Totem Pole PFC with GaN and SiC

Guido Schott, Ecomal Europe GmbH

Topics

- Basic PFC Topologies
  - Conventional Boost PFC
  - Bridgeless Boost PFC
  - Bridgeless Boost PFC with two DC/DC Circuits
  - Bridgeless Totem Pole PFC

- PFC Topologies Comparison

- Boost PFC Loss Calculation
- Totem Pole PFC Loss Calculation

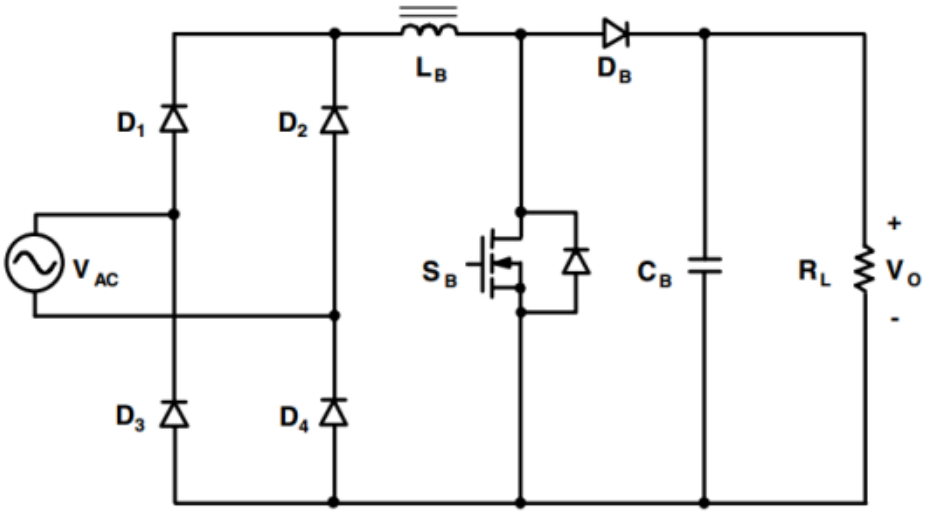
- Conclusion

Basic PFC Topologies

Conventional Boost PFC

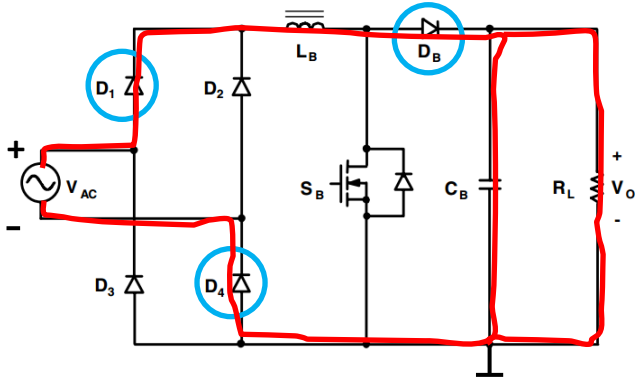
Conventional Boost PFC

PFC Inductor UF Boost Diode

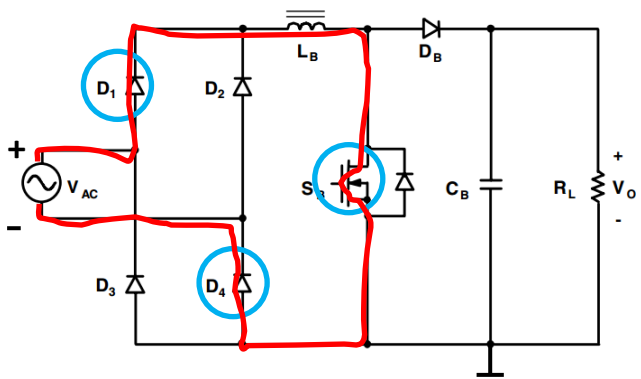


PFC Switch

Conventional Boost PFC



Switch open



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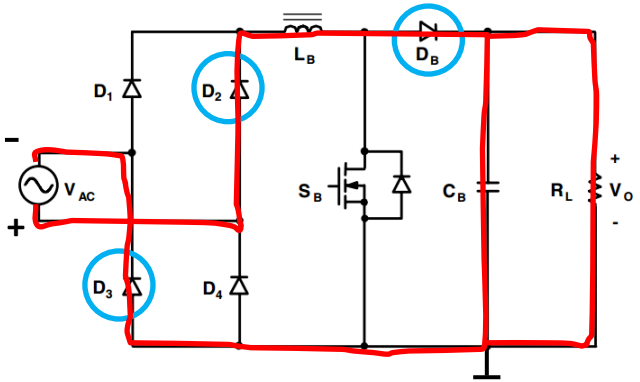
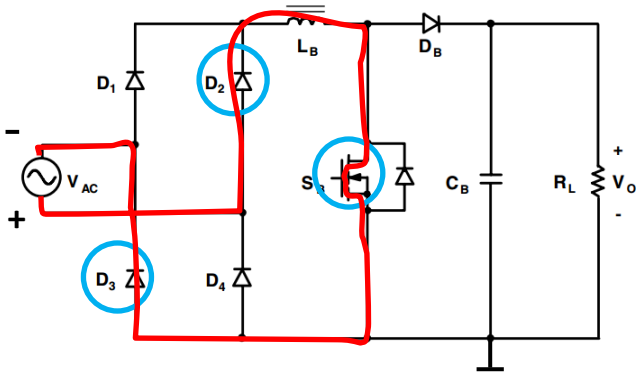
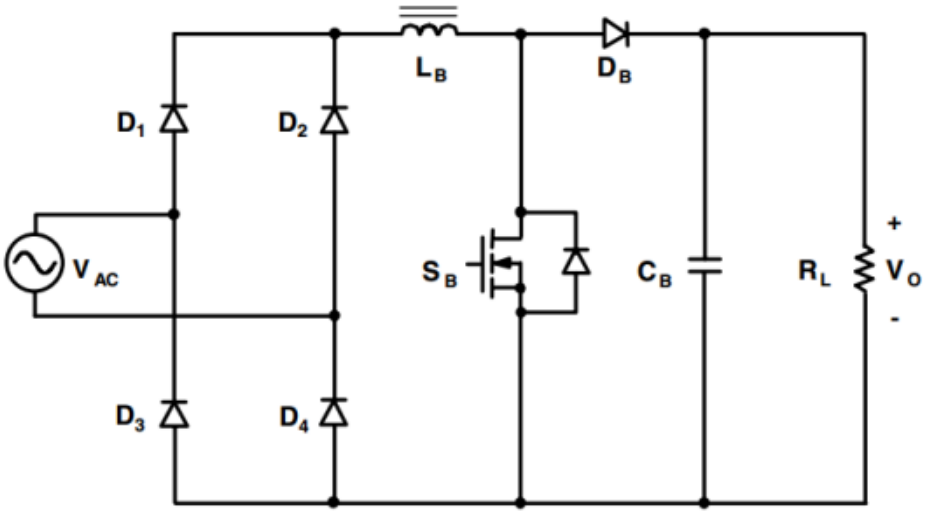




Conventional Boost PFC



\+ **Cheap**
low EMI

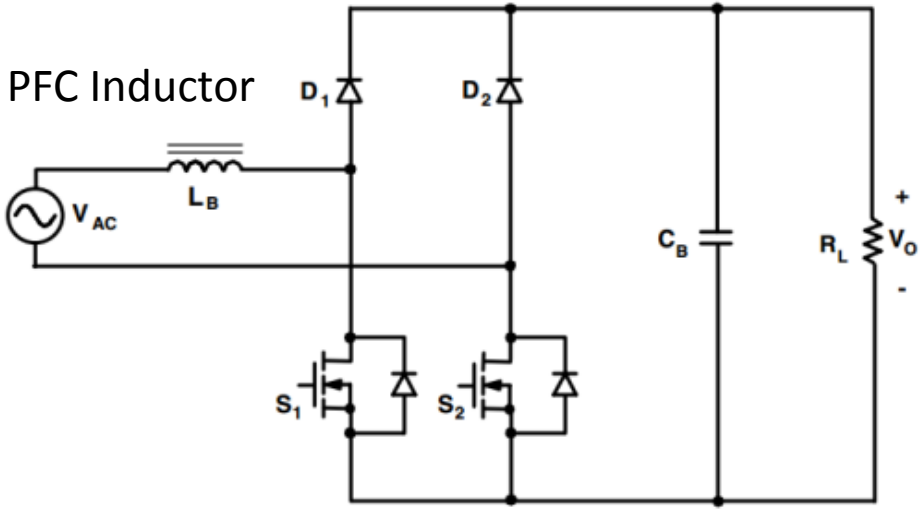
\- **High conduction losses due to 3 semiconductors**

Bridgeless Boost PFC

Bridgeless Boost PFC

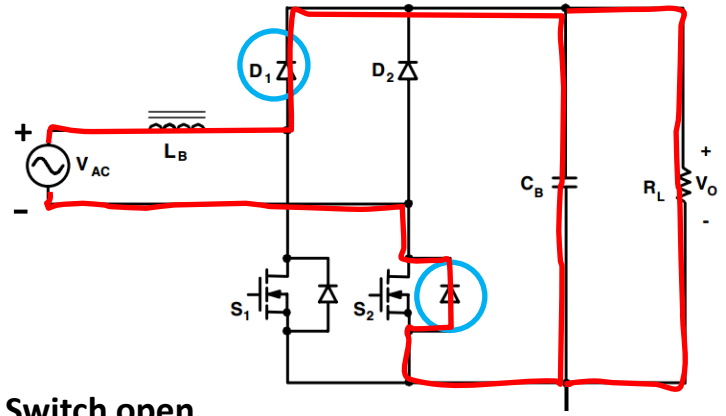
UF Diodes

PFC Inductor



PFC Switches

Bridgeless Boost PFC



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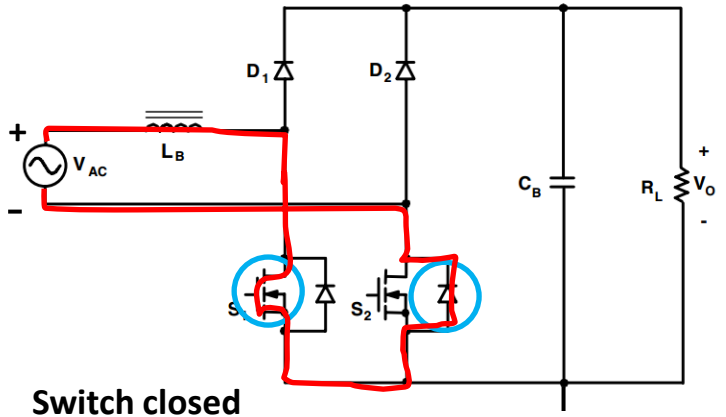

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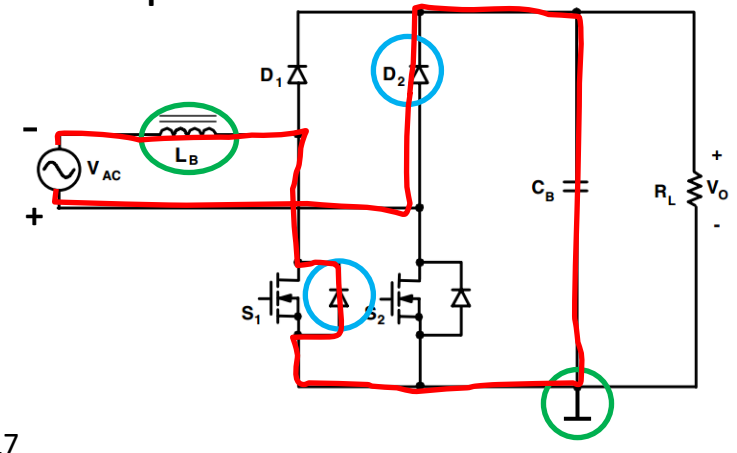
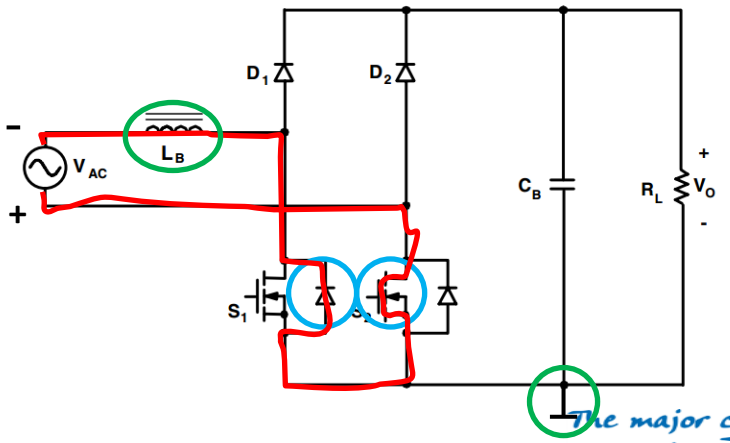
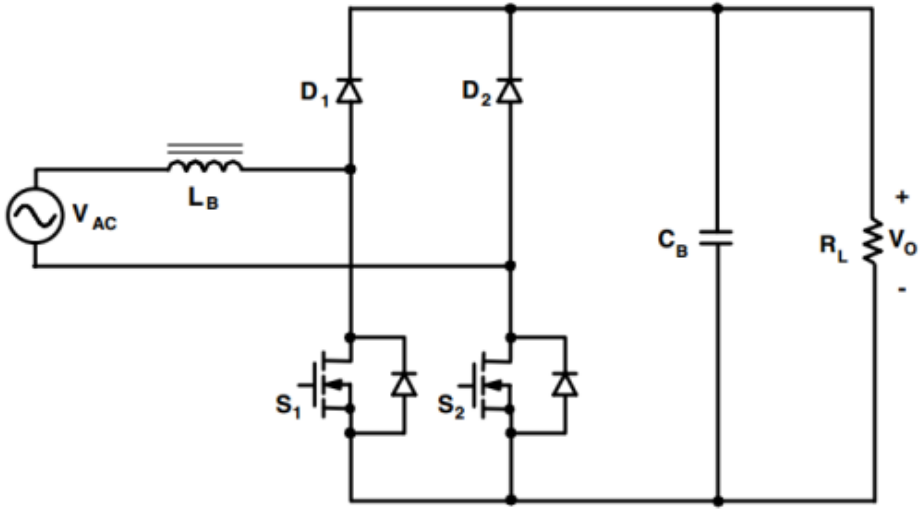




Bridgeless Boost PFC



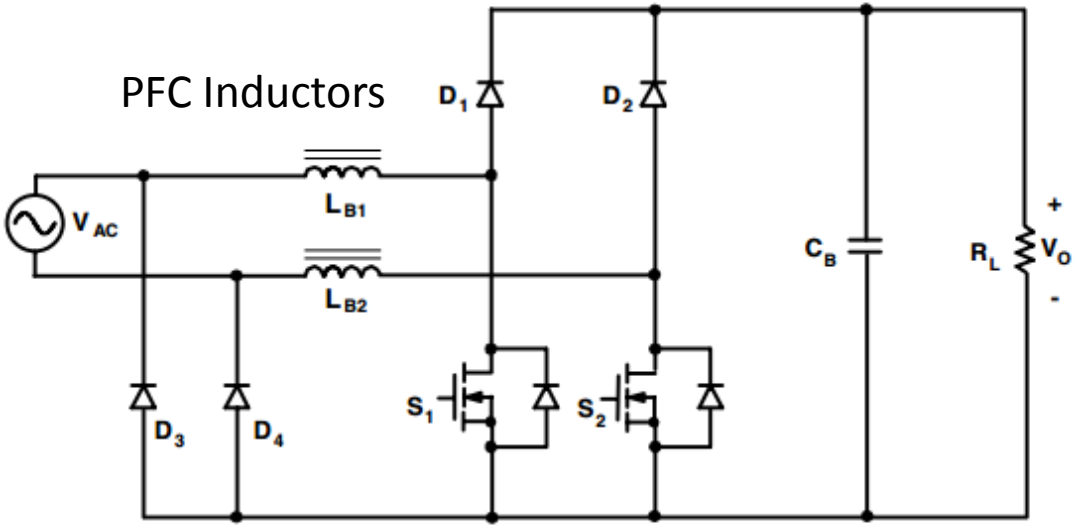
\+ **Reduced conduction losses**

\- **High EMI**
Decoupled GND between output ground and AC source
Needs UF diodes (ringing)

Bridgeless Boost PFC with two DC/DC circuits

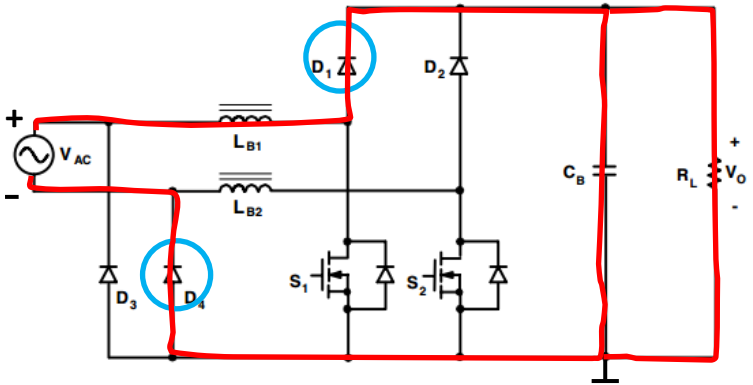
Bridgeless Boost PFC with two DC/DC circuits

UF Boost Diodes



PFC Switches

Bridgeless Boost PFC with two DC/DC circuits



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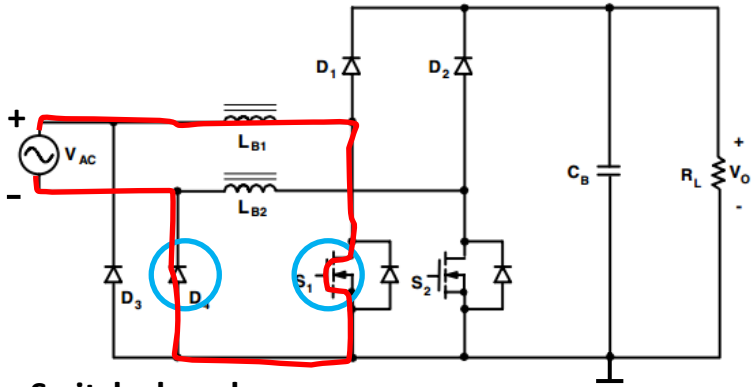

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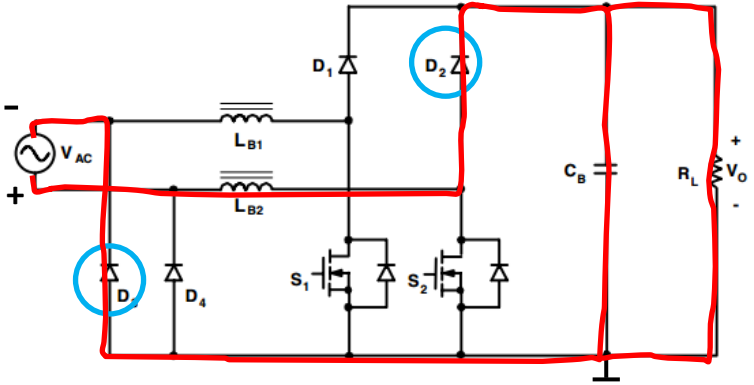
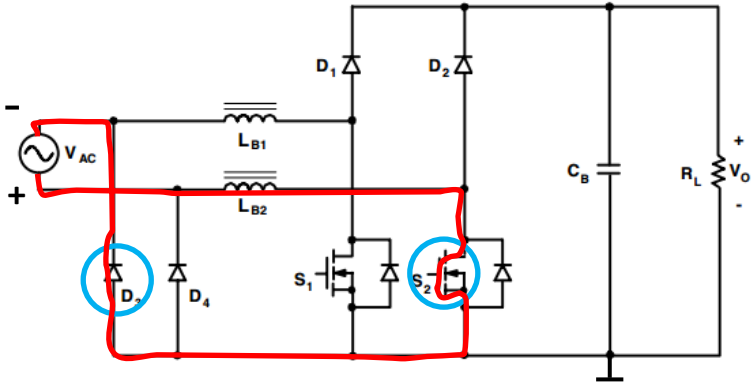
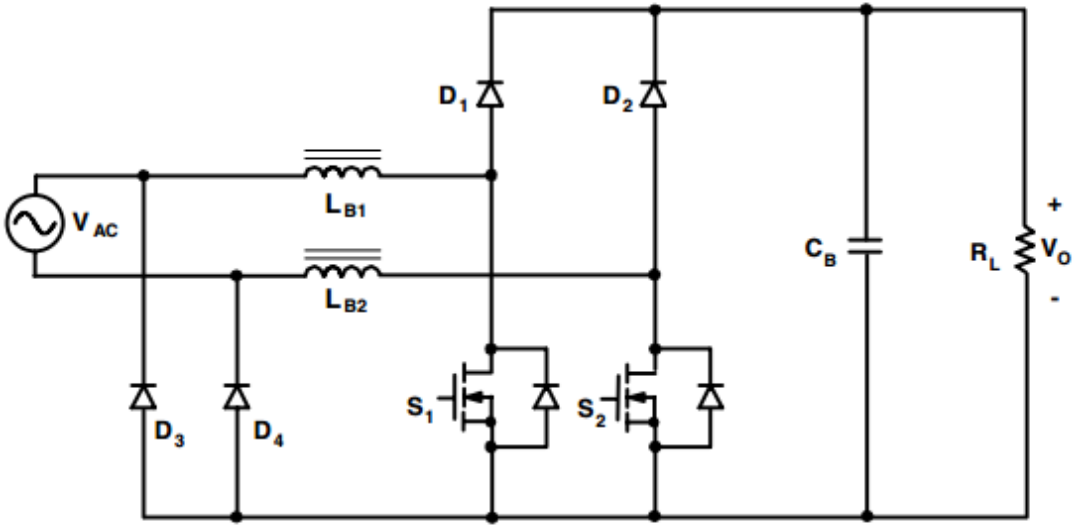




Bridgeless Boost PFC with two DC/DC circuits



\+ Low EMI

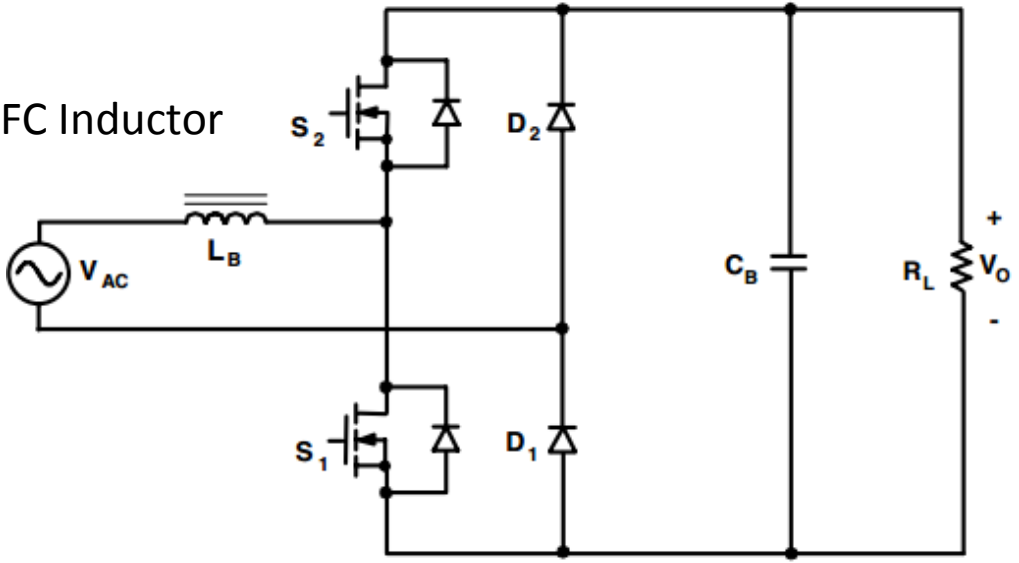
\- High component count
Expensive

Bridgeless Totem Pole PFC

Bridgeless Totem Pole PFC

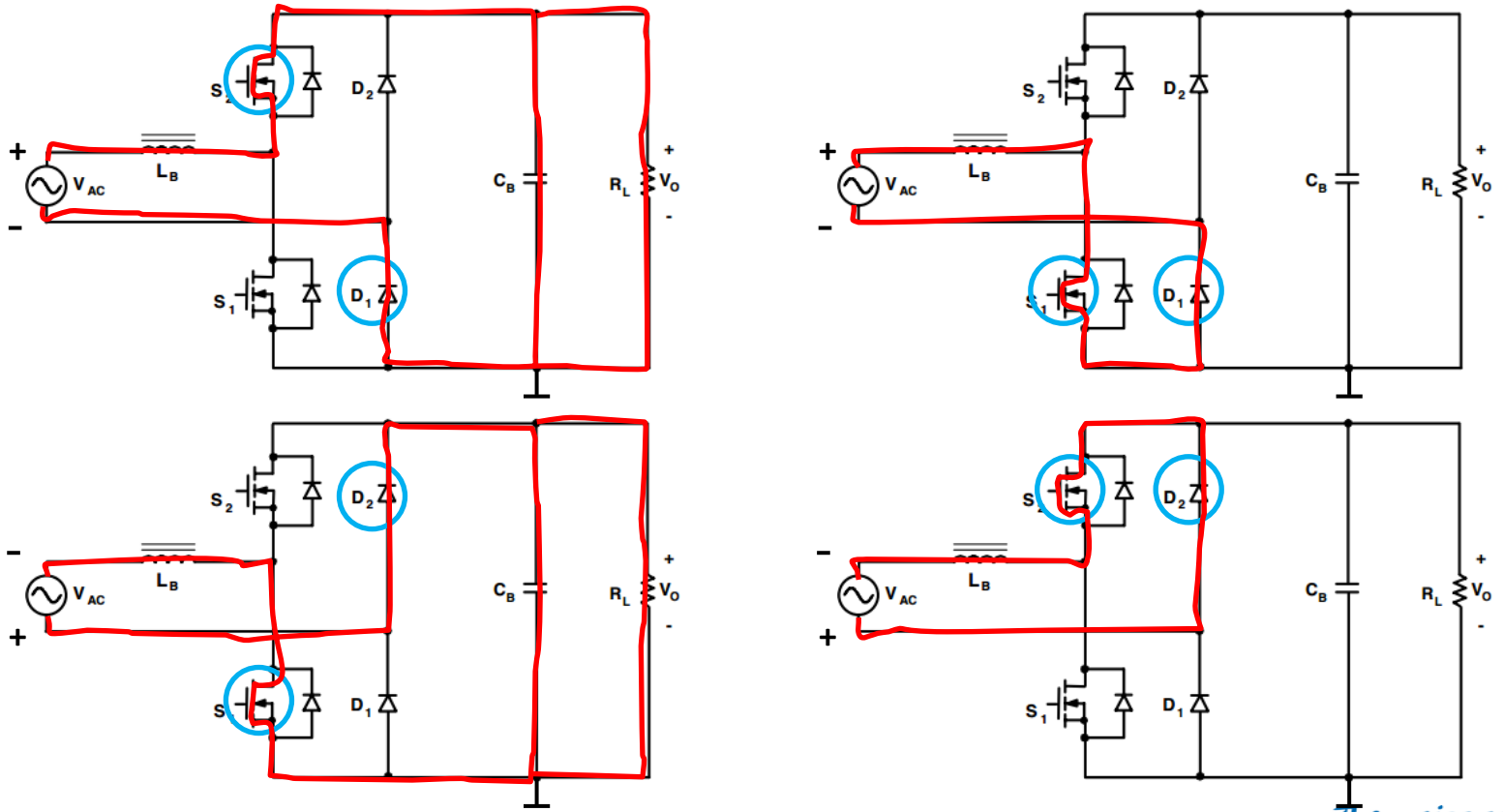
Diodes

PFC Inductor

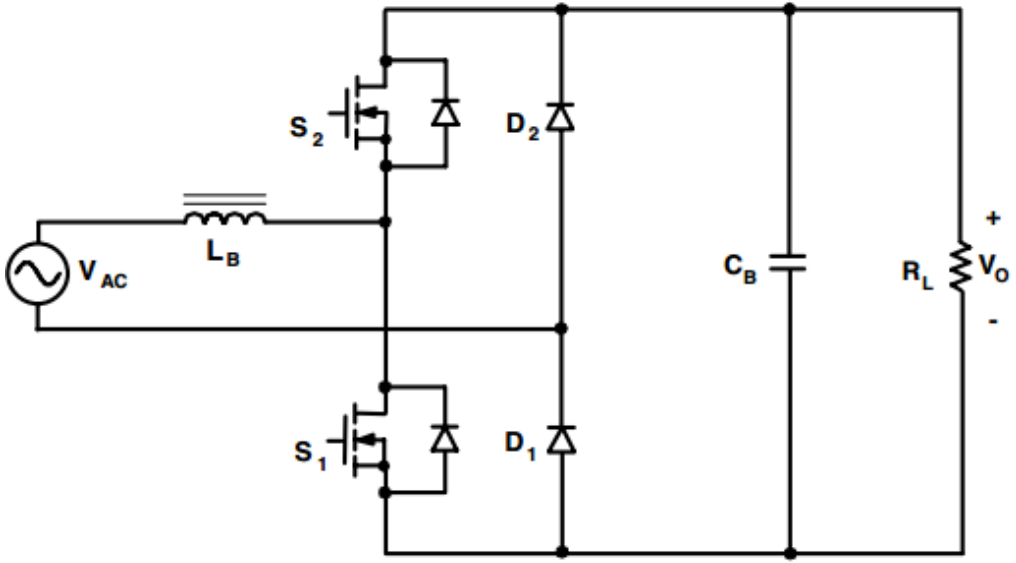


PFC Switches

Bridgeless Totem Pole PFC



Bridgeless Totem Pole PFC



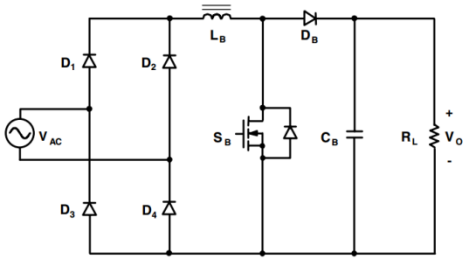
\+ Low component count
Low EMI
High efficiency

\- Only possible with GaN or SiC

PFC Topologies Comparison

PFC TOPOLOGIES COMPARISON

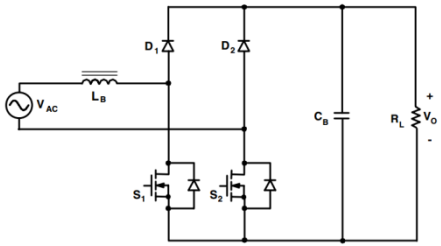
Conventional Boost PFC



+ Cheap
  Low EMI

- High conduction losses due to 3 semiconductors

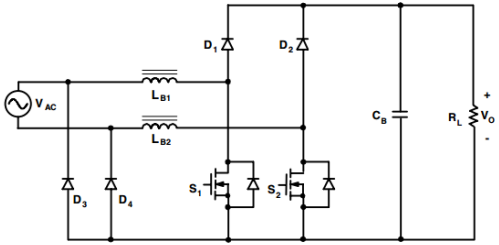
Bridgeless Boost PFC



+ Reduced conduction losses

- High EMI
  Decoupled GND between output ground and AC source
  Needs UF diodes (ringing)

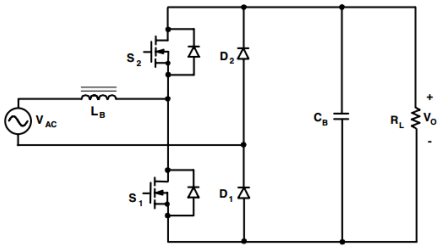
Bridgeless Boost PFC with two DC/DC circuits



+ Low EMI

- High component count
  Expensive

Bridgeless Totem Pole PFC



+ Low component count
  Low EMI
  High efficiency

- Only possible with GaN or SiC

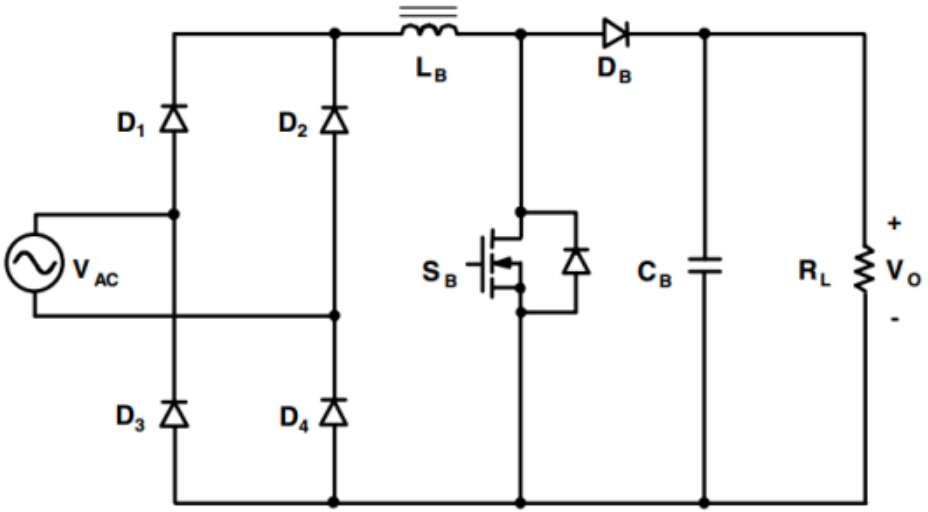
PFC-Topology	PFC Inductor	PFC Switch	Ultrafast Boost Diode
Conventional Boost PFC	1x	1x	1x
Bridgeless Boost PFC	1x	2x	2x
Bridgeless Boost PFC with two DC/DC circuits	2x	2x	2x
Bridgeless Totem Pole PFC	1x	2x	-

Boost PFC
Loss calculation

Switches used for Boost PFC loss calculation

	SI	SiC	GaN	Value
	Si Mos IPW65R045C7	Sic Cascode UJC06505K	Gan Transistor GS66508T	
	Switch 01	Switch 02	Switch 03	
$R_{DS\ On}$	0,045	0,045	0,0615	mOhm
C_{ISS}	4340	2107	260	pF
C_{rss}	75	5,7	2	pF
R_G	1,8	1,1	1,5	Ohm
V_g	12	12	6	V
V_{th}	3,5	5	1,3	V
V_{pl}	5,4	7	3	V
E_{oss}	11,7	7,5	7	µJ
Q_g	93	58	5,8	nC

Boost PFC loss calculation



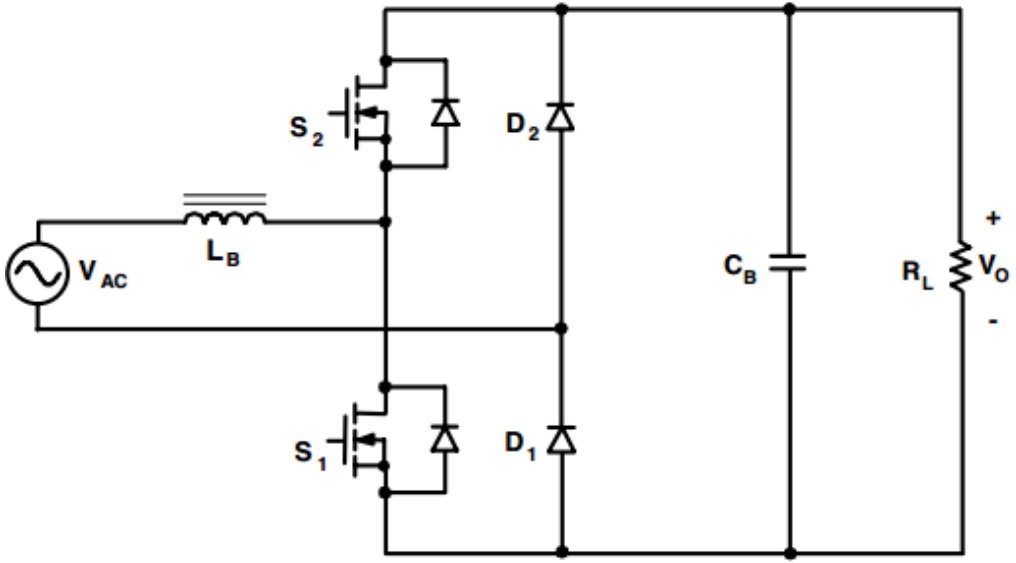
Start calculator

Totem Pole PFC Loss calculation

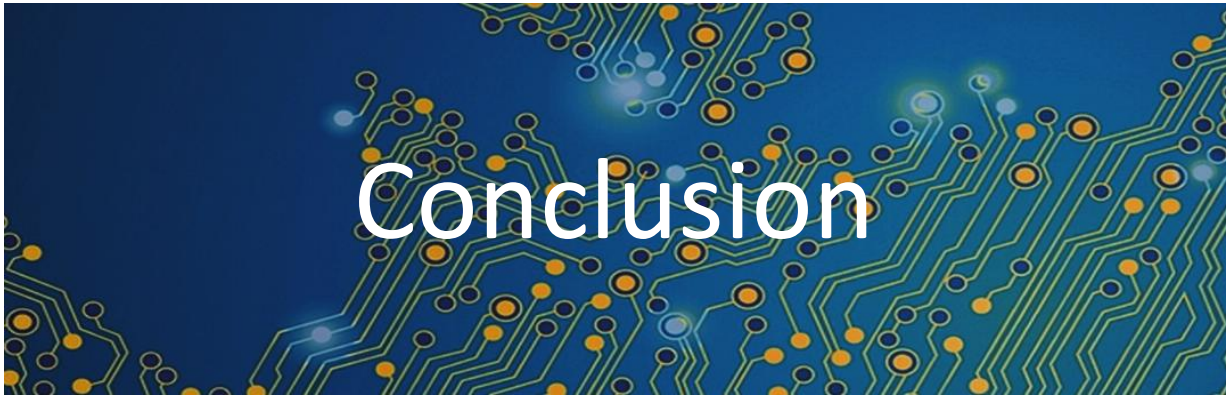
Switches used for Totem Pole PFC loss calculation

	SI	SiC	GaN	Value
	IPW65R110CFD	Sic Cascode UJC06505K	Gan Transistor GS66508T	
	Switch 01	Switch 02	Switch 03	
$R_{DS\ On}$	0,099	0,045	0,0615	mOhm
C_{ISS}	3240	2107	260	pF
C_{rss}	17	5,7	2	pF
R_G	1,3	1,1	1,5	Ohm
V_g	12	12	6	V
V_{th}	4	5	1,3	V
V_{pl}	6,4	7	3	V
E_{oss}	9	7,5	7	µJ
Q_g	118	58	5,8	nC
$Qrr_{\ Body\ diode}$	800	145	0	nC
$Vf_{\ Body\ Diode}$	0,9	1,7	0,5	V

Bridgeless Totem Pole PFC loss calculation



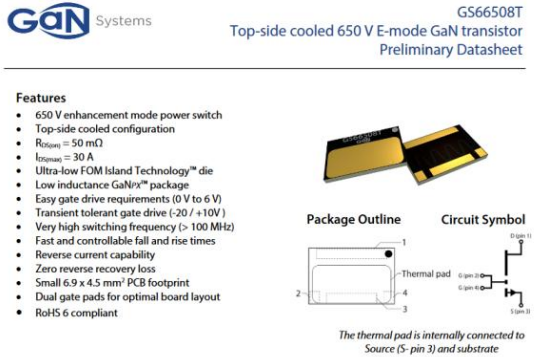
Start calculator


Conclusion

Conclusion: Totem Pole PFC with GaN and SiC

Latest generation Wide Band Gap (WBG) transistor technology make a truly bridgeless Power Factor Correction (PFC) topology a viable option.

Available WBG transistors (SiC and GaN) offer the needed low $R_{DS(ON)}$ and low charges.


GaN Systems

GS66508T
Top-side cooled 650 V E-mode GaN transistor
Preliminary Datasheet

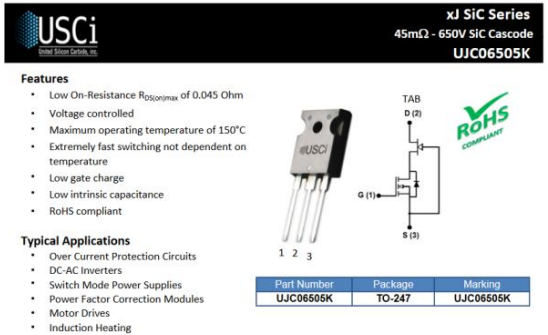
Features

- 650 V enhancement mode power switch
- Top-side cooled configuration
- $R_{DS(on)}$ = 50 mΩ
- $I_{DS(max)}$ = 30 A
- Ultra-low FOM Island Technology™ die
- Low inductance GaNpx™ package
- Easy gate drive requirements (0 V to 6 V)
- Transient tolerant gate drive (-20 / +10V)
- Very high switching frequency (> 100 MHz)
- Fast and controllable fall and rise times
- Reverse current capability
- Zero reverse recovery loss
- Small 6.9 x 4.5 mm² PCB footprint
- Dual gate pads for optimal board layout
- RoHS 6 compliant

Package Outline **Circuit Symbol**

Thermal pad

The thermal pad is internally connected to Source (5- pin 3) and substrate


USCi

xJ SiC Series
45mΩ - 650V SiC Cascode
UJC06505K

Features

- Low On-Resistance $R_{DS(on)max}$ of 0.045 Ohm
- Voltage controlled
- Maximum operating temperature of 150°C
- Extremely fast switching not dependent on temperature
- Low gate charge
- Low intrinsic capacitance
- RoHS compliant

TAB
D (2)
G (1)
S (3)
1 2 3

RoHS COMPLIANT

Typical Applications

- Over Current Protection Circuits
- DC-AC Inverters
- Switch Mode Power Supplies
- Power Factor Correction Modules
- Motor Drives
- Induction Heating

Part Number	Package	Marking
UJC06505K	TO-247	UJC06505K

Thank you for your attention!

CONTACT

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