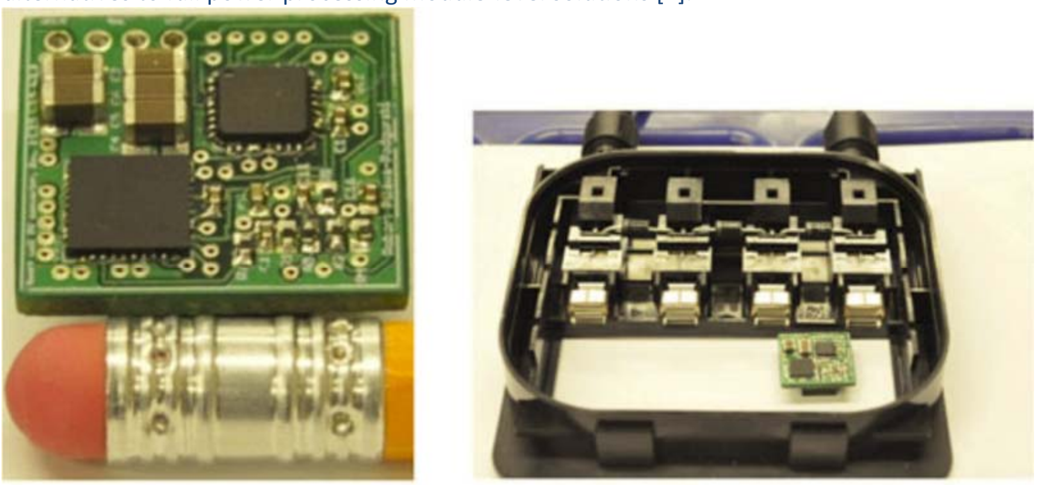
DC-DC Converter for PV Module Integration

Project background: Why module integrated converters (MIC)?

In the photovoltaic power converter industry, today one of the most exciting trend is represented by PV module integrated power electronics, DC modules, AC modules, or generally called Module Integrated Converters (MIC), which have the prospect to determine the next generation PV systems.

Photovoltaic (PV) systems are usually composed of series–parallel arrangements of PV modules, each module consisting of a string of series-connected PV cells. It is well known that mismatches due to manufacturing tolerances, partial shading, dirt, thermal gradients, or aging result in losses in energy captured by a PV system.

Recently, many PV architectures based on Module Integrated Converters (MICs), capable of module-level MPP tracking (MPPT) have been investigated, including DC-AC micro inverters, or DC-DC module-integrated converters (MICs). In these approaches, the impact of mismatches is reduced by performing module-level MPPT, at the expense of insertion losses and increased cost associated with the distributed power optimizers that are required to process full PV power even in the case when no mismatches are present. Furthermore, since it has been found that efficiency and energy capture can be improved further by performing finer-granularity MPPT in PV modules or systems, it is of interest to examine alternatives to full power processing module-level solutions [1].



(a) (b)

Figure 1. (a) A small submodule MPPT converter. (b) The submodule MPPT converter inside the junction box of the PV panel [3]

The MICs should operate either in buck either in boost mode, depending on the interconnection structure of the PV array. When connected in series, the MIC mainly operate in buck mode to supply the required output voltage on the DC link (Figure 2.), while in parallel connection they should operate in boost mode as each individual PV panel is connected to the DC link.

New trends in using wide band gap semiconductors (ex. Gallium Nitride – GaN) can result in improved converter efficiency (improved switching and conduction performance), higher power density and smaller size (smaller size of passive components due to higher switching frequency) [4][5].

The noninverting buck-boost topology has been shown to be a good candidate for MIC applications, since it provides wide voltage operating ranges both at input and output coupled with good efficiency and low component count.

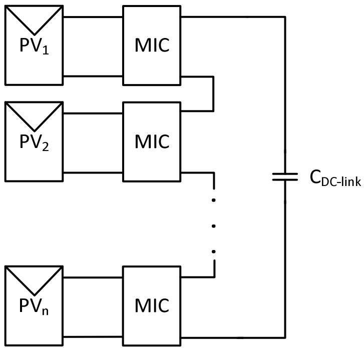


Figure 2. Series connected PV array with MIC

Objectives:

- Design of non-inverting buck-boost converter: component sizing, switching frequency, theoretical efficiency calculation. Optionally, a theoretical comparison of Si and GaN based converters performance can be carried out.
- Design of control system: small-signal model, controller design considering resistive load, Maximum Power Point Tracking (MPPT) for the PV panel
- Hardware implementation of the converter: selection of components, inductor design, gate drivers, measurement circuits, control platform
- Test and evaluation using PV simulator (available in the lab) and business perspectives.

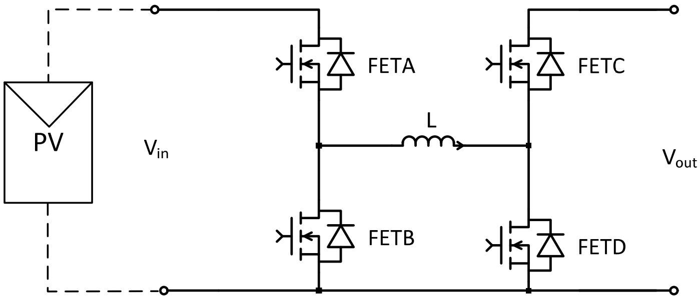


Figure 3. Noninverting buck-boost converter

Resources:

- Simulation software – LTSpice/Plecs/Matlab
- Hardware implementation: resources for PCB development and electrical components
- Plecs RT box/DSP for control and PWM generation

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Bibliography:

[1] C. Olalla, D. Clement, M. Rodriguez, and D. Maksimovic, "Architectures and Control of Submodule Integrated DC–DC Converters for Photovoltaic Applications," *IEEE Transactions on Power Electronics,* vol. 28, pp. 2980-2997, 2013.

[2] Doron Shmilovitz and Yoash Levron, "Distributed Maximum Power Point Tracking in Photovoltaic Systems–Emerging Architectures and Control Methods," *AUTOMATIKA: časopis za automatiku, mjerenje, elektroniku, računarstvo i komunikacije,* vol. 53, pp. 142-155, 2012.

[3] R. C. N. Pilawa-Podgurski and D. J. Perreault, "Submodule Integrated Distributed Maximum Power Point Tracking for Solar Photovoltaic Applications," *Power Electronics, IEEE Transactions on,* vol. 28, pp. 2957-2967, 2013.

[4] K. Kruse, M. Elbo and Z. Zhang, "GaN-based high efficiency bidirectional DC-DC converter with 10 MHz switching frequency," *2017 IEEE Applied Power Electronics Conference and Exposition (APEC)*, Tampa, FL, 2017, pp. 273-278.

[5] M. Acanski, J. Popovic-Gerber and J. A. Ferreira, "Comparison of Si and GaN power devices used in PV module integrated converters," *2011 IEEE Energy Conversion Congress and Exposition*, Phoenix, AZ, 2011, pp. 1217-1223.