Practical Designs for USB PD 3.0 + PPS Compliant Adapters with Simplest BOM
Agenda

- Why USB PD 3.0 + PPS
- Improved flyback topology offering high efficiency as a cost-effective solution that meets DoE(6) efficiency
- Wide-range flybacks - design optimization and challenges
- InnoSwitch™3-Pro: Highly integrated digital control with I²C interface
- Practical design examples
Need for Programmable Power Supplies

- I/F PMIC is a synchronous buck regulator – higher losses at higher voltages (9 V / 12 V)
- Direct “cold” charging with V-and-I control solves the phone’s heat problem

**AC IN**

- **@ 90% Efficiency**
  - 5 W = 0.5 W
  - 10 W = 1 W
  - 25 W = 2.5 W

**I/F PMIC** is a synchronous buck regulator

- Direct “cold” charging with V-and-I control solves the phone’s heat problem

**AC/DC**

**Hi Voltage Protocol IC**

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Need for Programmable Power Supplies

<table>
<thead>
<tr>
<th>Adapter Power Level</th>
<th>Mandatory USB PD Output Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 15 W</td>
<td>5 V only</td>
</tr>
<tr>
<td>15 – 27 W</td>
<td>5 V, 9 V</td>
</tr>
<tr>
<td>27-45 W</td>
<td>5 V, 9 V, 15 V</td>
</tr>
<tr>
<td>&gt; 45 W</td>
<td>5 V, 9 V, 15 V, 20 V</td>
</tr>
</tbody>
</table>

**USB PD 3.0 PPS Voltage and Current Specifications**

- I/F PMIC is a synchronous buck regulator – higher losses at higher voltages (9 V / 12 V)
- Direct “cold” charging with V-and-I control solves the phone’s heat problem
- PPS feature of USB PD 3.0 enables “load-directed-charging”
  - Power adapter voltage can be change in 20 mV steps and current limit in 50 mA steps with commands from the load
InnoSwitch3-Pro: Variable Frequency Flyback with Synchronous Rectification, QR and CCM/DCM Operation

- **Flyback simplicity ensures high reliability**
- **High efficiency reduces heat**
  - Synchronous rectification
  - Quasi-resonant switching in DCM
- **Wide output voltage range needs CCM and DCM**
  - Seamless and reliable control of SR during DCM-CCM transitions
- **Variable frequency enables high efficiency across load range**
  - Switching frequency is proportional to load
  - Extremely low operating frequency at no-load reduces input power
Precision SR Timing Optimizes Efficiency and Reliability

Discontinuous Mode (DCM)
- Precise primary-OFF to SR-ON timing improves efficiency
- Control architecture ensuring only one FET to be ON at a time
  - Allows precise and reliable CCM-DCM operation

Continuous Mode (CCM)
- Secondary SR is always OFF before primary MOSFET turns ON
  - Safe operation in continuous mode
Optimizations for EMI and Audible Noise

- Transformer shield windings reduce common-mode noise

- Frequency jitter reduces spectral peaks
  - Simplifies EMI filter design

No 3V–8V, 5A; 8V-20V Constant power; Programmable industrial power supply
Optimizations for EMI and Audible Noise

- Low frequency operation at light load increases light-load efficiency
  - At some loads frequency drops below 20 kHz and enters audible range

![Graph showing efficiency for 5V, 5A](image)

- Sophisticated state machine prevents operation at frequencies likely to cause audible noise
  - ~11 – 14 kHz

- Transformer design
  - Ensure $B_{AC}$ is < 120 mT when operating frequency < 20 kHz
InnoSwitch3-Pro: Highly Integrated Flyback with Digital I²C Interface for USB PD + PPS

- Efficient Switching
  - Multi-mode QR & CCM

- Digital Control over I²C Interface

- Pin optimized external USB PD Controller

- Load Discharge

- Direct load protection

- Secondary-Side Sensing

- 3.6 V Supply for External μC

- Fast Input UV/OV Protection

- Efficient Switching
  - Multi-mode QR & CCM

- Primary High Voltage FET

- Direct Control of SSR FET
  - Highest efficiency
  - Safe and reliable

- Digitally Controlled over I²C Interface

- Integrated Control of Low-Cost Series N-MOSFET Bus Switch

- MCU

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InnoSwitch3-Pro: Highly Integrated Flyback with Digital I\textsuperscript{2}C Interface for USB PD + PPS

- **Precise Control**
  - 3 to 24 V: 10 mV/step
  - Current: Step size 0.78% of FS
  - CC Adjust: 20-100% of FS

- **Communicate via USB Cable to USB PD devices**

- **Fully Configurable**
  - Rapid charging protocol neutral
  - Cable drop, constant power
  - Selectable secondary protection for OV, UV, OT, short cct

- **Telemetry**
  - Status & fault reporting
  - ADC voltage and current read-back

- **No-load Power < 30 mW**
  - Including external µC load of 8 mW
27 W USB PD adapter using InnoSwitch3-CP and WT6615F USB PD controller - 82 components used
Integrated I²C Interface Enables Use of Simpler External Microcontroller – Eliminates Complex Interface Circuit

27 W USB PD adapter using InnoSwitch3-Pro and WT6635P USB PD controller - 58 components used
Multiple Designs Passed Compliance Tests for USB PD + PPS

<table>
<thead>
<tr>
<th>DER#</th>
<th>Power</th>
<th>Specification</th>
<th>PD Controller</th>
</tr>
</thead>
<tbody>
<tr>
<td>DER-701</td>
<td>27 W</td>
<td>5 V 3 A; 9 V, 3 A; 3.3-11 V PPS</td>
<td>VP302</td>
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<tr>
<td>DER-702</td>
<td>45 W</td>
<td>5 V, 3 A, 9 V, 3 A, 15 V, 3 A; 3.3-21 V PPS</td>
<td>WT6635P</td>
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<tr>
<td>DER-703</td>
<td>27 W</td>
<td>5 V 3 A; 9 V, 3 A; 3.3-11 V PPS</td>
<td>WT6635P</td>
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<tr>
<td>DER-704</td>
<td>45 W</td>
<td>5 V, 3 A, 9 V, 3 A, 15 V, 3 A; 3.3-16 V PPS</td>
<td>VP302</td>
</tr>
<tr>
<td>DER-613</td>
<td>27 W</td>
<td>5 V 3 A; 9 V, 3 A; 3.3-11 V PPS</td>
<td>WT6635P</td>
</tr>
</tbody>
</table>
27 W Reference Designs - USB PD 3.0 + PPS Compliant

DER-703
27 W Reference Designs - USB PD 3.0 + PPS Compliant
45 W Reference Designs - USB PD 3.0 + PPS Compliant

DER-702

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45 W Reference Designs - USB PD 3.0 + PPS Compliant

DER-704
Summary

- Flyback with enhancements meets new USB PD 3.0 + PPS requirements
- Variable frequency, quasi-resonant switching and synchronous rectification increase efficiency
  - Enables compact size and meets US DoE and EU CoC efficiency requirements
- Wide output voltage variation of USB PD requires CCM/DCM mode operation
  - Needs master controller that reliably and seamlessly transitions between CCM and DCM
- Extremely low frequency operation at no-load for best standby power
- High level of integration with integration of I²C interface
  - Safe, reliable, compact enabling remote control and monitoring
- Successfully passed compliance tests for USB PD +PPS with multiple designs
  - Reference designs available