge. See Figure 21.

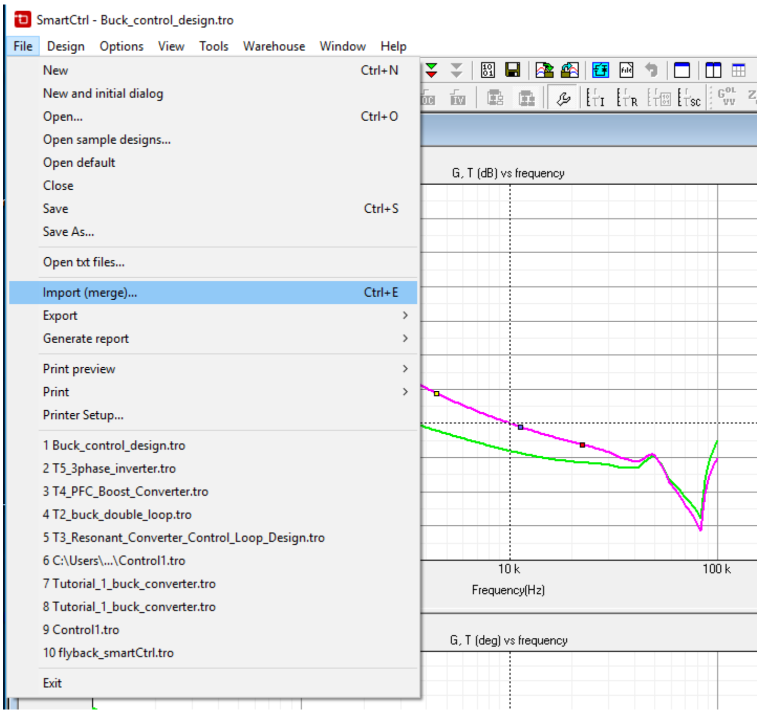

Figure 21: merge an external transfer function in SmartCtrl

5. Add the Psim AC sweep data and click OK. See Figure 22.

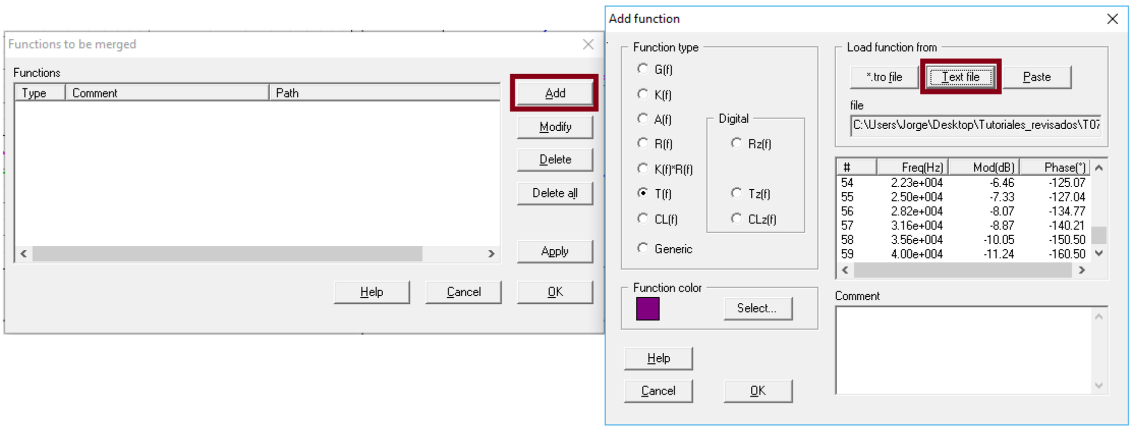

Figure 22: Importing txt data in SmartCtrl

6. Both traces: SmartCtrl one and the one imported from Psim will be represented on the same plots. See Figure 23.
7. As it can be seen in Figure 23, both are exactly the same. So, <u>SmartCtrl design is totally correct.</u>

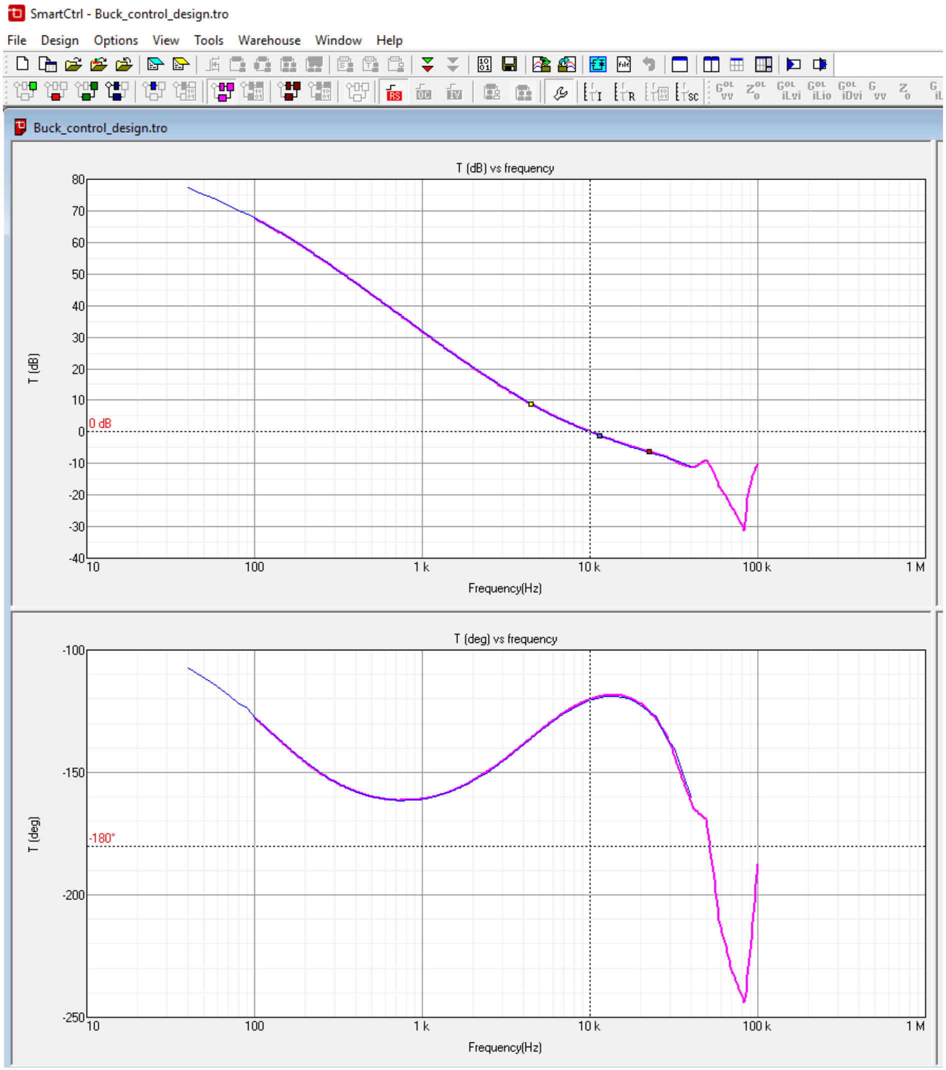

Figure 23: SmartCtrl open loop gain compared with Psim measured open loop gain