Quasi-resonant control with XMC1000 for LED ballast and SMPS

XMC^{TM} Microcontrollers

June 2016

Agenda

Agenda

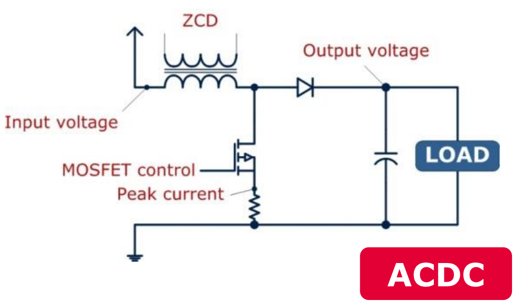
Quasi-resonant control with XMC1000 - Overview

- This training slides begin by introducing the losses in various power converter, especially the switching losses and how quasi-resonant control can be used to minimize switching losses
- The second part of this training slides showcase the implementations of quasi-resonant control with XMC1000 using its peripherals and how they can be implemented on LED ballast and other SMPS

Agenda

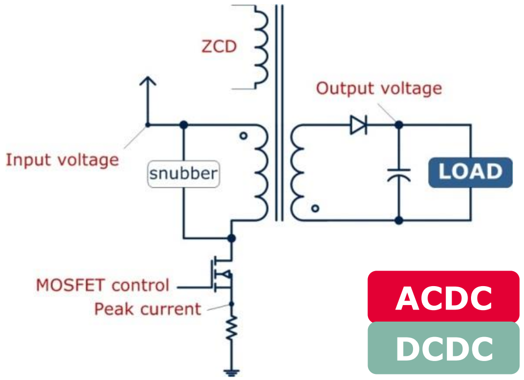
Introduction
Power topologies

› Boost



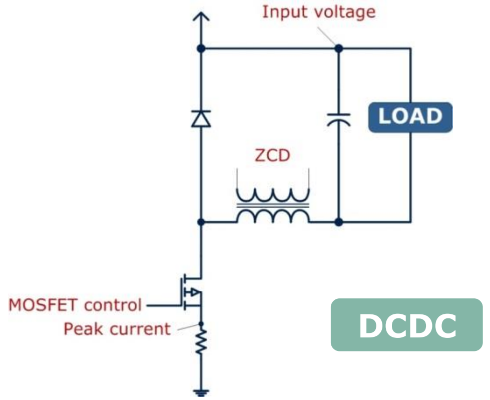
- $V_{out} > V_{in}$
- Power factor correction
- Constant ON time control

› Flyback



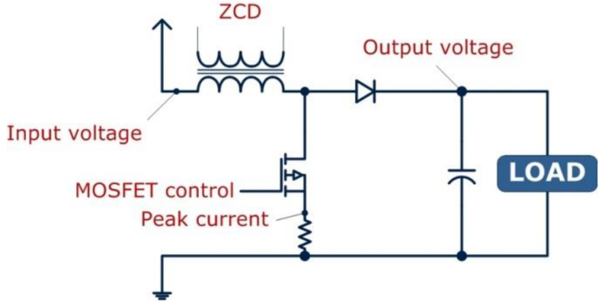
- Buck/boost
- Galvanic isolation
- Power factor correction + constant current control

› Buck

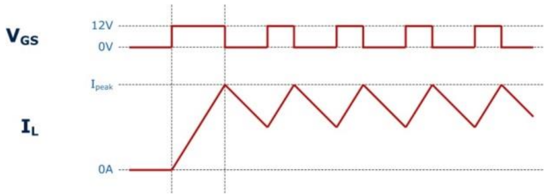


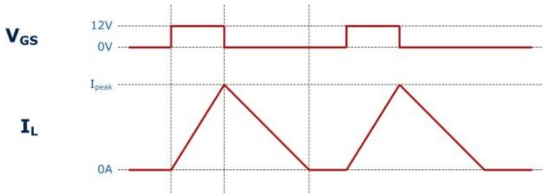
- $V_{out} < V_{in}$
- Peak current control
- Useful for LED driver stage

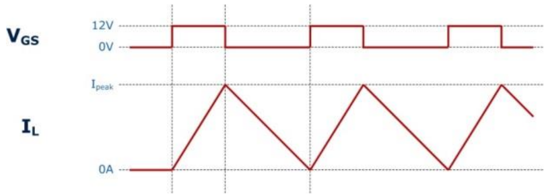
Introduction
Conduction mode



- Continuous conduction mode (CCM)
- Critical conduction mode (CrCM)
- Discontinuous conduction mode (DCM)

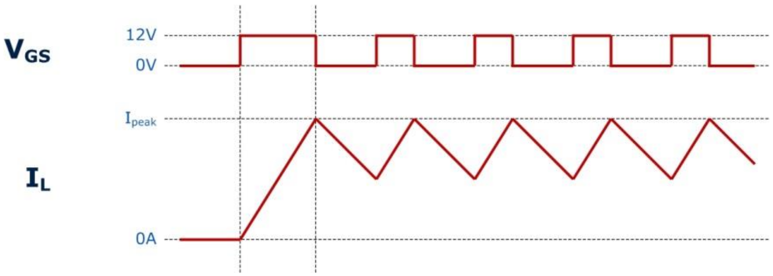


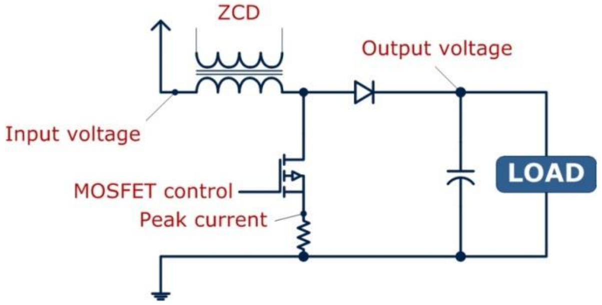




Introduction
Continuous conduction mode

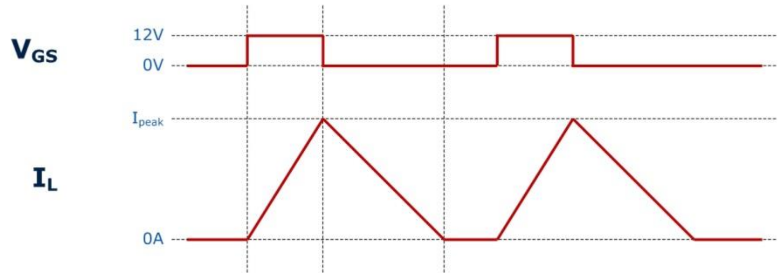
- MOSFET turned on while there is still current in the inductor
- Maximum switching loss. “Hard switching”

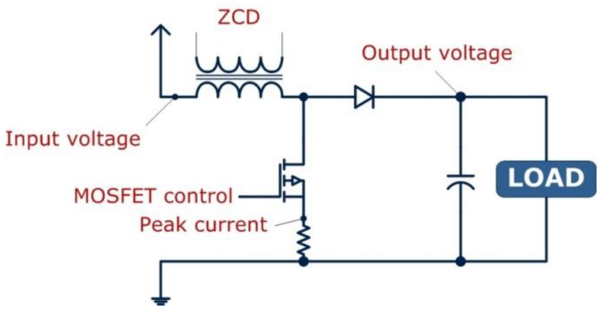




Introduction
Discontinuous conduction mode

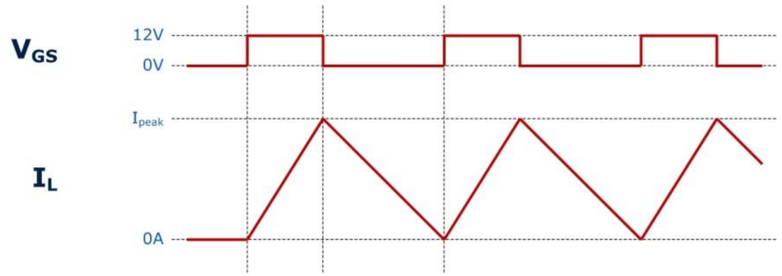
- MOSFET turned on sometime after inductor current reaches zero
- Zero current isn't detected
- V_{DS} oscillation is ignored
- This is the simple way

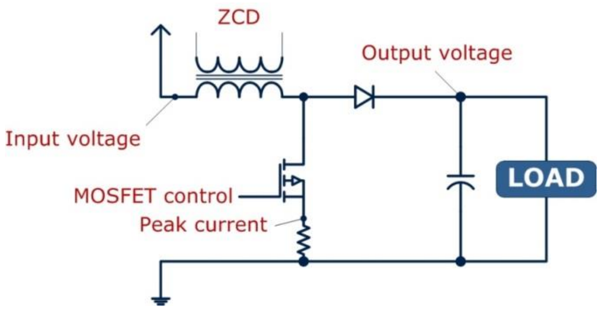




Introduction
Critical conduction mode

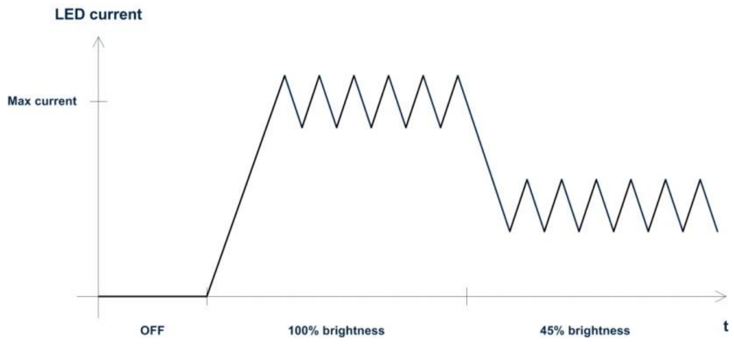
- Aka boundary conduction mode
- MOSFET turned on immediately as zero current is detected
  - Reduced turn-on loss





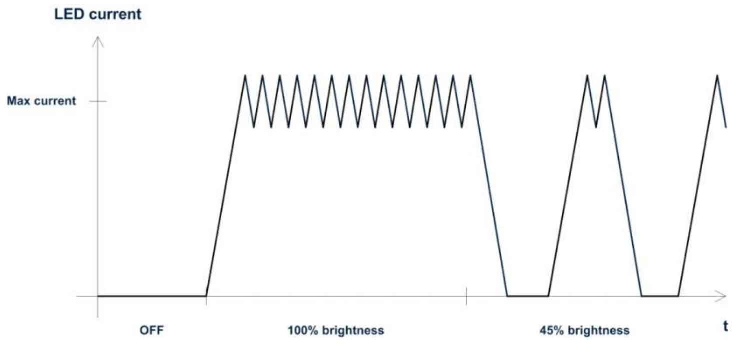
Introduction
LED dimming control

› Analog dimming



– Need good DAC for accuracy
– Classical, straightforward method

› Modulation dimming



– Simple DAC is sufficient.
– Need modulator. In XMC™: BCCU

› Both dimming controls work on any conduction mode

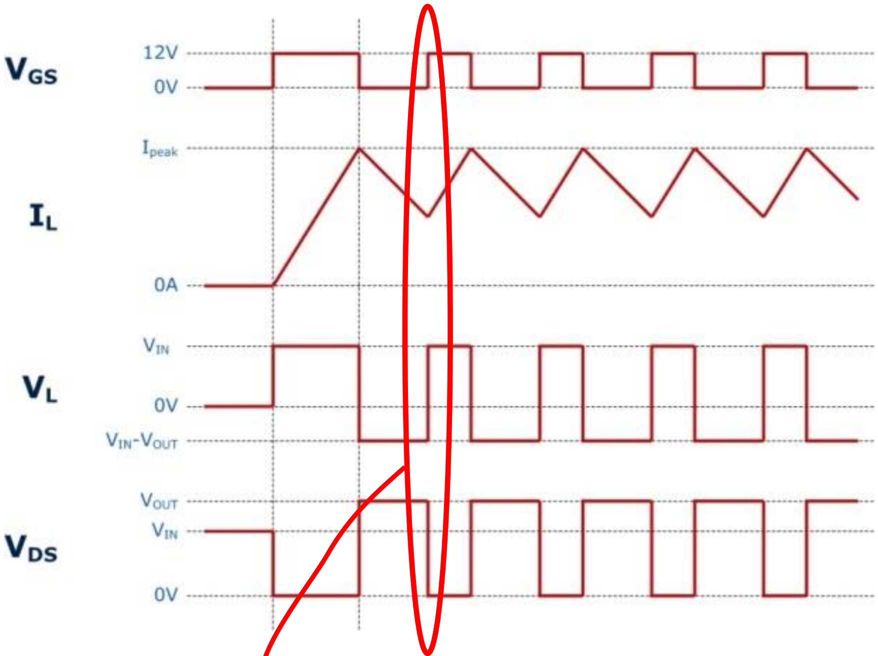
Agenda

Quasi-resonant control
Losses & efficiency

- Conduction losses
  - MOSFET: $I_D^2 * R_{DS,on}$
  - Diode: $I_F * V_F$
  - Shunt: $I_D^2 * R$
  - Inductor/transformer: $I^2 * R_{series}$
- Switching losses
  - MOSFET: C_{DS}, C_{GD}, C_{GS}, Q_{GD}, Q_{DS}
  - Diode: I_{RRM}, t_{RRM}

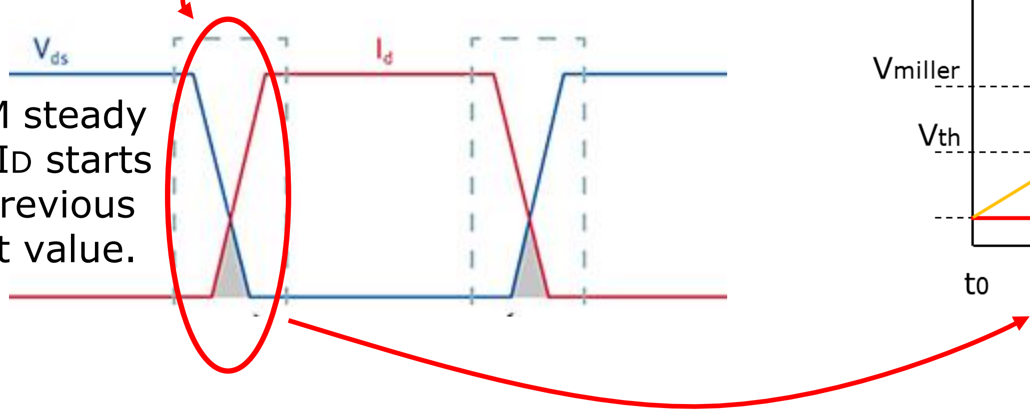
- Optimization strategy:
  - Use larger components
  - Wider PCB trace
- Optimization strategy:
  - Use faster components
  - **Optimize the switching scheme**

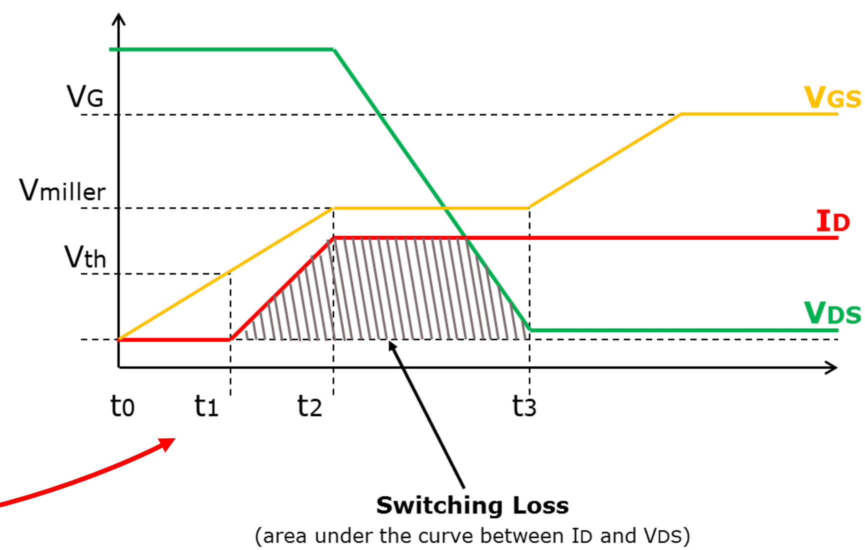
Quasi-resonant control
Losses & efficiency



- T0-T1: Gate driver charges CGS. VGS slope depends on gate driver current
- T1-T2: VGS passes gate threshold. Conducting channel available. Current starts flowing
- T2-T3: Miller plateau. Depend on CGD and VDS. **Longer plateau results in higher switching loss**
- T3 onwards: MOSFET is conducting, VDS depends on RDS(ON) and ID

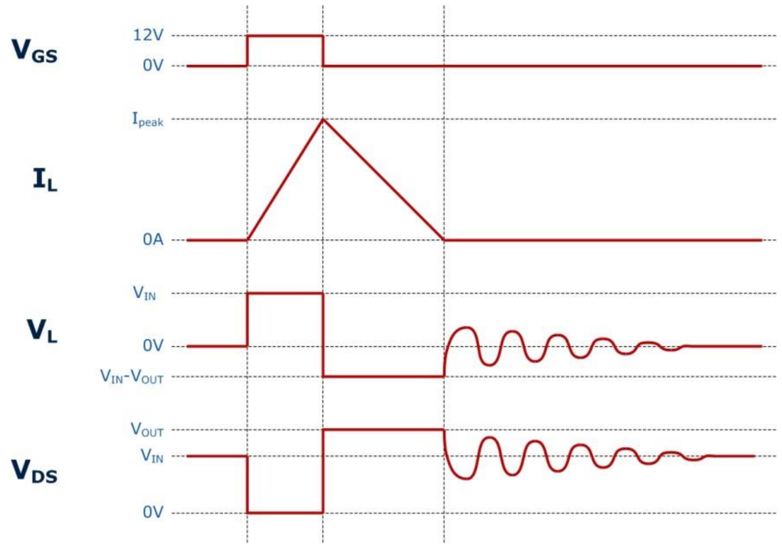
In CCM steady state, ID starts from previous current value.

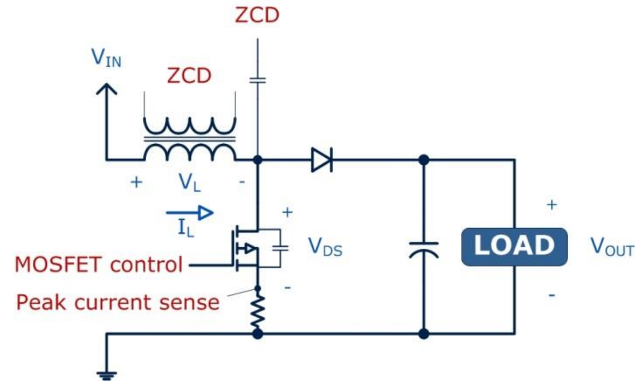




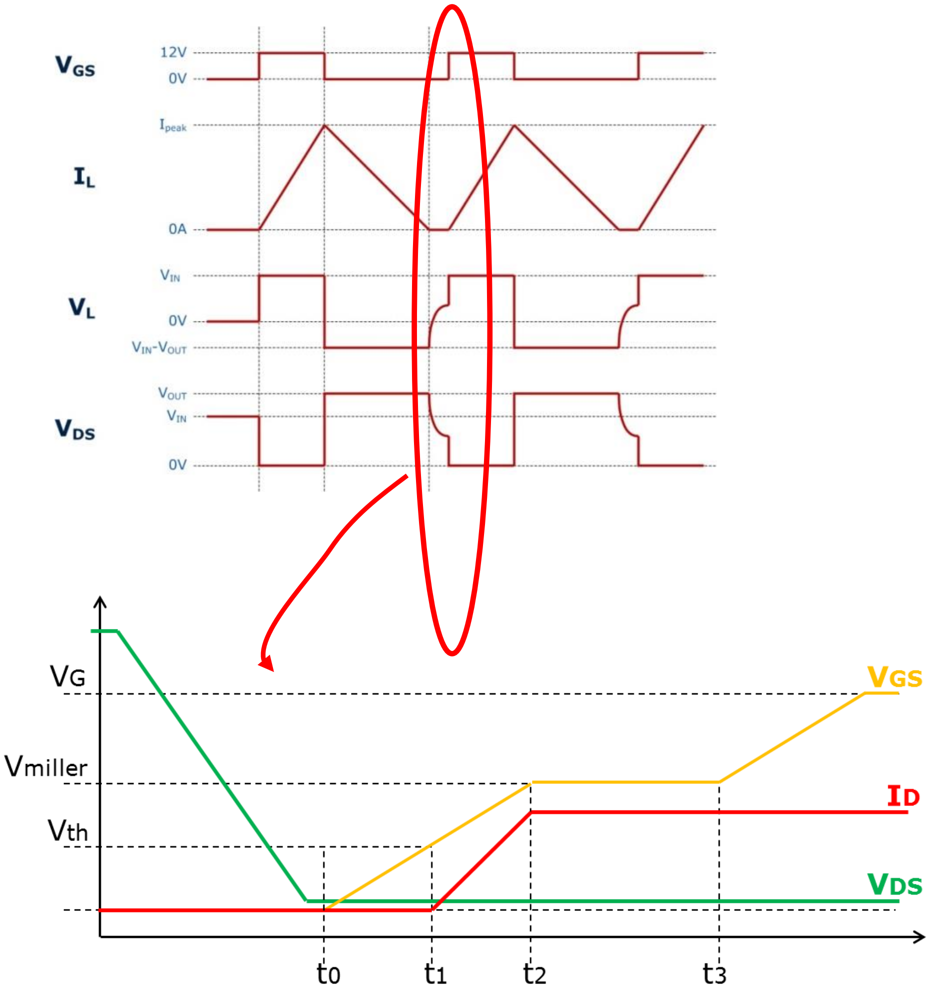
Quasi-resonant control
One time switching

- MOSFET turned on once
- V_L oscillates once the inductor current reaches zero
  - Frequency depends on main inductance and MOSFET output capacitance
  - High voltage oscillation that is easy to detect (ZCD)
    - Inductive coupling
    - Capacitive coupling
- ZCD circuits don't measure the actual inductor current!





Quasi-resonant control
Valley switching

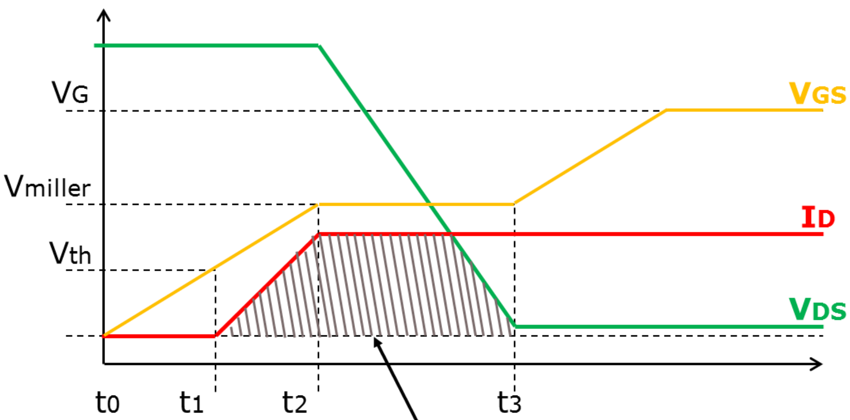


No Switching Loss
(area under the curve between ID and VDS)

- Wait for V_{DS} to fall when output current is fully discharged.
- Start the next switching cycle at the "valley"
- Known as "valley switching" or "soft switching"
- V_{DS} is ringing due to second order system behavior (LC)
- The lower the valley, the lower the switching loss

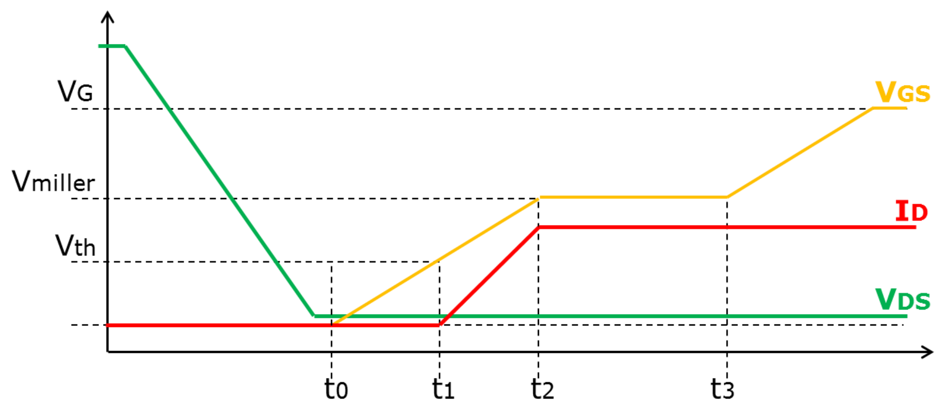
Quasi-resonant control
Hard switching vs soft switching

› Hard switching



Switching Loss
(area under the curve between I_D and V_{DS})

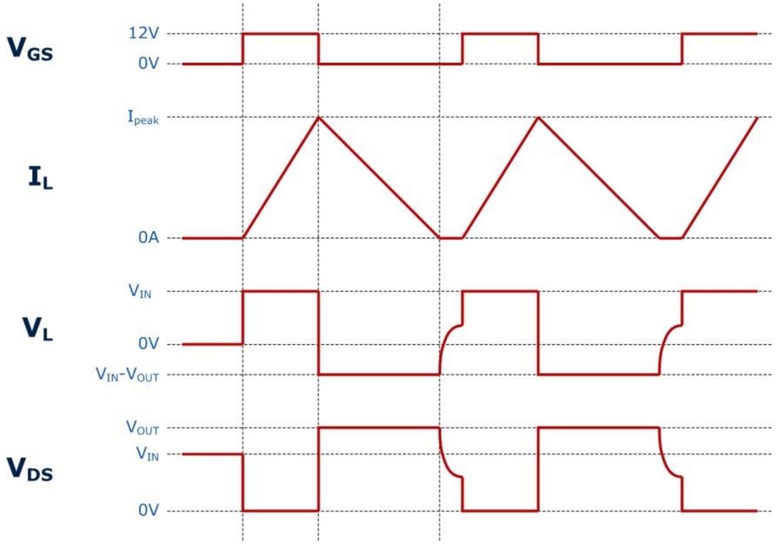
› Soft switching



No Switching Loss
(area under the curve between I_D and V_{DS})

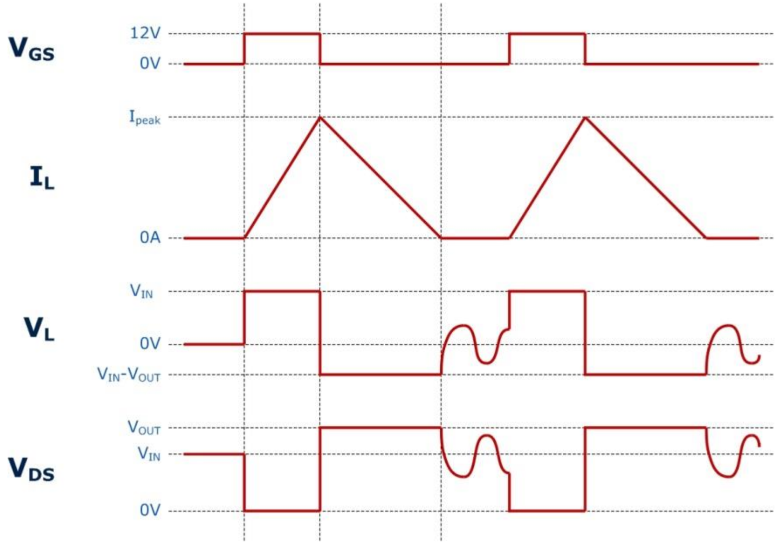
Quasi-resonant control
Valley skipping

- QR 1st valley



- MOSFET turned on at the first lowest point of V_{DS} oscillation
  - MOSFET turn-on loss minimized to lowest possible level

- QR 2nd valley



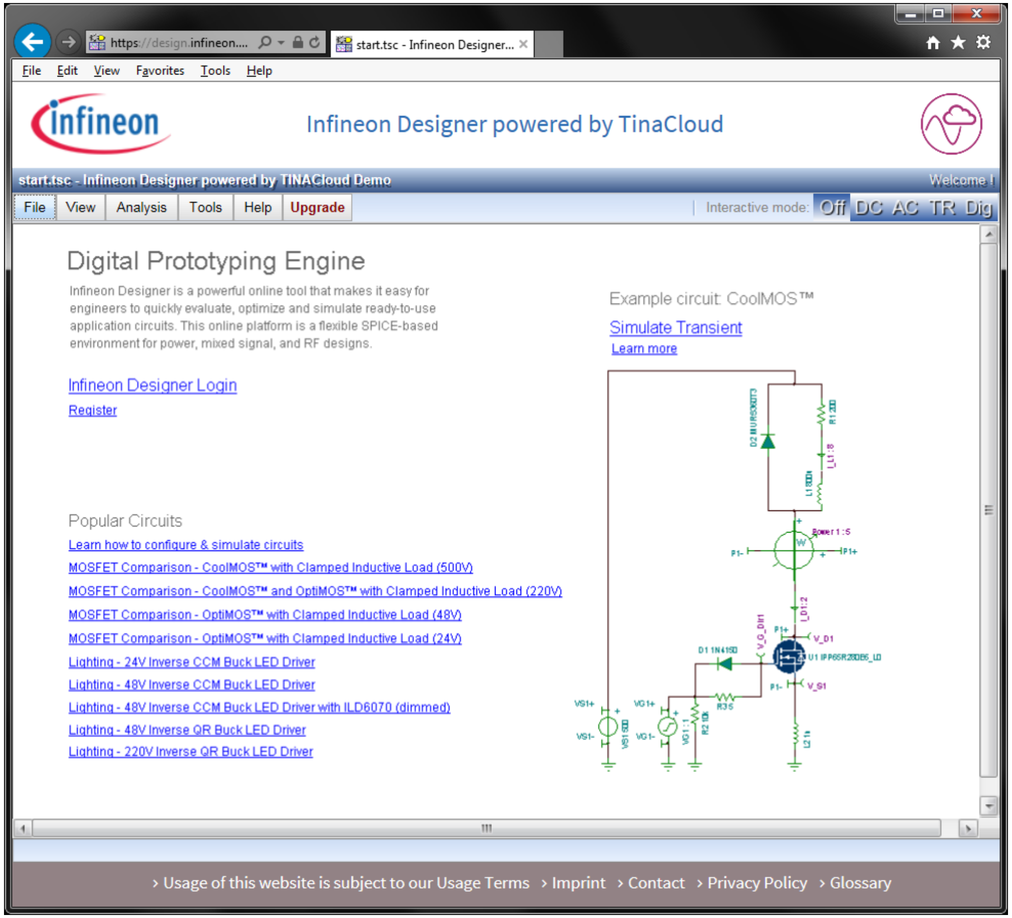
- MOSFET turned on at the second lowest point of V_{DS} oscillation
  - MOSFET turn-on loss minimized
  - Switching frequency reduced

Agenda

Infineon Designer
Digital prototyping engine

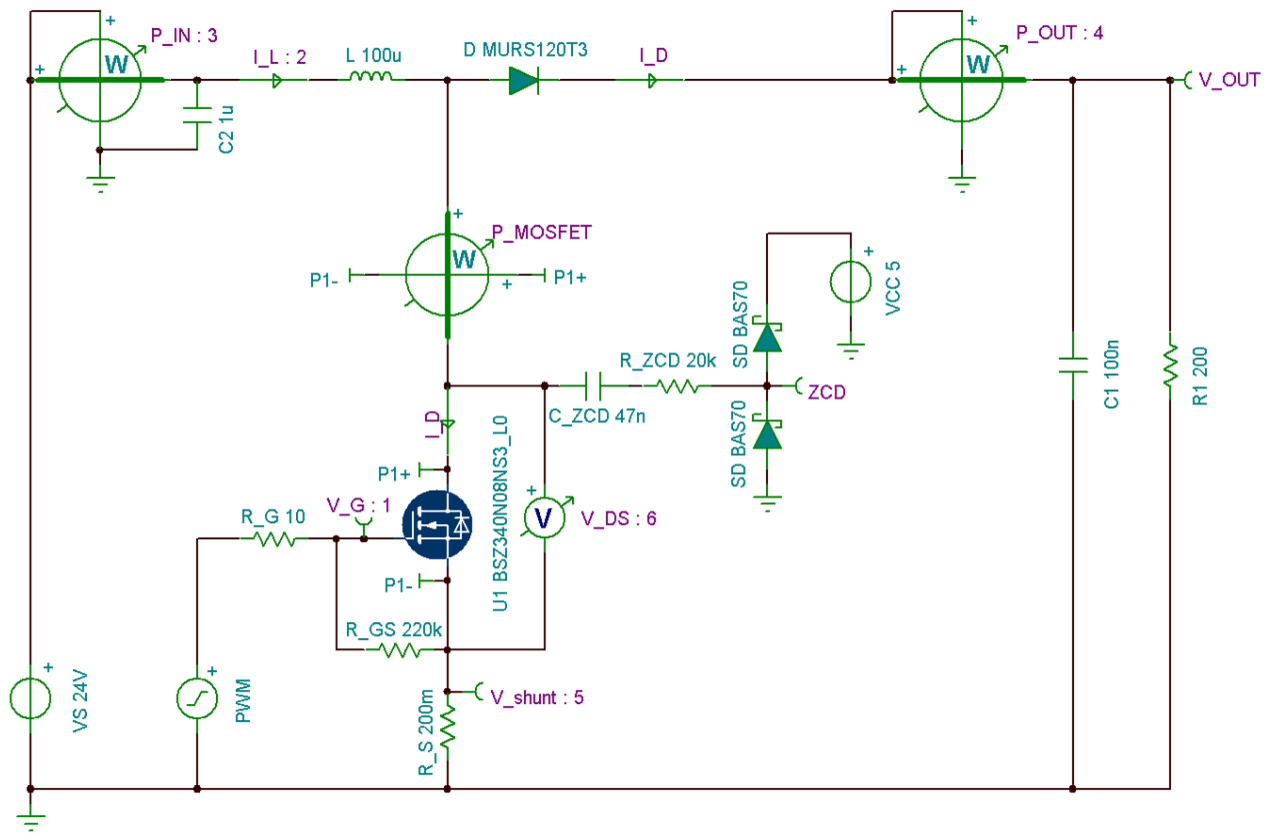
- Features
  - Circuit design
  - Circuit behavior (simulation)
  - Sharing
  - No hassle

- Infineon Designer is available to everyone: **www.infineon.com/ifxdesigner** *(login with MyInfineon account)*



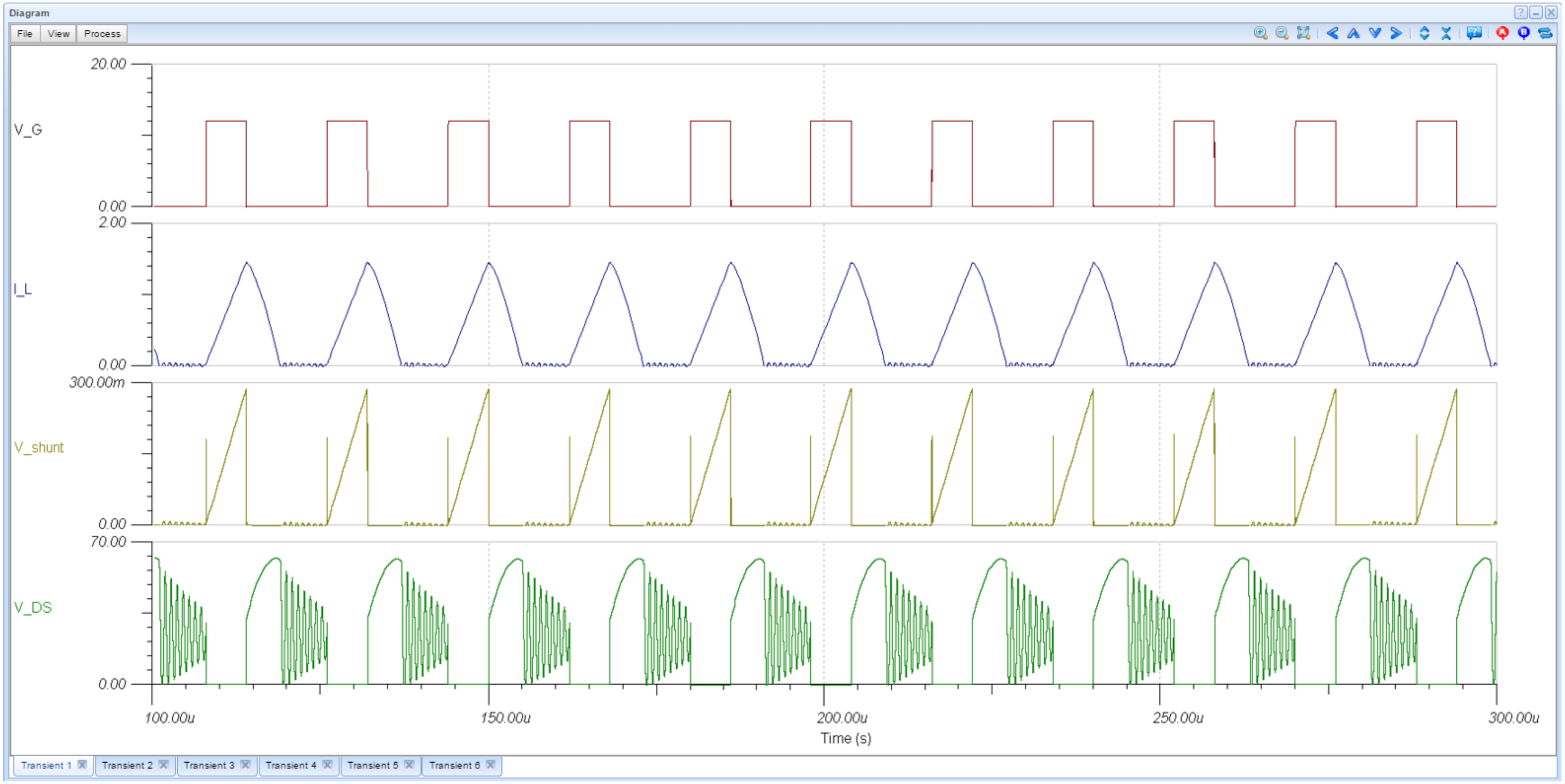
Infineon Designer
Boost converter

- BSZ340N08NS3 G (OptiMOS™)
- MURS120T3G
  - Ultrafast recovery diode



Infineon Designer
One time only

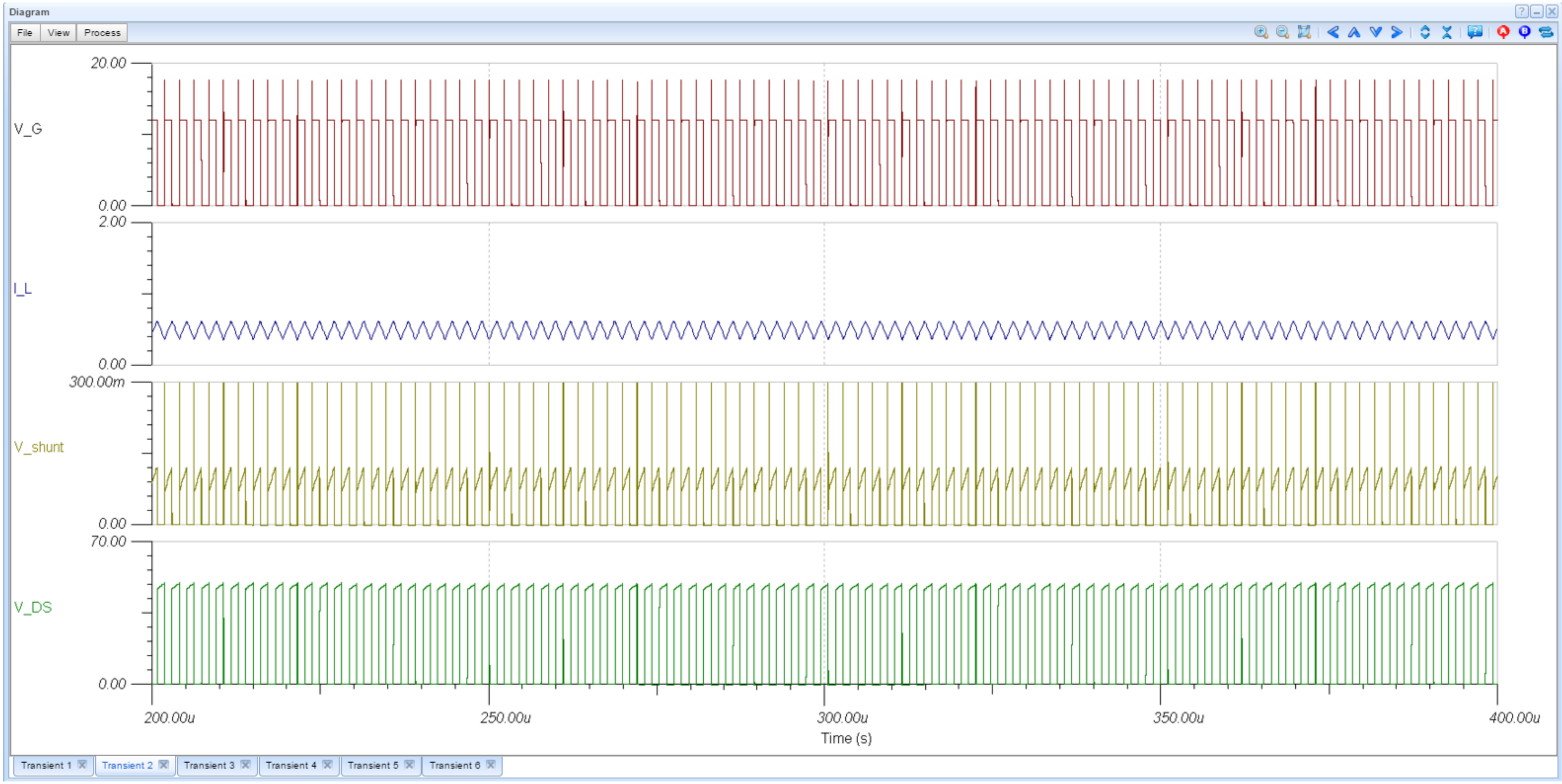
Efficiency: NA Frequency: 56 kHz



power_optimos_24V_boost_1_onetime.tsc

Infineon Designer
Continuous conduction mode

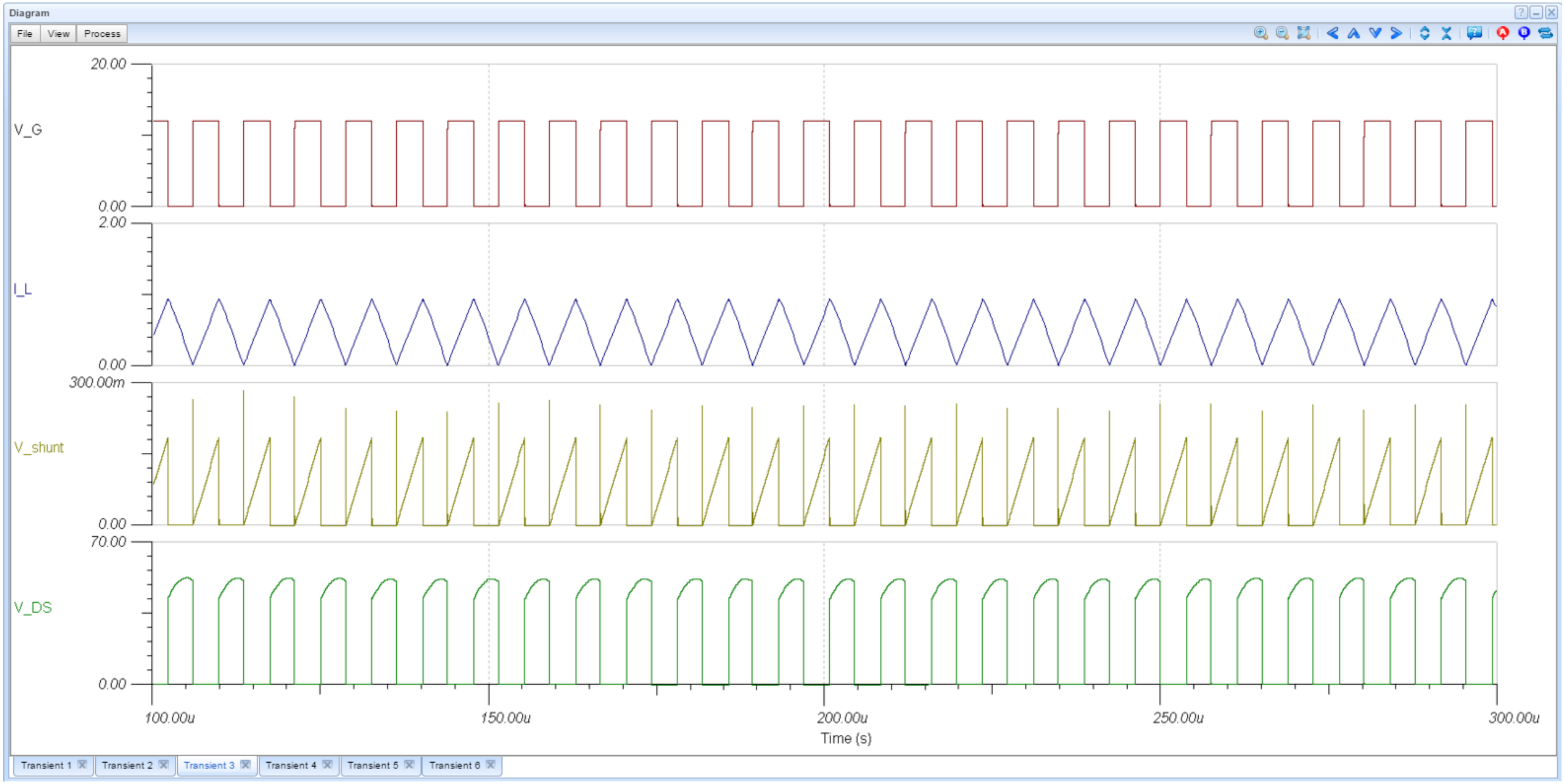
Efficiency: 92.7% Frequency: 456 kHz Large spikes



power_optimos_24V_boost_2_CCM.tsc

Infineon Designer
Critical conduction mode

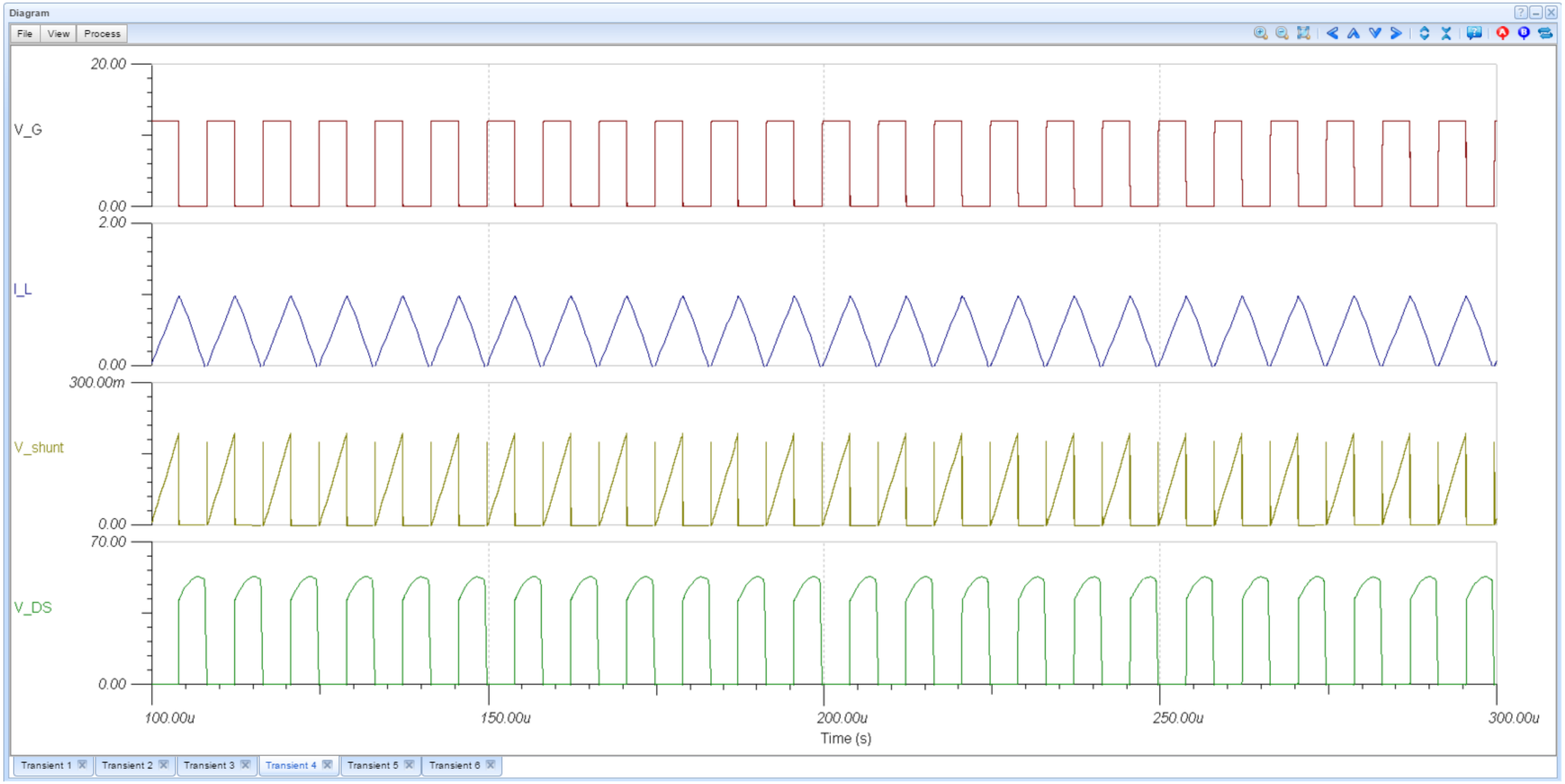
Efficiency: 97.6% Frequency: 132 kHz Medium-sized spikes



power_optimos_24V_boost_3_CrCM.tsc

Infineon Designer
Quasi-resonant conduction mode – 1st valley

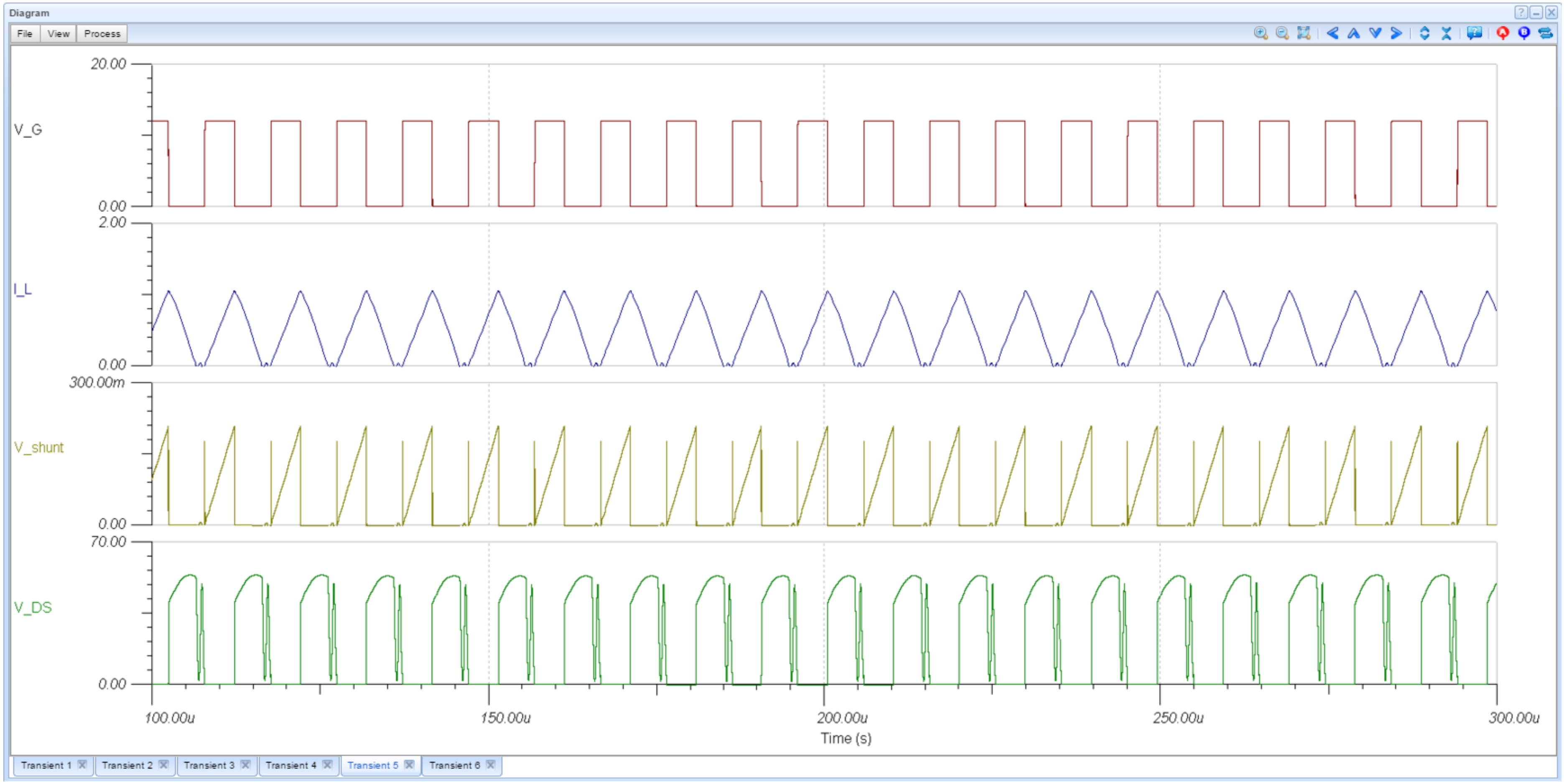
Efficiency: 97.9% Frequency: 120 kHz Small spikes



power_optimos_24V_boost_4_QR_1v.tsc

Infineon Designer
Quasi-resonant conduction mode – 2nd valley

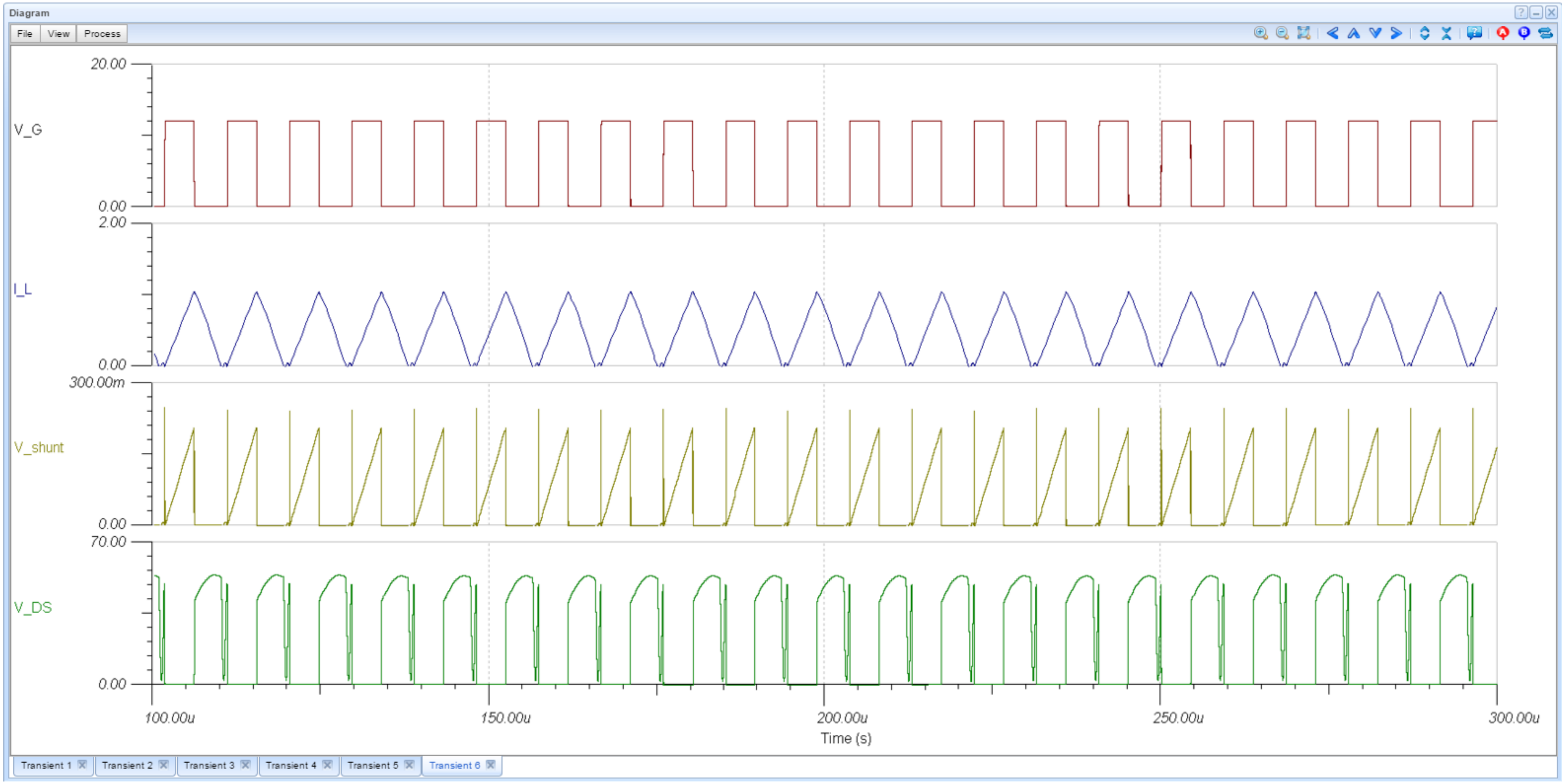
Efficiency: 97.9%   Frequency: 102 kHz   Small spikes



power_optimos_24V_boost_4_QR_2v.tsc

Infineon Designer
Discontinuous conduction mode

Efficiency: 97.5%   Frequency: 108 kHz   Medium-sized spikes



power_optimos_24V_boost_5_DCM.tsc

Infineon Designer – www.infineon.com/ifxdesigner
Different conduction modes

Mode	Effic.	Freq.	Link
One time	NA	56 kHz	power_optimos_24V_boost_1_onetime.tsc
CCM	92.7%	456 kHz	power_optimos_24V_boost_2_CCM.tsc
CrCM	97.6%	132 kHz	power_optimos_24V_boost_3_CrCM.tsc
QR-1	97.9%	120 kHz	power_optimos_24V_boost_4_QR_1v.tsc
QR-2	97.9%	102 kHz	power_optimos_24V_boost_4_QR_2v.tsc
DCM	97.5%	108 kHz	power_optimos_24V_boost_5_DCM.tsc

Agenda

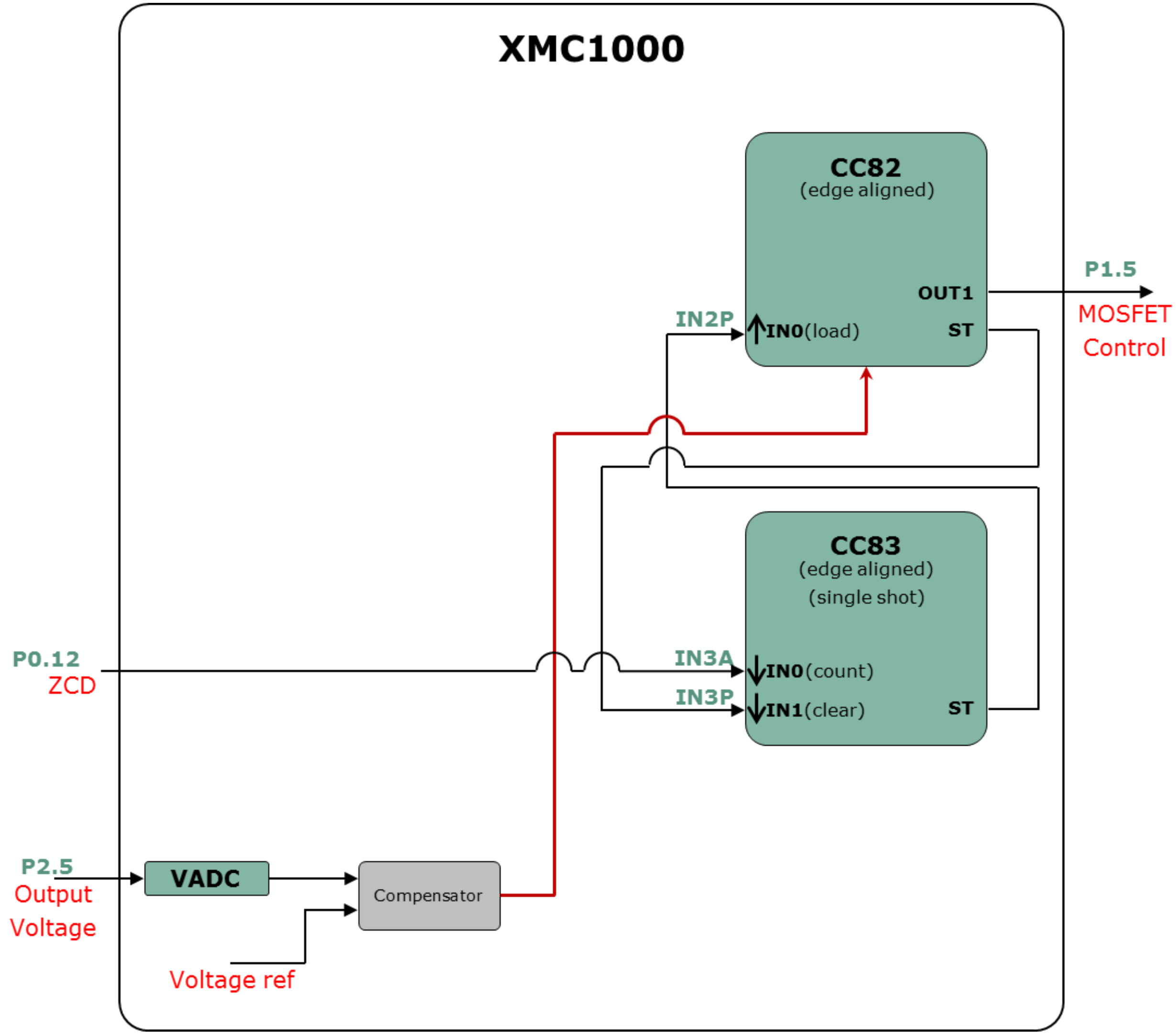
XMC1000 implementation
Quasi-resonant control

- XMC1000 peripherals + interconnects for quasi-resonant control
  - CCU8/CCU4, ACMP, ERU, BCCU
  - Fully hardware dependent: minimum CPU load
  - Full functionality including valley skipping, leading edge blanking

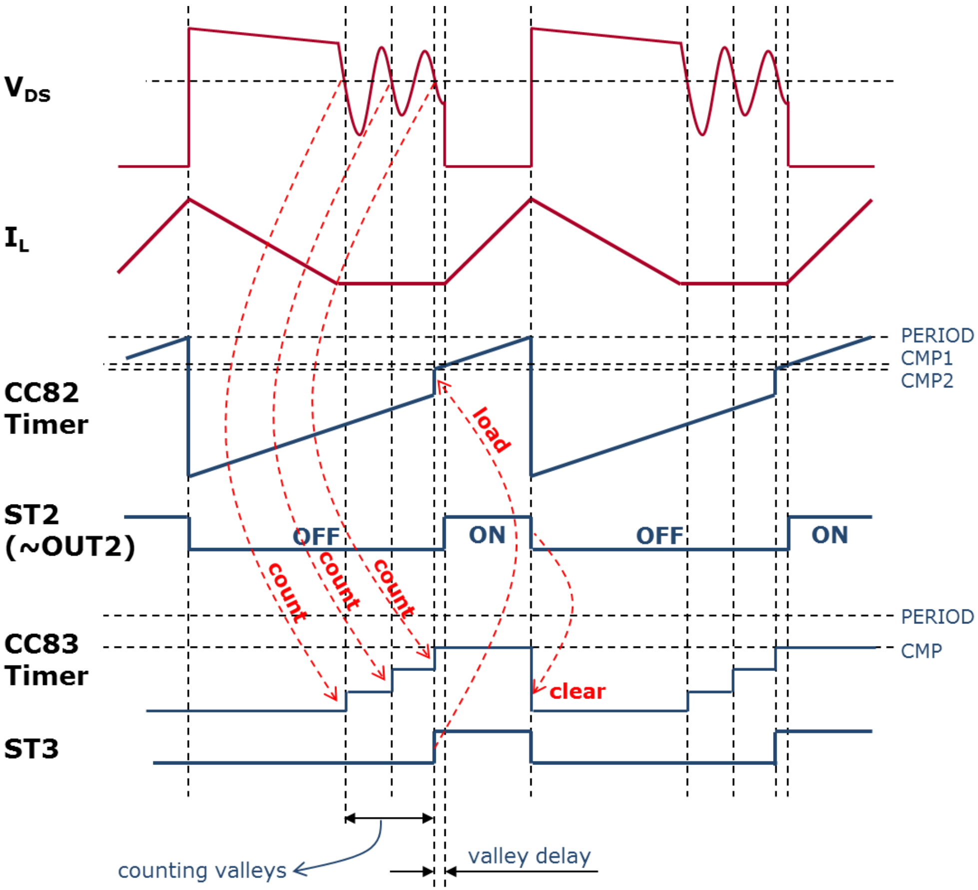
- Constant ON-time (CON)
  - ON-time is proportional to the amount of power transfer

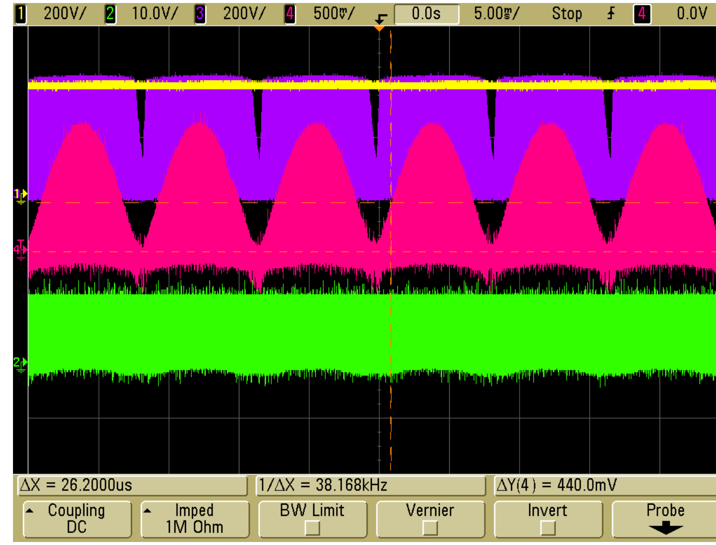
- Peak current control (PCC)
  - Twofold functionality: power transfer and protection
  - Dynamic OCP

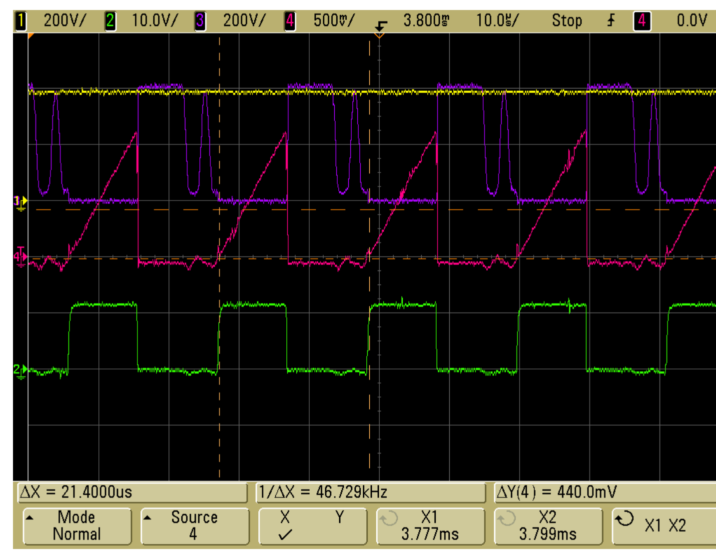
XMC1000 implementation
QR CON



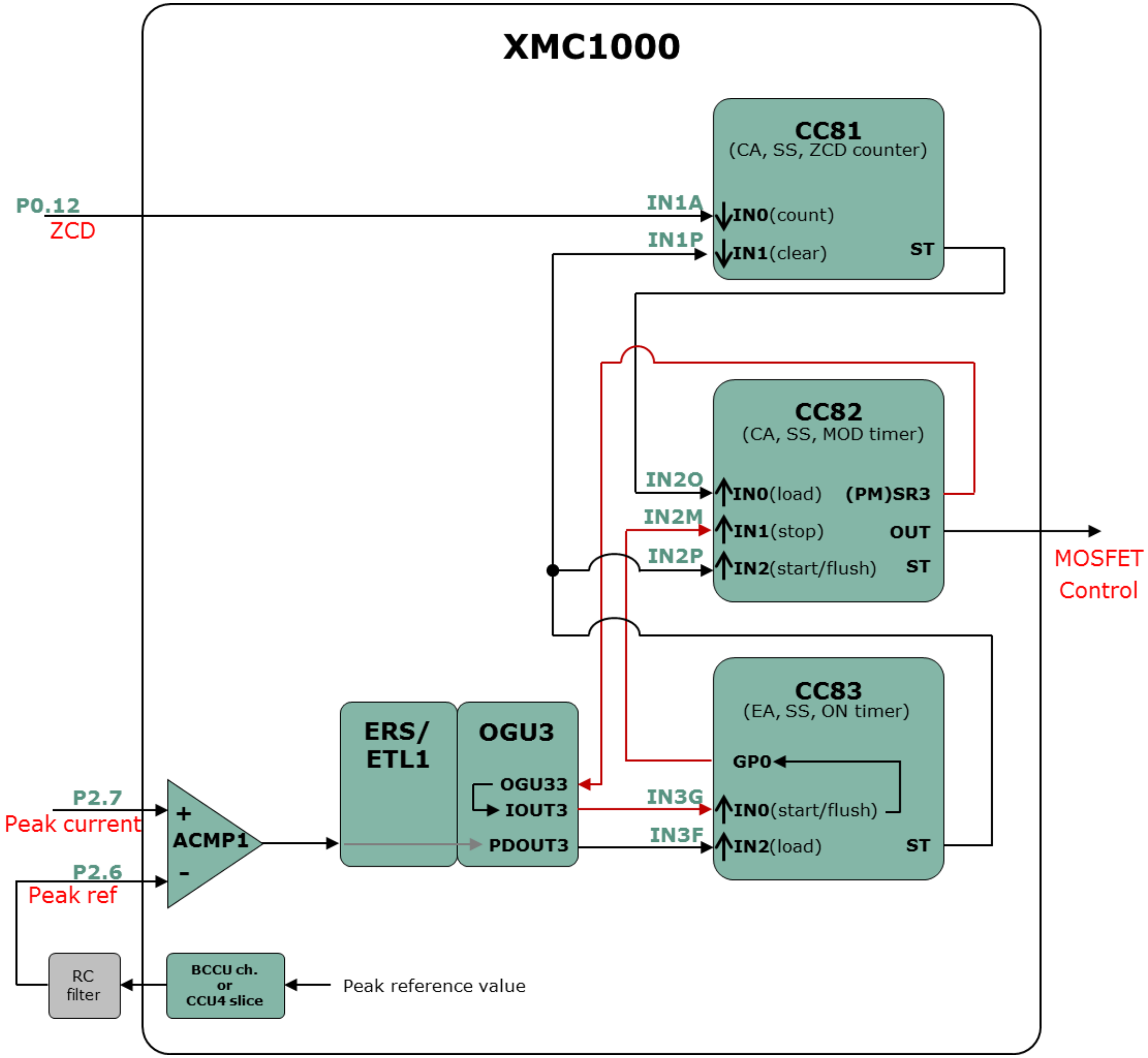
XMC1000 implementation
QR CON



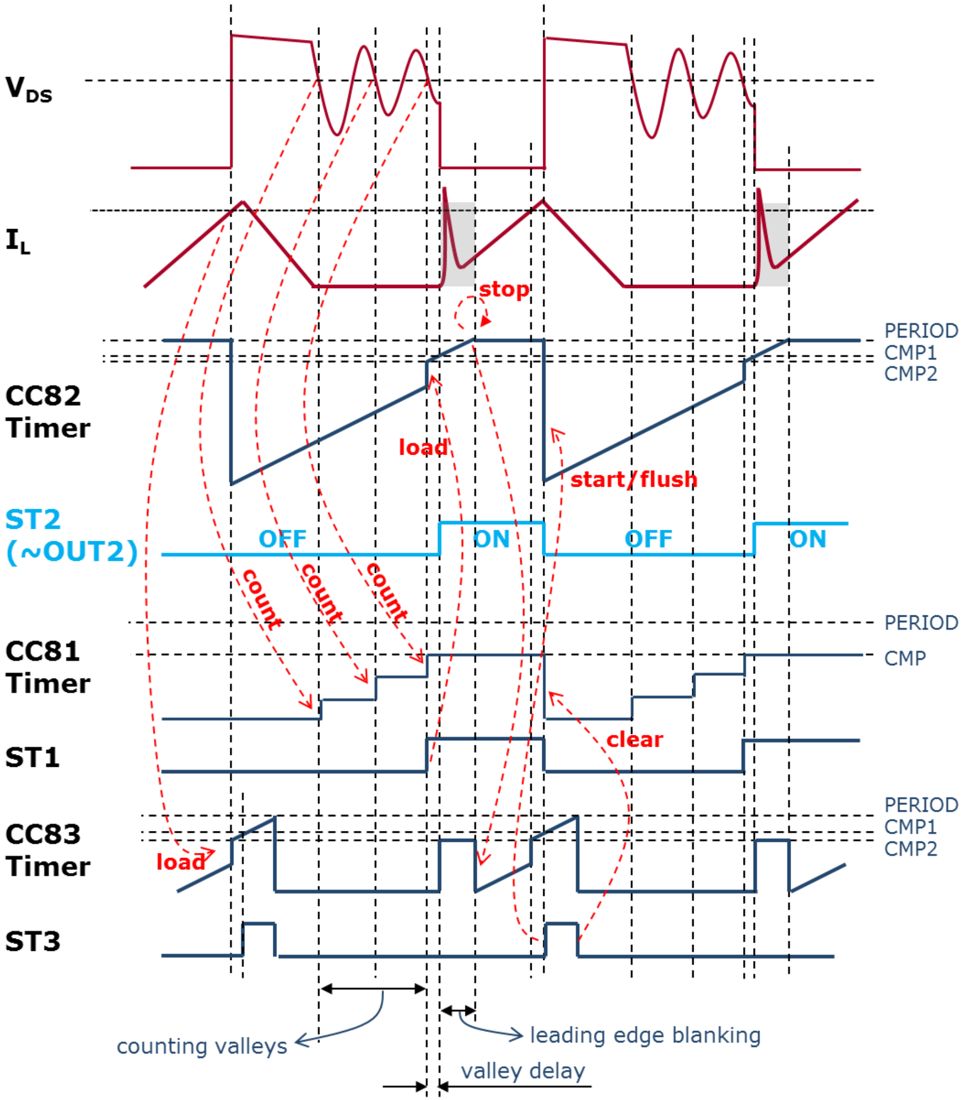


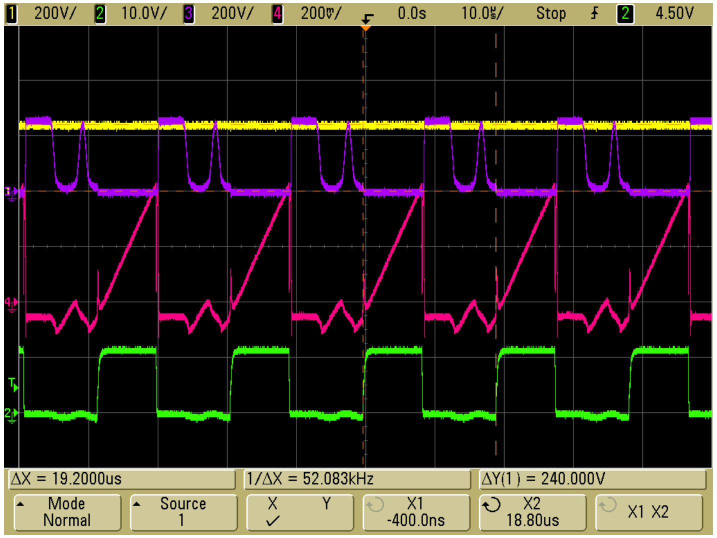


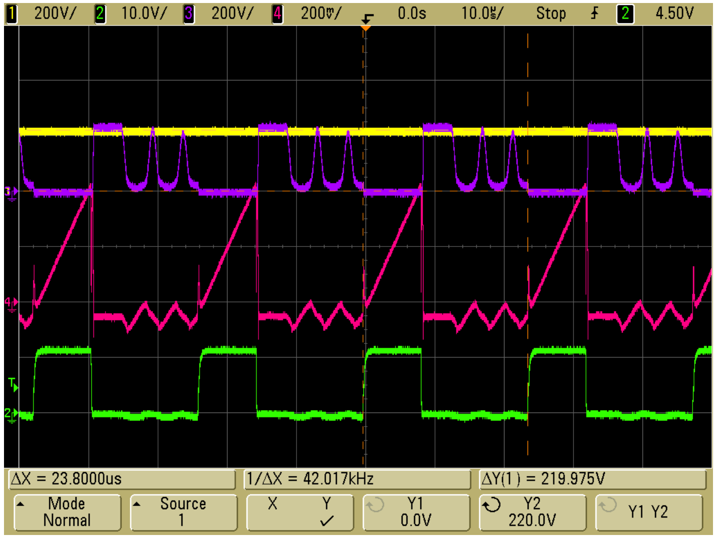
XMC1000 implementation
QR PCC



XMC1000 implementation
QR PCC

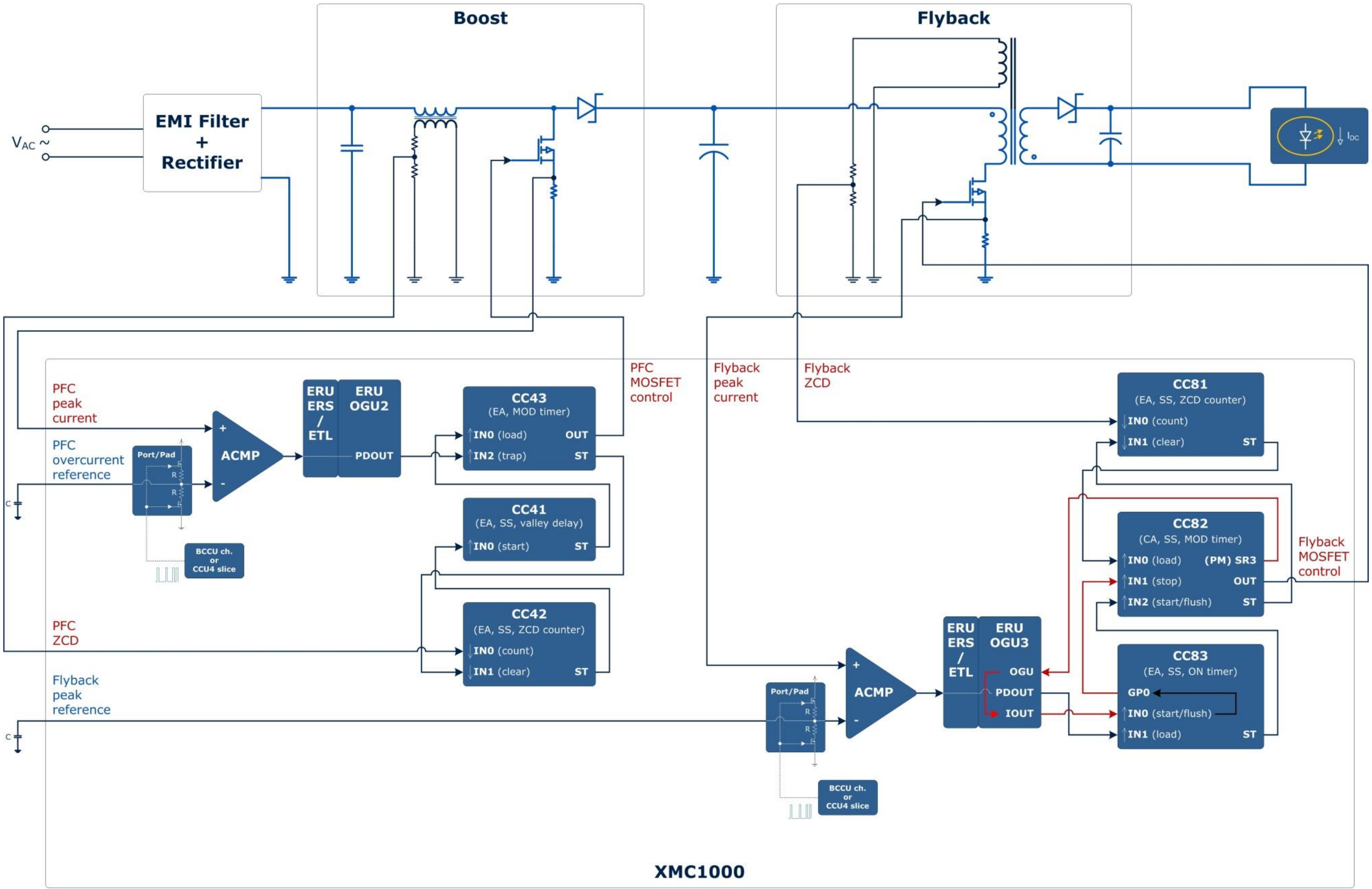




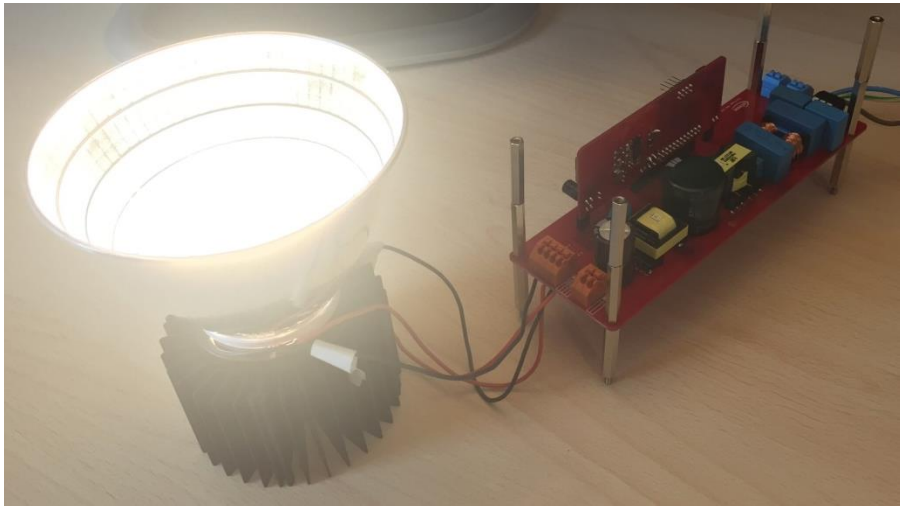


Agenda

Demo board
Two-stage LED ballast with XMC1300



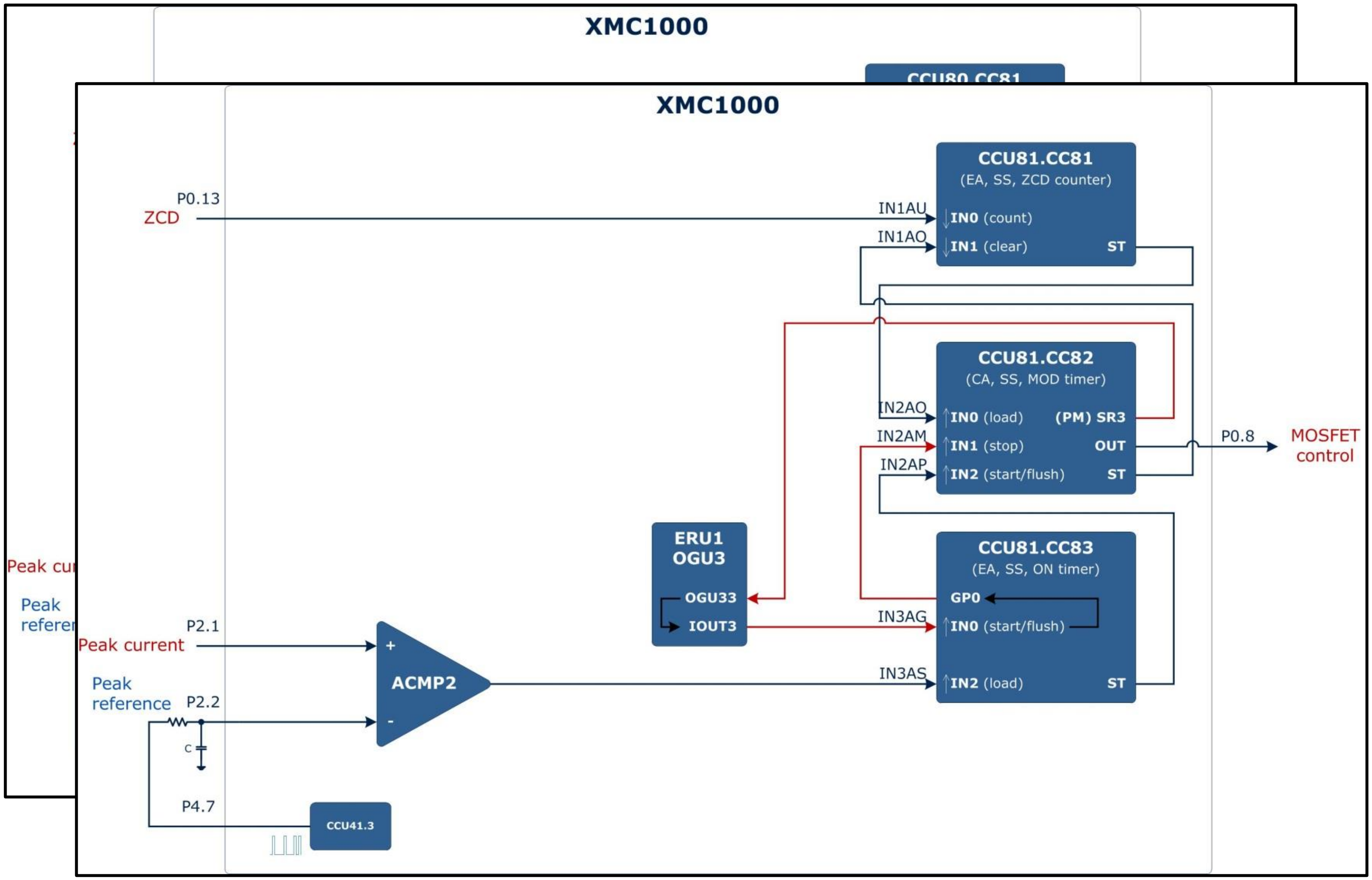
Demo board
Two-stage LED ballast with XMC1300



- Specification:
  - Rated power = 40 W
  - Input voltage = 90 V_{AC} to 277 V_{AC}
  - Output voltage = 60 V_{DC} max
  - Output current = 1 A max

- Two-stage LED ballast:
  - AC/DC boost PFC for power factor correction
  - DC/DC flyback for LED current and dimming control
- Quasi-resonant constant ON-time on PFC boost
- Quasi-resonant peak current control on flyback
- Tuneable white LED light
- Communication:
  - DALI, 10 V dimming, LEDset

Virtual designs
QR buck LED driver with XMC1400



Support material:

Collaterals and Brochures (Document, Info)	› Product Briefs › Selection Guides › Application Brochures › Presentations › Press Releases, Ads	› www.infineon.com/XMC
Technical Material (Tools, Evaluation Board)	› Application Notes › Technical Articles › Simulation Models › Datasheets, MCDS Files › PCB Design Data	› www.infineon.com/XMC › Kits and Boards › DAVE™ › Software and Tool Ecosystem
Videos (Play)	› Technical Videos › Product Information Videos	› Infineon Media Center › XMC Mediathek
Contact (Support)	› Forums › Product Support	› Infineon Forums › Technical Assistance Center (TAC)

Glossary abbreviations

› CON	Constant ON-time
› DAVE™	Free development IDE for XMC™
› OCP	Over Current Protection
› PCC	Peak Current Control
› PF	Power Factor
› PFC	Power Factor Correction
› PWM	Pulse Width Modulation
› QR	Quasi Resonant
› SMPS	Switched-Mode Power Supplies
› THD	Total Harmonics Distortion
› ZCD	Zero Crossing Detection

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