HIGH EFFICIENCY AC-DC LED DRIVER
WITHOUT ELECTROLYTIC CAPACITORS
FOR STREET LIGHTING

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Partners

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FIREFLY PROJECT

PATENT PENDING

FIREFLY PROJECT PATENT PENDING
Outline

- Introduction
- Proposed topology
- First stage & second stage
- Load analysis
- Third stage
- Experimental results
- Conclusions
INTRODUCTION
Aim of the project

Ac-dc converter for LED-based street lighting application

4 LED strings of 40 W (350 mA) each

Other mandatory conditions

- PFC
- No electrolytic capacitor
- Galvanic isolation
- Efficiency > 93%
- Universal range
- Constant frequency
- Dimming
- 180x60x45 (mm)
- Cost (of course)
PROPOSED TOPOLOGY
Chosen topology

3 stage topology

**KEY ISSUE**
Each stage is OPTIMIZED for JUST ONE task
High efficiency is possible

Power Factor Correction
Galvanic isolation
Regulation of the LED string current

Two output voltages!!
First stage

- **PFC Boost converter operating at constant frequency without electrolytic capacitors**

**PFC & Continuous Conduction Mode**

SiC Schottky diodes are the solution. The increase in cost is acceptable for AEG POWER SOLUTIONS.

**No electrolytic capacitors**

Output voltage ripple is high and one of the next stages will have to cancel it...

**PROVIDED BY AEG POWER SOLUTIONS**
Second stage

Electronic transformer → Galvanic isolation at very high efficiency but with unregulated outputs (fixed duty cycle)

High efficiency

ZCS in diodes
[Secondary leakage inductance-output capacitors] resonance
ZVS in MOSFETs
Energy stored in the primary leakage inductance (aided by the magnetizing current)

ZCS implies no output voltage regulating capabilities, hence…
Second stage

Electronic transformer → Galvanic isolation at very high efficiency but with unregulated outputs (fixed duty cycle)

Unregulated output voltages

\[ V_{out\_high} = V_{in} \cdot G_{high} \]
\[ V_{out\_low} = V_{in} \cdot G_{low} \]

Low-frequency ripple (PFC) needs to be canceled by third stages
Before analyzing the third stages...

The design of the third stages should take this into account.
Third stages

Maximum output voltage ($D=1$) $\rightarrow V_{3\text{\_high}}$

Minimum output voltage ($D=0$) $\rightarrow V_{3\text{\_low}}$

Not a real drawback if $V_{3\text{\_low}}$ is wisely chosen

And the advantages…?

MOSFET and diodes only have to withstand $V_{3\text{\_high}}-V_{3\text{\_low}}$

EFFICIENCY IS CONSIDERABLY HIGHER THAN IN BUCK CONVERTER
EXPERIMENTAL RESULTS
Prototype

Second stage
- 200 W
- Outputs 140 V & 80 V
- ETD 34

Third stages (4x)
- 50 W each
- E20
- Total Current Dimming

EXPERIMENTAL RESULTS
Second stage

**EXPERIMENTAL RESULTS**

*ZCS in the diodes of the ET*  
*ZVS in the MOSFETs of the ET*

![Waveform](image_url)

- **VGS (10 V/div)**
- **VDS (100 V/div)**
Third stage

Voltage withstood by MOSFET and diode

Input voltage of the filter

\[ V_{3\_high} - V_{3\_low} \]

\[ 140 \text{ V} - 80 \text{ V} = 60 \text{ V} \]
Second + third stage

Constant input voltage in second stage: 400 V

Input voltage (100 V/div)  Output current (100 mA/div)

Ripple in the input voltage of second stage: 70 V_{pp}
EXPERIMENTAL RESULTS

Efficiency of second and third stages

Peak efficiency = 95.9% at nominal current

η (%) vs. Pin (W)
SUMMARY & CONCLUSIONS
Summary & Conclusions

-A three-stage topology has been developed for LED-based street lighting applications

-Efficiency is high due to the optimization of each stage for just one task

-SiC technology allows us to develop a constant frequency application

-Third stages have been optimized taken into account the special features of the load (i.e., LEDs) without losing total dimming
THANKS!
ANY QUESTION?
Two-stage topology

Main features
- Low switching losses (BCM)
- No electrolytic capacitor
- Variable frequency
- Large output-voltage ripple

Main features
- Galvanic isolation
- Ripple cancelation
- Current regulation (dimming)
- N transformers (expensive)
Three-stage topology

Main features
- Low switching losses
- No electrolytic capacitor
- Variable frequency
- Large output-voltage ripple

Main features
- Galvanic isolation
- Ripple cancelation
- Variable frequency (typically)

Main features
- Current regulation (dimming)
- Reduces efficiency