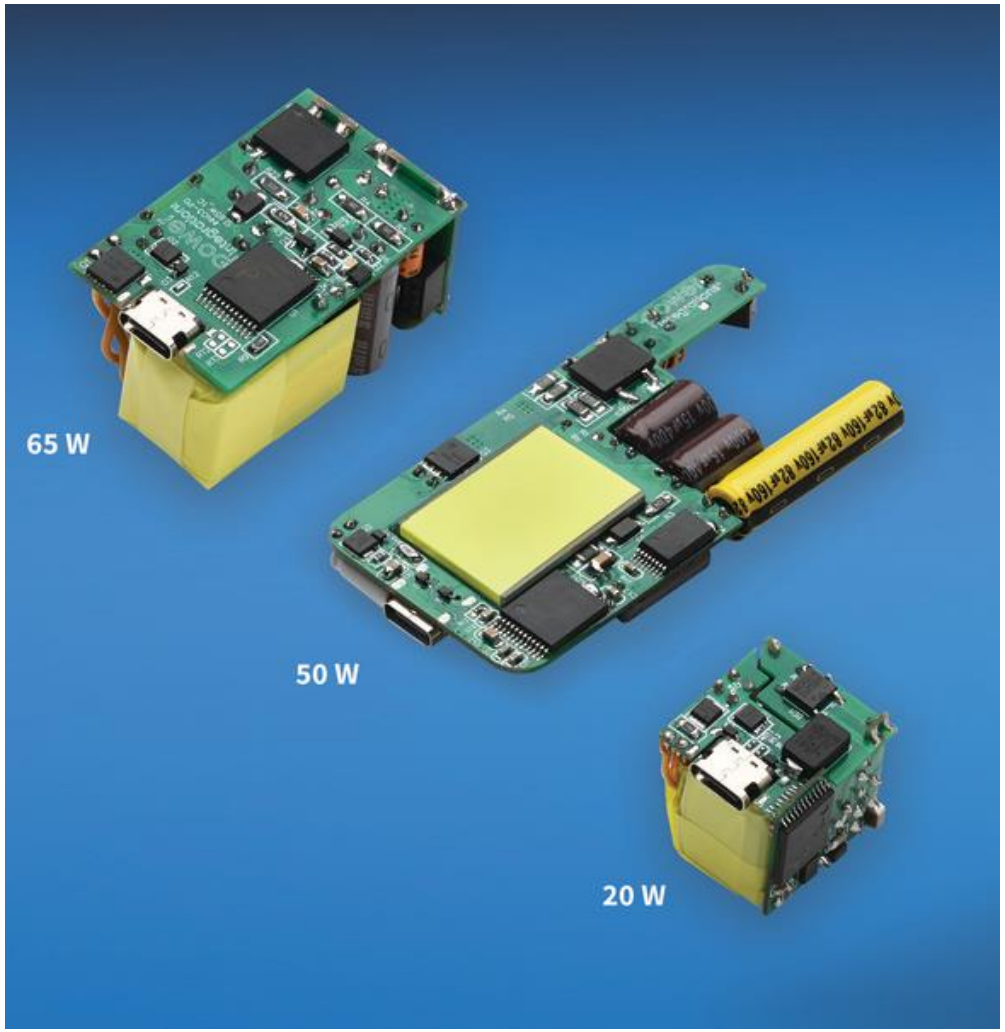
power integrations

Choosing the Correct GaN-Based Power Device for Your Fast Charger Design

Market Wants Smaller USB Fast Chargers with More Power

- **Bigger batteries (5G, bigger display…) need higher power for faster charging**
- **Number of electronic gadgets per user is growing**
  - Smartphone, tablet, notebook, smart-watch, wireless headphones…
- **Wide adoption of USB PD has created a new space for ultra-compact and slim chargers**
- **Adapter-free charging**
  - USB A/C ports embedded in wall-sockets, power strips, appliances and furniture
  - Requires small size and good thermals to support high ambient temperature

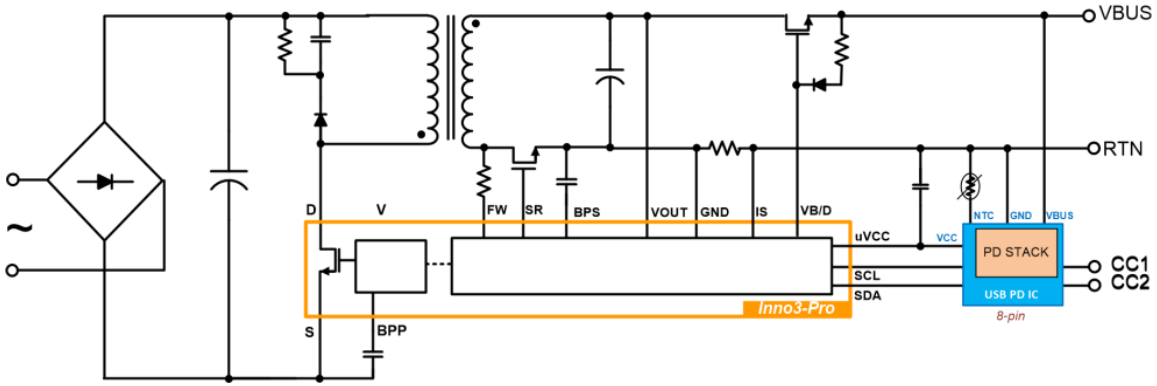


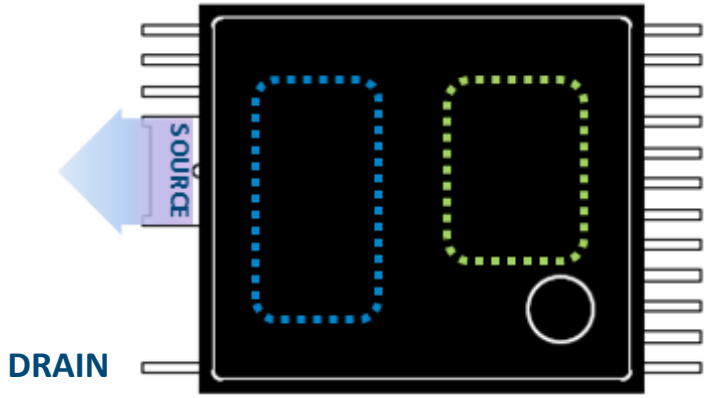
IC Families Featuring PowiGaN™ Switches for Rapid Charging

- **MinEcap – Bulk Capacitor Miniaturization and Inrush Management**
- **InnoSwitch™3-CP – Constant power**
- **InnoSwitch™3-Pro – Digitally programmable**
- **InnoSwitch™3-PD – Single chip solution for lowest part-count**
  - Integrated Microcontroller
- **InnoSwitch™4-CZ – High frequency Active Clamp Flyback**
  - Paired with ClampZero™

InnoSwitch3 Plus PowiGaN Optimized for High Density Applications

- **GaN is integrated with driver, controllers and feedback in a single package**
  - Low EMI – precisely controlled drive speed and very small gate drive loop
  - Low loss logic-level drive
  - Very low off-state leakage current
- **Lossless current sensing**
  - SenseFET structure
  - Noise immunity and fast protection
  - Completely eliminates sense resistors
- **Eliminates start-up circuitry**
  - High voltage start up integrated within primary switch
- **Grounded substrate and low specific $R_{DS(ON)}$**
  - PCB cooling connected to quiet non-switching node, low radiated EMI
  - Small die size enables compact package





Advantages of InnoSwitch3

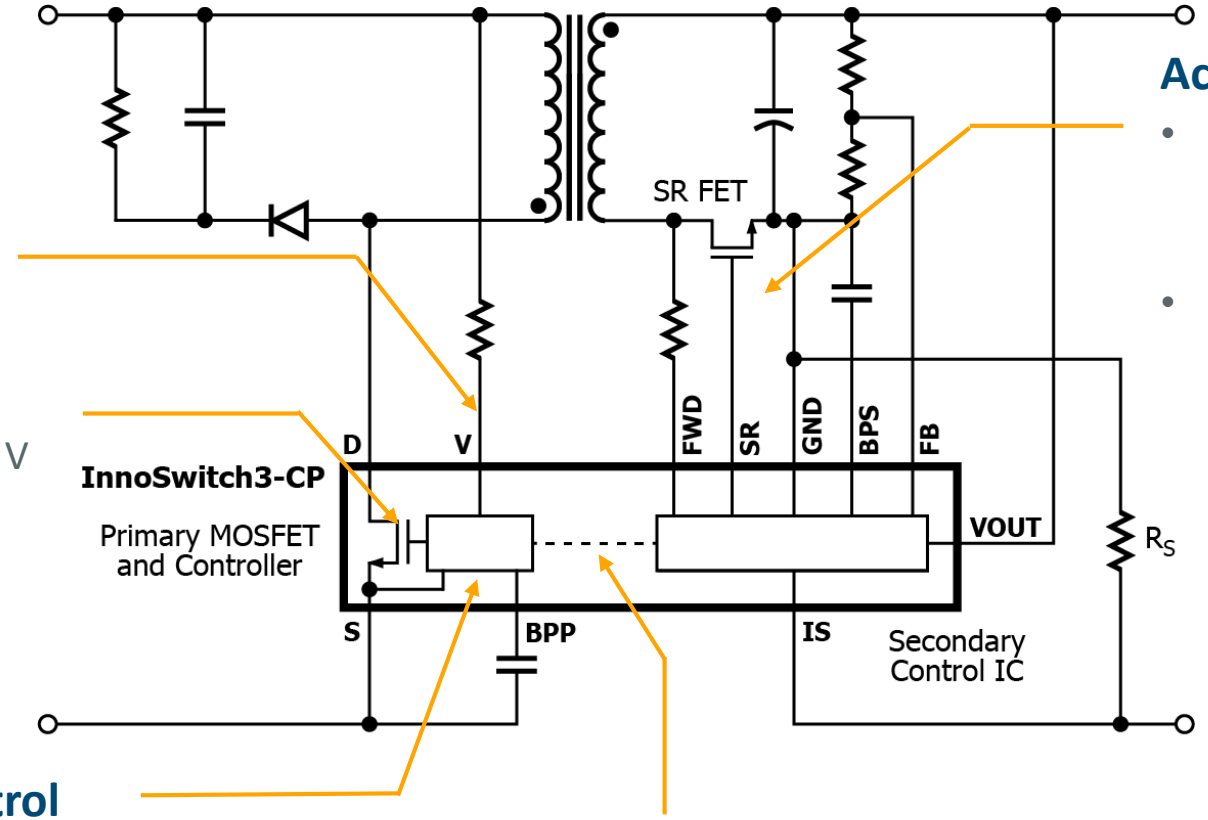
InnoSwitch3 ICs Employ FluxLink™ Digital Feedback to Eliminate Optocouplers

Lossless Sensing

- Protection from line surges
- Adds < 2 mW to no-load

Integrated Power FET

- 650 V / 725 V / 750 V / 900 V



Active Control of SR MOSFET

- Reduced diode conduction increases SR FET conduction time for best efficiency
- Seamless DCM-CCM transitions

Proprietary Switch & Control

- CCM and quasi-resonant switching
- Highest efficiency
- Lowest losses

FluxLink – Isolated Feedback

- High reliability, lifetime

Characteristic	Specification
Voltage tolerance	± 3%
Current tolerance	± 5%
Transient response	Excellent
No-load input power including line sense	< 15 mW

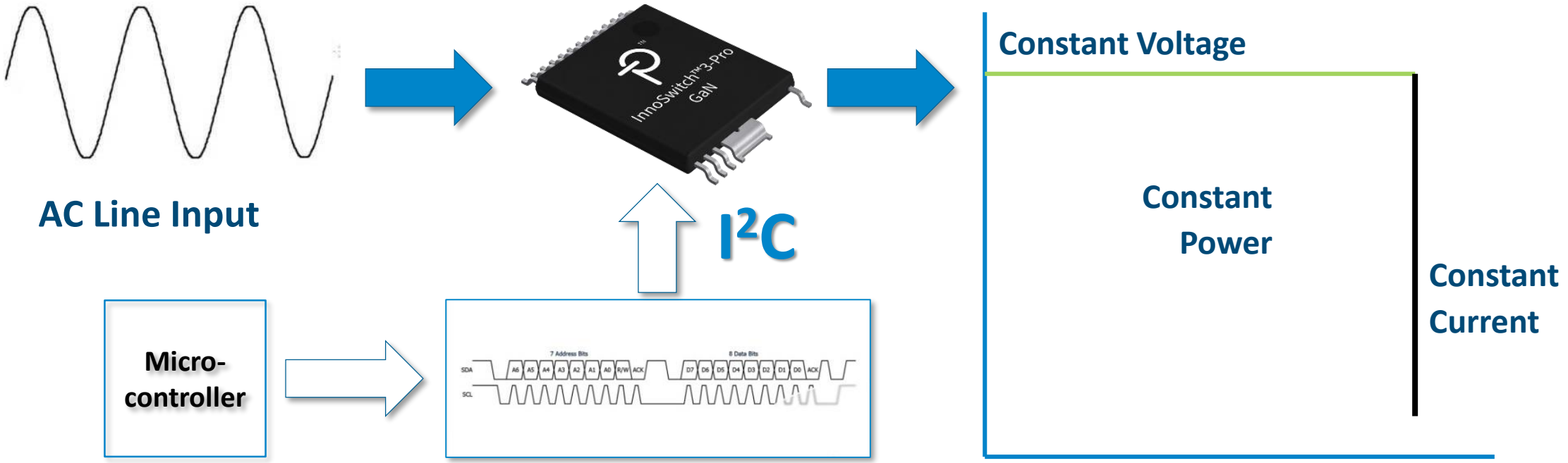
Up to 100 W Without Heatsink

725 / 750 V Part Number	230 VAC +/- 15%		85 - 264 VAC	
	Adapter (W)	Open Frame (W)	Adapter (W)	Open Frame (W)
INN3x74C	20	25	15	20
INN3x75C	25	30	22	25
INN3x76C	35	40	27	36
INN3x77C	40	45	36	40
INN3x78C	70	75	55	65
INN3x79C	80	85	65	75
INN3x70C	90	100	75	85

PowiGaN Switches

InnoSwitch3-Pro: Digitally Programmable Power Conversion

- **Advanced control engine with digital interface (I^2C)**
  - Output voltage and current control – CV/CC/CP output characteristic
  - Configurable protection – enable/disable, shutdown/auto-restart, trigger-points



Programming Interface

Adjust output to meet load requirement

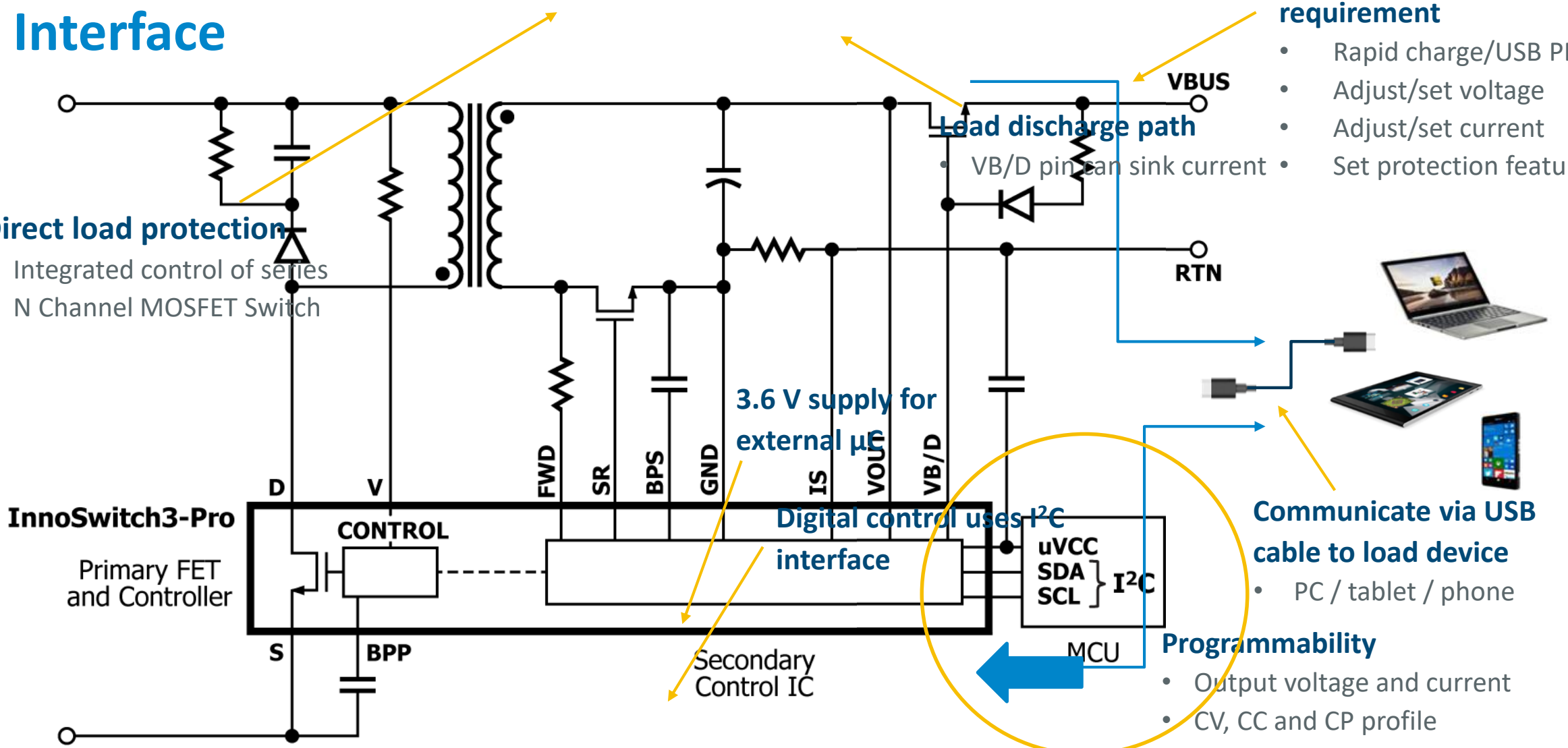
- Rapid charge/USB PD
- Adjust/set voltage
- Adjust/set current
- Set protection features

Load discharge path

- VB/D pin can sink current

Direct load protection

- Integrated control of series N Channel MOSFET Switch



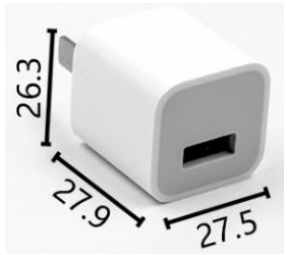
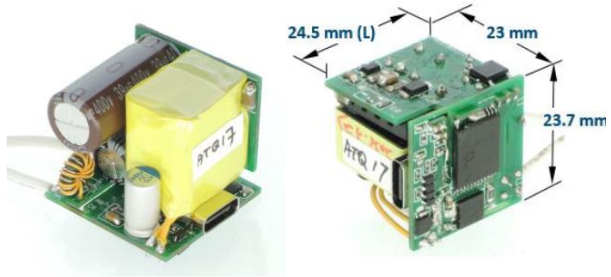
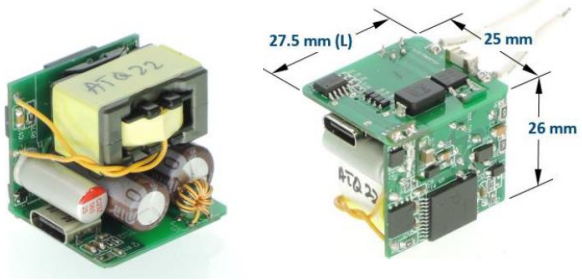
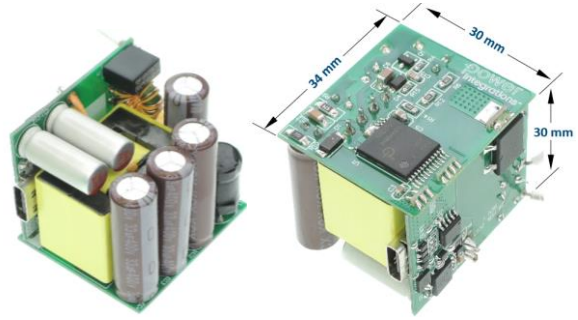
Communicate via USB cable to load device

- PC / tablet / phone

Programmability

- Output voltage and current
- CV, CC and CP profile
- Fault trigger points and response

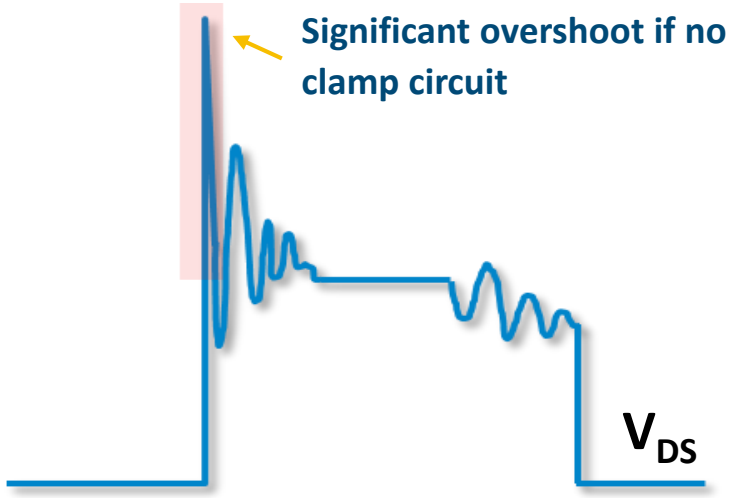
High Integration Enables Cube Designs with Just Two PCBs

Power Output	20 W 1C	30 W 1C	65 W 1C
Output	5 V 3 A, 9 V 2.22 A	5 V / 3 A, 9 V / 3 A 15 V / 2 A, 20 V / 1.5 A **PPS**: 3.3 – 11 V / 3 A	5 V / 3 A, 9 V / 3 A 15 V / 3 A, 20 V / 3.25 A **PPS**: 3.3 – 21 V / 3 A
PI Part Number (InnoSwitch3-Pro, **PowiGaN**)	INN3378C	INN3378C	INN3370C
Component count	54	54	60
PCB Size (mm)	23.7 x 23 x 24.5	25 x 26 x 27.5	30 x 30 x 34
			

InnoSwitch4-CZ + ClampZero

Clamp Circuit in a Flyback

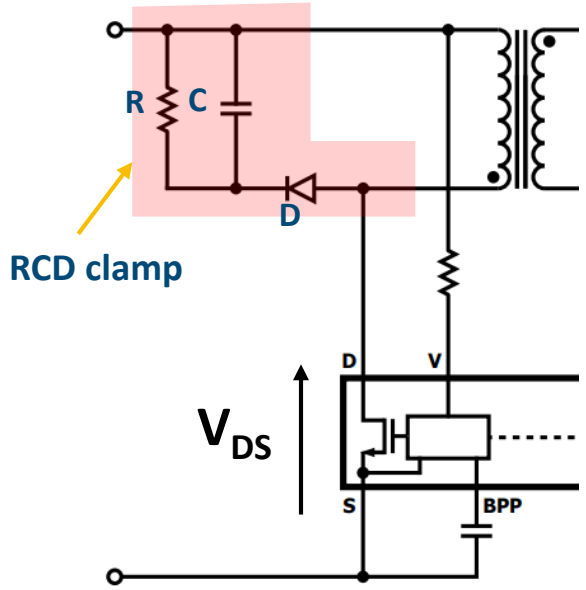
- **Flyback power supplies must use a protection circuit to prevent the voltage on the primary switch rising too high after it turns off**



Voltage on Primary Switch of a Conventional Flyback

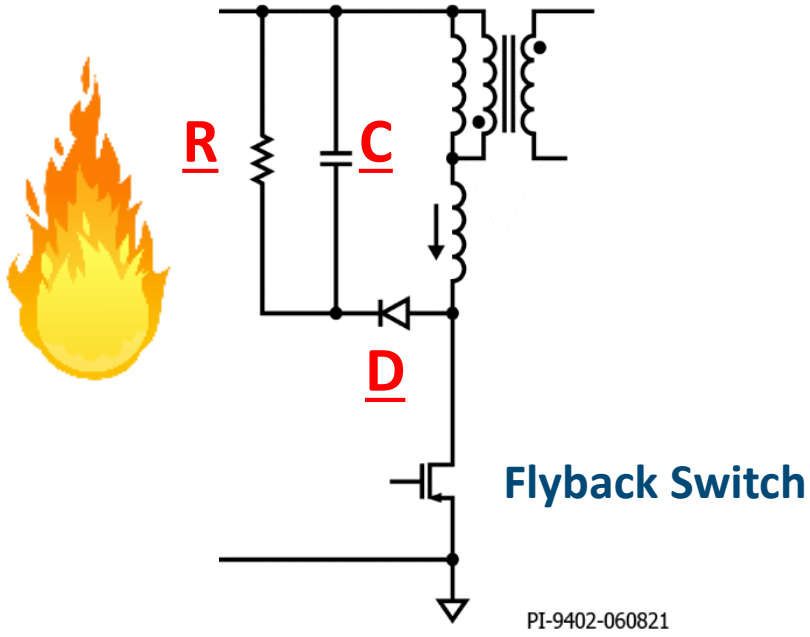
- **Circuit "clamps" voltage and keeps it to safe level**
  - Simplest type is RCD (**R**esistor, **C**apacitor, **D**iode)
  - Energy is diverted to the capacitor (C)

- **<u>BUT</u> energy in an RCD clamp is lost**
  - Resistor (R) dissipates the energy (and gets hot)
  - Reduces circuit efficiency



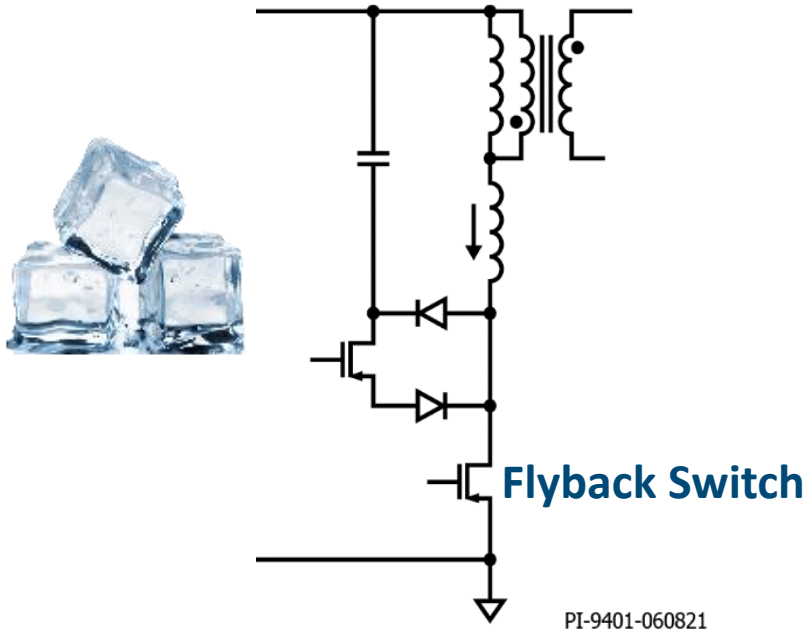
RCD Clamp Compared to Active Clamp

- Significant power loss in RCD clamp
  - Increases with switching frequency
- Leakage energy heats clamp resistor and diode
- Reduces flyback efficiency



RCD Clamp

- Leakage energy recycled through clamp FET
- ZVS on flyback switch reduces switching losses
- Increases circuit efficiency and reduces temperature



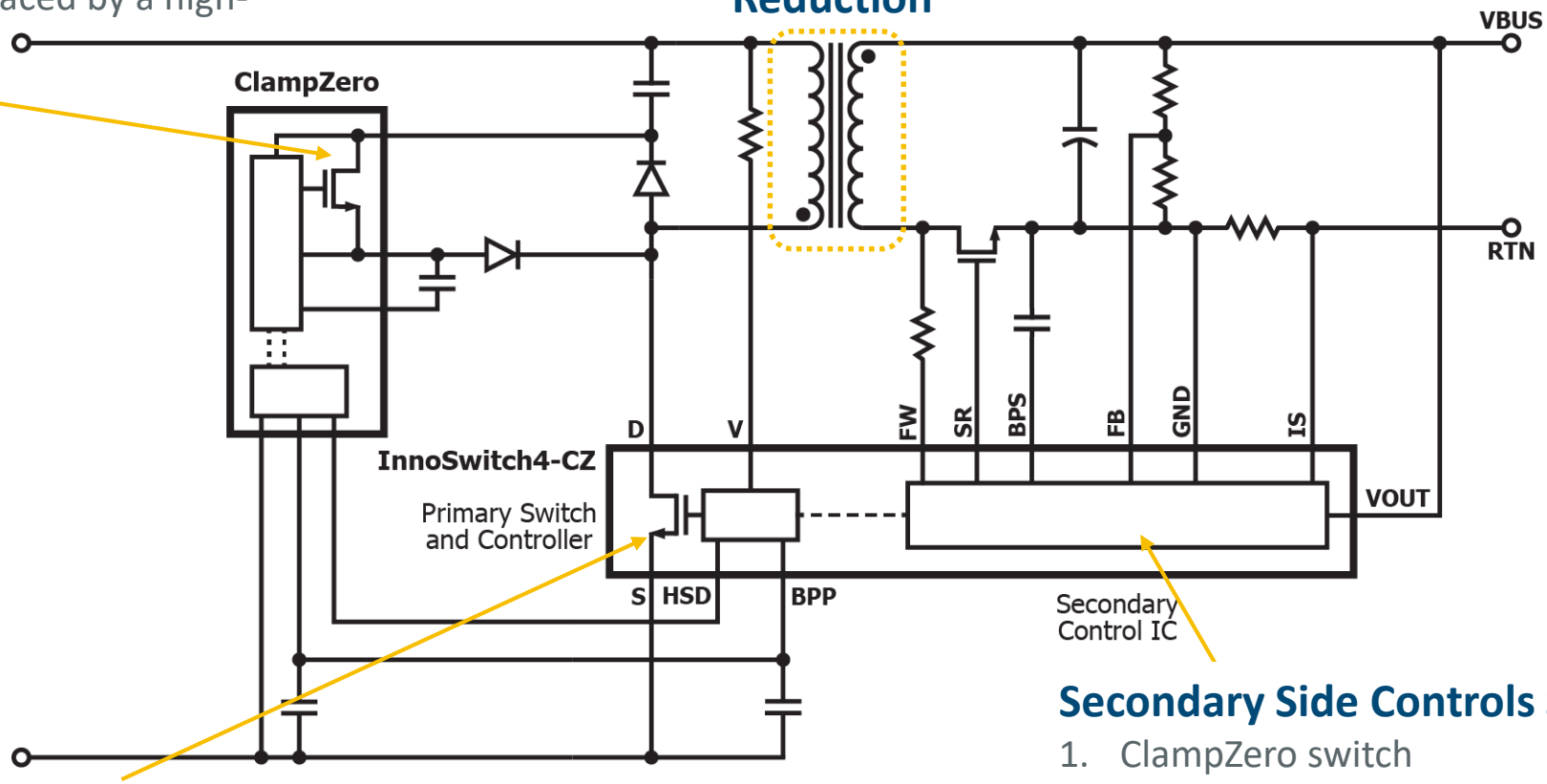
Active Clamp

InnoSwitch4-CZ & ClampZero Achieve High Efficiency at High Switching Frequency by Eliminating Primary Clamp and Turn-On Losses

Clamp Energy Recycled

- Resistor is replaced by a high-side switch

Transformer Size Reduction



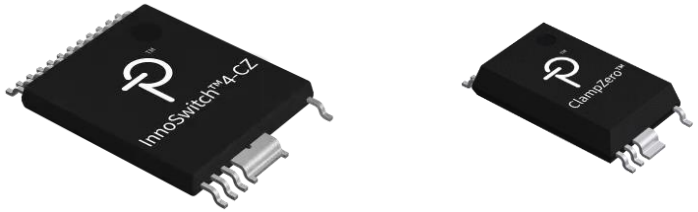
PowiGaN Switch + Primary Controller

Secondary Side Controls Switch Timing

1. ClampZero switch
2. Primary PowiGaN switch
3. Synchronous rectifier (SR) switch

InnoSwitch4-CZ & ClampZero Family Power Table

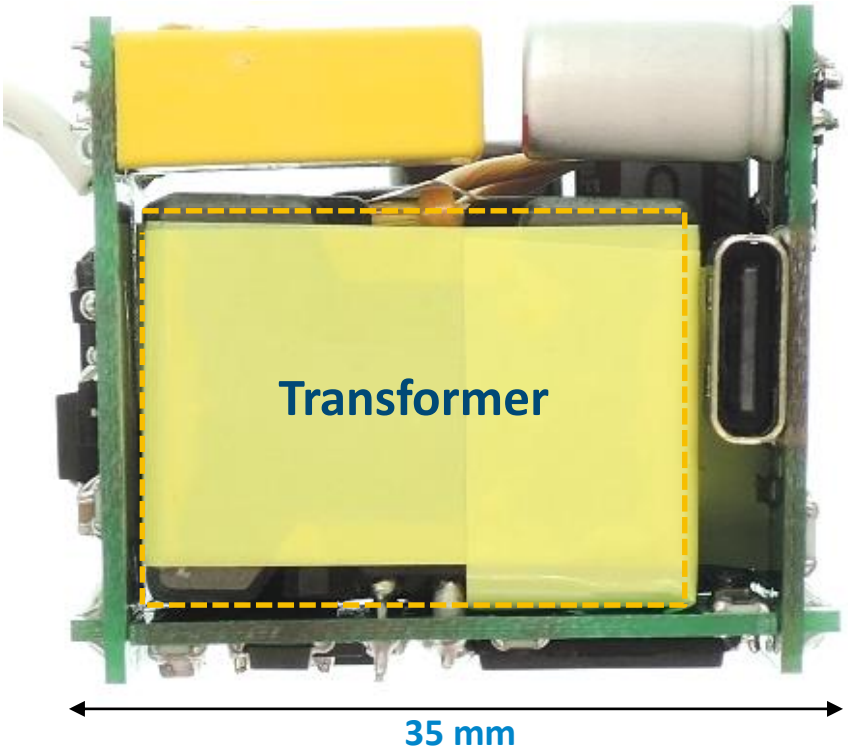
InnoSwitch4-CZ Part Number	ClampZero Part Number	85-264 VAC		385 VDC (PFC Input)	
		Adapter	Open Frame	Adapter	Open Frame
INN4073C	CPZ1061M	65 W	70 W	75 W	80 W
INN4074C	CPZ1062M	75 W	85 W	95 W	100 W
INN4075C		80 W	90 W	105 W	110 W



Eliminating Clamp & Turn-on Losses Allows Smaller Transformer & Less PCB Cooling

- **Operation up to 140 kHz**
  - Smallest size
- **Zero-voltage switching (ZVS) reduces temperature of InnoSwitch4-CZ**

InnoSwitch4-CZ



65 W Wide-Range Adapter Using Small ATQ23-12 Transformer – 23 x 12 mm

MinE-CAP

Higher Frequency:
Limited Size Savings, Added Cost

More EMI = larger input filter

What about the bulk capacitor?

- Controls peak power
- Is a big device

Must add active-clamp circuit to
reduce snubber and switching losses

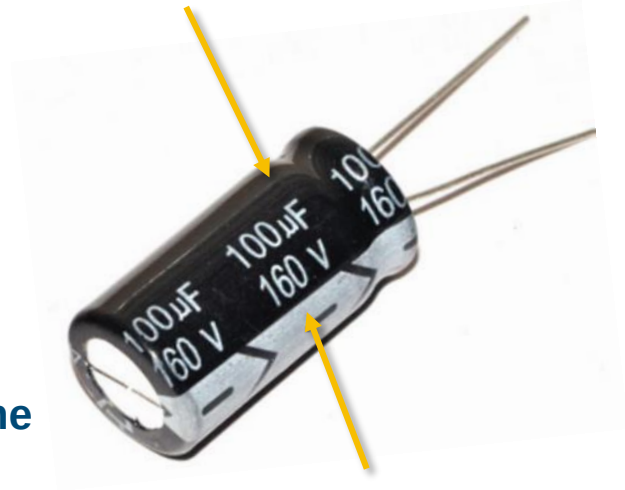
To Support Higher Voltage, Capacitor Makers Must Increase the Size of the Capacitor – A LOT!

Capacitance: 100 µF

18 x 36 mm

400 V max. voltage

Capacitance: 100 µF

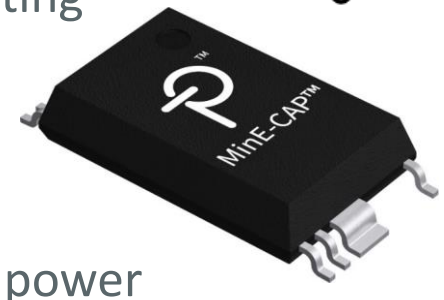


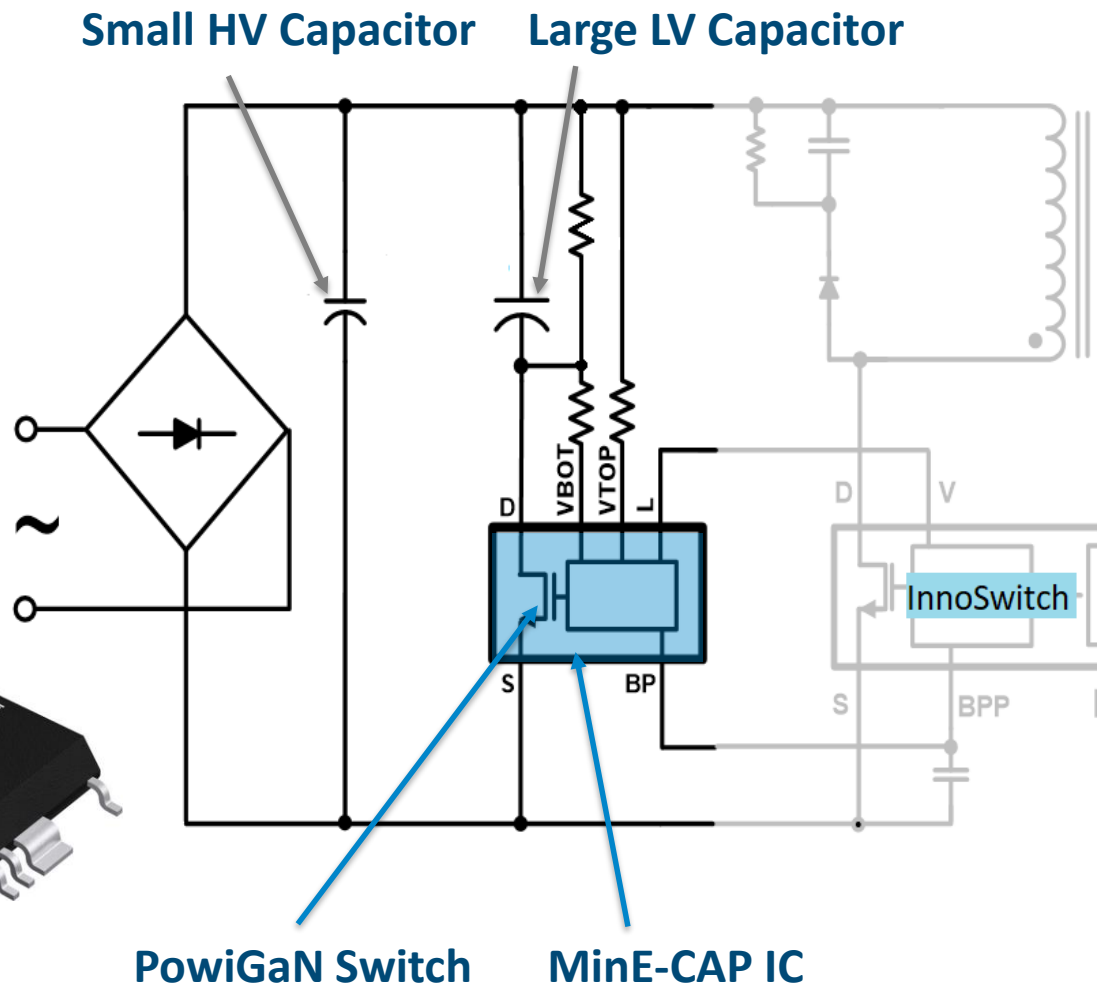
13 x 25 mm
~1/3 of volume

160 V max. voltage

MinE-CAP Adds Low-Voltage Capacitors at Low Line Voltage, and Removes them when Voltage Increases

- **Low-voltage (LV) capacitor connected by high efficiency PowiGaN switch**
  - High capacitance, low-voltage capacitor
  - Disconnected when VAC > $V_{CAP(Rating)}$
- **Allows optimization of capacitors**
  - High capacitance with low-voltage rating
  - Low capacitance at high-voltage (HV) rating
- **Other circuit benefits**
  - Reduces inrush current
  - Increase total capacitance – more peak power





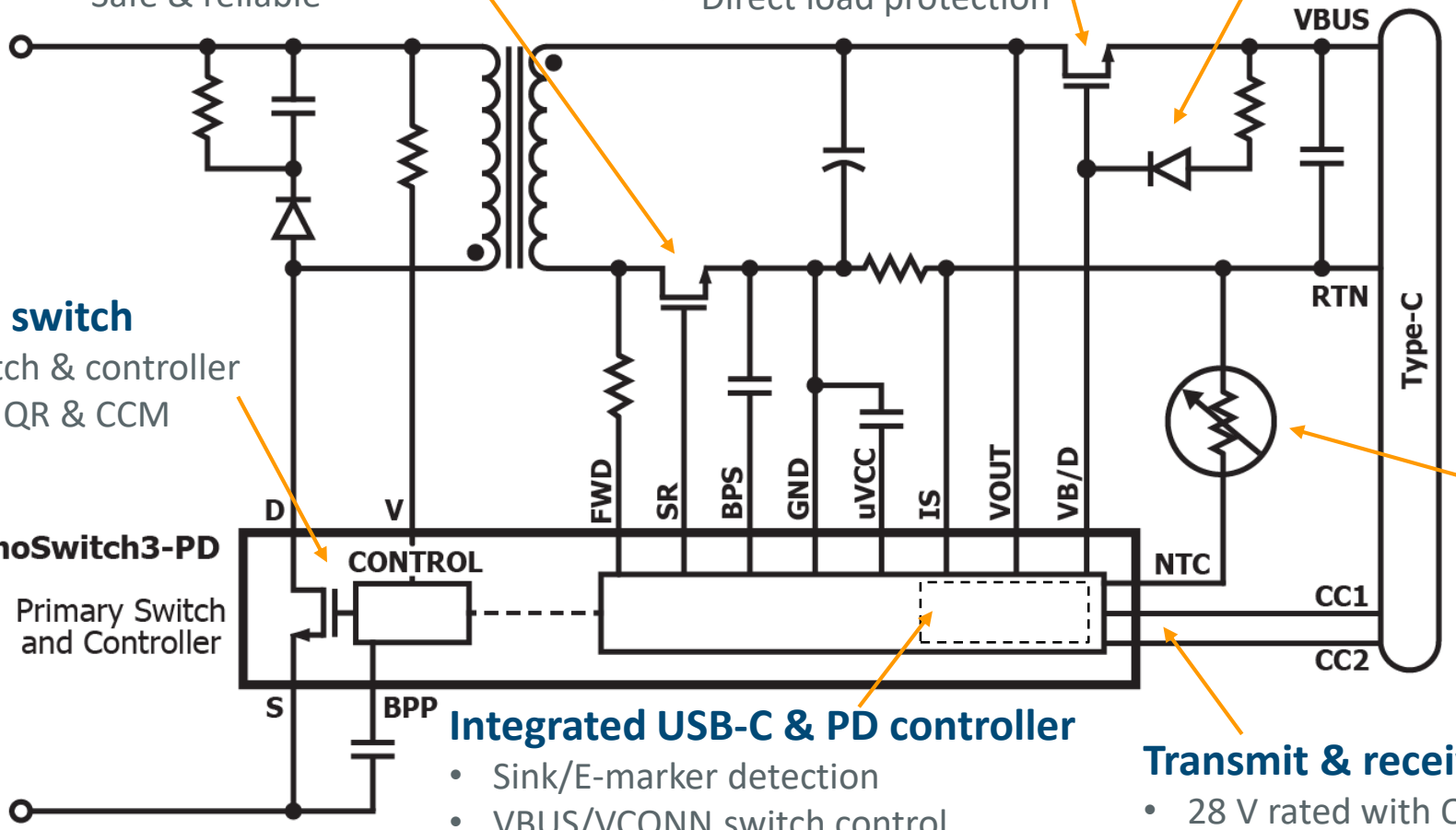
InnoSwitch3-PD

Fully Integrated InnoSwitch3-PD Simplifies BOM

Direct control of SR FET
- Highest efficiency
- Safe & reliable

Integrated N-channel load switch drive
- Direct load protection

VBUS discharge



Precise control
- 3-24 V: 10 mV/step
- CC control: 20-100% of FS
- Current step: 0.8% of FS

High-voltage switch
- Primary switch & controller
- Multi-mode QR & CCM

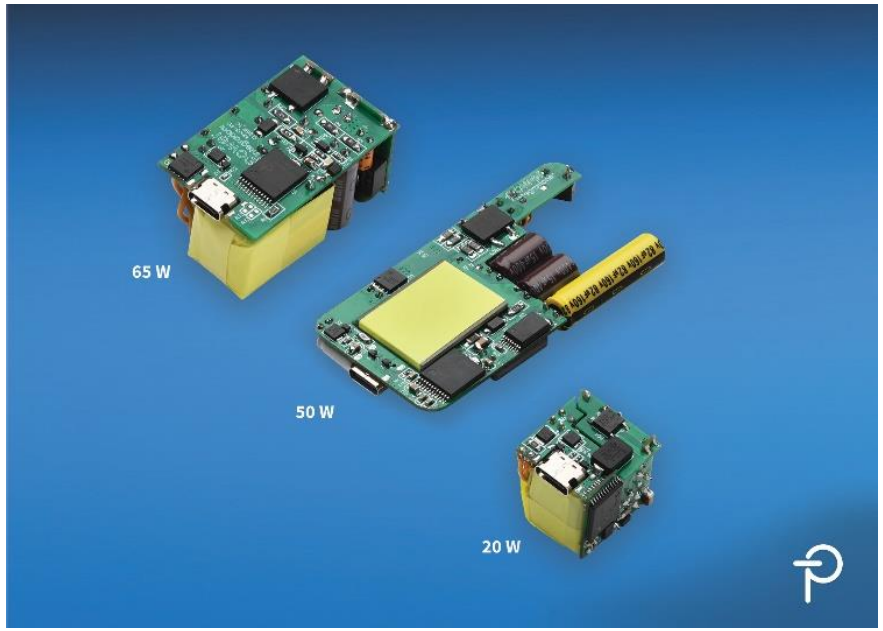
Temperature sense input

Integrated USB-C & PD controller
- Sink/E-marker detection
- VBUS/VCONN switch control
- Source only, supports PPS

Transmit & receive
- 28 V rated with OVP
- Integrated VCONN supply

InnoSwitch3-PD – Key Features for Rapid Charging

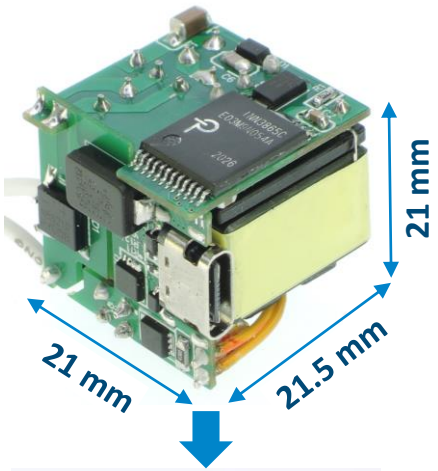
- **USB Power Delivery controller**
  - Supports USB PD 3.0 + PPS & QC4 protocols
  - One-Time Programmable (OTP) memory
- **Integration of type-C controller simplifies design**
  - Compliant with USB Type-C Rev. 1.3
    - Pull-up current-source for “sink” and cable detection
    - VCONN supply for electronically marked cables
  - Overvoltage protection for CC1/CC2 (28 V)
- **Provides all required USB-PD and PPS functionality**
  - Removes time/cost of software and interface development
- **Dedicated temperature sense pin for NTC resistor**

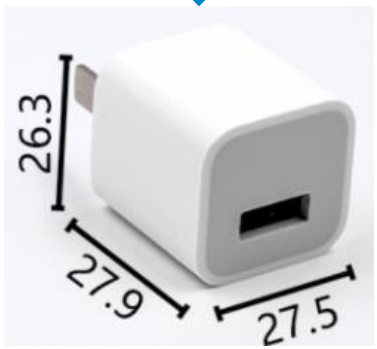


InnoSwitch3-PD enables the highest power density

Single-Chip Solution Halves Component Count for Ultra-Compact Designs

World's Smallest 20 W Cube, INN3865C



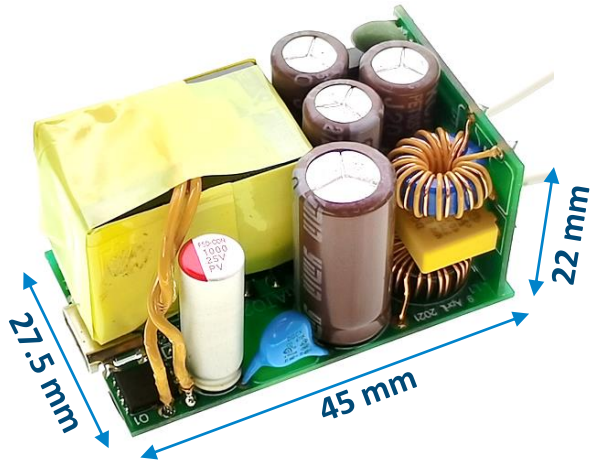


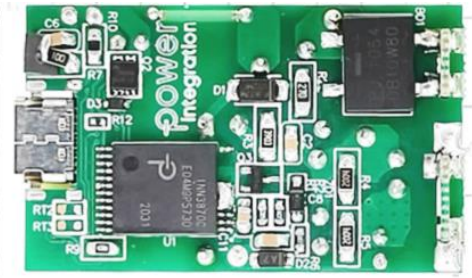
- Simple two-PCB design
- Part count: 44
- Power density: 1 W / cm³

50 W Slim, INN3870C + MinE-CAP

- Single PCB design, planar transformer
- Part count: 60
- Power density: 1.12 W/cm³

65 W Cube, INN3870C





- Simple two-PCB design
- Part count: 53
- Power density: 1.36 W / cm³

Up to 100 W Output Power

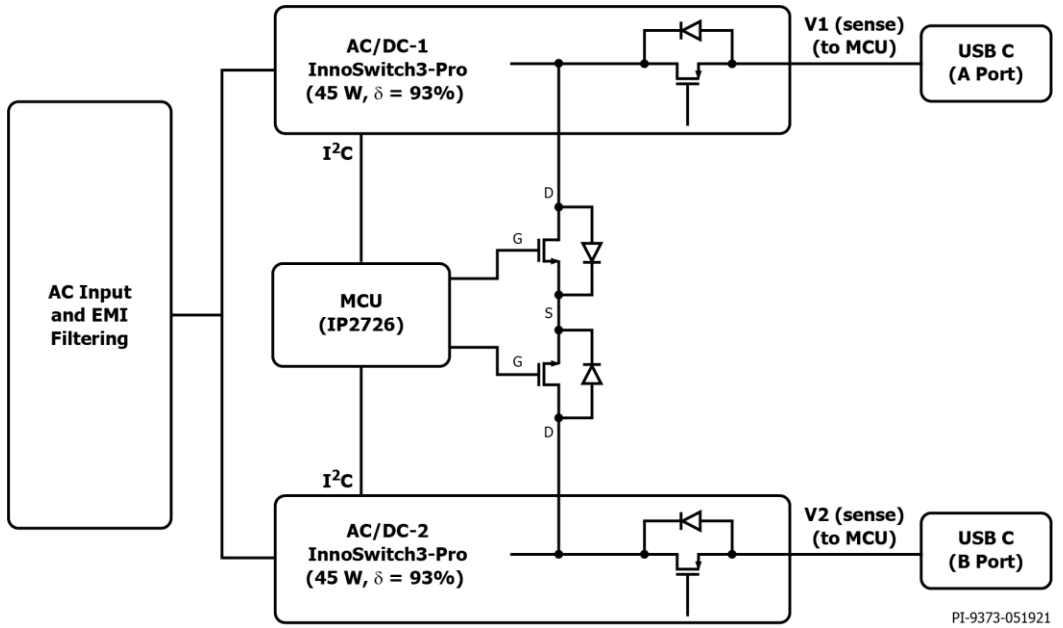
Part Number	Power Switch Voltage Rating (V)	Typical Maximum Output Power (W)			
		230 VAC ±15%		85-264 VAC	
		Adapter	Open Frame	Adapter	Open Frame
INN3865C	650	25	30	22	25
INN3866C	650	35	40	27	36
INN3867C	650	45	50	40	45
INN3878C	750	70	75	55	65
INN3879C	750	80	85	65	75
INN3870C	750	90	100	75	85

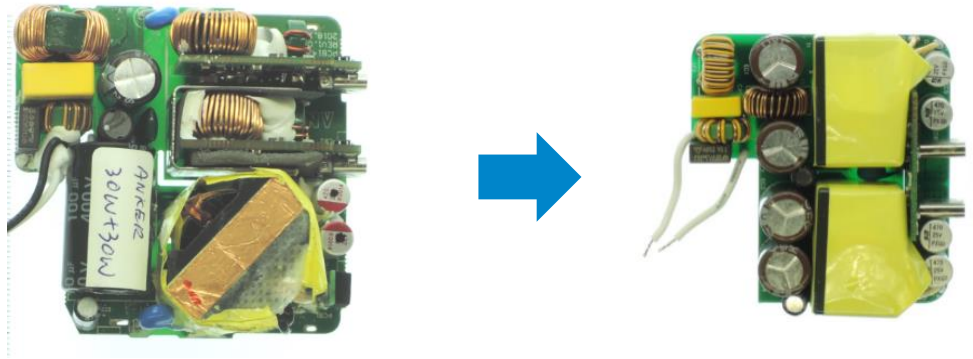
PowiGaN

Multi-Port Adapters

InnoSwitch3-Pro Enables Unique Current Sharing Architecture for Multi-Port Chargers

- **Single-stage conversion – 4% more efficient than conventional topologies**
  - >92% end-to-end efficiency
  - Lowest component count
- **Best thermal performance**
  - No hotspots
- **Eliminates high frequency DC-DC converters**
  - Reduces radiated EMI





Already Widely Adopted in the Market

2C，65 W Lenovo

2C，66 W Ugreen

2C，90 W RAVPower

2C，100 W Choetech

2C，100 W Ugreen

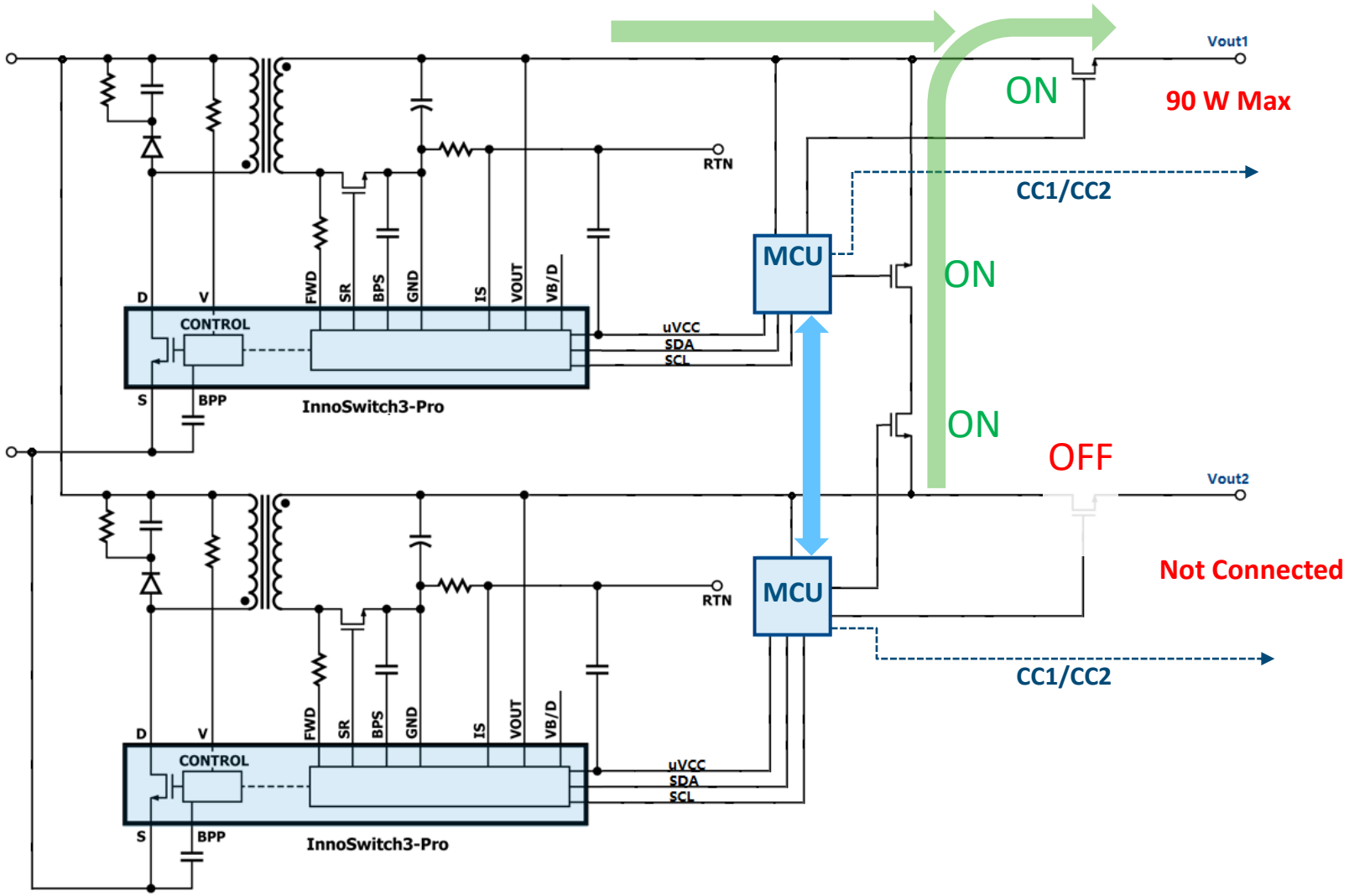
2C, 2A 65 W RAVPower

2C, 2A 120 W RAVPower

2A, 2C 130 W, Razer

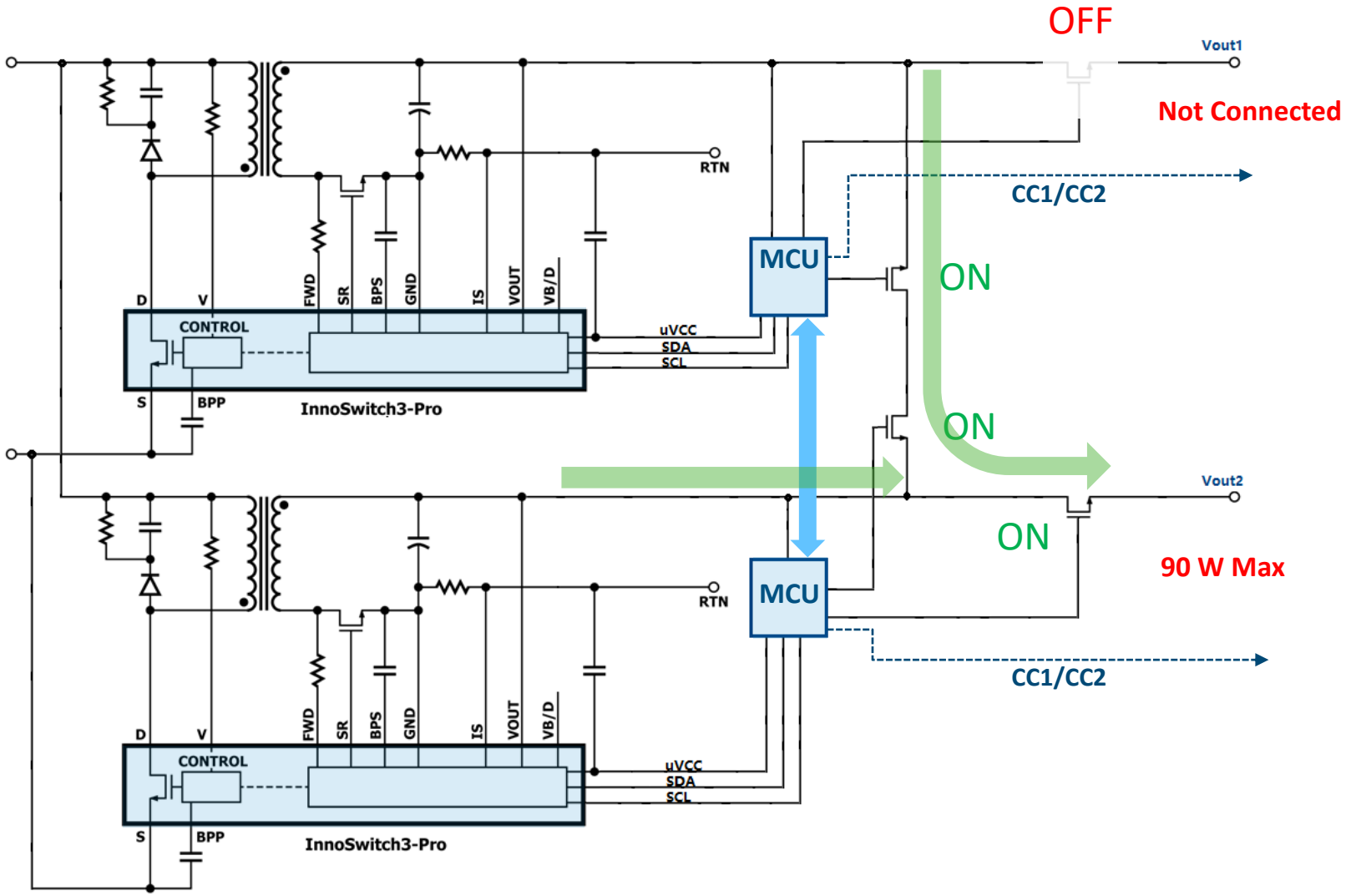
90 W with 2C Operating States: Single Port Connected

State 1	Port 1	Port 2
1) Single Port Operation	**90 W**	Not Connected



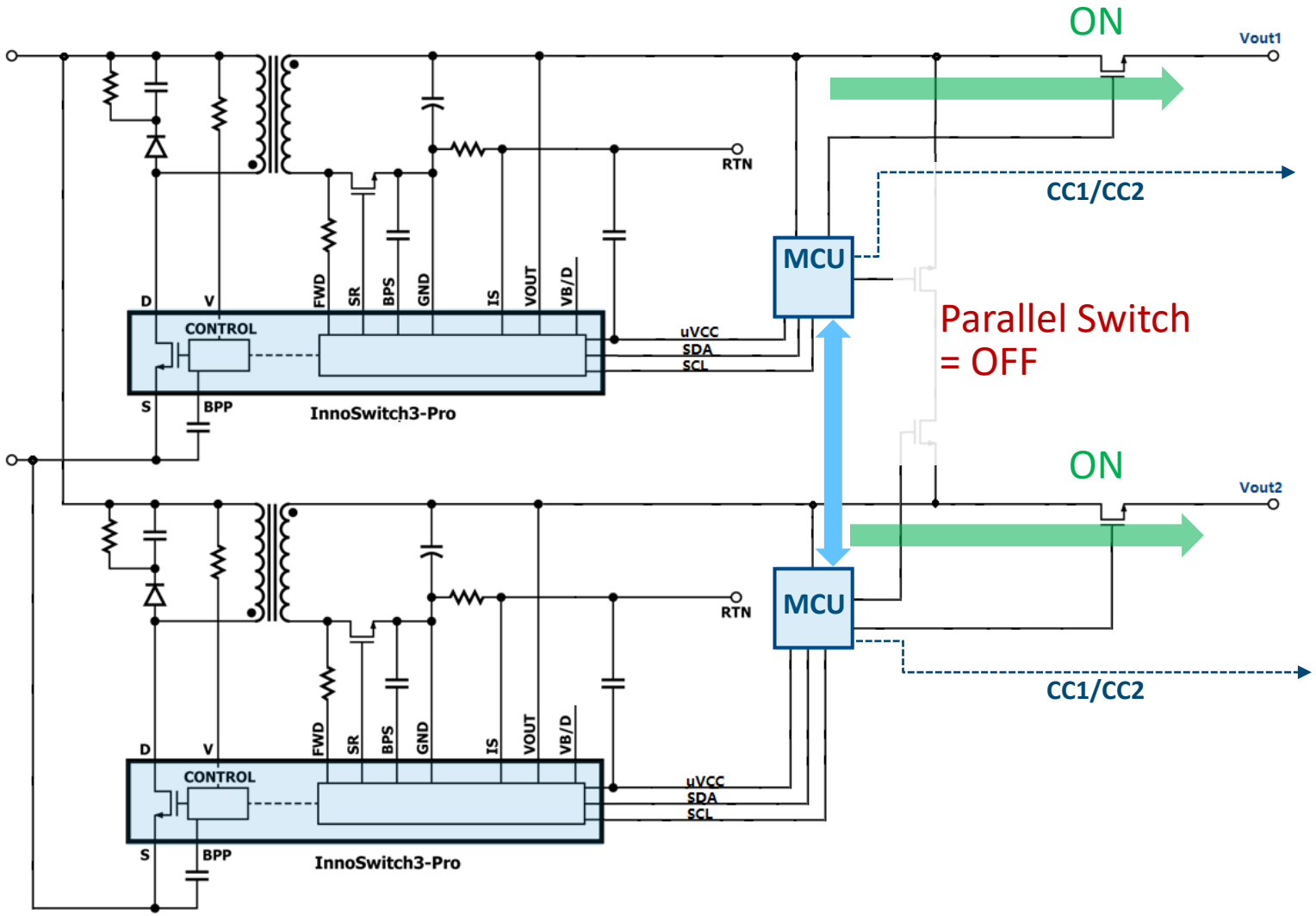
90 W with 2C Operating States: Single Port Connected

State 2	Port 1	Port 2
2) Single Port Operation	Not Connected	**90 W**



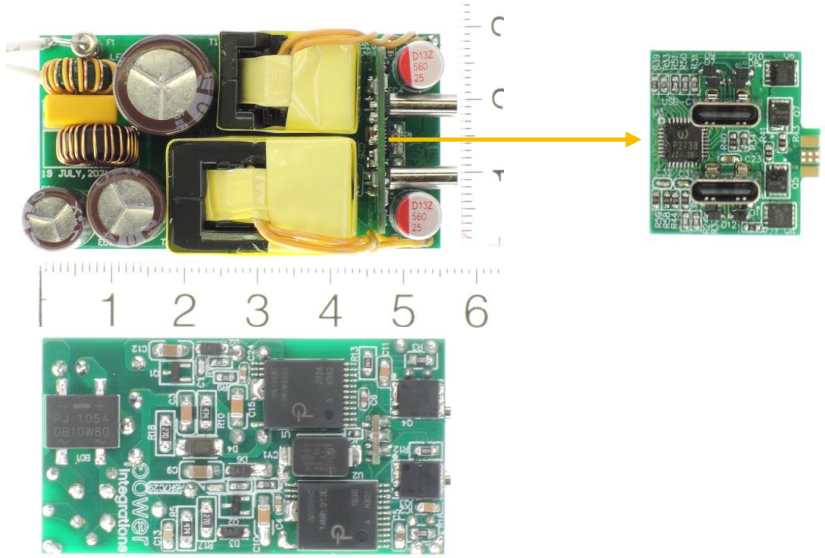
90 W with 2C Operating States: Both Ports Connected

State 3	Port 1	Port 2
Laptop + Laptop	45 W	45 W
Laptop + Tablet	45 W	30 W
Laptop + Phone	45 W	30 W



65 W 2C Design Example

2x InnoSwitch3-Pro (current sharing) + IP2738

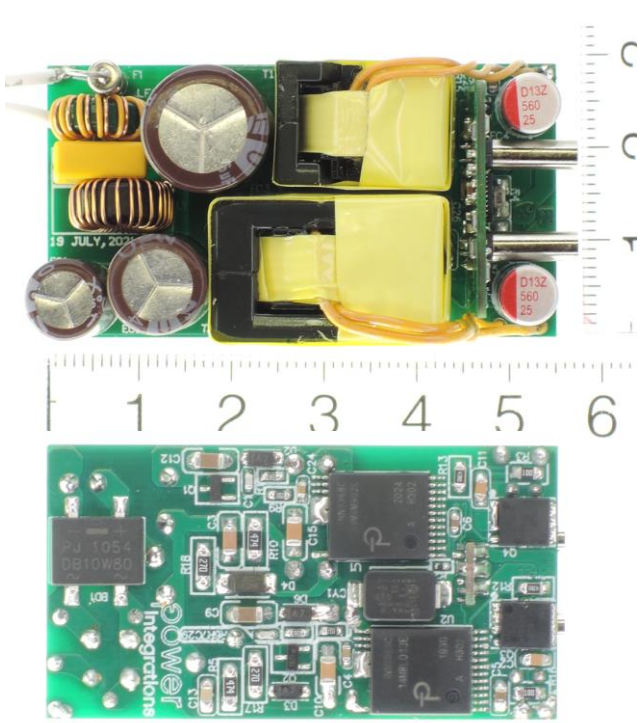


- Easy to manufacture - just 2 PCBs
- Single-stage conversion, η : 92%
- Very low component count

Conventional Solution

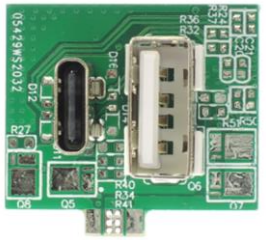
- Complex assembly, 4 PCBs
- Two-stage conversion: AC-DC + 2x DC-DC, η : 88%
- > 2 X component count

Next Generation Current Sharing Further Simplifies Design, Reduces System Cost

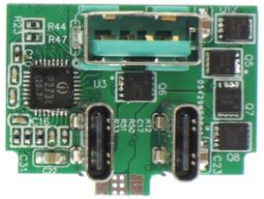


65 W

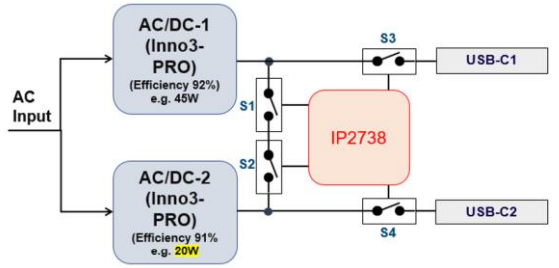
2C

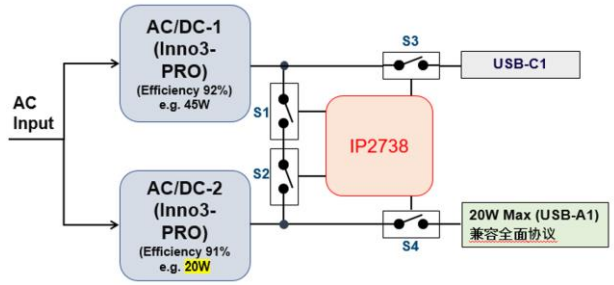


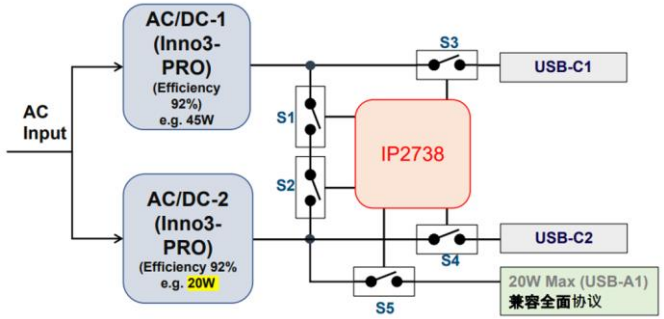
1C_1A



2C_1A







Ports in use	USB-C1	USB-C2
C1	65 W	-
C2	-	65 W
C1 + C2	45 W	20 W

Ports in use	USB-C1	USB-A1
C1	65 W	-
A1	-	20 W
C1 + A1	45 W	20 W

Ports in use	USB-C1	USB-C2	USB-A1
C1	65 W	-	-
C2	-	65 W	-
A1	-	-	20 W
C1 + C2	45 W	20 W	-
C1 + A1	45 W	-	20 W
C2 + A1	-	5 V / 5 A	
C1 + C2 + A1	45 W	5 V / 4 A	

InnoSwitch Products for All Market Needs

- **InnoSwitch4-CZ and ClampZero**
  - Increased switching frequency – smaller transformer
  - Highest power density
  - Pair with MinE-CAP

Smallest size

- **InnoSwitch3-CP**
  - Simple power solution
  - Ideal for lower density designs
  - Works with any microcontroller

Widest market

- **InnoSwitch3-Pro**
  - Versatile – customer configured PDOs and APDOs
  - Matches customer's "preferred" controller

Versatility

- **InnoSwitch3-PD**
  - Easy to manufacture, small size
  - No software development

Simple, fewest components

Supporting Materials: power.com

- **Reference design kits and design example reports**
- **Application notes, data sheets, and links to standards**
- **Award-winning PI Expert design software – a working design the first time**
  - Free PSU design tool automatically calculates all circuit requirements
    - Full bill-of-materials and schematic
    - Detailed transformer schematic and build information
    - Automatic component stress analysis
  - Fast, effective and reliable
    - Real-time design optimization
    - Closely matches hardware performance
    - Provides solutions that work the first-time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