CoolMOS™ SJ MOSFETs benefits

in both hard and soft switching SMPS topologies

www.infineon.com/coolmos

Hard and soft switching topologies, applications and suitable CoolMOS™ families

CoolMOS™ series

- Efficiency = CoolMOS™ C7
  Price/performance = 600 V, 700 V, 800 V CoolMOS™ P7
  CoolMOS™ C6/E6/CE/P6
- Efficiency = 600 V CoolMOS™ C7
  Price/performance = CoolMOS™ P7
  CoolMOS™ C6/E6/CE/P6
- CoolMOS™ CFD2/CFD7

SMPS switching topologies

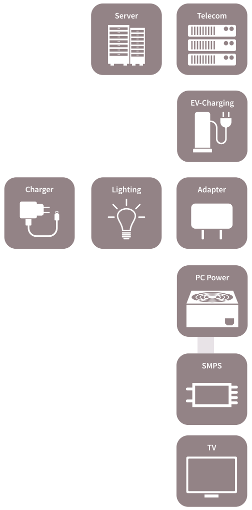
Hard switching topologies

- PFC
  - PFC
    - DCM
    - CCM
- PWM
  - Two transistor forward (TTF/ITTF)
  - Flyback/ quasi-resonant flyback

Soft switching topologies

- PWM
  - LLC
    - Half-bridge
    - Full-bridge
  - ZVS phase-shift
    - Full-bridge

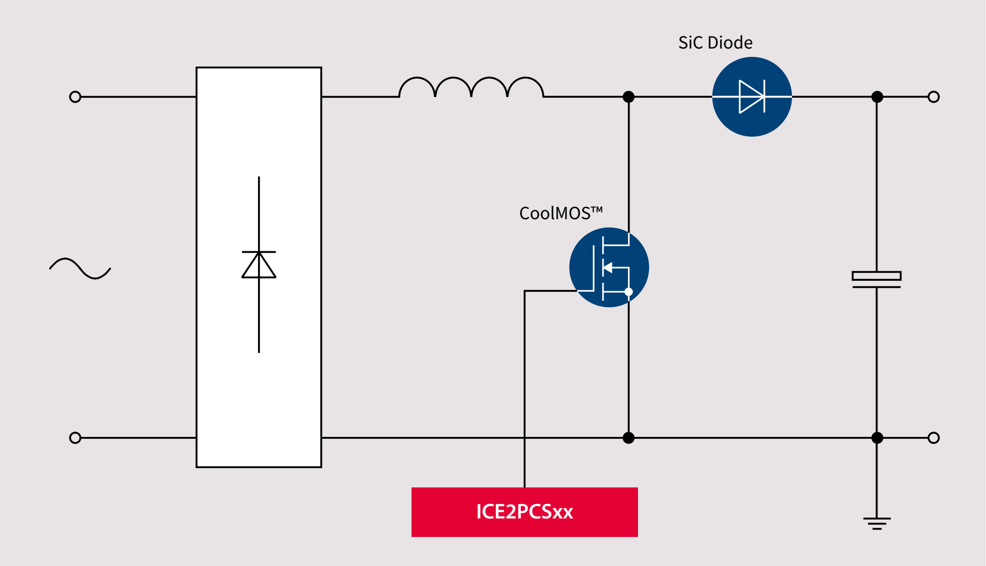
Applications



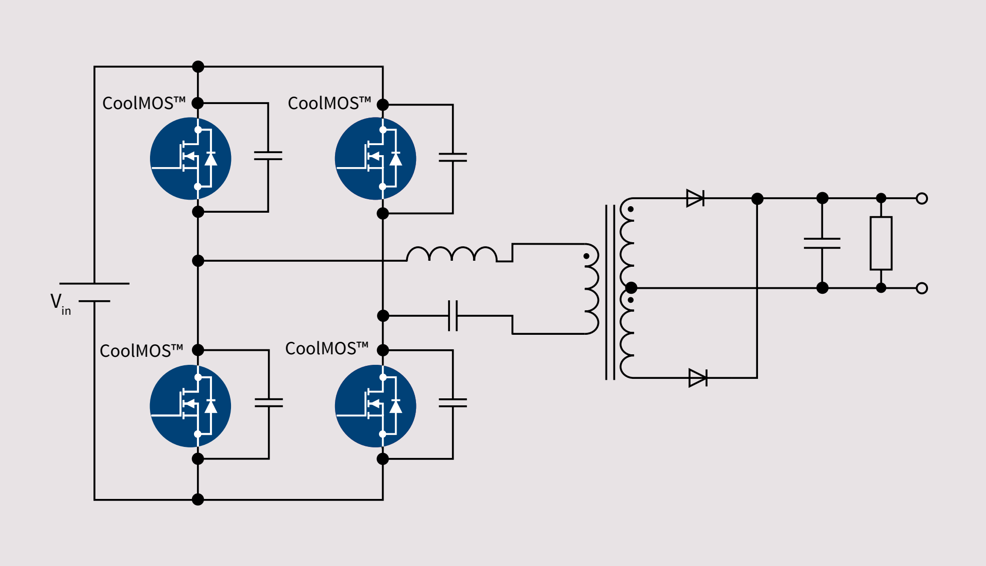
- Hard switching – PFC: Adapter (DCM); Server/telecom, EV charging, PC Silver box PFC (CCM)
- Hard switching – PWM: PC Silver box 80 + (Two transistor forward); Adapter/ LED lighting (Flyback/quasi-resonant flyback)
- Hard/soft switching: LCD TV
- Soft switching – PWM: EV charging; LED street lighting, PC Silver box 90 + (LLC); Server/telecom, UPC (ZVS phase-shift)

Examples of hard and soft switching topologies

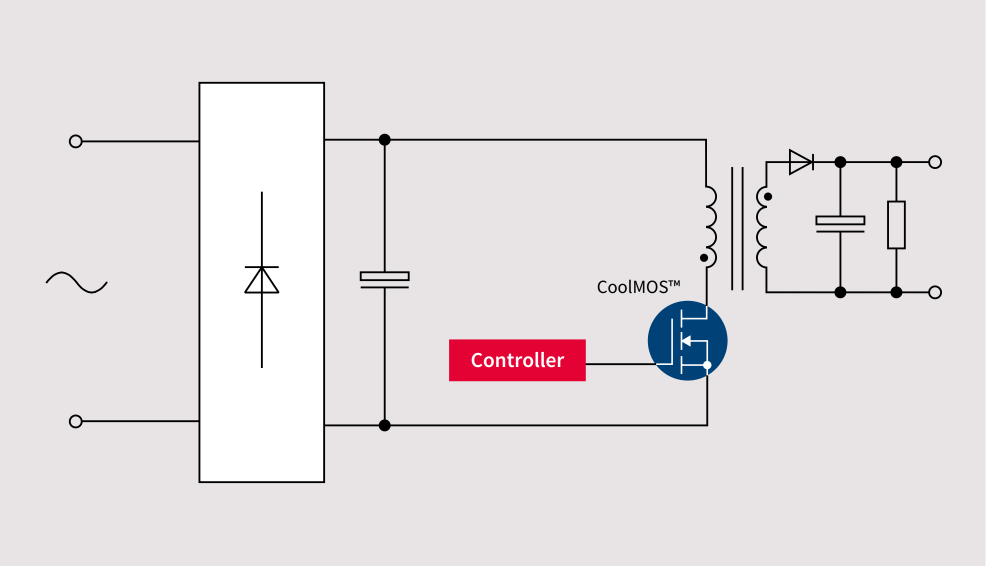
Hard switching: Power factor correction circuit



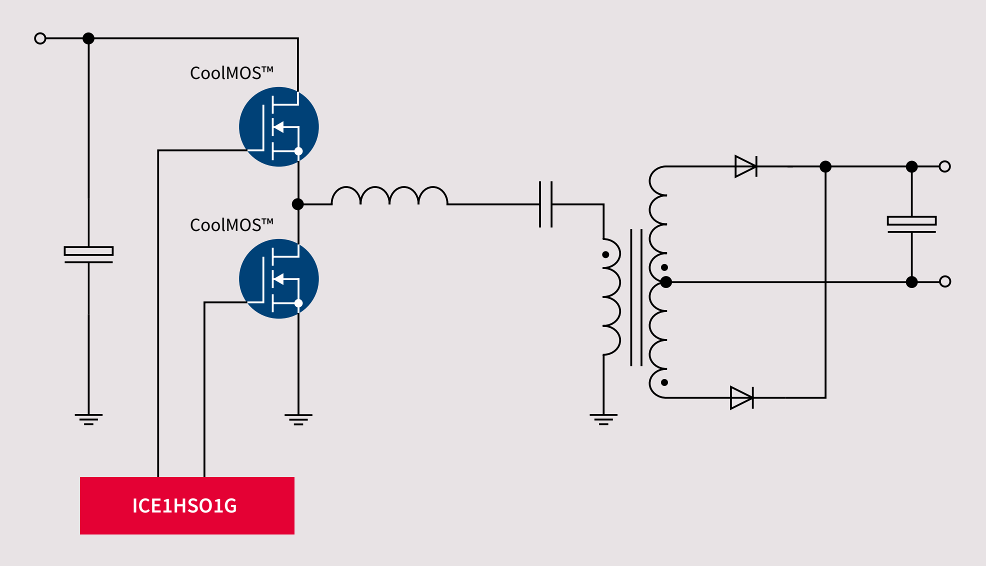
Soft switching: ZVS phase-shift full-bridge



Hard switching: Quasi-resonant flyback circuit



Soft switching: LLC half-bridge



Hard switching

What is hard switching?

› Hard switching occurs when there is an overlap between voltage and current when switching the transistor on and off.
› This overlap causes energy losses which can be minimized by increasing the di/dt and dv/dt.
› However, fast changing di/dt or dv/dt causes EMI to be generated. Therefore the di/dt and dv/dt should be optimized to avoid EMI issues.

To minimize the EMI effects and to improve efficiency, an improved hard switching technique called quasi-resonant switching was developed (mainly seen in flyback converters).

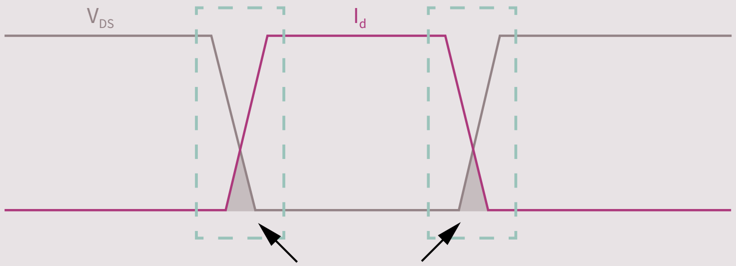
What is quasi-resonant (valley) switching?

› The transistor is turned on when the voltage across drain and source is at a minimum (in a valley) in order to minimize the switching losses and to improve efficiency.
› Switching the transistor when the voltage is at a minimum helps reduce the hard switching effect which causes EMI.
› Switching when a valley is detected – rather than at a fixed frequency – introduces frequency jitter. This has the benefit of spreading the RF emissions spectrum and reducing EMI overall.

Infineon CoolMOS™ series recommendations for hard switching topologies

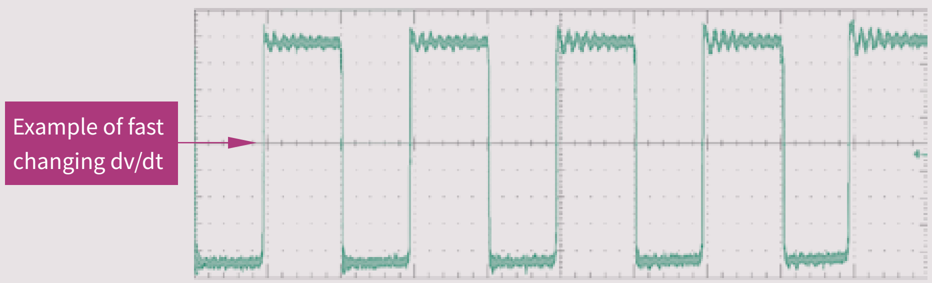
› For hard switching applications Infineon recommends CoolMOS™ C7 and CoolMOS™ P7

Hard switching "MOSFET" current and voltage waveform

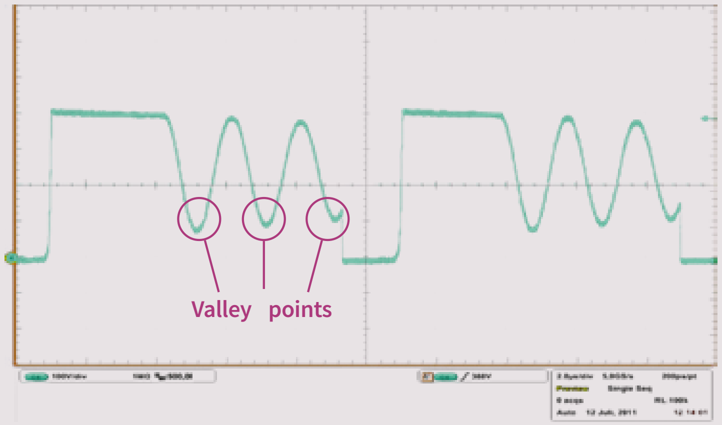


Switching losses area (reduced efficiency)

Real hard switched waveform (V_{DS}) (CCM PFC)



Real quasi-resonant (valley) switching waveform (V_{DS}) (QR flyback converter)



In order to minimize the switching losses, the turn on must be done in the V_{DS} "valleys"

Soft switching (resonant)

What is soft (resonant) switching?

- Soft switching begins one electrical parameter to zero (current or voltage) before the switch is turned on or off. This has benefits in terms of losses.
- The smooth resonant switching waveforms also minimize EMI.
- Common topologies like phase- shifted ZVS and LLC are soft switched only at turn-on.

What is the difference between zero voltage switching (ZVS) and zero current switching (ZCS)?

- As both names imply either voltage or current within the transistor is zero before switching occurs.
  - For ZVS, the transistor will be turned in at zero V_{DS} voltage to reduce the turn on switching loss.
  - For ZCS, the transistor will be turned off at zero I_D current to reduce the turn off switching loss.

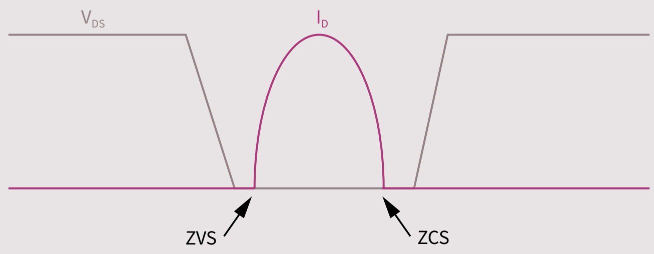
Why is there a need for a rugged or fast body diode?

- Most resonant circuits are half- or full-bridge topologies (2 or 4 transistors). As transistors are switched on and off, energy can be left in the transistor and this can cause failure. Due to switching times if this only happens occasionally a rugged body diode is sufficient (CoolMOS™ P7). If due to fast transition times it happens continually then a fast body diode is required to make sure all the energy will leave the transistor (CoolMOS™ CFD7 series).

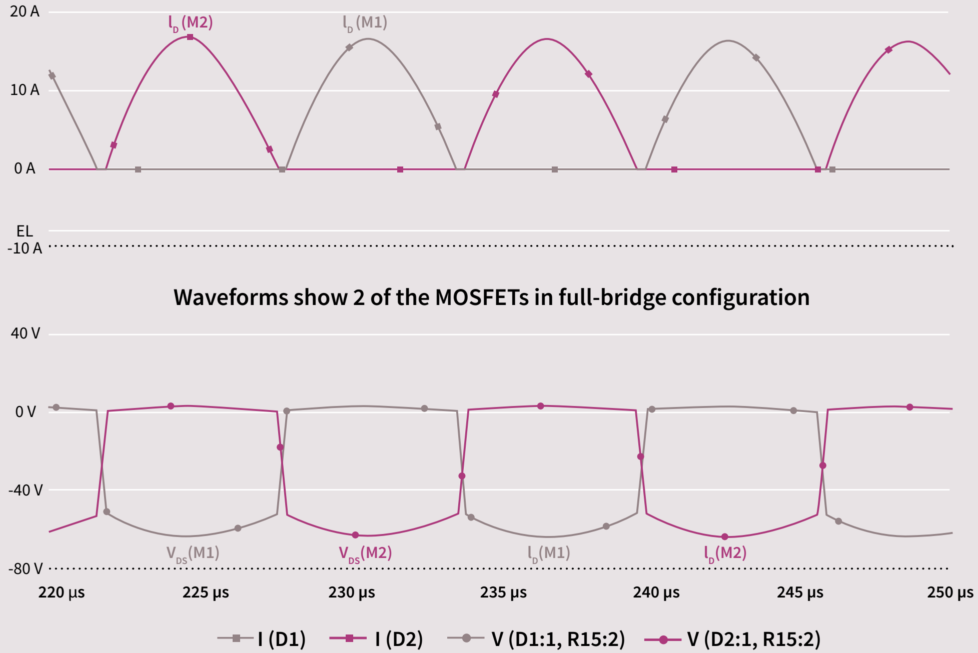
Infineon CoolMOS™ series recommendations for soft switching (resonant) topologies

- For soft switching applications such as phase-shifted ZVS and LLC, Infineon recommends either 600 V CoolMOS™ CFD7 or 600 V CoolMOS™ P7 series.

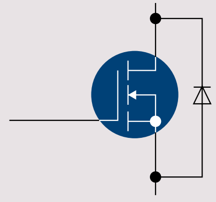
Soft switching "MOSFET" current and voltage waveform



Simulated phase-shift ZVS soft switching voltage and current waveforms



MOSFET with integrated fast body diode



CoolMOS™ product portfolio

CoolMOS™	ThinPAK 8X8	ThinPAK 5X6	TO-Leadless	TO-252 DPAK	TO-263 D²PAK	TO-220	TO-220 FullPAK	TO-220 FullPAK Wide Creepage	TO-220 FullPAK Narrow Lead	TO-251 IPAK	TO-251 IPAK SL	TO-251 I²PAK	TO-247	TO-247 4pin	TO-251 IPAK SL with ISO lead standoff	SOT-223
500 V CE				✓		✓	✓		✓	✓			✓			✓
600 V CE				✓			✓	✓	✓	✓	✓					✓
600 V C6/E6		✓		✓	✓	✓	✓					✓	✓			
600 V C7	✓			✓	✓	✓	✓						✓	✓		
600 V P6	✓	✓		✓		✓	✓						✓			
600 V CFD						✓	✓					✓	✓			
600 V CFD7	✓			✓		✓	✓						✓			
600 V P7	✓			✓	✓	✓	✓						✓	✓		
600 V P7S				✓			✓	✓								✓
650 V CE				✓			✓		✓		✓					✓
650 V C6/E6	✓	✓				✓	✓					✓	✓			
650 V C7	✓		✓	✓	✓	✓	✓						✓	✓		
650 V CFD2	✓			✓	✓	✓	✓					✓	✓			
700 V CE				✓							✓					✓
700 V P7				✓			✓		✓		✓				✓	✓
800 V CE				✓			✓			✓						
800 V P7				✓		✓	✓		✓	✓	✓		✓			✓

Hard switching
Soft switching
Hard/soft switching
✓ Standard parts

Hard switching	650 V CoolMOS™ C7:	NEW! Fastest switching series, best suited for high efficiency at hard switching topologies.
Hard/soft switching	CoolMOS™ E6:	CoolMOS™ C3 replacement series optimized for DCM applications in PFC and PWM. Improved low load efficiency over CoolMOS™ C3.
	CoolMOS™ C6:	CoolMOS™ C3 replacement series. Improved low load efficiency, also with improved “rugged” diode for use in cost sensitive soft switching topologies as well as hard switching.
	CoolMOS™ P6:	Price/performance series, suitable for hard and soft switching.
	600 V CoolMOS™ C7:	NEW! Fastest switching series, suitable for hard switching topologies and soft switching.
	CoolMOS™ CE:	Right fit for consumer applications with competitive cost, fast delivery and high quality for use in hard and soft switching topologies.
	600 V CoolMOS™ P7:	Replacement for P6, price/ performance series, suitability for wide range of applications in hard and soft switching topologies
	700 V/800 V CoolMOS™ P7:	Replacement for CE, designed and optimized for flyback topologies
Soft switching	CoolMOS™ CFD:	Original fast body diode series suitable for hard commutation resonant soft switching topologies.
	CoolMOS™ CFD2:	CoolMOS™ CFD replacement series. Improved low load efficiency and improved fast body diode control enabling lower EMI and overshoot voltage. Suitable for hard commutation resonant soft switching topologies.
	CoolMOS™ CFD7:	NEW! Replacement of CoolMOS™ CFD2 for new designs, improved efficiency and BIC robustness; suitable for hard commutation resonant soft switching topologies

For more information on individual CoolMOS™ parts in the above different series, please go to www.infineon.com/coolmos

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