High VOLT Interactive

Where power supply design meets collaboration

Design Considerations for USB type C Power Delivery

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What will I get out of this session?

- Purpose:

  1. Learn more about USB-C Power Delivery (PD) requirements.

  2. Understand architecture of USB-C PD, AC/DC power sources.

- Part numbers mentioned:
  - UCC28740, UCC24636
  - TPS40303, TPS25740
- Reference designs mentioned:
  - PMP11451
  - PMP11372, PMP20172
- Relevant End Equipments:
  - USB Chargers

The USB Connectors

C-to-C, C-to-A and C-to-B cables are defined.
C-to-DisplayPort are also available.

USB2.0

Type-A

Type-B

Mini-B

Micro-B

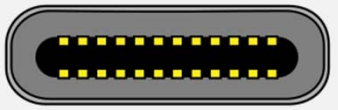
USB3.0

Type-A

Type-B

Micro-B

One size for USB2.0, 3.0, 3.1



Type-C

USB2.0

USB3.1

DisplayPort

Power Delivery

Priority of Power Modes

Precedence	Mode of Operation	Nominal Voltage	Maximum Current
Highest	USB PD	Up to 20 V	3A 5 A w/ active cable
	USB Type-C current @ 3A	5 V	3 A
	USB Type-C current @ 1.5A	5 V	1.5 A
	USB BC1.2	5 V	Up to 1.5 A
	USB 3.1	5V	900 mA
Lowest	USB 2.0	5V	500 mA

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USB-C Eco System

Power Role

Source-Only — DRP — Sink-Only

DFP = Downward Facing Port
DRP = Dual Role Power
DRD = Dual Role Data
UFP = Upward Facing Port

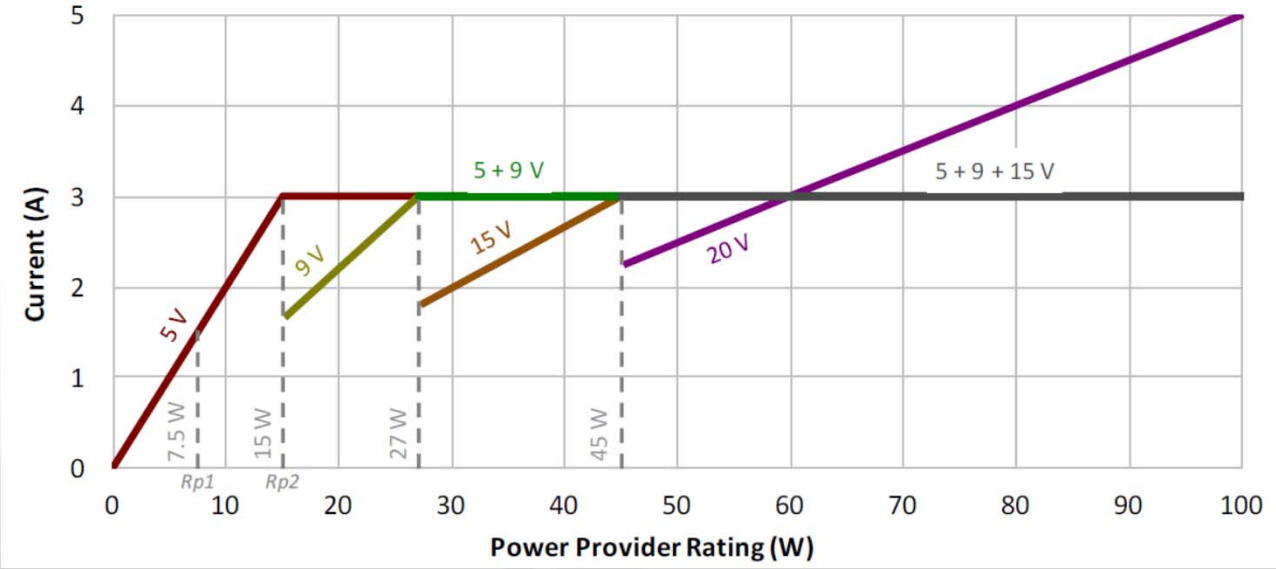
Data Role

Focus on Source-Only Application

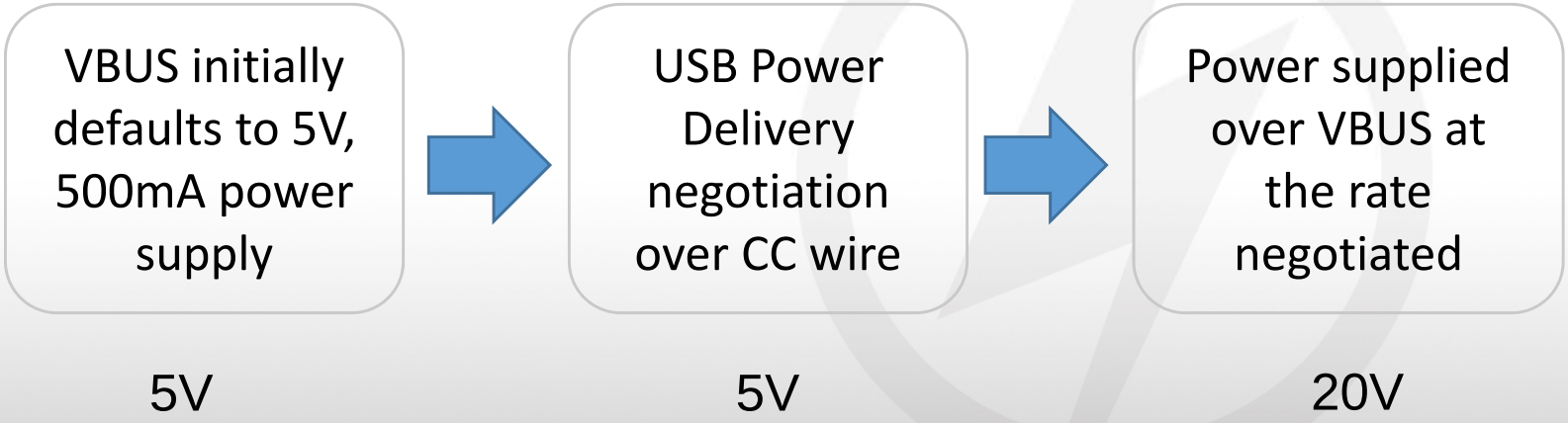
- There are many different applications that require different silicon solutions under the USB Type-C umbrella.
  - Laptops, docking station, monitors, tablets, etc.
- One benefit of the wide-spread adoption of this open standard is a realistic path to a universal charger and e-waste reduction.
  - One connector instead of the proliferation of different adaptors for different devices
  - **300,000 tons of e-waste** goes to landfills every year (according to UN)

Monotonic Incremental Power Rule

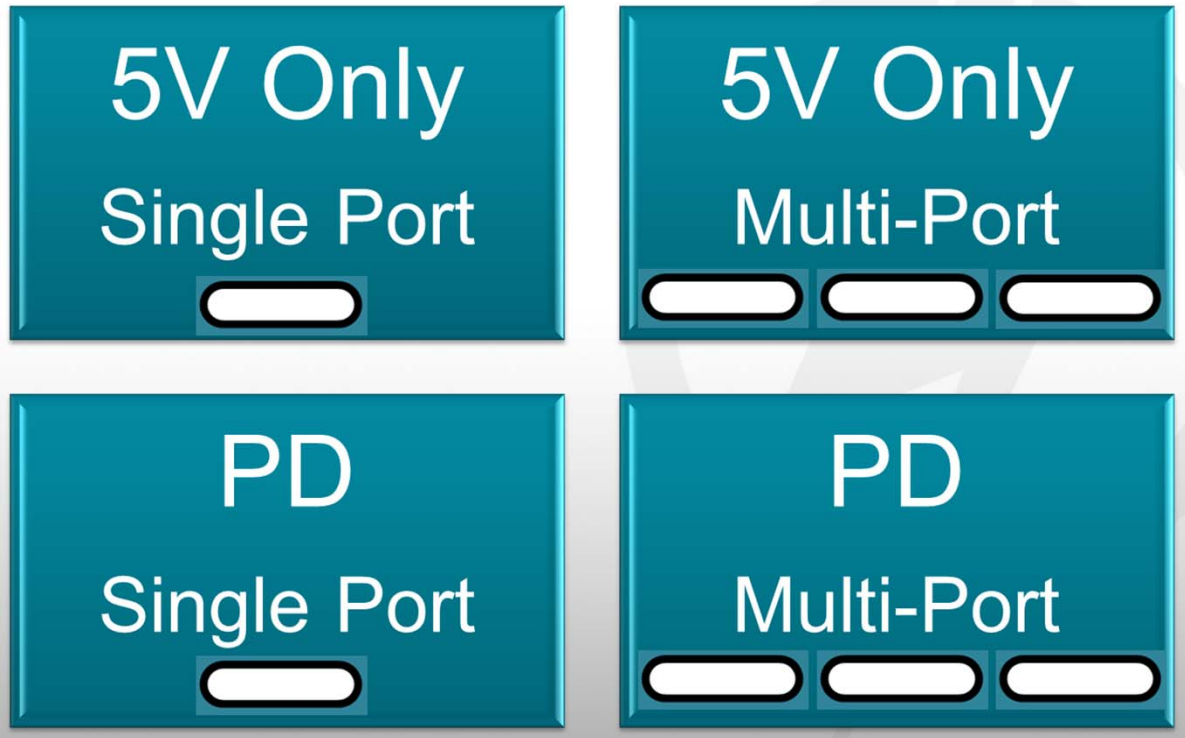
- USB PD enforces voltage profiles as a function of max power.
- e.g., if the power advertised on a port > 27W; 5V, 9V, and 15V shall be offered.
- Other voltages may be offered, but must not exceed highest required voltage rail



Typical PD Flow



USB Type-C DFP PD Systems



5V Output Voltage Requirements

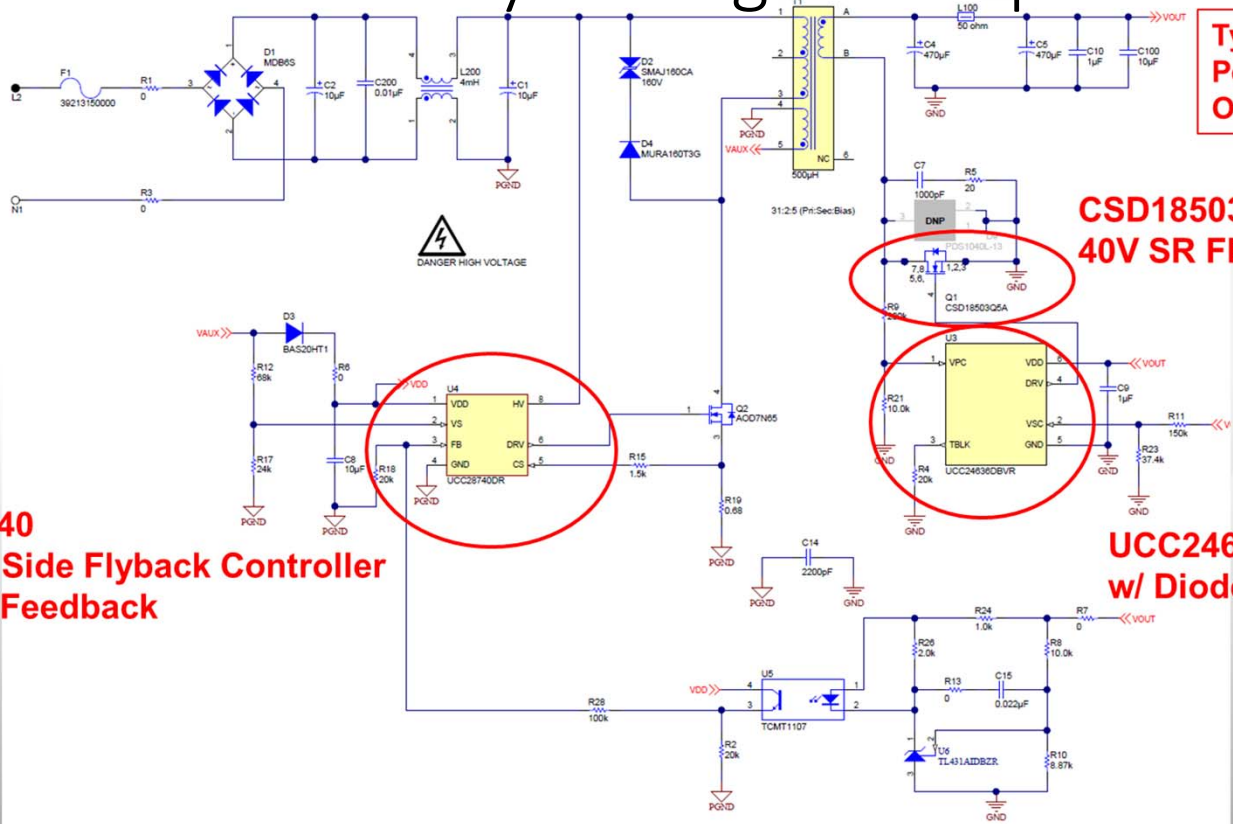
- Follow USB2.0 and 3.1 spec
- Range includes all of these error sources:
  - DC regulation accuracy
  - Line load regulation
  - Ripple
- Load Transients:
  - Stay within same range for 5V outputs
  - Test in 25% load step increments from:
    - Min load to max load
    - Max load to min load
  - Must pass this at receptacle

Min	Max
4.75V	5.5V

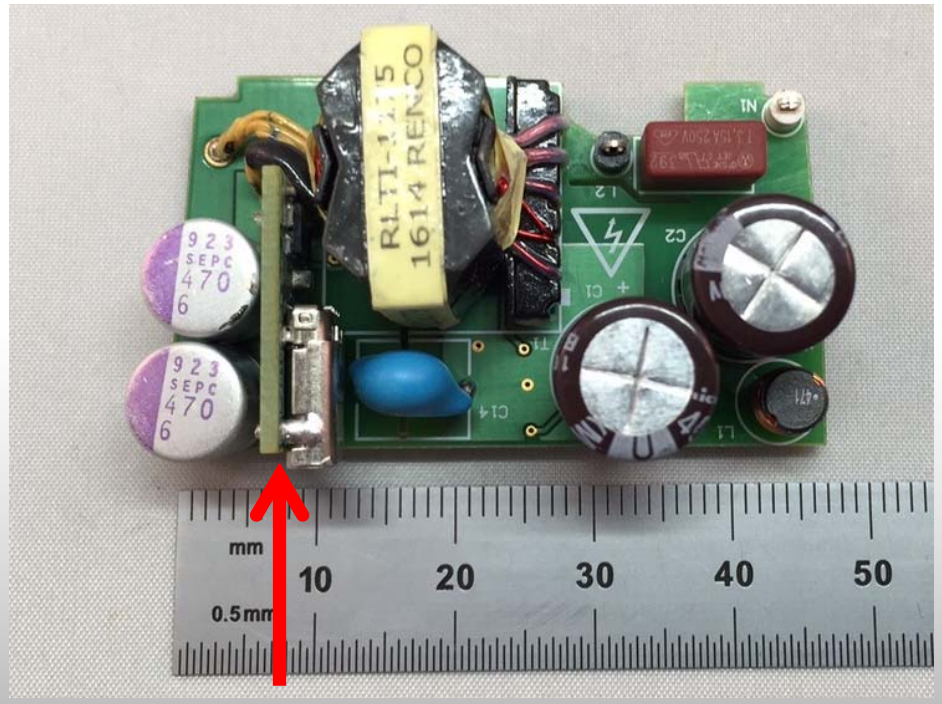
AC/DC 5V Only – Single Port

- Not much different from Type A adaptors
- More power than Type A (15W vs. 10W)
  - Requires synchronous rectifier in most cases
- Requires a port controller to advertise power and control disconnect switch
  - TPS25810 (integrated 30mΩ FET)
  - TUSB321 + external PFET
- Possible with PSR (Primary-Side Regulation)
  - No optocoupler for reduced cost

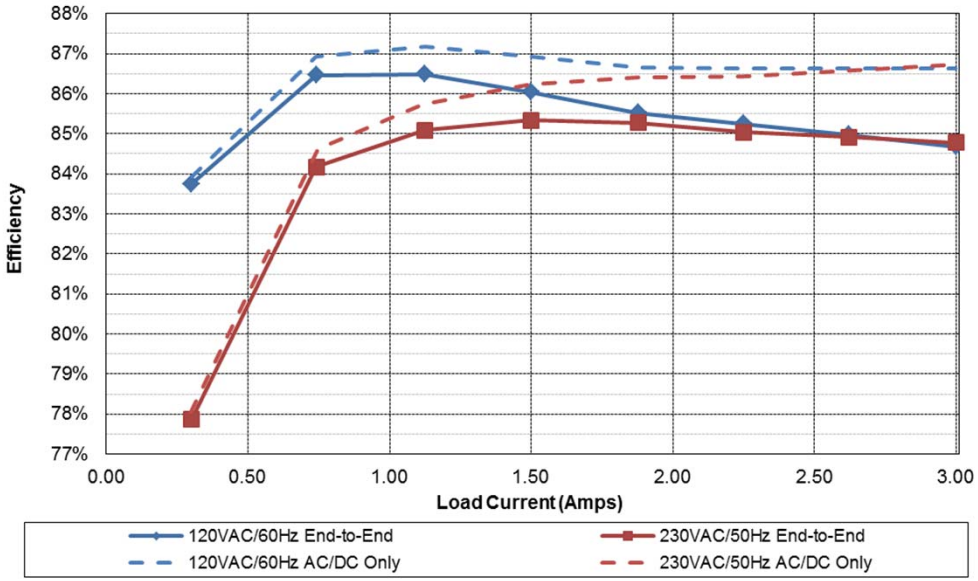
AC/DC Single Port – 5V Only : Design Example



AC/DC Single Port – 5V Only : Design Example

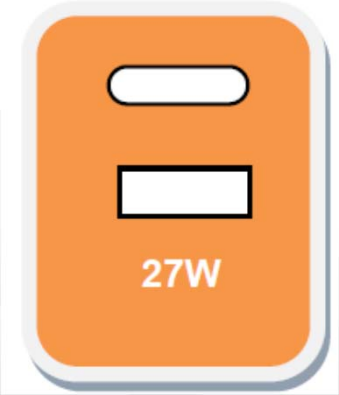


Daughter Card

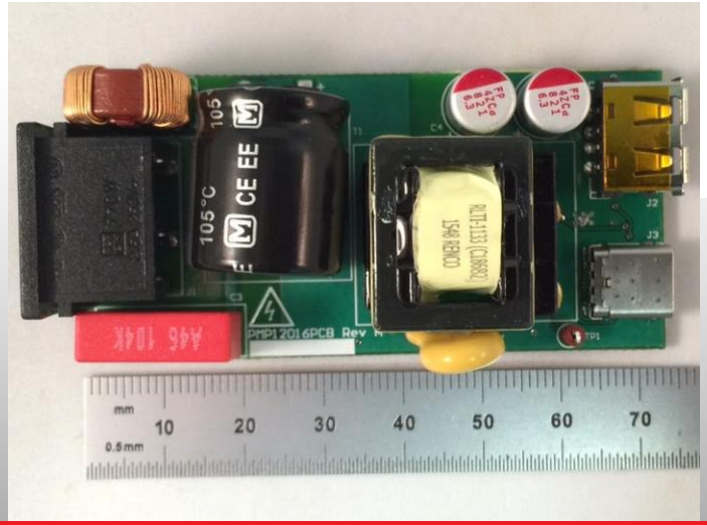


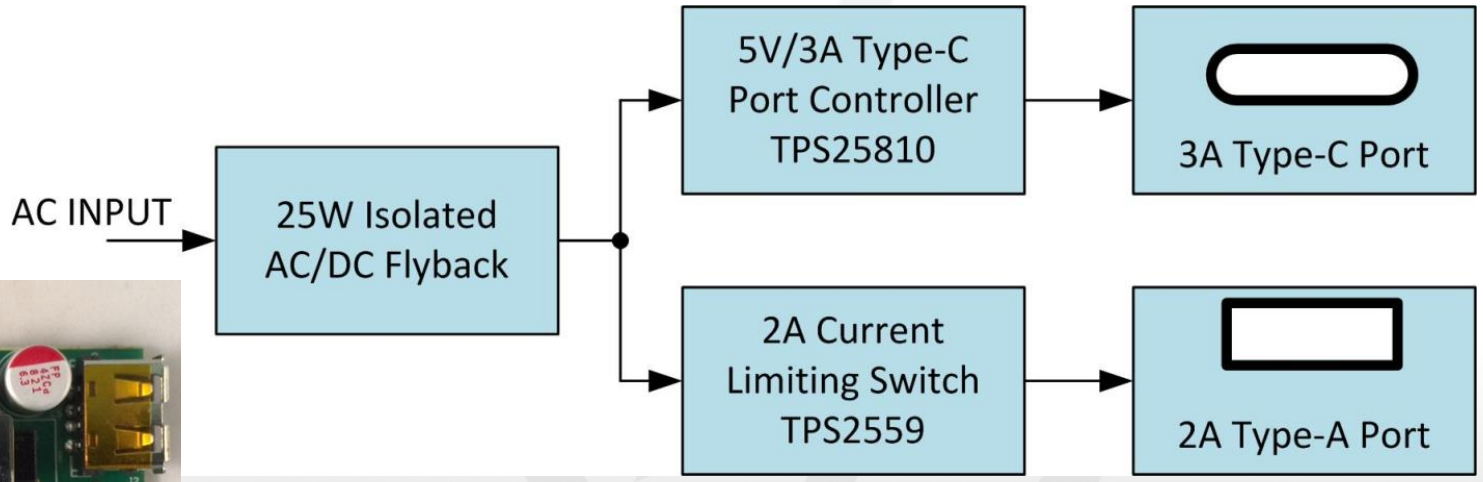
AC/DC 5V Only – Multi-Port

- Can be a mixture of Type A and Type C ports
- Each Type C port needs a port controller
- Total power level >15W
  - Definitely needs SR
- Secondary-side regulation recommended
  - Difficult to maintain regulation on all ports



AC/DC Multi-Port – 5V Only : Design Example





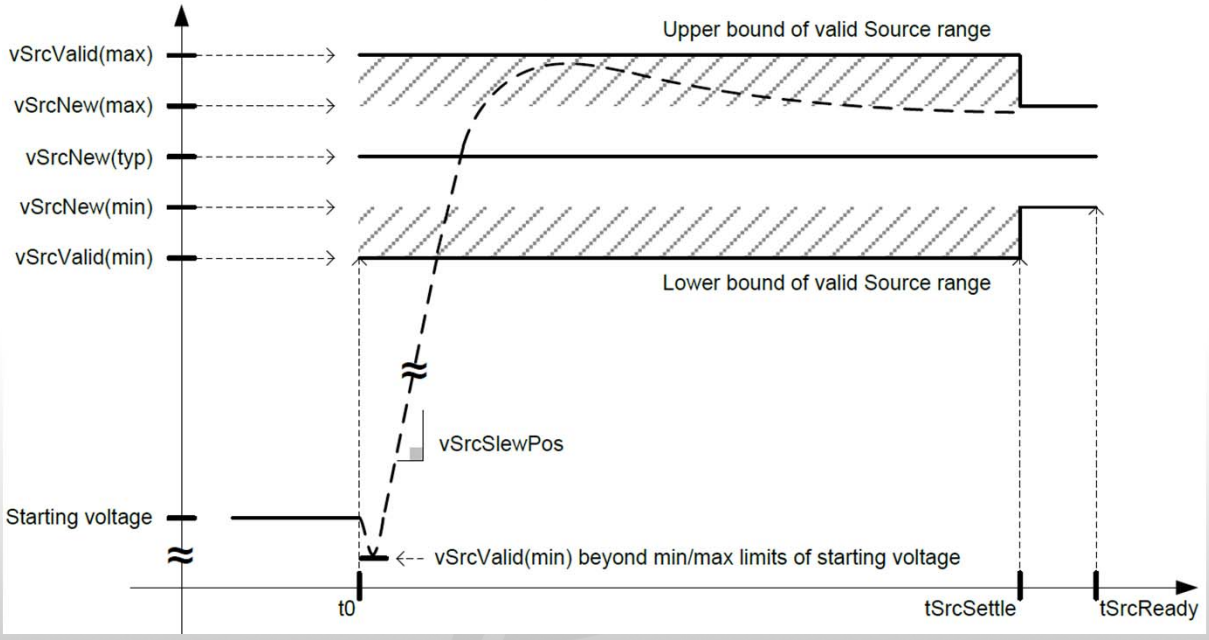
PD Regulation Requirements

- Range includes all of these error sources:
  - DC regulation accuracy
  - line load regulation
  - Ripple
- Must pass this at receptacle
- NV = new voltage
- If NV = 5V: Follow USB2.0 and 3.1 spec

NV	vSrcNew Min	vSrcNew Max
5 V	4.75 V	5.5 V
9 V	8.55 V	9.45 V
15 V	14.25 V	15.75 V
20 V	19.0 V	21.0 V

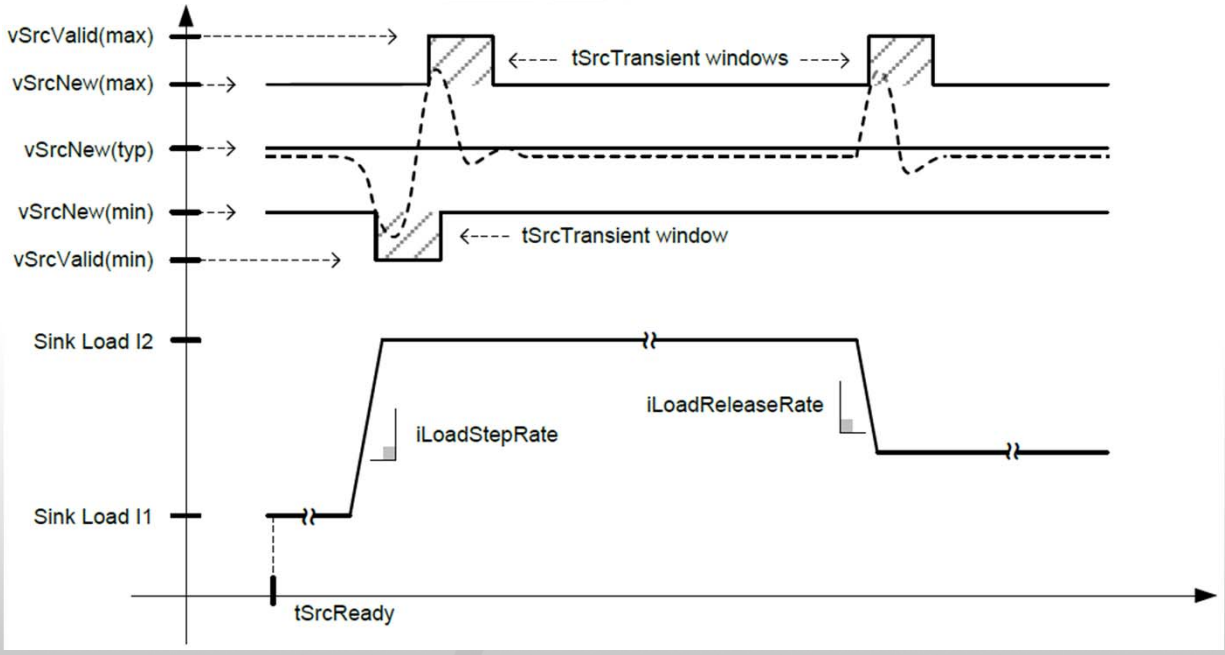
PD Voltage Transition Requirements

- If NV > 5V
  - vSrcNew = +/- 5% of NV
  - vSrcValid =VSrcNew +/- 0.5V
- vSrcSlewPos < 30mV/us
- tSrcSettle = 275ms
- tSrcReady = 285ms



PD Load Transient Requirements

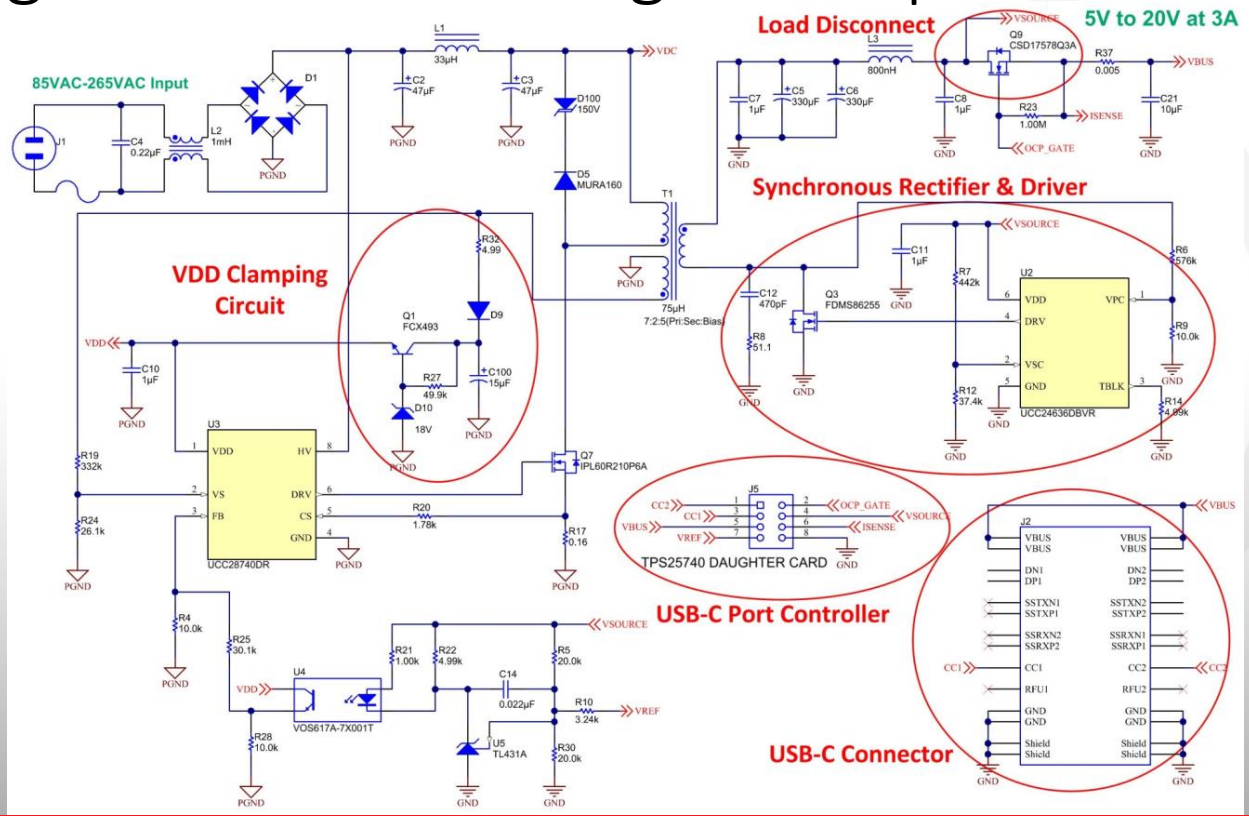
- Stay within vSrcValid
- Return to vSrcNew within 5ms
- Test in 25% load steps from:
  - min load to max load
  - max load to min load
- Must pass at receptacle



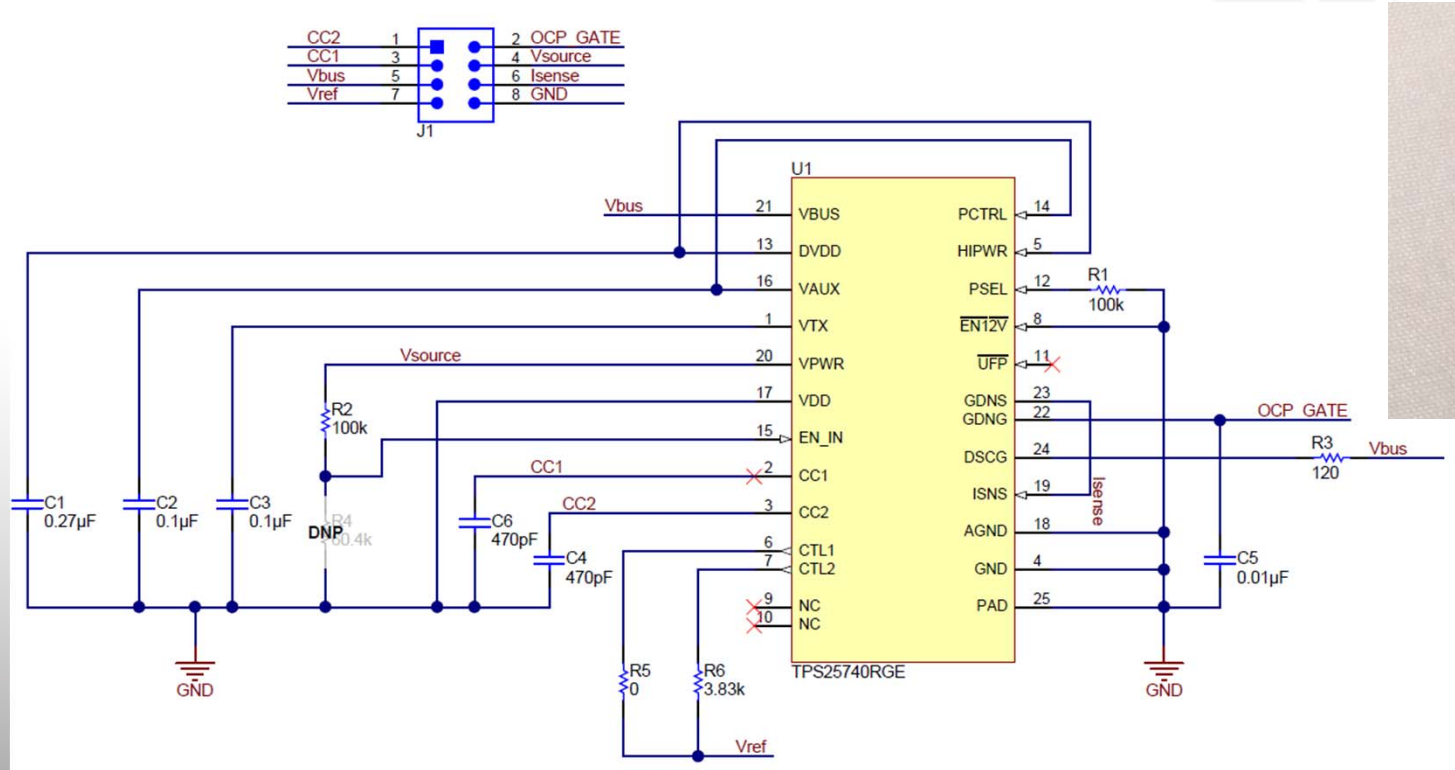
AC/DC PD – Single Port

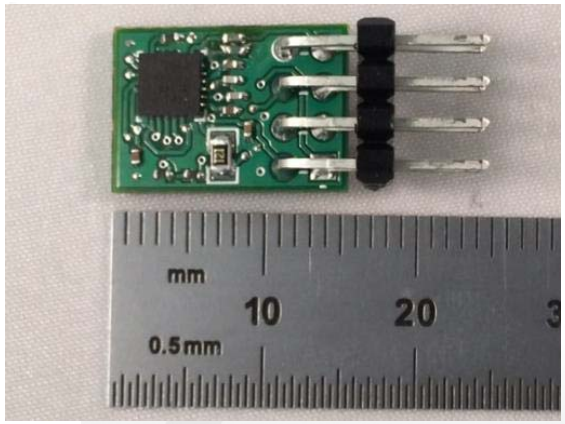
- Flyback is the best topology choice:
  - Tolerant of wide output voltage variations
  - Simple and low cost
  - Good efficiency and low standby power
- Secondary-side regulation is required to adjust output voltage
- Aux winding voltage is proportional to output voltage
  - VDD to the primary controller may need to be clamped

AC/DC Single Port – PD : Design Example

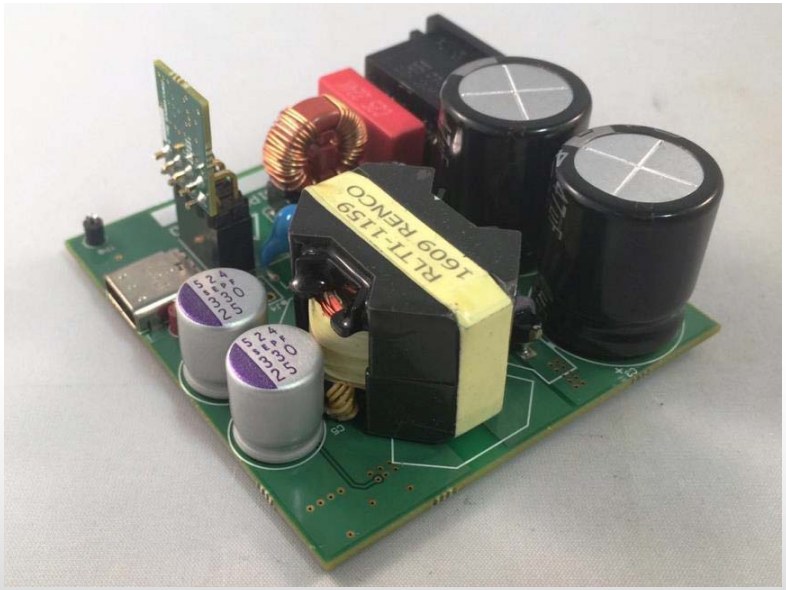


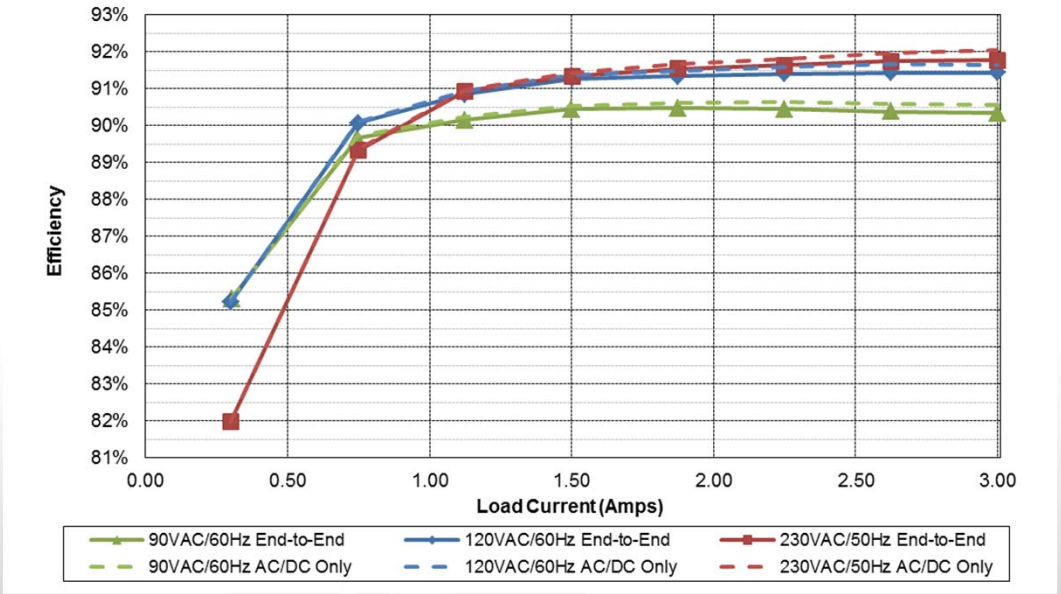
AC/DC Single Port – PD : Design Example





AC/DC Single-Port – PD: Design Example



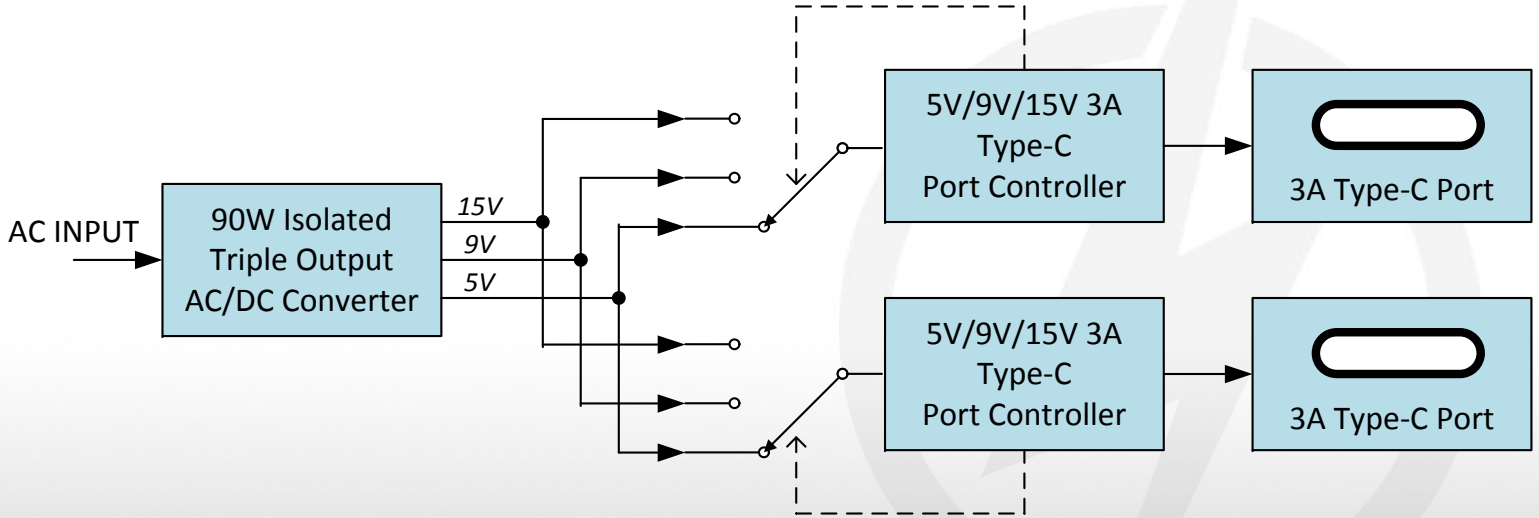


- PMP11451, www.ti.com/tool/PMP11451
- UCC28740, UCC24636, TPS25740 Flyback with SR and PD Control
- 5V/12V/20V 60W, 92% Efficiency

AC/DC PD – Multi-Port

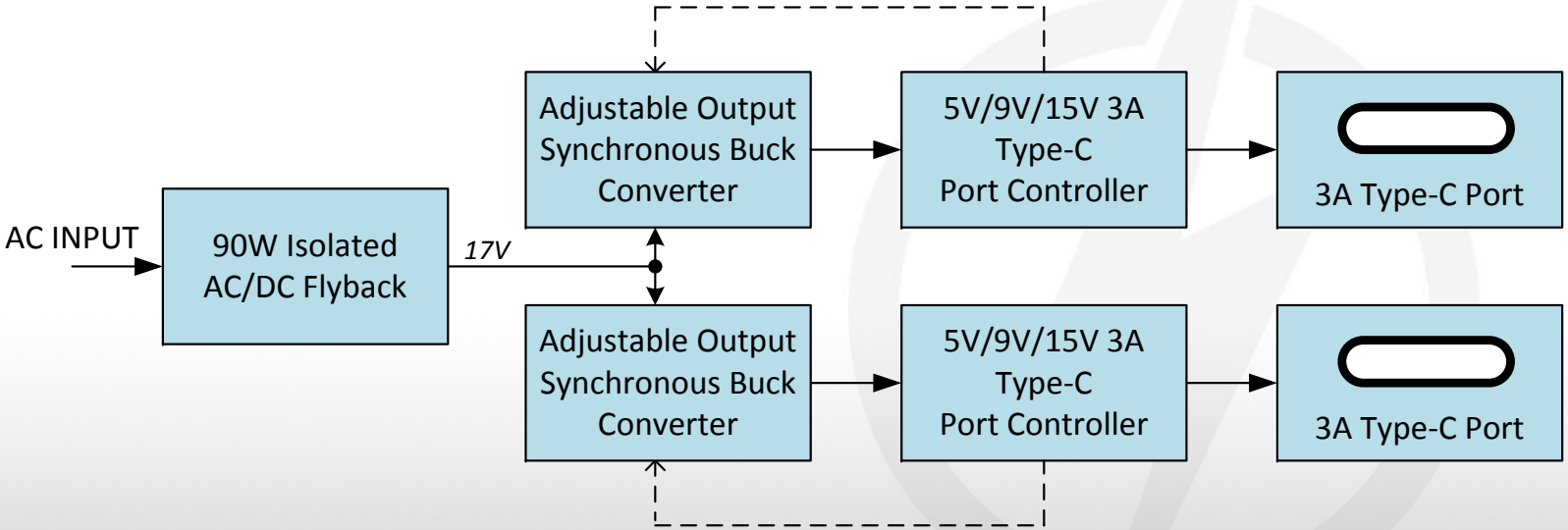
- Complicated because…
  - Must support multiple voltages simultaneously
- But, luckily…
  - Power/voltage contracts can be renegotiated at any time
- Possible architectures:
  - Generate multiple voltage rails and mux to ports
  - Generate intermediate bus and post regulate each port
- Power path management
  - Simple two port systems can be designed using built-in features of TPS25740
  - 3+ port systems require a microprocessor

5V/9V/15V PD with Multiple Ports - Muxing



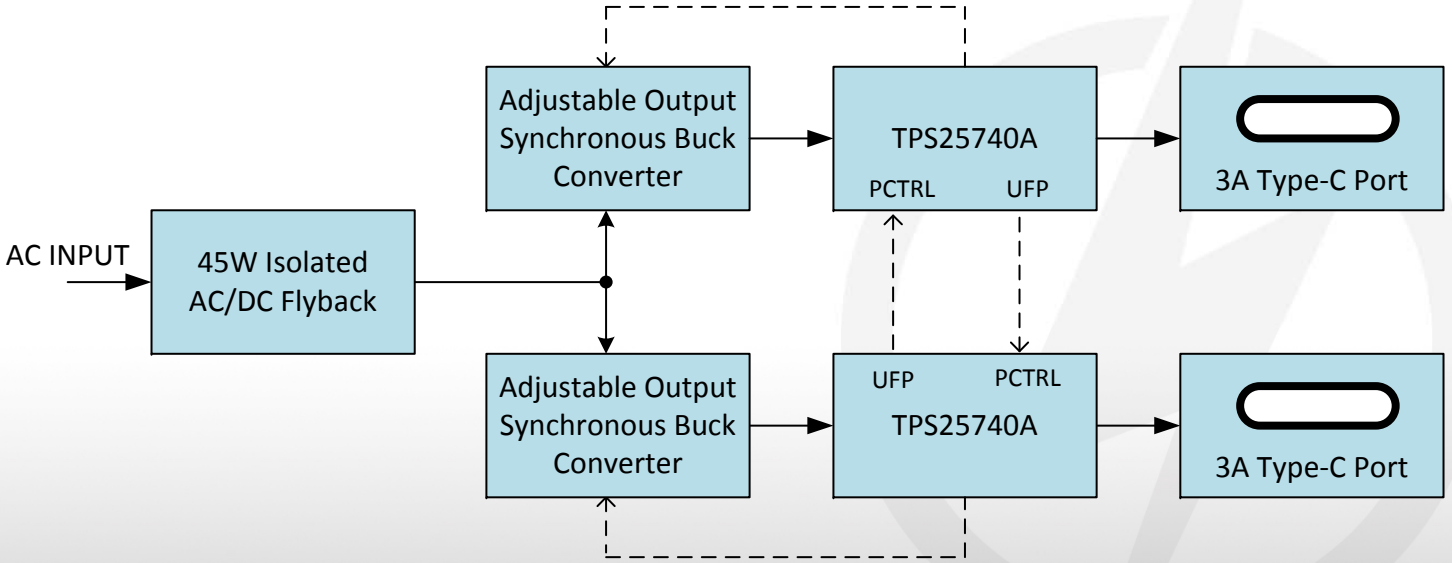
+ Good efficiency
- Poor regulation
- Complicated AC/DC design
- Difficult to control voltage slew rates
- Poor ultilization of AC/DC power capabilities

5V/9V/15V PD with Multiple Ports – Intermediate Bus



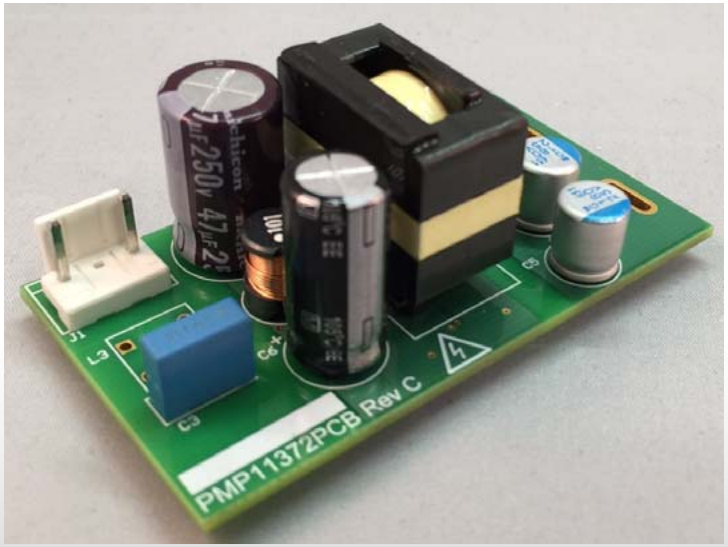
+ Good regulation
+ Simple, low-cost AC/DC converter
+ Full control of individual port voltages
- Poor ultilization of AC/DC power capabilities

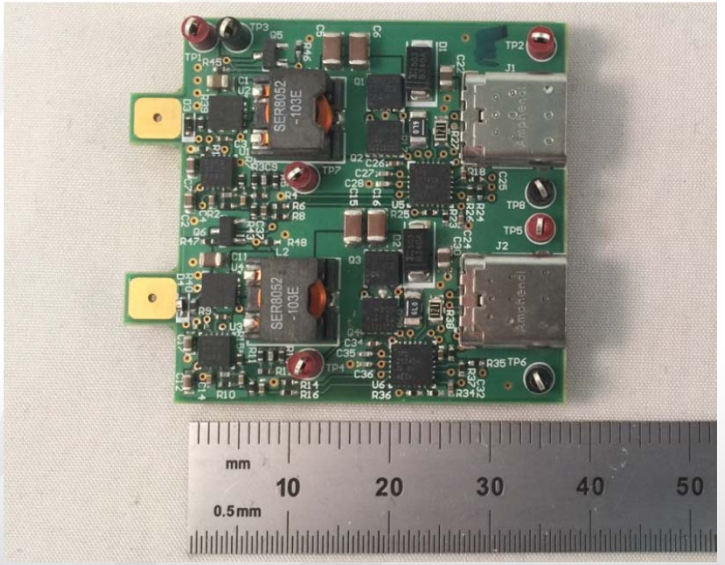
5V/9V/15V PD with Multiple Ports – Port Power Management



+ Good regulation
+ Simple, low-cost AC/DC converter
+ Full control of individual port voltages
+ Greatly reduced size
- Reduced power capabilities

AC/DC Multi-Port – PD: Design Example





- PMP11372, www.ti.com/tool/PMP11372
- UCC28740, UCC24636, Flyback with SR
- 17V/36W, 93% Efficiency

- PMP20172, www.ti.com/tool/PMP20172
- TPS40303, TPS25740, Sync Buck & PD Control
- 5V/9V/15V 36W, >98% Efficiency

Conclusions

- Understand the Type-C and PD rules before designing
- 5V only systems are fairly straight forward
- Single port PD solutions require:
  - Clamping circuit on VDD
  - Port controller
  - Disconnect FET
- Multiple port PD solutions benefit from:
  - Two stage approach
  - Smart port power management
  - High efficiency
  - High power density