Secondary regulation
Synchronous rectification controllers
Synchronous rectification

- Functionality and applications
- ST’s sync. rect. ICs topologies and offer
## Synchronous rectification ICs

<table>
<thead>
<tr>
<th>Function</th>
<th>• Drive power MOSFETs that replace the rectification diodes at the SMPS secondary side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target</td>
<td>• Increase SMPS efficiency especially in low-output-voltage and high-current power supplies</td>
</tr>
<tr>
<td>Topologies</td>
<td>• Different SR controllers topologies according to the type of primary-side converters</td>
</tr>
<tr>
<td>Features</td>
<td>• SR ICs allow space saving, cost reduction, reliability and performance improvement with respect to discrete solutions</td>
</tr>
</tbody>
</table>
SR – topologies & IC portfolio

**Flyback**
- STSR30
  - SO8

**Forward**
- STSR2P, STSR2PM
  - SO8

**LLC**
- SRK2000
  - SO8
- SRK2000A
  - SO8
- SRK2001
  - SSOP10
SR applications

- All-in-one
- Desktop PCs
- High-end TVs
- Console games
- Street lighting
- Industrial PSes
- Entry-level servers
- Adapters
STSR30 – SR x Flyback

Features:
- $V_{cc} = 4 - 5.5$ V
- Operating freq. = 20 – 500 kHz
- $I_{cc \ (no \ load)} = 3.2$ mA, with (DISABLE = 0) 15 µA
- Output peak current (typ): 1.5 A
- Inhibit blanking time: 700 ns
- Smart turn-off anticipation timing to avoid short circuit between primary and secondary sides
- Automatic turn-off for duty cycles less than 14%
- Disable pin allows turning off the device during no-load conditions
- Operates in DCM, CCM and QR configurations
- SO8

Application note:
- **AN2432**
  - EVALSTSR30-60W: 60 W AC-DC adapter with synchronous rectification using L6668 and STSR30

Application requirements:
- High current, medium power

Application target:
- High current adapter
STSR2P/STSR2PM – SR x Forward

- $V_{cc} = 4.5 – 5.5$ V
- Operating freq. = 20 – 750 kHz
- $I_{cc}$ (no load) = 3 mA
- Output peak current (typ): source 2 A, sink 3.5 A
- Smart turn-off anticipation timing preventing secondary side shoot-through conditions
- Operation independent from the forward magnetic reset technique
- STSR2P automatically turns off the outputs when duty-cycle < 13%
- STSR2PM works even at very low duty-cycle values
- Operates in DCM
- SO8

AN1645
STSR2P/STSR2PM simplifies implementation of synchronous rectifiers in forward converters

Application requirements
- Medium power, low output voltage, high current

Application target
- High-current forward converters for servers
- Low-output-voltage DC/DC forward modules
SRK2000 & SRK2000A – SR x LLC resonant

- **Features**
  - Vcc = 4.5 – 32 V
  - Operating freq. up to 500 kHz
  - Iq (typ) 250 µA
  - Protection against current reversal
  - Safe management of load transient, light load and startup conditions
  - Optimized state-machine control algorithm
  - Automatic sleep mode at light loads
  - Dual gate driver for N-channel MOSFETs with 1 A source and 3.5 A sink drive current
  - Programmable UVLO with hysteresis
  - SO8

- **SRK2000A** is P2P with SRK2000 and both feature the same electrical parameters
- **SRK2000A** features **matched turn-off thresholds** offering a **more balanced current in the two MOS**

- **Application requirements**
  - Space shrunk, slim form factor, high efficiency smaller heat sink

- **Application target**
  - AIO PCs, PCs, ATXs, servers
  - LCD TVs, console games, Industrial SMPSs
  - Adapters above 90 W

- **EVL400W-ADP/ATX** 12V - 400W SMPS for Adapter, Desktop and AIO using L4984D, L6699 and SRK2000A
High efficiency

- High efficiency at light loads
- SRK200A features matched turn-off thresholds offering more balanced current in the two MOSFETs

Energy saving

- Low quiescent current
- 80+/85+ compliant ATX SMPS
- 90+/92+ compliant server SMPS

Robustness and reliability

- Safe management of start-up, light load, burst mode conditions and dynamic load transitions
- Protection of the power supply against current inversion in the MOSFETs

Easy design

- Automatic sleep mode at light loads
- Programmable UVLO
- Drives both standard and logic-level MOSFETs

Minimal BOM

- Simple design with few external components
SRK2000 / SRK2000A
Key principles of operation

Switching mode
- Turn-on SR MOSFET after body diode starts conducting and turn-off when current approaches zero
- Drain sensing optimization to take into account parasitic elements effects on MOSFET turn-off and turn-on

Control logic with 3 state-machines
- Two state-machines for the two drivers, operating synchronously
- One state-machine for power states management: switching, sleep, idle modes

Sleep mode at light loads
- Enter when primary side stops switching or when SR conduction time is <40% of SR switching cycle
- Exit when conduction time of body diode is >60% of SR switching cycle
- After entering/exiting sleep mode, timing is ignored for 128/256 switching cycles
SRK2001 / SRK2001L
Adaptive SR x LLC resonant

- Vcc = 4.5 – 32 V
- Operating freq. up to 500 kHz
- Iq (typ) 50 µA
- Dual gate driver for N-channel MOSFETs
- 5 V / 10 V driving options
- Auto-compensation of parasitic inductance
- High voltage drain-to-source Kelvin sensing for each MOSFET
- Improved ZCD turn-off
- Turn-on logic with adaptive masking time
- Adaptive turn-off logic
- Improved control logic algorithms to avoid SR MOSFET conduction time jitter @ low current
- SO10

Features

Adaptive control algorithms for parasitic inductance self compensation
⇒ Maximum MOSFETs conduction & High efficiency in all load conditions

Flexibility in SR MOSFET selection
⇒ SRK2001 and SRK2001L compatible with standard and logic-level MOSFETs
SRK2001 / SRK2001L
Competitive advantages

High efficiency
- Maximum conduction of SR MOSFETs by means of adaptive turn-on which avoids current inversion and enhances efficiency

Energy saving
- Very low quiescent consumption ($I_q < 65 \, \mu A$)
- Meets stringent no-load requirements

Robustness and reliability
- Interlock logic and dedicated control algorithms to prevent current inversion
- Safe management of load transient, light-load and startup conditions

Easy design
- MOSFET Kelvin sensing to sense the drain-source voltage of each MOSFET
- Parasitic inductance self compensation
- Drives both standard and logic-level MOSFETs

Minimal BOM
- Only three external components around the IC
SRK2001
Key principles of operation

SR MOSFET driving
- MOSFET are switched on and off depending on the evolution of their drain-source voltages
- Proper driving is achieved through adaptive turn-on and turn-off control algorithms, by directly sensing the drain-source voltage $V_{DS}$ of either MOSFET

Control logic and operating mode configurations
- The logic that controls the driving of the two MOSFETs is based on two state machines working in parallel in interlocked way
- A third state machine manages the transitions from normal to sleep mode and vice versa

Sleep modes
- EN and PROG pins allow to configure automatic sleep operating modes by selecting $D_{OFF}$ and $D_{ON}$ conduction duty cycles with the $R_{EN}$ and $R_{PG}$ values setting

Automatic sleep mode enabled
- Sleep mode is entered when MOSFET conduction duty cycle becomes lower than $D_{OFF}$ for 512 consecutive clock cycles. As load increases, system exits sleep mode when the MOSFET body diode conduction duty cycle exceeds $D_{ON}$

Automatic sleep mode disabled
- Automatic sleep mode is disabled with $R_{EN}$ open and $D_{ON}$ conduction duty cycle is selected among the values available in the internal lookup table. When half-bridge converter switching activity stop is detected, SRK2001 enters low consumption state
## SRK2001 reference designs

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Application notes</th>
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<tr>
<td>STEVAL-ISA170V1</td>
<td>12 V, 150 W EuP Lot 6 resonant converter based on SRK2001, L6699 and L6563H</td>
<td>AN4677</td>
</tr>
<tr>
<td>STEVAL-ISA165V1</td>
<td>Plug-in board with SRK2001 and 40 V MOSFETs in TO220 package</td>
<td>AN4674</td>
</tr>
<tr>
<td>STEVAL-ISA166V1</td>
<td>Plug-in board with SRK2001 and 60 V MOSFETs in TO220 package</td>
<td>AN4674</td>
</tr>
<tr>
<td>STEVAL-ISA167V1</td>
<td>Plug-in board with SRK2001 and 60 V MOSFETs in PowerFLAT™ package</td>
<td>AN4674</td>
</tr>
<tr>
<td>STEVAL-ISA168V1</td>
<td>Plug-in board with SRK2001 and 40 V MOSFETs in PowerFLAT™ package</td>
<td>AN4674</td>
</tr>
<tr>
<td>STEVAL-ISA169V1</td>
<td>Plug-in with SRK2001L and 40 V MOSFETs in PowerFLAT™ package</td>
<td>AN4674</td>
</tr>
</tbody>
</table>
SRK2001
Reference design performance

150W-12V evaluation board STEVAL-ISA170V1 [L6563H + L6699 + SRK2001]

- Application target: AIO power supply, high power adapter
- No-load mains consumption: < 0.15 W at 230 Vac, according to European CoC ver. 5 Tier 2 requirements
- Avg. efficiency: > 91% at 115 Vac, according to ENERGY STAR® 6.1
- Light load efficiency: according to EuP Lot 6 Tier 2 requirements
- Full load efficiency: 90.96% @ 115 Vac and 93.16% @ 230 Vac
- EMI: according to EN55022-Class-B
- Safety: according to EN60950
Thank you!

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