Fast response HF DC-DC converter architecture for RF amplifiers based on a multilevel topology

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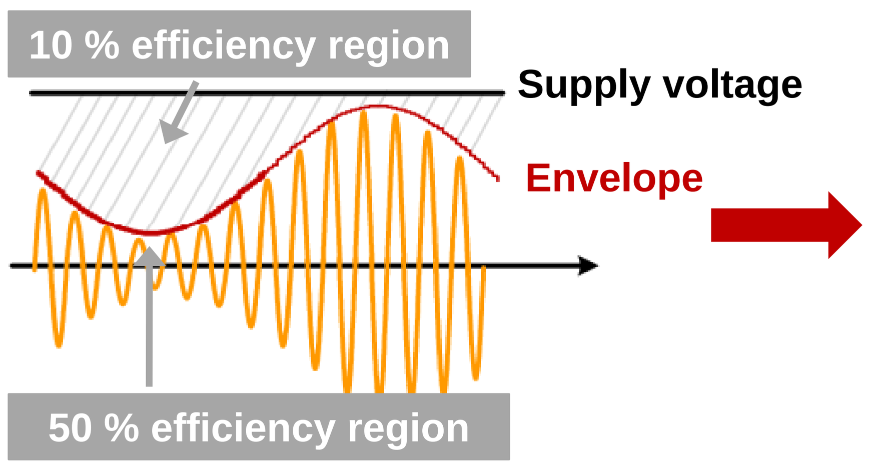
I. INTRODUCTION

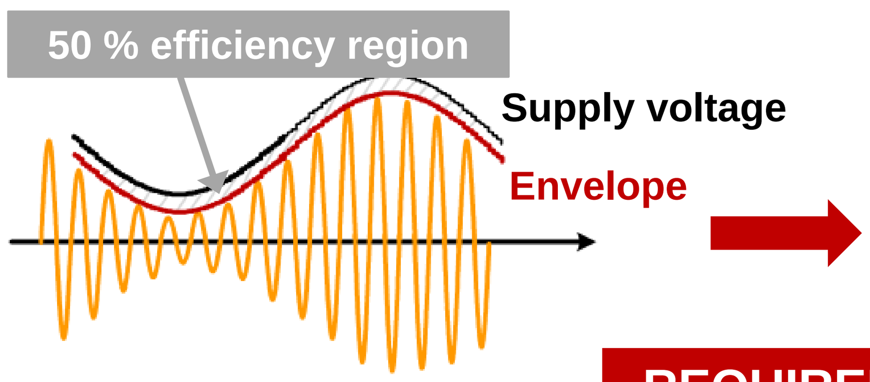
POWER SUPPLIES FOR LINEAR RF POWER AMPLIFIERS

Constant voltage



- ‘High’ efficiency operation regions besides very low ones
- Very low overall efficiency (10 %)
- Linear operation is mandatory due to the new modulation schemes

Variable voltage: ENVELOPE TRACKING



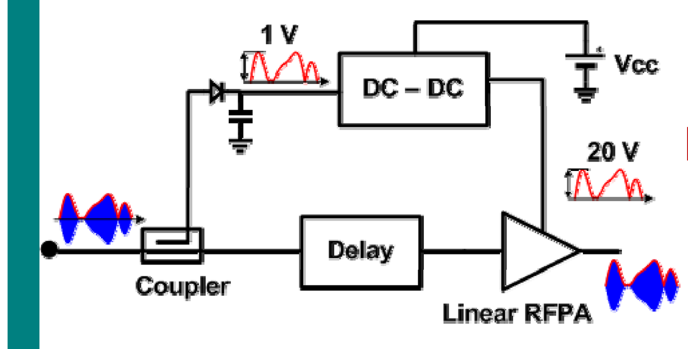
- Always operate in the high efficiency region
- Needs a special power supply

REQUIREMENTS

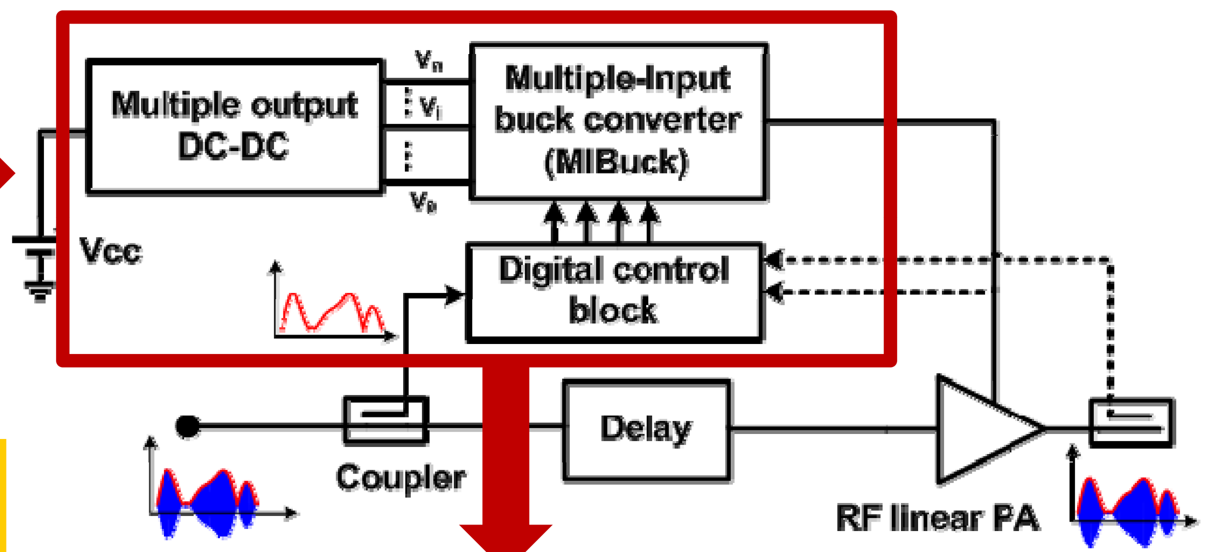
- Variable output voltage
- Fast response (determined by the transmitter architecture)
- Low output voltage ripple to avoid spectral regrowth
- Power capability depending on system specifications

II. SYSTEM ARCHITECTURE

Typical envelope tracking system



Proposed envelope tracking supply architecture

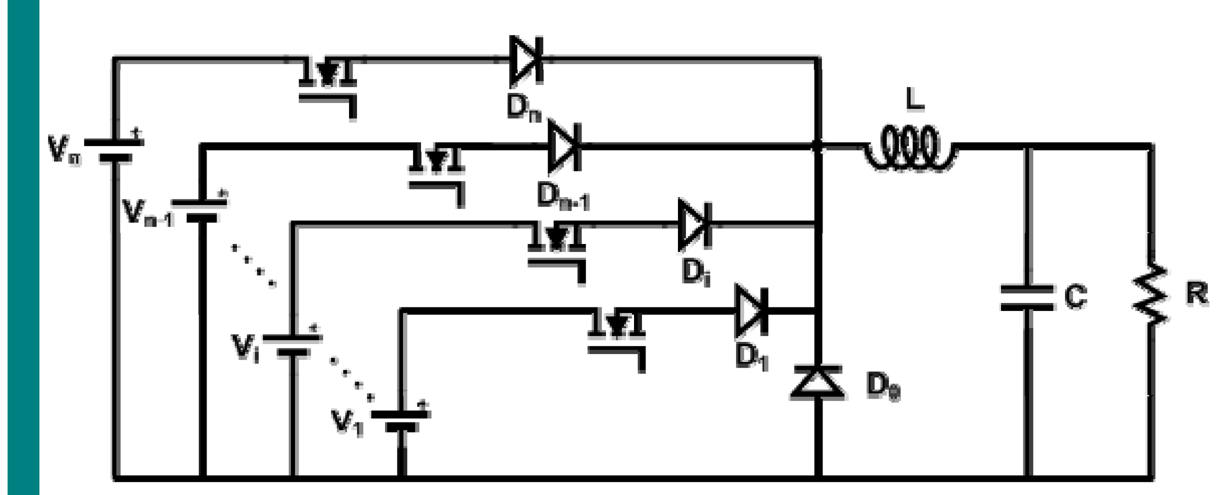


This work focuses on the MIBuck topology

Many integration possibilities

One of the main issues would be the integration of the MIBuck HF driving circuitry with the switches

III. MIBUCK TOPOLOGY



The intermediate voltages can be chosen to optimize the response when working with a certain modulation

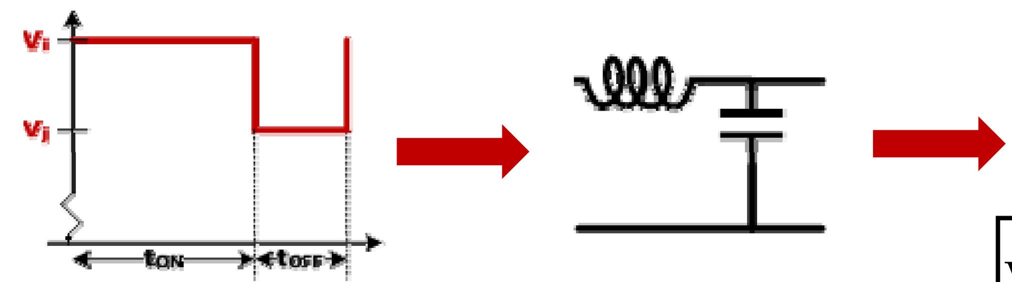
Here they have been chosen equally spaced, being V_{max} and 0 the maximum and minimum voltages respectively

STATIC BEHAVIOUR

$$V_i = \frac{V_{max}}{n}\cdot i,\ i = 0,1,\ldots,n$$

1 Conversion ratio in CCM

- The main idea of the MIBuck is to switch the voltage that enters the output lowpass filter between two close values
- The output voltage is easily obtained



$$V_{out} = d_{ij}\cdot\left(V_i - V_j\right) + V_j$$

Equally spaced

$$V_{out} = \frac{V_{max}}{n}\cdot\left(d_{ij}\cdot(i - j) + j\right)$$

2 Output voltage ripple

- The output voltage ripple is reduced by a factor of n

$$\Delta V_s = \frac{V_{max}\cdot d_{ij}\cdot\left(1 - d_{ij}\right)}{8\cdot L\cdot C\cdot f_s^2\cdot n}$$

- From a different point of view, the cut-off frequency of the output filter can be increased with respect to a conventional buck

3 Switching losses

- The MOSFETs switch between two close voltages, so that switching losses are smaller than those of a conventional buck topology
- The switching frequency can be increased substantially in comparison with a conventional buck

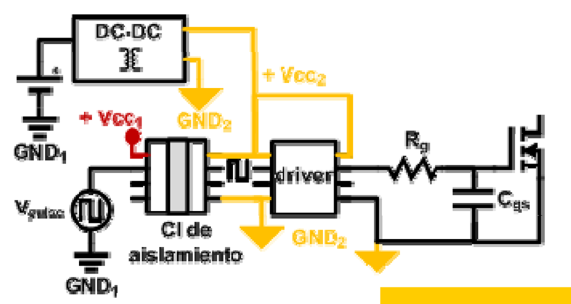
IV. EXPERIMENTAL RESULTS

The MIBuck is used to reproduce high frequency waveforms

Envelope tracking system simulation

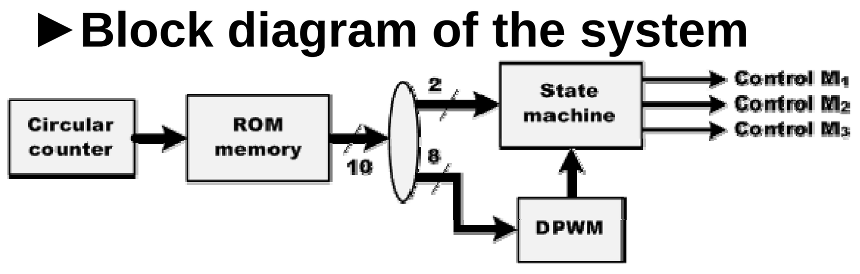
Power and driving section

- RF MOSFETs are used due to the high switching frequency (MRF373)
- Hard-switching and hard-gating
- Isolated driving circuitry: digital transmission circuits (IL610) and high frequency driver ICs (EL7156) , plus isolated power supply



Control section

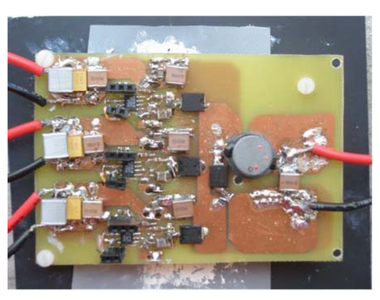
- FPGA Virtex 4 is used to generate the pulse pattern
- 4 MHz switching frequency
- Block diagram of the system



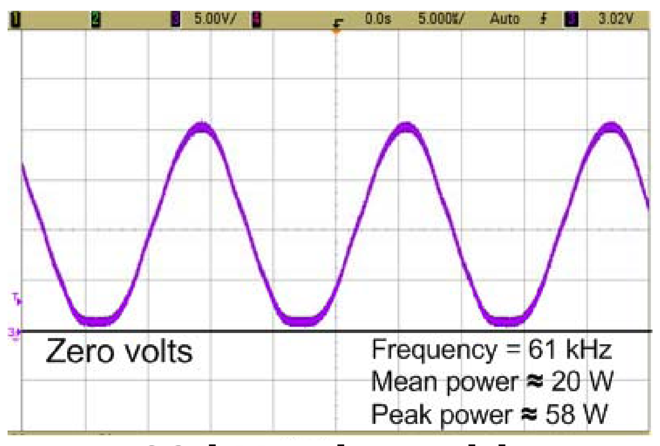
- The counter-based DPWM is the limiting factor: only a 5 bits resolution is possible using a 100 MHz clock

RESULTS

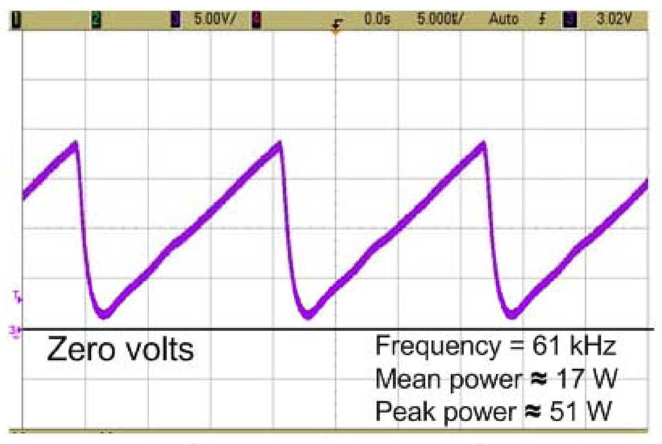
Prototype



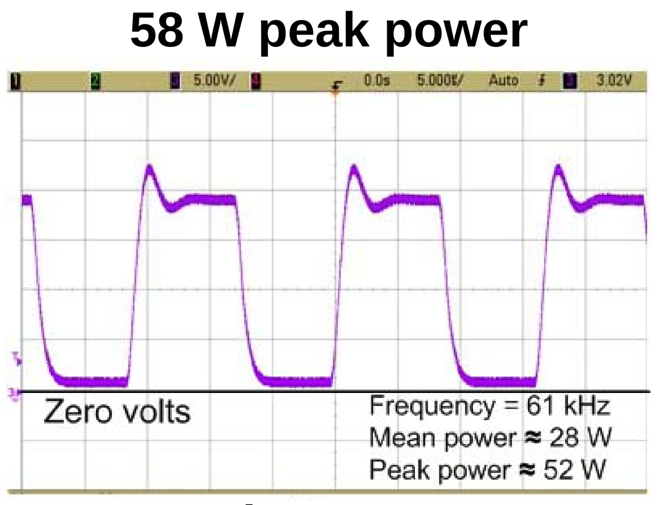
- 2-sided PCB
- 88 % efficiency
- 82 % taking the driver into account



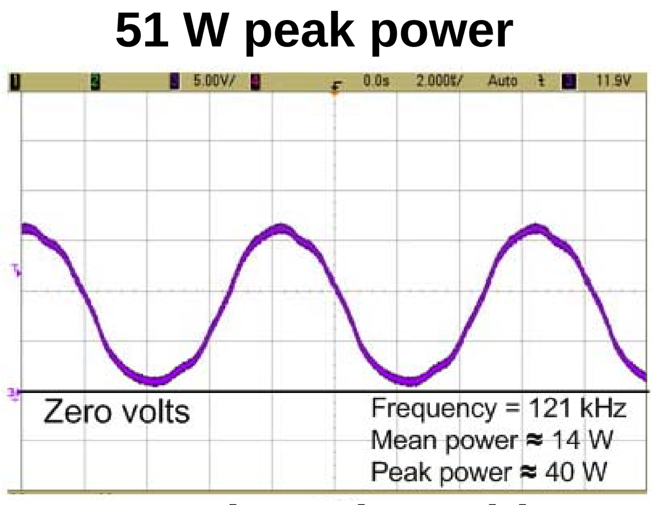
60 kHz sinusoid
58 W peak power



60 kHz sawtooth
51 W peak power



60 kHz square
52 W peak power



120 kHz sinusoid
40 W peak power

IV. CONCLUSIONS

1. The MIBuck topology is appropriate to be the cornerstone of an envelope tracking power supply
2. High frequency operation and fast response are achieved
3. Both the control system and the power topology should be modified to reach higher switching frequencies and faster responses

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