Primary-side regulation Controllers

October 2015

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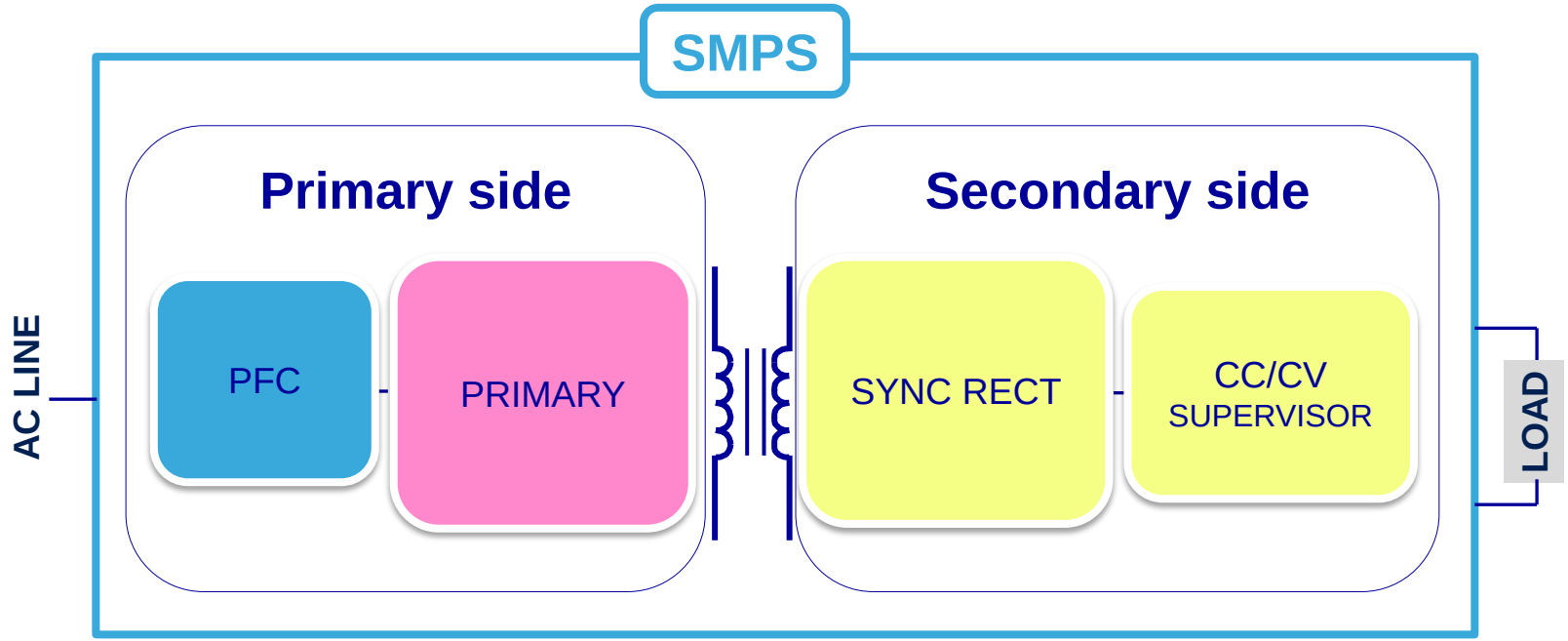
Contents

PRIMARY-SIDE REGULATION Controllers

- Functions and applications
- PSR controllers topologies and ST solutions



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Main applications

Computer peripherals

- Workstations
- Desktop PCs
- Servers
- Printers

Industrial

- SMPSs
- Home appliances – White goods
- Metering SMPSs

Consumer

- Games
- Flat panel TVs
- Set-top boxes
- AC-DC adapters

LED lighting

- LED signage
- Street lighting

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Competitive advantages

Robustness and reliability

- Advanced protection features integrated
- Output overvoltage, brownout detection, inductor saturation detection, and feedback loop disconnection

Regulation

- Blue Angel, Energy Star, EU Code of Conduct, DOE compliant

Easy design

- Perfect synergy with ST PFC controllers for all topologies: flyback, quasi-resonant, resonant and half-bridge
- Full support and tools available

WW reference

- L6599A LLC resonant controller recognized as worldwide reference

PSR controller topologies & portfolio

LLC resonant asymmetrical HB	• L6699 • L6599A/AT/AF • L6591 • L6598	SO16 DIP16, SO16 SO16 DIP16, SO16
Quasi-resonant	• L6566A/B/BH • L6565	SO16 DIP8, SO8
PWM FF	• L6668 • L6566A/B/BH • SG3524, SG3525 • UC384 2B/3B/4B/5B • L5991, L5991A	SO16 SO16 DIP16, SO16 SO8, DIP8 DIP16, SO16

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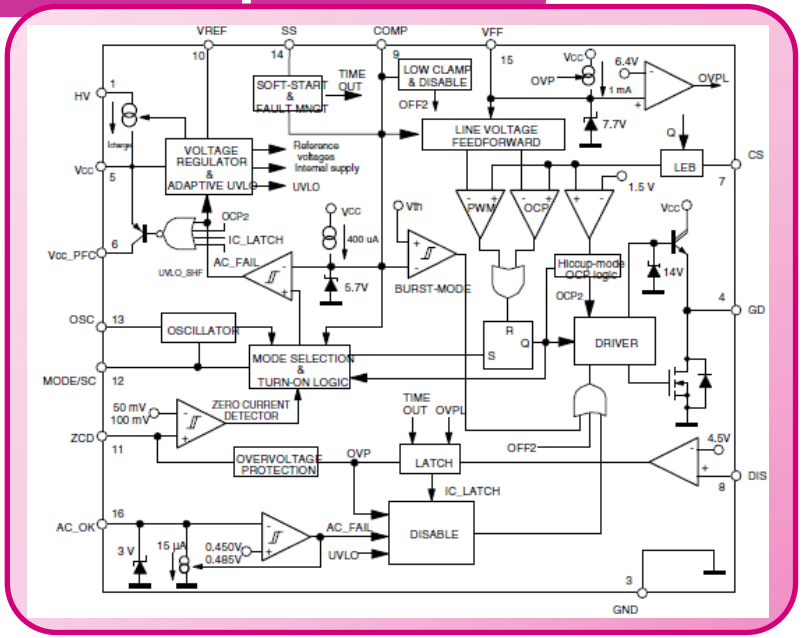
L6566A multi-mode controller

L6566A

16 pins



APPLICATIONS

- AC-DC adapters/chargers
- Notebook, TV and LCD monitor adapters
- Consumer appliances (DVD players, set-top boxes,..)
- IT equipment, games
- Server auxiliary power supplies
- Metering SMPS

FEATURES

L6566A → For SMPSs with PFC front-end

- Selectable multi-mode operation: fixed frequency or quasi-resonant
- On-board 700 V high-voltage startup
- Advanced light load management
- Low quiescent current (< 3 mA)
- Adaptive UVLO
- Line feed-forward for constant power capability vs. mains voltage
- Pulse-by-pulse OCP, shutdown on overload (latched or auto-restart)
- Transformer saturation detection
- Switched supply rail for PFC controller
- Latched or auto-restart OVP
- Brownout protection
- -600/+800 mA totem pole gate-driver with active pull-down during UVLO
- Package: SO16

APPLICATION NOTES & EVALUATION BOARDS

- AN2690: 19 V - 75 W adapter with pre-regulator PFC using the L6563 and the L6566A
- AN2941: 19 V - 75 W SMPS compliant with latest ENERGY STAR® criteria using the L6563S and the L6566A
- EVL6566A-75WES4: 19 V - 75 W SMPS compliant with latest Energy Star criteria using the L6563 and the L6566A
- EVL6566A-75WADP: 19 V - 75 W laptop adapter with tracking boost PFC pre-regulator, using the L6563 and the L6566A

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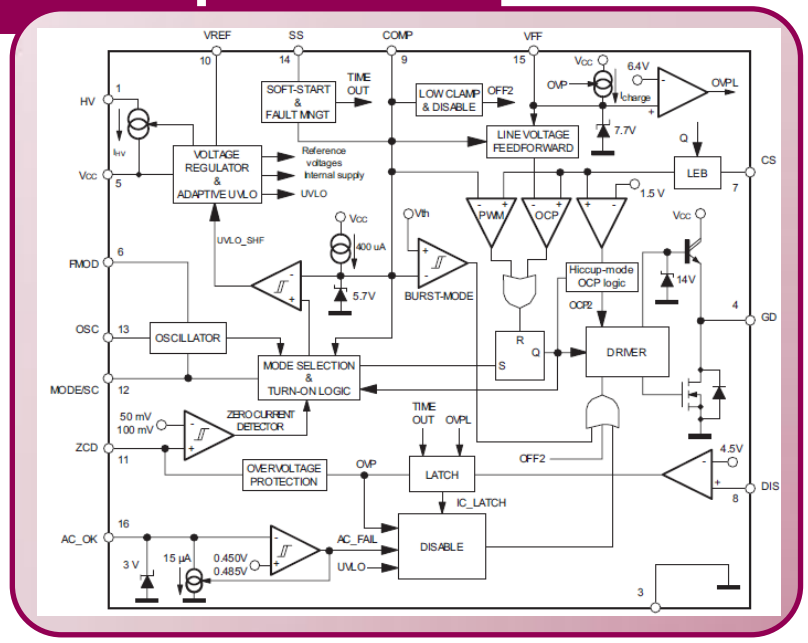
L6566B/BH multi-mode controllers

L6566B/BH
16 pins



FEATURES

L6566B → for single-stage SMPS
Recommended for power supplies below 75 W

- Same features and functions as L6566A plus:
- **Programmable frequency modulation for EMI reduction**

L6566BH → for single-stage SMPS
Recommended for power supplies below 75 W

- Same features and functions as L6566B plus:
- **On-board 840 V high-voltage startup**

APPLICATIONS

- AC-DC adapters/chargers
- TV and LCD monitor adapters
- Consumer appliances (DVD players, set-top boxes,..)
- IT equipment, games
- Server auxiliary power supplies
- Metering SMPS

APPLICATION NOTES & EVALUATION BOARDS

- AN3089: 19 V - 65 W quasi-resonant flyback adapter using L6566B and TSM1014
- AN4248: 60 W PSU design details for water purifier system
- STEVAL-ISA161V1: Evaluation board for the SEA01 constant voltage and current controller with online digital trimming
- EVL6566B-65W-SR: 12 V - 65 W FF flyback adapter with synchronous rectification featuring L6566B, STSR30 and SEA05L
- EVL6566B-40WSTB: 40 W wide input range flyback converter using L6566BH Multimode controller for SMPS
- EVL6566B-65W-QR: 19 V - 65 W quasi-resonant flyback adapter board

QR operating modes

Burst Mode @ No Load

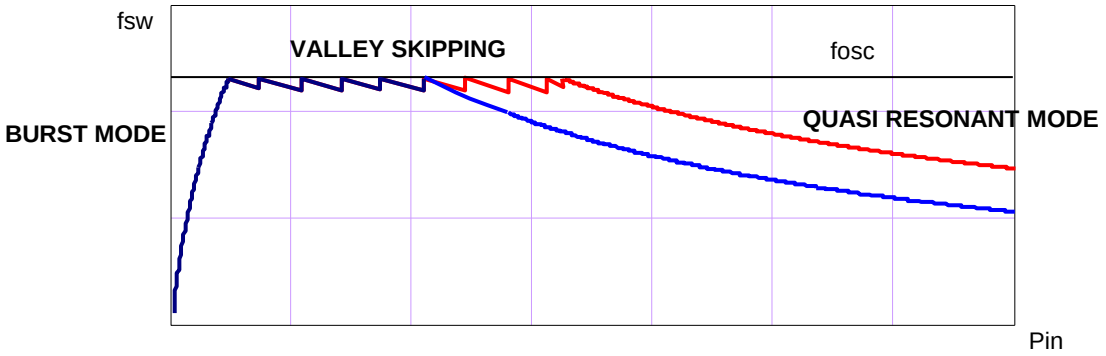
- Most switching cycles are skipped
- Average frequency reduction
- Constant peak switch current
- Threshold can be adjusted to get noise-free operation
- Very low stand-by consumption
- No audible noise (low peak current)

Valley Skipping @ Light Load

- Frequency does not exceed an externally programmed value
- Benefit on switching losses
- MOSFET turn-on always occurs on drain oscillation valleys to minimize losses and noise

Quasi-resonant @ Heavy Load

- Variable frequency operation
- Possible to achieve ZVS
- Low EMI (auto frequency jittering)
- Low capacitive losses (Coss + parasitic)



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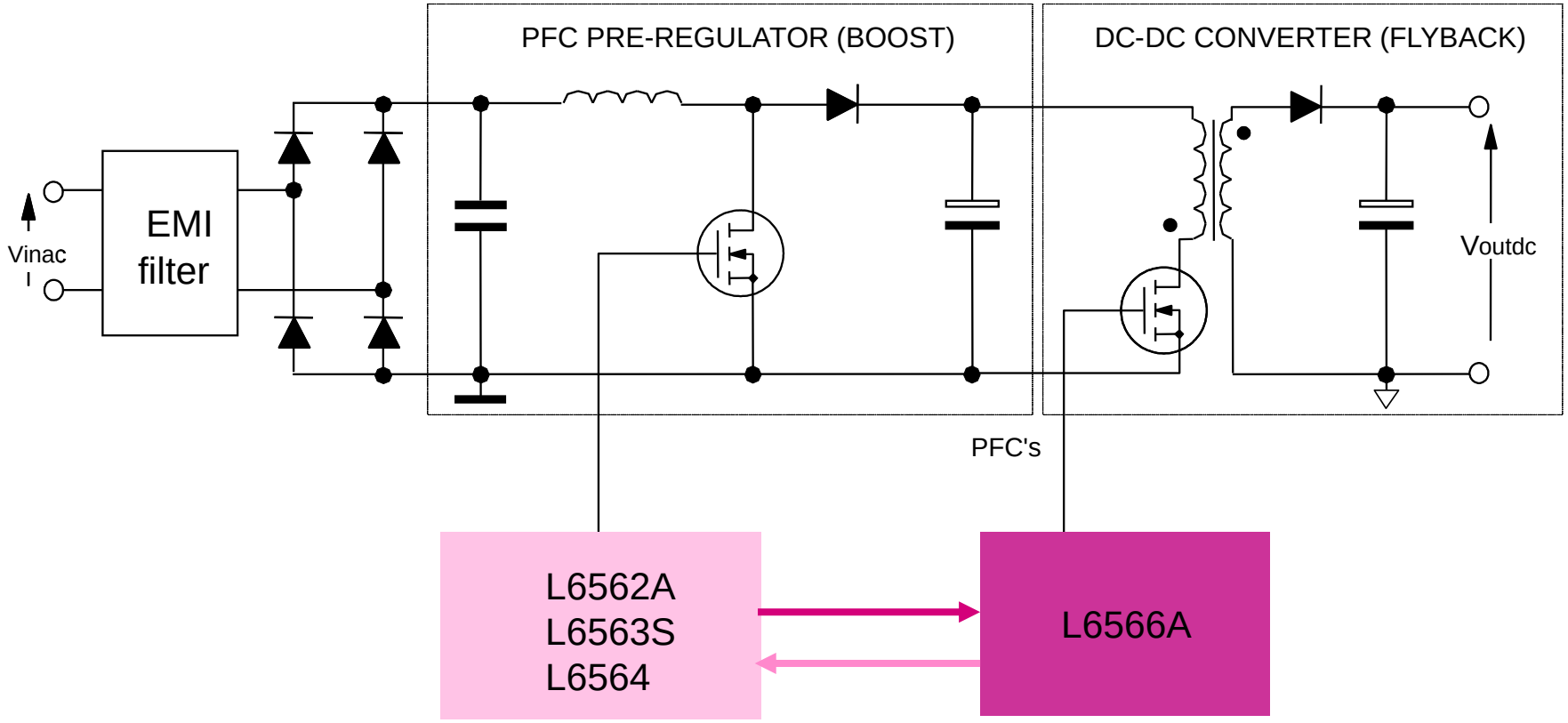
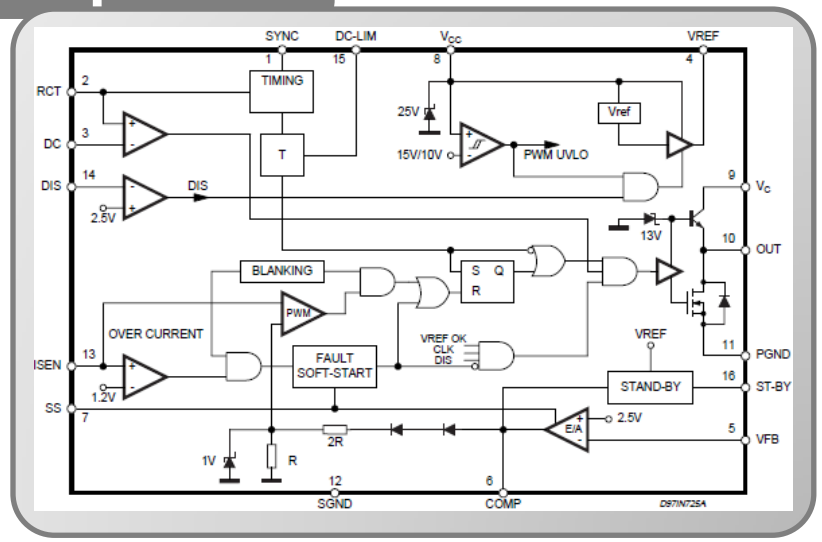
Typical QR schematic



L5991 PWM FF controllers

L5991/A
16 pins



FEATURES

- Current-mode control PWM
- Switching frequency up to 1 MHz
- Low start-up current (< 120 μA)
- High current output drive suitable for power MOSFET (1A)
- Fully latched PWM logic with double pulse suppression
- Programmable duty cycle
- 100% and 50% maximum duty cycle limit
- Standby function
- Programmable soft start
- Primary overcurrent fault detection with re-start delay
- PWM UVLO with hysteresis
- In/out synchronization
- Latched disable
- Internal 100 ns leading edge blanking of current sense
- Packages: SO16 and DIP16

APPLICATIONS

- Hi-end AC-DC adapters/chargers
- Desktop PCs, monitors, entry-level servers
- Telecom SMPS

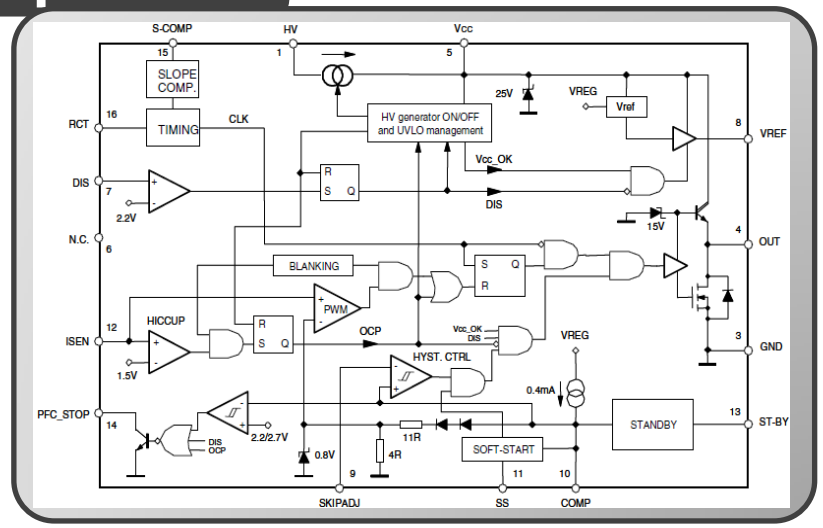
APPLICATION NOTES & EVALUATION BOARDS

- AN1049: Minimize power losses of lightly loaded flyback converters with the L5991 PWM controller
- AN1132: 90W SMPS for monitors with standby function
- AN1134: 45W AC-DC adapter with standby function
- AN1215: How to handle short circuit conditions with ST's advanced PWM controllers
- AN1537: A simple trick enhances L5991's standby function
- AN1620: 25W off-line autoranging battery charger with L5991A
- AN1621: 300W secondary controlled two-switch forward converter with L5991A
- AN1686: AN L5991-based converter with temporary extra power capability
- AN1842: 60W wide range power supply for LCD monitor or TV, using the L5991
- AN2131: High-power 3-phase auxiliary power supply design based on L5991 and ESBT STC08DE150
- AN2439: 27W Output power ultra wide range input flyback converter
- AN2623: Evaluation board for off-line forward converter based on L5991

L6668 PWM FF controllers

L6668

16 pins



FEATURES

- Load-dependent current-mode control: fixed frequency (heavy load), frequency fold-back (light load), burst-mode (no-load)
- On-board high-voltage start-up
- Improved standby function
- Low quiescent current (< 2 mA)
- Slope compensation
- Pulse-by-pulse and hiccup-mode OCP
- Interface with PFC controller
- Disable function (on/off control)
- Latched disable for OVT/OTP function
- Programmable soft-start
- Reference voltage with 2% precision externally available
- ±800 mA totem pole gate driver with internal clamp and UVLO pull-down
- Package: SO16

APPLICATIONS

- Hi-end AC-DC adapters/chargers
- TV monitors
- Digital consumer goods

APPLICATION NOTES & EVALUATION BOARDS

- AN2242: Reference design: high performance, L6668-based flyback converter for set-top boxes and PVRs
- AN2432: EVALSTSR30-60W: 60W AC-DC adapter with synchronous rectification using L6668 and STSR30
- AN2600: SMPS for high-end PVR based on L6668
- EVAL6668-STB: Reference design: high performance, L6668-based flyback converter for set-top boxes and PVRs

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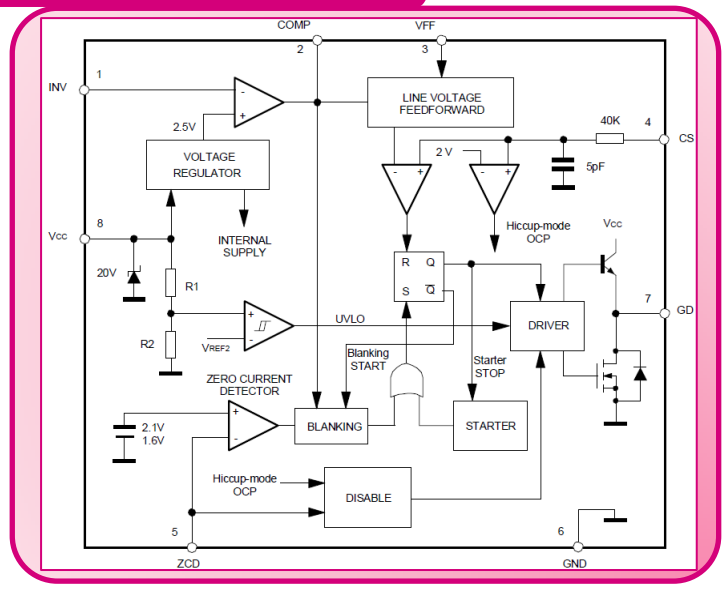
L6565 QR controllers

L6565
8 pins



FEATURES

- Quasi-resonant (QR) Zero Voltage Switching (ZVS)
- Line feed forward to deliver constant power vs. Mains change
- Frequency fold-back for optimum standby efficiency
- Pulse-by-pulse & Hiccup mode OCP
- Ultra-low start-up (< 70 µA) and quiescent current (< 3.5 mA)
- Disable function (on/off control)
- Internal voltage reference 1% precision (@ Tj = 25 °C)
- Totem pole gate driver with UVLO pull-down ±400 mA
- Packages: DIP8 and SO8

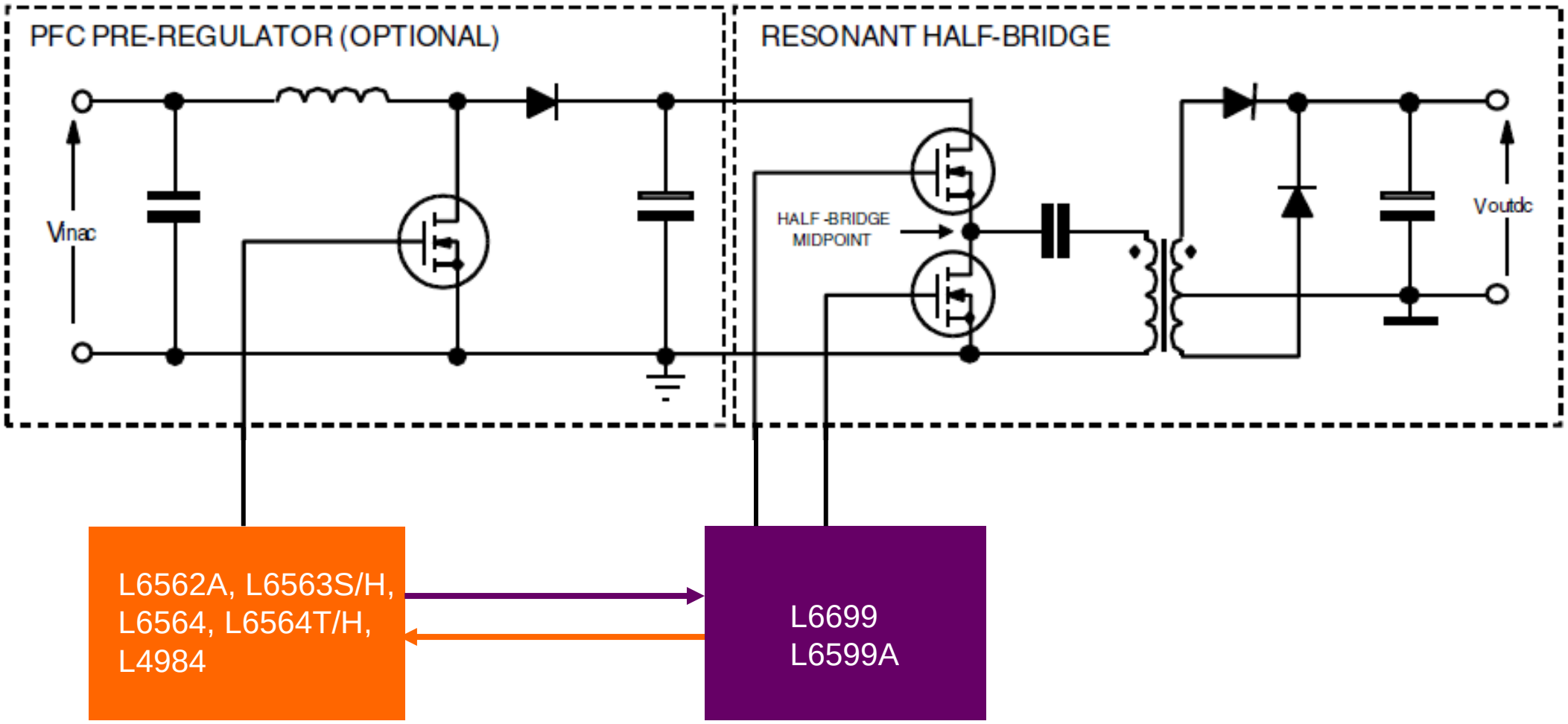
APPLICATIONS

- TV/monitor SMPS
- AC-DC adapters/chargers
- Digital consumer goods
- Printers and scanners

APPLICATION NOTES & EVALUATION BOARDS

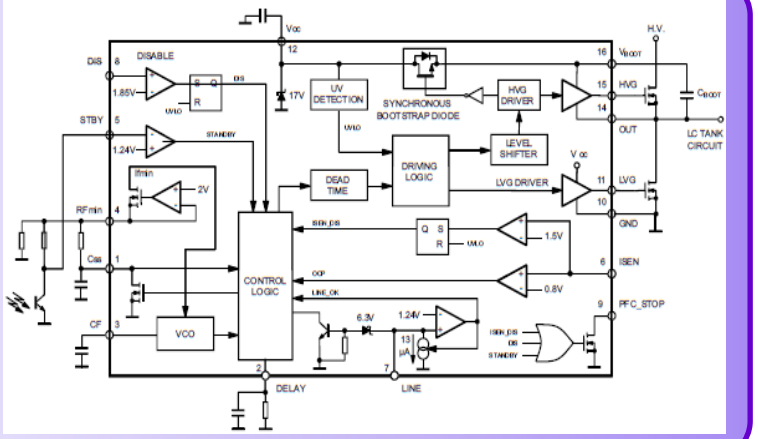
- AN1326: L6565 quasi-resonant controller
- AN1376: 25W quasi-resonant flyback converter for set-top box application using the L6565
- AN1439: 30 W AC-DC adapter with the L6565 quasi-resonant PWM controller
- AN1657: SMPS for CRT monitors with the L6565
- AN1729: L6565-based low cost SMPS for TV with less then 1W standby consumption
- AN2487: STEVAL-TSP001V1 power over Ethernet powered device demonstration board
- AN2528: Very wide input voltage range 6 W SMPS for metering
- AN2844: 15 W wide range SMPS for metering based on ESBT™ STC03DE220HV and L6565 PWM controller
- AN2936: 10 W SMPS with HV power MOSFET and L6565 for 3-phase industrial applications
- STEVAL-ISC001V1: 30 W AC-DC adapter based on the L6565

Typical LLC schematic



L6599A resonant controllers

L6599A
16 pins



FEATURES

L6599A

- 50% duty cycle, variable frequency control of resonant half bridge
- High-accuracy oscillator
- Up to 500 kHz operating frequency
- Two-level OCP: frequency-shift and latched shutdown
- Interface with PFC controller
- Latched disable input
- Burst mode operation at light load
- Input for power-on/off sequencing or brownout protection
- Non-linear soft-start for monotonic output voltage rise
- 600 V-rail compatible high-side gate driver with integrated bootstrap diode and high dv/dt immunity
- -300/800 mA high-side and low-side gate drivers with UVLO pull-down
- L6599A SIMPLIS and SPICE macro model available
- Packages: DIP16 and SO16

APPLICATIONS

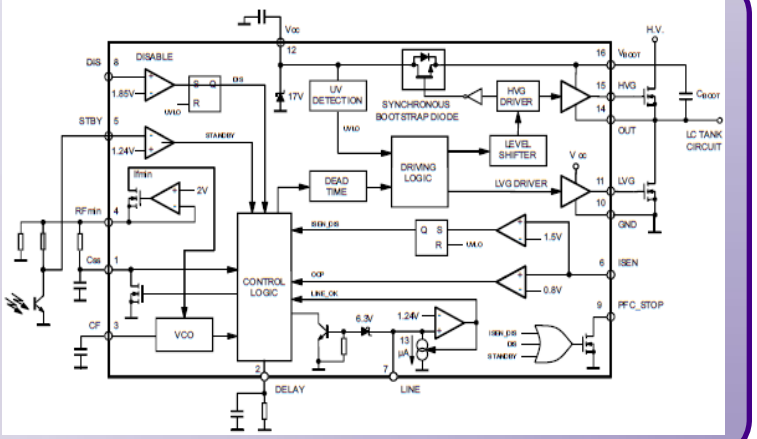
- LED drivers and street lighting
- Flat-panel TVs
- Desktop PCs and entry-level servers
- Telecom SMPS
- High efficiency industrial SMPS
- AC-DC adapters and open-frame SMPS

APPLICATION NOTES & EVALUATION BOARDS

- AN3014: 19 V, 90 W resonant converter with synchronous rectification using the L6563H, L6599A and SRK2000
- AN3172: 19 V - 90 W adapter with PFC for Laptop computers using the L6563H and L6599A
- AN3233: 12 V - 150 W resonant converter with synchronous rectification using the L6563H, L6599A, and SRK2000
- AN3329: 170 W power supply with PFC and standby supply for flat TV using the L6564, L6599A, and Viper27LN
- AN3339: 185 W power supply with PFC and standby supply for LED TV using the L6564, L6599A, and VIPER27LN
- STEVAL-ISA148V1: 19 V - 90 W adapter with PFC for laptop computers based on L6563H and L6599A
- EVL185W-LEDTV: 185 W power supply with PFC and standby supply for LED TV using the L6564, L6599A, and VIPER27L

L6599AT/AF resonant controllers

L6599AT/AF
16 pins



FEATURES

L6599AT

- Same features and functions as L6599A except:
- -300/700 mA high-side and low-side gate drivers with UVLO pull-down
- **Guaranteed over extended temperature range (-40 to 125 °C)**

L6599AF

- Same features and functions as L6599A except:
- -300/700 mA high-side and low-side gate drivers with UVLO pull-down
- **Guaranteed over super extended temperature range (-50 to 125 °C)**

APPLICATIONS

- LED drivers and street lighting
- Outdoor applications working at extreme temperatures

APPLICATION NOTES & EVALUATION BOARDS

- AN3014: 19 V, 90 W resonant converter with synchronous rectification using the L6563H, L6599A and SRK2000
- AN3172: 19 V - 90 W adapter with PFC for Laptop computers using the L6563H and L6599A
- AN3233: 12 V - 150 W resonant converter with synchronous rectification using the L6563H, L6599A, and SRK2000
- AN3329: 170 W power supply with PFC and standby supply for flat TV using the L6564, L6599A, and Viper27LN
- AN3339: 185 W power supply with PFC and standby supply for LED TV using the L6564, L6599A, and VIPER27LN
- AN3105: 48 V - 130 W high efficiency converter with PFC for LED street lighting applications - European version
- AN3106: 48 V - 130 W high-efficiency converter with PFC for LED street lighting applications
- EVL185W-LEDTV: 185 W power supply with PFC and standby supply for LED TV using the L6564, L6599A, and VIPER27L

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L6699 – LLC resonant controller

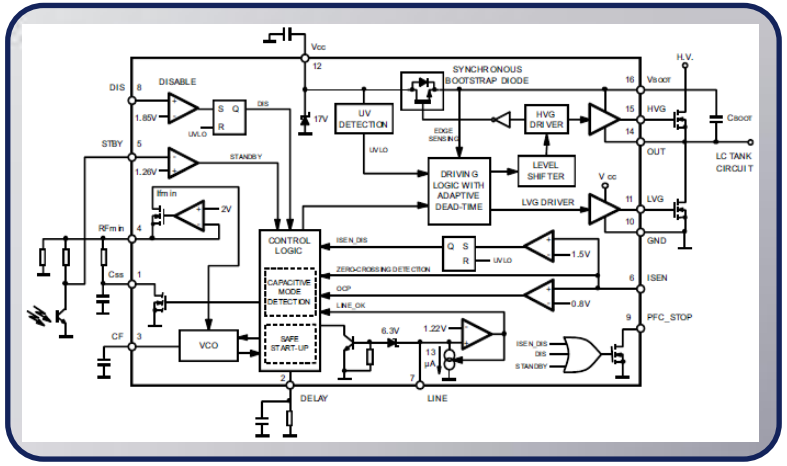
New generation of resonant controllers

- Double-ended controller specific for series-resonant, half-bridge topologies
- Innovative design optimized to reduce power supply unit complexity, form factor and costs
- Pin-to-pin compatible with previous generation devices (L6599A)

L6699 – LLC resonant controller

L6699

16 pins



FEATURES

- Symmetrical duty cycle, variable frequency control of resonant half bridge
- Self-adjusting adaptive dead-time
- Anti-capacitive-mode protection
- High-accuracy oscillator
- Two-level OCP: frequency-shift and immediate shutdown
- Interface with PFC controller
- Burst-mode operation at light load and no-load
- Input for brownout protection or power-on/off sequencing
- “Safe-start” procedure to prevent hard switching at startup
- 600V high side gate driver with integrated bootstrap diode and high dv/dt immunity
- -300/800 mA high-side and low-side gate drivers with UVLO pull-down
- L6699 SIMPLIS and ORCAD macro models available
- Package: SO16

APPLICATIONS

- High-power (> 90 W) AC-DC adapters
- Notebook, AIO, desktop PC and server power supplies targeting 80 PLUS® initiative
- Flat-panel TVs and game consoles
- High-power LED lighting

APPLICATION NOTES & EVALUATION BOARDS

- AN4026: 19 V - 90 W adapter with PFC for laptop computers using the L6563H and L6699
- AN4027: 12 V - 150 W resonant converter with synchronous rectification using the L6563H, L6699 and SRK2000A
- AN4599: STEVAL-ISA132V1 24 V 300 W peak power resonant converter
- AN4677: 12 V - 150 W resonant converter with synchronous rectification based on L6563H, L6699 and SRK2001
- AN4720: Half bridge resonant LLC converters and primary side MOSFET selection
- STEVAL-ISA143V1: 12 V - 150 W resonant converter with synchronous rectification using the L6563H, L6699 and SRK2000
- STEVAL-ISA138V1: 19 V - 90 W adapter with PFC for laptop computers using the L6563H and L6699
- STEVAL-ISA132V1: 300 W peak power (170 W continuous power) LLC resonant converter based on L6699, STB13N60M2 and STPS20M80CG
- STEVAL-ISA170V1:12 V - 150 W resonant converter with synchronous rectification based on L6563H, L6699 and SRK2001
- EVL400W-ADP/ATX: 12 V – 400 W SMPS for adapter, desktop and AIO power supplies using L4984D, L6699 and SRK2000A

L6699 key benefits

Anti-capacitive-mode protection

- Avoids dangerous hard-switching and potential MOSFET cross-conduction
- Rugged protection in case of improper or unsafe application circuit design
- Increased system reliability

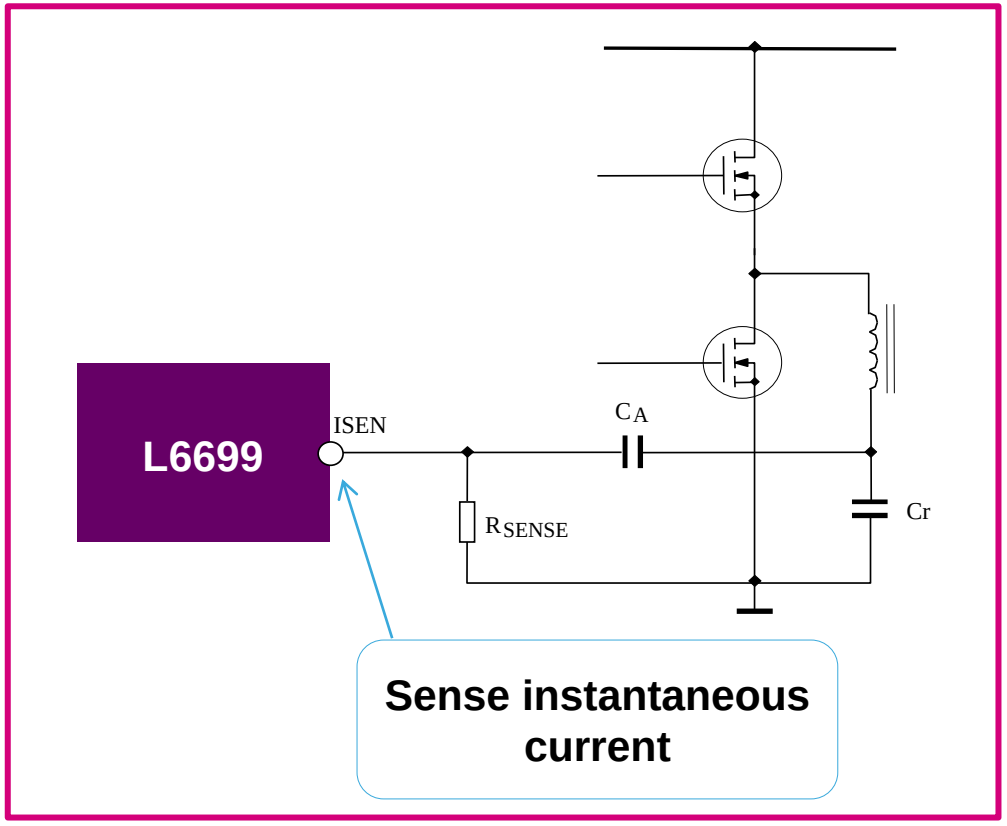
Self-adjusting adaptive dead-time

- Improves efficiency even at light load conditions
- Longer dead-time at low load and shorter at high load
- Optimized transformer design – possible to design the resonant tank for a lower magnetizing current

Enhanced Soft-start for extra-smooth startup

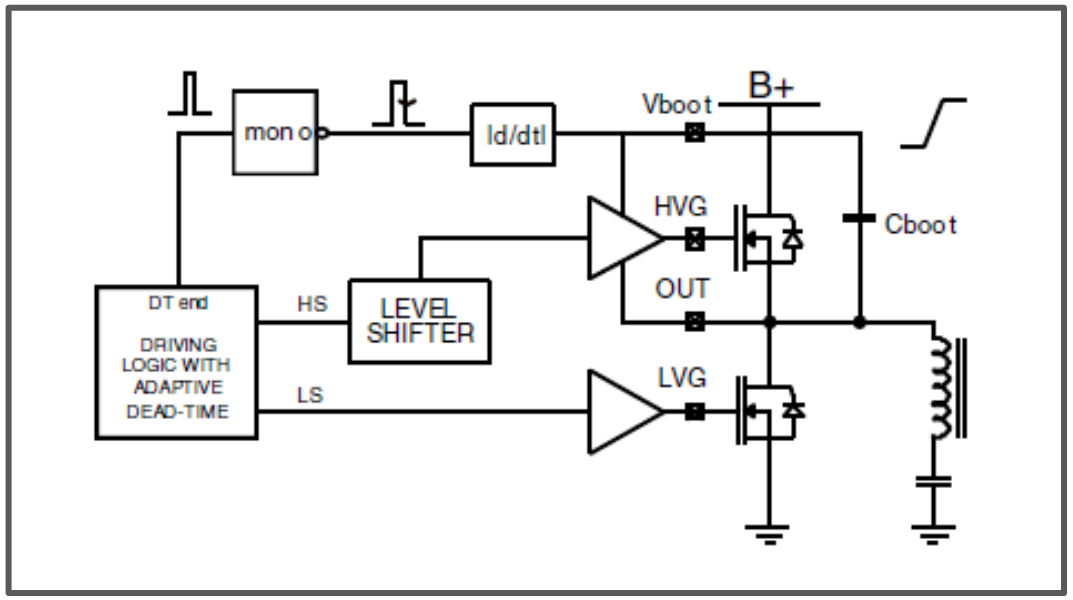
- A proprietary circuit prevents capacitive mode and hard-switching in the initial switching cycles due to V·s unbalance initially applied to the transformer or pre-charged resonant capacitor

Anti-capacitive-mode protection



- IC checks that tank current lags behind applied voltage (positive phase-shift)
- Pushes frequency up if phase-shift gets too close to zero
- Stops switching for 50 µs and then soft-restarts if phase-shift suddenly becomes negative
- During this idle period, the PFC_STOP pin is pulled low to stop the PFC stage as well

Self-adjustable dead-time



- A dead-time t_D is inserted between the turn-off of either switch and the turn-on of the complementary one to achieve soft switching
- t_D is automatically adjusted in order to ensure ZVS in all conditions
- This is done by tracking the transition time t_T , time needed for the rail-to-rail swing of the half bridge midpoint
- It is possible to design the resonant tank with low magnetizing current (high Lm) and maximize the efficiency under all loading conditions
- Efficiency is maximized: at full load with a short t_D; at light load with a longer t_D

L6699 competitive advantages

Efficiency

- Internal self-adjusting adaptive dead-time optimizes efficiency from full to light load conditions
- Optimized transformer design makes it possible to design the resonant tank for a lower magnetizing current

Reliability & protections

- Anti-capacitive-mode protection prevents the converter from working in or too close to the capacitive mode
- Smooth start-up prevents hard-switching from occurring in the initial cycles
- 600 V high-side gate driver with integrated bootstrap diode and high dV/dt immunity
- Two-level OCP: frequency-shift and immediate shutdown
- Input for brownout protection or power ON/OFF sequencing

Performance

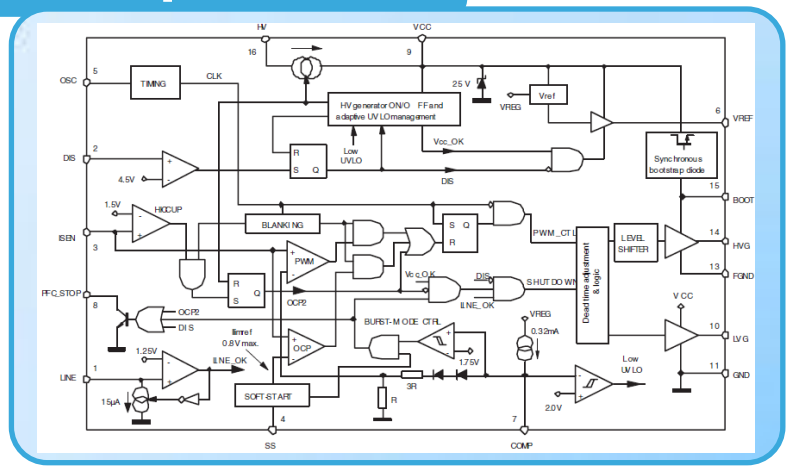
- Improved burst-mode operating at light-load and no-load conditions
- Reduced audible noise when entering burst-mode operation
- The first driver pulse length is shorter to prevent the initial peak current

L6591 – ZVS half-bridge controller

Asymmetrical half-bridge (AHB) topology

L6591

16 pins



FEATURES

- Complementary PWM control for soft-switched half-bridge with programmable dead-time
- Fixed-frequency peak-current mode
- Up to 500 kHz operating frequency
- Onboard 700 V high-voltage startup
- Advanced light-load management
- Adaptive UVLO
- Pulse-by-pulse OCP
- OLP (latched or auto-restart)
- Transformer saturation detection
- Interface with PFC controller
- Latched disable input
- Input for power-on sequencing or brownout protection
- Programmable soft-start
- 4% precision external reference
- 600 V-rail compatible high-side gate driver with integrated bootstrap diode and high dV/dt immunity
- Package: SO16

APPLICATIONS

- ATX desktop PCs
- Entry-level servers
- Telecom SMPS
- Audio systems
- LED high-current signage

APPLICATION NOTES & EVALUATION BOARDS

- AN2852: EVL6591-90WADP: 90 W AC-DC asymmetrical half-bridge adapter using L6591 and L6563
- AN3203: EVL250W-ATX80PL: 250 W ATX SMPS demonstration board
- EVL6591-90WADP: 90 W AC-DC asymmetrical half-bridge adapter using L6591 and L6563
- EVL250W-ATX80PL: 250 W ATX SMPS demonstration board

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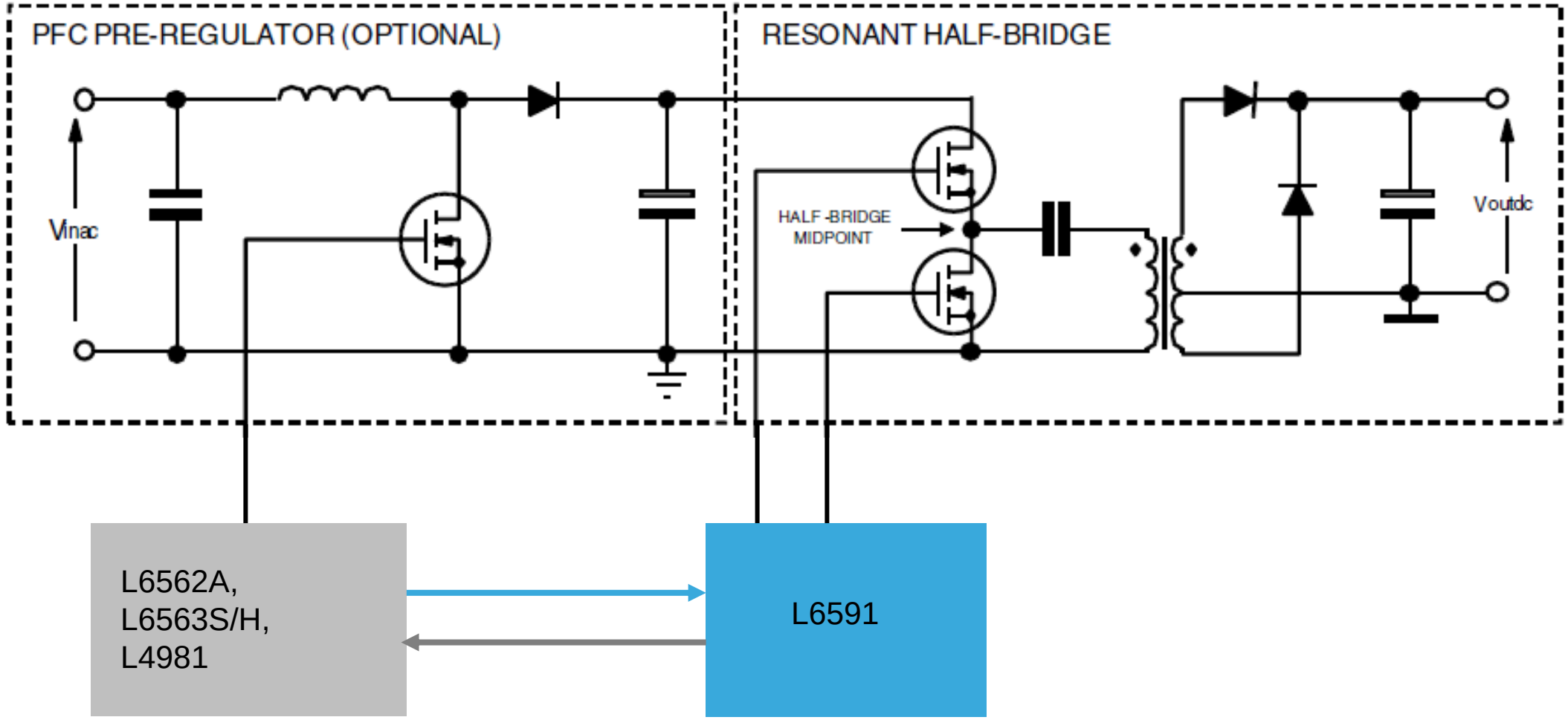
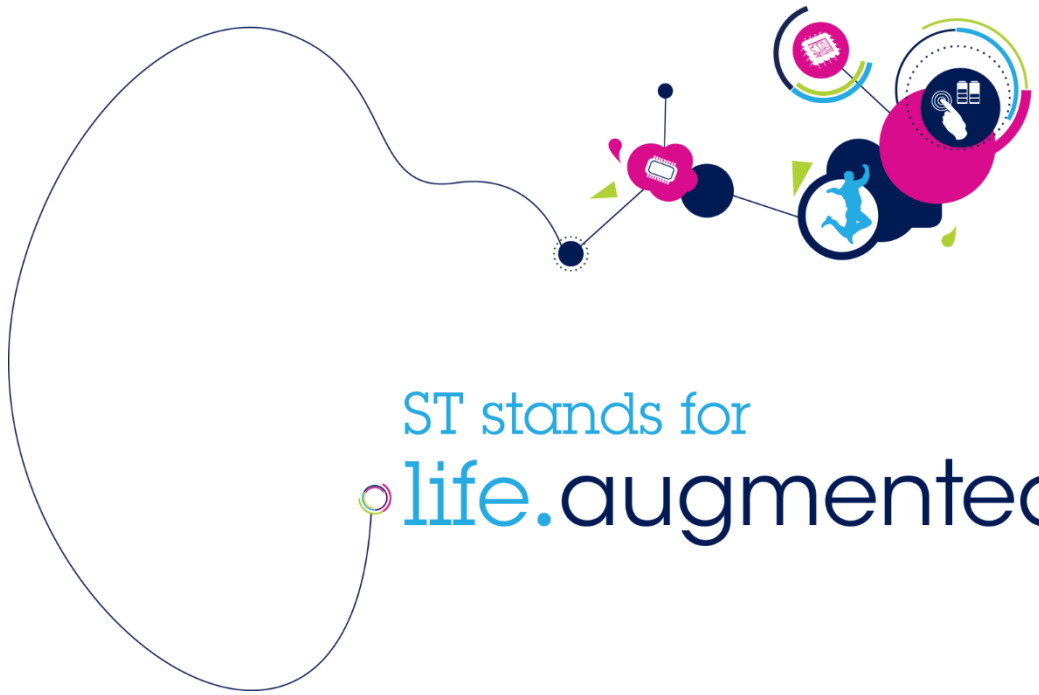
Typical AHB schematic



LLC versus AHB resonant topologies

	LLC resonant	Asymmetrical half-bridge
Control method	Variable frequency with fixed duty cycle ($D_{HS} = D_{LS}$)	Fixed frequency with asymmetrical duty cycle ($D_{HS} \neq D_{LS}$)
High-power capability	Voltage	Current
Secondary-side rectifier voltage stress	Twice the output voltage (center tapped transformer)	Usually about 3 to 6 times the output voltage for powering and freewheeling diodes, respectively (center tapped transformer)
Output capacitor current ripple	Almost twice the output current (peak-to-peak) Smooth waveform but higher ripple	Few tens % of output current (peak to peak) Lower ripple
Secondary-side capacitor	Bigger	Smaller
Inductor on secondary side	No	Yes, small
Switching conditions	ZVS easily achieved from full load to light load	ZVS difficult to achieve at light load ZVS relatively easy at full load
Other features	Tight tolerance of the resonant components (L, C) required Control loop difficult to stabilize (2^{nd} order, voltage mode)	Tight tolerance for the resonant components (L, C) not required Control loop easy to stabilize Good cross regulation thanks to the output inductor

Thank you!



ST stands for
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