LED Drivers in the Future – A Different Approach

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Content

- Motivation
- Capacitor-Free SIMO LED Driver
- Performance Evaluation
- Conclusion & Outlook

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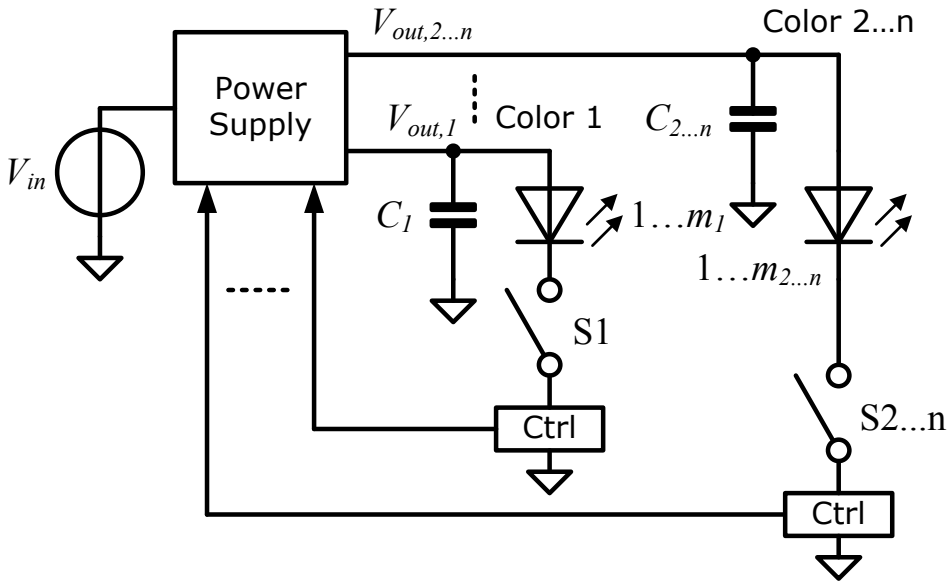
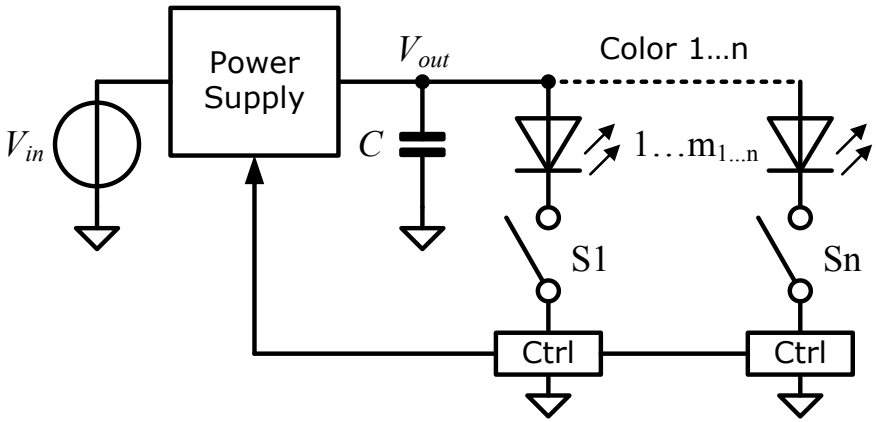
State-of-the-Art LED Drivers





- EU-law driven development of illumination
- LED lamps development still suffers
  - High-end products too expensive
  - Fixed color settings (e.g. warm / cold white)
- Arbitrary Single-Output / Multi-Output converters

Comparison: Single- vs. Multi-Output

	Single-Output	Multi-Output
# Power switches	2+n	1+2n
# External comp.	≥ 2	≥ 1+2n
# Inductors	1	1…n
Output voltage V_{out}	Set for biggest string	Individually controlled
Control losses	~ Very high	Low
Degree of freedom	Low	High
Application	Simple	Complex

n = # LED strings

n = 4 → RGBW

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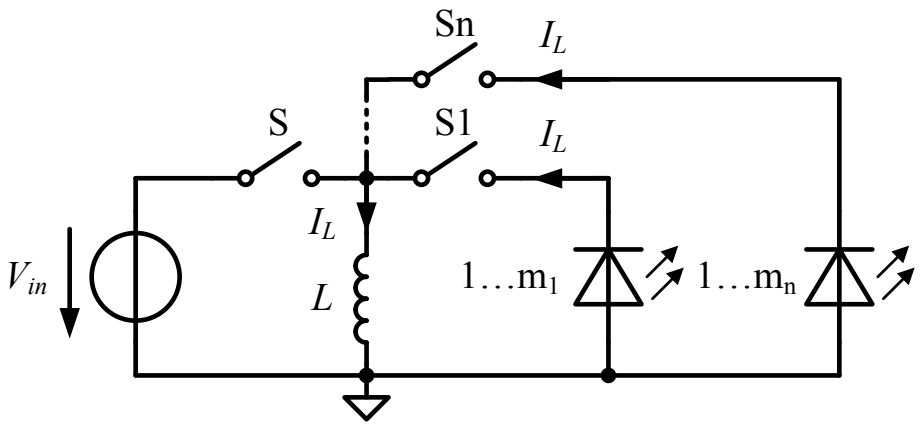
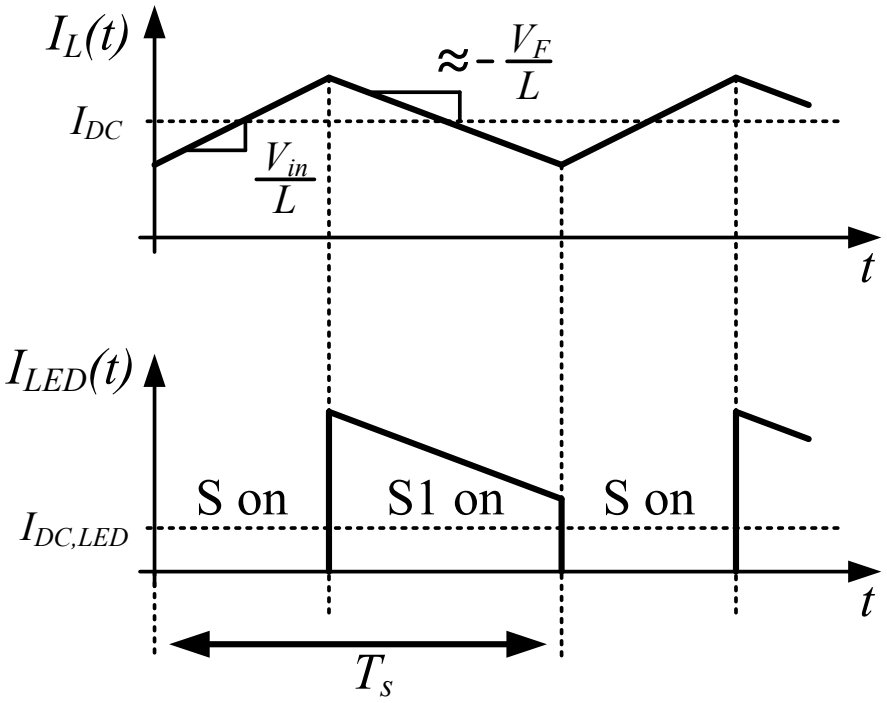
Capacitor-Free Single-Inductor Multiple-Output LED Driver



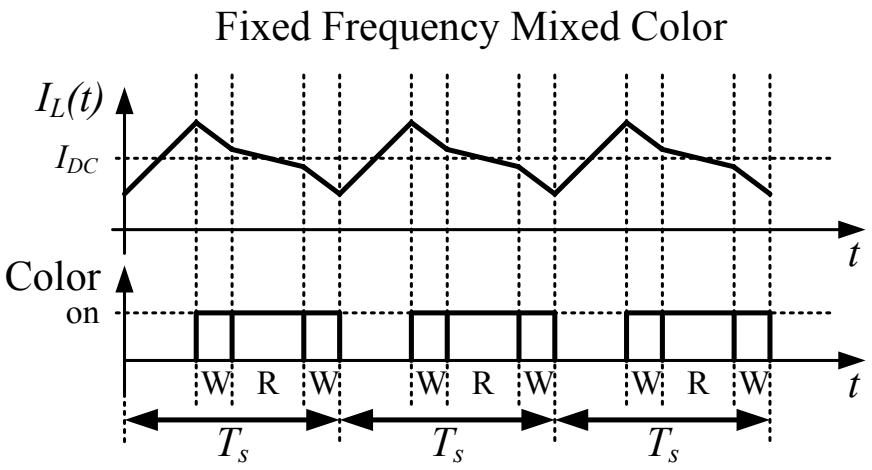


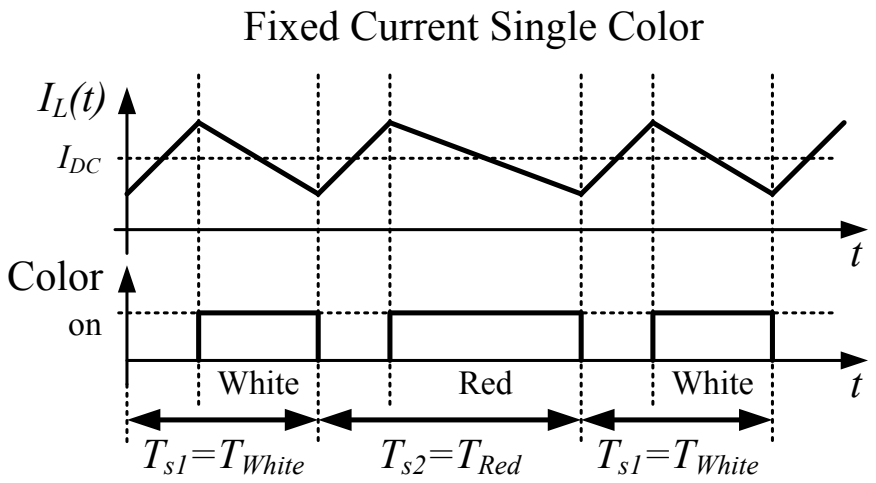
- Capacitor-free
  → Voltage across LEDs is set (diodes!!)
- One shared inductor as energy storage
- Multiple LED strings in parallel
  → Individual & variable # LEDs per string possible

Comparison: SIMO vs. Others

	SIMO	Best of: Single- & Multi-Output
# Power switches	1+n	2+n (Single)
# External comp.	1	≥ 2 (Single)
# Inductors	1	1 (Single)
Output voltage V_{out}	Automatic	Individually controlled (Multi)
Control losses	Low	Low (Multi)
Degree of freedom	High	High (Multi)
Application	Simple	Simple (Single)
Color control	Elaborate	Intuitive (Multi)

Color Control & Dimming





- One color per period + defined current in LED
- Hybrid AM/PWM dimming proposed
  - No filter capacitors → Current in inductor **will** flow
- Converter with ~ 1 MHz switching frequency
  - 1 MHz to 1 kHz → ~ 10 bit "PWM" resolution
  - Inductor current control → ~ 6 bit "AM" resolution

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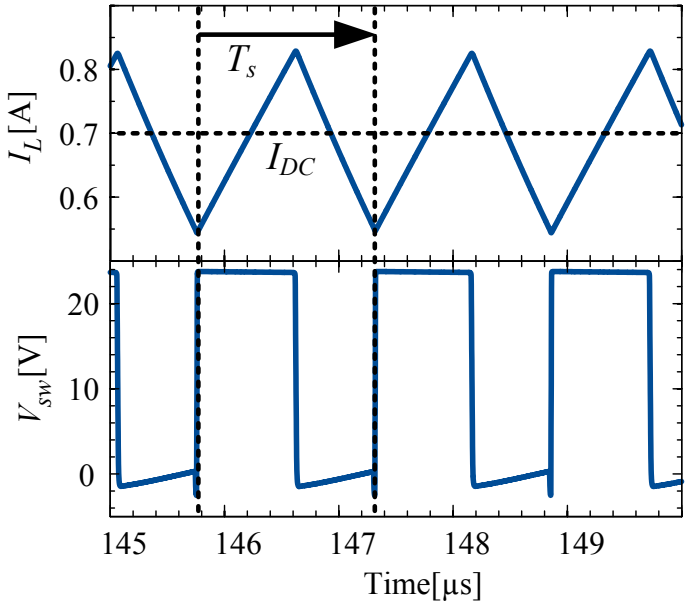
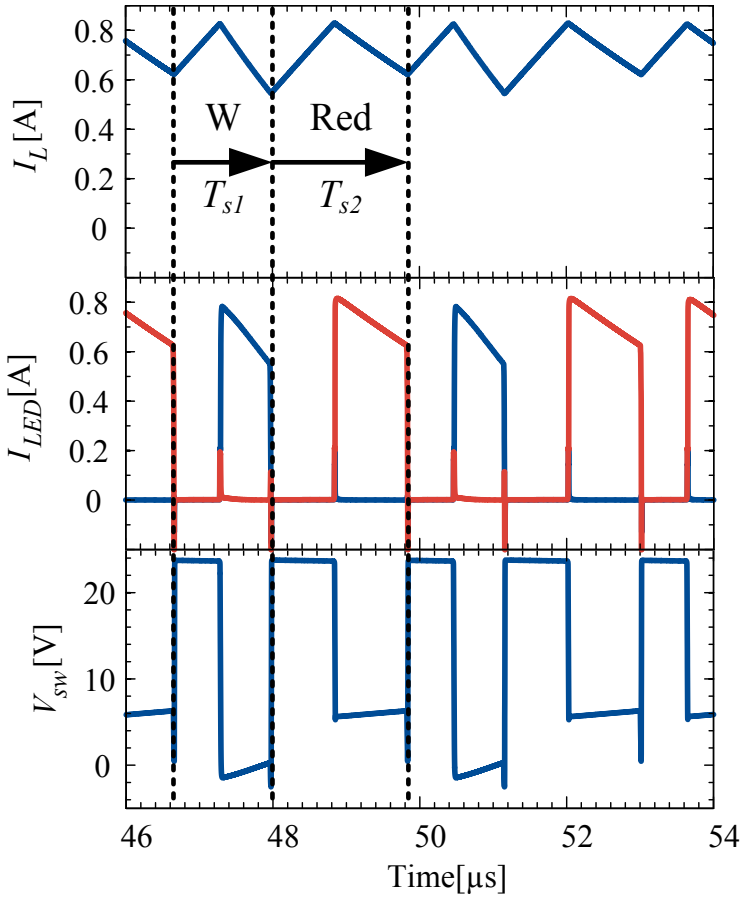
Continuous Conduction Mode

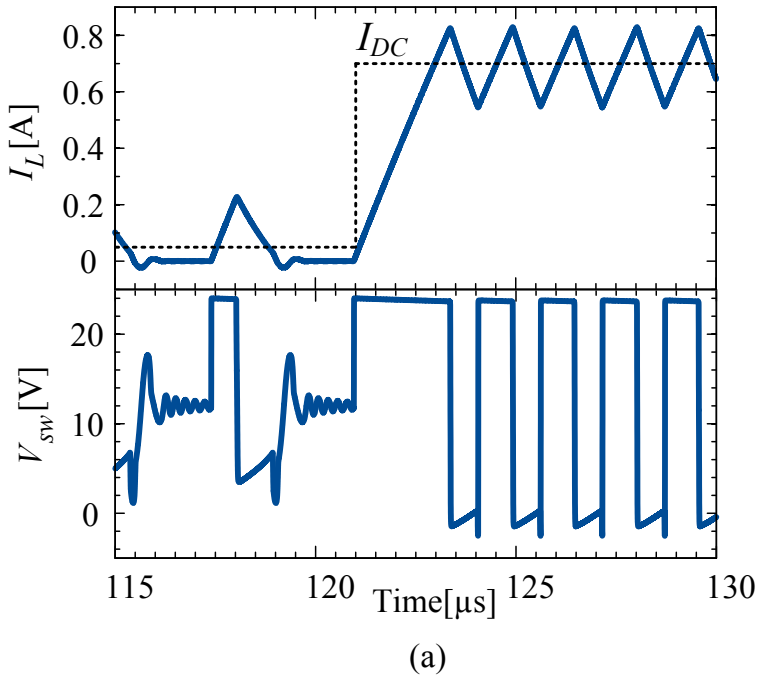


Parameter	Value
V_{in}	24 V
I_L	10 mA … 1 A
L	33 µH
f_s	≤ 1 MHz
η	Up to 90%

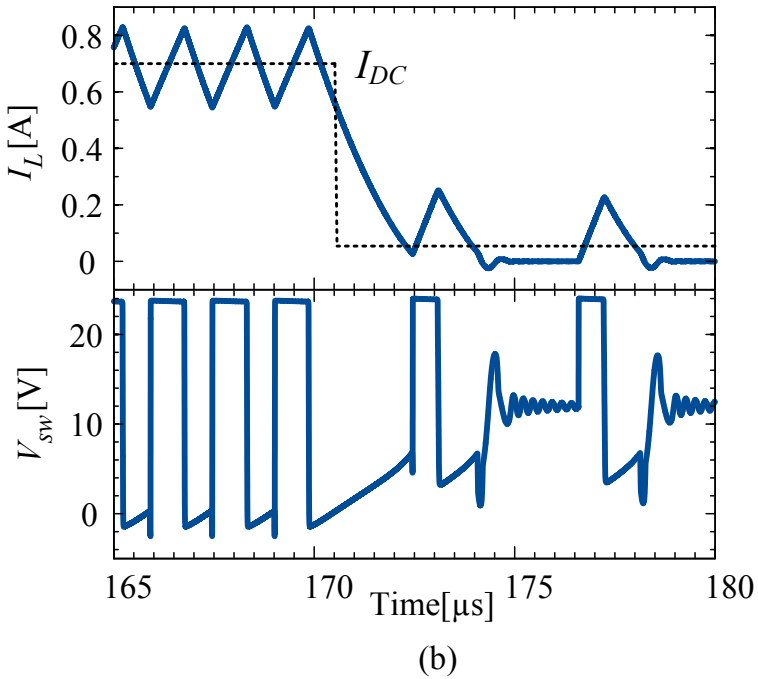


Waveforms for
Arbitrary White-Reddish Color

Load-Transient between Operation Modes



(a)



(b)

- I_L = 50 … 700 mA (a) , I_L = 700 … 50 mA (b)
- Transient settling = f (1/L)
- CCM f_s = 1 MHz @ 700 mA
- DCM f_s = 300 kHz @ 50 mA f_s = 3 kHz @ 1 mA

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Conclusion & Outlook

- Single-Inductor Multiple-Output (SIMO) LED Driver
- Capacitor-free
- Single current control to reduce complexity
- RGBW tunable white for general illumination
- Hybrid AM/PWM color mixing
- Automatic DCM/CCM mode operation
- Evaluation in a 0.18 µm technology

Acknowledgement

SPONSORED BY THE

Federal Ministry of Education and Research

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- **Energy efficient and intelligent lighting systems**
- ENIAC Joint Undertaking (ID: 270707-2)
- German Federal Ministry of Education & Research (FKZ: 16N11438, Subproject: Erforschung von Elektronikbausteinen für energieeffiziente, intelligente Beleuchtung)

Thank you

for your attention