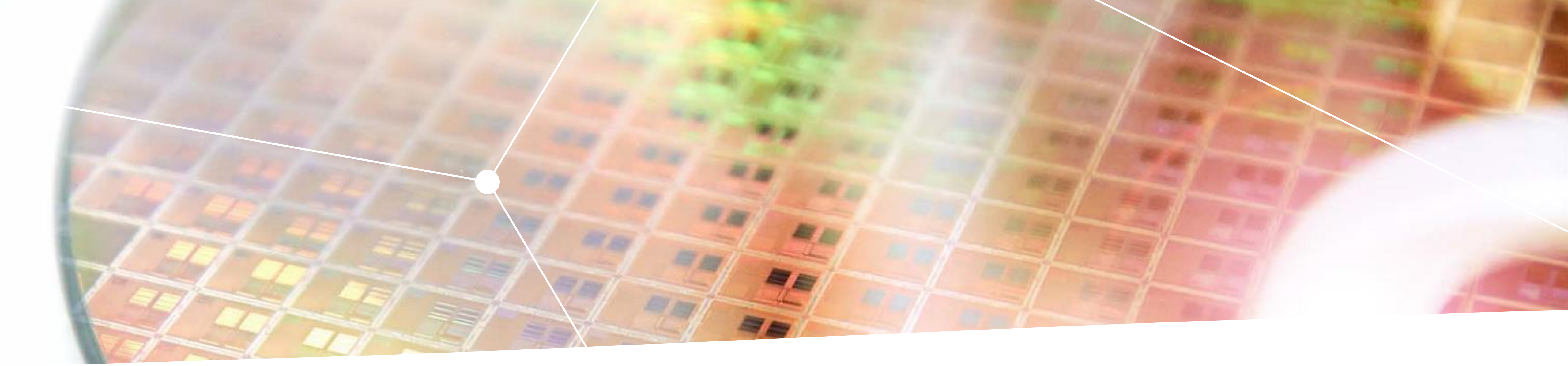


# Infineons CoolMOS S7 – MOSFETs for static switching

Power and Sensor Systems
September 23, 2021

- restricted -

# Agenda

# Agenda

# The Idea behind the S7 CoolMOS - Static switching applications!

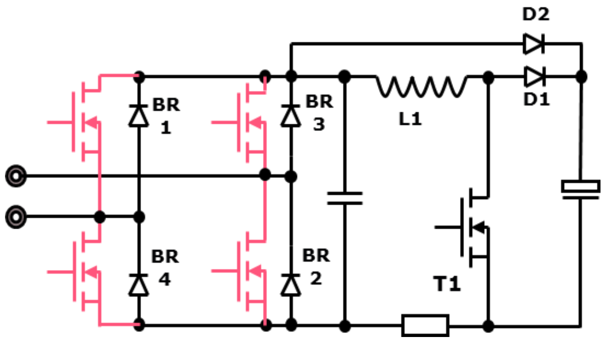
## What is a “static switching” application ?

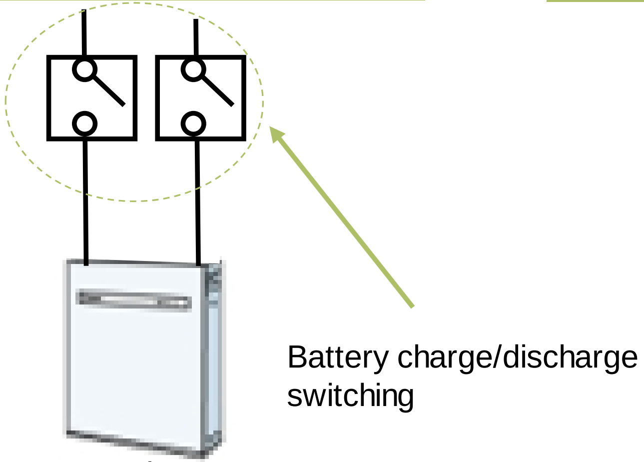
A system or part of it where power MOSFETs are switching at low frequency, from few time per minute to some KHz and where, consequently, the switching power losses of the MOSFET are not relevant

**Example 1**
Active rectification bridge

**Example 2**
Systems embedding circuit breaking or switching

**Example 3**
Solid state circuit breakers and relays




# CoolMOS™ S7 technology for static switching
# Cost optimized for best in class Rdson in the smallest packages

**Engineering a technology to best fit static switching applications**

**Solution**

- Based CoolMOS™ 7 platform
- Technology optimization towards conduction performance allowed to focus on:
  - Best in class $R_{DS(on)}$
  - Lowest footprint
  - Cost optimization, leading to best price performance

# Agenda

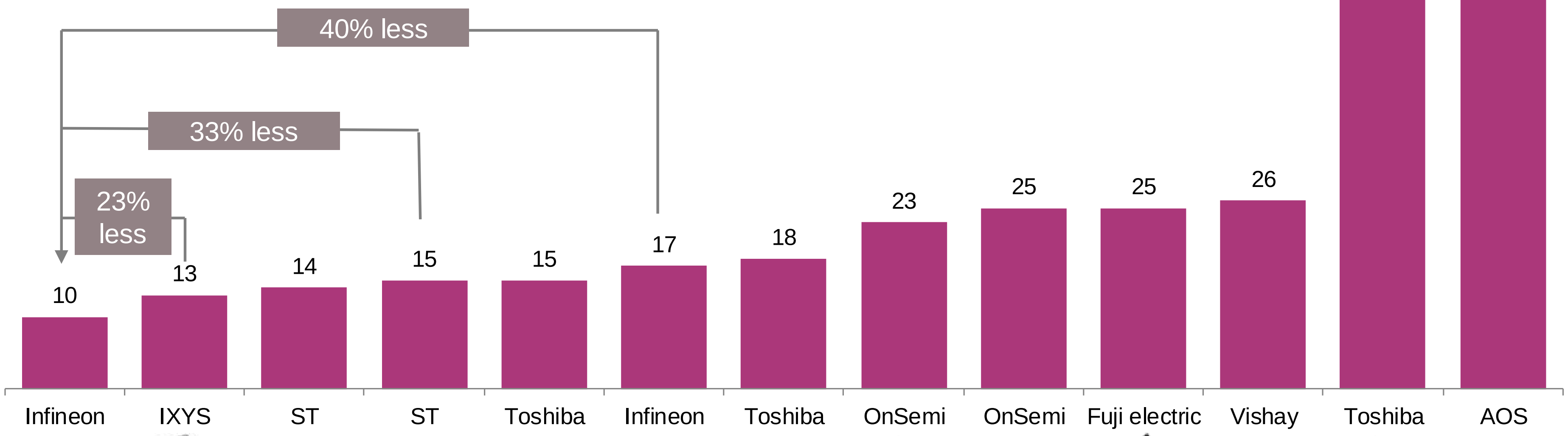
1. The Idea behind the CoolMOS S7 Products
2. Positioning and current portfolio of CoolMOS S7 products
3. Solid State Relais vs. Electro Mechanical Relais
4. CoolMOS S7 as next-generation technology for miniature solid-state relays 250 VAC
5. CoolMOS S7 in active rectification
6. Summery

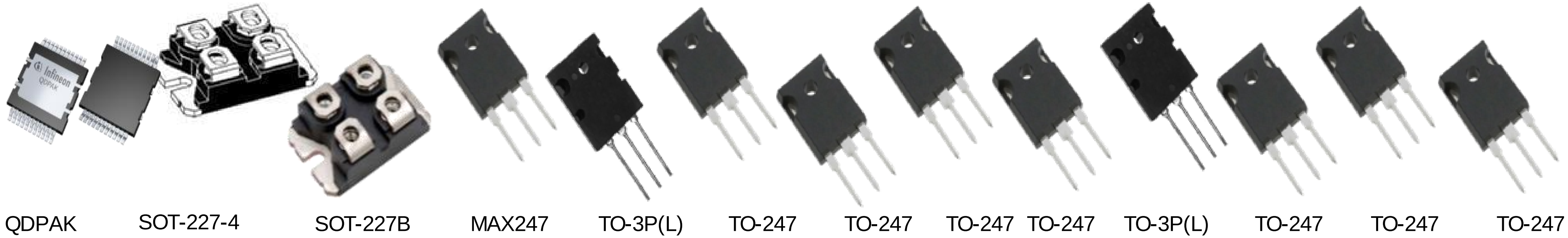
# Lowest RDSON high voltage SJ MOSFET in the World

## $R_{DSON,MAX}$ best in class MOSFETS 600V – 650V*

Lower = better

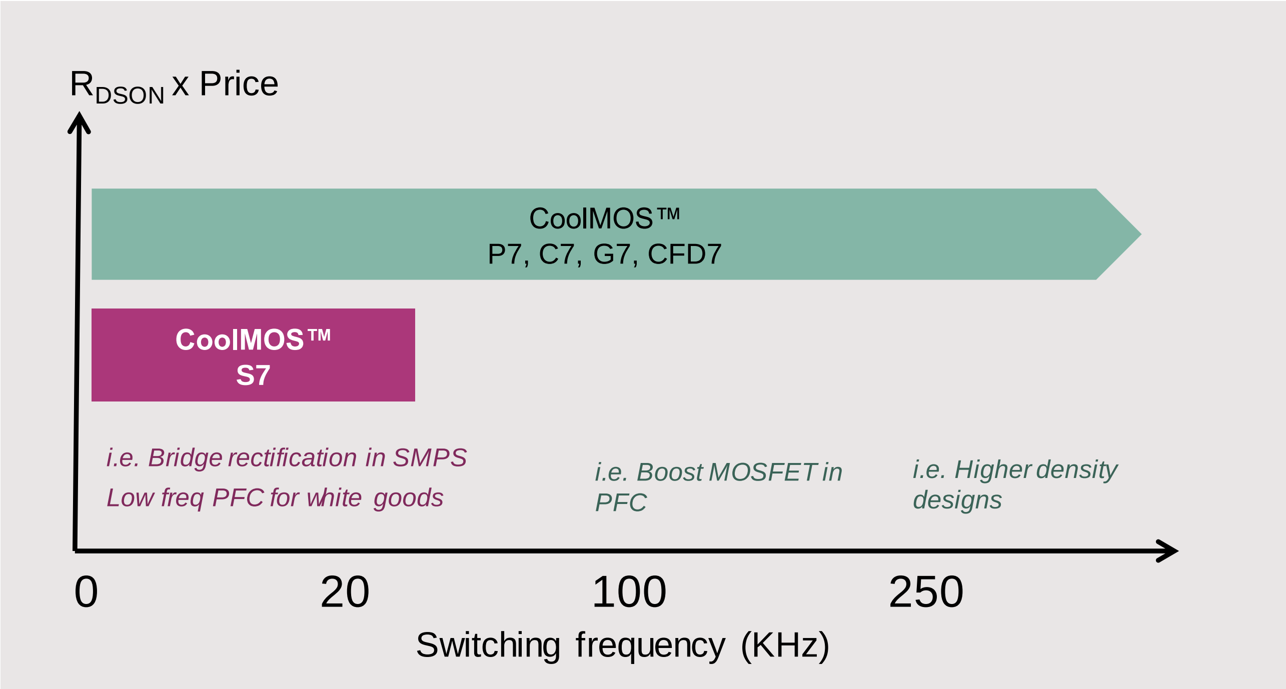
- **40% less** than BiC CooMOS C7
- **33% less** than BiC of a comparable size package
- **The only** ultra low ohmic **in SMD top side cooled**




** As per February 2020*

# CoolMOS™ S7/ S7A positioning
# Best RDSON x Price for low frequency applications

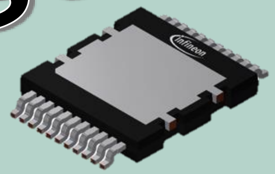
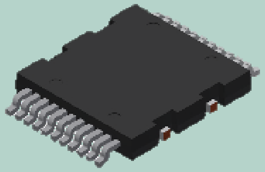



- S7 stands out for price performance
- No quality and reliability is neglected
- Cost optimization comes from tailoring the technology to the application

- Price performance is maximized in low frequency switching applications
- CoolMOS™ S7 is not recommended for boost PFC or LLC stages in SMPS

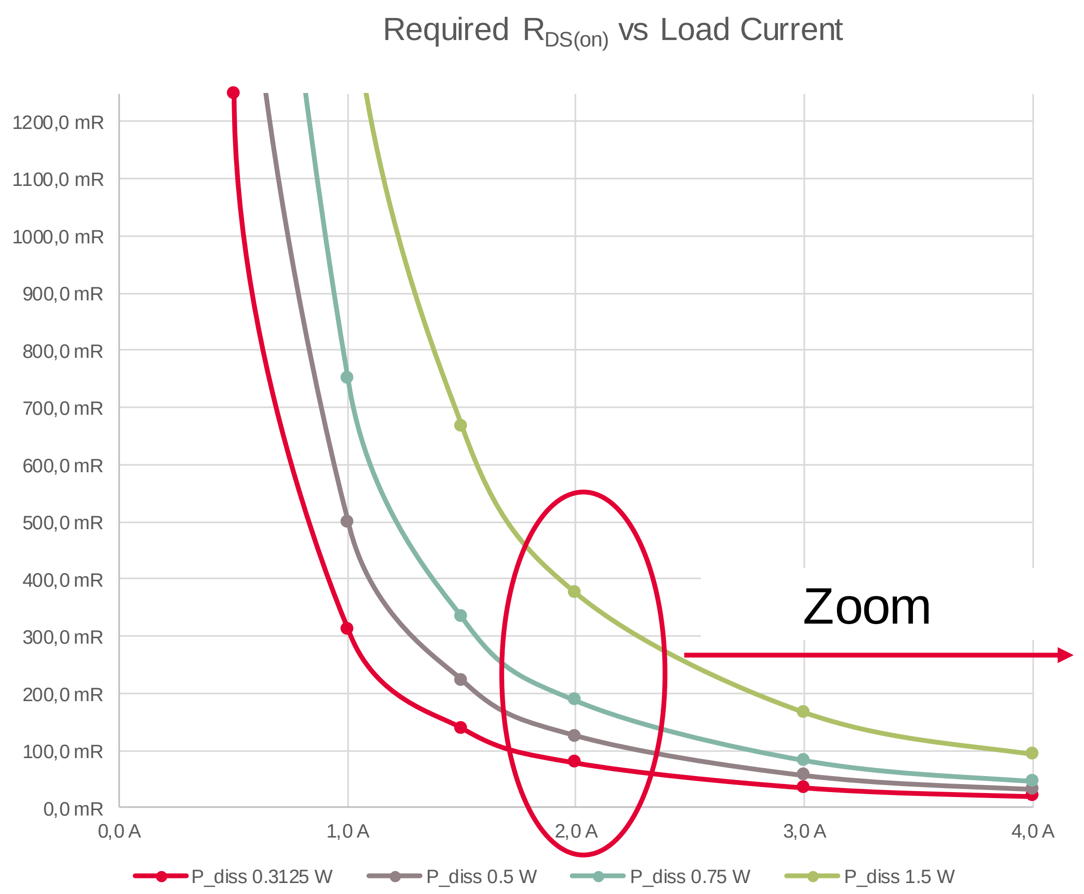
# 600 V CoolMOS™ S7 portfolio roll-out

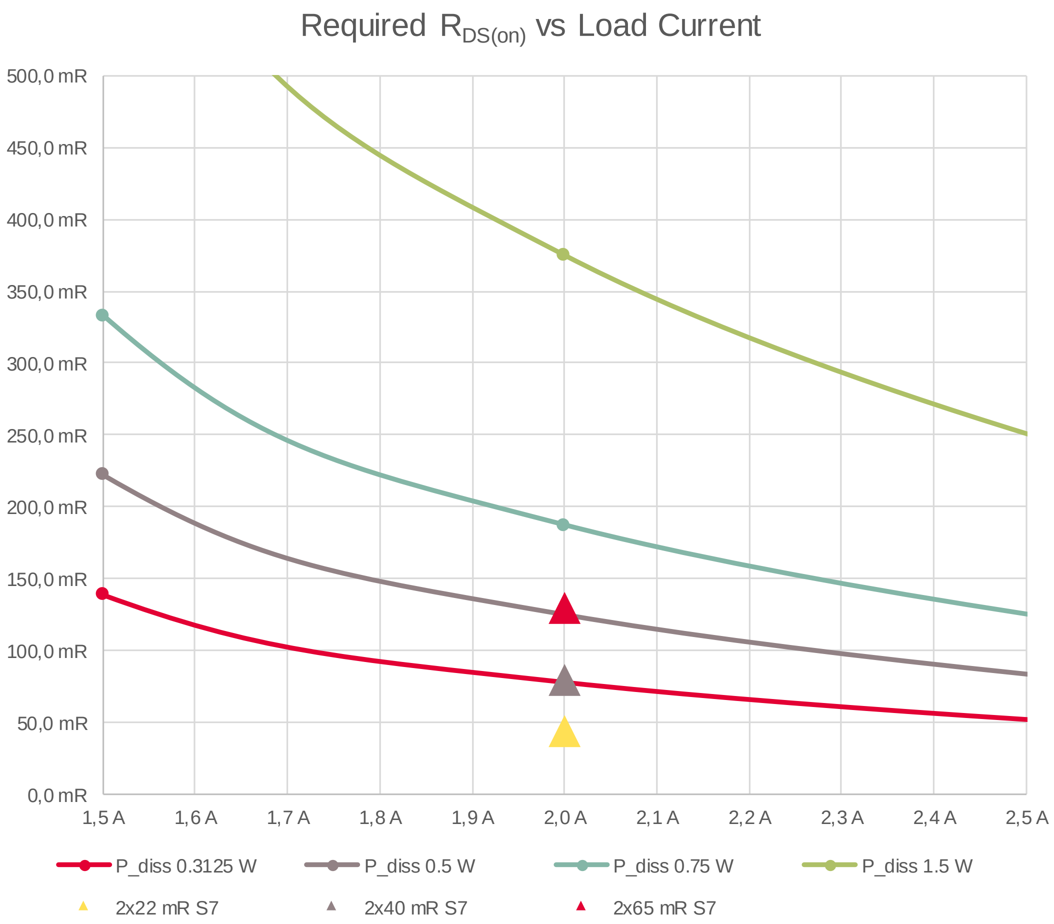
More variants coming soon!

| $R_{DS(on,max)}$ [mΩ] |  PG-TO220-3 |  PG-TO247-3 |  TOLL PG-HSOF-8 |  QDPAK TSC PG-HDSOP-22-1 |  QDPAK BSC PG-HDSOP-22-101 |
|---|---|---|---|---|---|
| 65 | IPP60R065S7** | IPW60R065S7** | IPT60R065S7* | IPDQ60R065S7** | |
| 40 | IPP60R040S7** | IPW60R040S7** | IPT60R040S7* | IPDQ60R040S7** | IPQC60R040S7** |
| 22 | IPP60R022S7* | IPW60R022S7** | IPT60R022S7* | IPDQ60R022S7** | IPQC60R022S7** |
| 17 | | IPW60R017S7** | | IPDQ60R017S7** | IPQC60R017S7** |
| 10 | | IPW60R010S7** | | IPDQ60R010S7* | IPQC60R010S7** |

**Released*
***Coming soon*

# $R_{DS(on)}$ requirements based on power dissipation budget




- Depending on the maximum allowed power dissipation, the total $R_{DS(on)}$ of the SSR can be selected

# Agenda

# Solid state versus electromechanical

| | EM RELAY / CB | SOLID STATE RELAYS and CIRCUIT BREAKERS | |
|---|---|---|---|
| X | Arching deteriorates contacts and cause safety concerns | No arching, stable contact resistance over time | ✓ |
| X | Slow | Faster response time | ✓ |
| X | Aging, deterioration, arching shorten lifetime | Longer lasting and less subject to deterioration | ✓ |
| X | Usually heavy and bulky, noisy | Light, compact, silent | ✓ |
| X | Vibration, orientation sensitive | Vibration, orientation insensitive | ✓ |
| ✓ | Inexpensive but difficult to design-in | More expensive | X |
| ✓ | Low conduction losses | Higher conduction losses | X |
| ✓ | Galvanic insulation and physical contact gap | NO physical contacts gap | X |

# Solid state versus electromehanical


| | EM RELAY / CB | SOLID STATE RELAYS and CIRCUIT BREAKERS | |
|---|---|---|---|
| X | Arching deteriorates contacts and cause safety concerns | No arching, stable contact resistance over time | ✓ |
| X | Usually heavy and bulky, noisy | Light, compact, silent | ✓ |
| X | Vibration, orientation sensitive, not “trustable” with aging | Vibration, orie… …ing insensitive | ✓ |
| X | Slow → safety concerns | Fas… …me | ✓ |
| X | Aging, deterioration, arching shorten lifetime | Less subject to … …nd deterioration | ✓ |
| ✓ | Inexpensive but difficult to design-in | More expensive | X |
| ✓ | Low conduction losses | Higher conduction losses | X |
| ✓ | Galvanic insulation and physical contact gap | Galvanic insulation but NO physical contact gap | X |

SSR limits

# Value of CoolMOS S7 versus the the solid state limits

SSR limits

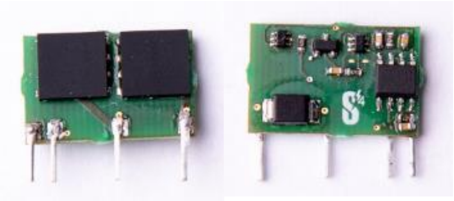
| Additonal cost | Galvanic insulation | Additional power losses |
|---|---|---|
| › But...BETTER TCO<br>› The overall infrastructure cost can be lower<br>› The overall maintenance cost is lower<br>› Not all EM devices are cheap | › But...THERE IS A SOLUTION<br>› Galvanic insulation is not always required<br>› The insulation can be ensured with hybrid solutions (mixed solid and EM) | › But...COOLMOS S7 IS BETTER<br>› This is true for solid state solutions based on TRIACs, IGBTs and planar MOSFETs |

S7 value

| | | |
|---|---|---|
| Losses reduction, constant in time -> OPEX reduction | Make the hybrid solution faster | Can reduce the losses to the EM level |

# Agenda

# SJ-FET as next-generation technology for miniature solid-state relays 250 $V_{AC}$



5A SSR in
28 x 15 x 5 $mm^3$

## EMR

**Legacy solution**

- Proven in use
- Known reliability issues
- Clicking noise
- Sensitive to vibration

## Triac-SSR

**Today's PCB SSRs**

Available technology

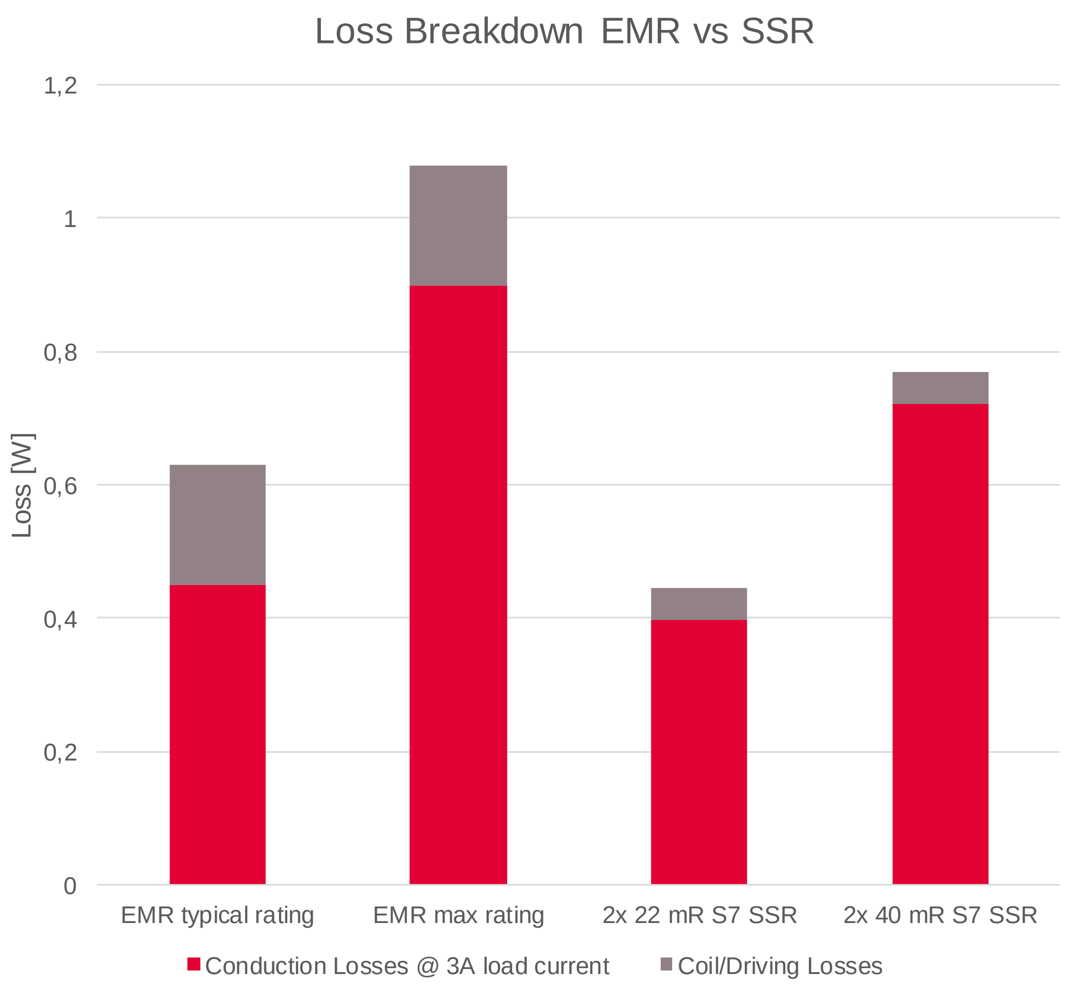
- Lower current rating than EMR
- Higher power dissipation than EMR
- Limited controllability (AC only)
- Larger size than EMR

## SJ-FET-SSR

**New SJ-FET SSRs**

- Optimized superjunction technology w/ BiC $R_{on}$*A
- Advanced control & featureset
- Low power dissipation
- Scalability to user needs
- AC and DC switching
- Same size and packaging density as EMR

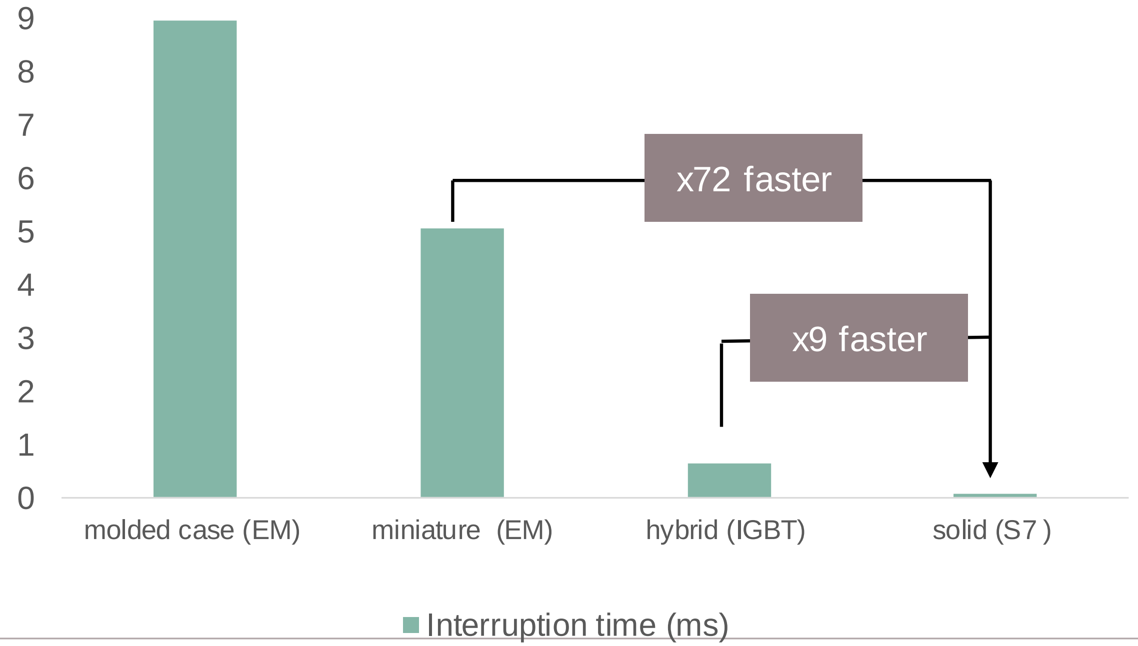
# Losses in EMRs and SSRs
## EMRs exhibit a strong degradation over lifetime



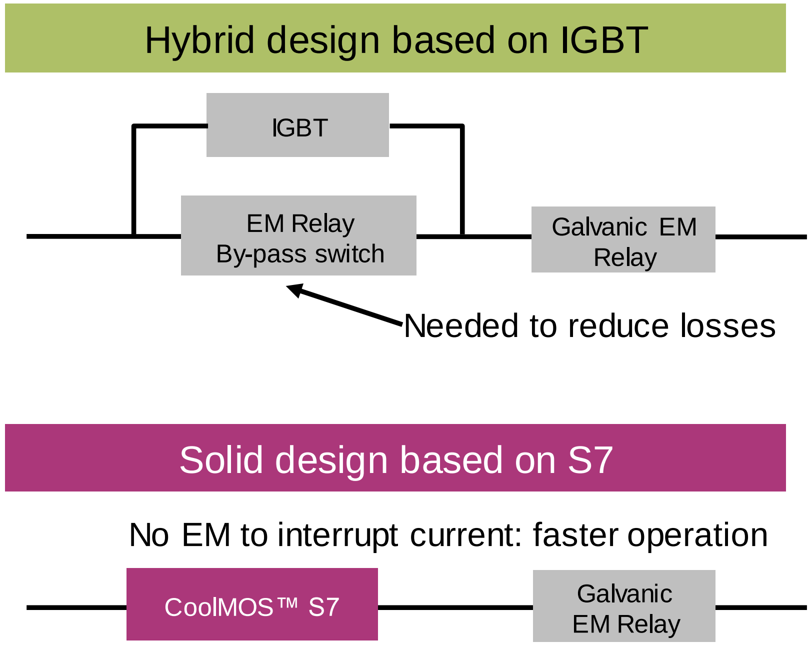

- EMRs typically show large variation in contact resistance over lifetime, due to ageing effects of the contacts
- Excitation power of the coil are typically in the hundreds of milliwatts range, adding to power dissipation
- SSR On-Resistance do not change over lifetime, and can be selected based on the FETs used for implementation
- Excitation power is minimal and independent of power class

# Solid state galvanic insulation
# Create the contact gap with a EM relay

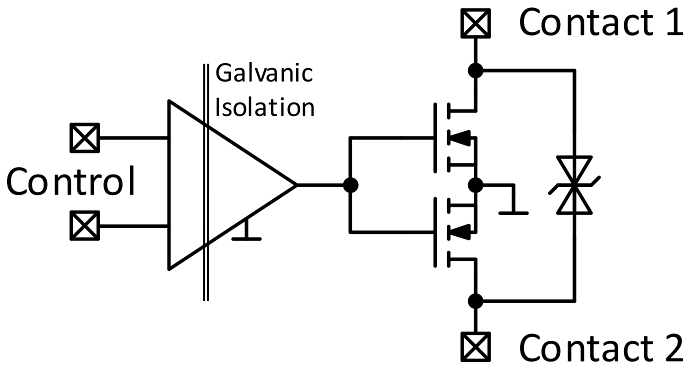
- Contact gap → semiconductor in series with a **<u>cheap</u>** mechanical relay
- **The galvanic relays opens at zero current** so the solution keeps all of the advantages compared to EM:
  - No arching
  - More reliability /less maintenance
  - More duration
  - Faster switching / more current limiting
  - Predictable behavior of resistance
- The galvanic relay adds **very little cost** to the solution

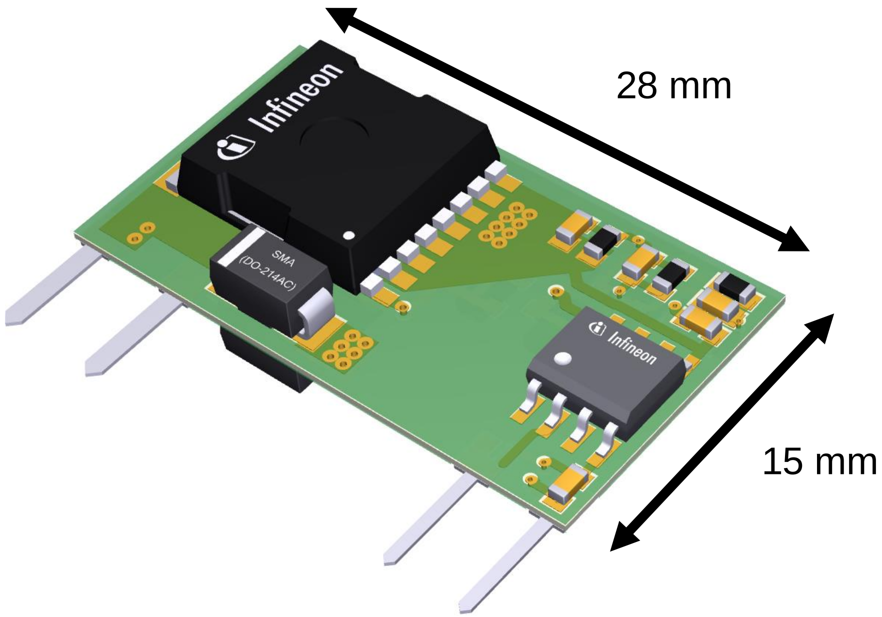



- **Example of SSCB: – hybrid and solid**



# Block Diagram & 5A Board Implementation for SSR demonstrator




- CoolMOS S7 enables the implementation of a solid state relay in the same form factor as traditional miniature EMRs

- Key benefits of SSRs compared to EMRs are:
  - No contact bounce, arcing or contact degradation
  - Very low excitation power
  - Power dissipation can be tailored with FET Rdson selection.
  - No increase of conduction losses over lifetime (constant contact resistance)

**Target: demonstrator and application note will be available In October 2021**

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5. CoolMOS S7 in active rectification
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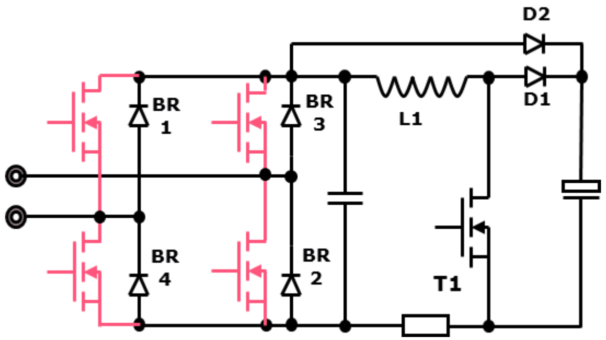
# The Idea behind the S7 CoolMOS - Static switching applications!

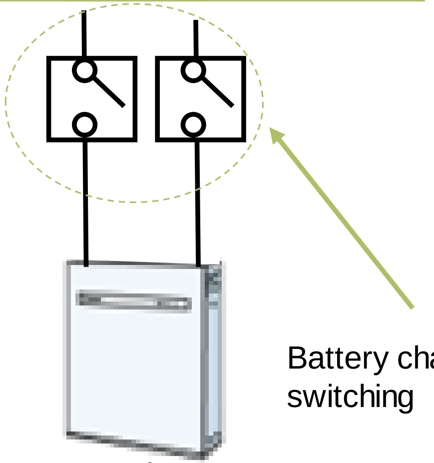
## What is a “static switching” application ?

A system or part of it where power MOSFETs are switching at low frequency, from few time per minute to some KHz and where, consequently, <u>the switching power losses of the MOSFET are not relevant</u>

**Example 1**
Active rectification bridge




**Example 2**
Systems embedding circuit breaking or switching



Battery charge/discharge switching

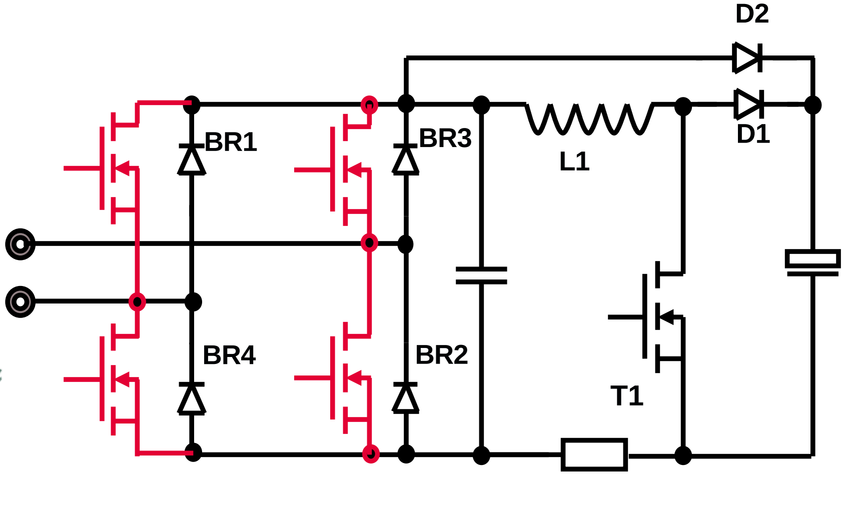
Storage battery

**Example 3**
Solid state circuit breakers and relays

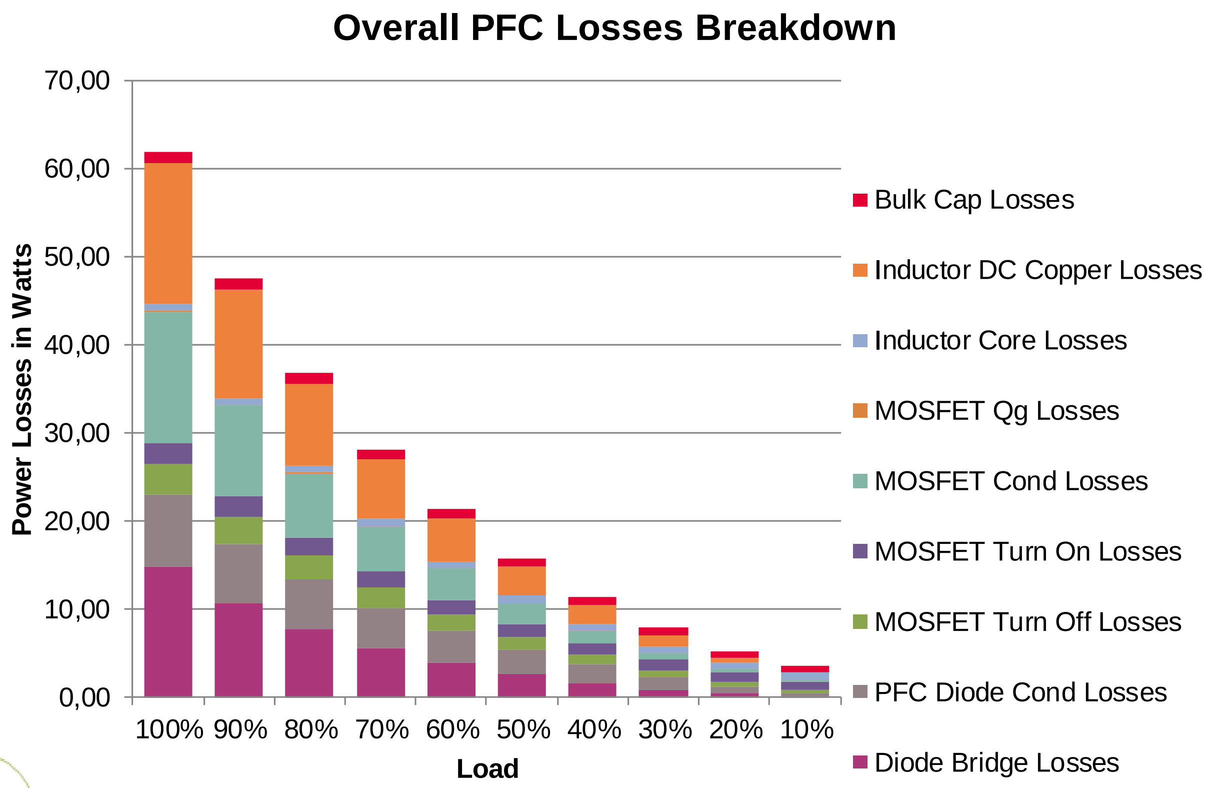
# Synchronous rectification
# CoolMOS™ S7 in active bridge for Titanium PSUs

**Classic PFC w/Sync Rect**

**1,3kW (115Vac)/ 2,5 kW (230 Vac)**



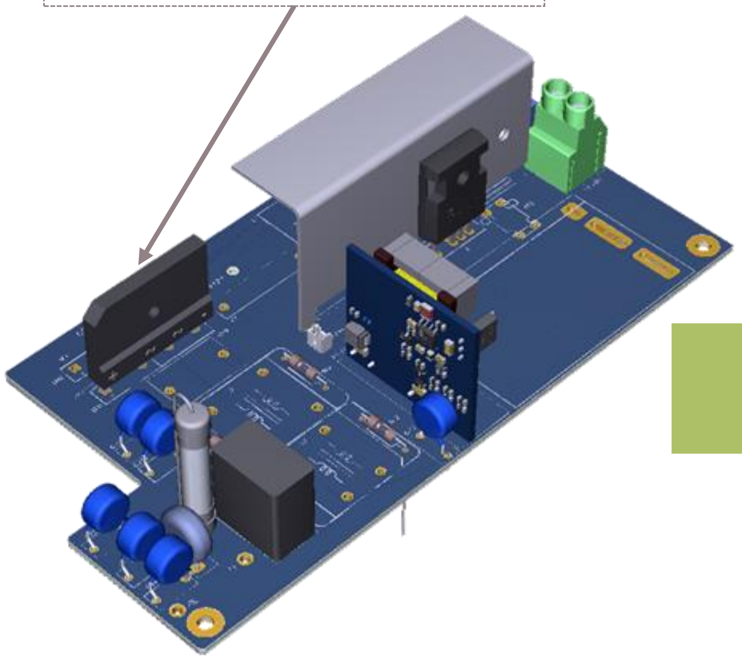

Add 4 x 22/40 mΩ MOSFETS to bridge rectifier



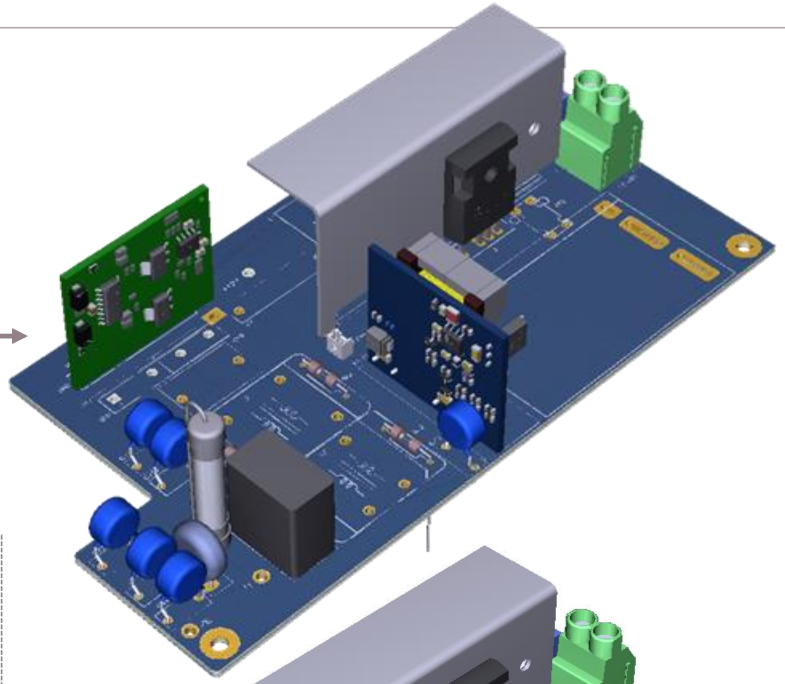

- 27% loss reduction (tunable via $R_{DS(on)}$)
- Enabling Titanium standard

# CoolMOS™ S7 in active bridge
## An easy way to Titanium

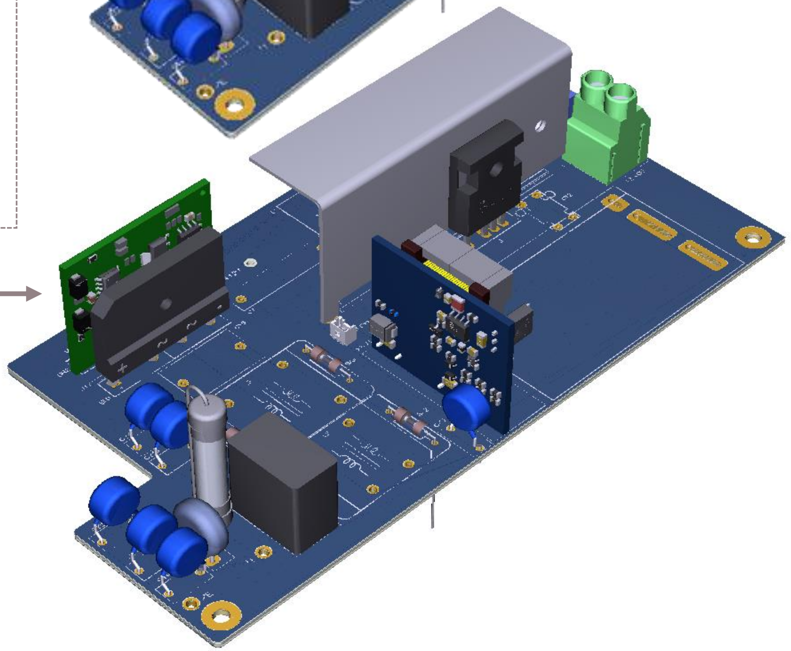
Diode rectification bridge



Active bridge with 4 x CoolMOS™ S7



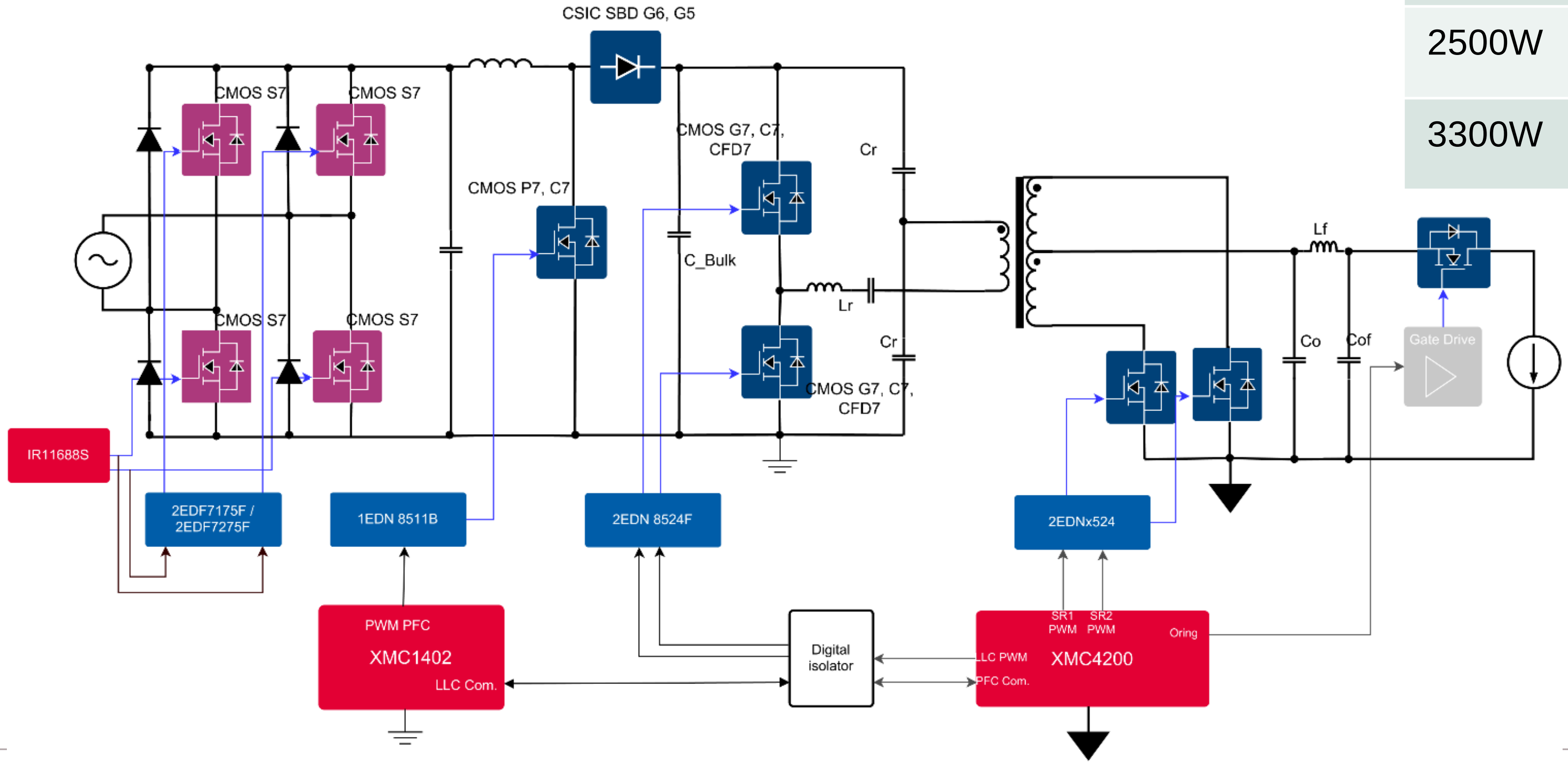
Active bridge with 4 x CoolMOS™ S7 in parallel to the diode bridge



# Application example
## SMPS classic PFC active bridge rectification

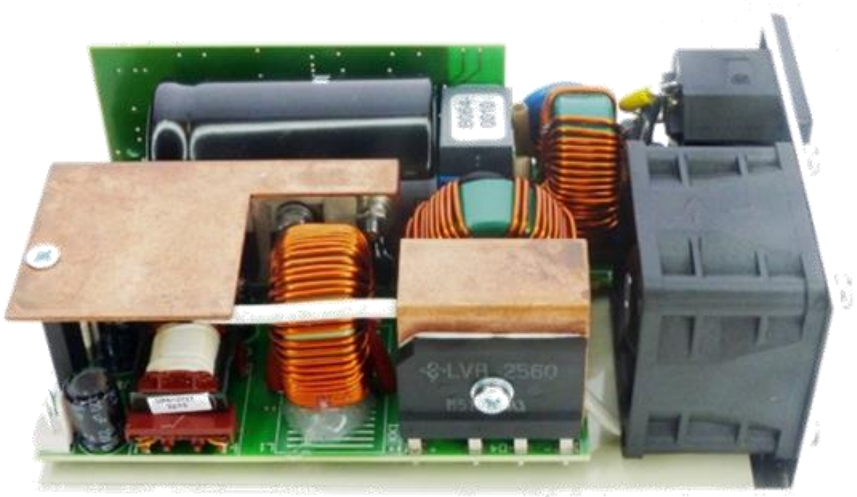
| Active Bridge | PFC | LLC | DC/DC |
|---|---|---|---|
| CoolMOS™ S7 | CoolMOS™ P7, C7<br>CoolSiC™ SBD G6 and G5 | CoolMOS™ G7, C7, CFD7 | |

| Active bridge | |
|---|---|
| **SMPS power** | **CoolMOS ™ S7** |
| 800W | 65 mΩ |
| 1300W | 40 & 65 mΩ |
| 2500W | 22 & 40 mΩ |
| 3300W | 22 mΩ |



# Application example 1:
# SMPS classic PFC active bridge rectification - 800W PFC

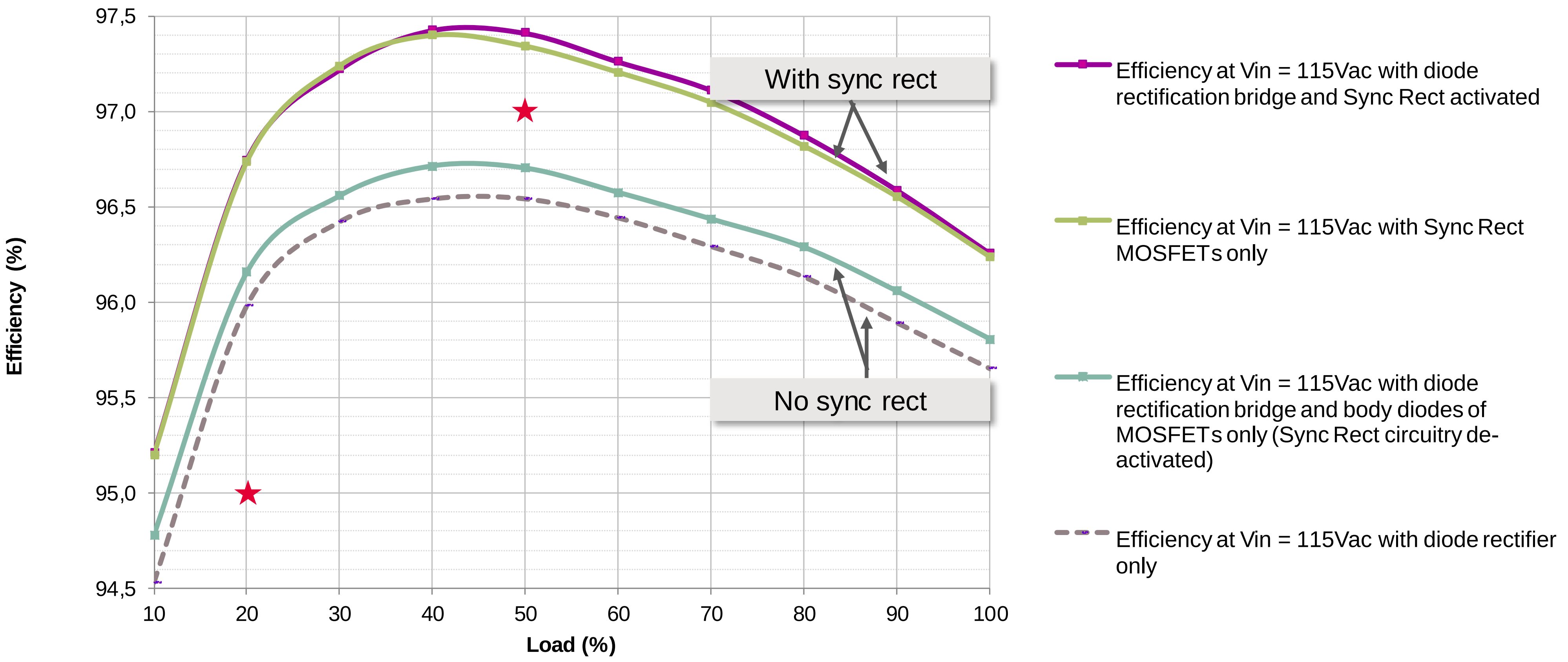
| Efficiency measurements | |
|---|---|
| EVAL_800W_PFC_P7<br>EVAL_800W_PFC_C7_V2 | |
| Input voltage | 90 – 265 Vac |
| Output voltage | 380 Vdc |
| Efficiency | > 97% from 20% load at Vin = 230Vac |
| Swtiching frequency | 65 kHz |
| Boost Diode | IDH06G65C5 |
| PFC MOSFET | 2x IPP60R180P7<br>2x IPP60R180C7 |
| Gate drivers | 2EDN7524F |
| PFC controller | ICE3PCS01G<br>XMC1402 |



Board used for test. Not the CoolMOS™ S7 demo board

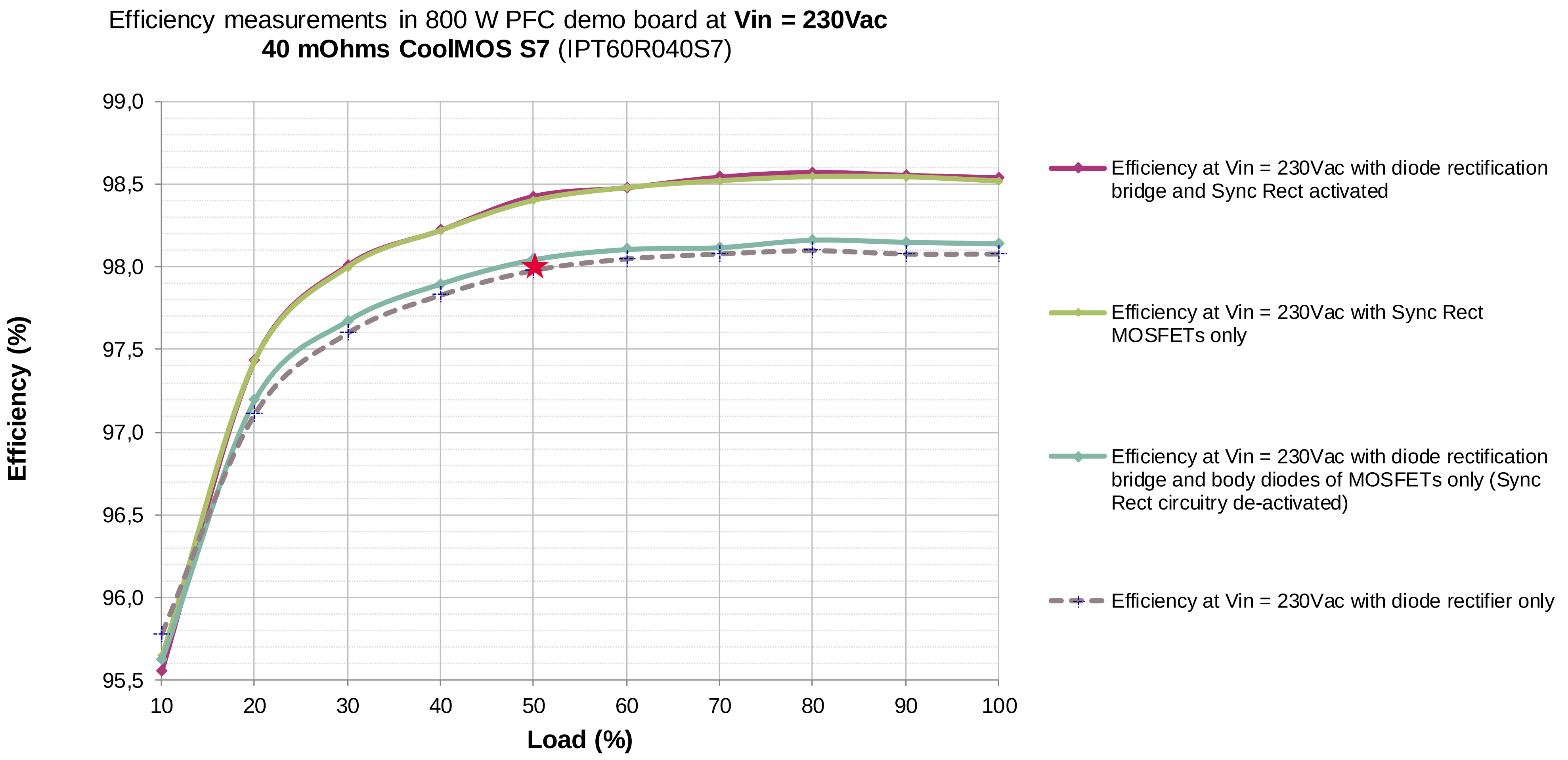
# Application example 1: SMPS Classic PFC active bridge rectification - 800W PFC

Efficiency measurements in 800 W PFC demo board at **Vin = 115Vac**
**40 mOhms CoolMOS S7** (IPT60R040S7)



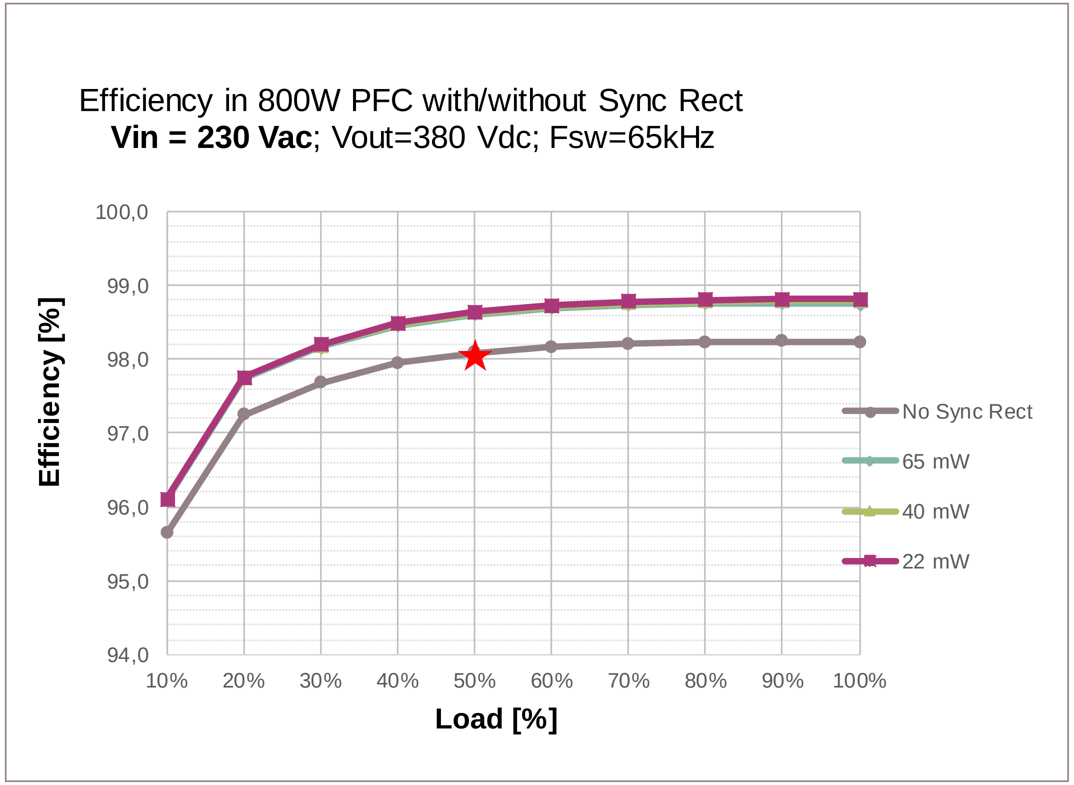

★ Ideal PFC efficiency for Titanium

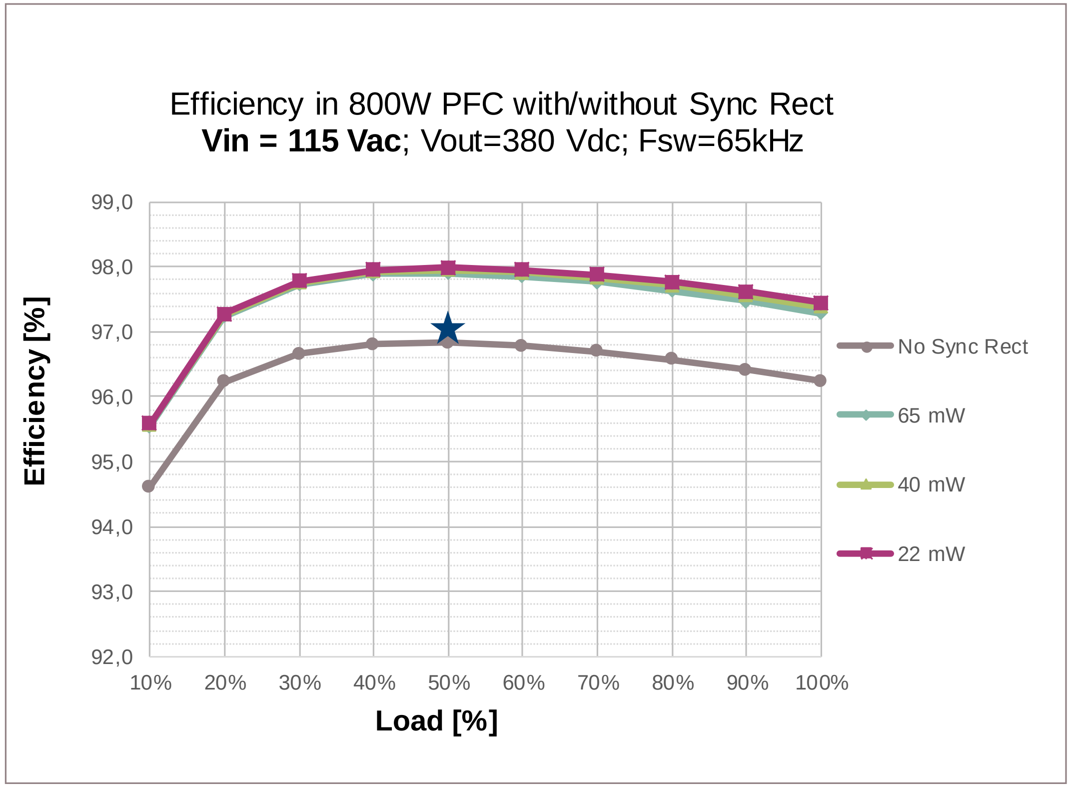
# Application example 1: SMPS Classic PFC active bridge rectification - 800W PFC




★ Ideal PFC efficiency for Titanium

# Application example 1: SMPS Classic PFC active bridge rectification – 800W PFC



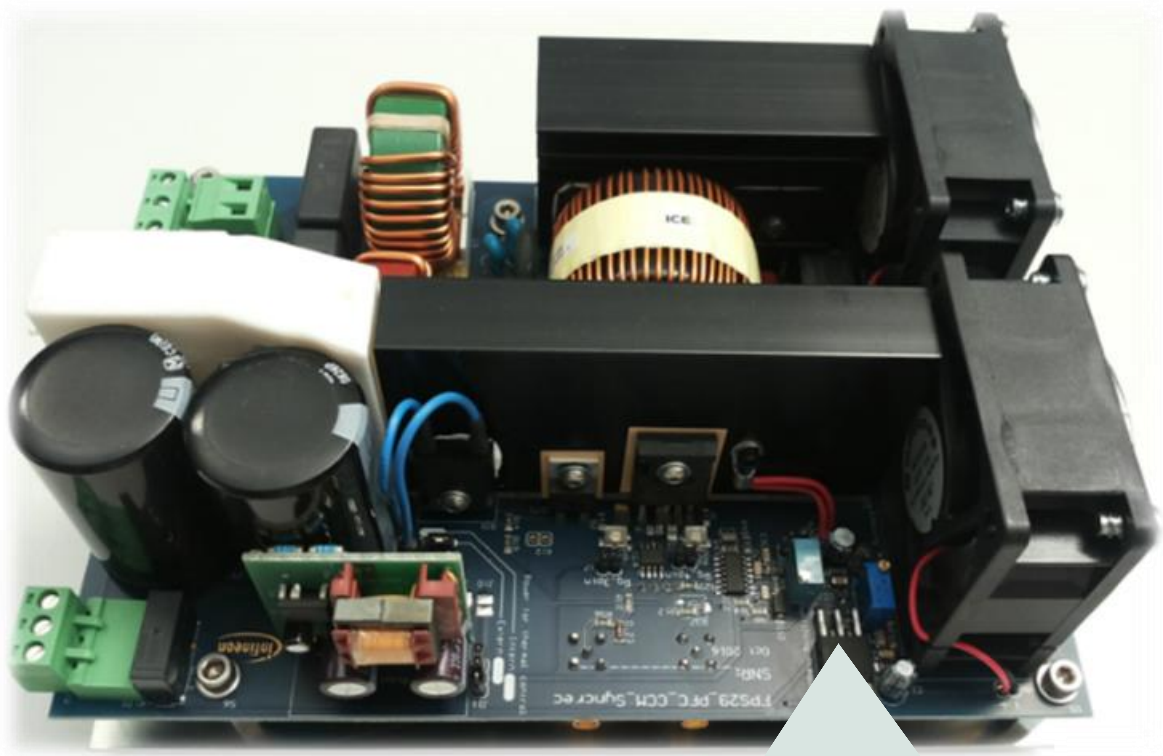

★ Titanium ideal PFC efficiency @ 230Vac

★ Titanium ideal PFC efficiency @ Vin = 115Vac

- **PFC Efficiency boost** ~ 1% at low line from 30% to 100% of the load. Delta efficiency depends on different Rdson used in the Sync rect from mid to full load.
- At high line and low line, efficiency difference is almost negligible among different Rds_on. Final selection depends on thermal and specific efficiency points of interest.

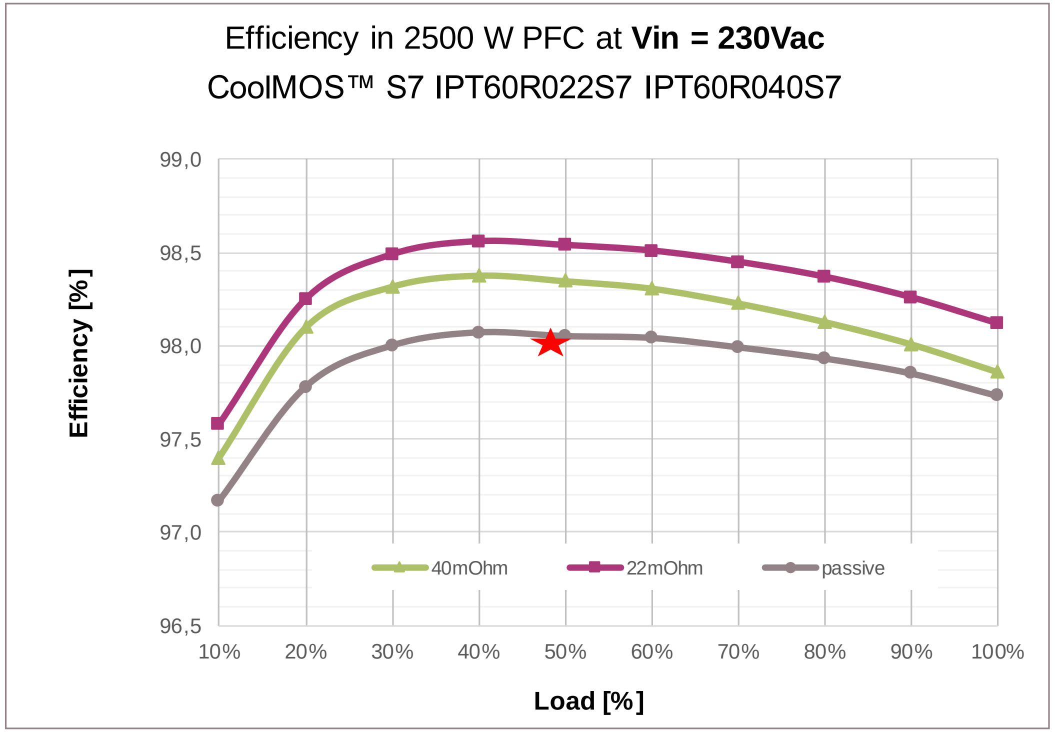
# Application example 2: SMPS Classic PFC active bridge rectification – 2400W PFC

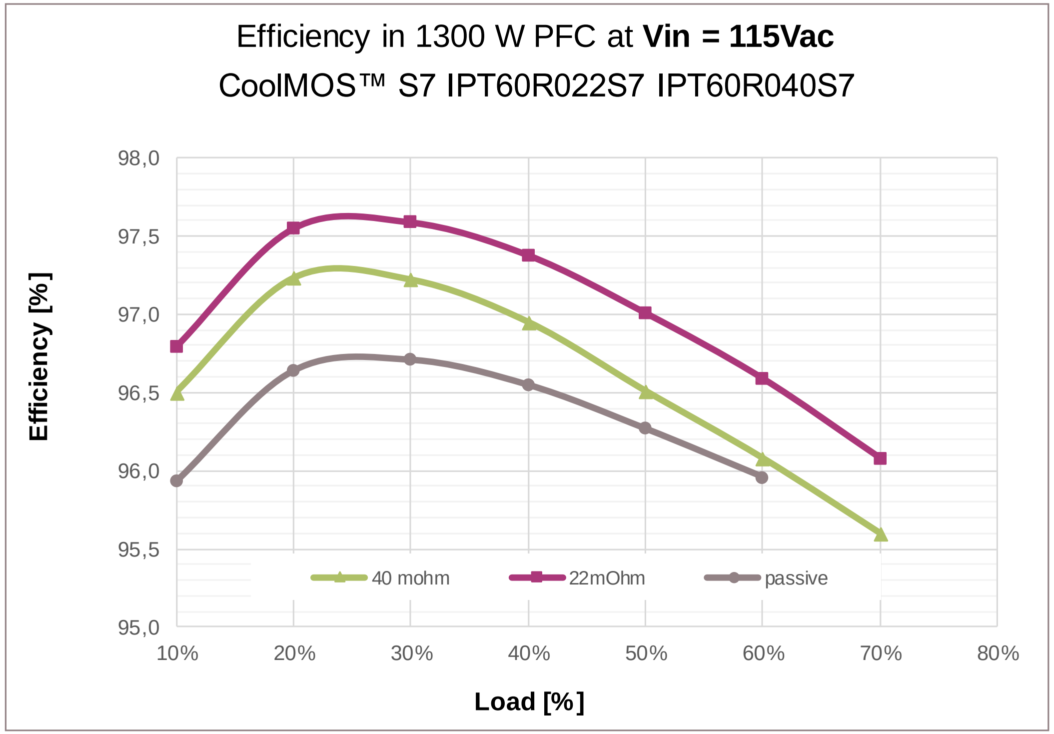
| Efficiency measurements | |
|---|---|
| EVAL_2K4W_ACT_BRD_S7 | |
| Low line | 90V, 1200W |
| High line | 230V, 2400W |
| Choke | 500µH flat wire |
| Shunt | 5 mΩ |
| Frequency | 65kHz |
| Boost Diode | IDH12G65C5 |
| PFC MOSFET | IPZ60R040C7 |
| Bridge MOSFETs | IPT60R022S7<br>IPT60R040S7<br>IPT60R065S7 |



Board used for test. Not the CoolMOS™ S7 demo board

# Application example 2: SMPS Classic PFC active bridge rectification – 2400W PFC




★ Ideal efficiency for Titanium

- **PFC Efficiency boost** to 98.5% to easily reach Titanium levels
- ~ 1% gain at low line to reduce losses and thermal requirements
- Delta efficiency depends on different Rdson used in the Sync rect from mid to full load.

# 2,4KW active rectification PFC with TOLL FETs

**Active-bridge CCM PFC demo board based on 600 V CoolMOS™ S7**
**2400 W 65 kHz high-efficiency and high power density design**
**Introduction**

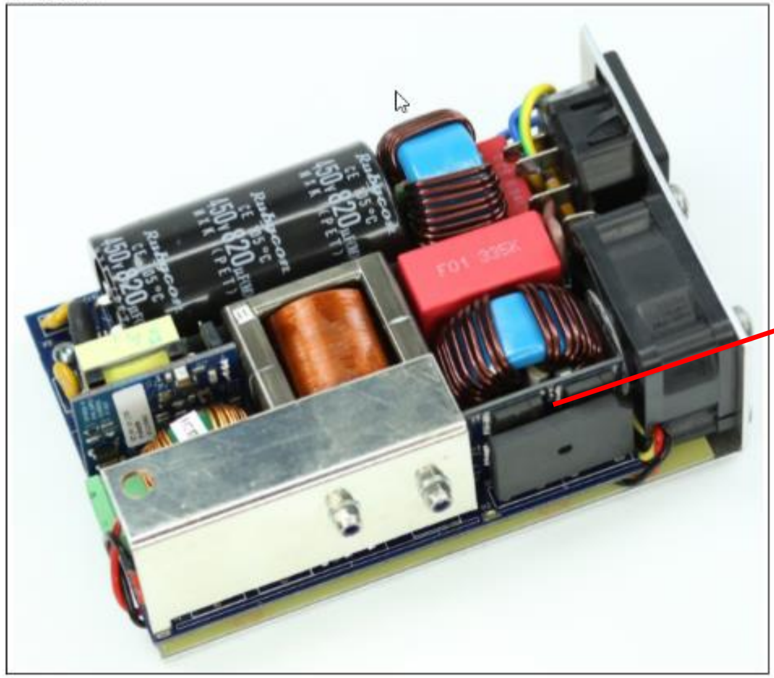


Figure 1 2400 W active-bridge CCM PFC based on 600 V CoolMOS™ S7

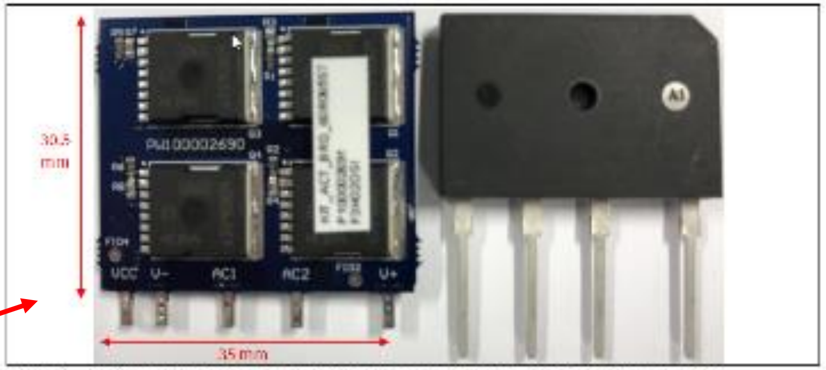
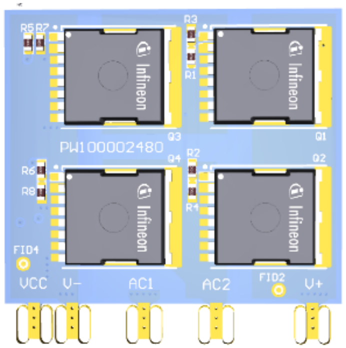
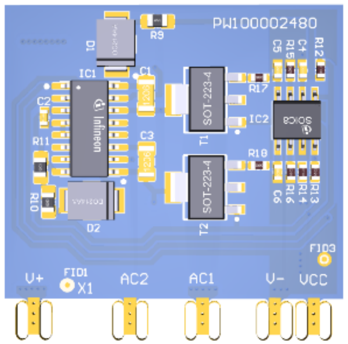



Figure 1 Active bridge daughter card (left) compared with a standard diode bridge (right)




- Dougther-Board Mounting of TOLL FETs
- Controller and driver on back side of Doughter Board
- Active Cooling
- The board is 127 mm long, with a width of 85 mm and a height of 44 mm, with a power density of 80W/in$^3$.
- Reduces space and flexibility due to use of Doughter-Board!

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# FET-SSRs combine the pro‘s of both, EMR and SCRs and enable important next-generation features

## EMR

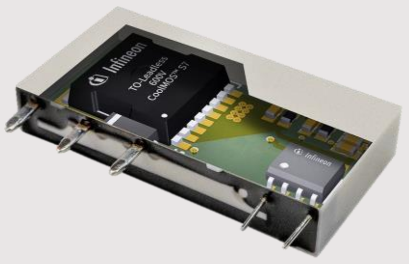
- Low conduction losses
- High power density
- High robustness
- Galvanic isolation

## SCR

- Arcing-free, wearless switching
- Low excitation power

## FET-Solid-State Relay

- Scalable conduction losses
- AC & DC switching
- Advanced control capability
- Channel-selective protection features



# Summary

- CoolMOS™ S7 is the first SJ technology in the market optimized for $R_{DS(on)}$ x A
- A proof-of-concept is available demonstrating functionality, protection features and control concepts; system demonstrators with minimum viable feature set available > Oct. 2021
- HV-FET-based SSR implementations offer several benefits vs. Triac-based implementations
  - Low- and scalable power dissipation, on-par with EMR
  - Miniature implementation enables drop-in replacement of standard EMRs
- CoolMOS™ S7 is available and portfolio is being extended, and **ready to sell** into SSR sockets
- The technology will be expanded with advanced features, a SSR GDU for full system integration will be developed

Products, details, documents, boards, tools & software, simulation, videos, training, support: www.infineon.com/S7 www.infineon.com/S7A

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