Power & Analog program

European Multi System Market Competence Center
POWER CONVERSION - agenda

- Power conversion
  - SMPS
    - Main topologies quick roundup
    - Power Factor Correction
    - PWM (offline & HV DCDC)
    - Low Voltage DC-DC Converters
  - Lighting
    - Fluorescent ballast
      - Analog driven
      - Digital driven / advanced
    - HID
    - LED / DISPLAY DRIVER
      - DC / DC driven
      - Offline driven
      - Display control
• Power conversion

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      – Display control
NOT isolated topologies

**BUCK (STEP-DOWN)**

\[ V_{\text{OUT}} = V_{\text{IN}} \times D \]

**BOOST (STEP-UP)**

\[ V_{\text{OUT}} = \frac{V_{\text{IN}}}{1-D} \]

**BUCK / BOOST**

\[ V_{\text{OUT}} = -\frac{V_{\text{IN}} \times D}{1-D} \]
Isolated topologies

**FLYBACK**

\[ V_{OUT} = V_{IN} \times D / (N \times (1-D)) \]

**SINGLE SWITCH**

**DOUBLE SWITCH**

**FORWARD**

\[ V_{OUT} = V_{IN} \times D \times N \]

**SINGLE SWITCH**

**DOUBLE SWITCH (asymmetrical half-bridge)**
Isolated topologies

**PUSH-PULL**

\[ V_{OUT} = 2 \times V_{IN} \times D / N \]

**HALF-BRIDGE**

\[ V_{OUT} = V_{IN} \times D / N \]

**FULL-BRIDGE**

\[ V_{OUT} = 2 \times V_{IN} \times D / N \]

Because of the number of components, the full bridge is for high power applications, ranging from 500 up to 2000W.
Primary side

HV Monolithic Switchers
- VIPer20/A, 50/A, 100/A
- VIPer12A, VIPer22A, VIPer53/E
- VIPer17 / 27 / 28 / 16

PFC Controllers

TM
- L6561
- L6562, L6563/A
- L6562A/T

FF-CCM
- L4981A/B

PWM Controllers

PWM - FF
- UC384x, L5991/A
- SG3524, SG3525
- L6668

QR
- L6565
- L6566

RESONANT
- L6598
- L6599

Secondary side

Synchr. Rectifier Controllers
- STSR2P, STSR2PM
- STSR3, STSR30

CV/CC Controllers

- TSM101, 103W
- TSM1011, 1012, 1013, 1014
- TSM1051, 1052

Supervisor/Housekeeping ICs

- TSM102, 104W, 106, 107, 109
- TSM111, 114, 115
- L6610, L6611
- TL77XX

Load-share Controller
- L6615
• Power conversion
  – SMPS
    • Main topologies quick roundup
    • Power Factor Correction
    • PWM (offline & HV DCDC)
    • Low Voltage DC-DC Converters
  – Lighting
    • Fluorescent ballast
      – Analog driven
      – Digital driven / advanced
    • HID
    • LED / DISPLAY DRIVER
      – DC / DC driven
      – Offline driven
      – Display control
• **Power Factor (PF) Concept**
  – Theoretical meaning and practical aspects

• **Power Factor Correction (PFC)**
  – Regulations and economical considerations
  – General PFC characteristics and impact on SMPS' performance
  – Topologies and control methods
  – PFC, application examples and design issues
P = V_{RMS} \cdot I_{RMS} \cdot \cos \varphi = \text{Re} [A]
Q = V_{RMS} \cdot I_{RMS} \cdot \sin \varphi = \text{Im} [A]
|A| = V_{RMS} \cdot I_{RMS} = \sqrt{P^2 + Q^2}
\varphi = \text{arg} (Z_L)

\text{P = Active (Real) Power}
\text{Q = Reactive Power}
\text{A = Apparent Power}

\text{PF} = \frac{P}{|A|} = \cos \varphi
Line Current Distortion at an SMPS Input
PF Definition Non-Sinusoidal Current

\[ \text{IRMS} = \sqrt{I_{\text{RMS}1}^2 + \sum_{n=2}^{\infty} I_{\text{RMS}n}^2} \]

\[ \phi_1 = \angle \text{IRMS}\_1 \quad ; \quad \cos \theta = \frac{\text{IRMS}_1}{\text{IRMS}} \]

\[ P = \text{Active (Real) Power} \]

\[ \theta \]

\[ H = \text{Fundamental App. Power} \]

\[ A = \text{Total Apparent Power} \]

\[ D = \text{Distortion Power} \]

\[ Q = \text{Reactive Power} \]

\[ \text{PF} = \frac{P}{|A|} = \cos \varphi \cdot \cos \theta \]

\[ \text{THD} = \sqrt{\sum_{n=2}^{\infty} \frac{I_{\text{RMS}n}^2}{I_{\text{RMS}1}}} \]

\[ P = \text{VRMS} \cdot \text{IRMS}_1 \cdot \cos \phi_1 \]

\[ Q = \text{VRMS} \cdot \text{IRMS}_1 \cdot \sin \phi_1 \]

\[ D = \text{VRMS} \cdot \sqrt{\sum_{n=2}^{\infty} \text{I}_{\text{RMS}n}^2} \]

\[ |H| = \text{VRMS} \cdot \text{IRMS}_1 = \sqrt{P^2 + Q^2} \]

\[ |A| = \text{VRMS} \cdot \text{IRMS} = \sqrt{H^2 + D^2} \]
• **FOR POWER DISTRIBUTION COMPANY**
  – Better efficiency in energy transportation and distribution networks
  – Cables cross-section may be reduced
  – Transformers' size reduction
  – Reduction of disturbances on the line

• **FOR USERS**
  – More total power available
  – More power available on each outlet
• **COMPLIANCE WITH REGULATIONS**
  – EN 61000-3-2 regulation is mandatory from year 2001 for input power > 75W

• **ECONOMICAL CONSIDERATIONS**
  – PFC causes additional costs, partly compensated by a cost reduction of the downstream converter
• Concerns harmonic current emission limits for equipment having an input current >16A per phase

• Equipment is divided up in 4 classes:
  – A: Balanced three-phase equipment and that not included in the other classes
  – B: Portable equipment
  – C: Lighting equipment
  – D: Equipment with special input current waveshape and input active power > 600W.

• No limitation is imposed on equipment with input active power <75W.
## Limits for Class A, B & C Equipment

<table>
<thead>
<tr>
<th>Harmonic order “n”</th>
<th>Max. harmonic current A</th>
<th>Harmonic order “n”</th>
<th>Max. harmonic current A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odd harmonics</td>
<td></td>
<td>Odd harmonics</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2.30</td>
<td>3</td>
<td>3.45</td>
</tr>
<tr>
<td>5</td>
<td>1.14</td>
<td>5</td>
<td>1.71</td>
</tr>
<tr>
<td>7</td>
<td>0.77</td>
<td>7</td>
<td>1.16</td>
</tr>
<tr>
<td>9</td>
<td>0.40</td>
<td>9</td>
<td>0.60</td>
</tr>
<tr>
<td>11</td>
<td>0.33</td>
<td>11</td>
<td>0.50</td>
</tr>
<tr>
<td>13</td>
<td>0.21</td>
<td>13</td>
<td>0.32</td>
</tr>
<tr>
<td>15≤n≤39</td>
<td>0.15 · 15 / n</td>
<td>15≤n≤39</td>
<td>0.23 · 15 / n</td>
</tr>
<tr>
<td>Even harmonics</td>
<td></td>
<td>Even harmonics</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.08</td>
<td>2</td>
<td>1.62</td>
</tr>
<tr>
<td>4</td>
<td>0.43</td>
<td>4</td>
<td>0.65</td>
</tr>
<tr>
<td>6</td>
<td>0.30</td>
<td>6</td>
<td>0.45</td>
</tr>
<tr>
<td>8≤n≤40</td>
<td>0.23 · 8 / n</td>
<td>8≤n≤40</td>
<td>0.35 · 8 / n</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Harmonic order n</th>
<th>Max. harmonic current (% of fundamental)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>30 · PF</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>11≤n≤39</td>
<td>3</td>
</tr>
</tbody>
</table>
### Class D

<table>
<thead>
<tr>
<th>Harmonic order ( n )</th>
<th>Max. harmonic current per Watt (mA/W)</th>
<th>Max. harmonic current ( A )</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3.4</td>
<td>2.30</td>
</tr>
<tr>
<td>5</td>
<td>1.9</td>
<td>1.14</td>
</tr>
<tr>
<td>7</td>
<td>1.0</td>
<td>0.77</td>
</tr>
<tr>
<td>9</td>
<td>0.5</td>
<td>0.40</td>
</tr>
<tr>
<td>11</td>
<td>0.35</td>
<td>0.33</td>
</tr>
<tr>
<td>( 13 \leq n \leq 39 ) (odd harm. only)</td>
<td>( 3.85 / n )</td>
<td>see class A</td>
</tr>
</tbody>
</table>

Limits for Class D Equipment

![Graph showing harmonic distribution](image)
- **Passive PFC**
  - Pros
    - Simple and reliable
  - Cons
    - PF@0.7-0.8, THD still high
    - Large L, big chokes

- **Active PFC (PFC Preregulator)**
  - Pros
    - PF=0.999, THD<3%
    - Wide-range Mains
    - SMPS optimization
  - Cons
    - Complexity and cost
PFC Impact on the System

- **EMI filter**
  - might need reinforcing

- **Bridge rectifier**
  - Diode current rating reduction or heatsink size reduction

- **On the downstream converter**
  - Converter's input bulk capacitor (= PFC output) reduced at 1/4
  - Power switch size reduction (RDS(on) can be 1/4), or heatsink size reduction
  - Transformer's size reduction and optimization (it is operated with low current and a nearly constant primary voltage)
  - Greater efficiency
  - Control loop dynamics not used to compensate input voltage changes, entirely available to control load changes
PFC Block Diagram

\[ V_{pk} \]

0

\[ V_{AC} \]

\[ C_{in} \]

\[ V_{out} \]

\[ 0 \]

\[ V_{REF} \]

\[ V_{AC} \]

\[ 0 \]

\[ C_{o} \]

\[ V_{out} \]

\[ V_{REF} \]
• Boost topology
• Wide-range mains operation (88 to 264 VAC)
• 400 V output voltage (in general, > Vpk)
• Small input cap
  – larger values cause input voltage waveform distortion and hurt PF
  – higher EMI level
• Current mode control
  – 2-loop control
• Narrow bandwidth voltage loop (typ. 20 Hz)
  – 100/120 Hz output ripple
  – Poor dynamic response
  • Input overcurrent and output overvoltage protections needed
PFC Control Methods

- **"CCM" type**
  - Fixed frequency, duty cycle modulation
  - Continuous conduction mode: $I_L$ never falls to zero.
  - Average current mode control, complexity, high performance, higher cost.
  - Suitable for higher power levels (>300W) approximately

- **"TM" type**
  - Variable switching frequency, constant $T_{ON}$
  - Operation on the boundary between continuous and discontinuous conduction mode, @ZVS
  - Peak current mode control, simple, low-cost.
  - Suitable for lower power levels (<300W) approximately
### FF-CCM or TM Type: which should I use?

<table>
<thead>
<tr>
<th></th>
<th>FF-CCM</th>
<th>TM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EMI Filter</strong></td>
<td>It must filter a current ripple usually equal to 20–40% of the line current</td>
<td>It must filter a current ripple as high as twice the line current</td>
</tr>
<tr>
<td><strong>Boost Inductor</strong></td>
<td>Inductance is usually higher, saturation current is lower, core and copper losses are lower</td>
<td>Inductance is usually lower, saturation current is higher, core and copper losses are higher; litz or multi-strand wire</td>
</tr>
<tr>
<td><strong>MOSFET</strong></td>
<td>Lower conduction losses (better current form-factor), high capacitive and switching losses. Additional losses due to boost diode reverse-recovery</td>
<td>Higher conduction losses (worse current form-factor), capacitive and switching losses significant at high line only (when ZVS at turn-on is lost)</td>
</tr>
<tr>
<td><strong>Diode</strong></td>
<td>Reverse-recovery characteristics are critical: additional losses in itself and in the MOSFET, higher EMI. Higher $V_F$ and conduction losses</td>
<td>Reverse-recovery not invoked: no additional losses and lower EMI. Lower $V_F$ and conduction losses.</td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td>Average current-mode: more complex, higher part count, expensive control IC</td>
<td>Peak current-mode: simpler, lower part count, cheap control IC</td>
</tr>
</tbody>
</table>

**CONCLUSION:** for $P_{out} < 100W$ definitely TM, for $P_{out} > 500W$ FF-CCM; careful (and complex!) trade-off required for intermediate levels
STM PFC Roadmap

L4981A/B
AVG CURRENT MODE PFC
Input voltage Feed-forward
Load Feed-forward
Progr. Turn-On Threshold
OVP & Over-current Protection

L6561
TM PFC
8pin
OVP stat./dyn.
L6561 pin-to-pin
Improved THD
Extended supply range
Powerful gate driver

L6562
IMPROVED TM PFC
L6562 enhanced
Lower CS threshold
New gate driver
Higher efficiency at light load

L6562A
TM PFC
L6563
ADVANCED TM PFC
TBO
FDBK disconnection
Brownout
Reduced consumption
PWM interface
Input volt. Feedforward
PFC: transition mode (TM) control

- Variable switching frequency, constant TON
- Operation close to the boundary between continuous and discontinuous conduction mode, @ZVS
- Peak current mode control, simple, low-cost.
- Suitable for lower power levels (< @150W approximately)

(*) L6563: 14 pin IC with advanced logic
PFC: continuous current mode (CCM) control

- Fixed frequency, duty cycle modulation
- Continuous conduction mode: IL never falls to zero (except for close to zero-crossings)
- $\Delta IL/IAC$ ratio < 1 (typ. 0.2-0.4)
- Average current mode control, greater complexity, high performance, higher cost.
- Suitable for higher power levels (> 250W approximately)
PFC: fixed-off-time (FOT) control

**TYPICAL QR CONTROL**
- TURN-OFF → PWM COMPARATOR (current peak)
- TURN-ON → INDUCTOR DEMAGNETIZATION (Aux. winding or RC on the drain)

**TRANSITION MODE** (boundary between DCM and CCM)

- Benefits:
  - 200-400W target
  - High efficiency (>92%)
  - Simple control
  - Reduced part count compared to CCM fixed frequency
L6562A

- Proprietary multiplier design for minimum THD of AC input current
- Very low power losses current sense for improved system efficiency
- Variable switching frequency, constant TON

-600/+800mA totem-pole gate driver with UVLO
- Disable function on Fb input
- Precise adjustable output overvoltage protection

L6562A vs L6562

<table>
<thead>
<tr>
<th>Parameter / Function</th>
<th>L6562</th>
<th>L6562A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current sense dynamics (typ.)</td>
<td>1.7V</td>
<td>1.1V</td>
</tr>
<tr>
<td>Disable function by grounding FB input</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>IC operating consumption @ 70kHz (typ.)</td>
<td>3.5mA</td>
<td>3.0mA</td>
</tr>
<tr>
<td>Dynamic OVP trigger current (typ.)</td>
<td>40μA</td>
<td>27μA</td>
</tr>
<tr>
<td>Digital Blanking time on current sense</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>ZCD arm/trigger/clamp thresholds (typ.)</td>
<td>2.1/1.6/0.7V</td>
<td>1.4/0.7/0V</td>
</tr>
<tr>
<td>IC turn-on &amp; turn-off thresholds (typ.)</td>
<td>12/9.5V</td>
<td>12.5/10V</td>
</tr>
<tr>
<td>Current sense propagation delay (typ.)</td>
<td>200ns</td>
<td>120ns</td>
</tr>
<tr>
<td>Turn-off threshold spread (max.)</td>
<td>±0.8V</td>
<td>±0.5V</td>
</tr>
<tr>
<td>Multiplier gain (typ.)</td>
<td>0.6</td>
<td>0.38</td>
</tr>
</tbody>
</table>
Power Factor Corrector with L6562A controller

This workbook is dedicated to the dimensioning of PFC board in boost topology using the STM L6562A controller, operating in Transition Mode.

**Design Specifications**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Model</th>
<th>Scale</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Switch</td>
<td>FWR135</td>
<td>25VA</td>
<td>PPM</td>
</tr>
<tr>
<td>Main Switch</td>
<td>FWR135</td>
<td>25VA</td>
<td>PPM</td>
</tr>
<tr>
<td>Input Capacitor</td>
<td>1000µF</td>
<td>100V</td>
<td>CBB</td>
</tr>
<tr>
<td>Input Capacitor</td>
<td>1000µF</td>
<td>100V</td>
<td>CBB</td>
</tr>
<tr>
<td>Diode</td>
<td>1N5822</td>
<td>150V</td>
<td>1A</td>
</tr>
<tr>
<td>Diode</td>
<td>1N5822</td>
<td>150V</td>
<td>1A</td>
</tr>
<tr>
<td>Inductor</td>
<td>L07110</td>
<td>10mH</td>
<td>1A</td>
</tr>
<tr>
<td>Inductor</td>
<td>L07110</td>
<td>10mH</td>
<td>1A</td>
</tr>
<tr>
<td>Transformer</td>
<td>T07215</td>
<td>25VA</td>
<td>1A</td>
</tr>
<tr>
<td>Transformer</td>
<td>T07215</td>
<td>25VA</td>
<td>1A</td>
</tr>
</tbody>
</table>

**Others Design Data**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Input Current</td>
<td>20A</td>
</tr>
<tr>
<td>Peak Input Current</td>
<td>20A</td>
</tr>
</tbody>
</table>

**Basics Diagram**

[Diagram of Power Factor Corrector with L6562A controller]
L6562A Promotional tools

- **SAMPLES:** AVAILABLE ON REQUEST
- **DATASHEETS:** AVAILABLE ON THE WEB
- **APPLICATION NOTES:**
  - AN2761 : Solution for designing a 80W TM PFC using the L6562A
  - AN2782 : Solution for designing a 400W FOT PFC using the L6562A
  - AN2755 : 400W FOT-controlled PFC pre-regulator with the L6562A
  - AN2711 : 15W Off Line TRIAC Dimmable LED Driver
- **DEMO BOARDS:**
  - EVL6562A-TM-80W (AVAILABLE)
    http://www.st.com/stonline/products/literature/bd/13799/evl6562a-tm-80w.pdf
  - EVL6562A-400W (AVAILABLE)
- **SOFTWARE TOOLS:**
  - DESIGNING A TM PFC USING THE L6562A (AVAILABLE UPON REQUEST)
    http://ims.st.com/ipc/off-line/controller/soft/l6562apfc_release%201.1.xls
  - DESIGNING A FOT PFC USING THE L6562A (AVAILABLE UPON REQUEST)
    http://ims.st.com/ipc/off-line/controller/soft/l6562a_fot_release%201.3.xls
L6563A

- Can manage output power in excess of 300W
- Input voltage Feed-forward
- Tracking-boost operation option
- AC Brownout Detection
- THD optimizer
- Power management interface with PWM section
- Feedback disconnection detection
- Protection against boost inductor saturation
- Internal 200ns LEB on Current Sense
- Low Start-up & Quiescent Current
- Package: SO-14

MAIN APPLICATIONS:
- IEC61000-3-2 Compliant SMPS
- Hi-end AC-DC Adapter/Charger
- SMPS for Desktop PC’s, Entry-level Servers
• Power conversion
  – SMPS
    • Main topologies quick roundup
    • Power Factor Correction
    • PWM (offline & HV DCDC)
    • Low Voltage DC-DC Converters
  – Lighting
    • Fluorescent ballast
      – Analog driven
      – Digital driven / advanced
    • HID
    • LED / DISPLAY DRIVER
      – DC / DC driven
      – Offline driven
      – Display control
STM PWM Roadmap

- **L6598**
  - HV Resonant Controller
  - 600V Level-shifter
  - Bootstrap Diode

- **L6668**
  - Smart Primary PWM Controller
  - 700V start-up
  - PFC interface
  - Burst-mode
  - Improved Stand-by

- **L6599**
  - Advanced HV Resonant Controller
  - 600V Level-shifter
  - Bootstrap Diode
  - PFC interface
  - Burst-mode
  - Brownout

- **L6666A/B**
  - PWM & Q-Res Controller
  - Selectable Q-Res or PWM
  - 700V Start-up
  - PWM with frequency mod.
  - Supporting single stage PFC

- **L6591**
  - ZVS HB PWM Controller
  - 600V Level-shifter
  - 700V start-up
  - PFC interface
  - Brownout

- **L6565**
  - Q-Resonant Controller

- **UC384xB**
  - Standard PWM

- **L5991/A**
  - Advanced PWM Controller

Power

100W – 700W

90W – 400W

Up to 90W

100W – 700W
L6668 main features

- ON-BOARD HIGH-VOLTAGE START-UP
- IMPROVED STANDBY FUNCTION
- LOW QUIESCENT CURRENT (< 2 mA)
- SLOPE COMPENSATION PIN
- PULSE-BY-PULSE & HICCUP-MODE OCP
- INTERFACE WITH PFC CONTROLLER
- DISABLE FUNCTION (ON/OFF CONTROL)
- LATCHED DISABLE FOR OVP/OTP FUNCTION
- PROGRAMMABLE SOFT-START
- 2% PRECISION REFERENCE VOLTAGE AVAILABLE
- ±800 mA TOTEM POLE GATE DRIVER WITH INTERNAL CLAMP AND UVLO PULL-DOWN
- SO16N PACKAGE

MAIN APPLICATIONS:

- HI-END AC-DC ADAPTERS & CHARGERS
- LCD/CRT MONITORS and LCD/CRT TV
- DIGITAL CONSUMER
L6668 load-dependent operating mode

**Burst-Mode @ No-load**
- Most of switching cycles are skipped
- Constant switch peak current
- Programmable threshold for noise-free operation
- Pin<0.2W@Pout=0 in an 80W-rated system achievable

**Fixed-frequency Mode @ Heavy Load**
- Identical to UC384x-based operation
- 75% Max. duty cycle

**Frequency Foldback Mode @ Light Load**
- Frequency is progressively reduced with the load
- Programmable reduction rate for optimum efficiency vs. input power

SMPS Compliant with Blue Angel, Energy Star, EU Code of Conduct, ….
L6668 – 40W/51Wpk HDD SET-TOP BOX SMPS

**SALIENT FEATURES:**
- Universal input mains range (90÷264Vac)
- Efficiency better than 78% at full load
- ST-by power <0.75W@230Vac & 5V-50mA load
- Meets EN55022 Class B (EMI)
- Meets EN60950 (Safety)
- PCB single layer 75x150 mm
- Low part count & diversity
- Low-cost approach
- SMT use for labor cost reduction

**OUTPUT VOLTAGES**
- +1.8: @1.7A
- +3V3: @0.5A
- +5V: @2.4A
- +12V: @1.9A/2.9Apk

Measured at maximum load and 230Vac. Limits according to EN55022 Class-B.
L6668 load-dependent operating mode

Latches off L6668 when L6563 detects feedback disconnection or inductor saturation

Power-on sequencing. Switches off L6563 when L6668 detects either light load or OV/OT or transformer saturation

OT sensing

Frequency foldback setting

Switching frequency setting

Burst-mode threshold setting

Voltage reference

PFC_STOP

STBY

RCT

Skip adjustment

COMP

GND

OUT

S-Comp

L6563

Vcc

PWM_LATCH

L6668

HV BUS

C8

Vcc

PFC

8

14

1

3

6

1

9

10

11

12

3

5

7

10

11

12

14

15

14

13

12

11

10

9

8

7

6

5

4

3

2

1

0

-
NEW
L6566A/B primary
Multi-mode
PWM/Q-RES Controller
SELECTABLE QR/FF OPERATION

FLEXIBILITY

ON-BOARD HV START-UP GEN.
LOW QUIESCENT CURRENT (<3mA)
BURST MODE @ LIGHT LOAD

POWER

CONSUMPTION

PULSE-BY-PULSE OCP
TRANSFORMER SAT. DETECTION
LATCHED OR AUTORESTART OVP
BROWNOUT PROTECTION
ADAPTIVE UVLO
LINE FEEDFORWARD

SAFETY

L6566A
PFC INTERFACE

POWER

CONSUMPTION

L6566B
FREQ MODULATION

EMI REDUCTION

L6566A/B Multimode Controller
**L6566A/B Multimode Controller**

**L6566A: FOR SMPS WITH PFC FRONT-END**

- HVS
- N.C.
- GND
- GD
- Vcc
- Vcc_PF
- CS
- DIS
- AC_OK
- VFF
- SS
- OSC
- MODE/SC
- ZCD
- VREF
- COM

**L6566B: FOR SINGLE STAGE SMPS**

- HVS
- N.C.
- GND
- GD
- Vcc
- Vcc_PF
- CS
- DIS
- AC_OK
- VFF
- SS
- OSC
- MODE/SC
- ZCD
- VREF
- COMP

**MAIN APPLICATIONS:**

- **High Power (75-120W) AC-DC adapt/Chargers**
- **SMPS for Printers**
- **LCD monitors, Small size LCD TV (21-28”)**

**MAIN APPLICATIONS:**

- **Low Power (30-75W) AC-DC Adapt/Chargers**
- **SMPS for Printers, Digital Consumer**
- **LCD monitor, Small size LCD TV (up to 21”)**
- **Single-stage PFC**
The L6566 is an extremely versatile current-mode primary controller IC specifically designed for high-performance offline flyback converters in applications supposed to comply with EN61000-3-2 or JEITA-MITI regulations. Both Fixed-frequency (FF) and Quasi-resonant (QR) operation are supported. The user can pick either of the two depending on application needs. The device features an externally programmable oscillator: it defines converter’s switching frequency in FF mode and the maximum allowed switching frequency in QR mode. When FF operation is selected, the IC works like a standard current-mode controller with a maximum duty cycle limited at 70% min. QR operation, when selected, occurs at heavy loads and is achieved through a transformer demagnetization sensing input that triggers MOSFET’s turn-on. Under some conditions, ZVS (Zero-voltage Switching) can be achieved. Converter’s power capability rise with the input voltage is compensated by line voltage feedforward. At medium and light load, as the QR operating frequency equals the oscillator frequency, a function (valley skipping) is activated to prevent further frequency rise and keep the operation as close to ZVS as possible. With either FF or QR operation, at very light load the IC enters a controlled burst-mode operation that, along with the built-in non-dissipative high-voltage start-up circuit and a reduced quiescent current, helps keep low the consumption from the mains and meet energy saving recommendations. To allow meeting them in two-stage power-factor-corrected systems as well, the L6566A provides an interface with the PFC controller that enables to turn off the pre-regulator at light load. An innovative adaptive UVLO helps minimize the issues related to the fluctuations of the self-supply voltage due to transformer’s parasitics. The protection functions included in this device are: not-latched input undervoltage (brownout), output OVP (auto-restart or latch-mode selectable), a first-level OCP with delayed shutdown to protect the system during overload or short circuit conditions (auto-restart or latch-mode selectable) and a second-level OCP that is invoked when the transformer saturates or the secondary diode fails short. A latched disable input allows easy implementation of OTP with an external NTC, while an internal thermal shutdown prevents IC overheating. Programmable soft-start, leading-edge blanking on the current sense input for greater noise immunity, slope compensation (in FF mode only), and a shutdown function for externally controlled burst-mode operation or remote ON/OFF control complete the equipment of this device.
L6566A/B Multimode Controller

Typical System Block Schematics

PFC PRE-REGULATOR (BOOST)

L6566 is turned off in case of PFC's anomalous operation, for safety

L6566 can be turned off at light load to ease compliance with energy saving requirements.

Optional Synchronous Rectification

OPERATION
- QR for Pout ≤ 60-70W
- FF for Pout > 70W
L6566A/B Block Diagram

- Programmable soft-start
- Feedback
- Voltage feed-forward
- Pulse-by-Pulse OCP & Hiccup mode
- 5V Reference
- HV start-up current generator
- 2.6mA typ quiescent current Adaptive UVLO
- PFC management or Freq. modulation
- Oscillator
- QR or FF setting
- Slope comp.
- ZCD & OVP
- Brown-out
- Latched device protection

- Gate driver
- 1.5V
- 7.7V
- Off
- Pulse-by-Pulse OCP & Hiccup mode
- 4.5V
- + -
- + -
- + -
- + -
L6566A/B: Main Features

- Selectable Quasi-Resonant (QR) or Fixed Frequency (FF) Operation
- Load-Dependent Current-Mode Control: Quasi-Resonant, Valley Skipping or Burst-Mode
- On-Board High-Voltage Start-Up Generator
- Low Quiescent Current (< 3 mA)
- Adaptive UVLO
- Line Feedforward for Constant Power Capability
- Pulse-By-Pulse OCP with Delayed Shutdown
- Transformer Saturation Detection
- Latched or Auto Restart OVP
- Brownout Protection with Hysteresis
- Programmable Soft-Start
- 2% Precision Reference Voltage Externally Available
- -600/+800 mA Totem Pole Gate Driver
- Switched Supply Rail for PFC Controller (L6566A)
- Programmable Frequency Modulation for EMI Reduction (L6566B)
- SO16N Package

Blue Angel, Energy Star, EU Code of Conduct Compliant
75W Adapter with PFC, using L6566A and L6563
Typical low-cost application schematic
Typical full-feature application schematic

COMPANY CONFIDENTIAL
L6566A/B Promotional Tools

- **SAMPLES:** AVAILABLE NOW (PRODUCTION PHASE)
- **DATASHEETS:** AVAILABLE ON THE WEB
- **DEMO BOARDS:**
  - EVL6566A-75WADP in FF mode (AVAILABLE)
  - EVL6566A-75WADP in QR mode (IN PROGRESS)
    - 19V/3.9A adapter with PFC pre-regulator, using L6563, L6565A and TSM1014, EPA 4.0 Compliant
  - EVL6566B-65W in FF mode (AVAILABLE)
    - 12V/5.4A wide-range mains adapter using L6566B and TSM1014
  - EVL6566B-60WQR in QR mode (AVAILABLE)
    - 12V/5A wide range mains adapter using L6566B
  - EVL6566B-60WFF in FF mode (AVAILABLE)
    - 12V/5A wide range mains adapter using L6566B
  - EVL6566B-40WSTB in FF mode (multiple output) (AVAILABLE)
    - 12V, 5V, 3.3V and 1.8V 40W Fly-Back converter for digital consumer market
- **DESIGN SOFTWARE:** UNDER DEVELOPMENT
NEW
L6591
high performance PWM controller for Asymmetrical Half Bridge
L6591: HB ZVS PWM Primary Controller

- Half Bridge Topology
- Power Density
- Zero Voltage Switching
- No Switching Losses @ Turn On
- Up To 500KHz Oper. Freq.
- Small Magnetics and Cap, Short Response Times, Small Filters, Low Noise Levels
- Soft Switching
- Power Consumption
- On-Board HV Start-Up Gen. Low Quiescent Current (<3mA)
- Burst Mode @ Light Load Interface Pin with PFC
- Pulse-By-Pulse OCP
- Transformer Sat. Detection Latched or AutoRestart OVP Brownout Protection Adaptive UVLO
- Safety

L6591: HB ZVS PWM Primary Controller

SO16N
The L6591 is a double-ended PWM controller specific for the soft-switched half-bridge topology. It provides complementary PWM control, where the high-side switch is driven ON for a duty cycle $D$ and the low-side switch for a duty cycle $1-D$, with $D \leq 50\%$. An externally programmable dead-time inserted between the turn-off of one switch and the turn-on of the other one guarantees soft-switching and enables high-frequency operation.

To drive the high-side switch with the bootstrap approach, the IC incorporates a high-voltage floating structure able to withstand more than 600V with a synchronous-driven high-voltage DMOS that replaces the external fast-recovery bootstrap diode. The IC enables the designer to set the operating frequency of the converter by means of an externally programmable oscillator: the maximum duty cycle is digitally clipped at 50% by a T-flip-flop, so that the operating frequency will be half that of the oscillator. At very light load the IC enters a controlled burst-mode operation that, along with the built-in non-dissipative high-voltage start-up circuit and the low quiescent current, helps keep low the consumption from the mains and be compliant with energy saving recommendations. To allow compliance with these standards in two-stage power-factor-corrected systems as well, an interface with the PFC controller is provided that enables to switch off the pre-regulator between one burst and the following one. An innovative adaptive UVLO helps minimize the issues related to the fluctuations of the self-supply voltage with the output load, due to transformer’s parasitics. IC’s protection functions include: not-latched input undervoltage (brownout), a first-level OCP with delayed shutdown able to protect the system during overload and short circuit conditions (either auto-restart or latch mode can be selected) and a second-level OCP that latches off the IC when the transformer saturates or one of the secondary diodes fails short. Finally, a latched disable function allows easy implementation of OTP or OVP. Programmable soft-start and digital leading-edge blanking on current sense input pin complete the equipment of the IC.

The L6591 is an advanced current-mode PWM controller specific for fixed-frequency, peak-current-mode-controlled ZVS half-bridge converters. In these converters the switches (MOSFET’s) are controlled with complementary duty cycle: the high-side MOSFET is driven ON for a duty cycle $D$ and the low-side MOSFET for a duty cycle $1-D$. For a proper operation the maximum allowed duty cycle must be limited below 50%.

An externally programmable dead-time $TD$ inserted between the turn-off of one MOSFET and the turn-on of the other one ensures soft-switching and enables high-frequency operation with high efficiency and low EMI emissions. See “Oscillator and dead-time programming” section for more information on how to program $TD$.

STMicroelectronics; 14/11/2007
L6591: HB ZVS PWM Primary Controller

**Application:**
- High Power AC-DC Adapters/Chargers > 90W
- ATX Desktop PCs (80+, 85+ initiative)
- Telecom SMPS
- Audio Applications
- printers
**L6591 block diagram**

- RC oscillator with programmable dead-time
- Latched device protection
- Pulse-by-Pulse OCP & Hiccup mode
- PFC management
- Power-up and power-down sequencing
- 1.7mA typ. quiescent current Adaptive UVLO
- 600 V-rated floating driver with integrated bootstrap diode
- 5V Reference
- HV start-up current generator
- HV generator ON/OFF and adaptive UVLO management
- HV generator ON/OFF and adaptive UVLO management
- 1.7mA typ. quiescent current Adaptive UVLO
- 600 V-rated floating driver with integrated bootstrap diode
- HS DRIVER $D_{MAX} = 50\%$
- LS DRIVER $D_{MAX} = 100\%$
- Programmable soft-start
- Burst-mode at light load
- Power-up and power-down sequencing
- Programmable soft-start
- Burst-mode at light load
- RC oscillator with programmable dead-time
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- Power-up and power-down sequencing
- Programmable soft-start
- Burst-mode at light load
Good Cross Regulation
Low ripple Low Out Cap

Auxiliary Stage:
• VIPer17/15 for std-by up to 5W
• VIPer27/25 for std-by from 5W to 10W
• L6566A/B with external Mosfet for higher power levels

ZVS Operation

Typical Asymmetrical Half Bridge Architecture
AHB Architecture with Synchronous Rectification

Supporting also Housekeeping function on secondary side with TSM104

Higher Efficiency

Better Form Factor
Asymmetrical Half Bridge Waveforms

- **Vin**: Input voltage
- **Q1 current**: Current through Q1
- **D1 current**: Current through D1
- **Iload**: Load current
- **Lout current**: Output current from the tank circuit
- **HB midpoint voltage**: Voltage at the midpoint of the half bridge
- **Tank circuit current**: Current through the tank circuit

*AHB Controller L6591*
AHB secondary side waveforms

\[ V_{\text{rect}} = V_{\text{in}} \cdot (1-D)/n_1 \]
\[ V_{\text{rect}} = V_{\text{in}} \cdot D/n_2 \]

\[ I_{\text{Lout}} = I_{\text{out}} \]

\[ I_{D1} = I_{\text{SEC1}} \]

\[ I_{D2} = I_{\text{SEC2}} \]

Rectifiers reverse voltages

\[ V_{D1} = V_{\text{in}} \cdot D \cdot \left( \frac{1}{n_1} + \frac{1}{n_2} \right) \]

\[ V_{D2} = V_{\text{in}} \cdot (1-D) \cdot \left( \frac{1}{n_1} + \frac{1}{n_2} \right) \]
AHB waveforms summary

- Gate-drive signals
- HB mid-point Voltage
- DC blocking cap voltage
- Transformer currents
- Diode voltages
- Diode currents

- Dead-time
- Magnetizing current
- Tank circuit current
- Secondary current reflected to primary
- Output current
AHB topology key features

• **CONTROL**
  – PWM fixed frequency (Dmax = 50%)
  – Dead time between HG and LG to allow ZVS

• **HALF BRIDGE**
  – ZVS operation: Soft Switching - No switching losses @ turn-on

• **SECONDARY SIDE**
  – Balanced or unbalanced (Ns1≠Ns2) transformer
  – Output inductor needed
    • Can be coupled for multiple outputs

• **TRANSFORMER**
  – Unbalanced transformer: no need of high Llk to obtain ZVS
### Table 1. Efficiency @ 115Vrms

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### Table 2. Efficiency @ 230Vrms

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<td>89.3</td>
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<td>4.7</td>
<td>100</td>
<td>19.10</td>
<td>89.83</td>
<td>89.9</td>
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### Table 3. No load consumption

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<th>115Vac</th>
<th>230Vac</th>
<th>264Vac</th>
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<tbody>
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<td>Pin [W]</td>
<td>0.24</td>
<td>0.25</td>
<td>0.31</td>
<td>0.34</td>
</tr>
</tbody>
</table>
• SAMPLES: AVAILABLE NOW (PRODUCTION PHASE)
• DATASHEETs: AVAILABLE ON REQUEST
• APPLICATION NOTES:
  – 12V/90W AC-DC ADAPTER WITH PFC USING L6563 AND L6591 (IN PROGRESS)
  – 400W (85+ COMPLIANT) L6591-BASED AHB ZVS CONVERTER WITH PFC FOR DESKTOP PC (COMING NEXT)
• DEMO BOARDS:
  – 12V/90W AC-DC ADAPTER WITH PFC USING L6563 + L6591 (IN PROGRESS)
  – 400W ATX (85+ COMPLIANT), 12V and 5V outputs (COMING NEXT)
• DESIGN SOFTWARE:
  – UNDER DEVELOPMENT
**Off-line Resonant Controllers Roadmap**

- **L6598**
  - High Voltage Resonant Contr.
  - HV Gate driver
  - Soft start
  - Spare OP AMP
  - Latching & non-latching pins

- **L6599A**
  - High Performance Resonant Contr.
  - HV Gate driver
  - Burst-mode
  - Two levels OCP
  - PFC interface
  - Brown-out/seq. input
  - DIS pin latch for OVP

60
Resonant SMPS: LLC Topology
Resonant SMPS : LLC Circuit

3 reactive elements, 2 resonant frequencies

\[ f_{r1} = \frac{1}{2\pi\sqrt{LSC_r}} \quad f_{r1} > f_{r2} \]

\[ f_{r2} = \frac{1}{2\pi\sqrt{(Ls + L_p)C_1}} \]

\[ M = \frac{a \cdot V_{out}}{V_{in}} \]

Capacitive region
Current leading (ZCS)

Inductive region
Current lagging (ZVS)

ZVS-ZCS borderline

Resonance:
Load-independent point
All curve have slope = \(-\frac{1}{k}\)

\[ f = f_{r2} \]

\[ f = f_{r1} \]

\[ q = \sqrt{\frac{1}{1 + k}} \]
OFF-LINE
RESONANT CONTROLLERS
CONTROL:
- Variable frequency control, fixed 50% duty cycle for both MOSFETs
- Dead-time between LG and HG to allow MOSFET’s ZVS @ turn-on

HALF BRIDGE:
- ZVS operation: no switching losses @turn-on
- \( f_{sw} \approx f_r \), sinusoidal waveforms: low turn-off losses, low EMI

SECONDARY SIDE:
- Equal voltage & current stress for both rectifiers
- No output choke required: cost saving
- ZCS: no recovery losses, less EMI
- \( V_{RRM} = 1.25 \times 2V_{out} \) if secondary is CT,

TRANSFORMER
- Integrated magnetics: both L’s can be realized with the transformer

HIGH EFFICIENCY: >96% achievable
Resonant SMPS : LLC Circuit

OPERATING SEQUENCE (1 of 5)

Diode current
Resonant SMPS: LLC Circuit

Operating Sequence (2 of 5)

Diode Current

+V_{BUS}

Q1

Q2

OUT

I_{Q1}

I_{Q2}

I_{L1}

V_{C1}

V_{in} \cdot D

D_2

D_1

LOAD

L_M

C_{PIN}

L_s

Q1

D_{Q1}

OUT

D_{Q2}

CRES
Resonant SMPS: LLC Circuit

OPERATING SEQUENCE (3 of 5)

Q1
Q2
OUT
I_{Q2}
I_{Q1}
I_{L1}
V_{C1}
I_D

Diode current

\[ V_{IN} \cdot D \]

+V_{BUS}

Q1
D_{Q1}

Q2
D_{Q2}

L_s
C_{RES}

L_M

LOAD

C_{PIN}
Resonant SMPS: LLC Circuit

OPERATING SEQUENCE (4 of 5)
Resonant SMPS : LLC Circuit

OPERATING SEQUENCE (5 of 5)
L6599A: an IC to remember

- Superior stand-by performance (burst-mode operation at light load)
- Interface with PFC controller (L6561/62/63)
- High performance protections

200/400W demoboard with L6563

NEW
L6599A: an IC to remember

- 50% Duty Cycle, variable frequency control of ZVS resonant Half Bridge (HB)
- Up to 500KHz operating frequency
- Superior stand-by performance
  - Burst-mode operating at light load
  - Direct interface with PFC controller
- High performance protections
  - Two-level OCP: frequency-shift and latched shutdown
  - Latched disable input
  - Input for brownout protection or power ON/OFF sequencing
- Non linear soft-start for monotonic output voltage rise
- High accuracy oscillator
- 600V 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
- Available in PDIP16 and SO16N packages
• DATA SHEET: AVAILABLE ON THE WEB

• APPLICATION NOTES:
  – LLC RESONANT HALF-BRIDGE CONVERTER DESIGN GUIDELINE (AN2450)
  – 19V-90W ADAPTER BOARD WITH PFC USING L6599 AND L6563 (AN2321)
  – 400W L6599-BASED HB LLC RESONANT CONVERTER FOR PDP (AN2492)
  – 200W L6599-BASED HB LLC RESONANT CONVERTER FOR LCD TV & FLAT PANELS (AN2393)

• DEMO BOARDS:
  – 19V-90W BOARD WITH PFC USING L6599 AND L6563 (EVAL6599-90W)
  – 200W SMPS FOR LCD TV, USING L6599, L6563 and VIPer12A (EVAL6599-200W)
  – 400W SMPS FOR PDP USING L6599, L6563 and VIPer12A (EVAL6599-400W-S)
  – 400W GENERIC SMPS USING L6599, L6563 and VIPer12A (EVAL6599-400W-T)
  – 350W 80+ DESKTOP SMPS (IN DESIGN)

• DESIGN SOFTWARE:
  – L6599 RESONANT CONVERTER DESIGN WORKBOOK (EXCEL SPREADSHEET, AVAILABLE ON REQUEST)
Summary of topologies

Fixed frequency pwm

Quasi-resonant

Resonant

PFC can be turned off at light load to ease compliance with energy saving regulations.

PWM is turned off in case of PFC’s anomalous operation for safety.

L6561/2 or L6563

L6591

L6566A

L6599
Summary of frequency related operation mode

Quasi-resonant (L6566)

Resonant (L6599)

Fixed freq. pwm (L6591)
**Summary**

<table>
<thead>
<tr>
<th>L6566</th>
<th>PWM QR</th>
<th>Flyback</th>
<th>CCM</th>
<th>High power capability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ZVS: No switching losses @ on</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>High operating frequency</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>Low output peak current</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>Low output ripple (Cout lower than Flyback)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>L6591</th>
<th>PWM</th>
<th>ZVS Half Bridge</th>
<th>CCM</th>
<th>High power capability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ZVS of HB MOSFETs &amp; ZCS of output diodes:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No switching losses @ on, very low @ off</td>
</tr>
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<td></td>
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<td></td>
<td>High operating frequency</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>No recovery losses of output diode</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Very high noise immunity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>L6599</th>
<th>RES</th>
<th>LLC</th>
<th>CCM DCM</th>
<th>High power capability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ZVS of HB MOSFETs &amp; ZCS of output diodes:</td>
</tr>
<tr>
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<td>High operating frequency</td>
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<td></td>
<td>No recovery losses of output diode</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>Very high noise immunity</td>
</tr>
</tbody>
</table>

**Key Points**

- **Flyback**
  - Low peak current in rectifier and switch
  - Low output current/voltage ripple respect to DCM (Cout lower than DCM)
  - Recovery time rectifier losses (fast recovery diodes needed)
  - Feedback loop difficult to stabilize – 2nd order system (2 poles and right half plane zero)

- **ZVS Half Bridge**
  - Zero turn-on losses for the power switch
  - Good transient line/load response (1st order system), feedback loop (single pole) easy to stabilize
  - Recovery time rectifier not critical: current is zero well before reverse voltage is applied
  - High peak current (high RMS) in rectifier and switch
  - High output current/voltage ripple (Cout higher than CCM)

- **LLC**
  - High peak current (high RMS) in rectifier and switch
  - High output current/voltage ripple (Cout higher than CCM)

**Complexity**

- Feedback loop difficult to stabilize
- Peak current (RMS) in rectifiers and switches
## Application Summary

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>L6566A</strong></td>
<td><strong>PWM</strong></td>
<td>AC-DC Adapters from 70 to 120W, High End Consumer</td>
</tr>
<tr>
<td></td>
<td><strong>QR</strong></td>
<td>LCD TVs and Monitors (20 to 28”), SPMS for Printers &gt; 70W, Auxiliary</td>
</tr>
<tr>
<td><strong>L6566B</strong></td>
<td><strong>PWM</strong></td>
<td>AC-DC Adapters from 25 to 70W, Low End Consumer</td>
</tr>
<tr>
<td></td>
<td><strong>QR</strong></td>
<td>LCD TVs and Monitors &lt; 20”, SPMS for Printers &lt; 70W, Auxiliary</td>
</tr>
</tbody>
</table>
| **L6591** | **PWM** | High Power AC-DC Adapters > 90W  
High Output Current SMPS  
Multiple output SMPS  
SMPS for Audio applications > 75W  
ATX Desktop PCs (80+, 85+ initiative) |
| **L6599** | **RES** | High Power AC-DC Adapters > 90W  
SMPS for Video application – LCD/PDP TVs > 28”  
High Output Voltage SMPS  
Servers (90+ initiative) |
Robustness and effectiveness SMPS.....

HIGH PERFORMANCES LOW CONSUMPTION HIGH RELIABILITY LOW COMPONENTS COUNTS ADVANCED TECNOLOGY HIGH PERFORMANCES LOW

.....with VIPer +
VIPer+ introduces:

- AGGRESSIVE stand-by losses
- ROBUSTNESS power section and high level protection
- REDUCTION of total SMPS components count and EASY SMPS design
- PORTFOLIO differentiation: better TAILORED to specific applications
VIPer+ introduces: +differentiation

**FIXED FREQUENCY**

- **30W**
  - GND
  - VDD
  - CONT
  - FB
  - DRAIN
  - BR
  - VIPer37
  - 2009

- **0W**
  - GND
  - VDD
  - CONT
  - FB
  - DRAIN
  - BR
  - VIPer27x
  - N
  - VIPer28x
  - D

- **20Ω**
  - GND
  - VDD
  - CONT
  - FB
  - DRAIN
  - BR
  - VIPer15x
  - N
  - VIPer16x
  - D

**QUASI RESONANT**

- **1Ω**
  - GND
  - VDD
  - ZCD
  - FB
  - DRAIN
  - BR
  - VIPer35
  - 2009

- **Extension N: DIP7 package**
- **Extension D: SO16N package**

- **Brown out protection**
- **Peak power capability**
- **Self supply without auxiliary winding**
- **Buck and buck-boost converters**
- **Zero Current Detection**
- **Brown out protection**

* VIPER16xD, VIPER28xD, VIPER15xD: engineering samples available on request
* VIPER27xD, VIPER25xD, VIPER25xN: engineering samples on Q2/2009
VIPer+ selection

<table>
<thead>
<tr>
<th>Feature</th>
<th>VIPER1 5</th>
<th>VIPER1 6</th>
<th>VIPER1 7</th>
<th>VIPER2 5</th>
<th>VIPER2 6</th>
<th>VIPER2 7</th>
<th>VIPER2 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Frequency PWM current mode controller</td>
<td>√</td>
<td></td>
<td>√</td>
<td>√</td>
<td>√</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quasi Resonant PWM current mode controller</td>
<td></td>
<td>√</td>
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<td></td>
</tr>
<tr>
<td>Fixed frequency PWM current mode controller with embedded EA</td>
<td></td>
<td></td>
<td>√</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limiting Drain current with adjustable set point</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Fixed frequency (60kHz or 115kHz) with JITTERING</td>
<td></td>
<td>√</td>
<td></td>
<td>√</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced Stand-by management</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Automatic Autorestart after fault</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Advanced Over Load and short circuit management</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Accurate Over Voltage Protection</td>
<td>√</td>
<td></td>
<td>√</td>
<td></td>
<td>√</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open loop failure detection</td>
<td></td>
<td>√</td>
<td></td>
<td>√</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feed Forward Compensation</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On board soft start up</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Hysteretic Thermal shut-down</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Brown-out protection</td>
<td></td>
<td></td>
<td></td>
<td>√</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extra Power Timer for Peak Power management</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td>√</td>
</tr>
<tr>
<td>Eliminates bias winding supply</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td>√</td>
</tr>
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</table>

**POWER SECTION: 800V avalanche rugged**

<table>
<thead>
<tr>
<th>Packages</th>
<th>DIP7 &amp; SO16N</th>
<th>DIP7 &amp; SO16N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum output power</td>
<td>up to 10W</td>
<td>up to 20W</td>
</tr>
</tbody>
</table>
### VIPer+ selection (by SMPS topology)

<table>
<thead>
<tr>
<th>800V avalanche rugged</th>
<th>20 Ohm</th>
<th>7 Ohm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>400mA</td>
<td>400mA</td>
</tr>
<tr>
<td>VIPER1 5</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>VIPER1 6</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>VIPER1 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIPER2 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIPER2 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIPER2 7</td>
<td></td>
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</tr>
<tr>
<td>VIPER2 8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Buck converter
- 400mA: ✓
- 700mA: ✓
- 800mA: ✓

#### Buck-Boost converter
- 400mA: ✓
- 700mA: ✓
- 800mA: ✓

#### Fly-back isolated converter
- 400mA: ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
- 700mA: ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
- 800mA: ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓

#### Fly-back primary regulation converter
- 400mA: ✓ ✓ ☹ ✓ ✓ ☹ ✓ ✓
- 700mA: ✓ ✓ ☹ ✓ ✓ ☹ ✓ ✓
- 800mA: ✓ ✓ ☹ ✓ ✓ ☹ ✓ ✓

#### Fly-back non isolated converter
- 400mA: ✓ ✓ ☹ ✓ ✓ ☹ ✓ ✓
- 700mA: ✓ ✓ ☹ ✓ ✓ ☹ ✓ ✓
- 800mA: ✓ ✓ ☹ ✓ ✓ ☹ ✓ ✓

- Up to 10W
- Up to 20W

### Home appliances
- **2-10W**
  - VIPer17
  - VIPer16
  - VIPer27
  - VIPer28
  - VIPer15
  - VIPer53x

### Consumer equipments
- **5-40W**
  - VIPer17
  - VIPer27
  - VIPer28
  - VIPer15

### Metering equipments
- **4-8W**
  - VIPer16
  - VIPer27
  - VIPer28

### Battery Charger
- **4-6W**
  - VIPer16
  - VIPer17
  - VIPer15

### Lighting
- **2-8 Leds**
  - VIPer16
  - VIPer17
  - VIPer27
  - VIPer28
  - VIPer15
New double chip approach helps in flexibility

SuperMESH, 800V avalanche rugged

BCD6 Mixed Signal

High voltage start up

Temperature sensor
• HV start up current generator
  (typ, 3mA or 600uA after a fault)
• Start up threshold (typ, 14V)
• Auto-restart threshold (typ, 4.5V)
• Turn-off threshold (typ, 8.5V)
• VDD from 8.5V to 23V (with clamp)
• VDS START 80V
• HV Current Source:
  enabled only if \( V(DRAIN) > V_{\text{DRAIN \_ START}} \) (50V typ.)
  - \( I_{DDch1} \) (typ, 1mA): during start up
  - \( I_{DDch2} \) (typ, 10mA): during steady state

• Three VDD thresholds:
  - \( V_{DDon} \) (typ, 13V): Start Up threshold
  - \( V_{DDons} \) (typ, 10.5V): Current Source ON threshold
  - \( V_{DDoff} \) (typ, 7V): Switching OFF threshold

![Diagram of VDD PIN functionalities]

\[ V_{DDon} \]
\[ V_{DDons} \]
\[ V_{DDoff} \]
\[ I_{DDch1} \]
\[ I_{DDch2} \]

\[ V(DRAIN) < V_{\text{DRAIN \_ START}} \]

Switching ON

Switching OFF
- Loop compensation for PWM operations
- Over load protection
- Burst mode sensing

FB pin

50 mW

Over load delay = \( V_{FB} \times \frac{4.8V - 3.3V}{3 \mu A} \)

- \( V_{FB_{lin}} \)
- \( V_{FB_{olp}} \)
- Over load delay
- Burst mode light load
- Drain current is depending from the load
- \( V_{FB_{bm}} \)
- \( V_{FB_{bm\_hys}} \)
• Adjustment of the current limit set point

*default value when the pin is floating (or \( R_{\text{LIM}} > 100\text{kOhm} \))*

• Over voltage protection (OVP)

*with digital filter for noise immunity*

<table>
<thead>
<tr>
<th>( I_{\text{DLIM}} ) default value</th>
<th>VIPER17</th>
<th>400mA</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIPER27</td>
<td>700mA</td>
<td></td>
</tr>
<tr>
<td>VIPER28</td>
<td>800mA</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>( I_{\text{DLIM}} )</th>
<th>± 5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_J ) 27°C</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>( I_{\text{DLIM}} )</th>
<th>± 10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_J ) from -25°C to 125°C</td>
<td></td>
</tr>
</tbody>
</table>
Zero Current Detection

Line feed-forward compensation

Current Limit set point ($I_{DLIM}$)

Output over voltage protection (OVP)

Feed forward compensation

QR operation with top frequency limited
Extra Power Timer **for extra power capability**

- $I_{Dlim} = 800mA$
- $I_{Dlim\_EPT} = 85\% I_{DLIM}$
- *When $I_{DRAIN}$ is higher then $I_{Dlim\_EPT}$ a delay time starts: the time depends from $C_{DOVL}$*
- *After the delay time if the over load is still present the converters is switched OFF*
BR pin (only VIPer17, 27, 15 & 25)

BROWN OUT PROTECTION

Switching is stopped* if the BR pin voltage ($V_{BR}$) fall down the $V_{BRTH}$ threshold (450mV, typ value).

Double $V_{BRTH}$ hysteresis: current and voltage.

* Function is disabled if BR is connected to GND.
VIPer16

Solutions for replacement of capacitive power supply

Auxiliary power supply for: Home appliances, Power metering, LED drivers

- 800V avalanche rugged power section
- Frequency jittering for low EMI
- Two operating fixed frequency: 60 or 115 kHz
- Automatic self-supply
- Limiting current with adjustable set point
- Safe auto restart after a fault condition
- Hysteretic thermal shutdown
- Advanced protections: over load and feedback loop failur
Buck-Boost converter

Feedback loop → Loop compensation

AC input voltage

DC output voltage

VPer16

GND
VDD
LIM
FB
COMP

R
LIM
C
C
C
R
COM
R
FB1
R
FB2
D
D
D
L
OUT
C
OUT

DC output voltage

Loop compensation

Innovation and
Fly-back converter, nonisolated

Feedback loop → Loop compensation

AC input voltage

DC output voltage

GND DRAIN
VDD DRAIN
LIM DRAIN
FB COMP

VIPer16

C1

Rlim

Cout

Rfb1

Rfb2

C2

C3

Ccom

P

P

VDD

LIM

FB

COMP

Rcom

P

D5

Fuse D0

+ -

+ -

+ -
Fly-back converter, isolated

Loop compensation +

FB to GND

Loop feedback

Diagram showing component connections and labels:
- GND
- DRAIN
- VDD
- LIM
- FB
- COMP
- VIPer16
- FB to GND
- Loop feedback
- DC output voltage
- AC input voltage
- C1, C2, C3
- R1, R2, R3, R4
- R_UP
- R_DOWN
- D0
<table>
<thead>
<tr>
<th>ORDER CODE</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>APPLICATION NOTE</th>
<th>INPUT VOLTAGE</th>
<th>OUTPUT VOLTAGE</th>
<th>OUTPUT CURRENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEVAL-ISA060V1</td>
<td>VIPER17HN</td>
<td>Off line isolated FLY-BACK</td>
<td>AN2753</td>
<td>85-265VAC</td>
<td>12V</td>
<td>500mA</td>
</tr>
<tr>
<td>EVALVIPER17L-6W</td>
<td>VIPER17LN</td>
<td>Off line isolated FLY-BACK</td>
<td>AN2803</td>
<td>85-265VAC</td>
<td>12V</td>
<td>500mA</td>
</tr>
<tr>
<td>EVLVIP17-5WCHG</td>
<td>VIPER17HN</td>
<td>Off line isolated FLY-BACK for Battery Charger</td>
<td>TBD</td>
<td>85-265VAC</td>
<td>5V</td>
<td>1A</td>
</tr>
<tr>
<td>STEVAL-ISA058V1</td>
<td>VIPER17LN</td>
<td>High performance VIPER17LN Demo (Low consumption in Stand-</td>
<td>TBD (draft</td>
<td>85-265VAC</td>
<td>5V</td>
<td>1A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>by and low Load).                                             document)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STEVAL-ILL017V1</td>
<td>VIPER17HN</td>
<td>Off line non isolated FLY-BACK for constant current LED</td>
<td>AN2811</td>
<td>220VAC ±20%</td>
<td>7V max</td>
<td>500mA</td>
</tr>
<tr>
<td>EVALVIPER28H-10W</td>
<td>VIPER28HN</td>
<td>Off line isolated FLY-BACK</td>
<td>TBD</td>
<td>85-265VAC</td>
<td>5V</td>
<td>2.4A</td>
</tr>
<tr>
<td>EVALVIPER28L-10W</td>
<td>VIPER28LN</td>
<td>Off line isolated FLY-BACK</td>
<td>TBD</td>
<td>85-265VAC</td>
<td>5V</td>
<td>2.4A</td>
</tr>
<tr>
<td>EVLVIPER16H-4WPN</td>
<td>VIPER16HN</td>
<td>Off line non isolated FLY-BACK</td>
<td>TBD</td>
<td>85-265VAC</td>
<td>16V</td>
<td>250mA</td>
</tr>
<tr>
<td>EVLVIPER16L-4WPN</td>
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<td>Off line non isolated FLY-BACK</td>
<td>TBD</td>
<td>85-265VAC</td>
<td>16V</td>
<td>250mA</td>
</tr>
<tr>
<td>EVLVIPER16H-4WFL</td>
<td>VIPER16HN</td>
<td>Off line isolated FLY-BACK</td>
<td>TBD</td>
<td>85-265VAC</td>
<td>16V</td>
<td>250mA</td>
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<tr>
<td>EVLVIPER16L-4WFL</td>
<td>VIPER16LN</td>
<td>Off line isolated FLY-BACK</td>
<td>TBD</td>
<td>85-265VAC</td>
<td>16V</td>
<td>250mA</td>
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<tr>
<td>TBD</td>
<td>VIPER16LN</td>
<td>Buck converter with ultra input wide range</td>
<td>AN_TBD (draft</td>
<td>85-500VAC</td>
<td>+12V, +5V</td>
<td>150mA (total)</td>
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Power & Analog program

European Multi System Market Competence Center
• Power conversion

  – **SMPS**
    • Main topologies quick roundup
    • Power Factor Correction
    • PWM (offline & HV DCDC)
    • **Low Voltage DC-DC Converters**

  – **Lighting**
    • Fluorescent ballast
      – Analog driven
      – Digital driven / advanced
    • HID
    • **LED / DISPLAY DRIVER**
      – DC / DC driven
      – Offline driven
      – Display control
**High Efficiency Monolithic Switching Regulators to suit different markets**

**Major area of focus:** *enlarge product portfolio for: Industrial, Consumer, Peripheral, Telecom and Battery powered equipments*

- **Computer & Peripheral**
  - Peripherals: Printers, Mouse Ext./Int. Data storage

- **Consumer**
  - Office/Home entertainment: PDP/LCD TV Monitors STB, DVD, Games

- **Automotive & Industrial**
  - Hand-Held Equipment: PDA, MP3, DSC, GPS

- **Data-Com.**
  - Power train, car body, PLC, PLA

- **XDSL Modems**
- **Video Phone**
- **WLess Access point**

- **L497x, L597x, L598x**

- **L692x**

- **L497x, L597x, L598x**

- **L497x, L597x, L598x A597x**

- **L597x, L598x**
L497x family

- Up to 3.5A available both in DIP and SO packages
- Wide voltage input range (8V up to 55V) and output range (0.5V up to 50V)
- Internal current limit
- Inhibit pin*
- OVP*
- External reference**

**Suggested for new projects When Vin>36V and Iout>2A**

<table>
<thead>
<tr>
<th>Device</th>
<th>Package</th>
<th>Ipk [A]</th>
<th>Iout [A]</th>
<th>Vin (V)</th>
<th>Vout (V)</th>
<th>Fsw [KHz]</th>
<th>Extra functions</th>
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<tr>
<td>L4976</td>
<td>DIP8, SO16W</td>
<td>1.5</td>
<td>1</td>
<td>8V to 55V</td>
<td>0.5 to 50</td>
<td>up to 300</td>
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<td>3.3 to 50</td>
<td>up to 300</td>
<td>Inhibit</td>
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<td>L4974</td>
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<td>8V to 55V</td>
<td>3.3 to 50</td>
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<tr>
<td>L4973 v.3.3</td>
<td>DIP18, SO20</td>
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<td>5.1 to 50</td>
<td>up to 300</td>
<td>Inhibit, Vref, Sync</td>
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* all but L4976 , **L4976 and L4973
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<td>AN937</td>
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<td>AN1061</td>
<td>EVAL4971</td>
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<tr>
<td>L4973</td>
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<td>AN938, AN1126</td>
<td>EVAL4973</td>
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</table>
**L597x Family**

- More than 2A in small SO8 package with minimum external component count
- P-channel power MOS: no bootstrap capacitor
- Wide input voltage range (4.4V up to 36V)
- High switching frequency (250KHz/500KHz, sync up to 700KHz*)
- Inhibit pin*
- Embedded protection features
- Typ $R_{DS(on)}=250\Omega$

---

**Suggested for new projects When Vin>18V**

<table>
<thead>
<tr>
<th>Device</th>
<th>Package</th>
<th>Ipk [A]</th>
<th>Iout [A]</th>
<th>Vin (V)</th>
<th>Vout (V)</th>
<th>Fsw [KHz]</th>
<th>Extra functions</th>
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<tbody>
<tr>
<td>L5970D</td>
<td>SO8</td>
<td>1.5</td>
<td>1</td>
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<td>0.5V to Vin</td>
<td>250</td>
<td>Inhibit, Vref, Sync</td>
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<td>SO8</td>
<td>1.5</td>
<td>1</td>
<td>4.4V to 36V</td>
<td>0.5V to Vin</td>
<td>500</td>
<td>Inhibit, Vref, Sync</td>
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<tr>
<td>L5972D</td>
<td>SO8</td>
<td>2</td>
<td>1.5</td>
<td>4.4V to 36V</td>
<td>1.23V to Vin</td>
<td>250</td>
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</tr>
<tr>
<td>L5973AD</td>
<td>HSOP8</td>
<td>2</td>
<td>1.5</td>
<td>4.4V to 36V</td>
<td>0.5V to Vin</td>
<td>500</td>
<td>Inhibit, Vref, Sync</td>
</tr>
<tr>
<td>L5973D</td>
<td>HSOP8</td>
<td>2.5</td>
<td>2</td>
<td>4.4V to 36V</td>
<td>0.5V to Vin</td>
<td>250</td>
<td>Inhibit, Vref, Sync</td>
</tr>
</tbody>
</table>

* all but L5972D

---

HSO8 - Rth j-amb 40C/W

SO8 - Rth j-amb 115C/W

Rth j-amb 62C/W for L5972D
L597x: Test Application Circuit

VIN = 4.4V to 25V
C1 10μF 25V CERAMIC

C4 22nF
C3 220pF
R3 4.7K

VCC 3.3V
VREF 6
OUT 1
L1 33μH
D1 STPS2L25U
R1 5.6K
C2 100μF 10V
R2 3.3K

D03IN1437

GND 7
INH. 3
FB 5

VOUT=3.3V
L6902D Key Features

- 1A in small SO8 package with minimum external component count
- P-channel power MOS: no bootstrap capacitor
- Wide input voltage range (8V up to 36V)
- Adjustable current limit ($V_{CS+} - V_{CS-} = 100$ mV)
- High switching frequency (250KHz)
- External $V_{REF}$ available
- Embedded protection features
- OVP available when driving LED
<table>
<thead>
<tr>
<th>P/N</th>
<th>Datasheet</th>
<th>Application note</th>
<th>Evaluation board</th>
</tr>
</thead>
<tbody>
<tr>
<td>L5970D</td>
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<td>EVAL5973D</td>
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<td>Data brief</td>
<td>EVAL6902D</td>
</tr>
</tbody>
</table>

L597x promotional tools
### L598x Family

- Up to 3A in small QFN3x3-8L or HSOP8 package with minimum external component count
- P-channel power MOS: no bootstrap capacitor
- Wide input voltage range (2.9V up to 18V)
- High switching frequency (250KHz, adjustable up to 1MHz) with Synchronization capability (180° out of phase)
- Internal Soft-start
- Inhibit pin
- Embedded protection features
- Suitable for MLCC output filter
- Typ $R_{DSon} = 140\,\text{m}Ω$

#### Suggested for new projects When Vin<18V

<table>
<thead>
<tr>
<th></th>
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<td>Inh, AdjFsw, Sync</td>
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<tr>
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<td>QFN3x3-8L</td>
<td>1.5</td>
<td>1</td>
<td>2.9V to 18V</td>
<td>0.6V to Vin</td>
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<td>Inh, AdjFsw, Sync</td>
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<tr>
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<td>QFN3x3-8L</td>
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<td>0.6V to Vin</td>
<td>250</td>
<td>Inh, AdjFsw, Sync</td>
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<tr>
<td>L5986/A</td>
<td>QFN3x3-8L / HSOP8</td>
<td>3</td>
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<td>2.9V to 18V</td>
<td>0.6V to Vin</td>
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<td>Inh, AdjFsw, Sync</td>
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<tr>
<td>L5987/A</td>
<td>QFN3x3-8L / HSOP8</td>
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<td>3</td>
<td>2.9V to 18V</td>
<td>0.6V to Vin</td>
<td>250</td>
<td>Inh, AdjFsw, Sync</td>
</tr>
</tbody>
</table>

* Low cost versions with cheaper testing procedure

---

QFN 3x3 8L - Rth j-amb 60°C/W

HSO8 - Rth j-amb 40°C C/W
VIN=2.9V to 18V

L598x

VCC 8

INH 3

GND 7

FSW 6

COMP 4

OUT 1

SYNCH 2

FB 5

D1

R1

L1

Cout

Vout=0.6V to VCC

C5

R3

C3

R2

Cin
# L598x Promotional tools

<table>
<thead>
<tr>
<th>P/N</th>
<th>Datasheet with App. info</th>
<th>Evaluation Board</th>
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</thead>
<tbody>
<tr>
<td>L5980</td>
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</table>

Evaluation board available also for the “A” versions as: EVAL5945A, EVAL5986A, EVAL5987A and EVAL5947A

**SPREAD SHEET:**
- to dimension output filter
- to compensate the loop
- to estimate $T_j$ and efficiency

Now available on request
A597x Key Features

- More than 2A in small SO8 package with minimum external component count
- P-channel power MOS: no bootstrap capacitor
- Wide input voltage range (4V up to 36V)
- High switching frequency (250KHz/500KHz, synch up to 700KHz*)
- Inhibit pin*
- Embedded protection features
- All Parameters tested over the -40°C to +125°C junction temperature range
- BURN-IN test for high reliability (B5973D)

**Suggested for new Automotive projects**

<table>
<thead>
<tr>
<th>Device</th>
<th>Package</th>
<th>Ipk (A)</th>
<th>Iout (A)</th>
<th>Vin (V)</th>
<th>Vout (V)</th>
<th>Fsw (kHz)</th>
<th>Tj Operating</th>
<th>Extra functions</th>
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<tr>
<td>A5970D</td>
<td>SO8</td>
<td>1.5</td>
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<td>0.5V to Vin</td>
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<td>-40°C to +150°C</td>
<td>Inhibit, Vref, Sync</td>
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<td>0.5V to Vin</td>
<td>500</td>
<td>-40°C to +150°C</td>
<td>Inhibit, Vref, Sync</td>
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<td>A5972D</td>
<td>SO8</td>
<td>2</td>
<td>1.5</td>
<td>4V to 36V</td>
<td>1.23V to Vin</td>
<td>250</td>
<td>-40°C to +150°C</td>
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<tr>
<td>A5973AD</td>
<td>HSOP8</td>
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<td>1.5</td>
<td>4V to 36V</td>
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<td>A5973D</td>
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<td>250</td>
<td>-40°C to +150°C</td>
<td>Inhibit, Vref, Sync</td>
</tr>
</tbody>
</table>

**SO8 - Rth j-amb 115°C C/W**
**Rth j-amb 62°C C/W for L5972D**

*all but A5972D

**HSO8 - Rth j-amb 40°C C/W**

The A597x family is tailored for Automotive applications, qualified following the AEC-Q100* specifications

*PPAP available for details
A597x Customers & Applications

**MAJOR CUSTOMERS**
- harman international
- DELPHI
- BOSCH
- Continental
- Visteon
- HELLA
- MAGNETI MARELLI

**MAJOR APPLICATIONS**
- ELECTRONIC POWER STEERING
- TRANSMISSION & POWER TRAIN
- CAR INFOTAINMENT
- ANTI-LOCK SYSTEM
- LIGHTING
- DOOR & WINDOW CONTROL
Few examples...

- **L5973D in integrated navigation system**
- **A597xD rear camera Modules and lighting Modules**
- **MAGNETI MARELLI 5973D/AD in integrated navigation systems**
- **KELLA B5973D in electronic control unit for active steering**
- **Continental**
A597x: Application Circuit Example

VIN = 4V to 36V

A597xD
B5973D

C1 100uF
I_{RMS} = 1A

C2 330uF 6.3V

C3 220pF
R3 4k7

R1 5.6k

D1 STPS340U

L1 15uH

VOUT = 3.3V

1 2 3 4 5 6 7 8

INH SYNCH VREF 3.3V GND FB OUT

VCC

A597x: Application Circuit Example
A6902D Key Features

- 1A in small SO8 package with minimum external component count
- P-channel power MOS: no bootstrap capacitor
- Wide input voltage range (8V up to 36V)
- High switching frequency (250KHz)
- External $V_{\text{REF}}$ available
- Embedded protection features
- Operates over the -40°C to +125°C junction temperature range

The A6902D is tailored for Automotive applications, qualified following the AEC-Q100* specifications

*PPAP available for details
A6902D: Application Circuit Example

- **V**<sub>IN</sub>=8V to 36V
- C<sub>1</sub> = 100μF
- I<sub>RMS</sub> = 500mA
- C<sub>3</sub> = 220pF
- R<sub>2</sub> = 3K
- R<sub>3</sub> = 4.7K
- C<sub>4</sub> = 22nF

- STPS2L25U
- D1
- CS+ to CS-
- R<sub>1</sub> = 7.5K
- R<sub>4</sub> = 100 mhom

- Vcc
- COMP
- OUT
- FB
- 15uH
- 100uF to 10V
### L692x Key Features

- Very small packages
- Internal synchronous switch
- Small number of external components
- Micro power consumption
- High efficiency
- Short circuit protection, OVP, thermal shutdown
- Battery detection

**Suggested for Portable application**

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<td>1</td>
<td>0.5</td>
<td>0.6 - 5.5</td>
<td>2 - 5.2</td>
<td>up to 1000</td>
<td>LBI&amp;LBO, Vref, SHDN</td>
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<tr>
<td>L6920DB</td>
<td>MSOP8</td>
<td>SU</td>
<td>0.8</td>
<td>0.4</td>
<td>0.6 - 5.5</td>
<td>1.8 - 5.2</td>
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<td>L6925D</td>
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<td>0.8</td>
<td>2.7 - 5.5</td>
<td>0.6 - Vin</td>
<td>600</td>
<td>UVLO 2.7V, LBI&amp;LBO</td>
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<td>0.8</td>
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<td>0.6 - Vin</td>
<td>1400</td>
<td>PGOOD, RUN, SYNC</td>
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</tbody>
</table>

**Values:**
- Vin: Input voltage range
- Iout: Output current range
- Vout: Output voltage range
- Fsw: Switching frequency range

**Packages:**
- TSSOP8
- QFN3x3
- MSOP8
L692x: Application Circuits

L6926/8

L6920D/DB

L6924D

L6925
L6924x Key Features

- Fully integrated solution, with a power MOSFET, reverse blocking diode, sense resistor, and thermal protection
- Both linear and quasi-pulse operation
- Closed loop thermal control
- Vin from 2.5V to 12V
- USB BUS-compatible (L6924U)
- Programmable charge current up to 1A
- Programmable charge current up to 500 mA in USB mode (L6924U)
- Programmable pre-charge current (L6924D)
- Support for USB high and low power input (L6924U)
- Programmable end-of-charge current
- Programmable pre-charge voltage threshold (L6924D)
- Programmable charge timer
- Programmable output voltage at 4.1V and 4.2V, with ±1% output voltage accuracy (L6924D)
- NTC or PTC thermistor interface for battery temperature monitoring and protection
- Flexible charge process termination (L6924D)
- Full set of default charging parameters
- Status outputs to drive LEDs or to interface with a host processor
- Small VFQFPN 16-leads package (3mm x 3mm)
# L692x promotional tools

<table>
<thead>
<tr>
<th>P/N</th>
<th>Dataset</th>
<th>Application note</th>
<th>Evaluation board</th>
</tr>
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<tbody>
<tr>
<td>L6920D</td>
<td>Available</td>
<td>--</td>
<td>EVAL6920D</td>
</tr>
<tr>
<td>L6920DB</td>
<td>Available</td>
<td>AN2206</td>
<td>EVAL6920DB1</td>
</tr>
<tr>
<td>L6924D</td>
<td>Available</td>
<td>--</td>
<td>EVAL6924D</td>
</tr>
<tr>
<td>L6924U</td>
<td>Available</td>
<td>--</td>
<td>EVAL6924U</td>
</tr>
<tr>
<td>L6925</td>
<td>Available</td>
<td>AN1893</td>
<td>On request *</td>
</tr>
<tr>
<td>L6926</td>
<td>Available</td>
<td>AN1881</td>
<td>EVAL6926</td>
</tr>
<tr>
<td>L6928</td>
<td>Available</td>
<td>AN2115</td>
<td>EVAL6928</td>
</tr>
</tbody>
</table>

* please refer to the I&PC division application lab

---

**L6924D**

- 9 mm
- 12 mm

**L6925D/26/28D**

- 7.2 mm
- 12.5 mm

---

* EVAL6924D
* EVAL6924U
* EVAL6925
* EVAL6926
* EVAL6928

---

Available: Currently available.
On request: Available upon request.
NEW COMERS!!!
Soon in Mass Production
Suggested in new projects only when:

Vin < 18V
Iout > 3A
L5988-9D Key Features

- Up to 4A in small HTSSOP 16 package with minimum external component count
- Synchronous rectification with P-channel power MOS: no bootstrap capacitor
- Wide input voltage range (2.9V up to 18V)
- High switching frequency (400KHz, adjustable up to 1MHz)
- Adjustable Soft-start and Inhibit function
- Embedded over current (adjustable threshold), over voltage and thermal protection
- PGood signal (L5989D) Synchronization capability (180° out of phase) (L5988D)
- Pre-bias start-up capability
- Multifunction pin (adjustable UVLO, latched/no latched OVP and sink-mode capability)
- 1.8v ± 2% reference voltage
- Suitable for MLCC output filter
- Typ \( R_{D\text{son}} = 75\Omega \) for HS and 65\( \Omega \) for the LS

<table>
<thead>
<tr>
<th>Device</th>
<th>Package</th>
<th>( I_{pk} ) [A]</th>
<th>( I_{out} ) [A]</th>
<th>( V_{in} ) (V)</th>
<th>( V_{out} ) (V)</th>
<th>( F_{sw} ) [KHz]</th>
<th>Extra functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>L5988D</td>
<td>HTSSOP 16</td>
<td>5</td>
<td>4</td>
<td>2.9V to 18V</td>
<td>0.6V to Vin</td>
<td>400</td>
<td>Synchronization</td>
</tr>
<tr>
<td>L5989D</td>
<td>HTSSOP 16</td>
<td>5</td>
<td>4</td>
<td>2.9V to 18V</td>
<td>0.6V to Vin</td>
<td>400</td>
<td>Pgood</td>
</tr>
</tbody>
</table>

Mass Prod. End Q1-’09

ES available

For an higher EFFICIENCY

SYNCH. RECT.
L5988D Application Test Circuit

VIN = 2.9V to 18V

VOUT = 0.6V to Vcc

L5988D

Cin

VREF

O/U/S

SS/INH

Ccss

GND

L1

FB

COM

P

Cout

VCC
PM668x: dual step-down controller

- **Vin Range:** 4.5V to 36V
- **Frequency selectable** 200kHz to 500kHz
- **SENSORLESS Current sense (LS MOSFET RDSON)**
- **Protections:** UVL, OVP, ILIM, Power Good
- **PLUS:** Internal Soft Start, Power Good, Soft Off discharge COUT

**LINEAR REGULATOR:**
- 5V -200mA peak

**Excel worksheet available to facilitate the design**

<table>
<thead>
<tr>
<th>PN</th>
<th>V_OUT # (SW +LDO)</th>
<th>V_OUTSW 1</th>
<th>V_OUTSW 2</th>
<th>V_OUTLDO</th>
<th>I_LDO</th>
<th>V_IN range</th>
<th>package</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM6680</td>
<td>2+1</td>
<td>Adj.</td>
<td>Adj.</td>
<td>5V</td>
<td>200mA</td>
<td>Up to 28V</td>
<td>QFN 5x5</td>
</tr>
<tr>
<td>PM6680A</td>
<td>2+1</td>
<td>Adj.</td>
<td>Adj.</td>
<td>5V</td>
<td>200mA</td>
<td>Up to 36V</td>
<td>QFN 5x5</td>
</tr>
<tr>
<td>PM6685</td>
<td>2+2</td>
<td>3.3V</td>
<td>5V</td>
<td>(1)3.3V + (2)5V</td>
<td>100mA</td>
<td>up to 28V</td>
<td>QFN 5x5</td>
</tr>
</tbody>
</table>
**PM6680A: application**

**STEVAL-PSQ001V1**: PM6680A + L5970A - System Supply Board for FPGA and MPU

- **Input protection**
- **Input 5-36V**
- **Skip mode settings**
- **PM6680A**
- **L5970AD**
- **LK112M 33**
- **STM6719**
- **KF25**

**Voltage Settings**:
- **E/D + start up sequence settings**
- **Vi/o voltage settings**
- **Vcore voltage settings**

**Signal Connections**:
- **Reset signal**
- **Analog**
  - 5V analog 500mA
  - 3.3V analog 150mA
- **Output 3**
  - Vsys 3.3V 400mA
  - Vaux 2.5V 400mA
- **Output 2**
  - Vi/o 0.9 – 3.3V 2A
- **Output 1**
  - Vcore 0.9 – 2.5V 4A

**Notes**:
- **PM6680A + L5970A - System Supply Board for FPGA and MPU**
- **STEVAL-PSQ001V1**
- **Input protection**
- **Input 5-36V**
- **Skip mode settings**
- **PM6680A**
- **L5970AD**
- **LK112M 33**
- **STM6719**
- **KF25**

**Additional Information**:
- **Vi/o 0.9 – 3.3V 2A**
- **Vcore 0.9 – 2.5V 4A**
- **E/D Vsys + Vaux**
- **FB Vi/o**
- **FB Vcore**
**STxS0yy family**

**Single / dual synchronous rectification with reset or inhibit**

<table>
<thead>
<tr>
<th>DEVICE</th>
<th>$I_{OUT}(A)$</th>
<th>$V_{OUT} (V)$</th>
<th>$V_{IN}(V)$</th>
<th>$Fsw(MHz)$</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST1S03</td>
<td>1.5</td>
<td>Adj from 0.8V to 12V</td>
<td>2.7 to 6V</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>ST1S06</td>
<td>1.5</td>
<td>Adj from 0.8V to 5.5V</td>
<td>2.5 to 7V</td>
<td>1.5</td>
<td>SR I + SR</td>
</tr>
<tr>
<td>ST1S06A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST1S09</td>
<td>2</td>
<td>Adj from 0.8 to 5V</td>
<td>4.5 to 5.5V</td>
<td>1.5</td>
<td>PG I</td>
</tr>
<tr>
<td>ST1S10</td>
<td>3</td>
<td>Adj from 0.8 to 15V</td>
<td>2.5 to 18V</td>
<td>1</td>
<td>Ext Synch from 0.4MHz to 1.2MHz</td>
</tr>
<tr>
<td>ST2S06A</td>
<td>0.5+0.5</td>
<td>Adj from 0.8 to 5V</td>
<td>From 2.5 to 5.5V</td>
<td>1.5</td>
<td>Ro I</td>
</tr>
<tr>
<td>ST2S06B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$I$= Inhibit  
$PG$= Power Good  
$SR$ = Synchronous Rectification  
$Ri,o$=Reset input, output
STxS0yy family – typ application

- Single output
- Current mode with internal 1.5A power switch.
- Internal compensation.
- Switching frequency reduction in light load condition (<250mA typ.)
- Soft Start
- Thermal Shut down Tj=150°C
- Cycle-by-cycle Current Limiting

- Dual output
- Current mode with internal 0.5A power switch.
- Internal compensation.
- Soft Start
- Thermal Shut down Tj=150°C
- Cycle-by-cycle Current Limiting
Main Characteristics:

- Switching Frequency: 1.5MHz
- Output Current Capability: 2A max over all operating conditions
- Output Voltage: Adjustable from 0.8V or 1.2, 1.5, 1.8, 2.5, 3, 3.3V Fixed Output Voltages under customer request
- Max Operating input Voltage: 5.5V
- Soft-Start circuit to reduce inrush current
- Efficiency: up to 95%
- Fast Transient Response
- Short Circuit and Thermal Protection
- Power-on Delay (50-100μs)
- QFN 3x3mm Package Type
- ST1S09 with Power Good Function (on PIN 6)
- ST1S09I with Inhibit Function (on PIN6)
Main Characteristics:

- **PWM fixed frequency 900KHz. It can be ext synch from 0.4 to 1.2MHz**
- **Output Current Capability: 3A max over all operating conditions**
- **Output Voltage: Adjustable from 0.8V feedback voltage**
- **Ceramic Capacitors and small Inductor**
- **3.3V, 5V Fixed Output Voltages under customer request**
- **Max Operating Input voltage up to 18V**
- **Soft-Start circuit to reduce inrush current**
- **Efficiency: up to 90%**
- **Fast Transient Response**
- **Available with logic control Electronic Shutdown**
- **SO8-EP and DFN 4*4 6L**
Main Characteristics:

- **PWM fixed frequency 1.7MHz.**
- **Output Current Capability:** 0.7A max over all operating conditions
- **Output Voltage:** Adjustable from 0.6V or fixed (1V to 3.3V under customer request)
- **Input Voltage:** from 2.5V to 6V
- **Ceramic Capacitors and small Inductor** (2.2uH suggested value)
- **Soft-Start circuit to reduce inrush current**
- **Efficiency:** up to 93%
- **Fast Transient Response**
- **Logic control Electronic Shutdown**
- **SOT23-5L Package**
Main characteristics:

- Adjustable Output Voltage: from 0.8V to 5V
- DC-DC Switching Frequency: 1.5MHz
- Output Current 1: up to 500mA
- Output Current 2: up to 500mA
- Internal Synchronous Rectification
- Efficiency up to 95%
- Logic Control Electronic Shutdown
- Reset

Typical Applications:

- Optical Storage: CD, DVD-RW
- Hard Disk Drives
- Cameras
- Video cameras
- Cellular phones
- Palmtops
- Battery powered equipments

QFN-8L 4x4mm
Main characteristics:

- Adjustable Output Voltage: from 6V to 12V
- DC-DC Switching Frequency: 1.2MHz or 600Khz
- Output Current: up to 1A
- Internal Synchronous Rectification
- Efficiency up to 90% (Output set to 9V)
- Logic Control Electronic Shutdown
- True Shutdown
L6726 / L6727 / L6728: PWM controllers

- Minimum part count conversion from 5V / 12V bus (Vin up to 19V) up to higher current
- High precision regulation (<1%)
- Protection on board:
  - Sensor-less OCP → no RSENSE
  - Programmable OCP
  - Feedback disconnection
- Features:
  - Disable & Soft Start
    - to ensure regulation control
- Pin to pin compatible with:
  - ISL6520, FAN6520,
  - NCP1583, SC2608, etc.

<table>
<thead>
<tr>
<th>Part Number</th>
<th>$V_{INPUT}/V_{OUT}$ range</th>
<th>$F_{SW}$</th>
<th>features</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>L6726A</td>
<td>4.1V to 13.2V/19V(*) $V_{INPUT}$, 0.8V min $V_{OUT}$</td>
<td>270KHz</td>
<td>EN, SS, OCP, fixed $F_{SW}$ 270KHz</td>
<td>SO8</td>
</tr>
<tr>
<td>L6727</td>
<td>4.1V to 19V $V_{INPUT}$, 0.8V min $V_{OUT}$</td>
<td>300KHz</td>
<td>EN, SS, OVP, UVP, OCP, fixed $F_{SW}$ 300KHz</td>
<td>SO8</td>
</tr>
<tr>
<td>L6728</td>
<td>4.1V to 13.2V $V_{INPUT}$, 0.8V min $V_{OUT}$</td>
<td>300KHz</td>
<td>EN, SS, OVP, OCP, PGOOD, fixed $F_{SW}$ 300KHz</td>
<td>DFN10 3x3</td>
</tr>
</tbody>
</table>
PoE: Introduction

- Power over Ethernet (PoE) is a widely adopted technology used to transfer both data and electrical power over an RJ-45 cable.
- Safely powers devices of up to 13W (IEEE 802.3af).
- New on-going standardization process for powering devices of up to 60W (IEEE 802.3at), called PoE+.
**Option A:** nominal 48V supplied through DATA transformer center tap

**Option B:** Power sourced through SPARE pairs
PM8800A: PoE interface

- IEEE802.3af Compliant
- 100V, 0.5Ω, 800mA hot-swap MOSFET
- PoE+ Layer2 compatible, allowing power >12.95W
- Under-Voltage Lockout thresholds
- Programmable Inrush and DC Current
- Signature and classification Resistor Disconnection
- UVLO override for auxiliary sources < 38.5V
- Inrush and DC protection with auxiliary sources
- Thermal Overload Protection
PM8800A: Integrated PWM controller

- Internal Start-up Bias Regulator
- Current Mode Control
- Error Amplifier disabled in case of optocoupler connection
- Internal Slope Compensation
- Cycle-by-Cycle Over-Current Protection
- Leading Edge Blanking
- Programmable Soft-Start
- Programmable Oscillator freq. y
- Thermal Shutdown