Power Supply topologies for Metering Applications

EMEA Marketing & Application team
Agenda

• Power supply requirements
• AC/DC topologies for single- and three-phase meters
• ST component selection and usage
• Application reference designs
• AC/DC converters & controllers
• DC/DC converters
• Low-dropout voltage regulators (LDOs)
• Power MOSFETs for Metering
Metering SMPS Requirements
Power supply requirements - Input

- **Single phase**
  - From $60$ to $180$ V$_{AC}$
  - To $265$ to $300$ V$_{AC}$
  - In short periods of time (6 hours – one week)
  - To $440$ to $500$ V$_{AC}$
  - Preferred single rectifier – for non-isolated SMPS

- **Poly phase**
  - From $60$ to $180$ V$_{AC}$
  - To $440$ to $500$ V$_{AC}$
  - Input connection
    - Bridge connection – SMPS works even if only 2 wires are connected
    - Single rectifier – SMPS stops working if the Neutral is disconnected
  - Common requirements – high level of surge protection ($4$ to $6$ kV)
Power supply requirements - Output

• Simple e-meter
  • No communication – only measurement and data processing
  • Output power: ~ 1 to 5 W
  • Output voltage: 3.3/5 V – typical supply for MCU, metering, and display
• Smart e-meter – includes communication – PLC, GSM
  • Output power
    • Average: 2 to 6 W
    • Peak power: up to 5 to 15 W
  • Output voltages: 3.3/5 V and 10 to 15 V
• Concentrator
  • Output power: 10 to 25 W
  • Output voltages: 3.3/5 V and 10 to 15 V
Power supply requirements - Others

- Operating frequency
  - The communication frequency of Smart meters is typically between 60 and 100 kHz
  - Therefore, the preferred operating frequency is > 100 kHz

- Magnetic field immunity
  - The SMPS must be able to survive magnetic fields up to 0.5 T!!!
  - Distance of field source to SMPS – several centimeters
  - Typically the SMPS must survive, but operation can be halted
  - In certain cases, limited operation may also be required in this condition
E-meter supply topology

An SMPS consists of:

- **AC/DC converter**
- **10 to 15 V** – communication – typically directly generated by AC/DC
- **3.3/5V** – MCU and other circuits
  - Directly generated by SMPS
    - + simple, - lower precision
  - DC-DC from 10 to 15 V
    - + more components, - precision of both outputs is good
  - LDO – either from unregulated output of AC/DC or from 10 to 15 V
- **3.3V/5V ISO** – mandatory for 3-phase e-meter using shunts – either isolated DC-DC or other output from AC/DC from transformer
AC/DC - Topologies
AC/DC Topologies applicable for Metering SMPS

**BUCK** converter – eMeters

**FLYBACK** converter
SMART meters and Concentrators
Buck Converter Limitations and Advantages

• Output
  • 5 to 15 V, up to 300 mA (Viper26)
  • Tolerance ±1 V

• Input
  • Considering 100 V surge pulse up to 700 V_{DC}
  • It means 500 V_{AC}
  • Minimum voltage from 40 V_{DC} (Viper06) to 100 V_{DC} (Viper26)

• Operating frequency
  • 30 or 60 kHz for Viper06
  • 60 kHz for Viper16 or Viper26
  • 115 kHz recommended only in case of 15 V output and no operation in CCM

• Applicable components
  • Viperx6, Viperx1
Flyback Converter Limitations and Advantages

- **Output**
  - Any voltage (typically 3.3V and 15V)
  - Simple to realize more outputs
  - High precision for one output (±3%)
- **Power**
  - Altair04-900: 4 to 12 W (peak)
  - Viperx1/6: 12 to 20 W
  - L6566BH: Up to 30 W (in fact, not limited)
- **Input maximum**
  - Viper: Up to 440 V\(_{\text{AC}}\) for a limited time
  - Altair04-900: Up to 460 V\(_{\text{AC}}\) (permanent connection)
  - L6566BH + 950V/1.2kV MOSFET: Up to 500 V\(_{\text{AC}}\)
- **Operating frequency**
  - Typically above 100 kHz (115 kHz, 100 to 130 kHz)
ST components selection and usage
Simple e-Meter – Buck converter

Monolithic solution

VIPerPlus family
Off-line converters (controller + HV MOSFET)
VIper06X, Viper06L, Viper01X, Viper11X, Viper16L, Viper26L

LDK220, LDL212, ST715

Regulators

Ultrafast high-voltage rectifier
STTH108

Monolithic solution
1 - phase meter, Concentrator – Flyback no isol.

Monolithic solution – limitation 800V MOSFET

Transient voltage surge suppressor
(400W – 600W – 100V – 200V)
SMAJ, SMAJ6J, SMBJ, P6KE

Ultrafast high-voltage rectifier
STTH108
(200V-300V 1A, 2A families)
STTH*02

Ultrafast high-voltage rectifier
STTH108

PWM Controller

VIPerPlus family
Off-line converters (controller + HV MOSFET)
Viper01H, Viper11H, Viper06H, Viper16H, and Viper26H

Schottky diodes
(60V to 150V families)
STPS*60, STPS*80, STPS*100, STPS*150

Signal Schottky diodes
(30V to 80V families)
BAT*, BAR*
*6263, TMBYV*

10V - 15V
3.3V - 5V
VDD
GND
VDD
GND
1-phase meter, Concentrator – Flyback no isol

Discrete solution – MOSFET up to 1.5 kV available, drawback higher complexity

- **Transistor**: STx2N95K5, STx5N95K5 (950V)
- **Transistor**: STx2N105K5, STx5N105K5, STx7N105K5 (1050V)
- **Transistor**: STx1N120K5, STx8N120K5 (1200V)

**Off-line controller**
- **L6566BH**

**Ultrafast high-voltage rectifier**
- **STTH108**

**Ultrafast high-voltage rectifier**
- **STTH*02**

**Schottky diodes**
- (60V to 150V families)
  - STPS*60, STPS*80, STPS*100, STPS*150

**Signal Schottky diodes**
- (30V to 80V families)
  - BAT*, BAR*
  - *6263, TMBYV*

**Standard OA**
- TS391

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**Transistor** K5 Power MOSFET
- **STx2N95K5**, **STx5N95K5** (950V)
- **STx2N105K5**, **STx5N105K5**, **STx7N105K5** (1050V)
- **STx1N120K5**, **STx8N120K5** (1200V)

**Ultrafast high-voltage rectifier**
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**Ultrafast high-voltage rectifier**
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**Schottky diodes**
- (60V to 150V families)
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**Signal Schottky diodes**
- (30V to 80V families)
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**Standard OA**
- TS391
3-phase meter – Flyback, single rectifier

Monolithic solution – simple, drawback peak power limited up to 8 – 9W

- **Ultrafast high-voltage rectifier**
  - (200V-300V 1A, 2A families)
  - STTH*02

- **Ultrafast high-voltage surge suppressor**
  - (400W – 600W – 100V – 200V)
  - SMAJ, SMAJ6J, SMBJ, P6KE

- **Transistor**
  - T1

- **PWM Controller**

- **Altair04-900**

Off-line converters (controller + 900V MOSFET)

- **3.3V – 5V**
- **10V – 15V**

- **3.3V**

- **10V – 15V**

- **5V**

- **3.3V**

- **200V – 300V 1A, 2A families**

- **SMAJ, SMAJ6J, SMBJ, P6KE**

- **Monolithic solution**

- **Transistor**

- **PWM Controller**

- **Altair04-900**

- **Off-line converters (controller + 900V MOSFET)**

- **3.3V – 5V**

- **10V – 15V**

- **5V**

- **3.3V**
3-phase meter – Flyback, single rectifier

Discrete solution – MOSFET up to 1.5 kV available, no power limitation, drawback higher complexity

- **K5 Power MOSFET**
  - STx2N95K5, STx5N95K5 (950V)
  - STx2N105K5, STx5N105K5, STx7N105K5 (1050V)
  - STx1N120K5, STx8N120K5 (1200V)

- **Transient voltage surge suppressor**
  - (400W – 600W – 100V – 200V)
  - SMAJ, SMAJ6J, SMBJ, P6KE

- **Ultrafast high-voltage rectifier**
  - STTH108

- **Ultrafast high-voltage rectifier**
  - (200V-300V 1A, 2A families)
  - STTH*02

- **Off-line controller**
  - L6566BH

- **Schottky diodes**
  - (60V to 150V families)
  - STPS*60, STPS*80, STPS*100, STPS*150

- **Signal Schottky diodes**
  - (30V to 80V families)
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  - *6263, TMBYV*

- **Standard OA**
  - TS391
3-phase meter – Flyback, bridge rectifier

Monolithic solution – simple, drawback peak power limited up to 8 – 9W

- Transient voltage surge suppressor
  - (400W – 600W; 100V – 200V)
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- Ultrafast high-voltage rectifier
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- Schottky diodes
  - (60V to 150V families)
  - STPS*60, STPS*80, STPS*100, STPS*150

- Off-line converters (controller + 900V MOSFET)
  - Altair04-900

PWM Controller

U1 Altair04-900

Drain

R5

C6

R7

C7

R6

C9

D3

C2

3.3V - 5V

10V - 15V

GND

Off-line converters (controller + 900V MOSFET)

Altair04-900

PWM Controller

Transistor

Capacitor

Diode

Resistor

Inductor
3-phase meter – Flyback, bridge rectifier
Reference designs
**Demo board - STEVAL-ISA010V1**

Super Wide Input Range Viper16 Buck Converter

**Documentation:** AN2872

- Buck topology
- Common Neutral
- Input voltage range: 85 to 500 V\(_{AC}\)
- Output voltages: 12V and 5V
- Output current (max.): 150 mA (total for both outputs)
- Conductive EMI EN55022 Class B
- Stand-by less than 100 mW at 230 V\(_{AC}\)
Demo board - STEVAL-ISA105V1

Power supply for energy meter and power line modem based on Altair04-900

Documentation: AN4154

- Flyback
- Input voltage range: 90 to 480 V\textsubscript{AC}
- Output power: 7W peak
- Output voltages: 5, 3.3, and 12V
AC-DC converters and controllers
VIPerPlus Family

Advanced controller with embedded 800V Power MOSFET

Robustness and Reliability
800V Power MOSFET, thermal shutdown, soft start, OLP protection, auto-restart

Energy saving
Power consumption less than 30mW at no load

High integration
Direct feedback, jittering, HV start-up

Flexibility
Power scalability up to 12W, no auxiliary winding, clamp-less design, no CM EMC filter

..directly from AC Mains voltage...

Input rectification and filtering

PWM Controller

Feedback

.. to +/- DC bus (3V3, 5V, 12V) to supply:
- Microcontroller
- PWM driver
- Relay

Output rectification and filtering

Output rectification and filtering

.. to +/- DC bus (3V3, 5V, 12V)

to supply:
- Microcontroller
- PWM driver
- Relay

Input rectification and filtering

Output rectification and filtering

.. to +/- DC bus (3V3, 5V, 12V)

Robustness and Reliability
800V Power MOSFET, thermal shutdown, soft start, OLP protection, auto-restart

Energy saving
Power consumption less than 30mW at no load

High integration
Direct feedback, jittering, HV start-up

Flexibility
Power scalability up to 12W, no auxiliary winding, clamp-less design, no CM EMC filter
ST Offline Converters Overview

<table>
<thead>
<tr>
<th>Buck Converter</th>
<th>150mA</th>
<th>200mA</th>
<th>350mA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly-back Converter</td>
<td>5W</td>
<td>8W</td>
<td>12W</td>
</tr>
<tr>
<td>80-265VAC</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

800V

- 32Ω 350mA
- 24Ω 400mA
- 20Ω 480/600 mA
- 19Ω (900V) Ext RSENSE
- 14Ω Ext RSENSE
- 7Ω 700mA
- 4.5Ω 1/1.15A

VIPerPlus0P
VIPerPlus*1
VIPerPlus*5
VIPerPlus*6
VIPerPlus*7
VIPerPlus*8
Altair0*

In development
Main features

- CC/CV regulation with no opto-coupler
- Avalanche rugged internal power MOSFET
- Internal HV start-up circuit
- Quasi-resonant ZVS operation
- Valley skipping at medium-light load
- Burst mode operation at no-load for under 60 mW consumption
- Automatic self-supply
- Input voltage feed-forward for mains-independent CC regulation
- Overcurrent protection against transformer saturation and secondary diode short circuit
- Low quiescent current (< 1 mA)

**ALTAIR family: Off-line all-primary sensing switching regulator**

<table>
<thead>
<tr>
<th>ALTAIR04</th>
<th>ALTAIR05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakdown voltage</td>
<td>900 V</td>
</tr>
<tr>
<td>Resistance Drain Source (Tj = 25°C)</td>
<td>16 Ω</td>
</tr>
<tr>
<td>Minimum Drain start-up voltage</td>
<td>50 V</td>
</tr>
<tr>
<td>Supply voltage range</td>
<td>11.5 to 23 V</td>
</tr>
</tbody>
</table>

Maximum output power for $V_{IN} = 85$ to $265$ V$_{AC}$
L6566 family: Multi-mode controllers

**Common features**

- **Fixed frequency or quasi resonant operations**
- **Advanced light load management**
- **On-board high-voltage start-up generator**
- **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**
- **Latched or auto-restart OVP**
- **Brownout protection**
- **-600/+800 mA totem pole gate driver with active pull-down during ULVO**
- **SO16N package**

**Controllers with selectable quasi-resonant (QR) or fixed-frequency (FF) operation**

**Primary controllers**

- **L6566A**
  - 700V high-voltage start-up
  - Switched supply rail for PFC controller
  - Suited for SMPS with PFC front end

- **L6566B**
  - 700V high-voltage start-up
  - Programmable frequency modulation for EMI reduction
  - Suited for single stage SMPS

- **L6566BH**
  - 840V high-voltage start-up
  - Programmable frequency modulation for EMI reduction
  - Suited for single stage SMPS running off rectified 3-phase input line

**Suited for SMPS with PFC front end**

**Suited for single stage SMPS running off rectified 3-phase input line**
DC-DC converters
DC-DC – post regulation

ST1S4x ST1S5x
L6984
High-efficiency (Sync. Rect.)
Low BOM
Cost-effective
Low Stand-by Consumption (ST1S5x)

ST1S31/32, ST1S12
(ST1S4x and ST1S5x)
High-efficiency (Sync. Rect.)
Low BOM
Cost-effective
Low Stand-by Consumption (ST1S5x)
Main benefits

- Maximize battery life
- Reduce standby power consumption
- Minimized PCB area occupation
- Easy design and implementation

Linear Regulators: Low quiescent current LDOs

- **Ultra low quiescent current (Iq)** (down to 1.4 µA)
- Very low dropout
- Wide range of miniaturized packages
- Output current from 50 to 150 mA
- Extended input voltage range (up to 24V on ST715)
LDOs
Linear Regulators: Cost-effective LDOs

**LDK120**
- Max $V_{IN}$ 5.5V
- 200 mA, low dropout, Noise reduction pin
- Available in SOT23-5L, SC70, and DFN6 1.2x1.3 mm

**LDK130**
- Max $V_{IN}$ 5.5V
- 300 mA, low dropout, Noise reduction pin
- Available in SOT23-5L, SC70, and DFN6 1.2x1.3 mm

**LDK220**
- Max $V_{IN}$ 16V (In development)
- 200 mA, low dropout
- Available in SOT23-5L, SC70, and DFN6 1.2x1.3 mm

**LDL112**
- Max $V_{IN}$ 5.5V
- 1.2A, very low dropout, Reverse current protection
- Available in SO8, and DFN6 2x2 mm and 3x3 mm

**LDL212**
- Max $V_{IN}$ 16V
- 1.2A, very low dropout
- Available in SO8, and DFN6 2x2 mm and 3x3 mm

**LDLxx:**
- Low current (up to 300mA)
- Medium current (1.2 A)
Power MOSFETs for metering applications
K5 Power MOSFET Series

Higher power density, **Best-in-class** $R_{D\text{S(on)}}$ MDmesh™ K5 series

**Widest Super-Junction MOSFET Product Portfolio**
- 800V, 900V, 950V, 1050V, 1200V, up to 1500V

**BEST silicon performance in the Market**
- Outstanding $R_{D\text{S(on)}}$ to optimize efficiency

**Designed for High Efficiency**
- Ultra-low gate charge (Qg) for faster switching
- Low Ciss and Coss for reduced energy losses
## MDmesh™ K5 series selection
### SMPS < 75 W

<table>
<thead>
<tr>
<th>BV_{DSS}[V]</th>
<th>R_{DS(on)}[Ω]</th>
<th>Max I_D [A]</th>
<th>Sales Type</th>
<th>Packages</th>
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<tr>
<td>3.25</td>
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<td>STx3LN80K5</td>
<td>DPAK / I2PAKFP</td>
<td>TO-220 / FP</td>
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<td>2.6</td>
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<td>DPAK / I2PAKFP</td>
<td>TO-220 / FP</td>
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<td>1.75</td>
<td>3.8</td>
<td>STx5N80K5</td>
<td>DPAK / TO-220 / TO-220FP/DPAK/I2PAK/I2PAKFP</td>
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<td>1.15</td>
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<td>4</td>
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<td>TO-247/ TO-220 / FP</td>
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<td>2.4</td>
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</table>
eDesignSuite is a software platform that helps developers select the right product for power conversion and speeds up the design-in.

**AC-DC & DC-DC converters are supported by eDesignSuite**

- Go to [my.st.com/analogsimulator](http://my.st.com/analogsimulator)
- Register the first time and log in
- Insert your design specifications
- Get the suitable products
- Choose one, simulate and **purchase**
  - Circuit BOM
  - Electrical waveforms
  - Additional information (stability, efficiency, etc.)
eDesignSuite

- Defined specs
- Standard functions
- Components that can be fine-tuned
- Operating point
- Waveforms
- Efficiency
- Bode plots
- Losses split