power integrations™

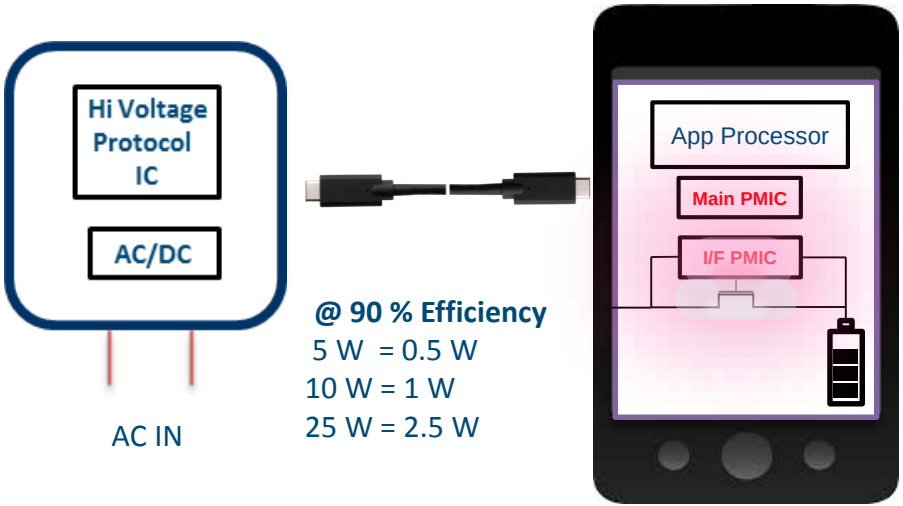
Practical Designs for USB PD 3.0 + PPS Compliant Adapters with Simplest BOM

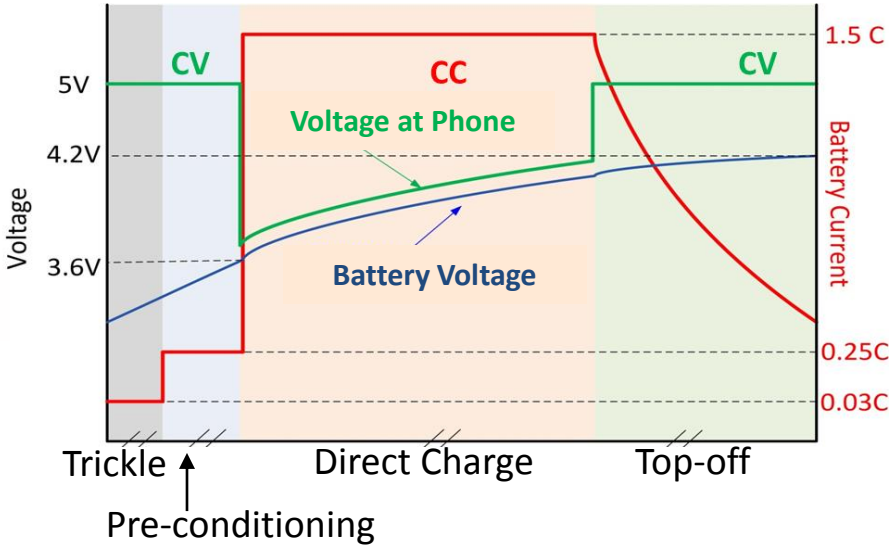
ac-dc converters | led drivers | gate drivers

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 I^2C 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

Need for Programmable Power Supplies

Adapter Power Level	Mandatory USB PD Output Capability
< 15 W	5 V only
15 – 27 W	5 V, 9 V
27-45 W	5 V, 9 V, 15 V
> 45 W	5 V, 9 V, 15 V, 20 V

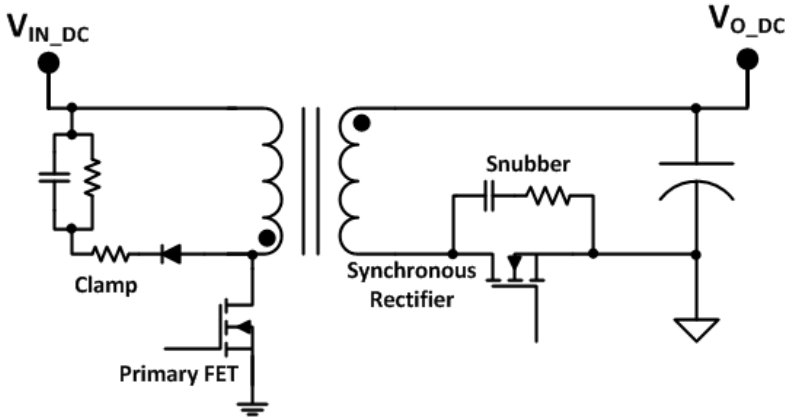
Aspect	Fixed Source	Programmable Power Source
Constant voltage mode	5 V 9 V 15 V 20 V	3.3 V to 5.9 V 3.3 V to 11.0 V 3.3 V to 16.0 V 3.3 V to 21.0 V
Voltage Step Size	None	Nominal 20 mV
Current-Limit -Mode Step Size	None	Nominal 50 mA

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

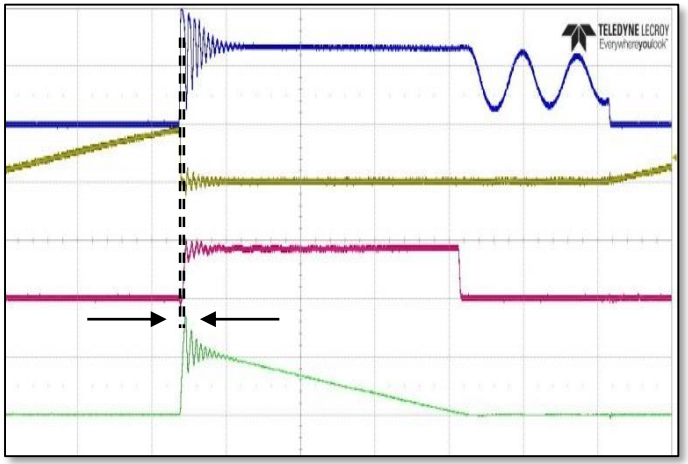
InnoSwitch3-Pro: Variable Frequency Flyback with Synchronous Rectification, QR and CCM/DCM Operation

- **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)



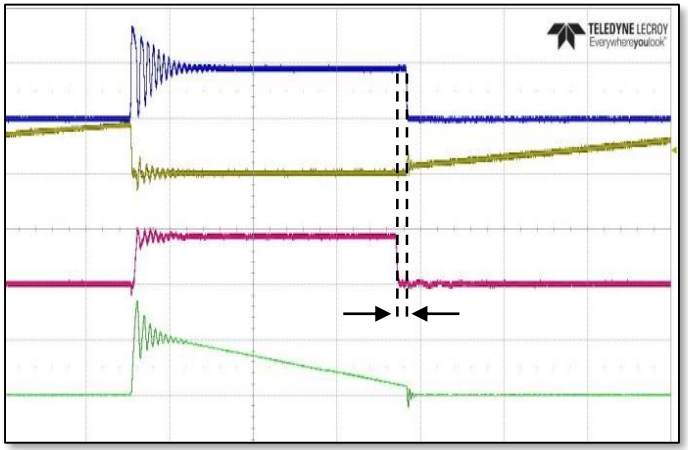
Primary Drain Voltage

Primary Drain Current

Secondary SR Gate Drive

Secondary Current

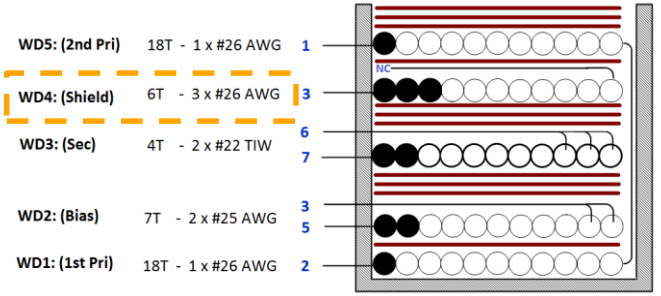
Continuous Mode (CCM)



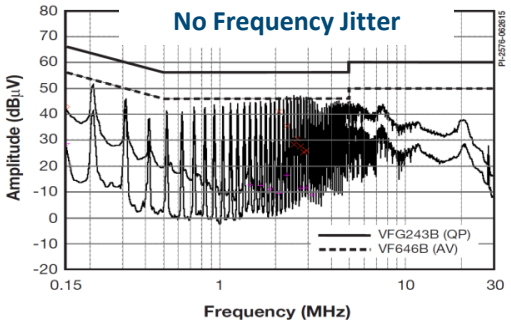
- Precise primary-OFF to SR-ON timing improves efficiency
- Secondary SR is always OFF before primary MOSFET turns ON
  - Safe operation in continuous mode
- Control architecture ensuring only one FET to be ON at a time
  - Allows precise and reliable CCM-DCM operation

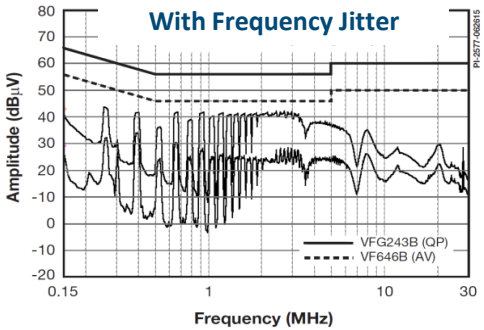
Optimizations for EMI and Audible Noise

- **Transformer shield windings reduce common-mode noise**



- **Frequency jitter reduces spectral peaks**
  - Simplifies EMI filter design

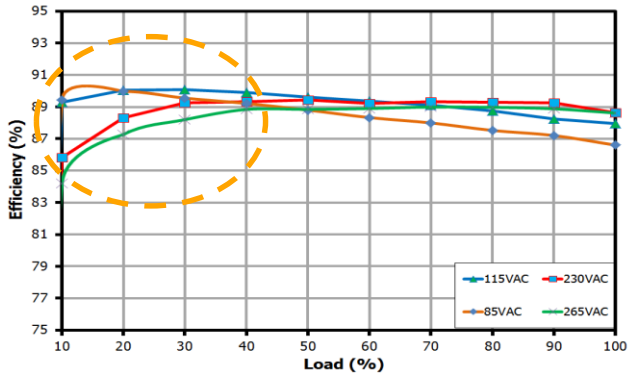




No 3V–8V,5A; 8V-20V Constant power; Programmable industrial power supply

Optimizations for EMI and Audible Noise

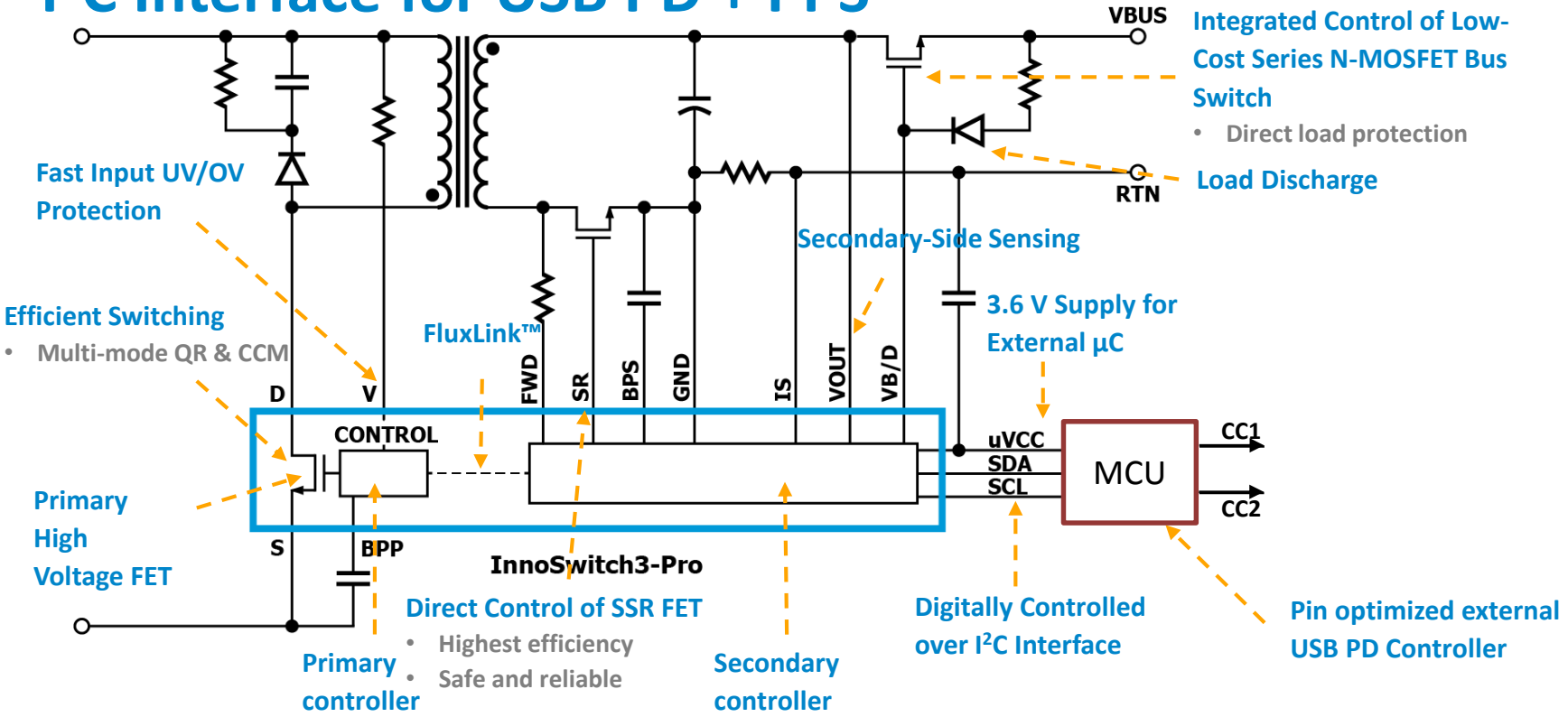
- **Low frequency operation at light load increases light-load efficiency**
  - At some loads frequency drops below 20 kHz and enters audible range



Efficiency for 5 V , 5 A

- **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



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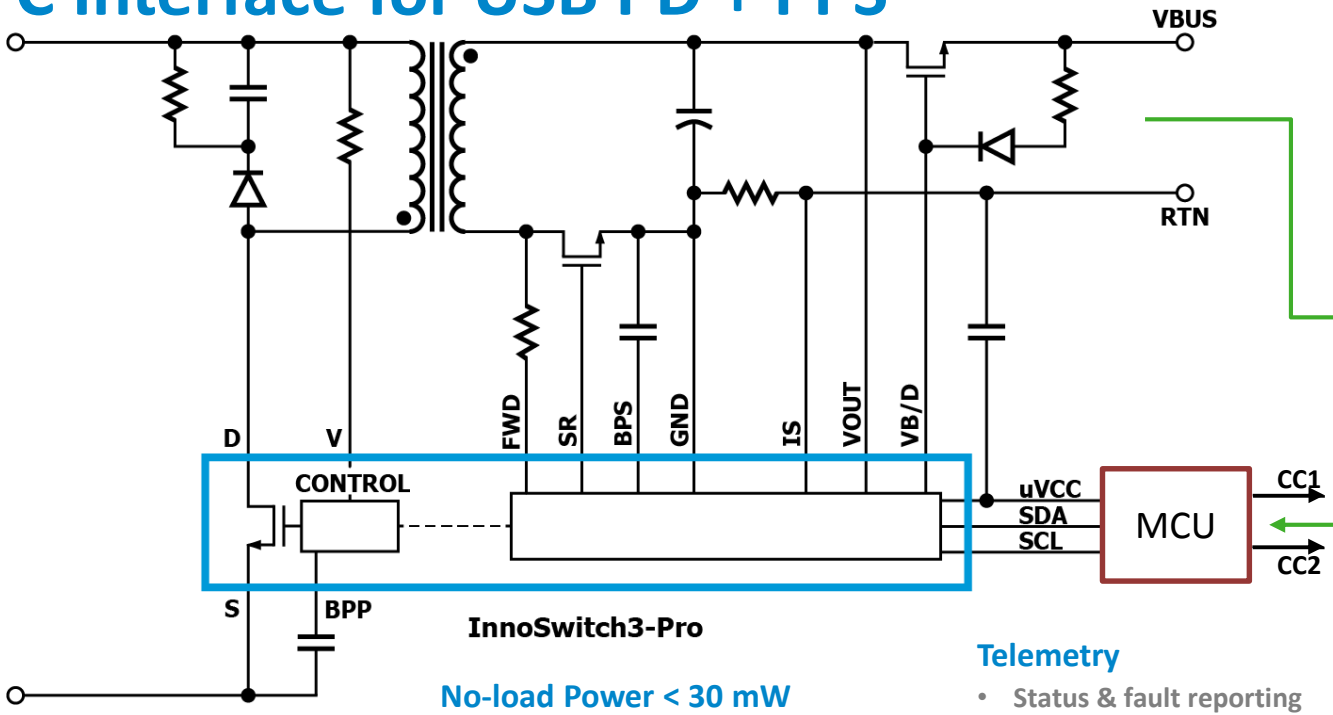


Precise Control

- 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

No-load Power < 30 mW

- Including external µC load of 8 mW

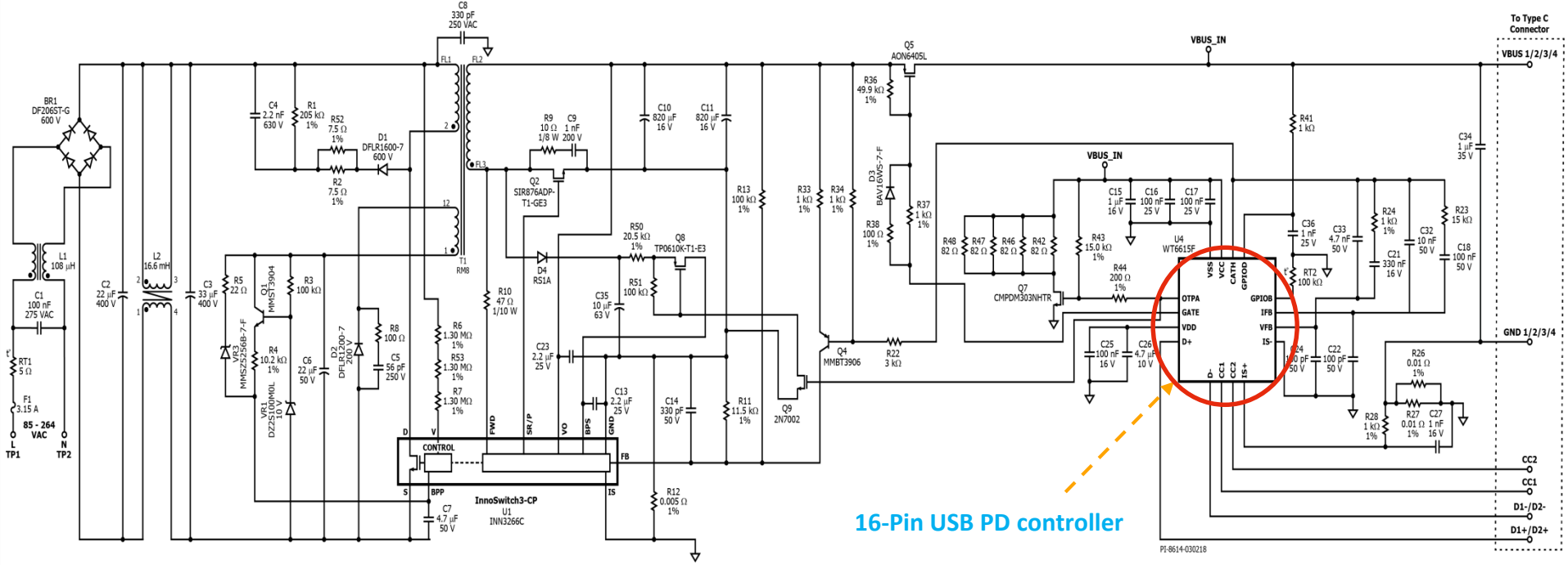
Telemetry

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

Fully Configurable

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

Integrated I²C Interface Enables Use of Simpler External Microcontroller – Eliminates Complex Interface Circuit



27 W USB PD adapter using InnoSwitch3-CP and WT6615F USB PD controller - 82 components used

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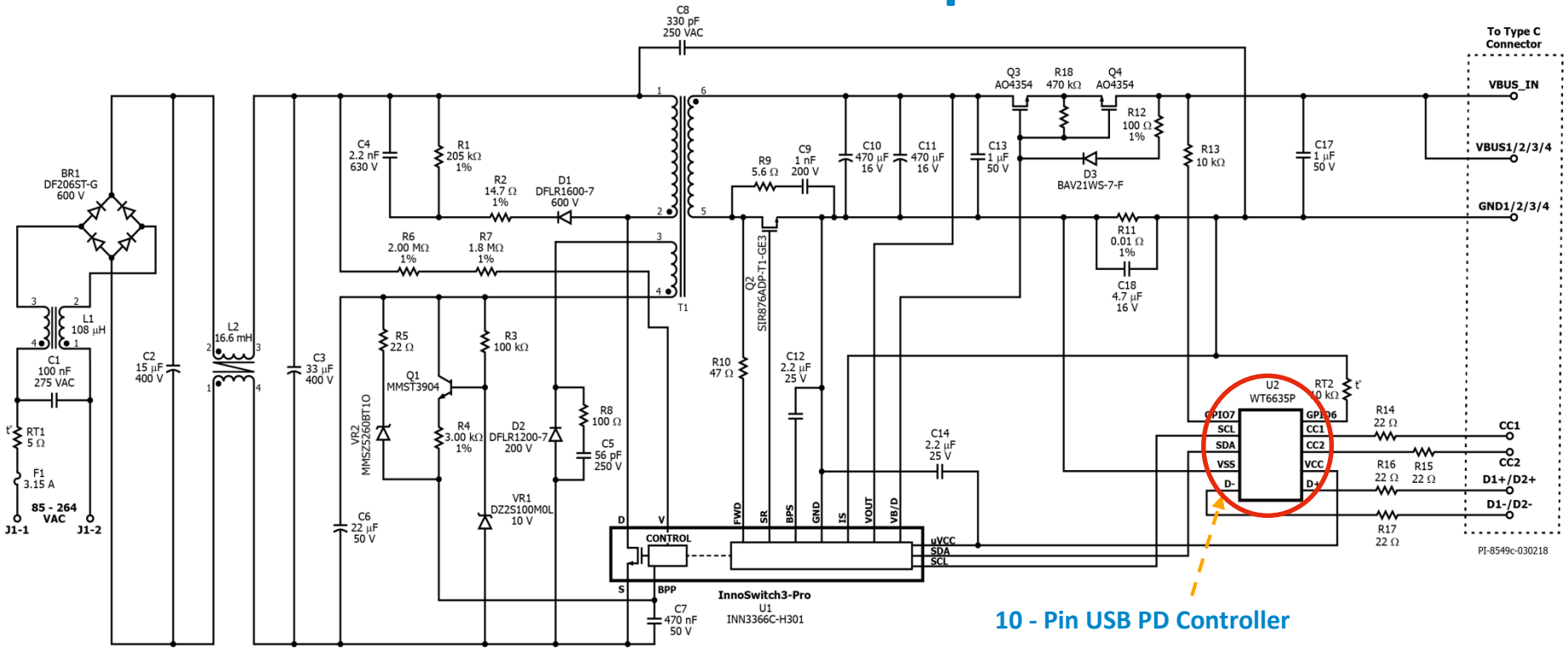
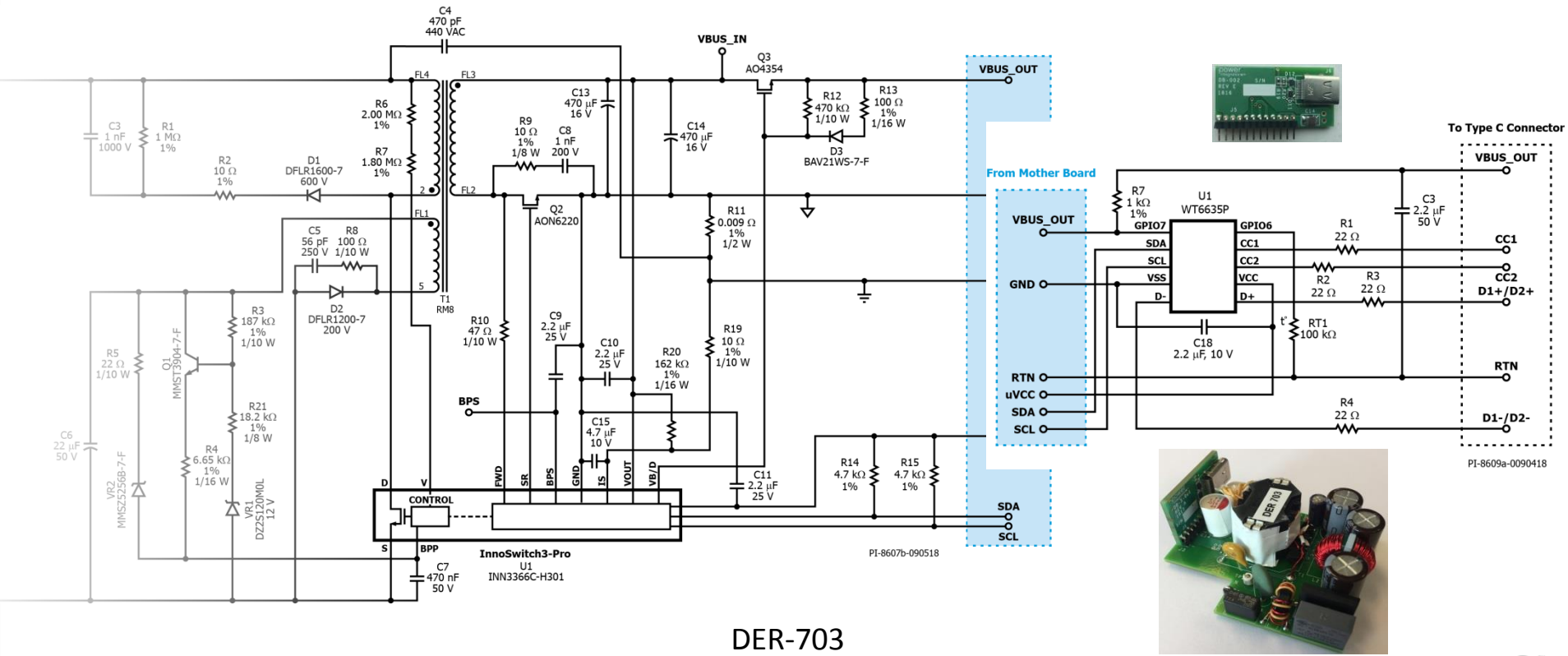


27 W USB PD adapter using InnoSwitch3-Pro and WT6635P USB PD controller - 58 components used

Multiple Designs Passed Compliance Tests for USB PD + PPS

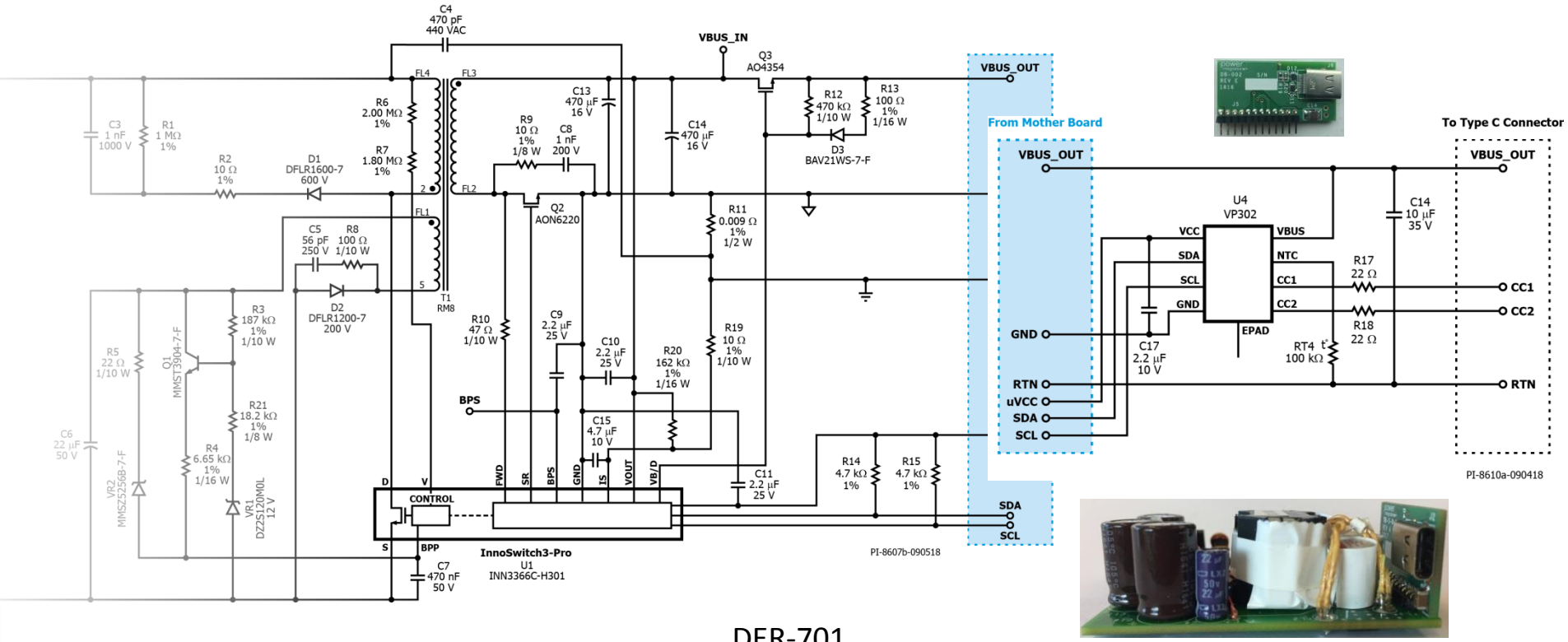
DER#	Power	Specification	PD Controller
DER-701	27 W	5 V 3 A; 9 V, 3 A; 3.3-11 V PPS	VP302
DER-702	45 W	5 V, 3 A, 9 V, 3 A, 15 V, 3 A; 3.3-21 V PPS	WT6635P
DER-703	27 W	5 V 3 A; 9 V, 3 A; 3.3-11 V PPS	WT6635P
DER-704	45 W	5 V, 3 A, 9 V, 3 A, 15 V, 3 A; 3.3-16 V PPS	VP302
DER-613	27 W	5 V 3 A; 9 V, 3A; 3.3-11 V PPS	WT6635P

27 W Reference Designs - USB PD 3.0 + PPS Compliant



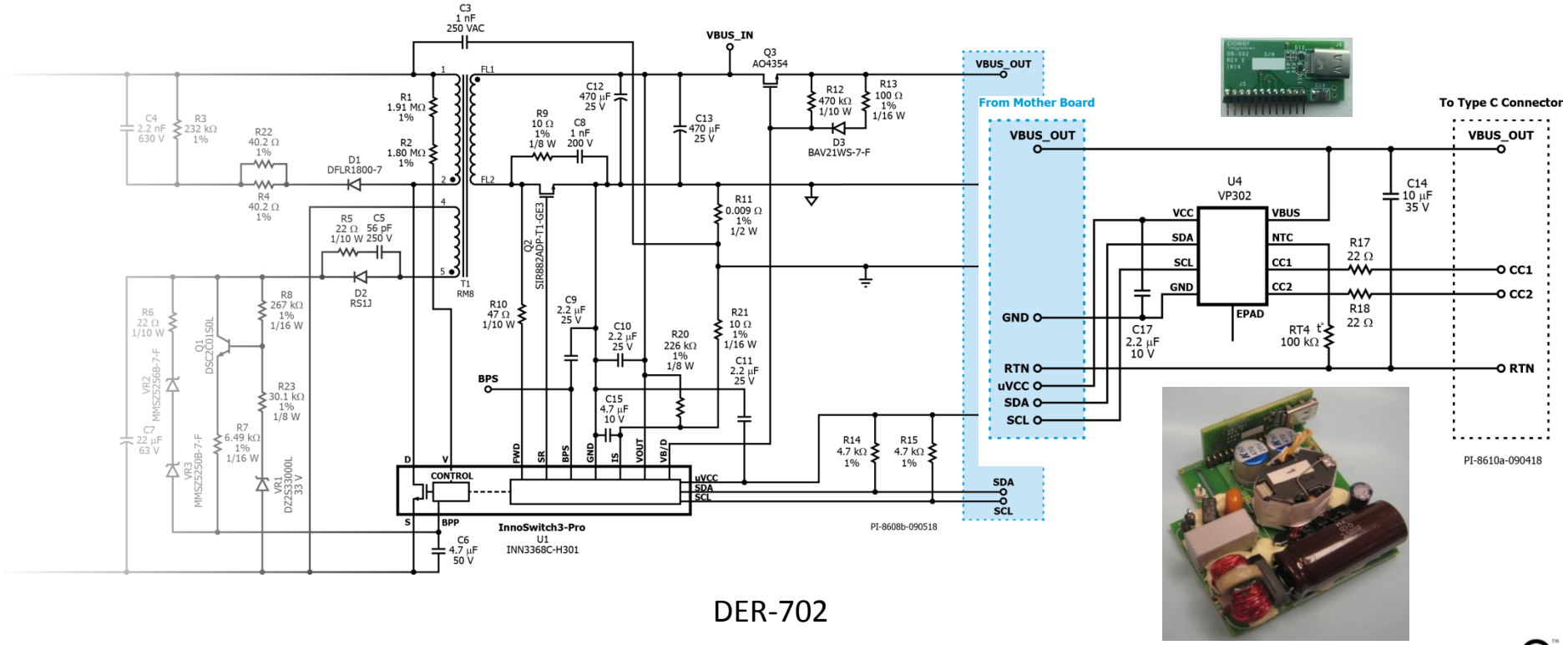
DER-703

27 W Reference Designs - USB PD 3.0 + PPS Compliant



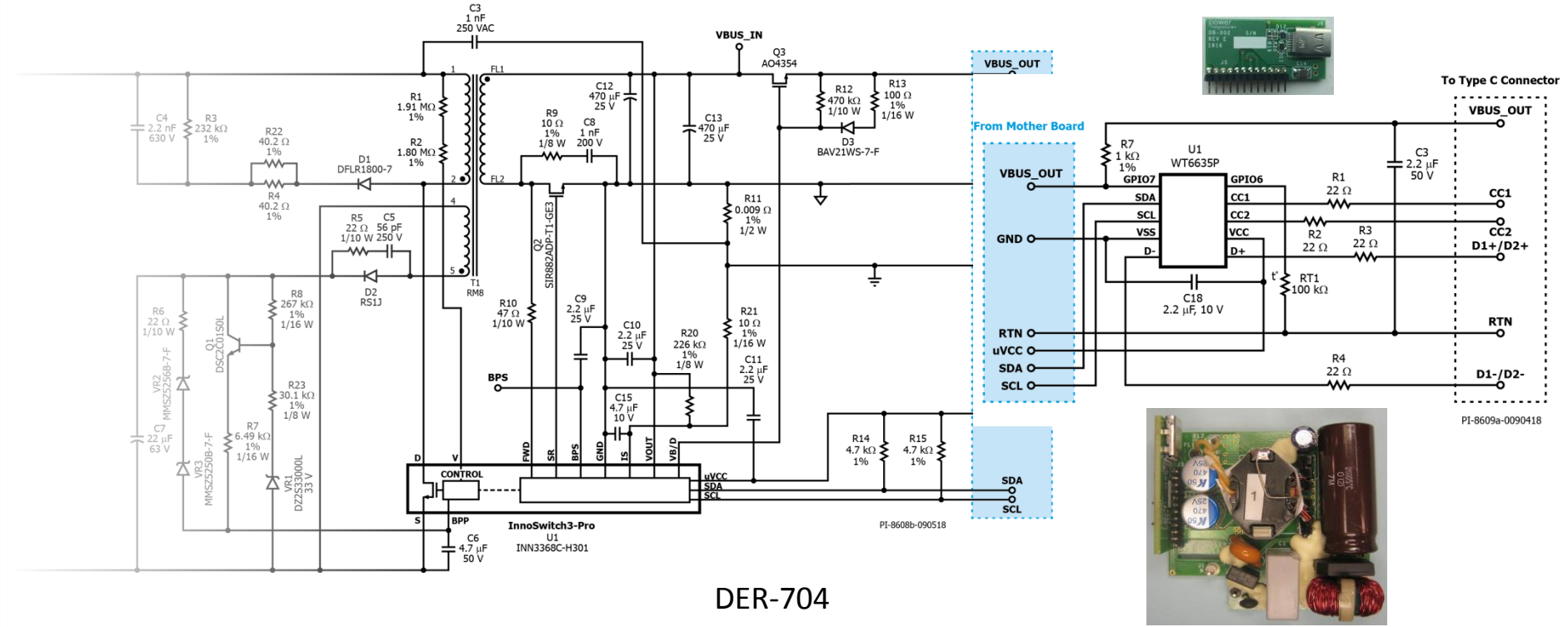
DER-701

45 W Reference Designs - USB PD 3.0 + PPS Compliant



DER-702

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 I^2C interface**
  - Safe, reliable, compact enabling remote control and monitoring
- **Successfully passed compliance tests for USB PD +PPS with multiple designs**
  - Reference designs available

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